4.3. The [range()](https://docs.python.org/3/library/stdtypes.html#range) Function

If you do need to iterate over a sequence of numbers, the built-in function [range()](https://docs.python.org/3/library/stdtypes.html#range) comes in handy. It generates arithmetic progressions:

>>>

**>>> for** i **in** range(5):

**...**  print(i)

**...**

0

1

2

3

4

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

range(5, 10)

5 through 9

range(0, 10, 3)

0, 3, 6, 9

range(-10, -100, -30)

-10, -40, -70

To iterate over the indices of a sequence, you can combine [range()](https://docs.python.org/3/library/stdtypes.html#range) and [len()](https://docs.python.org/3/library/functions.html#len) as follows:

>>>

**>>>** a = ['Mary', 'had', 'a', 'little', 'lamb']

**>>> for** i **in** range(len(a)):

**...**  print(i, a[i])

**...**

0 Mary

1 had

2 a

3 little

4 lamb

In most such cases, however, it is convenient to use the [enumerate()](https://docs.python.org/3/library/functions.html#enumerate) function, see [Looping Techniques](https://docs.python.org/3/tutorial/datastructures.html#tut-loopidioms).

A strange thing happens if you just print a range:

>>>

**>>>** print(range(10))

range(0, 10)

In many ways the object returned by [range()](https://docs.python.org/3/library/stdtypes.html#range) behaves as if it is a list, but in fact it isn’t. It is an object which returns the successive items of the desired sequence when you iterate over it, but it doesn’t really make the list, thus saving space.

We say such an object is *iterable*, that is, suitable as a target for functions and constructs that expect something from which they can obtain successive items until the supply is exhausted. We have seen that the [for](https://docs.python.org/3/reference/compound_stmts.html#for) statement is such an *iterator*. The function [list()](https://docs.python.org/3/library/stdtypes.html#list) is another; it creates lists from iterables:

>>>

**>>>** list(range(5))

[0, 1, 2, 3, 4]

Later we will see more functions that return iterables and take iterables as argument.

4.4. [break](https://docs.python.org/3/reference/simple_stmts.html#break) and [continue](https://docs.python.org/3/reference/simple_stmts.html#continue) Statements, and [else](https://docs.python.org/3/reference/compound_stmts.html#else) Clauses on Loops

The [break](https://docs.python.org/3/reference/simple_stmts.html#break) statement, like in C, breaks out of the smallest enclosing [for](https://docs.python.org/3/reference/compound_stmts.html#for) or [while](https://docs.python.org/3/reference/compound_stmts.html#while) loop.

Loop statements may have an else clause; it is executed when the loop terminates through exhaustion of the list (with [for](https://docs.python.org/3/reference/compound_stmts.html#for)) or when the condition becomes false (with [while](https://docs.python.org/3/reference/compound_stmts.html#while)), but not when the loop is terminated by a [break](https://docs.python.org/3/reference/simple_stmts.html#break) statement. This is exemplified by the following loop, which searches for prime numbers:

>>>

**>>> for** n **in** range(2, 10):

**...**  **for** x **in** range(2, n):

**...**  **if** n % x == 0:

**...**  print(n, 'equals', x, '\*', n//x)

**...**  **break**

**...**  **else**:

**...**  *# loop fell through without finding a factor*

**...**  print(n, 'is a prime number')

**...**

2 is a prime number

3 is a prime number

4 equals 2 \* 2

5 is a prime number

6 equals 2 \* 3

7 is a prime number

8 equals 2 \* 4

9 equals 3 \* 3

(Yes, this is the correct code. Look closely: the else clause belongs to the [for](https://docs.python.org/3/reference/compound_stmts.html#for) loop, **not** the [if](https://docs.python.org/3/reference/compound_stmts.html#if)statement.)

When used with a loop, the else clause has more in common with the else clause of a [try](https://docs.python.org/3/reference/compound_stmts.html#try)statement than it does that of [if](https://docs.python.org/3/reference/compound_stmts.html#if) statements: a [try](https://docs.python.org/3/reference/compound_stmts.html#try) statement’s else clause runs when no exception occurs, and a loop’s else clause runs when no break occurs. For more on the [try](https://docs.python.org/3/reference/compound_stmts.html#try) statement and exceptions, see [Handling Exceptions](https://docs.python.org/3/tutorial/errors.html#tut-handling).

The [continue](https://docs.python.org/3/reference/simple_stmts.html#continue) statement, also borrowed from C, continues with the next iteration of the loop:

>>>

**>>> for** num **in** range(2, 10):

**...**  **if** num % 2 == 0:

**...**  print("Found an even number", num)

**...**  **continue**

**...**  print("Found a number", num)

Found an even number 2

Found a number 3

Found an even number 4

Found a number 5

Found an even number 6

Found a number 7

Found an even number 8

Found a number 9

4.5. [pass](https://docs.python.org/3/reference/simple_stmts.html#pass) Statements

The [pass](https://docs.python.org/3/reference/simple_stmts.html#pass) statement does nothing. It can be used when a statement is required syntactically but the program requires no action. For example:

>>>

**>>> while** **True**:

**...**  **pass** *# Busy-wait for keyboard interrupt (Ctrl+C)*

**...**

This is commonly used for creating minimal classes:

>>>

**>>> class** **MyEmptyClass**:

**...**  **pass**

**...**

Another place [pass](https://docs.python.org/3/reference/simple_stmts.html#pass) can be used is as a place-holder for a function or conditional body when you are working on new code, allowing you to keep thinking at a more abstract level. The [pass](https://docs.python.org/3/reference/simple_stmts.html#pass) is silently ignored:

>>>

**>>> def** initlog(\*args):

**...**  **pass** *# Remember to implement this!*

**...**

4.6. Defining Functions

We can create a function that writes the Fibonacci series to an arbitrary boundary:

>>>

**>>> def** fib(n): *# write Fibonacci series up to n*

**...**  *"""Print a Fibonacci series up to n."""*

**...**  a, b = 0, 1

**...**  **while** a < n:

**...**  print(a, end=' ')

**...**  a, b = b, a+b

**...**  print()

**...**

**>>>** *# Now call the function we just defined:*

**...** fib(2000)

0 1 1 2 3 5 8 13 21 34 55 89 144 233 377 610 987 1597

The keyword [def](https://docs.python.org/3/reference/compound_stmts.html#def) introduces a function *definition*. It must be followed by the function name and the parenthesized list of formal parameters. The statements that form the body of the function start at the next line, and must be indented.

The first statement of the function body can optionally be a string literal; this string literal is the function’s documentation string, or *docstring*. (More about docstrings can be found in the section[Documentation Strings](https://docs.python.org/3/tutorial/controlflow.html#tut-docstrings).) There are tools which use docstrings to automatically produce online or printed documentation, or to let the user interactively browse through code; it’s good practice to include docstrings in code that you write, so make a habit of it.

The *execution* of a function introduces a new symbol table used for the local variables of the function. More precisely, all variable assignments in a function store the value in the local symbol table; whereas variable references first look in the local symbol table, then in the local symbol tables of enclosing functions, then in the global symbol table, and finally in the table of built-in names. Thus, global variables cannot be directly assigned a value within a function (unless named in a [global](https://docs.python.org/3/reference/simple_stmts.html#global)statement), although they may be referenced.

The actual parameters (arguments) to a function call are introduced in the local symbol table of the called function when it is called; thus, arguments are passed using *call by value* (where the *value* is always an object *reference*, not the value of the object). [[1]](https://docs.python.org/3/tutorial/controlflow.html#id2) When a function calls another function, a new local symbol table is created for that call.

A function definition introduces the function name in the current symbol table. The value of the function name has a type that is recognized by the interpreter as a user-defined function. This value can be assigned to another name which can then also be used as a function. This serves as a general renaming mechanism:

>>>

**>>>** fib

<function fib at 10042ed0>

**>>>** f = fib

**>>>** f(100)

0 1 1 2 3 5 8 13 21 34 55 89

Coming from other languages, you might object that fib is not a function but a procedure since it doesn’t return a value. In fact, even functions without a [return](https://docs.python.org/3/reference/simple_stmts.html#return) statement do return a value, albeit a rather boring one. This value is called None (it’s a built-in name). Writing the value None is normally suppressed by the interpreter if it would be the only value written. You can see it if you really want to using [print()](https://docs.python.org/3/library/functions.html#print):

>>>

**>>>** fib(0)

**>>>** print(fib(0))

None

It is simple to write a function that returns a list of the numbers of the Fibonacci series, instead of printing it:

>>>

**>>> def** fib2(n): *# return Fibonacci series up to n*

**...**  *"""Return a list containing the Fibonacci series up to n."""*

**...**  result = []

**...**  a, b = 0, 1

**...**  **while** a < n:

**...**  result.append(a) *# see below*

**...**  a, b = b, a+b

**...**  **return** result

**...**

**>>>** f100 = fib2(100) *# call it*

**>>>** f100 *# write the result*

[0, 1, 1, 2, 3, 5, 8, 13, 21, 34, 55, 89]

This example, as usual, demonstrates some new Python features:

* The [return](https://docs.python.org/3/reference/simple_stmts.html#return) statement returns with a value from a function. [return](https://docs.python.org/3/reference/simple_stmts.html#return) without an expression argument returns None. Falling off the end of a function also returns None.
* The statement result.append(a) calls a *method* of the list object result. A method is a function that ‘belongs’ to an object and is named obj.methodname, where obj is some object (this may be an expression), and methodname is the name of a method that is defined by the object’s type. Different types define different methods. Methods of different types may have the same name without causing ambiguity. (It is possible to define your own object types and methods, using *classes*, see [Classes](https://docs.python.org/3/tutorial/classes.html#tut-classes)) The method append() shown in the example is defined for list objects; it adds a new element at the end of the list. In this example it is equivalent toresult = result + [a], but more efficient.

4.7. More on Defining Functions

It is also possible to define functions with a variable number of arguments. There are three forms, which can be combined.

4.7.1. Default Argument Values

The most useful form is to specify a default value for one or more arguments. This creates a function that can be called with fewer arguments than it is defined to allow. For example:

**def** ask\_ok(prompt, retries=4, reminder='Please try again!'):

**while** **True**:

ok = input(prompt)

**if** ok **in** ('y', 'ye', 'yes'):

**return** **True**

**if** ok **in** ('n', 'no', 'nop', 'nope'):

**return** **False**

retries = retries - 1

**if** retries < 0:

**raise** ValueError('invalid user response')

print(reminder)

This function can be called in several ways:

* giving only the mandatory argument: ask\_ok('Do you really want to quit?')
* giving one of the optional arguments: ask\_ok('OK to overwrite the file?', 2)
* or even giving all arguments: ask\_ok('OK to overwrite the file?', 2, 'Come on, onlyyes or no!')

This example also introduces the [in](https://docs.python.org/3/reference/expressions.html#in) keyword. This tests whether or not a sequence contains a certain value.

The default values are evaluated at the point of function definition in the *defining* scope, so that

i = 5

**def** f(arg=i):

print(arg)

i = 6

f()

will print 5.

**Important warning:** The default value is evaluated only once. This makes a difference when the default is a mutable object such as a list, dictionary, or instances of most classes. For example, the following function accumulates the arguments passed to it on subsequent calls:

**def** f(a, L=[]):

L.append(a)

**return** L

print(f(1))

print(f(2))

print(f(3))

This will print

[1]

[1, 2]

[1, 2, 3]

If you don’t want the default to be shared between subsequent calls, you can write the function like this instead:

**def** f(a, L=**None**):

**if** L **is** **None**:

L = []

L.append(a)

**return** L

4.7.2. Keyword Arguments

Functions can also be called using [keyword arguments](https://docs.python.org/3/glossary.html#term-keyword-argument) of the form kwarg=value. For instance, the following function:

**def** parrot(voltage, state='a stiff', action='voom', type='Norwegian Blue'):

print("-- This parrot wouldn't", action, end=' ')

print("if you put", voltage, "volts through it.")

print("-- Lovely plumage, the", type)

print("-- It's", state, "!")

accepts one required argument (voltage) and three optional arguments (state, action, and type). This function can be called in any of the following ways:

parrot(1000) *# 1 positional argument*

parrot(voltage=1000) *# 1 keyword argument*

parrot(voltage=1000000, action='VOOOOOM') *# 2 keyword arguments*

parrot(action='VOOOOOM', voltage=1000000) *# 2 keyword arguments*

parrot('a million', 'bereft of life', 'jump') *# 3 positional arguments*

parrot('a thousand', state='pushing up the daisies') *# 1 positional, 1 keyword*

but all the following calls would be invalid:

parrot() *# required argument missing*

parrot(voltage=5.0, 'dead') *# non-keyword argument after a keyword argument*

parrot(110, voltage=220) *# duplicate value for the same argument*

parrot(actor='John Cleese') *# unknown keyword argument*

In a function call, keyword arguments must follow positional arguments. All the keyword arguments passed must match one of the arguments accepted by the function (e.g. actor is not a valid argument for the parrot function), and their order is not important. This also includes non-optional arguments (e.g. parrot(voltage=1000) is valid too). No argument may receive a value more than once. Here’s an example that fails due to this restriction:

>>>

**>>> def** function(a):

**...**  **pass**

**...**

**>>>** function(0, a=0)

Traceback (most recent call last):

File "<stdin>", line 1, in ?

TypeError: function() got multiple values for keyword argument 'a'

When a final formal parameter of the form \*\*name is present, it receives a dictionary (see [Mapping Types — dict](https://docs.python.org/3/library/stdtypes.html#typesmapping)) containing all keyword arguments except for those corresponding to a formal parameter. This may be combined with a formal parameter of the form \*name (described in the next subsection) which receives a tuple containing the positional arguments beyond the formal parameter list. (\*namemust occur before \*\*name.) For example, if we define a function like this:

**def** cheeseshop(kind, \*arguments, \*\*keywords):

print("-- Do you have any", kind, "?")

print("-- I'm sorry, we're all out of", kind)

**for** arg **in** arguments:

print(arg)

print("-" \* 40)

keys = sorted(keywords.keys())

**for** kw **in** keys:

print(kw, ":", keywords[kw])

It could be called like this:

cheeseshop("Limburger", "It's very runny, sir.",

"It's really very, VERY runny, sir.",

shopkeeper="Michael Palin",

client="John Cleese",

sketch="Cheese Shop Sketch")

and of course it would print:

-- Do you have any Limburger ?

-- I'm sorry, we're all out of Limburger

It's very runny, sir.

It's really very, VERY runny, sir.

----------------------------------------

client : John Cleese

shopkeeper : Michael Palin

sketch : Cheese Shop Sketch

Note that the list of keyword argument names is created by sorting the result of the keywords dictionary’s keys() method before printing its contents; if this is not done, the order in which the arguments are printed is undefined.

4.7.3. Arbitrary Argument Lists

Finally, the least frequently used option is to specify that a function can be called with an arbitrary number of arguments. These arguments will be wrapped up in a tuple (see [Tuples and Sequences](https://docs.python.org/3/tutorial/datastructures.html#tut-tuples)). Before the variable number of arguments, zero or more normal arguments may occur.

**def** write\_multiple\_items(file, separator, \*args):

file.write(separator.join(args))

Normally, these variadic arguments will be last in the list of formal parameters, because they scoop up all remaining input arguments that are passed to the function. Any formal parameters which occur after the \*args parameter are ‘keyword-only’ arguments, meaning that they can only be used as keywords rather than positional arguments.

>>>

**>>> def** concat(\*args, sep="/"):

**...**  **return** sep.join(args)

**...**

**>>>** concat("earth", "mars", "venus")

'earth/mars/venus'

**>>>** concat("earth", "mars", "venus", sep=".")

'earth.mars.venus'

4.7.4. Unpacking Argument Lists

The reverse situation occurs when the arguments are already in a list or tuple but need to be unpacked for a function call requiring separate positional arguments. For instance, the built-in [range()](https://docs.python.org/3/library/stdtypes.html#range)function expects separate *start* and *stop* arguments. If they are not available separately, write the function call with the \*-operator to unpack the arguments out of a list or tuple:

>>>

**>>>** list(range(3, 6)) *# normal call with separate arguments*

[3, 4, 5]

**>>>** args = [3, 6]

**>>>** list(range(\*args)) *# call with arguments unpacked from a list*

[3, 4, 5]

In the same fashion, dictionaries can deliver keyword arguments with the \*\*-operator:

>>>

**>>> def** parrot(voltage, state='a stiff', action='voom'):

**...**  print("-- This parrot wouldn't", action, end=' ')

**...**  print("if you put", voltage, "volts through it.", end=' ')

**...**  print("E's", state, "!")

**...**

**>>>** d = {"voltage": "four million", "state": "bleedin' demised", "action": "VOOM"}

**>>>** parrot(\*\*d)

-- This parrot wouldn't VOOM if you put four million volts through it. E's bleedin' demised !

4.7.5. Lambda Expressions

Small anonymous functions can be created with the [lambda](https://docs.python.org/3/reference/expressions.html#lambda) keyword. This function returns the sum of its two arguments: lambda a, b: a+b. Lambda functions can be used wherever function objects are required. They are syntactically restricted to a single expression. Semantically, they are just syntactic sugar for a normal function definition. Like nested function definitions, lambda functions can reference variables from the containing scope:

>>>

**>>> def** make\_incrementor(n):

**...**  **return** **lambda** x: x + n

**...**

**>>>** f = make\_incrementor(42)

**>>>** f(0)

42

**>>>** f(1)

43

The above example uses a lambda expression to return a function. Another use is to pass a small function as an argument:

>>>

**>>>** pairs = [(1, 'one'), (2, 'two'), (3, 'three'), (4, 'four')]

**>>>** pairs.sort(key=**lambda** pair: pair[1])

**>>>** pairs

[(4, 'four'), (1, 'one'), (3, 'three'), (2, 'two')]

4.7.6. Documentation Strings

Here are some conventions about the content and formatting of documentation strings.

The first line should always be a short, concise summary of the object’s purpose. For brevity, it should not explicitly state the object’s name or type, since these are available by other means (except if the name happens to be a verb describing a function’s operation). This line should begin with a capital letter and end with a period.

If there are more lines in the documentation string, the second line should be blank, visually separating the summary from the rest of the description. The following lines should be one or more paragraphs describing the object’s calling conventions, its side effects, etc.

The Python parser does not strip indentation from multi-line string literals in Python, so tools that process documentation have to strip indentation if desired. This is done using the following convention. The first non-blank line *after* the first line of the string determines the amount of indentation for the entire documentation string. (We can’t use the first line since it is generally adjacent to the string’s opening quotes so its indentation is not apparent in the string literal.) Whitespace “equivalent” to this indentation is then stripped from the start of all lines of the string. Lines that are indented less should not occur, but if they occur all their leading whitespace should be stripped. Equivalence of whitespace should be tested after expansion of tabs (to 8 spaces, normally).

Here is an example of a multi-line docstring:

>>>

**>>> def** my\_function():

**...**  *"""Do nothing, but document it.*

**...**

**...**  *No, really, it doesn't do anything.*

**...**  *"""*

**...**  **pass**

**...**

**>>>** print(my\_function.\_\_doc\_\_)

Do nothing, but document it.

No, really, it doesn't do anything.

4.7.7. Function Annotations

[Function annotations](https://docs.python.org/3/reference/compound_stmts.html#function) are completely optional metadata information about the types used by user-defined functions (see [**PEP 484**](https://www.python.org/dev/peps/pep-0484) for more information).

Annotations are stored in the \_\_annotations\_\_ attribute of the function as a dictionary and have no effect on any other part of the function. Parameter annotations are defined by a colon after the parameter name, followed by an expression evaluating to the value of the annotation. Return annotations are defined by a literal ->, followed by an expression, between the parameter list and the colon denoting the end of the [def](https://docs.python.org/3/reference/compound_stmts.html#def) statement. The following example has a positional argument, a keyword argument, and the return value annotated:

>>>

**>>> def** f(ham: str, eggs: str = 'eggs') -> str:

**...**  print("Annotations:", f.\_\_annotations\_\_)

**...**  print("Arguments:", ham, eggs)

**...**  **return** ham + ' and ' + eggs

**...**

**>>>** f('spam')

Annotations: {'ham': <class 'str'>, 'return': <class 'str'>, 'eggs': <class 'str'>}

Arguments: spam eggs

'spam and eggs'

4.8. Intermezzo: Coding Style

Now that you are about to write longer, more complex pieces of Python, it is a good time to talk about*coding style*. Most languages can be written (or more concise, *formatted*) in different styles; some are more readable than others. Making it easy for others to read your code is always a good idea, and adopting a nice coding style helps tremendously for that.

For Python, [**PEP 8**](https://www.python.org/dev/peps/pep-0008) has emerged as the style guide that most projects adhere to; it promotes a very readable and eye-pleasing coding style. Every Python developer should read it at some point; here are the most important points extracted for you:

* Use 4-space indentation, and no tabs.

4 spaces are a good compromise between small indentation (allows greater nesting depth) and large indentation (easier to read). Tabs introduce confusion, and are best left out.

* Wrap lines so that they don’t exceed 79 characters.

This helps users with small displays and makes it possible to have several code files side-by-side on larger displays.

* Use blank lines to separate functions and classes, and larger blocks of code inside functions.
* When possible, put comments on a line of their own.
* Use docstrings.
* Use spaces around operators and after commas, but not directly inside bracketing constructs: a= f(1, 2) + g(3, 4).
* Name your classes and functions consistently; the convention is to use CamelCase for classes and lower\_case\_with\_underscores for functions and methods. Always use self as the name for the first method argument (see [A First Look at Classes](https://docs.python.org/3/tutorial/classes.html#tut-firstclasses) for more on classes and methods).
* Don’t use fancy encodings if your code is meant to be used in international environments. Python’s default, UTF-8, or even plain ASCII work best in any case.
* Likewise, don’t use non-ASCII characters in identifiers if there is only the slightest chance people speaking a different language will read or maintain the code.

**Footnotes**

|  |  |
| --- | --- |
| [[1]](https://docs.python.org/3/tutorial/controlflow.html#id1) | Actually, *call by object reference* would be a better description, since if a mutable object is passed, the caller will see any changes the callee makes to it (items inserted into a list). |

4.4. [break](https://docs.python.org/3/reference/simple_stmts.html#break) and [continue](https://docs.python.org/3/reference/simple_stmts.html#continue) Statements, and [else](https://docs.python.org/3/reference/compound_stmts.html#else) Clauses on Loops

The [break](https://docs.python.org/3/reference/simple_stmts.html#break) statement, like in C, breaks out of the smallest enclosing [for](https://docs.python.org/3/reference/compound_stmts.html#for) or [while](https://docs.python.org/3/reference/compound_stmts.html#while) loop.

Loop statements may have an else clause; it is executed when the loop terminates through exhaustion of the list (with [for](https://docs.python.org/3/reference/compound_stmts.html#for)) or when the condition becomes false (with [while](https://docs.python.org/3/reference/compound_stmts.html#while)), but not when the loop is terminated by a [break](https://docs.python.org/3/reference/simple_stmts.html#break) statement. This is exemplified by the following loop, which searches for prime numbers:

>>>

**>>> for** n **in** range(2, 10):

**...**  **for** x **in** range(2, n):

**...**  **if** n % x == 0:

**...**  print(n, 'equals', x, '\*', n//x)

**...**  **break**

**...**  **else**:

**...**  *# loop fell through without finding a factor*

**...**  print(n, 'is a prime number')

**...**

2 is a prime number

3 is a prime number

4 equals 2 \* 2

5 is a prime number

6 equals 2 \* 3

7 is a prime number

8 equals 2 \* 4

9 equals 3 \* 3

(Yes, this is the correct code. Look closely: the else clause belongs to the [for](https://docs.python.org/3/reference/compound_stmts.html#for) loop, **not** the [if](https://docs.python.org/3/reference/compound_stmts.html#if)statement.)

When used with a loop, the else clause has more in common with the else clause of a [try](https://docs.python.org/3/reference/compound_stmts.html#try)statement than it does that of [if](https://docs.python.org/3/reference/compound_stmts.html#if) statements: a [try](https://docs.python.org/3/reference/compound_stmts.html#try) statement’s else clause runs when no exception occurs, and a loop’s else clause runs when no break occurs. For more on the [try](https://docs.python.org/3/reference/compound_stmts.html#try) statement and exceptions, see [Handling Exceptions](https://docs.python.org/3/tutorial/errors.html#tut-handling).

The [continue](https://docs.python.org/3/reference/simple_stmts.html#continue) statement, also borrowed from C, continues with the next iteration of the loop:

>>>

**>>> for** num **in** range(2, 10):

**...**  **if** num % 2 == 0:

**...**  print("Found an even number", num)

**...**  **continue**

**...**  print("Found a number", num)

Found an even number 2

Found a number 3

Found an even number 4

Found a number 5

Found an even number 6

Found a number 7

Found an even number 8

Found a number 9

4.5. [pass](https://docs.python.org/3/reference/simple_stmts.html#pass) Statements

The [pass](https://docs.python.org/3/reference/simple_stmts.html#pass) statement does nothing. It can be used when a statement is required syntactically but the program requires no action. For example:

>>>

**>>> while** **True**:

**...**  **pass** *# Busy-wait for keyboard interrupt (Ctrl+C)*

**...**

This is commonly used for creating minimal classes:

>>>

**>>> class** **MyEmptyClass**:

**...**  **pass**

**...**

Another place [pass](https://docs.python.org/3/reference/simple_stmts.html#pass) can be used is as a place-holder for a function or conditional body when you are working on new code, allowing you to keep thinking at a more abstract level. The [pass](https://docs.python.org/3/reference/simple_stmts.html#pass) is silently ignored:

>>>

**>>> def** initlog(\*args):

**...**  **pass** *# Remember to implement this!*

**...**

4.6. Defining Functions

We can create a function that writes the Fibonacci series to an arbitrary boundary:

>>>

**>>> def** fib(n): *# write Fibonacci series up to n*

**...**  *"""Print a Fibonacci series up to n."""*

**...**  a, b = 0, 1

**...**  **while** a < n:

**...**  print(a, end=' ')

**...**  a, b = b, a+b

**...**  print()

**...**

**>>>** *# Now call the function we just defined:*

**...** fib(2000)

0 1 1 2 3 5 8 13 21 34 55 89 144 233 377 610 987 1597

The keyword [def](https://docs.python.org/3/reference/compound_stmts.html#def) introduces a function *definition*. It must be followed by the function name and the parenthesized list of formal parameters. The statements that form the body of the function start at the next line, and must be indented.

The first statement of the function body can optionally be a string literal; this string literal is the function’s documentation string, or *docstring*. (More about docstrings can be found in the section[Documentation Strings](https://docs.python.org/3/tutorial/controlflow.html#tut-docstrings).) There are tools which use docstrings to automatically produce online or printed documentation, or to let the user interactively browse through code; it’s good practice to include docstrings in code that you write, so make a habit of it.

The *execution* of a function introduces a new symbol table used for the local variables of the function. More precisely, all variable assignments in a function store the value in the local symbol table; whereas variable references first look in the local symbol table, then in the local symbol tables of enclosing functions, then in the global symbol table, and finally in the table of built-in names. Thus, global variables cannot be directly assigned a value within a function (unless named in a [global](https://docs.python.org/3/reference/simple_stmts.html#global)statement), although they may be referenced.

The actual parameters (arguments) to a function call are introduced in the local symbol table of the called function when it is called; thus, arguments are passed using *call by value* (where the *value* is always an object *reference*, not the value of the object). [[1]](https://docs.python.org/3/tutorial/controlflow.html#id2) When a function calls another function, a new local symbol table is created for that call.

A function definition introduces the function name in the current symbol table. The value of the function name has a type that is recognized by the interpreter as a user-defined function. This value can be assigned to another name which can then also be used as a function. This serves as a general renaming mechanism:

>>>

**>>>** fib

<function fib at 10042ed0>

**>>>** f = fib

**>>>** f(100)

0 1 1 2 3 5 8 13 21 34 55 89

Coming from other languages, you might object that fib is not a function but a procedure since it doesn’t return a value. In fact, even functions without a [return](https://docs.python.org/3/reference/simple_stmts.html#return) statement do return a value, albeit a rather boring one. This value is called None (it’s a built-in name). Writing the value None is normally suppressed by the interpreter if it would be the only value written. You can see it if you really want to using [print()](https://docs.python.org/3/library/functions.html#print):

>>>

**>>>** fib(0)

**>>>** print(fib(0))

None

It is simple to write a function that returns a list of the numbers of the Fibonacci series, instead of printing it:

>>>

**>>> def** fib2(n): *# return Fibonacci series up to n*

**...**  *"""Return a list containing the Fibonacci series up to n."""*

**...**  result = []

**...**  a, b = 0, 1

**...**  **while** a < n:

**...**  result.append(a) *# see below*

**...**  a, b = b, a+b

**...**  **return** result

**...**

**>>>** f100 = fib2(100) *# call it*

**>>>** f100 *# write the result*

[0, 1, 1, 2, 3, 5, 8, 13, 21, 34, 55, 89]

This example, as usual, demonstrates some new Python features:

* The [return](https://docs.python.org/3/reference/simple_stmts.html#return) statement returns with a value from a function. [return](https://docs.python.org/3/reference/simple_stmts.html#return) without an expression argument returns None. Falling off the end of a function also returns None.
* The statement result.append(a) calls a *method* of the list object result. A method is a function that ‘belongs’ to an object and is named obj.methodname, where obj is some object (this may be an expression), and methodname is the name of a method that is defined by the object’s type. Different types define different methods. Methods of different types may have the same name without causing ambiguity. (It is possible to define your own object types and methods, using *classes*, see [Classes](https://docs.python.org/3/tutorial/classes.html#tut-classes)) The method append() shown in the example is defined for list objects; it adds a new element at the end of the list. In this example it is equivalent toresult = result + [a], but more efficient.

4.7. More on Defining Functions

It is also possible to define functions with a variable number of arguments. There are three forms, which can be combined.

4.7.1. Default Argument Values

The most useful form is to specify a default value for one or more arguments. This creates a function that can be called with fewer arguments than it is defined to allow. For example:

**def** ask\_ok(prompt, retries=4, reminder='Please try again!'):

**while** **True**:

ok = input(prompt)

**if** ok **in** ('y', 'ye', 'yes'):

**return** **True**

**if** ok **in** ('n', 'no', 'nop', 'nope'):

**return** **False**

retries = retries - 1

**if** retries < 0:

**raise** ValueError('invalid user response')

print(reminder)

This function can be called in several ways:

* giving only the mandatory argument: ask\_ok('Do you really want to quit?')
* giving one of the optional arguments: ask\_ok('OK to overwrite the file?', 2)
* or even giving all arguments: ask\_ok('OK to overwrite the file?', 2, 'Come on, onlyyes or no!')

This example also introduces the [in](https://docs.python.org/3/reference/expressions.html#in) keyword. This tests whether or not a sequence contains a certain value.

The default values are evaluated at the point of function definition in the *defining* scope, so that

i = 5

**def** f(arg=i):

print(arg)

i = 6

f()

will print 5.

**Important warning:** The default value is evaluated only once. This makes a difference when the default is a mutable object such as a list, dictionary, or instances of most classes. For example, the following function accumulates the arguments passed to it on subsequent calls:

**def** f(a, L=[]):

L.append(a)

**return** L

print(f(1))

print(f(2))

print(f(3))

This will print

[1]

[1, 2]

[1, 2, 3]

If you don’t want the default to be shared between subsequent calls, you can write the function like this instead:

**def** f(a, L=**None**):

**if** L **is** **None**:

L = []

L.append(a)

**return** L

4.7.2. Keyword Arguments

Functions can also be called using [keyword arguments](https://docs.python.org/3/glossary.html#term-keyword-argument) of the form kwarg=value. For instance, the following function:

**def** parrot(voltage, state='a stiff', action='voom', type='Norwegian Blue'):

print("-- This parrot wouldn't", action, end=' ')

print("if you put", voltage, "volts through it.")

print("-- Lovely plumage, the", type)

print("-- It's", state, "!")

accepts one required argument (voltage) and three optional arguments (state, action, and type). This function can be called in any of the following ways:

parrot(1000) *# 1 positional argument*

parrot(voltage=1000) *# 1 keyword argument*

parrot(voltage=1000000, action='VOOOOOM') *# 2 keyword arguments*

parrot(action='VOOOOOM', voltage=1000000) *# 2 keyword arguments*

parrot('a million', 'bereft of life', 'jump') *# 3 positional arguments*

parrot('a thousand', state='pushing up the daisies') *# 1 positional, 1 keyword*

but all the following calls would be invalid:

parrot() *# required argument missing*

parrot(voltage=5.0, 'dead') *# non-keyword argument after a keyword argument*

parrot(110, voltage=220) *# duplicate value for the same argument*

parrot(actor='John Cleese') *# unknown keyword argument*

In a function call, keyword arguments must follow positional arguments. All the keyword arguments passed must match one of the arguments accepted by the function (e.g. actor is not a valid argument for the parrot function), and their order is not important. This also includes non-optional arguments (e.g. parrot(voltage=1000) is valid too). No argument may receive a value more than once. Here’s an example that fails due to this restriction:

>>>

**>>> def** function(a):

**...**  **pass**

**...**

**>>>** function(0, a=0)

Traceback (most recent call last):

File "<stdin>", line 1, in ?

TypeError: function() got multiple values for keyword argument 'a'

When a final formal parameter of the form \*\*name is present, it receives a dictionary (see [Mapping Types — dict](https://docs.python.org/3/library/stdtypes.html#typesmapping)) containing all keyword arguments except for those corresponding to a formal parameter. This may be combined with a formal parameter of the form \*name (described in the next subsection) which receives a tuple containing the positional arguments beyond the formal parameter list. (\*namemust occur before \*\*name.) For example, if we define a function like this:

**def** cheeseshop(kind, \*arguments, \*\*keywords):

print("-- Do you have any", kind, "?")

print("-- I'm sorry, we're all out of", kind)

**for** arg **in** arguments:

print(arg)

print("-" \* 40)

keys = sorted(keywords.keys())

**for** kw **in** keys:

print(kw, ":", keywords[kw])

It could be called like this:

cheeseshop("Limburger", "It's very runny, sir.",

"It's really very, VERY runny, sir.",

shopkeeper="Michael Palin",

client="John Cleese",

sketch="Cheese Shop Sketch")

and of course it would print:

-- Do you have any Limburger ?

-- I'm sorry, we're all out of Limburger

It's very runny, sir.

It's really very, VERY runny, sir.

----------------------------------------

client : John Cleese

shopkeeper : Michael Palin

sketch : Cheese Shop Sketch

Note that the list of keyword argument names is created by sorting the result of the keywords dictionary’s keys() method before printing its contents; if this is not done, the order in which the arguments are printed is undefined.

4.7.3. Arbitrary Argument Lists

Finally, the least frequently used option is to specify that a function can be called with an arbitrary number of arguments. These arguments will be wrapped up in a tuple (see [Tuples and Sequences](https://docs.python.org/3/tutorial/datastructures.html#tut-tuples)). Before the variable number of arguments, zero or more normal arguments may occur.

**def** write\_multiple\_items(file, separator, \*args):

file.write(separator.join(args))

Normally, these variadic arguments will be last in the list of formal parameters, because they scoop up all remaining input arguments that are passed to the function. Any formal parameters which occur after the \*args parameter are ‘keyword-only’ arguments, meaning that they can only be used as keywords rather than positional arguments.

>>>

**>>> def** concat(\*args, sep="/"):

**...**  **return** sep.join(args)

**...**

**>>>** concat("earth", "mars", "venus")

'earth/mars/venus'

**>>>** concat("earth", "mars", "venus", sep=".")

'earth.mars.venus'

4.7.4. Unpacking Argument Lists

The reverse situation occurs when the arguments are already in a list or tuple but need to be unpacked for a function call requiring separate positional arguments. For instance, the built-in [range()](https://docs.python.org/3/library/stdtypes.html#range)function expects separate *start* and *stop* arguments. If they are not available separately, write the function call with the \*-operator to unpack the arguments out of a list or tuple:

>>>

**>>>** list(range(3, 6)) *# normal call with separate arguments*

[3, 4, 5]

**>>>** args = [3, 6]

**>>>** list(range(\*args)) *# call with arguments unpacked from a list*

[3, 4, 5]

In the same fashion, dictionaries can deliver keyword arguments with the \*\*-operator:

>>>

**>>> def** parrot(voltage, state='a stiff', action='voom'):

**...**  print("-- This parrot wouldn't", action, end=' ')

**...**  print("if you put", voltage, "volts through it.", end=' ')

**...**  print("E's", state, "!")

**...**

**>>>** d = {"voltage": "four million", "state": "bleedin' demised", "action": "VOOM"}

**>>>** parrot(\*\*d)

-- This parrot wouldn't VOOM if you put four million volts through it. E's bleedin' demised !

4.7.5. Lambda Expressions

Small anonymous functions can be created with the [lambda](https://docs.python.org/3/reference/expressions.html#lambda) keyword. This function returns the sum of its two arguments: lambda a, b: a+b. Lambda functions can be used wherever function objects are required. They are syntactically restricted to a single expression. Semantically, they are just syntactic sugar for a normal function definition. Like nested function definitions, lambda functions can reference variables from the containing scope:

>>>

**>>> def** make\_incrementor(n):

**...**  **return** **lambda** x: x + n

**...**

**>>>** f = make\_incrementor(42)

**>>>** f(0)

42

**>>>** f(1)

43

The above example uses a lambda expression to return a function. Another use is to pass a small function as an argument:

>>>

**>>>** pairs = [(1, 'one'), (2, 'two'), (3, 'three'), (4, 'four')]

**>>>** pairs.sort(key=**lambda** pair: pair[1])

**>>>** pairs

[(4, 'four'), (1, 'one'), (3, 'three'), (2, 'two')]

4.7.6. Documentation Strings

Here are some conventions about the content and formatting of documentation strings.

The first line should always be a short, concise summary of the object’s purpose. For brevity, it should not explicitly state the object’s name or type, since these are available by other means (except if the name happens to be a verb describing a function’s operation). This line should begin with a capital letter and end with a period.

If there are more lines in the documentation string, the second line should be blank, visually separating the summary from the rest of the description. The following lines should be one or more paragraphs describing the object’s calling conventions, its side effects, etc.

The Python parser does not strip indentation from multi-line string literals in Python, so tools that process documentation have to strip indentation if desired. This is done using the following convention. The first non-blank line *after* the first line of the string determines the amount of indentation for the entire documentation string. (We can’t use the first line since it is generally adjacent to the string’s opening quotes so its indentation is not apparent in the string literal.) Whitespace “equivalent” to this indentation is then stripped from the start of all lines of the string. Lines that are indented less should not occur, but if they occur all their leading whitespace should be stripped. Equivalence of whitespace should be tested after expansion of tabs (to 8 spaces, normally).

Here is an example of a multi-line docstring:

>>>

**>>> def** my\_function():

**...**  *"""Do nothing, but document it.*

**...**

**...**  *No, really, it doesn't do anything.*

**...**  *"""*

**...**  **pass**

**...**

**>>>** print(my\_function.\_\_doc\_\_)

Do nothing, but document it.

No, really, it doesn't do anything.

4.7.7. Function Annotations

[Function annotations](https://docs.python.org/3/reference/compound_stmts.html#function) are completely optional metadata information about the types used by user-defined functions (see [**PEP 484**](https://www.python.org/dev/peps/pep-0484) for more information).

Annotations are stored in the \_\_annotations\_\_ attribute of the function as a dictionary and have no effect on any other part of the function. Parameter annotations are defined by a colon after the parameter name, followed by an expression evaluating to the value of the annotation. Return annotations are defined by a literal ->, followed by an expression, between the parameter list and the colon denoting the end of the [def](https://docs.python.org/3/reference/compound_stmts.html#def) statement. The following example has a positional argument, a keyword argument, and the return value annotated:

>>>

**>>> def** f(ham: str, eggs: str = 'eggs') -> str:

**...**  print("Annotations:", f.\_\_annotations\_\_)

**...**  print("Arguments:", ham, eggs)

**...**  **return** ham + ' and ' + eggs

**...**

**>>>** f('spam')

Annotations: {'ham': <class 'str'>, 'return': <class 'str'>, 'eggs': <class 'str'>}

Arguments: spam eggs

'spam and eggs'

4.8. Intermezzo: Coding Style

Now that you are about to write longer, more complex pieces of Python, it is a good time to talk about*coding style*. Most languages can be written (or more concise, *formatted*) in different styles; some are more readable than others. Making it easy for others to read your code is always a good idea, and adopting a nice coding style helps tremendously for that.

For Python, [**PEP 8**](https://www.python.org/dev/peps/pep-0008) has emerged as the style guide that most projects adhere to; it promotes a very readable and eye-pleasing coding style. Every Python developer should read it at some point; here are the most important points extracted for you:

* Use 4-space indentation, and no tabs.

4 spaces are a good compromise between small indentation (allows greater nesting depth) and large indentation (easier to read). Tabs introduce confusion, and are best left out.

* Wrap lines so that they don’t exceed 79 characters.

This helps users with small displays and makes it possible to have several code files side-by-side on larger displays.

* Use blank lines to separate functions and classes, and larger blocks of code inside functions.
* When possible, put comments on a line of their own.
* Use docstrings.
* Use spaces around operators and after commas, but not directly inside bracketing constructs: a= f(1, 2) + g(3, 4).
* Name your classes and functions consistently; the convention is to use CamelCase for classes and lower\_case\_with\_underscores for functions and methods. Always use self as the name for the first method argument (see [A First Look at Classes](https://docs.python.org/3/tutorial/classes.html#tut-firstclasses) for more on classes and methods).
* Don’t use fancy encodings if your code is meant to be used in international environments. Python’s default, UTF-8, or even plain ASCII work best in any case.
* Likewise, don’t use non-ASCII characters in identifiers if there is only the slightest chance people speaking a different language will read or maintain the code.

**Footnotes**

|  |  |
| --- | --- |
| [[1]](https://docs.python.org/3/tutorial/controlflow.html#id1) | Actually, *call by object reference* would be a better description, since if a mutable object is passed, the caller will see any changes the callee makes to it (items inserted into a list). |

# 4. More Control Flow Tools

Besides the [while](https://docs.python.org/3/reference/compound_stmts.html#while) statement just introduced, Python knows the usual control flow statements known from other languages, with some twists.

## 4.1. [if](https://docs.python.org/3/reference/compound_stmts.html#if) Statements

Perhaps the most well-known statement type is the [if](https://docs.python.org/3/reference/compound_stmts.html#if) statement. For example:

>>>

**>>>** x = int(input("Please enter an integer: "))

Please enter an integer: 42

**>>> if** x < 0:

**...**  x = 0

**...**  print('Negative changed to zero')

**... elif** x == 0:

**...**  print('Zero')

**... elif** x == 1:

**...**  print('Single')

**... else**:

**...**  print('More')

**...**

More

There can be zero or more [elif](https://docs.python.org/3/reference/compound_stmts.html#elif) parts, and the [else](https://docs.python.org/3/reference/compound_stmts.html#else) part is optional. The keyword ‘[elif](https://docs.python.org/3/reference/compound_stmts.html#elif)‘ is short for ‘else if’, and is useful to avoid excessive indentation. An [if](https://docs.python.org/3/reference/compound_stmts.html#if) ... [elif](https://docs.python.org/3/reference/compound_stmts.html#elif) ... [elif](https://docs.python.org/3/reference/compound_stmts.html#elif) ... sequence is a substitute for the switch or case statements found in other languages.

## 4.2. [for](https://docs.python.org/3/reference/compound_stmts.html#for) Statements

The [for](https://docs.python.org/3/reference/compound_stmts.html#for) statement in Python differs a bit from what you may be used to in C or Pascal. Rather than always iterating over an arithmetic progression of numbers (like in Pascal), or giving the user the ability to define both the iteration step and halting condition (as C), Python’s [for](https://docs.python.org/3/reference/compound_stmts.html#for) statement iterates over the items of any sequence (a list or a string), in the order that they appear in the sequence. For example (no pun intended):

>>>

**>>>** *# Measure some strings:*

**...** words = ['cat', 'window', 'defenestrate']

**>>> for** w **in** words:

**...**  print(w, len(w))

**...**

cat 3

window 6

defenestrate 12

If you need to modify the sequence you are iterating over while inside the loop (for example to duplicate selected items), it is recommended that you first make a copy. Iterating over a sequence does not implicitly make a copy. The slice notation makes this especially convenient:

>>>

**>>> for** w **in** words[:]: *# Loop over a slice copy of the entire list.*

**...**  **if** len(w) > 6:

**...**  words.insert(0, w)

**...**

**>>>** words

['defenestrate', 'cat', 'window', 'defenestrate']

## 4.3. The [range()](https://docs.python.org/3/library/stdtypes.html#range) Function

If you do need to iterate over a sequence of numbers, the built-in function [range()](https://docs.python.org/3/library/stdtypes.html#range) comes in handy. It generates arithmetic progressions:

>>>

**>>> for** i **in** range(5):

**...**  print(i)

**...**

0

1

2

3

4

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

range(5, 10)

5 through 9

range(0, 10, 3)

0, 3, 6, 9

range(-10, -100, -30)

-10, -40, -70

To iterate over the indices of a sequence, you can combine [range()](https://docs.python.org/3/library/stdtypes.html#range) and [len()](https://docs.python.org/3/library/functions.html#len) as follows:

>>>

**>>>** a = ['Mary', 'had', 'a', 'little', 'lamb']

**>>> for** i **in** range(len(a)):

**...**  print(i, a[i])

**...**

0 Mary

1 had

2 a

3 little

4 lamb

In most such cases, however, it is convenient to use the [enumerate()](https://docs.python.org/3/library/functions.html#enumerate) function, see [Looping Techniques](https://docs.python.org/3/tutorial/datastructures.html#tut-loopidioms).

A strange thing happens if you just print a range:

>>>

**>>>** print(range(10))

range(0, 10)

In many ways the object returned by [range()](https://docs.python.org/3/library/stdtypes.html#range) behaves as if it is a list, but in fact it isn’t. It is an object which returns the successive items of the desired sequence when you iterate over it, but it doesn’t really make the list, thus saving space.

We say such an object is iterable, that is, suitable as a target for functions and constructs that expect something from which they can obtain successive items until the supply is exhausted. We have seen that the [for](https://docs.python.org/3/reference/compound_stmts.html#for) statement is such an iterator. The function [list()](https://docs.python.org/3/library/stdtypes.html#list) is another; it creates lists from iterables:

>>>

**>>>** list(range(5))

[0, 1, 2, 3, 4]

Later we will see more functions that return iterables and take iterables as argument.

## 4.4. [break](https://docs.python.org/3/reference/simple_stmts.html#break) and [continue](https://docs.python.org/3/reference/simple_stmts.html#continue) Statements, and [else](https://docs.python.org/3/reference/compound_stmts.html#else) Clauses on Loops

The [break](https://docs.python.org/3/reference/simple_stmts.html#break) statement, like in C, breaks out of the smallest enclosing [for](https://docs.python.org/3/reference/compound_stmts.html#for) or [while](https://docs.python.org/3/reference/compound_stmts.html#while) loop.

Loop statements may have an else clause; it is executed when the loop terminates through exhaustion of the list (with [for](https://docs.python.org/3/reference/compound_stmts.html#for)) or when the condition becomes false (with [while](https://docs.python.org/3/reference/compound_stmts.html#while)), but not when the loop is terminated by a [break](https://docs.python.org/3/reference/simple_stmts.html#break) statement. This is exemplified by the following loop, which searches for prime numbers:

>>>

**>>> for** n **in** range(2, 10):

**...**  **for** x **in** range(2, n):

**...**  **if** n % x == 0:

**...**  print(n, 'equals', x, '\*', n//x)

**...**  **break**

**...**  **else**:

**...**  *# loop fell through without finding a factor*

**...**  print(n, 'is a prime number')

**...**

2 is a prime number

3 is a prime number

4 equals 2 \* 2

5 is a prime number

6 equals 2 \* 3

7 is a prime number

8 equals 2 \* 4

9 equals 3 \* 3

(Yes, this is the correct code. Look closely: the else clause belongs to the [for](https://docs.python.org/3/reference/compound_stmts.html#for) loop, **not** the [if](https://docs.python.org/3/reference/compound_stmts.html#if)statement.)

When used with a loop, the else clause has more in common with the else clause of a [try](https://docs.python.org/3/reference/compound_stmts.html#try)statement than it does that of [if](https://docs.python.org/3/reference/compound_stmts.html#if) statements: a [try](https://docs.python.org/3/reference/compound_stmts.html#try) statement’s else clause runs when no exception occurs, and a loop’s else clause runs when no break occurs. For more on the [try](https://docs.python.org/3/reference/compound_stmts.html#try) statement and exceptions, see [Handling Exceptions](https://docs.python.org/3/tutorial/errors.html#tut-handling).

The [continue](https://docs.python.org/3/reference/simple_stmts.html#continue) statement, also borrowed from C, continues with the next iteration of the loop:

>>>

**>>> for** num **in** range(2, 10):

**...**  **if** num % 2 == 0:

**...**  print("Found an even number", num)

**...**  **continue**

**...**  print("Found a number", num)

Found an even number 2

Found a number 3

Found an even number 4

Found a number 5

Found an even number 6

Found a number 7

Found an even number 8

Found a number 9

## 4.5. [pass](https://docs.python.org/3/reference/simple_stmts.html#pass) Statements

The [pass](https://docs.python.org/3/reference/simple_stmts.html#pass) statement does nothing. It can be used when a statement is required syntactically but the program requires no action. For example:

>>>

**>>> while** **True**:

**...**  **pass** *# Busy-wait for keyboard interrupt (Ctrl+C)*

**...**

This is commonly used for creating minimal classes:

>>>

**>>> class** **MyEmptyClass**:

**...**  **pass**

**...**

Another place [pass](https://docs.python.org/3/reference/simple_stmts.html#pass) can be used is as a place-holder for a function or conditional body when you are working on new code, allowing you to keep thinking at a more abstract level. The [pass](https://docs.python.org/3/reference/simple_stmts.html#pass) is silently ignored:

>>>

**>>> def** initlog(\*args):

**...**  **pass** *# Remember to implement this!*

**...**

## 4.6. Defining Functions

We can create a function that writes the Fibonacci series to an arbitrary boundary:

>>>

**>>> def** fib(n): *# write Fibonacci series up to n*

**...**  *"""Print a Fibonacci series up to n."""*

**...**  a, b = 0, 1

**...**  **while** a < n:

**...**  print(a, end=' ')

**...**  a, b = b, a+b

**...**  print()

**...**

**>>>** *# Now call the function we just defined:*

**...** fib(2000)

0 1 1 2 3 5 8 13 21 34 55 89 144 233 377 610 987 1597

The keyword [def](https://docs.python.org/3/reference/compound_stmts.html#def) introduces a function definition. It must be followed by the function name and the parenthesized list of formal parameters. The statements that form the body of the function start at the next line, and must be indented.

The first statement of the function body can optionally be a string literal; this string literal is the function’s documentation string, or docstring. (More about docstrings can be found in the section[Documentation Strings](https://docs.python.org/3/tutorial/controlflow.html#tut-docstrings).) There are tools which use docstrings to automatically produce online or printed documentation, or to let the user interactively browse through code; it’s good practice to include docstrings in code that you write, so make a habit of it.

The execution of a function introduces a new symbol table used for the local variables of the function. More precisely, all variable assignments in a function store the value in the local symbol table; whereas variable references first look in the local symbol table, then in the local symbol tables of enclosing functions, then in the global symbol table, and finally in the table of built-in names. Thus, global variables cannot be directly assigned a value within a function (unless named in a [global](https://docs.python.org/3/reference/simple_stmts.html#global)statement), although they may be referenced.

The actual parameters (arguments) to a function call are introduced in the local symbol table of the called function when it is called; thus, arguments are passed using call by value (where the value is always an object reference, not the value of the object). [[1]](https://docs.python.org/3/tutorial/controlflow.html#id2) When a function calls another function, a new local symbol table is created for that call.

A function definition introduces the function name in the current symbol table. The value of the function name has a type that is recognized by the interpreter as a user-defined function. This value can be assigned to another name which can then also be used as a function. This serves as a general renaming mechanism:

>>>

**>>>** fib

<function fib at 10042ed0>

**>>>** f = fib

**>>>** f(100)

0 1 1 2 3 5 8 13 21 34 55 89

Coming from other languages, you might object that fib is not a function but a procedure since it doesn’t return a value. In fact, even functions without a [return](https://docs.python.org/3/reference/simple_stmts.html#return) statement do return a value, albeit a rather boring one. This value is called None (it’s a built-in name). Writing the value None is normally suppressed by the interpreter if it would be the only value written. You can see it if you really want to using [print()](https://docs.python.org/3/library/functions.html#print):

>>>

**>>>** fib(0)

**>>>** print(fib(0))

None

It is simple to write a function that returns a list of the numbers of the Fibonacci series, instead of printing it:

>>>

**>>> def** fib2(n): *# return Fibonacci series up to n*

**...**  *"""Return a list containing the Fibonacci series up to n."""*

**...**  result = []

**...**  a, b = 0, 1

**...**  **while** a < n:

**...**  result.append(a) *# see below*

**...**  a, b = b, a+b

**...**  **return** result

**...**

**>>>** f100 = fib2(100) *# call it*

**>>>** f100 *# write the result*

[0, 1, 1, 2, 3, 5, 8, 13, 21, 34, 55, 89]

This example, as usual, demonstrates some new Python features:

* The [return](https://docs.python.org/3/reference/simple_stmts.html#return) statement returns with a value from a function. [return](https://docs.python.org/3/reference/simple_stmts.html#return) without an expression argument returns None. Falling off the end of a function also returns None.
* The statement result.append(a) calls a method of the list object result. A method is a function that ‘belongs’ to an object and is named obj.methodname, where obj is some object (this may be an expression), and methodname is the name of a method that is defined by the object’s type. Different types define different methods. Methods of different types may have the same name without causing ambiguity. (It is possible to define your own object types and methods, using classes, see [Classes](https://docs.python.org/3/tutorial/classes.html#tut-classes)) The method append() shown in the example is defined for list objects; it adds a new element at the end of the list. In this example it is equivalent toresult = result + [a], but more efficient.

## 4.7. More on Defining Functions

It is also possible to define functions with a variable number of arguments. There are three forms, which can be combined.

### 4.7.1. Default Argument Values

The most useful form is to specify a default value for one or more arguments. This creates a function that can be called with fewer arguments than it is defined to allow. For example:

**def** ask\_ok(prompt, retries=4, reminder='Please try again!'):

**while** **True**:

ok = input(prompt)

**if** ok **in** ('y', 'ye', 'yes'):

**return** **True**

**if** ok **in** ('n', 'no', 'nop', 'nope'):

**return** **False**

retries = retries - 1

**if** retries < 0:

**raise** ValueError('invalid user response')

print(reminder)

This function can be called in several ways:

* giving only the mandatory argument: ask\_ok('Do you really want to quit?')
* giving one of the optional arguments: ask\_ok('OK to overwrite the file?', 2)
* or even giving all arguments: ask\_ok('OK to overwrite the file?', 2, 'Come on, onlyyes or no!')

This example also introduces the [in](https://docs.python.org/3/reference/expressions.html#in) keyword. This tests whether or not a sequence contains a certain value.

The default values are evaluated at the point of function definition in the defining scope, so that

i = 5

**def** f(arg=i):

print(arg)

i = 6

f()

will print 5.

**Important warning:** The default value is evaluated only once. This makes a difference when the default is a mutable object such as a list, dictionary, or instances of most classes. For example, the following function accumulates the arguments passed to it on subsequent calls:

**def** f(a, L=[]):

L.append(a)

**return** L

print(f(1))

print(f(2))

print(f(3))

This will print

[1]

[1, 2]

[1, 2, 3]

If you don’t want the default to be shared between subsequent calls, you can write the function like this instead:

**def** f(a, L=**None**):

**if** L **is** **None**:

L = []

L.append(a)

**return** L

### 4.7.2. Keyword Arguments

Functions can also be called using [keyword arguments](https://docs.python.org/3/glossary.html#term-keyword-argument) of the form kwarg=value. For instance, the following function:

**def** parrot(voltage, state='a stiff', action='voom', type='Norwegian Blue'):

print("-- This parrot wouldn't", action, end=' ')

print("if you put", voltage, "volts through it.")

print("-- Lovely plumage, the", type)

print("-- It's", state, "!")

accepts one required argument (voltage) and three optional arguments (state, action, and type). This function can be called in any of the following ways:

parrot(1000) *# 1 positional argument*

parrot(voltage=1000) *# 1 keyword argument*

parrot(voltage=1000000, action='VOOOOOM') *# 2 keyword arguments*

parrot(action='VOOOOOM', voltage=1000000) *# 2 keyword arguments*

parrot('a million', 'bereft of life', 'jump') *# 3 positional arguments*

parrot('a thousand', state='pushing up the daisies') *# 1 positional, 1 keyword*

but all the following calls would be invalid:

parrot() *# required argument missing*

parrot(voltage=5.0, 'dead') *# non-keyword argument after a keyword argument*

parrot(110, voltage=220) *# duplicate value for the same argument*

parrot(actor='John Cleese') *# unknown keyword argument*

In a function call, keyword arguments must follow positional arguments. All the keyword arguments passed must match one of the arguments accepted by the function (e.g. actor is not a valid argument for the parrot function), and their order is not important. This also includes non-optional arguments (e.g. parrot(voltage=1000) is valid too). No argument may receive a value more than once. Here’s an example that fails due to this restriction:

>>>

**>>> def** function(a):

**...**  **pass**

**...**

**>>>** function(0, a=0)

Traceback (most recent call last):

File "<stdin>", line 1, in ?

TypeError: function() got multiple values for keyword argument 'a'

When a final formal parameter of the form \*\*name is present, it receives a dictionary (see [Mapping Types — dict](https://docs.python.org/3/library/stdtypes.html#typesmapping)) containing all keyword arguments except for those corresponding to a formal parameter. This may be combined with a formal parameter of the form \*name (described in the next subsection) which receives a tuple containing the positional arguments beyond the formal parameter list. (\*namemust occur before \*\*name.) For example, if we define a function like this:

**def** cheeseshop(kind, \*arguments, \*\*keywords):

print("-- Do you have any", kind, "?")

print("-- I'm sorry, we're all out of", kind)

**for** arg **in** arguments:

print(arg)

print("-" \* 40)

keys = sorted(keywords.keys())

**for** kw **in** keys:

print(kw, ":", keywords[kw])

It could be called like this:

cheeseshop("Limburger", "It's very runny, sir.",

"It's really very, VERY runny, sir.",

shopkeeper="Michael Palin",

client="John Cleese",

sketch="Cheese Shop Sketch")

and of course it would print:

-- Do you have any Limburger ?

-- I'm sorry, we're all out of Limburger

It's very runny, sir.

It's really very, VERY runny, sir.

----------------------------------------

client : John Cleese

shopkeeper : Michael Palin

sketch : Cheese Shop Sketch

Note that the list of keyword argument names is created by sorting the result of the keywords dictionary’s keys() method before printing its contents; if this is not done, the order in which the arguments are printed is undefined.

### 4.7.3. Arbitrary Argument Lists

Finally, the least frequently used option is to specify that a function can be called with an arbitrary number of arguments. These arguments will be wrapped up in a tuple (see [Tuples and Sequences](https://docs.python.org/3/tutorial/datastructures.html#tut-tuples)). Before the variable number of arguments, zero or more normal arguments may occur.

**def** write\_multiple\_items(file, separator, \*args):

file.write(separator.join(args))

Normally, these variadic arguments will be last in the list of formal parameters, because they scoop up all remaining input arguments that are passed to the function. Any formal parameters which occur after the \*args parameter are ‘keyword-only’ arguments, meaning that they can only be used as keywords rather than positional arguments.

>>>

**>>> def** concat(\*args, sep="/"):

**...**  **return** sep.join(args)

**...**

**>>>** concat("earth", "mars", "venus")

'earth/mars/venus'

**>>>** concat("earth", "mars", "venus", sep=".")

'earth.mars.venus'

### 4.7.4. Unpacking Argument Lists

The reverse situation occurs when the arguments are already in a list or tuple but need to be unpacked for a function call requiring separate positional arguments. For instance, the built-in [range()](https://docs.python.org/3/library/stdtypes.html#range)function expects separate start and stop arguments. If they are not available separately, write the function call with the \*-operator to unpack the arguments out of a list or tuple:

>>>

**>>>** list(range(3, 6)) *# normal call with separate arguments*

[3, 4, 5]

**>>>** args = [3, 6]

**>>>** list(range(\*args)) *# call with arguments unpacked from a list*

[3, 4, 5]

In the same fashion, dictionaries can deliver keyword arguments with the \*\*-operator:

>>>

**>>> def** parrot(voltage, state='a stiff', action='voom'):

**...**  print("-- This parrot wouldn't", action, end=' ')

**...**  print("if you put", voltage, "volts through it.", end=' ')

**...**  print("E's", state, "!")

**...**

**>>>** d = {"voltage": "four million", "state": "bleedin' demised", "action": "VOOM"}

**>>>** parrot(\*\*d)

-- This parrot wouldn't VOOM if you put four million volts through it. E's bleedin' demised !

### 4.7.5. Lambda Expressions

Small anonymous functions can be created with the [lambda](https://docs.python.org/3/reference/expressions.html#lambda) keyword. This function returns the sum of its two arguments: lambda a, b: a+b. Lambda functions can be used wherever function objects are required. They are syntactically restricted to a single expression. Semantically, they are just syntactic sugar for a normal function definition. Like nested function definitions, lambda functions can reference variables from the containing scope:

>>>

**>>> def** make\_incrementor(n):

**...**  **return** **lambda** x: x + n

**...**

**>>>** f = make\_incrementor(42)

**>>>** f(0)

42

**>>>** f(1)

43

The above example uses a lambda expression to return a function. Another use is to pass a small function as an argument:

>>>

**>>>** pairs = [(1, 'one'), (2, 'two'), (3, 'three'), (4, 'four')]

**>>>** pairs.sort(key=**lambda** pair: pair[1])

**>>>** pairs

[(4, 'four'), (1, 'one'), (3, 'three'), (2, 'two')]

### 4.7.6. Documentation Strings

Here are some conventions about the content and formatting of documentation strings.

The first line should always be a short, concise summary of the object’s purpose. For brevity, it should not explicitly state the object’s name or type, since these are available by other means (except if the name happens to be a verb describing a function’s operation). This line should begin with a capital letter and end with a period.

If there are more lines in the documentation string, the second line should be blank, visually separating the summary from the rest of the description. The following lines should be one or more paragraphs describing the object’s calling conventions, its side effects, etc.

The Python parser does not strip indentation from multi-line string literals in Python, so tools that process documentation have to strip indentation if desired. This is done using the following convention. The first non-blank line after the first line of the string determines the amount of indentation for the entire documentation string. (We can’t use the first line since it is generally adjacent to the string’s opening quotes so its indentation is not apparent in the string literal.) Whitespace “equivalent” to this indentation is then stripped from the start of all lines of the string. Lines that are indented less should not occur, but if they occur all their leading whitespace should be stripped. Equivalence of whitespace should be tested after expansion of tabs (to 8 spaces, normally).

Here is an example of a multi-line docstring:

>>>

**>>> def** my\_function():

**...**  *"""Do nothing, but document it.*

**...**

**...**  *No, really, it doesn't do anything.*

**...**  *"""*

**...**  **pass**

**...**

**>>>** print(my\_function.\_\_doc\_\_)

Do nothing, but document it.

No, really, it doesn't do anything.

### 4.7.7. Function Annotations

[Function annotations](https://docs.python.org/3/reference/compound_stmts.html#function) are completely optional metadata information about the types used by user-defined functions (see [**PEP 484**](https://www.python.org/dev/peps/pep-0484) for more information).

Annotations are stored in the \_\_annotations\_\_ attribute of the function as a dictionary and have no effect on any other part of the function. Parameter annotations are defined by a colon after the parameter name, followed by an expression evaluating to the value of the annotation. Return annotations are defined by a literal ->, followed by an expression, between the parameter list and the colon denoting the end of the [def](https://docs.python.org/3/reference/compound_stmts.html#def) statement. The following example has a positional argument, a keyword argument, and the return value annotated:

>>>

**>>> def** f(ham: str, eggs: str = 'eggs') -> str:

**...**  print("Annotations:", f.\_\_annotations\_\_)

**...**  print("Arguments:", ham, eggs)

**...**  **return** ham + ' and ' + eggs

**...**

**>>>** f('spam')

Annotations: {'ham': <class 'str'>, 'return': <class 'str'>, 'eggs': <class 'str'>}

Arguments: spam eggs

'spam and eggs'

## 4.8. Intermezzo: Coding Style

Now that you are about to write longer, more complex pieces of Python, it is a good time to talk aboutcoding style. Most languages can be written (or more concise, formatted) in different styles; some are more readable than others. Making it easy for others to read your code is always a good idea, and adopting a nice coding style helps tremendously for that.

For Python, [**PEP 8**](https://www.python.org/dev/peps/pep-0008) has emerged as the style guide that most projects adhere to; it promotes a very readable and eye-pleasing coding style. Every Python developer should read it at some point; here are the most important points extracted for you:

* Use 4-space indentation, and no tabs.

4 spaces are a good compromise between small indentation (allows greater nesting depth) and large indentation (easier to read). Tabs introduce confusion, and are best left out.

* Wrap lines so that they don’t exceed 79 characters.

This helps users with small displays and makes it possible to have several code files side-by-side on larger displays.

* Use blank lines to separate functions and classes, and larger blocks of code inside functions.
* When possible, put comments on a line of their own.
* Use docstrings.
* Use spaces around operators and after commas, but not directly inside bracketing constructs: a= f(1, 2) + g(3, 4).
* Name your classes and functions consistently; the convention is to use CamelCase for classes and lower\_case\_with\_underscores for functions and methods. Always use self as the name for the first method argument (see [A First Look at Classes](https://docs.python.org/3/tutorial/classes.html#tut-firstclasses) for more on classes and methods).
* Don’t use fancy encodings if your code is meant to be used in international environments. Python’s default, UTF-8, or even plain ASCII work best in any case.
* Likewise, don’t use non-ASCII characters in identifiers if there is only the slightest chance people speaking a different language will read or maintain the code.

**Footnotes**

|  |  |
| --- | --- |
| [[1]](https://docs.python.org/3/tutorial/controlflow.html#id1) | Actually, call by object reference would be a better description, since if a mutable object is passed, the caller will see any changes the callee makes to it (items inserted into a list). |

4.6. Defining Functions

We can create a function that writes the Fibonacci series to an arbitrary boundary:

>>>

**>>> def** fib(n): *# write Fibonacci series up to n*

**...**  *"""Print a Fibonacci series up to n."""*

**...**  a, b = 0, 1

**...**  **while** a < n:

**...**  print(a, end=' ')

**...**  a, b = b, a+b

**...**  print()

**...**

**>>>** *# Now call the function we just defined:*

**...** fib(2000)

0 1 1 2 3 5 8 13 21 34 55 89 144 233 377 610 987 1597

The keyword [def](https://docs.python.org/3/reference/compound_stmts.html#def) introduces a function *definition*. It must be followed by the function name and the parenthesized list of formal parameters. The statements that form the body of the function start at the next line, and must be indented.

The first statement of the function body can optionally be a string literal; this string literal is the function’s documentation string, or *docstring*. (More about docstrings can be found in the section[Documentation Strings](https://docs.python.org/3/tutorial/controlflow.html#tut-docstrings).) There are tools which use docstrings to automatically produce online or printed documentation, or to let the user interactively browse through code; it’s good practice to include docstrings in code that you write, so make a habit of it.

The *execution* of a function introduces a new symbol table used for the local variables of the function. More precisely, all variable assignments in a function store the value in the local symbol table; whereas variable references first look in the local symbol table, then in the local symbol tables of enclosing functions, then in the global symbol table, and finally in the table of built-in names. Thus, global variables cannot be directly assigned a value within a function (unless named in a [global](https://docs.python.org/3/reference/simple_stmts.html#global)statement), although they may be referenced.

The actual parameters (arguments) to a function call are introduced in the local symbol table of the called function when it is called; thus, arguments are passed using *call by value* (where the *value* is always an object *reference*, not the value of the object). [[1]](https://docs.python.org/3/tutorial/controlflow.html#id2) When a function calls another function, a new local symbol table is created for that call.

A function definition introduces the function name in the current symbol table. The value of the function name has a type that is recognized by the interpreter as a user-defined function. This value can be assigned to another name which can then also be used as a function. This serves as a general renaming mechanism:

>>>

**>>>** fib

<function fib at 10042ed0>

**>>>** f = fib

**>>>** f(100)

0 1 1 2 3 5 8 13 21 34 55 89

Coming from other languages, you might object that fib is not a function but a procedure since it doesn’t return a value. In fact, even functions without a [return](https://docs.python.org/3/reference/simple_stmts.html#return) statement do return a value, albeit a rather boring one. This value is called None (it’s a built-in name). Writing the value None is normally suppressed by the interpreter if it would be the only value written. You can see it if you really want to using [print()](https://docs.python.org/3/library/functions.html#print):

>>>

**>>>** fib(0)

**>>>** print(fib(0))

None

It is simple to write a function that returns a list of the numbers of the Fibonacci series, instead of printing it:

>>>

**>>> def** fib2(n): *# return Fibonacci series up to n*

**...**  *"""Return a list containing the Fibonacci series up to n."""*

**...**  result = []

**...**  a, b = 0, 1

**...**  **while** a < n:

**...**  result.append(a) *# see below*

**...**  a, b = b, a+b

**...**  **return** result

**...**

**>>>** f100 = fib2(100) *# call it*

**>>>** f100 *# write the result*

[0, 1, 1, 2, 3, 5, 8, 13, 21, 34, 55, 89]

This example, as usual, demonstrates some new Python features:

* The [return](https://docs.python.org/3/reference/simple_stmts.html#return) statement returns with a value from a function. [return](https://docs.python.org/3/reference/simple_stmts.html#return) without an expression argument returns None. Falling off the end of a function also returns None.
* The statement result.append(a) calls a *method* of the list object result. A method is a function that ‘belongs’ to an object and is named obj.methodname, where obj is some object (this may be an expression), and methodname is the name of a method that is defined by the object’s type. Different types define different methods. Methods of different types may have the same name without causing ambiguity. (It is possible to define your own object types and methods, using *classes*, see [Classes](https://docs.python.org/3/tutorial/classes.html#tut-classes)) The method append() shown in the example is defined for list objects; it adds a new element at the end of the list. In this example it is equivalent toresult = result + [a], but more efficient.

4.7. More on Defining Functions

It is also possible to define functions with a variable number of arguments. There are three forms, which can be combined.

4.7.1. Default Argument Values

The most useful form is to specify a default value for one or more arguments. This creates a function that can be called with fewer arguments than it is defined to allow. For example:

**def** ask\_ok(prompt, retries=4, reminder='Please try again!'):

**while** **True**:

ok = input(prompt)

**if** ok **in** ('y', 'ye', 'yes'):

**return** **True**

**if** ok **in** ('n', 'no', 'nop', 'nope'):

**return** **False**

retries = retries - 1

**if** retries < 0:

**raise** ValueError('invalid user response')

print(reminder)

This function can be called in several ways:

* giving only the mandatory argument: ask\_ok('Do you really want to quit?')
* giving one of the optional arguments: ask\_ok('OK to overwrite the file?', 2)
* or even giving all arguments: ask\_ok('OK to overwrite the file?', 2, 'Come on, onlyyes or no!')

This example also introduces the [in](https://docs.python.org/3/reference/expressions.html#in) keyword. This tests whether or not a sequence contains a certain value.

The default values are evaluated at the point of function definition in the *defining* scope, so that

i = 5

**def** f(arg=i):

print(arg)

i = 6

f()

will print 5.

**Important warning:** The default value is evaluated only once. This makes a difference when the default is a mutable object such as a list, dictionary, or instances of most classes. For example, the following function accumulates the arguments passed to it on subsequent calls:

**def** f(a, L=[]):

L.append(a)

**return** L

print(f(1))

print(f(2))

print(f(3))

This will print

[1]

[1, 2]

[1, 2, 3]

If you don’t want the default to be shared between subsequent calls, you can write the function like this instead:

**def** f(a, L=**None**):

**if** L **is** **None**:

L = []

L.append(a)

**return** L

4.7.2. Keyword Arguments

Functions can also be called using [keyword arguments](https://docs.python.org/3/glossary.html#term-keyword-argument) of the form kwarg=value. For instance, the following function:

**def** parrot(voltage, state='a stiff', action='voom', type='Norwegian Blue'):

print("-- This parrot wouldn't", action, end=' ')

print("if you put", voltage, "volts through it.")

print("-- Lovely plumage, the", type)

print("-- It's", state, "!")

accepts one required argument (voltage) and three optional arguments (state, action, and type). This function can be called in any of the following ways:

parrot(1000) *# 1 positional argument*

parrot(voltage=1000) *# 1 keyword argument*

parrot(voltage=1000000, action='VOOOOOM') *# 2 keyword arguments*

parrot(action='VOOOOOM', voltage=1000000) *# 2 keyword arguments*

parrot('a million', 'bereft of life', 'jump') *# 3 positional arguments*

parrot('a thousand', state='pushing up the daisies') *# 1 positional, 1 keyword*

but all the following calls would be invalid:

parrot() *# required argument missing*

parrot(voltage=5.0, 'dead') *# non-keyword argument after a keyword argument*

parrot(110, voltage=220) *# duplicate value for the same argument*

parrot(actor='John Cleese') *# unknown keyword argument*

In a function call, keyword arguments must follow positional arguments. All the keyword arguments passed must match one of the arguments accepted by the function (e.g. actor is not a valid argument for the parrot function), and their order is not important. This also includes non-optional arguments (e.g. parrot(voltage=1000) is valid too). No argument may receive a value more than once. Here’s an example that fails due to this restriction:

>>>

**>>> def** function(a):

**...**  **pass**

**...**

**>>>** function(0, a=0)

Traceback (most recent call last):

File "<stdin>", line 1, in ?

TypeError: function() got multiple values for keyword argument 'a'

When a final formal parameter of the form \*\*name is present, it receives a dictionary (see [Mapping Types — dict](https://docs.python.org/3/library/stdtypes.html#typesmapping)) containing all keyword arguments except for those corresponding to a formal parameter. This may be combined with a formal parameter of the form \*name (described in the next subsection) which receives a tuple containing the positional arguments beyond the formal parameter list. (\*namemust occur before \*\*name.) For example, if we define a function like this:

**def** cheeseshop(kind, \*arguments, \*\*keywords):

print("-- Do you have any", kind, "?")

print("-- I'm sorry, we're all out of", kind)

**for** arg **in** arguments:

print(arg)

print("-" \* 40)

keys = sorted(keywords.keys())

**for** kw **in** keys:

print(kw, ":", keywords[kw])

It could be called like this:

cheeseshop("Limburger", "It's very runny, sir.",

"It's really very, VERY runny, sir.",

shopkeeper="Michael Palin",

client="John Cleese",

sketch="Cheese Shop Sketch")

and of course it would print:

-- Do you have any Limburger ?

-- I'm sorry, we're all out of Limburger

It's very runny, sir.

It's really very, VERY runny, sir.

----------------------------------------

client : John Cleese

shopkeeper : Michael Palin

sketch : Cheese Shop Sketch

Note that the list of keyword argument names is created by sorting the result of the keywords dictionary’s keys() method before printing its contents; if this is not done, the order in which the arguments are printed is undefined.

4.7.3. Arbitrary Argument Lists

Finally, the least frequently used option is to specify that a function can be called with an arbitrary number of arguments. These arguments will be wrapped up in a tuple (see [Tuples and Sequences](https://docs.python.org/3/tutorial/datastructures.html#tut-tuples)). Before the variable number of arguments, zero or more normal arguments may occur.

**def** write\_multiple\_items(file, separator, \*args):

file.write(separator.join(args))

Normally, these variadic arguments will be last in the list of formal parameters, because they scoop up all remaining input arguments that are passed to the function. Any formal parameters which occur after the \*args parameter are ‘keyword-only’ arguments, meaning that they can only be used as keywords rather than positional arguments.

>>>

**>>> def** concat(\*args, sep="/"):

**...**  **return** sep.join(args)

**...**

**>>>** concat("earth", "mars", "venus")

'earth/mars/venus'

**>>>** concat("earth", "mars", "venus", sep=".")

'earth.mars.venus'

4.7.4. Unpacking Argument Lists

The reverse situation occurs when the arguments are already in a list or tuple but need to be unpacked for a function call requiring separate positional arguments. For instance, the built-in [range()](https://docs.python.org/3/library/stdtypes.html#range)function expects separate *start* and *stop* arguments. If they are not available separately, write the function call with the \*-operator to unpack the arguments out of a list or tuple:

>>>

**>>>** list(range(3, 6)) *# normal call with separate arguments*

[3, 4, 5]

**>>>** args = [3, 6]

**>>>** list(range(\*args)) *# call with arguments unpacked from a list*

[3, 4, 5]

In the same fashion, dictionaries can deliver keyword arguments with the \*\*-operator:

>>>

**>>> def** parrot(voltage, state='a stiff', action='voom'):

**...**  print("-- This parrot wouldn't", action, end=' ')

**...**  print("if you put", voltage, "volts through it.", end=' ')

**...**  print("E's", state, "!")

**...**

**>>>** d = {"voltage": "four million", "state": "bleedin' demised", "action": "VOOM"}

**>>>** parrot(\*\*d)

-- This parrot wouldn't VOOM if you put four million volts through it. E's bleedin' demised !

4.7.5. Lambda Expressions

Small anonymous functions can be created with the [lambda](https://docs.python.org/3/reference/expressions.html#lambda) keyword. This function returns the sum of its two arguments: lambda a, b: a+b. Lambda functions can be used wherever function objects are required. They are syntactically restricted to a single expression. Semantically, they are just syntactic sugar for a normal function definition. Like nested function definitions, lambda functions can reference variables from the containing scope:

>>>

**>>> def** make\_incrementor(n):

**...**  **return** **lambda** x: x + n

**...**

**>>>** f = make\_incrementor(42)

**>>>** f(0)

42

**>>>** f(1)

43

The above example uses a lambda expression to return a function. Another use is to pass a small function as an argument:

>>>

**>>>** pairs = [(1, 'one'), (2, 'two'), (3, 'three'), (4, 'four')]

**>>>** pairs.sort(key=**lambda** pair: pair[1])

**>>>** pairs

[(4, 'four'), (1, 'one'), (3, 'three'), (2, 'two')]

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Here are some conventions about the content and formatting of documentation strings.

The first line should always be a short, concise summary of the object’s purpose. For brevity, it should not explicitly state the object’s name or type, since these are available by other means (except if the name happens to be a verb describing a function’s operation). This line should begin with a capital letter and end with a period.

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Here is an example of a multi-line docstring:

>>>

**>>> def** my\_function():

**...**  *"""Do nothing, but document it.*

**...**

**...**  *No, really, it doesn't do anything.*

**...**  *"""*

**...**  **pass**

**...**

**>>>** print(my\_function.\_\_doc\_\_)

Do nothing, but document it.

No, really, it doesn't do anything.

4.7.7. Function Annotations

[Function annotations](https://docs.python.org/3/reference/compound_stmts.html#function) are completely optional metadata information about the types used by user-defined functions (see [**PEP 484**](https://www.python.org/dev/peps/pep-0484) for more information).

Annotations are stored in the \_\_annotations\_\_ attribute of the function as a dictionary and have no effect on any other part of the function. Parameter annotations are defined by a colon after the parameter name, followed by an expression evaluating to the value of the annotation. Return annotations are defined by a literal ->, followed by an expression, between the parameter list and the colon denoting the end of the [def](https://docs.python.org/3/reference/compound_stmts.html#def) statement. The following example has a positional argument, a keyword argument, and the return value annotated:

>>>

**>>> def** f(ham: str, eggs: str = 'eggs') -> str:

**...**  print("Annotations:", f.\_\_annotations\_\_)

**...**  print("Arguments:", ham, eggs)

**...**  **return** ham + ' and ' + eggs

**...**

**>>>** f('spam')

Annotations: {'ham': <class 'str'>, 'return': <class 'str'>, 'eggs': <class 'str'>}

Arguments: spam eggs

'spam and eggs'

4.8. Intermezzo: Coding Style

Now that you are about to write longer, more complex pieces of Python, it is a good time to talk about*coding style*. Most languages can be written (or more concise, *formatted*) in different styles; some are more readable than others. Making it easy for others to read your code is always a good idea, and adopting a nice coding style helps tremendously for that.

For Python, [**PEP 8**](https://www.python.org/dev/peps/pep-0008) has emerged as the style guide that most projects adhere to; it promotes a very readable and eye-pleasing coding style. Every Python developer should read it at some point; here are the most important points extracted for you:

* Use 4-space indentation, and no tabs.

4 spaces are a good compromise between small indentation (allows greater nesting depth) and large indentation (easier to read). Tabs introduce confusion, and are best left out.

* Wrap lines so that they don’t exceed 79 characters.

This helps users with small displays and makes it possible to have several code files side-by-side on larger displays.

* Use blank lines to separate functions and classes, and larger blocks of code inside functions.
* When possible, put comments on a line of their own.
* Use docstrings.
* Use spaces around operators and after commas, but not directly inside bracketing constructs: a= f(1, 2) + g(3, 4).
* Name your classes and functions consistently; the convention is to use CamelCase for classes and lower\_case\_with\_underscores for functions and methods. Always use self as the name for the first method argument (see [A First Look at Classes](https://docs.python.org/3/tutorial/classes.html#tut-firstclasses) for more on classes and methods).
* Don’t use fancy encodings if your code is meant to be used in international environments. Python’s default, UTF-8, or even plain ASCII work best in any case.
* Likewise, don’t use non-ASCII characters in identifiers if there is only the slightest chance people speaking a different language will read or maintain the code.

**Footnotes**

|  |  |
| --- | --- |
| [[1]](https://docs.python.org/3/tutorial/controlflow.html#id1) | Actually, *call by object reference* would be a better description, since if a mutable object is passed, the caller will see any changes the callee makes to it (items inserted into a list). |

4.7. More on Defining Functions

It is also possible to define functions with a variable number of arguments. There are three forms, which can be combined.

4.7.1. Default Argument Values

The most useful form is to specify a default value for one or more arguments. This creates a function that can be called with fewer arguments than it is defined to allow. For example:

**def** ask\_ok(prompt, retries=4, reminder='Please try again!'):

**while** **True**:

ok = input(prompt)

**if** ok **in** ('y', 'ye', 'yes'):

**return** **True**

**if** ok **in** ('n', 'no', 'nop', 'nope'):

**return** **False**

retries = retries - 1

**if** retries < 0:

**raise** ValueError('invalid user response')

print(reminder)

This function can be called in several ways:

* giving only the mandatory argument: ask\_ok('Do you really want to quit?')
* giving one of the optional arguments: ask\_ok('OK to overwrite the file?', 2)
* or even giving all arguments: ask\_ok('OK to overwrite the file?', 2, 'Come on, onlyyes or no!')

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The default values are evaluated at the point of function definition in the *defining* scope, so that

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**def** f(arg=i):

print(arg)

i = 6

f()

will print 5.

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**def** f(a, L=[]):

L.append(a)

**return** L

print(f(1))

print(f(2))

print(f(3))

This will print

[1]

[1, 2]

[1, 2, 3]

If you don’t want the default to be shared between subsequent calls, you can write the function like this instead:

**def** f(a, L=**None**):

**if** L **is** **None**:

L = []

L.append(a)

**return** L

4.7.2. Keyword Arguments

Functions can also be called using [keyword arguments](https://docs.python.org/3/glossary.html#term-keyword-argument) of the form kwarg=value. For instance, the following function:

**def** parrot(voltage, state='a stiff', action='voom', type='Norwegian Blue'):

print("-- This parrot wouldn't", action, end=' ')

print("if you put", voltage, "volts through it.")

print("-- Lovely plumage, the", type)

print("-- It's", state, "!")

accepts one required argument (voltage) and three optional arguments (state, action, and type). This function can be called in any of the following ways:

parrot(1000) *# 1 positional argument*

parrot(voltage=1000) *# 1 keyword argument*

parrot(voltage=1000000, action='VOOOOOM') *# 2 keyword arguments*

parrot(action='VOOOOOM', voltage=1000000) *# 2 keyword arguments*

parrot('a million', 'bereft of life', 'jump') *# 3 positional arguments*

parrot('a thousand', state='pushing up the daisies') *# 1 positional, 1 keyword*

but all the following calls would be invalid:

parrot() *# required argument missing*

parrot(voltage=5.0, 'dead') *# non-keyword argument after a keyword argument*

parrot(110, voltage=220) *# duplicate value for the same argument*

parrot(actor='John Cleese') *# unknown keyword argument*

In a function call, keyword arguments must follow positional arguments. All the keyword arguments passed must match one of the arguments accepted by the function (e.g. actor is not a valid argument for the parrot function), and their order is not important. This also includes non-optional arguments (e.g. parrot(voltage=1000) is valid too). No argument may receive a value more than once. Here’s an example that fails due to this restriction:

>>>

**>>> def** function(a):

**...**  **pass**

**...**

**>>>** function(0, a=0)

Traceback (most recent call last):

File "<stdin>", line 1, in ?

TypeError: function() got multiple values for keyword argument 'a'

When a final formal parameter of the form \*\*name is present, it receives a dictionary (see [Mapping Types — dict](https://docs.python.org/3/library/stdtypes.html#typesmapping)) containing all keyword arguments except for those corresponding to a formal parameter. This may be combined with a formal parameter of the form \*name (described in the next subsection) which receives a tuple containing the positional arguments beyond the formal parameter list. (\*namemust occur before \*\*name.) For example, if we define a function like this:

**def** cheeseshop(kind, \*arguments, \*\*keywords):

print("-- Do you have any", kind, "?")

print("-- I'm sorry, we're all out of", kind)

**for** arg **in** arguments:

print(arg)

print("-" \* 40)

keys = sorted(keywords.keys())

**for** kw **in** keys:

print(kw, ":", keywords[kw])

It could be called like this:

cheeseshop("Limburger", "It's very runny, sir.",

"It's really very, VERY runny, sir.",

shopkeeper="Michael Palin",

client="John Cleese",

sketch="Cheese Shop Sketch")

and of course it would print:

-- Do you have any Limburger ?

-- I'm sorry, we're all out of Limburger

It's very runny, sir.

It's really very, VERY runny, sir.

----------------------------------------

client : John Cleese

shopkeeper : Michael Palin

sketch : Cheese Shop Sketch

Note that the list of keyword argument names is created by sorting the result of the keywords dictionary’s keys() method before printing its contents; if this is not done, the order in which the arguments are printed is undefined.

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Finally, the least frequently used option is to specify that a function can be called with an arbitrary number of arguments. These arguments will be wrapped up in a tuple (see [Tuples and Sequences](https://docs.python.org/3/tutorial/datastructures.html#tut-tuples)). Before the variable number of arguments, zero or more normal arguments may occur.

**def** write\_multiple\_items(file, separator, \*args):

file.write(separator.join(args))

Normally, these variadic arguments will be last in the list of formal parameters, because they scoop up all remaining input arguments that are passed to the function. Any formal parameters which occur after the \*args parameter are ‘keyword-only’ arguments, meaning that they can only be used as keywords rather than positional arguments.

>>>

**>>> def** concat(\*args, sep="/"):

**...**  **return** sep.join(args)

**...**

**>>>** concat("earth", "mars", "venus")

'earth/mars/venus'

**>>>** concat("earth", "mars", "venus", sep=".")

'earth.mars.venus'

4.7.4. Unpacking Argument Lists

The reverse situation occurs when the arguments are already in a list or tuple but need to be unpacked for a function call requiring separate positional arguments. For instance, the built-in [range()](https://docs.python.org/3/library/stdtypes.html#range)function expects separate *start* and *stop* arguments. If they are not available separately, write the function call with the \*-operator to unpack the arguments out of a list or tuple:

>>>

**>>>** list(range(3, 6)) *# normal call with separate arguments*

[3, 4, 5]

**>>>** args = [3, 6]

**>>>** list(range(\*args)) *# call with arguments unpacked from a list*

[3, 4, 5]

In the same fashion, dictionaries can deliver keyword arguments with the \*\*-operator:

>>>

**>>> def** parrot(voltage, state='a stiff', action='voom'):

**...**  print("-- This parrot wouldn't", action, end=' ')

**...**  print("if you put", voltage, "volts through it.", end=' ')

**...**  print("E's", state, "!")

**...**

**>>>** d = {"voltage": "four million", "state": "bleedin' demised", "action": "VOOM"}

**>>>** parrot(\*\*d)

-- This parrot wouldn't VOOM if you put four million volts through it. E's bleedin' demised !

4.7.5. Lambda Expressions

Small anonymous functions can be created with the [lambda](https://docs.python.org/3/reference/expressions.html#lambda) keyword. This function returns the sum of its two arguments: lambda a, b: a+b. Lambda functions can be used wherever function objects are required. They are syntactically restricted to a single expression. Semantically, they are just syntactic sugar for a normal function definition. Like nested function definitions, lambda functions can reference variables from the containing scope:

>>>

**>>> def** make\_incrementor(n):

**...**  **return** **lambda** x: x + n

**...**

**>>>** f = make\_incrementor(42)

**>>>** f(0)

42

**>>>** f(1)

43

The above example uses a lambda expression to return a function. Another use is to pass a small function as an argument:

>>>

**>>>** pairs = [(1, 'one'), (2, 'two'), (3, 'three'), (4, 'four')]

**>>>** pairs.sort(key=**lambda** pair: pair[1])

**>>>** pairs

[(4, 'four'), (1, 'one'), (3, 'three'), (2, 'two')]

4.7.6. Documentation Strings

Here are some conventions about the content and formatting of documentation strings.

The first line should always be a short, concise summary of the object’s purpose. For brevity, it should not explicitly state the object’s name or type, since these are available by other means (except if the name happens to be a verb describing a function’s operation). This line should begin with a capital letter and end with a period.

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Here is an example of a multi-line docstring:

>>>

**>>> def** my\_function():

**...**  *"""Do nothing, but document it.*

**...**

**...**  *No, really, it doesn't do anything.*

**...**  *"""*

**...**  **pass**

**...**

**>>>** print(my\_function.\_\_doc\_\_)

Do nothing, but document it.

No, really, it doesn't do anything.

4.7.7. Function Annotations

[Function annotations](https://docs.python.org/3/reference/compound_stmts.html#function) are completely optional metadata information about the types used by user-defined functions (see [**PEP 484**](https://www.python.org/dev/peps/pep-0484) for more information).

Annotations are stored in the \_\_annotations\_\_ attribute of the function as a dictionary and have no effect on any other part of the function. Parameter annotations are defined by a colon after the parameter name, followed by an expression evaluating to the value of the annotation. Return annotations are defined by a literal ->, followed by an expression, between the parameter list and the colon denoting the end of the [def](https://docs.python.org/3/reference/compound_stmts.html#def) statement. The following example has a positional argument, a keyword argument, and the return value annotated:

>>>

**>>> def** f(ham: str, eggs: str = 'eggs') -> str:

**...**  print("Annotations:", f.\_\_annotations\_\_)

**...**  print("Arguments:", ham, eggs)

**...**  **return** ham + ' and ' + eggs

**...**

**>>>** f('spam')

Annotations: {'ham': <class 'str'>, 'return': <class 'str'>, 'eggs': <class 'str'>}

Arguments: spam eggs

'spam and eggs'

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* Use docstrings.
* Use spaces around operators and after commas, but not directly inside bracketing constructs: a= f(1, 2) + g(3, 4).
* Name your classes and functions consistently; the convention is to use CamelCase for classes and lower\_case\_with\_underscores for functions and methods. Always use self as the name for the first method argument (see [A First Look at Classes](https://docs.python.org/3/tutorial/classes.html#tut-firstclasses) for more on classes and methods).
* Don’t use fancy encodings if your code is meant to be used in international environments. Python’s default, UTF-8, or even plain ASCII work best in any case.
* Likewise, don’t use non-ASCII characters in identifiers if there is only the slightest chance people speaking a different language will read or maintain the code.

**Footnotes**

|  |  |
| --- | --- |
| [[1]](https://docs.python.org/3/tutorial/controlflow.html#id1) | Actually, *call by object reference* would be a better description, since if a mutable object is passed, the caller will see any changes the callee makes to it (items inserted into a list). |

4.7.1. Default Argument Values

The most useful form is to specify a default value for one or more arguments. This creates a function that can be called with fewer arguments than it is defined to allow. For example:

**def** ask\_ok(prompt, retries=4, reminder='Please try again!'):

**while** **True**:

ok = input(prompt)

**if** ok **in** ('y', 'ye', 'yes'):

**return** **True**

**if** ok **in** ('n', 'no', 'nop', 'nope'):

**return** **False**

retries = retries - 1

**if** retries < 0:

**raise** ValueError('invalid user response')

print(reminder)

This function can be called in several ways:

* giving only the mandatory argument: ask\_ok('Do you really want to quit?')
* giving one of the optional arguments: ask\_ok('OK to overwrite the file?', 2)
* or even giving all arguments: ask\_ok('OK to overwrite the file?', 2, 'Come on, onlyyes or no!')

This example also introduces the [in](https://docs.python.org/3/reference/expressions.html#in) keyword. This tests whether or not a sequence contains a certain value.

The default values are evaluated at the point of function definition in the *defining* scope, so that

i = 5

**def** f(arg=i):

print(arg)

i = 6

f()

will print 5.

**Important warning:** The default value is evaluated only once. This makes a difference when the default is a mutable object such as a list, dictionary, or instances of most classes. For example, the following function accumulates the arguments passed to it on subsequent calls:

**def** f(a, L=[]):

L.append(a)

**return** L

print(f(1))

print(f(2))

print(f(3))

This will print

[1]

[1, 2]

[1, 2, 3]

If you don’t want the default to be shared between subsequent calls, you can write the function like this instead:

**def** f(a, L=**None**):

**if** L **is** **None**:

L = []

L.append(a)

**return** L

4.7.2. Keyword Arguments

Functions can also be called using [keyword arguments](https://docs.python.org/3/glossary.html#term-keyword-argument) of the form kwarg=value. For instance, the following function:

**def** parrot(voltage, state='a stiff', action='voom', type='Norwegian Blue'):

print("-- This parrot wouldn't", action, end=' ')

print("if you put", voltage, "volts through it.")

print("-- Lovely plumage, the", type)

print("-- It's", state, "!")

accepts one required argument (voltage) and three optional arguments (state, action, and type). This function can be called in any of the following ways:

parrot(1000) *# 1 positional argument*

parrot(voltage=1000) *# 1 keyword argument*

parrot(voltage=1000000, action='VOOOOOM') *# 2 keyword arguments*

parrot(action='VOOOOOM', voltage=1000000) *# 2 keyword arguments*

parrot('a million', 'bereft of life', 'jump') *# 3 positional arguments*

parrot('a thousand', state='pushing up the daisies') *# 1 positional, 1 keyword*

but all the following calls would be invalid:

parrot() *# required argument missing*

parrot(voltage=5.0, 'dead') *# non-keyword argument after a keyword argument*

parrot(110, voltage=220) *# duplicate value for the same argument*

parrot(actor='John Cleese') *# unknown keyword argument*

In a function call, keyword arguments must follow positional arguments. All the keyword arguments passed must match one of the arguments accepted by the function (e.g. actor is not a valid argument for the parrot function), and their order is not important. This also includes non-optional arguments (e.g. parrot(voltage=1000) is valid too). No argument may receive a value more than once. Here’s an example that fails due to this restriction:

>>>

**>>> def** function(a):

**...**  **pass**

**...**

**>>>** function(0, a=0)

Traceback (most recent call last):

File "<stdin>", line 1, in ?

TypeError: function() got multiple values for keyword argument 'a'

When a final formal parameter of the form \*\*name is present, it receives a dictionary (see [Mapping Types — dict](https://docs.python.org/3/library/stdtypes.html#typesmapping)) containing all keyword arguments except for those corresponding to a formal parameter. This may be combined with a formal parameter of the form \*name (described in the next subsection) which receives a tuple containing the positional arguments beyond the formal parameter list. (\*namemust occur before \*\*name.) For example, if we define a function like this:

**def** cheeseshop(kind, \*arguments, \*\*keywords):

print("-- Do you have any", kind, "?")

print("-- I'm sorry, we're all out of", kind)

**for** arg **in** arguments:

print(arg)

print("-" \* 40)

keys = sorted(keywords.keys())

**for** kw **in** keys:

print(kw, ":", keywords[kw])

It could be called like this:

cheeseshop("Limburger", "It's very runny, sir.",

"It's really very, VERY runny, sir.",

shopkeeper="Michael Palin",

client="John Cleese",

sketch="Cheese Shop Sketch")

and of course it would print:

-- Do you have any Limburger ?

-- I'm sorry, we're all out of Limburger

It's very runny, sir.

It's really very, VERY runny, sir.

----------------------------------------

client : John Cleese

shopkeeper : Michael Palin

sketch : Cheese Shop Sketch

Note that the list of keyword argument names is created by sorting the result of the keywords dictionary’s keys() method before printing its contents; if this is not done, the order in which the arguments are printed is undefined.

4.7.3. Arbitrary Argument Lists

Finally, the least frequently used option is to specify that a function can be called with an arbitrary number of arguments. These arguments will be wrapped up in a tuple (see [Tuples and Sequences](https://docs.python.org/3/tutorial/datastructures.html#tut-tuples)). Before the variable number of arguments, zero or more normal arguments may occur.

**def** write\_multiple\_items(file, separator, \*args):

file.write(separator.join(args))

Normally, these variadic arguments will be last in the list of formal parameters, because they scoop up all remaining input arguments that are passed to the function. Any formal parameters which occur after the \*args parameter are ‘keyword-only’ arguments, meaning that they can only be used as keywords rather than positional arguments.

>>>

**>>> def** concat(\*args, sep="/"):

**...**  **return** sep.join(args)

**...**

**>>>** concat("earth", "mars", "venus")

'earth/mars/venus'

**>>>** concat("earth", "mars", "venus", sep=".")

'earth.mars.venus'

4.7.4. Unpacking Argument Lists

The reverse situation occurs when the arguments are already in a list or tuple but need to be unpacked for a function call requiring separate positional arguments. For instance, the built-in [range()](https://docs.python.org/3/library/stdtypes.html#range)function expects separate *start* and *stop* arguments. If they are not available separately, write the function call with the \*-operator to unpack the arguments out of a list or tuple:

>>>

**>>>** list(range(3, 6)) *# normal call with separate arguments*

[3, 4, 5]

**>>>** args = [3, 6]

**>>>** list(range(\*args)) *# call with arguments unpacked from a list*

[3, 4, 5]

In the same fashion, dictionaries can deliver keyword arguments with the \*\*-operator:

>>>

**>>> def** parrot(voltage, state='a stiff', action='voom'):

**...**  print("-- This parrot wouldn't", action, end=' ')

**...**  print("if you put", voltage, "volts through it.", end=' ')

**...**  print("E's", state, "!")

**...**

**>>>** d = {"voltage": "four million", "state": "bleedin' demised", "action": "VOOM"}

**>>>** parrot(\*\*d)

-- This parrot wouldn't VOOM if you put four million volts through it. E's bleedin' demised !

4.7.5. Lambda Expressions

Small anonymous functions can be created with the [lambda](https://docs.python.org/3/reference/expressions.html#lambda) keyword. This function returns the sum of its two arguments: lambda a, b: a+b. Lambda functions can be used wherever function objects are required. They are syntactically restricted to a single expression. Semantically, they are just syntactic sugar for a normal function definition. Like nested function definitions, lambda functions can reference variables from the containing scope:

>>>

**>>> def** make\_incrementor(n):

**...**  **return** **lambda** x: x + n

**...**

**>>>** f = make\_incrementor(42)

**>>>** f(0)

42

**>>>** f(1)

43

The above example uses a lambda expression to return a function. Another use is to pass a small function as an argument:

>>>

**>>>** pairs = [(1, 'one'), (2, 'two'), (3, 'three'), (4, 'four')]

**>>>** pairs.sort(key=**lambda** pair: pair[1])

**>>>** pairs

[(4, 'four'), (1, 'one'), (3, 'three'), (2, 'two')]

4.7.6. Documentation Strings

Here are some conventions about the content and formatting of documentation strings.

The first line should always be a short, concise summary of the object’s purpose. For brevity, it should not explicitly state the object’s name or type, since these are available by other means (except if the name happens to be a verb describing a function’s operation). This line should begin with a capital letter and end with a period.

If there are more lines in the documentation string, the second line should be blank, visually separating the summary from the rest of the description. The following lines should be one or more paragraphs describing the object’s calling conventions, its side effects, etc.

The Python parser does not strip indentation from multi-line string literals in Python, so tools that process documentation have to strip indentation if desired. This is done using the following convention. The first non-blank line *after* the first line of the string determines the amount of indentation for the entire documentation string. (We can’t use the first line since it is generally adjacent to the string’s opening quotes so its indentation is not apparent in the string literal.) Whitespace “equivalent” to this indentation is then stripped from the start of all lines of the string. Lines that are indented less should not occur, but if they occur all their leading whitespace should be stripped. Equivalence of whitespace should be tested after expansion of tabs (to 8 spaces, normally).

Here is an example of a multi-line docstring:

>>>

**>>> def** my\_function():

**...**  *"""Do nothing, but document it.*

**...**

**...**  *No, really, it doesn't do anything.*

**...**  *"""*

**...**  **pass**

**...**

**>>>** print(my\_function.\_\_doc\_\_)

Do nothing, but document it.

No, really, it doesn't do anything.

4.7.7. Function Annotations

[Function annotations](https://docs.python.org/3/reference/compound_stmts.html#function) are completely optional metadata information about the types used by user-defined functions (see [**PEP 484**](https://www.python.org/dev/peps/pep-0484) for more information).

Annotations are stored in the \_\_annotations\_\_ attribute of the function as a dictionary and have no effect on any other part of the function. Parameter annotations are defined by a colon after the parameter name, followed by an expression evaluating to the value of the annotation. Return annotations are defined by a literal ->, followed by an expression, between the parameter list and the colon denoting the end of the [def](https://docs.python.org/3/reference/compound_stmts.html#def) statement. The following example has a positional argument, a keyword argument, and the return value annotated:

>>>

**>>> def** f(ham: str, eggs: str = 'eggs') -> str:

**...**  print("Annotations:", f.\_\_annotations\_\_)

**...**  print("Arguments:", ham, eggs)

**...**  **return** ham + ' and ' + eggs

**...**

**>>>** f('spam')

Annotations: {'ham': <class 'str'>, 'return': <class 'str'>, 'eggs': <class 'str'>}

Arguments: spam eggs

'spam and eggs'

4.8. Intermezzo: Coding Style

Now that you are about to write longer, more complex pieces of Python, it is a good time to talk about*coding style*. Most languages can be written (or more concise, *formatted*) in different styles; some are more readable than others. Making it easy for others to read your code is always a good idea, and adopting a nice coding style helps tremendously for that.

For Python, [**PEP 8**](https://www.python.org/dev/peps/pep-0008) has emerged as the style guide that most projects adhere to; it promotes a very readable and eye-pleasing coding style. Every Python developer should read it at some point; here are the most important points extracted for you:

* Use 4-space indentation, and no tabs.

4 spaces are a good compromise between small indentation (allows greater nesting depth) and large indentation (easier to read). Tabs introduce confusion, and are best left out.

* Wrap lines so that they don’t exceed 79 characters.

This helps users with small displays and makes it possible to have several code files side-by-side on larger displays.

* Use blank lines to separate functions and classes, and larger blocks of code inside functions.
* When possible, put comments on a line of their own.
* Use docstrings.
* Use spaces around operators and after commas, but not directly inside bracketing constructs: a= f(1, 2) + g(3, 4).
* Name your classes and functions consistently; the convention is to use CamelCase for classes and lower\_case\_with\_underscores for functions and methods. Always use self as the name for the first method argument (see [A First Look at Classes](https://docs.python.org/3/tutorial/classes.html#tut-firstclasses) for more on classes and methods).
* Don’t use fancy encodings if your code is meant to be used in international environments. Python’s default, UTF-8, or even plain ASCII work best in any case.
* Likewise, don’t use non-ASCII characters in identifiers if there is only the slightest chance people speaking a different language will read or maintain the code.

**Footnotes**

|  |  |
| --- | --- |
| [[1]](https://docs.python.org/3/tutorial/controlflow.html#id1) | Actually, *call by object reference* would be a better description, since if a mutable object is passed, the caller will see any changes the callee makes to it (items inserted into a list). |

# 4. More Control Flow Tools

Besides the [while](https://docs.python.org/3/reference/compound_stmts.html#while) statement just introduced, Python knows the usual control flow statements known from other languages, with some twists.

## 4.1. [if](https://docs.python.org/3/reference/compound_stmts.html#if) Statements

Perhaps the most well-known statement type is the [if](https://docs.python.org/3/reference/compound_stmts.html#if) statement. For example:

>>>

**>>>** x = int(input("Please enter an integer: "))

Please enter an integer: 42

**>>> if** x < 0:

**...**  x = 0

**...**  print('Negative changed to zero')

**... elif** x == 0:

**...**  print('Zero')

**... elif** x == 1:

**...**  print('Single')

**... else**:

**...**  print('More')

**...**

More

There can be zero or more [elif](https://docs.python.org/3/reference/compound_stmts.html#elif) parts, and the [else](https://docs.python.org/3/reference/compound_stmts.html#else) part is optional. The keyword ‘[elif](https://docs.python.org/3/reference/compound_stmts.html#elif)‘ is short for ‘else if’, and is useful to avoid excessive indentation. An [if](https://docs.python.org/3/reference/compound_stmts.html#if) ... [elif](https://docs.python.org/3/reference/compound_stmts.html#elif) ... [elif](https://docs.python.org/3/reference/compound_stmts.html#elif) ... sequence is a substitute for the switch or case statements found in other languages.

## 4.2. [for](https://docs.python.org/3/reference/compound_stmts.html#for) Statements

The [for](https://docs.python.org/3/reference/compound_stmts.html#for) statement in Python differs a bit from what you may be used to in C or Pascal. Rather than always iterating over an arithmetic progression of numbers (like in Pascal), or giving the user the ability to define both the iteration step and halting condition (as C), Python’s [for](https://docs.python.org/3/reference/compound_stmts.html#for) statement iterates over the items of any sequence (a list or a string), in the order that they appear in the sequence. For example (no pun intended):

>>>

**>>>** *# Measure some strings:*

**...** words = ['cat', 'window', 'defenestrate']

**>>> for** w **in** words:

**...**  print(w, len(w))

**...**

cat 3

window 6

defenestrate 12

If you need to modify the sequence you are iterating over while inside the loop (for example to duplicate selected items), it is recommended that you first make a copy. Iterating over a sequence does not implicitly make a copy. The slice notation makes this especially convenient:

>>>

**>>> for** w **in** words[:]: *# Loop over a slice copy of the entire list.*

**...**  **if** len(w) > 6:

**...**  words.insert(0, w)

**...**

**>>>** words

['defenestrate', 'cat', 'window', 'defenestrate']

## 4.3. The [range()](https://docs.python.org/3/library/stdtypes.html#range) Function

If you do need to iterate over a sequence of numbers, the built-in function [range()](https://docs.python.org/3/library/stdtypes.html#range) comes in handy. It generates arithmetic progressions:

>>>

**>>> for** i **in** range(5):

**...**  print(i)

**...**

0

1

2

3

4

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

range(5, 10)

5 through 9

range(0, 10, 3)

0, 3, 6, 9

range(-10, -100, -30)

-10, -40, -70

To iterate over the indices of a sequence, you can combine [range()](https://docs.python.org/3/library/stdtypes.html#range) and [len()](https://docs.python.org/3/library/functions.html#len) as follows:

>>>

**>>>** a = ['Mary', 'had', 'a', 'little', 'lamb']

**>>> for** i **in** range(len(a)):

**...**  print(i, a[i])

**...**

0 Mary

1 had

2 a

3 little

4 lamb

In most such cases, however, it is convenient to use the [enumerate()](https://docs.python.org/3/library/functions.html#enumerate) function, see [Looping Techniques](https://docs.python.org/3/tutorial/datastructures.html#tut-loopidioms).

A strange thing happens if you just print a range:

>>>

**>>>** print(range(10))

range(0, 10)

In many ways the object returned by [range()](https://docs.python.org/3/library/stdtypes.html#range) behaves as if it is a list, but in fact it isn’t. It is an object which returns the successive items of the desired sequence when you iterate over it, but it doesn’t really make the list, thus saving space.

We say such an object is iterable, that is, suitable as a target for functions and constructs that expect something from which they can obtain successive items until the supply is exhausted. We have seen that the [for](https://docs.python.org/3/reference/compound_stmts.html#for) statement is such an iterator. The function [list()](https://docs.python.org/3/library/stdtypes.html#list) is another; it creates lists from iterables:

>>>

**>>>** list(range(5))

[0, 1, 2, 3, 4]

Later we will see more functions that return iterables and take iterables as argument.

## 4.4. [break](https://docs.python.org/3/reference/simple_stmts.html#break) and [continue](https://docs.python.org/3/reference/simple_stmts.html#continue) Statements, and [else](https://docs.python.org/3/reference/compound_stmts.html#else) Clauses on Loops

The [break](https://docs.python.org/3/reference/simple_stmts.html#break) statement, like in C, breaks out of the smallest enclosing [for](https://docs.python.org/3/reference/compound_stmts.html#for) or [while](https://docs.python.org/3/reference/compound_stmts.html#while) loop.

Loop statements may have an else clause; it is executed when the loop terminates through exhaustion of the list (with [for](https://docs.python.org/3/reference/compound_stmts.html#for)) or when the condition becomes false (with [while](https://docs.python.org/3/reference/compound_stmts.html#while)), but not when the loop is terminated by a [break](https://docs.python.org/3/reference/simple_stmts.html#break) statement. This is exemplified by the following loop, which searches for prime numbers:

>>>

**>>> for** n **in** range(2, 10):

**...**  **for** x **in** range(2, n):

**...**  **if** n % x == 0:

**...**  print(n, 'equals', x, '\*', n//x)

**...**  **break**

**...**  **else**:

**...**  *# loop fell through without finding a factor*

**...**  print(n, 'is a prime number')

**...**

2 is a prime number

3 is a prime number

4 equals 2 \* 2

5 is a prime number

6 equals 2 \* 3

7 is a prime number

8 equals 2 \* 4

9 equals 3 \* 3

(Yes, this is the correct code. Look closely: the else clause belongs to the [for](https://docs.python.org/3/reference/compound_stmts.html#for) loop, **not** the [if](https://docs.python.org/3/reference/compound_stmts.html#if)statement.)

When used with a loop, the else clause has more in common with the else clause of a [try](https://docs.python.org/3/reference/compound_stmts.html#try)statement than it does that of [if](https://docs.python.org/3/reference/compound_stmts.html#if) statements: a [try](https://docs.python.org/3/reference/compound_stmts.html#try) statement’s else clause runs when no exception occurs, and a loop’s else clause runs when no break occurs. For more on the [try](https://docs.python.org/3/reference/compound_stmts.html#try) statement and exceptions, see [Handling Exceptions](https://docs.python.org/3/tutorial/errors.html#tut-handling).

The [continue](https://docs.python.org/3/reference/simple_stmts.html#continue) statement, also borrowed from C, continues with the next iteration of the loop:

>>>

**>>> for** num **in** range(2, 10):

**...**  **if** num % 2 == 0:

**...**  print("Found an even number", num)

**...**  **continue**

**...**  print("Found a number", num)

Found an even number 2

Found a number 3

Found an even number 4

Found a number 5

Found an even number 6

Found a number 7

Found an even number 8

Found a number 9

## 4.5. [pass](https://docs.python.org/3/reference/simple_stmts.html#pass) Statements

The [pass](https://docs.python.org/3/reference/simple_stmts.html#pass) statement does nothing. It can be used when a statement is required syntactically but the program requires no action. For example:

>>>

**>>> while** **True**:

**...**  **pass** *# Busy-wait for keyboard interrupt (Ctrl+C)*

**...**

This is commonly used for creating minimal classes:

>>>

**>>> class** **MyEmptyClass**:

**...**  **pass**

**...**

Another place [pass](https://docs.python.org/3/reference/simple_stmts.html#pass) can be used is as a place-holder for a function or conditional body when you are working on new code, allowing you to keep thinking at a more abstract level. The [pass](https://docs.python.org/3/reference/simple_stmts.html#pass) is silently ignored:

>>>

**>>> def** initlog(\*args):

**...**  **pass** *# Remember to implement this!*

**...**

## 4.6. Defining Functions

We can create a function that writes the Fibonacci series to an arbitrary boundary:

>>>

**>>> def** fib(n): *# write Fibonacci series up to n*

**...**  *"""Print a Fibonacci series up to n."""*

**...**  a, b = 0, 1

**...**  **while** a < n:

**...**  print(a, end=' ')

**...**  a, b = b, a+b

**...**  print()

**...**

**>>>** *# Now call the function we just defined:*

**...** fib(2000)

0 1 1 2 3 5 8 13 21 34 55 89 144 233 377 610 987 1597

The keyword [def](https://docs.python.org/3/reference/compound_stmts.html#def) introduces a function definition. It must be followed by the function name and the parenthesized list of formal parameters. The statements that form the body of the function start at the next line, and must be indented.

The first statement of the function body can optionally be a string literal; this string literal is the function’s documentation string, or docstring. (More about docstrings can be found in the section[Documentation Strings](https://docs.python.org/3/tutorial/controlflow.html#tut-docstrings).) There are tools which use docstrings to automatically produce online or printed documentation, or to let the user interactively browse through code; it’s good practice to include docstrings in code that you write, so make a habit of it.

The execution of a function introduces a new symbol table used for the local variables of the function. More precisely, all variable assignments in a function store the value in the local symbol table; whereas variable references first look in the local symbol table, then in the local symbol tables of enclosing functions, then in the global symbol table, and finally in the table of built-in names. Thus, global variables cannot be directly assigned a value within a function (unless named in a [global](https://docs.python.org/3/reference/simple_stmts.html#global)statement), although they may be referenced.

The actual parameters (arguments) to a function call are introduced in the local symbol table of the called function when it is called; thus, arguments are passed using call by value (where the value is always an object reference, not the value of the object). [[1]](https://docs.python.org/3/tutorial/controlflow.html#id2) When a function calls another function, a new local symbol table is created for that call.

A function definition introduces the function name in the current symbol table. The value of the function name has a type that is recognized by the interpreter as a user-defined function. This value can be assigned to another name which can then also be used as a function. This serves as a general renaming mechanism:

>>>

**>>>** fib

<function fib at 10042ed0>

**>>>** f = fib

**>>>** f(100)

0 1 1 2 3 5 8 13 21 34 55 89

Coming from other languages, you might object that fib is not a function but a procedure since it doesn’t return a value. In fact, even functions without a [return](https://docs.python.org/3/reference/simple_stmts.html#return) statement do return a value, albeit a rather boring one. This value is called None (it’s a built-in name). Writing the value None is normally suppressed by the interpreter if it would be the only value written. You can see it if you really want to using [print()](https://docs.python.org/3/library/functions.html#print):

>>>

**>>>** fib(0)

**>>>** print(fib(0))

None

It is simple to write a function that returns a list of the numbers of the Fibonacci series, instead of printing it:

>>>

**>>> def** fib2(n): *# return Fibonacci series up to n*

**...**  *"""Return a list containing the Fibonacci series up to n."""*

**...**  result = []

**...**  a, b = 0, 1

**...**  **while** a < n:

**...**  result.append(a) *# see below*

**...**  a, b = b, a+b

**...**  **return** result

**...**

**>>>** f100 = fib2(100) *# call it*

**>>>** f100 *# write the result*

[0, 1, 1, 2, 3, 5, 8, 13, 21, 34, 55, 89]

This example, as usual, demonstrates some new Python features:

* The [return](https://docs.python.org/3/reference/simple_stmts.html#return) statement returns with a value from a function. [return](https://docs.python.org/3/reference/simple_stmts.html#return) without an expression argument returns None. Falling off the end of a function also returns None.
* The statement result.append(a) calls a method of the list object result. A method is a function that ‘belongs’ to an object and is named obj.methodname, where obj is some object (this may be an expression), and methodname is the name of a method that is defined by the object’s type. Different types define different methods. Methods of different types may have the same name without causing ambiguity. (It is possible to define your own object types and methods, using classes, see [Classes](https://docs.python.org/3/tutorial/classes.html#tut-classes)) The method append() shown in the example is defined for list objects; it adds a new element at the end of the list. In this example it is equivalent toresult = result + [a], but more efficient.

## 4.7. More on Defining Functions

It is also possible to define functions with a variable number of arguments. There are three forms, which can be combined.

### 4.7.1. Default Argument Values

The most useful form is to specify a default value for one or more arguments. This creates a function that can be called with fewer arguments than it is defined to allow. For example:

**def** ask\_ok(prompt, retries=4, reminder='Please try again!'):

**while** **True**:

ok = input(prompt)

**if** ok **in** ('y', 'ye', 'yes'):

**return** **True**

**if** ok **in** ('n', 'no', 'nop', 'nope'):

**return** **False**

retries = retries - 1

**if** retries < 0:

**raise** ValueError('invalid user response')

print(reminder)

This function can be called in several ways:

* giving only the mandatory argument: ask\_ok('Do you really want to quit?')
* giving one of the optional arguments: ask\_ok('OK to overwrite the file?', 2)
* or even giving all arguments: ask\_ok('OK to overwrite the file?', 2, 'Come on, onlyyes or no!')

This example also introduces the [in](https://docs.python.org/3/reference/expressions.html#in) keyword. This tests whether or not a sequence contains a certain value.

The default values are evaluated at the point of function definition in the defining scope, so that

i = 5

**def** f(arg=i):

print(arg)

i = 6

f()

will print 5.

**Important warning:** The default value is evaluated only once. This makes a difference when the default is a mutable object such as a list, dictionary, or instances of most classes. For example, the following function accumulates the arguments passed to it on subsequent calls:

**def** f(a, L=[]):

L.append(a)

**return** L

print(f(1))

print(f(2))

print(f(3))

This will print

[1]

[1, 2]

[1, 2, 3]

If you don’t want the default to be shared between subsequent calls, you can write the function like this instead:

**def** f(a, L=**None**):

**if** L **is** **None**:

L = []

L.append(a)

**return** L

### 4.7.2. Keyword Arguments

Functions can also be called using [keyword arguments](https://docs.python.org/3/glossary.html#term-keyword-argument) of the form kwarg=value. For instance, the following function:

**def** parrot(voltage, state='a stiff', action='voom', type='Norwegian Blue'):

print("-- This parrot wouldn't", action, end=' ')

print("if you put", voltage, "volts through it.")

print("-- Lovely plumage, the", type)

print("-- It's", state, "!")

accepts one required argument (voltage) and three optional arguments (state, action, and type). This function can be called in any of the following ways:

parrot(1000) *# 1 positional argument*

parrot(voltage=1000) *# 1 keyword argument*

parrot(voltage=1000000, action='VOOOOOM') *# 2 keyword arguments*

parrot(action='VOOOOOM', voltage=1000000) *# 2 keyword arguments*

parrot('a million', 'bereft of life', 'jump') *# 3 positional arguments*

parrot('a thousand', state='pushing up the daisies') *# 1 positional, 1 keyword*

but all the following calls would be invalid:

parrot() *# required argument missing*

parrot(voltage=5.0, 'dead') *# non-keyword argument after a keyword argument*

parrot(110, voltage=220) *# duplicate value for the same argument*

parrot(actor='John Cleese') *# unknown keyword argument*

In a function call, keyword arguments must follow positional arguments. All the keyword arguments passed must match one of the arguments accepted by the function (e.g. actor is not a valid argument for the parrot function), and their order is not important. This also includes non-optional arguments (e.g. parrot(voltage=1000) is valid too). No argument may receive a value more than once. Here’s an example that fails due to this restriction:

>>>

**>>> def** function(a):

**...**  **pass**

**...**

**>>>** function(0, a=0)

Traceback (most recent call last):

File "<stdin>", line 1, in ?

TypeError: function() got multiple values for keyword argument 'a'

When a final formal parameter of the form \*\*name is present, it receives a dictionary (see [Mapping Types — dict](https://docs.python.org/3/library/stdtypes.html#typesmapping)) containing all keyword arguments except for those corresponding to a formal parameter. This may be combined with a formal parameter of the form \*name (described in the next subsection) which receives a tuple containing the positional arguments beyond the formal parameter list. (\*namemust occur before \*\*name.) For example, if we define a function like this:

**def** cheeseshop(kind, \*arguments, \*\*keywords):

print("-- Do you have any", kind, "?")

print("-- I'm sorry, we're all out of", kind)

**for** arg **in** arguments:

print(arg)

print("-" \* 40)

keys = sorted(keywords.keys())

**for** kw **in** keys:

print(kw, ":", keywords[kw])

It could be called like this:

cheeseshop("Limburger", "It's very runny, sir.",

"It's really very, VERY runny, sir.",

shopkeeper="Michael Palin",

client="John Cleese",

sketch="Cheese Shop Sketch")

and of course it would print:

-- Do you have any Limburger ?

-- I'm sorry, we're all out of Limburger

It's very runny, sir.

It's really very, VERY runny, sir.

----------------------------------------

client : John Cleese

shopkeeper : Michael Palin

sketch : Cheese Shop Sketch

Note that the list of keyword argument names is created by sorting the result of the keywords dictionary’s keys() method before printing its contents; if this is not done, the order in which the arguments are printed is undefined.

### 4.7.3. Arbitrary Argument Lists

Finally, the least frequently used option is to specify that a function can be called with an arbitrary number of arguments. These arguments will be wrapped up in a tuple (see [Tuples and Sequences](https://docs.python.org/3/tutorial/datastructures.html#tut-tuples)). Before the variable number of arguments, zero or more normal arguments may occur.

**def** write\_multiple\_items(file, separator, \*args):

file.write(separator.join(args))

Normally, these variadic arguments will be last in the list of formal parameters, because they scoop up all remaining input arguments that are passed to the function. Any formal parameters which occur after the \*args parameter are ‘keyword-only’ arguments, meaning that they can only be used as keywords rather than positional arguments.

>>>

**>>> def** concat(\*args, sep="/"):

**...**  **return** sep.join(args)

**...**

**>>>** concat("earth", "mars", "venus")

'earth/mars/venus'

**>>>** concat("earth", "mars", "venus", sep=".")

'earth.mars.venus'

### 4.7.4. Unpacking Argument Lists

The reverse situation occurs when the arguments are already in a list or tuple but need to be unpacked for a function call requiring separate positional arguments. For instance, the built-in [range()](https://docs.python.org/3/library/stdtypes.html#range)function expects separate start and stop arguments. If they are not available separately, write the function call with the \*-operator to unpack the arguments out of a list or tuple:

>>>

**>>>** list(range(3, 6)) *# normal call with separate arguments*

[3, 4, 5]

**>>>** args = [3, 6]

**>>>** list(range(\*args)) *# call with arguments unpacked from a list*

[3, 4, 5]

In the same fashion, dictionaries can deliver keyword arguments with the \*\*-operator:

>>>

**>>> def** parrot(voltage, state='a stiff', action='voom'):

**...**  print("-- This parrot wouldn't", action, end=' ')

**...**  print("if you put", voltage, "volts through it.", end=' ')

**...**  print("E's", state, "!")

**...**

**>>>** d = {"voltage": "four million", "state": "bleedin' demised", "action": "VOOM"}

**>>>** parrot(\*\*d)

-- This parrot wouldn't VOOM if you put four million volts through it. E's bleedin' demised !

### 4.7.5. Lambda Expressions

Small anonymous functions can be created with the [lambda](https://docs.python.org/3/reference/expressions.html#lambda) keyword. This function returns the sum of its two arguments: lambda a, b: a+b. Lambda functions can be used wherever function objects are required. They are syntactically restricted to a single expression. Semantically, they are just syntactic sugar for a normal function definition. Like nested function definitions, lambda functions can reference variables from the containing scope:

>>>

**>>> def** make\_incrementor(n):

**...**  **return** **lambda** x: x + n

**...**

**>>>** f = make\_incrementor(42)

**>>>** f(0)

42

**>>>** f(1)

43

The above example uses a lambda expression to return a function. Another use is to pass a small function as an argument:

>>>

**>>>** pairs = [(1, 'one'), (2, 'two'), (3, 'three'), (4, 'four')]

**>>>** pairs.sort(key=**lambda** pair: pair[1])

**>>>** pairs

[(4, 'four'), (1, 'one'), (3, 'three'), (2, 'two')]

### 4.7.6. Documentation Strings

Here are some conventions about the content and formatting of documentation strings.

The first line should always be a short, concise summary of the object’s purpose. For brevity, it should not explicitly state the object’s name or type, since these are available by other means (except if the name happens to be a verb describing a function’s operation). This line should begin with a capital letter and end with a period.

If there are more lines in the documentation string, the second line should be blank, visually separating the summary from the rest of the description. The following lines should be one or more paragraphs describing the object’s calling conventions, its side effects, etc.

The Python parser does not strip indentation from multi-line string literals in Python, so tools that process documentation have to strip indentation if desired. This is done using the following convention. The first non-blank line after the first line of the string determines the amount of indentation for the entire documentation string. (We can’t use the first line since it is generally adjacent to the string’s opening quotes so its indentation is not apparent in the string literal.) Whitespace “equivalent” to this indentation is then stripped from the start of all lines of the string. Lines that are indented less should not occur, but if they occur all their leading whitespace should be stripped. Equivalence of whitespace should be tested after expansion of tabs (to 8 spaces, normally).

Here is an example of a multi-line docstring:

>>>

**>>> def** my\_function():

**...**  *"""Do nothing, but document it.*

**...**

**...**  *No, really, it doesn't do anything.*

**...**  *"""*

**...**  **pass**

**...**

**>>>** print(my\_function.\_\_doc\_\_)

Do nothing, but document it.

No, really, it doesn't do anything.

### 4.7.7. Function Annotations

[Function annotations](https://docs.python.org/3/reference/compound_stmts.html#function) are completely optional metadata information about the types used by user-defined functions (see [**PEP 484**](https://www.python.org/dev/peps/pep-0484) for more information).

Annotations are stored in the \_\_annotations\_\_ attribute of the function as a dictionary and have no effect on any other part of the function. Parameter annotations are defined by a colon after the parameter name, followed by an expression evaluating to the value of the annotation. Return annotations are defined by a literal ->, followed by an expression, between the parameter list and the colon denoting the end of the [def](https://docs.python.org/3/reference/compound_stmts.html#def) statement. The following example has a positional argument, a keyword argument, and the return value annotated:

>>>

**>>> def** f(ham: str, eggs: str = 'eggs') -> str:

**...**  print("Annotations:", f.\_\_annotations\_\_)

**...**  print("Arguments:", ham, eggs)

**...**  **return** ham + ' and ' + eggs

**...**

**>>>** f('spam')

Annotations: {'ham': <class 'str'>, 'return': <class 'str'>, 'eggs': <class 'str'>}

Arguments: spam eggs

'spam and eggs'

## 4.8. Intermezzo: Coding Style

Now that you are about to write longer, more complex pieces of Python, it is a good time to talk aboutcoding style. Most languages can be written (or more concise, formatted) in different styles; some are more readable than others. Making it easy for others to read your code is always a good idea, and adopting a nice coding style helps tremendously for that.

For Python, [**PEP 8**](https://www.python.org/dev/peps/pep-0008) has emerged as the style guide that most projects adhere to; it promotes a very readable and eye-pleasing coding style. Every Python developer should read it at some point; here are the most important points extracted for you:

* Use 4-space indentation, and no tabs.

4 spaces are a good compromise between small indentation (allows greater nesting depth) and large indentation (easier to read). Tabs introduce confusion, and are best left out.

* Wrap lines so that they don’t exceed 79 characters.

This helps users with small displays and makes it possible to have several code files side-by-side on larger displays.

* Use blank lines to separate functions and classes, and larger blocks of code inside functions.
* When possible, put comments on a line of their own.
* Use docstrings.
* Use spaces around operators and after commas, but not directly inside bracketing constructs: a= f(1, 2) + g(3, 4).
* Name your classes and functions consistently; the convention is to use CamelCase for classes and lower\_case\_with\_underscores for functions and methods. Always use self as the name for the first method argument (see [A First Look at Classes](https://docs.python.org/3/tutorial/classes.html#tut-firstclasses) for more on classes and methods).
* Don’t use fancy encodings if your code is meant to be used in international environments. Python’s default, UTF-8, or even plain ASCII work best in any case.
* Likewise, don’t use non-ASCII characters in identifiers if there is only the slightest chance people speaking a different language will read or maintain the code.

**Footnotes**

|  |  |
| --- | --- |
| [[1]](https://docs.python.org/3/tutorial/controlflow.html#id1) | Actually, call by object reference would be a better description, since if a mutable object is passed, the caller will see any changes the callee makes to it (items inserted into a list). |

# 4. More Control Flow Tools

Besides the [while](https://docs.python.org/3/reference/compound_stmts.html#while) statement just introduced, Python knows the usual control flow statements known from other languages, with some twists.

## 4.1. [if](https://docs.python.org/3/reference/compound_stmts.html#if) Statements

Perhaps the most well-known statement type is the [if](https://docs.python.org/3/reference/compound_stmts.html#if) statement. For example:

>>>

**>>>** x = int(input("Please enter an integer: "))

Please enter an integer: 42

**>>> if** x < 0:

**...**  x = 0

**...**  print('Negative changed to zero')

**... elif** x == 0:

**...**  print('Zero')

**... elif** x == 1:

**...**  print('Single')

**... else**:

**...**  print('More')

**...**

More

There can be zero or more [elif](https://docs.python.org/3/reference/compound_stmts.html#elif) parts, and the [else](https://docs.python.org/3/reference/compound_stmts.html#else) part is optional. The keyword ‘[elif](https://docs.python.org/3/reference/compound_stmts.html#elif)‘ is short for ‘else if’, and is useful to avoid excessive indentation. An [if](https://docs.python.org/3/reference/compound_stmts.html#if) ... [elif](https://docs.python.org/3/reference/compound_stmts.html#elif) ... [elif](https://docs.python.org/3/reference/compound_stmts.html#elif) ... sequence is a substitute for the switch or case statements found in other languages.

## 4.2. [for](https://docs.python.org/3/reference/compound_stmts.html#for) Statements

The [for](https://docs.python.org/3/reference/compound_stmts.html#for) statement in Python differs a bit from what you may be used to in C or Pascal. Rather than always iterating over an arithmetic progression of numbers (like in Pascal), or giving the user the ability to define both the iteration step and halting condition (as C), Python’s [for](https://docs.python.org/3/reference/compound_stmts.html#for) statement iterates over the items of any sequence (a list or a string), in the order that they appear in the sequence. For example (no pun intended):

>>>

**>>>** *# Measure some strings:*

**...** words = ['cat', 'window', 'defenestrate']

**>>> for** w **in** words:

**...**  print(w, len(w))

**...**

cat 3

window 6

defenestrate 12

If you need to modify the sequence you are iterating over while inside the loop (for example to duplicate selected items), it is recommended that you first make a copy. Iterating over a sequence does not implicitly make a copy. The slice notation makes this especially convenient:

>>>

**>>> for** w **in** words[:]: *# Loop over a slice copy of the entire list.*

**...**  **if** len(w) > 6:

**...**  words.insert(0, w)

**...**

**>>>** words

['defenestrate', 'cat', 'window', 'defenestrate']

## 4.3. The [range()](https://docs.python.org/3/library/stdtypes.html#range) Function

If you do need to iterate over a sequence of numbers, the built-in function [range()](https://docs.python.org/3/library/stdtypes.html#range) comes in handy. It generates arithmetic progressions:

>>>

**>>> for** i **in** range(5):

**...**  print(i)

**...**

0

1

2

3

4

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

range(5, 10)

5 through 9

range(0, 10, 3)

0, 3, 6, 9

range(-10, -100, -30)

-10, -40, -70

To iterate over the indices of a sequence, you can combine [range()](https://docs.python.org/3/library/stdtypes.html#range) and [len()](https://docs.python.org/3/library/functions.html#len) as follows:

>>>

**>>>** a = ['Mary', 'had', 'a', 'little', 'lamb']

**>>> for** i **in** range(len(a)):

**...**  print(i, a[i])

**...**

0 Mary

1 had

2 a

3 little

4 lamb

In most such cases, however, it is convenient to use the [enumerate()](https://docs.python.org/3/library/functions.html#enumerate) function, see [Looping Techniques](https://docs.python.org/3/tutorial/datastructures.html#tut-loopidioms).

A strange thing happens if you just print a range:

>>>

**>>>** print(range(10))

range(0, 10)

In many ways the object returned by [range()](https://docs.python.org/3/library/stdtypes.html#range) behaves as if it is a list, but in fact it isn’t. It is an object which returns the successive items of the desired sequence when you iterate over it, but it doesn’t really make the list, thus saving space.

We say such an object is iterable, that is, suitable as a target for functions and constructs that expect something from which they can obtain successive items until the supply is exhausted. We have seen that the [for](https://docs.python.org/3/reference/compound_stmts.html#for) statement is such an iterator. The function [list()](https://docs.python.org/3/library/stdtypes.html#list) is another; it creates lists from iterables:

>>>

**>>>** list(range(5))

[0, 1, 2, 3, 4]

Later we will see more functions that return iterables and take iterables as argument.

## 4.4. [break](https://docs.python.org/3/reference/simple_stmts.html#break) and [continue](https://docs.python.org/3/reference/simple_stmts.html#continue) Statements, and [else](https://docs.python.org/3/reference/compound_stmts.html#else) Clauses on Loops

The [break](https://docs.python.org/3/reference/simple_stmts.html#break) statement, like in C, breaks out of the smallest enclosing [for](https://docs.python.org/3/reference/compound_stmts.html#for) or [while](https://docs.python.org/3/reference/compound_stmts.html#while) loop.

Loop statements may have an else clause; it is executed when the loop terminates through exhaustion of the list (with [for](https://docs.python.org/3/reference/compound_stmts.html#for)) or when the condition becomes false (with [while](https://docs.python.org/3/reference/compound_stmts.html#while)), but not when the loop is terminated by a [break](https://docs.python.org/3/reference/simple_stmts.html#break) statement. This is exemplified by the following loop, which searches for prime numbers:

>>>

**>>> for** n **in** range(2, 10):

**...**  **for** x **in** range(2, n):

**...**  **if** n % x == 0:

**...**  print(n, 'equals', x, '\*', n//x)

**...**  **break**

**...**  **else**:

**...**  *# loop fell through without finding a factor*

**...**  print(n, 'is a prime number')

**...**

2 is a prime number

3 is a prime number

4 equals 2 \* 2

5 is a prime number

6 equals 2 \* 3

7 is a prime number

8 equals 2 \* 4

9 equals 3 \* 3

(Yes, this is the correct code. Look closely: the else clause belongs to the [for](https://docs.python.org/3/reference/compound_stmts.html#for) loop, **not** the [if](https://docs.python.org/3/reference/compound_stmts.html#if)statement.)

When used with a loop, the else clause has more in common with the else clause of a [try](https://docs.python.org/3/reference/compound_stmts.html#try)statement than it does that of [if](https://docs.python.org/3/reference/compound_stmts.html#if) statements: a [try](https://docs.python.org/3/reference/compound_stmts.html#try) statement’s else clause runs when no exception occurs, and a loop’s else clause runs when no break occurs. For more on the [try](https://docs.python.org/3/reference/compound_stmts.html#try) statement and exceptions, see [Handling Exceptions](https://docs.python.org/3/tutorial/errors.html#tut-handling).

The [continue](https://docs.python.org/3/reference/simple_stmts.html#continue) statement, also borrowed from C, continues with the next iteration of the loop:

>>>

**>>> for** num **in** range(2, 10):

**...**  **if** num % 2 == 0:

**...**  print("Found an even number", num)

**...**  **continue**

**...**  print("Found a number", num)

Found an even number 2

Found a number 3

Found an even number 4

Found a number 5

Found an even number 6

Found a number 7

Found an even number 8

Found a number 9

## 4.5. [pass](https://docs.python.org/3/reference/simple_stmts.html#pass) Statements

The [pass](https://docs.python.org/3/reference/simple_stmts.html#pass) statement does nothing. It can be used when a statement is required syntactically but the program requires no action. For example:

>>>

**>>> while** **True**:

**...**  **pass** *# Busy-wait for keyboard interrupt (Ctrl+C)*

**...**

This is commonly used for creating minimal classes:

>>>

**>>> class** **MyEmptyClass**:

**...**  **pass**

**...**

Another place [pass](https://docs.python.org/3/reference/simple_stmts.html#pass) can be used is as a place-holder for a function or conditional body when you are working on new code, allowing you to keep thinking at a more abstract level. The [pass](https://docs.python.org/3/reference/simple_stmts.html#pass) is silently ignored:

>>>

**>>> def** initlog(\*args):

**...**  **pass** *# Remember to implement this!*

**...**

## 4.6. Defining Functions

We can create a function that writes the Fibonacci series to an arbitrary boundary:

>>>

**>>> def** fib(n): *# write Fibonacci series up to n*

**...**  *"""Print a Fibonacci series up to n."""*

**...**  a, b = 0, 1

**...**  **while** a < n:

**...**  print(a, end=' ')

**...**  a, b = b, a+b

**...**  print()

**...**

**>>>** *# Now call the function we just defined:*

**...** fib(2000)

0 1 1 2 3 5 8 13 21 34 55 89 144 233 377 610 987 1597

The keyword [def](https://docs.python.org/3/reference/compound_stmts.html#def) introduces a function definition. It must be followed by the function name and the parenthesized list of formal parameters. The statements that form the body of the function start at the next line, and must be indented.

The first statement of the function body can optionally be a string literal; this string literal is the function’s documentation string, or docstring. (More about docstrings can be found in the section[Documentation Strings](https://docs.python.org/3/tutorial/controlflow.html#tut-docstrings).) There are tools which use docstrings to automatically produce online or printed documentation, or to let the user interactively browse through code; it’s good practice to include docstrings in code that you write, so make a habit of it.

The execution of a function introduces a new symbol table used for the local variables of the function. More precisely, all variable assignments in a function store the value in the local symbol table; whereas variable references first look in the local symbol table, then in the local symbol tables of enclosing functions, then in the global symbol table, and finally in the table of built-in names. Thus, global variables cannot be directly assigned a value within a function (unless named in a [global](https://docs.python.org/3/reference/simple_stmts.html#global)statement), although they may be referenced.

The actual parameters (arguments) to a function call are introduced in the local symbol table of the called function when it is called; thus, arguments are passed using call by value (where the value is always an object reference, not the value of the object). [[1]](https://docs.python.org/3/tutorial/controlflow.html#id2) When a function calls another function, a new local symbol table is created for that call.

A function definition introduces the function name in the current symbol table. The value of the function name has a type that is recognized by the interpreter as a user-defined function. This value can be assigned to another name which can then also be used as a function. This serves as a general renaming mechanism:

>>>

**>>>** fib

<function fib at 10042ed0>

**>>>** f = fib

**>>>** f(100)

0 1 1 2 3 5 8 13 21 34 55 89

Coming from other languages, you might object that fib is not a function but a procedure since it doesn’t return a value. In fact, even functions without a [return](https://docs.python.org/3/reference/simple_stmts.html#return) statement do return a value, albeit a rather boring one. This value is called None (it’s a built-in name). Writing the value None is normally suppressed by the interpreter if it would be the only value written. You can see it if you really want to using [print()](https://docs.python.org/3/library/functions.html#print):

>>>

**>>>** fib(0)

**>>>** print(fib(0))

None

It is simple to write a function that returns a list of the numbers of the Fibonacci series, instead of printing it:

>>>

**>>> def** fib2(n): *# return Fibonacci series up to n*

**...**  *"""Return a list containing the Fibonacci series up to n."""*

**...**  result = []

**...**  a, b = 0, 1

**...**  **while** a < n:

**...**  result.append(a) *# see below*

**...**  a, b = b, a+b

**...**  **return** result

**...**

**>>>** f100 = fib2(100) *# call it*

**>>>** f100 *# write the result*

[0, 1, 1, 2, 3, 5, 8, 13, 21, 34, 55, 89]

This example, as usual, demonstrates some new Python features:

* The [return](https://docs.python.org/3/reference/simple_stmts.html#return) statement returns with a value from a function. [return](https://docs.python.org/3/reference/simple_stmts.html#return) without an expression argument returns None. Falling off the end of a function also returns None.
* The statement result.append(a) calls a method of the list object result. A method is a function that ‘belongs’ to an object and is named obj.methodname, where obj is some object (this may be an expression), and methodname is the name of a method that is defined by the object’s type. Different types define different methods. Methods of different types may have the same name without causing ambiguity. (It is possible to define your own object types and methods, using classes, see [Classes](https://docs.python.org/3/tutorial/classes.html#tut-classes)) The method append() shown in the example is defined for list objects; it adds a new element at the end of the list. In this example it is equivalent toresult = result + [a], but more efficient.

## 4.7. More on Defining Functions

It is also possible to define functions with a variable number of arguments. There are three forms, which can be combined.

### 4.7.1. Default Argument Values

The most useful form is to specify a default value for one or more arguments. This creates a function that can be called with fewer arguments than it is defined to allow. For example:

**def** ask\_ok(prompt, retries=4, reminder='Please try again!'):

**while** **True**:

ok = input(prompt)

**if** ok **in** ('y', 'ye', 'yes'):

**return** **True**

**if** ok **in** ('n', 'no', 'nop', 'nope'):

**return** **False**

retries = retries - 1

**if** retries < 0:

**raise** ValueError('invalid user response')

print(reminder)

This function can be called in several ways:

* giving only the mandatory argument: ask\_ok('Do you really want to quit?')
* giving one of the optional arguments: ask\_ok('OK to overwrite the file?', 2)
* or even giving all arguments: ask\_ok('OK to overwrite the file?', 2, 'Come on, onlyyes or no!')

This example also introduces the [in](https://docs.python.org/3/reference/expressions.html#in) keyword. This tests whether or not a sequence contains a certain value.

The default values are evaluated at the point of function definition in the defining scope, so that

i = 5

**def** f(arg=i):

print(arg)

i = 6

f()

will print 5.

**Important warning:** The default value is evaluated only once. This makes a difference when the default is a mutable object such as a list, dictionary, or instances of most classes. For example, the following function accumulates the arguments passed to it on subsequent calls:

**def** f(a, L=[]):

L.append(a)

**return** L

print(f(1))

print(f(2))

print(f(3))

This will print

[1]

[1, 2]

[1, 2, 3]

If you don’t want the default to be shared between subsequent calls, you can write the function like this instead:

**def** f(a, L=**None**):

**if** L **is** **None**:

L = []

L.append(a)

**return** L

### 4.7.2. Keyword Arguments

Functions can also be called using [keyword arguments](https://docs.python.org/3/glossary.html#term-keyword-argument) of the form kwarg=value. For instance, the following function:

**def** parrot(voltage, state='a stiff', action='voom', type='Norwegian Blue'):

print("-- This parrot wouldn't", action, end=' ')

print("if you put", voltage, "volts through it.")

print("-- Lovely plumage, the", type)

print("-- It's", state, "!")

accepts one required argument (voltage) and three optional arguments (state, action, and type). This function can be called in any of the following ways:

parrot(1000) *# 1 positional argument*

parrot(voltage=1000) *# 1 keyword argument*

parrot(voltage=1000000, action='VOOOOOM') *# 2 keyword arguments*

parrot(action='VOOOOOM', voltage=1000000) *# 2 keyword arguments*

parrot('a million', 'bereft of life', 'jump') *# 3 positional arguments*

parrot('a thousand', state='pushing up the daisies') *# 1 positional, 1 keyword*

but all the following calls would be invalid:

parrot() *# required argument missing*

parrot(voltage=5.0, 'dead') *# non-keyword argument after a keyword argument*

parrot(110, voltage=220) *# duplicate value for the same argument*

parrot(actor='John Cleese') *# unknown keyword argument*

In a function call, keyword arguments must follow positional arguments. All the keyword arguments passed must match one of the arguments accepted by the function (e.g. actor is not a valid argument for the parrot function), and their order is not important. This also includes non-optional arguments (e.g. parrot(voltage=1000) is valid too). No argument may receive a value more than once. Here’s an example that fails due to this restriction:

>>>

**>>> def** function(a):

**...**  **pass**

**...**

**>>>** function(0, a=0)

Traceback (most recent call last):

File "<stdin>", line 1, in ?

TypeError: function() got multiple values for keyword argument 'a'

When a final formal parameter of the form \*\*name is present, it receives a dictionary (see [Mapping Types — dict](https://docs.python.org/3/library/stdtypes.html#typesmapping)) containing all keyword arguments except for those corresponding to a formal parameter. This may be combined with a formal parameter of the form \*name (described in the next subsection) which receives a tuple containing the positional arguments beyond the formal parameter list. (\*namemust occur before \*\*name.) For example, if we define a function like this:

**def** cheeseshop(kind, \*arguments, \*\*keywords):

print("-- Do you have any", kind, "?")

print("-- I'm sorry, we're all out of", kind)

**for** arg **in** arguments:

print(arg)

print("-" \* 40)

keys = sorted(keywords.keys())

**for** kw **in** keys:

print(kw, ":", keywords[kw])

It could be called like this:

cheeseshop("Limburger", "It's very runny, sir.",

"It's really very, VERY runny, sir.",

shopkeeper="Michael Palin",

client="John Cleese",

sketch="Cheese Shop Sketch")

and of course it would print:

-- Do you have any Limburger ?

-- I'm sorry, we're all out of Limburger

It's very runny, sir.

It's really very, VERY runny, sir.

----------------------------------------

client : John Cleese

shopkeeper : Michael Palin

sketch : Cheese Shop Sketch

Note that the list of keyword argument names is created by sorting the result of the keywords dictionary’s keys() method before printing its contents; if this is not done, the order in which the arguments are printed is undefined.

### 4.7.3. Arbitrary Argument Lists

Finally, the least frequently used option is to specify that a function can be called with an arbitrary number of arguments. These arguments will be wrapped up in a tuple (see [Tuples and Sequences](https://docs.python.org/3/tutorial/datastructures.html#tut-tuples)). Before the variable number of arguments, zero or more normal arguments may occur.

**def** write\_multiple\_items(file, separator, \*args):

file.write(separator.join(args))

Normally, these variadic arguments will be last in the list of formal parameters, because they scoop up all remaining input arguments that are passed to the function. Any formal parameters which occur after the \*args parameter are ‘keyword-only’ arguments, meaning that they can only be used as keywords rather than positional arguments.

>>>

**>>> def** concat(\*args, sep="/"):

**...**  **return** sep.join(args)

**...**

**>>>** concat("earth", "mars", "venus")

'earth/mars/venus'

**>>>** concat("earth", "mars", "venus", sep=".")

'earth.mars.venus'

### 4.7.4. Unpacking Argument Lists

The reverse situation occurs when the arguments are already in a list or tuple but need to be unpacked for a function call requiring separate positional arguments. For instance, the built-in [range()](https://docs.python.org/3/library/stdtypes.html#range)function expects separate start and stop arguments. If they are not available separately, write the function call with the \*-operator to unpack the arguments out of a list or tuple:

>>>

**>>>** list(range(3, 6)) *# normal call with separate arguments*

[3, 4, 5]

**>>>** args = [3, 6]

**>>>** list(range(\*args)) *# call with arguments unpacked from a list*

[3, 4, 5]

In the same fashion, dictionaries can deliver keyword arguments with the \*\*-operator:

>>>

**>>> def** parrot(voltage, state='a stiff', action='voom'):

**...**  print("-- This parrot wouldn't", action, end=' ')

**...**  print("if you put", voltage, "volts through it.", end=' ')

**...**  print("E's", state, "!")

**...**

**>>>** d = {"voltage": "four million", "state": "bleedin' demised", "action": "VOOM"}

**>>>** parrot(\*\*d)

-- This parrot wouldn't VOOM if you put four million volts through it. E's bleedin' demised !

### 4.7.5. Lambda Expressions

Small anonymous functions can be created with the [lambda](https://docs.python.org/3/reference/expressions.html#lambda) keyword. This function returns the sum of its two arguments: lambda a, b: a+b. Lambda functions can be used wherever function objects are required. They are syntactically restricted to a single expression. Semantically, they are just syntactic sugar for a normal function definition. Like nested function definitions, lambda functions can reference variables from the containing scope:

>>>

**>>> def** make\_incrementor(n):

**...**  **return** **lambda** x: x + n

**...**

**>>>** f = make\_incrementor(42)

**>>>** f(0)

42

**>>>** f(1)

43

The above example uses a lambda expression to return a function. Another use is to pass a small function as an argument:

>>>

**>>>** pairs = [(1, 'one'), (2, 'two'), (3, 'three'), (4, 'four')]

**>>>** pairs.sort(key=**lambda** pair: pair[1])

**>>>** pairs

[(4, 'four'), (1, 'one'), (3, 'three'), (2, 'two')]

### 4.7.6. Documentation Strings

Here are some conventions about the content and formatting of documentation strings.

The first line should always be a short, concise summary of the object’s purpose. For brevity, it should not explicitly state the object’s name or type, since these are available by other means (except if the name happens to be a verb describing a function’s operation). This line should begin with a capital letter and end with a period.

If there are more lines in the documentation string, the second line should be blank, visually separating the summary from the rest of the description. The following lines should be one or more paragraphs describing the object’s calling conventions, its side effects, etc.

The Python parser does not strip indentation from multi-line string literals in Python, so tools that process documentation have to strip indentation if desired. This is done using the following convention. The first non-blank line after the first line of the string determines the amount of indentation for the entire documentation string. (We can’t use the first line since it is generally adjacent to the string’s opening quotes so its indentation is not apparent in the string literal.) Whitespace “equivalent” to this indentation is then stripped from the start of all lines of the string. Lines that are indented less should not occur, but if they occur all their leading whitespace should be stripped. Equivalence of whitespace should be tested after expansion of tabs (to 8 spaces, normally).

Here is an example of a multi-line docstring:

>>>

**>>> def** my\_function():

**...**  *"""Do nothing, but document it.*

**...**

**...**  *No, really, it doesn't do anything.*

**...**  *"""*

**...**  **pass**

**...**

**>>>** print(my\_function.\_\_doc\_\_)

Do nothing, but document it.

No, really, it doesn't do anything.

### 4.7.7. Function Annotations

[Function annotations](https://docs.python.org/3/reference/compound_stmts.html#function) are completely optional metadata information about the types used by user-defined functions (see [**PEP 484**](https://www.python.org/dev/peps/pep-0484) for more information).

Annotations are stored in the \_\_annotations\_\_ attribute of the function as a dictionary and have no effect on any other part of the function. Parameter annotations are defined by a colon after the parameter name, followed by an expression evaluating to the value of the annotation. Return annotations are defined by a literal ->, followed by an expression, between the parameter list and the colon denoting the end of the [def](https://docs.python.org/3/reference/compound_stmts.html#def) statement. The following example has a positional argument, a keyword argument, and the return value annotated:

>>>

**>>> def** f(ham: str, eggs: str = 'eggs') -> str:

**...**  print("Annotations:", f.\_\_annotations\_\_)

**...**  print("Arguments:", ham, eggs)

**...**  **return** ham + ' and ' + eggs

**...**

**>>>** f('spam')

Annotations: {'ham': <class 'str'>, 'return': <class 'str'>, 'eggs': <class 'str'>}

Arguments: spam eggs

'spam and eggs'

## 4.8. Intermezzo: Coding Style

Now that you are about to write longer, more complex pieces of Python, it is a good time to talk aboutcoding style. Most languages can be written (or more concise, formatted) in different styles; some are more readable than others. Making it easy for others to read your code is always a good idea, and adopting a nice coding style helps tremendously for that.

For Python, [**PEP 8**](https://www.python.org/dev/peps/pep-0008) has emerged as the style guide that most projects adhere to; it promotes a very readable and eye-pleasing coding style. Every Python developer should read it at some point; here are the most important points extracted for you:

* Use 4-space indentation, and no tabs.

4 spaces are a good compromise between small indentation (allows greater nesting depth) and large indentation (easier to read). Tabs introduce confusion, and are best left out.

* Wrap lines so that they don’t exceed 79 characters.

This helps users with small displays and makes it possible to have several code files side-by-side on larger displays.

* Use blank lines to separate functions and classes, and larger blocks of code inside functions.
* When possible, put comments on a line of their own.
* Use docstrings.
* Use spaces around operators and after commas, but not directly inside bracketing constructs: a= f(1, 2) + g(3, 4).
* Name your classes and functions consistently; the convention is to use CamelCase for classes and lower\_case\_with\_underscores for functions and methods. Always use self as the name for the first method argument (see [A First Look at Classes](https://docs.python.org/3/tutorial/classes.html#tut-firstclasses) for more on classes and methods).
* Don’t use fancy encodings if your code is meant to be used in international environments. Python’s default, UTF-8, or even plain ASCII work best in any case.
* Likewise, don’t use non-ASCII characters in identifiers if there is only the slightest chance people speaking a different language will read or maintain the code.

**Footnotes**

|  |  |
| --- | --- |
| [[1]](https://docs.python.org/3/tutorial/controlflow.html#id1) | Actually, call by object reference would be a better description, since if a mutable object is passed, the caller will see any changes the callee makes to it (items inserted into a list). |

# 4. More Control Flow Tools

Besides the [while](https://docs.python.org/3/reference/compound_stmts.html#while) statement just introduced, Python knows the usual control flow statements known from other languages, with some twists.

## 4.1. [if](https://docs.python.org/3/reference/compound_stmts.html#if) Statements

Perhaps the most well-known statement type is the [if](https://docs.python.org/3/reference/compound_stmts.html#if) statement. For example:

>>>

**>>>** x = int(input("Please enter an integer: "))

Please enter an integer: 42

**>>> if** x < 0:

**...**  x = 0

**...**  print('Negative changed to zero')

**... elif** x == 0:

**...**  print('Zero')

**... elif** x == 1:

**...**  print('Single')

**... else**:

**...**  print('More')

**...**

More

There can be zero or more [elif](https://docs.python.org/3/reference/compound_stmts.html#elif) parts, and the [else](https://docs.python.org/3/reference/compound_stmts.html#else) part is optional. The keyword ‘[elif](https://docs.python.org/3/reference/compound_stmts.html#elif)‘ is short for ‘else if’, and is useful to avoid excessive indentation. An [if](https://docs.python.org/3/reference/compound_stmts.html#if) ... [elif](https://docs.python.org/3/reference/compound_stmts.html#elif) ... [elif](https://docs.python.org/3/reference/compound_stmts.html#elif) ... sequence is a substitute for the switch or case statements found in other languages.

## 4.2. [for](https://docs.python.org/3/reference/compound_stmts.html#for) Statements

The [for](https://docs.python.org/3/reference/compound_stmts.html#for) statement in Python differs a bit from what you may be used to in C or Pascal. Rather than always iterating over an arithmetic progression of numbers (like in Pascal), or giving the user the ability to define both the iteration step and halting condition (as C), Python’s [for](https://docs.python.org/3/reference/compound_stmts.html#for) statement iterates over the items of any sequence (a list or a string), in the order that they appear in the sequence. For example (no pun intended):

>>>

**>>>** *# Measure some strings:*

**...** words = ['cat', 'window', 'defenestrate']

**>>> for** w **in** words:

**...**  print(w, len(w))

**...**

cat 3

window 6

defenestrate 12

If you need to modify the sequence you are iterating over while inside the loop (for example to duplicate selected items), it is recommended that you first make a copy. Iterating over a sequence does not implicitly make a copy. The slice notation makes this especially convenient:

>>>

**>>> for** w **in** words[:]: *# Loop over a slice copy of the entire list.*

**...**  **if** len(w) > 6:

**...**  words.insert(0, w)

**...**

**>>>** words

['defenestrate', 'cat', 'window', 'defenestrate']

## 4.3. The [range()](https://docs.python.org/3/library/stdtypes.html#range) Function

If you do need to iterate over a sequence of numbers, the built-in function [range()](https://docs.python.org/3/library/stdtypes.html#range) comes in handy. It generates arithmetic progressions:

>>>

**>>> for** i **in** range(5):

**...**  print(i)

**...**

0

1

2

3

4

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

range(5, 10)

5 through 9

range(0, 10, 3)

0, 3, 6, 9

range(-10, -100, -30)

-10, -40, -70

To iterate over the indices of a sequence, you can combine [range()](https://docs.python.org/3/library/stdtypes.html#range) and [len()](https://docs.python.org/3/library/functions.html#len) as follows:

>>>

**>>>** a = ['Mary', 'had', 'a', 'little', 'lamb']

**>>> for** i **in** range(len(a)):

**...**  print(i, a[i])

**...**

0 Mary

1 had

2 a

3 little

4 lamb

In most such cases, however, it is convenient to use the [enumerate()](https://docs.python.org/3/library/functions.html#enumerate) function, see [Looping Techniques](https://docs.python.org/3/tutorial/datastructures.html#tut-loopidioms).

A strange thing happens if you just print a range:

>>>

**>>>** print(range(10))

range(0, 10)

In many ways the object returned by [range()](https://docs.python.org/3/library/stdtypes.html#range) behaves as if it is a list, but in fact it isn’t. It is an object which returns the successive items of the desired sequence when you iterate over it, but it doesn’t really make the list, thus saving space.

We say such an object is iterable, that is, suitable as a target for functions and constructs that expect something from which they can obtain successive items until the supply is exhausted. We have seen that the [for](https://docs.python.org/3/reference/compound_stmts.html#for) statement is such an iterator. The function [list()](https://docs.python.org/3/library/stdtypes.html#list) is another; it creates lists from iterables:

>>>

**>>>** list(range(5))

[0, 1, 2, 3, 4]

Later we will see more functions that return iterables and take iterables as argument.

## 4.4. [break](https://docs.python.org/3/reference/simple_stmts.html#break) and [continue](https://docs.python.org/3/reference/simple_stmts.html#continue) Statements, and [else](https://docs.python.org/3/reference/compound_stmts.html#else) Clauses on Loops

The [break](https://docs.python.org/3/reference/simple_stmts.html#break) statement, like in C, breaks out of the smallest enclosing [for](https://docs.python.org/3/reference/compound_stmts.html#for) or [while](https://docs.python.org/3/reference/compound_stmts.html#while) loop.

Loop statements may have an else clause; it is executed when the loop terminates through exhaustion of the list (with [for](https://docs.python.org/3/reference/compound_stmts.html#for)) or when the condition becomes false (with [while](https://docs.python.org/3/reference/compound_stmts.html#while)), but not when the loop is terminated by a [break](https://docs.python.org/3/reference/simple_stmts.html#break) statement. This is exemplified by the following loop, which searches for prime numbers:

>>>

**>>> for** n **in** range(2, 10):

**...**  **for** x **in** range(2, n):

**...**  **if** n % x == 0:

**...**  print(n, 'equals', x, '\*', n//x)

**...**  **break**

**...**  **else**:

**...**  *# loop fell through without finding a factor*

**...**  print(n, 'is a prime number')

**...**

2 is a prime number

3 is a prime number

4 equals 2 \* 2

5 is a prime number

6 equals 2 \* 3

7 is a prime number

8 equals 2 \* 4

9 equals 3 \* 3

(Yes, this is the correct code. Look closely: the else clause belongs to the [for](https://docs.python.org/3/reference/compound_stmts.html#for) loop, **not** the [if](https://docs.python.org/3/reference/compound_stmts.html#if)statement.)

When used with a loop, the else clause has more in common with the else clause of a [try](https://docs.python.org/3/reference/compound_stmts.html#try)statement than it does that of [if](https://docs.python.org/3/reference/compound_stmts.html#if) statements: a [try](https://docs.python.org/3/reference/compound_stmts.html#try) statement’s else clause runs when no exception occurs, and a loop’s else clause runs when no break occurs. For more on the [try](https://docs.python.org/3/reference/compound_stmts.html#try) statement and exceptions, see [Handling Exceptions](https://docs.python.org/3/tutorial/errors.html#tut-handling).

The [continue](https://docs.python.org/3/reference/simple_stmts.html#continue) statement, also borrowed from C, continues with the next iteration of the loop:

>>>

**>>> for** num **in** range(2, 10):

**...**  **if** num % 2 == 0:

**...**  print("Found an even number", num)

**...**  **continue**

**...**  print("Found a number", num)

Found an even number 2

Found a number 3

Found an even number 4

Found a number 5

Found an even number 6

Found a number 7

Found an even number 8

Found a number 9

## 4.5. [pass](https://docs.python.org/3/reference/simple_stmts.html#pass) Statements

The [pass](https://docs.python.org/3/reference/simple_stmts.html#pass) statement does nothing. It can be used when a statement is required syntactically but the program requires no action. For example:

>>>

**>>> while** **True**:

**...**  **pass** *# Busy-wait for keyboard interrupt (Ctrl+C)*

**...**

This is commonly used for creating minimal classes:

>>>

**>>> class** **MyEmptyClass**:

**...**  **pass**

**...**

Another place [pass](https://docs.python.org/3/reference/simple_stmts.html#pass) can be used is as a place-holder for a function or conditional body when you are working on new code, allowing you to keep thinking at a more abstract level. The [pass](https://docs.python.org/3/reference/simple_stmts.html#pass) is silently ignored:

>>>

**>>> def** initlog(\*args):

**...**  **pass** *# Remember to implement this!*

**...**

## 4.6. Defining Functions

We can create a function that writes the Fibonacci series to an arbitrary boundary:

>>>

**>>> def** fib(n): *# write Fibonacci series up to n*

**...**  *"""Print a Fibonacci series up to n."""*

**...**  a, b = 0, 1

**...**  **while** a < n:

**...**  print(a, end=' ')

**...**  a, b = b, a+b

**...**  print()

**...**

**>>>** *# Now call the function we just defined:*

**...** fib(2000)

0 1 1 2 3 5 8 13 21 34 55 89 144 233 377 610 987 1597

The keyword [def](https://docs.python.org/3/reference/compound_stmts.html#def) introduces a function definition. It must be followed by the function name and the parenthesized list of formal parameters. The statements that form the body of the function start at the next line, and must be indented.

The first statement of the function body can optionally be a string literal; this string literal is the function’s documentation string, or docstring. (More about docstrings can be found in the section[Documentation Strings](https://docs.python.org/3/tutorial/controlflow.html#tut-docstrings).) There are tools which use docstrings to automatically produce online or printed documentation, or to let the user interactively browse through code; it’s good practice to include docstrings in code that you write, so make a habit of it.

The execution of a function introduces a new symbol table used for the local variables of the function. More precisely, all variable assignments in a function store the value in the local symbol table; whereas variable references first look in the local symbol table, then in the local symbol tables of enclosing functions, then in the global symbol table, and finally in the table of built-in names. Thus, global variables cannot be directly assigned a value within a function (unless named in a [global](https://docs.python.org/3/reference/simple_stmts.html#global)statement), although they may be referenced.

The actual parameters (arguments) to a function call are introduced in the local symbol table of the called function when it is called; thus, arguments are passed using call by value (where the value is always an object reference, not the value of the object). [[1]](https://docs.python.org/3/tutorial/controlflow.html#id2) When a function calls another function, a new local symbol table is created for that call.

A function definition introduces the function name in the current symbol table. The value of the function name has a type that is recognized by the interpreter as a user-defined function. This value can be assigned to another name which can then also be used as a function. This serves as a general renaming mechanism:

>>>

**>>>** fib

<function fib at 10042ed0>

**>>>** f = fib

**>>>** f(100)

0 1 1 2 3 5 8 13 21 34 55 89

Coming from other languages, you might object that fib is not a function but a procedure since it doesn’t return a value. In fact, even functions without a [return](https://docs.python.org/3/reference/simple_stmts.html#return) statement do return a value, albeit a rather boring one. This value is called None (it’s a built-in name). Writing the value None is normally suppressed by the interpreter if it would be the only value written. You can see it if you really want to using [print()](https://docs.python.org/3/library/functions.html#print):

>>>

**>>>** fib(0)

**>>>** print(fib(0))

None

It is simple to write a function that returns a list of the numbers of the Fibonacci series, instead of printing it:

>>>

**>>> def** fib2(n): *# return Fibonacci series up to n*

**...**  *"""Return a list containing the Fibonacci series up to n."""*

**...**  result = []

**...**  a, b = 0, 1

**...**  **while** a < n:

**...**  result.append(a) *# see below*

**...**  a, b = b, a+b

**...**  **return** result

**...**

**>>>** f100 = fib2(100) *# call it*

**>>>** f100 *# write the result*

[0, 1, 1, 2, 3, 5, 8, 13, 21, 34, 55, 89]

This example, as usual, demonstrates some new Python features:

* The [return](https://docs.python.org/3/reference/simple_stmts.html#return) statement returns with a value from a function. [return](https://docs.python.org/3/reference/simple_stmts.html#return) without an expression argument returns None. Falling off the end of a function also returns None.
* The statement result.append(a) calls a method of the list object result. A method is a function that ‘belongs’ to an object and is named obj.methodname, where obj is some object (this may be an expression), and methodname is the name of a method that is defined by the object’s type. Different types define different methods. Methods of different types may have the same name without causing ambiguity. (It is possible to define your own object types and methods, using classes, see [Classes](https://docs.python.org/3/tutorial/classes.html#tut-classes)) The method append() shown in the example is defined for list objects; it adds a new element at the end of the list. In this example it is equivalent toresult = result + [a], but more efficient.

## 4.7. More on Defining Functions

It is also possible to define functions with a variable number of arguments. There are three forms, which can be combined.

### 4.7.1. Default Argument Values

The most useful form is to specify a default value for one or more arguments. This creates a function that can be called with fewer arguments than it is defined to allow. For example:

**def** ask\_ok(prompt, retries=4, reminder='Please try again!'):

**while** **True**:

ok = input(prompt)

**if** ok **in** ('y', 'ye', 'yes'):

**return** **True**

**if** ok **in** ('n', 'no', 'nop', 'nope'):

**return** **False**

retries = retries - 1

**if** retries < 0:

**raise** ValueError('invalid user response')

print(reminder)

This function can be called in several ways:

* giving only the mandatory argument: ask\_ok('Do you really want to quit?')
* giving one of the optional arguments: ask\_ok('OK to overwrite the file?', 2)
* or even giving all arguments: ask\_ok('OK to overwrite the file?', 2, 'Come on, onlyyes or no!')

This example also introduces the [in](https://docs.python.org/3/reference/expressions.html#in) keyword. This tests whether or not a sequence contains a certain value.

The default values are evaluated at the point of function definition in the defining scope, so that

i = 5

**def** f(arg=i):

print(arg)

i = 6

f()

will print 5.

**Important warning:** The default value is evaluated only once. This makes a difference when the default is a mutable object such as a list, dictionary, or instances of most classes. For example, the following function accumulates the arguments passed to it on subsequent calls:

**def** f(a, L=[]):

L.append(a)

**return** L

print(f(1))

print(f(2))

print(f(3))

This will print

[1]

[1, 2]

[1, 2, 3]

If you don’t want the default to be shared between subsequent calls, you can write the function like this instead:

**def** f(a, L=**None**):

**if** L **is** **None**:

L = []

L.append(a)

**return** L

### 4.7.2. Keyword Arguments

Functions can also be called using [keyword arguments](https://docs.python.org/3/glossary.html#term-keyword-argument) of the form kwarg=value. For instance, the following function:

**def** parrot(voltage, state='a stiff', action='voom', type='Norwegian Blue'):

print("-- This parrot wouldn't", action, end=' ')

print("if you put", voltage, "volts through it.")

print("-- Lovely plumage, the", type)

print("-- It's", state, "!")

accepts one required argument (voltage) and three optional arguments (state, action, and type). This function can be called in any of the following ways:

parrot(1000) *# 1 positional argument*

parrot(voltage=1000) *# 1 keyword argument*

parrot(voltage=1000000, action='VOOOOOM') *# 2 keyword arguments*

parrot(action='VOOOOOM', voltage=1000000) *# 2 keyword arguments*

parrot('a million', 'bereft of life', 'jump') *# 3 positional arguments*

parrot('a thousand', state='pushing up the daisies') *# 1 positional, 1 keyword*

but all the following calls would be invalid:

parrot() *# required argument missing*

parrot(voltage=5.0, 'dead') *# non-keyword argument after a keyword argument*

parrot(110, voltage=220) *# duplicate value for the same argument*

parrot(actor='John Cleese') *# unknown keyword argument*

In a function call, keyword arguments must follow positional arguments. All the keyword arguments passed must match one of the arguments accepted by the function (e.g. actor is not a valid argument for the parrot function), and their order is not important. This also includes non-optional arguments (e.g. parrot(voltage=1000) is valid too). No argument may receive a value more than once. Here’s an example that fails due to this restriction:

>>>

**>>> def** function(a):

**...**  **pass**

**...**

**>>>** function(0, a=0)

Traceback (most recent call last):

File "<stdin>", line 1, in ?

TypeError: function() got multiple values for keyword argument 'a'

When a final formal parameter of the form \*\*name is present, it receives a dictionary (see [Mapping Types — dict](https://docs.python.org/3/library/stdtypes.html#typesmapping)) containing all keyword arguments except for those corresponding to a formal parameter. This may be combined with a formal parameter of the form \*name (described in the next subsection) which receives a tuple containing the positional arguments beyond the formal parameter list. (\*namemust occur before \*\*name.) For example, if we define a function like this:

**def** cheeseshop(kind, \*arguments, \*\*keywords):

print("-- Do you have any", kind, "?")

print("-- I'm sorry, we're all out of", kind)

**for** arg **in** arguments:

print(arg)

print("-" \* 40)

keys = sorted(keywords.keys())

**for** kw **in** keys:

print(kw, ":", keywords[kw])

It could be called like this:

cheeseshop("Limburger", "It's very runny, sir.",

"It's really very, VERY runny, sir.",

shopkeeper="Michael Palin",

client="John Cleese",

sketch="Cheese Shop Sketch")

and of course it would print:

-- Do you have any Limburger ?

-- I'm sorry, we're all out of Limburger

It's very runny, sir.

It's really very, VERY runny, sir.

----------------------------------------

client : John Cleese

shopkeeper : Michael Palin

sketch : Cheese Shop Sketch

Note that the list of keyword argument names is created by sorting the result of the keywords dictionary’s keys() method before printing its contents; if this is not done, the order in which the arguments are printed is undefined.

### 4.7.3. Arbitrary Argument Lists

Finally, the least frequently used option is to specify that a function can be called with an arbitrary number of arguments. These arguments will be wrapped up in a tuple (see [Tuples and Sequences](https://docs.python.org/3/tutorial/datastructures.html#tut-tuples)). Before the variable number of arguments, zero or more normal arguments may occur.

**def** write\_multiple\_items(file, separator, \*args):

file.write(separator.join(args))

Normally, these variadic arguments will be last in the list of formal parameters, because they scoop up all remaining input arguments that are passed to the function. Any formal parameters which occur after the \*args parameter are ‘keyword-only’ arguments, meaning that they can only be used as keywords rather than positional arguments.

>>>

**>>> def** concat(\*args, sep="/"):

**...**  **return** sep.join(args)

**...**

**>>>** concat("earth", "mars", "venus")

'earth/mars/venus'

**>>>** concat("earth", "mars", "venus", sep=".")

'earth.mars.venus'

### 4.7.4. Unpacking Argument Lists

The reverse situation occurs when the arguments are already in a list or tuple but need to be unpacked for a function call requiring separate positional arguments. For instance, the built-in [range()](https://docs.python.org/3/library/stdtypes.html#range)function expects separate start and stop arguments. If they are not available separately, write the function call with the \*-operator to unpack the arguments out of a list or tuple:

>>>

**>>>** list(range(3, 6)) *# normal call with separate arguments*

[3, 4, 5]

**>>>** args = [3, 6]

**>>>** list(range(\*args)) *# call with arguments unpacked from a list*

[3, 4, 5]

In the same fashion, dictionaries can deliver keyword arguments with the \*\*-operator:

>>>

**>>> def** parrot(voltage, state='a stiff', action='voom'):

**...**  print("-- This parrot wouldn't", action, end=' ')

**...**  print("if you put", voltage, "volts through it.", end=' ')

**...**  print("E's", state, "!")

**...**

**>>>** d = {"voltage": "four million", "state": "bleedin' demised", "action": "VOOM"}

**>>>** parrot(\*\*d)

-- This parrot wouldn't VOOM if you put four million volts through it. E's bleedin' demised !

### 4.7.5. Lambda Expressions

Small anonymous functions can be created with the [lambda](https://docs.python.org/3/reference/expressions.html#lambda) keyword. This function returns the sum of its two arguments: lambda a, b: a+b. Lambda functions can be used wherever function objects are required. They are syntactically restricted to a single expression. Semantically, they are just syntactic sugar for a normal function definition. Like nested function definitions, lambda functions can reference variables from the containing scope:

>>>

**>>> def** make\_incrementor(n):

**...**  **return** **lambda** x: x + n

**...**

**>>>** f = make\_incrementor(42)

**>>>** f(0)

42

**>>>** f(1)

43

The above example uses a lambda expression to return a function. Another use is to pass a small function as an argument:

>>>

**>>>** pairs = [(1, 'one'), (2, 'two'), (3, 'three'), (4, 'four')]

**>>>** pairs.sort(key=**lambda** pair: pair[1])

**>>>** pairs

[(4, 'four'), (1, 'one'), (3, 'three'), (2, 'two')]

### 4.7.6. Documentation Strings

Here are some conventions about the content and formatting of documentation strings.

The first line should always be a short, concise summary of the object’s purpose. For brevity, it should not explicitly state the object’s name or type, since these are available by other means (except if the name happens to be a verb describing a function’s operation). This line should begin with a capital letter and end with a period.

If there are more lines in the documentation string, the second line should be blank, visually separating the summary from the rest of the description. The following lines should be one or more paragraphs describing the object’s calling conventions, its side effects, etc.

The Python parser does not strip indentation from multi-line string literals in Python, so tools that process documentation have to strip indentation if desired. This is done using the following convention. The first non-blank line after the first line of the string determines the amount of indentation for the entire documentation string. (We can’t use the first line since it is generally adjacent to the string’s opening quotes so its indentation is not apparent in the string literal.) Whitespace “equivalent” to this indentation is then stripped from the start of all lines of the string. Lines that are indented less should not occur, but if they occur all their leading whitespace should be stripped. Equivalence of whitespace should be tested after expansion of tabs (to 8 spaces, normally).

Here is an example of a multi-line docstring:

>>>

**>>> def** my\_function():

**...**  *"""Do nothing, but document it.*

**...**

**...**  *No, really, it doesn't do anything.*

**...**  *"""*

**...**  **pass**

**...**

**>>>** print(my\_function.\_\_doc\_\_)

Do nothing, but document it.

No, really, it doesn't do anything.

### 4.7.7. Function Annotations

[Function annotations](https://docs.python.org/3/reference/compound_stmts.html#function) are completely optional metadata information about the types used by user-defined functions (see [**PEP 484**](https://www.python.org/dev/peps/pep-0484) for more information).

Annotations are stored in the \_\_annotations\_\_ attribute of the function as a dictionary and have no effect on any other part of the function. Parameter annotations are defined by a colon after the parameter name, followed by an expression evaluating to the value of the annotation. Return annotations are defined by a literal ->, followed by an expression, between the parameter list and the colon denoting the end of the [def](https://docs.python.org/3/reference/compound_stmts.html#def) statement. The following example has a positional argument, a keyword argument, and the return value annotated:

>>>

**>>> def** f(ham: str, eggs: str = 'eggs') -> str:

**...**  print("Annotations:", f.\_\_annotations\_\_)

**...**  print("Arguments:", ham, eggs)

**...**  **return** ham + ' and ' + eggs

**...**

**>>>** f('spam')

Annotations: {'ham': <class 'str'>, 'return': <class 'str'>, 'eggs': <class 'str'>}

Arguments: spam eggs

'spam and eggs'

## 4.8. Intermezzo: Coding Style

Now that you are about to write longer, more complex pieces of Python, it is a good time to talk aboutcoding style. Most languages can be written (or more concise, formatted) in different styles; some are more readable than others. Making it easy for others to read your code is always a good idea, and adopting a nice coding style helps tremendously for that.

For Python, [**PEP 8**](https://www.python.org/dev/peps/pep-0008) has emerged as the style guide that most projects adhere to; it promotes a very readable and eye-pleasing coding style. Every Python developer should read it at some point; here are the most important points extracted for you:

* Use 4-space indentation, and no tabs.

4 spaces are a good compromise between small indentation (allows greater nesting depth) and large indentation (easier to read). Tabs introduce confusion, and are best left out.

* Wrap lines so that they don’t exceed 79 characters.

This helps users with small displays and makes it possible to have several code files side-by-side on larger displays.

* Use blank lines to separate functions and classes, and larger blocks of code inside functions.
* When possible, put comments on a line of their own.
* Use docstrings.
* Use spaces around operators and after commas, but not directly inside bracketing constructs: a= f(1, 2) + g(3, 4).
* Name your classes and functions consistently; the convention is to use CamelCase for classes and lower\_case\_with\_underscores for functions and methods. Always use self as the name for the first method argument (see [A First Look at Classes](https://docs.python.org/3/tutorial/classes.html#tut-firstclasses) for more on classes and methods).
* Don’t use fancy encodings if your code is meant to be used in international environments. Python’s default, UTF-8, or even plain ASCII work best in any case.
* Likewise, don’t use non-ASCII characters in identifiers if there is only the slightest chance people speaking a different language will read or maintain the code.

**Footnotes**

|  |  |
| --- | --- |
| [[1]](https://docs.python.org/3/tutorial/controlflow.html#id1) | Actually, call by object reference would be a better description, since if a mutable object is passed, the caller will see any changes the callee makes to it (items inserted into a list). |

# 4. More Control Flow Tools

Besides the [while](https://docs.python.org/3/reference/compound_stmts.html#while) statement just introduced, Python knows the usual control flow statements known from other languages, with some twists.

## 4.1. [if](https://docs.python.org/3/reference/compound_stmts.html#if) Statements

Perhaps the most well-known statement type is the [if](https://docs.python.org/3/reference/compound_stmts.html#if) statement. For example:

>>>

**>>>** x = int(input("Please enter an integer: "))

Please enter an integer: 42

**>>> if** x < 0:

**...**  x = 0

**...**  print('Negative changed to zero')

**... elif** x == 0:

**...**  print('Zero')

**... elif** x == 1:

**...**  print('Single')

**... else**:

**...**  print('More')

**...**

More

There can be zero or more [elif](https://docs.python.org/3/reference/compound_stmts.html#elif) parts, and the [else](https://docs.python.org/3/reference/compound_stmts.html#else) part is optional. The keyword ‘[elif](https://docs.python.org/3/reference/compound_stmts.html#elif)‘ is short for ‘else if’, and is useful to avoid excessive indentation. An [if](https://docs.python.org/3/reference/compound_stmts.html#if) ... [elif](https://docs.python.org/3/reference/compound_stmts.html#elif) ... [elif](https://docs.python.org/3/reference/compound_stmts.html#elif) ... sequence is a substitute for the switch or case statements found in other languages.

## 4.2. [for](https://docs.python.org/3/reference/compound_stmts.html#for) Statements

The [for](https://docs.python.org/3/reference/compound_stmts.html#for) statement in Python differs a bit from what you may be used to in C or Pascal. Rather than always iterating over an arithmetic progression of numbers (like in Pascal), or giving the user the ability to define both the iteration step and halting condition (as C), Python’s [for](https://docs.python.org/3/reference/compound_stmts.html#for) statement iterates over the items of any sequence (a list or a string), in the order that they appear in the sequence. For example (no pun intended):

>>>

**>>>** *# Measure some strings:*

**...** words = ['cat', 'window', 'defenestrate']

**>>> for** w **in** words:

**...**  print(w, len(w))

**...**

cat 3

window 6

defenestrate 12

If you need to modify the sequence you are iterating over while inside the loop (for example to duplicate selected items), it is recommended that you first make a copy. Iterating over a sequence does not implicitly make a copy. The slice notation makes this especially convenient:

>>>

**>>> for** w **in** words[:]: *# Loop over a slice copy of the entire list.*

**...**  **if** len(w) > 6:

**...**  words.insert(0, w)

**...**

**>>>** words

['defenestrate', 'cat', 'window', 'defenestrate']

## 4.3. The [range()](https://docs.python.org/3/library/stdtypes.html#range) Function

If you do need to iterate over a sequence of numbers, the built-in function [range()](https://docs.python.org/3/library/stdtypes.html#range) comes in handy. It generates arithmetic progressions:

>>>

**>>> for** i **in** range(5):

**...**  print(i)

**...**

0

1

2

3

4

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

range(5, 10)

5 through 9

range(0, 10, 3)

0, 3, 6, 9

range(-10, -100, -30)

-10, -40, -70

To iterate over the indices of a sequence, you can combine [range()](https://docs.python.org/3/library/stdtypes.html#range) and [len()](https://docs.python.org/3/library/functions.html#len) as follows:

>>>

**>>>** a = ['Mary', 'had', 'a', 'little', 'lamb']

**>>> for** i **in** range(len(a)):

**...**  print(i, a[i])

**...**

0 Mary

1 had

2 a

3 little

4 lamb

In most such cases, however, it is convenient to use the [enumerate()](https://docs.python.org/3/library/functions.html#enumerate) function, see [Looping Techniques](https://docs.python.org/3/tutorial/datastructures.html#tut-loopidioms).

A strange thing happens if you just print a range:

>>>

**>>>** print(range(10))

range(0, 10)

In many ways the object returned by [range()](https://docs.python.org/3/library/stdtypes.html#range) behaves as if it is a list, but in fact it isn’t. It is an object which returns the successive items of the desired sequence when you iterate over it, but it doesn’t really make the list, thus saving space.

We say such an object is iterable, that is, suitable as a target for functions and constructs that expect something from which they can obtain successive items until the supply is exhausted. We have seen that the [for](https://docs.python.org/3/reference/compound_stmts.html#for) statement is such an iterator. The function [list()](https://docs.python.org/3/library/stdtypes.html#list) is another; it creates lists from iterables:

>>>

**>>>** list(range(5))

[0, 1, 2, 3, 4]

Later we will see more functions that return iterables and take iterables as argument.

## 4.4. [break](https://docs.python.org/3/reference/simple_stmts.html#break) and [continue](https://docs.python.org/3/reference/simple_stmts.html#continue) Statements, and [else](https://docs.python.org/3/reference/compound_stmts.html#else) Clauses on Loops

The [break](https://docs.python.org/3/reference/simple_stmts.html#break) statement, like in C, breaks out of the smallest enclosing [for](https://docs.python.org/3/reference/compound_stmts.html#for) or [while](https://docs.python.org/3/reference/compound_stmts.html#while) loop.

Loop statements may have an else clause; it is executed when the loop terminates through exhaustion of the list (with [for](https://docs.python.org/3/reference/compound_stmts.html#for)) or when the condition becomes false (with [while](https://docs.python.org/3/reference/compound_stmts.html#while)), but not when the loop is terminated by a [break](https://docs.python.org/3/reference/simple_stmts.html#break) statement. This is exemplified by the following loop, which searches for prime numbers:

>>>

**>>> for** n **in** range(2, 10):

**...**  **for** x **in** range(2, n):

**...**  **if** n % x == 0:

**...**  print(n, 'equals', x, '\*', n//x)

**...**  **break**

**...**  **else**:

**...**  *# loop fell through without finding a factor*

**...**  print(n, 'is a prime number')

**...**

2 is a prime number

3 is a prime number

4 equals 2 \* 2

5 is a prime number

6 equals 2 \* 3

7 is a prime number

8 equals 2 \* 4

9 equals 3 \* 3

(Yes, this is the correct code. Look closely: the else clause belongs to the [for](https://docs.python.org/3/reference/compound_stmts.html#for) loop, **not** the [if](https://docs.python.org/3/reference/compound_stmts.html#if)statement.)

When used with a loop, the else clause has more in common with the else clause of a [try](https://docs.python.org/3/reference/compound_stmts.html#try)statement than it does that of [if](https://docs.python.org/3/reference/compound_stmts.html#if) statements: a [try](https://docs.python.org/3/reference/compound_stmts.html#try) statement’s else clause runs when no exception occurs, and a loop’s else clause runs when no break occurs. For more on the [try](https://docs.python.org/3/reference/compound_stmts.html#try) statement and exceptions, see [Handling Exceptions](https://docs.python.org/3/tutorial/errors.html#tut-handling).

The [continue](https://docs.python.org/3/reference/simple_stmts.html#continue) statement, also borrowed from C, continues with the next iteration of the loop:

>>>

**>>> for** num **in** range(2, 10):

**...**  **if** num % 2 == 0:

**...**  print("Found an even number", num)

**...**  **continue**

**...**  print("Found a number", num)

Found an even number 2

Found a number 3

Found an even number 4

Found a number 5

Found an even number 6

Found a number 7

Found an even number 8

Found a number 9

## 4.5. [pass](https://docs.python.org/3/reference/simple_stmts.html#pass) Statements

The [pass](https://docs.python.org/3/reference/simple_stmts.html#pass) statement does nothing. It can be used when a statement is required syntactically but the program requires no action. For example:

>>>

**>>> while** **True**:

**...**  **pass** *# Busy-wait for keyboard interrupt (Ctrl+C)*

**...**

This is commonly used for creating minimal classes:

>>>

**>>> class** **MyEmptyClass**:

**...**  **pass**

**...**

Another place [pass](https://docs.python.org/3/reference/simple_stmts.html#pass) can be used is as a place-holder for a function or conditional body when you are working on new code, allowing you to keep thinking at a more abstract level. The [pass](https://docs.python.org/3/reference/simple_stmts.html#pass) is silently ignored:

>>>

**>>> def** initlog(\*args):

**...**  **pass** *# Remember to implement this!*

**...**

## 4.6. Defining Functions

We can create a function that writes the Fibonacci series to an arbitrary boundary:

>>>

**>>> def** fib(n): *# write Fibonacci series up to n*

**...**  *"""Print a Fibonacci series up to n."""*

**...**  a, b = 0, 1

**...**  **while** a < n:

**...**  print(a, end=' ')

**...**  a, b = b, a+b

**...**  print()

**...**

**>>>** *# Now call the function we just defined:*

**...** fib(2000)

0 1 1 2 3 5 8 13 21 34 55 89 144 233 377 610 987 1597

The keyword [def](https://docs.python.org/3/reference/compound_stmts.html#def) introduces a function definition. It must be followed by the function name and the parenthesized list of formal parameters. The statements that form the body of the function start at the next line, and must be indented.

The first statement of the function body can optionally be a string literal; this string literal is the function’s documentation string, or docstring. (More about docstrings can be found in the section[Documentation Strings](https://docs.python.org/3/tutorial/controlflow.html#tut-docstrings).) There are tools which use docstrings to automatically produce online or printed documentation, or to let the user interactively browse through code; it’s good practice to include docstrings in code that you write, so make a habit of it.

The execution of a function introduces a new symbol table used for the local variables of the function. More precisely, all variable assignments in a function store the value in the local symbol table; whereas variable references first look in the local symbol table, then in the local symbol tables of enclosing functions, then in the global symbol table, and finally in the table of built-in names. Thus, global variables cannot be directly assigned a value within a function (unless named in a [global](https://docs.python.org/3/reference/simple_stmts.html#global)statement), although they may be referenced.

The actual parameters (arguments) to a function call are introduced in the local symbol table of the called function when it is called; thus, arguments are passed using call by value (where the value is always an object reference, not the value of the object). [[1]](https://docs.python.org/3/tutorial/controlflow.html#id2) When a function calls another function, a new local symbol table is created for that call.

A function definition introduces the function name in the current symbol table. The value of the function name has a type that is recognized by the interpreter as a user-defined function. This value can be assigned to another name which can then also be used as a function. This serves as a general renaming mechanism:

>>>

**>>>** fib

<function fib at 10042ed0>

**>>>** f = fib

**>>>** f(100)

0 1 1 2 3 5 8 13 21 34 55 89

Coming from other languages, you might object that fib is not a function but a procedure since it doesn’t return a value. In fact, even functions without a [return](https://docs.python.org/3/reference/simple_stmts.html#return) statement do return a value, albeit a rather boring one. This value is called None (it’s a built-in name). Writing the value None is normally suppressed by the interpreter if it would be the only value written. You can see it if you really want to using [print()](https://docs.python.org/3/library/functions.html#print):

>>>

**>>>** fib(0)

**>>>** print(fib(0))

None

It is simple to write a function that returns a list of the numbers of the Fibonacci series, instead of printing it:

>>>

**>>> def** fib2(n): *# return Fibonacci series up to n*

**...**  *"""Return a list containing the Fibonacci series up to n."""*

**...**  result = []

**...**  a, b = 0, 1

**...**  **while** a < n:

**...**  result.append(a) *# see below*

**...**  a, b = b, a+b

**...**  **return** result

**...**

**>>>** f100 = fib2(100) *# call it*

**>>>** f100 *# write the result*

[0, 1, 1, 2, 3, 5, 8, 13, 21, 34, 55, 89]

This example, as usual, demonstrates some new Python features:

* The [return](https://docs.python.org/3/reference/simple_stmts.html#return) statement returns with a value from a function. [return](https://docs.python.org/3/reference/simple_stmts.html#return) without an expression argument returns None. Falling off the end of a function also returns None.
* The statement result.append(a) calls a method of the list object result. A method is a function that ‘belongs’ to an object and is named obj.methodname, where obj is some object (this may be an expression), and methodname is the name of a method that is defined by the object’s type. Different types define different methods. Methods of different types may have the same name without causing ambiguity. (It is possible to define your own object types and methods, using classes, see [Classes](https://docs.python.org/3/tutorial/classes.html#tut-classes)) The method append() shown in the example is defined for list objects; it adds a new element at the end of the list. In this example it is equivalent toresult = result + [a], but more efficient.

## 4.7. More on Defining Functions

It is also possible to define functions with a variable number of arguments. There are three forms, which can be combined.

### 4.7.1. Default Argument Values

The most useful form is to specify a default value for one or more arguments. This creates a function that can be called with fewer arguments than it is defined to allow. For example:

**def** ask\_ok(prompt, retries=4, reminder='Please try again!'):

**while** **True**:

ok = input(prompt)

**if** ok **in** ('y', 'ye', 'yes'):

**return** **True**

**if** ok **in** ('n', 'no', 'nop', 'nope'):

**return** **False**

retries = retries - 1

**if** retries < 0:

**raise** ValueError('invalid user response')

print(reminder)

This function can be called in several ways:

* giving only the mandatory argument: ask\_ok('Do you really want to quit?')
* giving one of the optional arguments: ask\_ok('OK to overwrite the file?', 2)
* or even giving all arguments: ask\_ok('OK to overwrite the file?', 2, 'Come on, onlyyes or no!')

This example also introduces the [in](https://docs.python.org/3/reference/expressions.html#in) keyword. This tests whether or not a sequence contains a certain value.

The default values are evaluated at the point of function definition in the defining scope, so that

i = 5

**def** f(arg=i):

print(arg)

i = 6

f()

will print 5.

**Important warning:** The default value is evaluated only once. This makes a difference when the default is a mutable object such as a list, dictionary, or instances of most classes. For example, the following function accumulates the arguments passed to it on subsequent calls:

**def** f(a, L=[]):

L.append(a)

**return** L

print(f(1))

print(f(2))

print(f(3))

This will print

[1]

[1, 2]

[1, 2, 3]

If you don’t want the default to be shared between subsequent calls, you can write the function like this instead:

**def** f(a, L=**None**):

**if** L **is** **None**:

L = []

L.append(a)

**return** L

### 4.7.2. Keyword Arguments

Functions can also be called using [keyword arguments](https://docs.python.org/3/glossary.html#term-keyword-argument) of the form kwarg=value. For instance, the following function:

**def** parrot(voltage, state='a stiff', action='voom', type='Norwegian Blue'):

print("-- This parrot wouldn't", action, end=' ')

print("if you put", voltage, "volts through it.")

print("-- Lovely plumage, the", type)

print("-- It's", state, "!")

accepts one required argument (voltage) and three optional arguments (state, action, and type). This function can be called in any of the following ways:

parrot(1000) *# 1 positional argument*

parrot(voltage=1000) *# 1 keyword argument*

parrot(voltage=1000000, action='VOOOOOM') *# 2 keyword arguments*

parrot(action='VOOOOOM', voltage=1000000) *# 2 keyword arguments*

parrot('a million', 'bereft of life', 'jump') *# 3 positional arguments*

parrot('a thousand', state='pushing up the daisies') *# 1 positional, 1 keyword*

but all the following calls would be invalid:

parrot() *# required argument missing*

parrot(voltage=5.0, 'dead') *# non-keyword argument after a keyword argument*

parrot(110, voltage=220) *# duplicate value for the same argument*

parrot(actor='John Cleese') *# unknown keyword argument*

In a function call, keyword arguments must follow positional arguments. All the keyword arguments passed must match one of the arguments accepted by the function (e.g. actor is not a valid argument for the parrot function), and their order is not important. This also includes non-optional arguments (e.g. parrot(voltage=1000) is valid too). No argument may receive a value more than once. Here’s an example that fails due to this restriction:

>>>

**>>> def** function(a):

**...**  **pass**

**...**

**>>>** function(0, a=0)

Traceback (most recent call last):

File "<stdin>", line 1, in ?

TypeError: function() got multiple values for keyword argument 'a'

When a final formal parameter of the form \*\*name is present, it receives a dictionary (see [Mapping Types — dict](https://docs.python.org/3/library/stdtypes.html#typesmapping)) containing all keyword arguments except for those corresponding to a formal parameter. This may be combined with a formal parameter of the form \*name (described in the next subsection) which receives a tuple containing the positional arguments beyond the formal parameter list. (\*namemust occur before \*\*name.) For example, if we define a function like this:

**def** cheeseshop(kind, \*arguments, \*\*keywords):

print("-- Do you have any", kind, "?")

print("-- I'm sorry, we're all out of", kind)

**for** arg **in** arguments:

print(arg)

print("-" \* 40)

keys = sorted(keywords.keys())

**for** kw **in** keys:

print(kw, ":", keywords[kw])

It could be called like this:

cheeseshop("Limburger", "It's very runny, sir.",

"It's really very, VERY runny, sir.",

shopkeeper="Michael Palin",

client="John Cleese",

sketch="Cheese Shop Sketch")

and of course it would print:

-- Do you have any Limburger ?

-- I'm sorry, we're all out of Limburger

It's very runny, sir.

It's really very, VERY runny, sir.

----------------------------------------

client : John Cleese

shopkeeper : Michael Palin

sketch : Cheese Shop Sketch

Note that the list of keyword argument names is created by sorting the result of the keywords dictionary’s keys() method before printing its contents; if this is not done, the order in which the arguments are printed is undefined.

### 4.7.3. Arbitrary Argument Lists

Finally, the least frequently used option is to specify that a function can be called with an arbitrary number of arguments. These arguments will be wrapped up in a tuple (see [Tuples and Sequences](https://docs.python.org/3/tutorial/datastructures.html#tut-tuples)). Before the variable number of arguments, zero or more normal arguments may occur.

**def** write\_multiple\_items(file, separator, \*args):

file.write(separator.join(args))

Normally, these variadic arguments will be last in the list of formal parameters, because they scoop up all remaining input arguments that are passed to the function. Any formal parameters which occur after the \*args parameter are ‘keyword-only’ arguments, meaning that they can only be used as keywords rather than positional arguments.

>>>

**>>> def** concat(\*args, sep="/"):

**...**  **return** sep.join(args)

**...**

**>>>** concat("earth", "mars", "venus")

'earth/mars/venus'

**>>>** concat("earth", "mars", "venus", sep=".")

'earth.mars.venus'

### 4.7.4. Unpacking Argument Lists

The reverse situation occurs when the arguments are already in a list or tuple but need to be unpacked for a function call requiring separate positional arguments. For instance, the built-in [range()](https://docs.python.org/3/library/stdtypes.html#range)function expects separate start and stop arguments. If they are not available separately, write the function call with the \*-operator to unpack the arguments out of a list or tuple:

>>>

**>>>** list(range(3, 6)) *# normal call with separate arguments*

[3, 4, 5]

**>>>** args = [3, 6]

**>>>** list(range(\*args)) *# call with arguments unpacked from a list*

[3, 4, 5]

In the same fashion, dictionaries can deliver keyword arguments with the \*\*-operator:

>>>

**>>> def** parrot(voltage, state='a stiff', action='voom'):

**...**  print("-- This parrot wouldn't", action, end=' ')

**...**  print("if you put", voltage, "volts through it.", end=' ')

**...**  print("E's", state, "!")

**...**

**>>>** d = {"voltage": "four million", "state": "bleedin' demised", "action": "VOOM"}

**>>>** parrot(\*\*d)

-- This parrot wouldn't VOOM if you put four million volts through it. E's bleedin' demised !

### 4.7.5. Lambda Expressions

Small anonymous functions can be created with the [lambda](https://docs.python.org/3/reference/expressions.html#lambda) keyword. This function returns the sum of its two arguments: lambda a, b: a+b. Lambda functions can be used wherever function objects are required. They are syntactically restricted to a single expression. Semantically, they are just syntactic sugar for a normal function definition. Like nested function definitions, lambda functions can reference variables from the containing scope:

>>>

**>>> def** make\_incrementor(n):

**...**  **return** **lambda** x: x + n

**...**

**>>>** f = make\_incrementor(42)

**>>>** f(0)

42

**>>>** f(1)

43

The above example uses a lambda expression to return a function. Another use is to pass a small function as an argument:

>>>

**>>>** pairs = [(1, 'one'), (2, 'two'), (3, 'three'), (4, 'four')]

**>>>** pairs.sort(key=**lambda** pair: pair[1])

**>>>** pairs

[(4, 'four'), (1, 'one'), (3, 'three'), (2, 'two')]

### 4.7.6. Documentation Strings

Here are some conventions about the content and formatting of documentation strings.

The first line should always be a short, concise summary of the object’s purpose. For brevity, it should not explicitly state the object’s name or type, since these are available by other means (except if the name happens to be a verb describing a function’s operation). This line should begin with a capital letter and end with a period.

If there are more lines in the documentation string, the second line should be blank, visually separating the summary from the rest of the description. The following lines should be one or more paragraphs describing the object’s calling conventions, its side effects, etc.

The Python parser does not strip indentation from multi-line string literals in Python, so tools that process documentation have to strip indentation if desired. This is done using the following convention. The first non-blank line after the first line of the string determines the amount of indentation for the entire documentation string. (We can’t use the first line since it is generally adjacent to the string’s opening quotes so its indentation is not apparent in the string literal.) Whitespace “equivalent” to this indentation is then stripped from the start of all lines of the string. Lines that are indented less should not occur, but if they occur all their leading whitespace should be stripped. Equivalence of whitespace should be tested after expansion of tabs (to 8 spaces, normally).

Here is an example of a multi-line docstring:

>>>

**>>> def** my\_function():

**...**  *"""Do nothing, but document it.*

**...**

**...**  *No, really, it doesn't do anything.*

**...**  *"""*

**...**  **pass**

**...**

**>>>** print(my\_function.\_\_doc\_\_)

Do nothing, but document it.

No, really, it doesn't do anything.

### 4.7.7. Function Annotations

[Function annotations](https://docs.python.org/3/reference/compound_stmts.html#function) are completely optional metadata information about the types used by user-defined functions (see [**PEP 484**](https://www.python.org/dev/peps/pep-0484) for more information).

Annotations are stored in the \_\_annotations\_\_ attribute of the function as a dictionary and have no effect on any other part of the function. Parameter annotations are defined by a colon after the parameter name, followed by an expression evaluating to the value of the annotation. Return annotations are defined by a literal ->, followed by an expression, between the parameter list and the colon denoting the end of the [def](https://docs.python.org/3/reference/compound_stmts.html#def) statement. The following example has a positional argument, a keyword argument, and the return value annotated:

>>>

**>>> def** f(ham: str, eggs: str = 'eggs') -> str:

**...**  print("Annotations:", f.\_\_annotations\_\_)

**...**  print("Arguments:", ham, eggs)

**...**  **return** ham + ' and ' + eggs

**...**

**>>>** f('spam')

Annotations: {'ham': <class 'str'>, 'return': <class 'str'>, 'eggs': <class 'str'>}

Arguments: spam eggs

'spam and eggs'

## 4.8. Intermezzo: Coding Style

Now that you are about to write longer, more complex pieces of Python, it is a good time to talk aboutcoding style. Most languages can be written (or more concise, formatted) in different styles; some are more readable than others. Making it easy for others to read your code is always a good idea, and adopting a nice coding style helps tremendously for that.

For Python, [**PEP 8**](https://www.python.org/dev/peps/pep-0008) has emerged as the style guide that most projects adhere to; it promotes a very readable and eye-pleasing coding style. Every Python developer should read it at some point; here are the most important points extracted for you:

* Use 4-space indentation, and no tabs.

4 spaces are a good compromise between small indentation (allows greater nesting depth) and large indentation (easier to read). Tabs introduce confusion, and are best left out.

* Wrap lines so that they don’t exceed 79 characters.

This helps users with small displays and makes it possible to have several code files side-by-side on larger displays.

* Use blank lines to separate functions and classes, and larger blocks of code inside functions.
* When possible, put comments on a line of their own.
* Use docstrings.
* Use spaces around operators and after commas, but not directly inside bracketing constructs: a= f(1, 2) + g(3, 4).
* Name your classes and functions consistently; the convention is to use CamelCase for classes and lower\_case\_with\_underscores for functions and methods. Always use self as the name for the first method argument (see [A First Look at Classes](https://docs.python.org/3/tutorial/classes.html#tut-firstclasses) for more on classes and methods).
* Don’t use fancy encodings if your code is meant to be used in international environments. Python’s default, UTF-8, or even plain ASCII work best in any case.
* Likewise, don’t use non-ASCII characters in identifiers if there is only the slightest chance people speaking a different language will read or maintain the code.

**Footnotes**

|  |  |
| --- | --- |
| [[1]](https://docs.python.org/3/tutorial/controlflow.html#id1) | Actually, call by object reference would be a better description, since if a mutable object is passed, the caller will see any changes the callee makes to it (items inserted into a list). |

# 4. More Control Flow Tools

Besides the [while](https://docs.python.org/3/reference/compound_stmts.html#while) statement just introduced, Python knows the usual control flow statements known from other languages, with some twists.

## 4.1. [if](https://docs.python.org/3/reference/compound_stmts.html#if) Statements

Perhaps the most well-known statement type is the [if](https://docs.python.org/3/reference/compound_stmts.html#if) statement. For example:

>>>

**>>>** x = int(input("Please enter an integer: "))

Please enter an integer: 42

**>>> if** x < 0:

**...**  x = 0

**...**  print('Negative changed to zero')

**... elif** x == 0:

**...**  print('Zero')

**... elif** x == 1:

**...**  print('Single')

**... else**:

**...**  print('More')

**...**

More

There can be zero or more [elif](https://docs.python.org/3/reference/compound_stmts.html#elif) parts, and the [else](https://docs.python.org/3/reference/compound_stmts.html#else) part is optional. The keyword ‘[elif](https://docs.python.org/3/reference/compound_stmts.html#elif)‘ is short for ‘else if’, and is useful to avoid excessive indentation. An [if](https://docs.python.org/3/reference/compound_stmts.html#if) ... [elif](https://docs.python.org/3/reference/compound_stmts.html#elif) ... [elif](https://docs.python.org/3/reference/compound_stmts.html#elif) ... sequence is a substitute for the switch or case statements found in other languages.

## 4.2. [for](https://docs.python.org/3/reference/compound_stmts.html#for) Statements

The [for](https://docs.python.org/3/reference/compound_stmts.html#for) statement in Python differs a bit from what you may be used to in C or Pascal. Rather than always iterating over an arithmetic progression of numbers (like in Pascal), or giving the user the ability to define both the iteration step and halting condition (as C), Python’s [for](https://docs.python.org/3/reference/compound_stmts.html#for) statement iterates over the items of any sequence (a list or a string), in the order that they appear in the sequence. For example (no pun intended):

>>>

**>>>** *# Measure some strings:*

**...** words = ['cat', 'window', 'defenestrate']

**>>> for** w **in** words:

**...**  print(w, len(w))

**...**

cat 3

window 6

defenestrate 12

If you need to modify the sequence you are iterating over while inside the loop (for example to duplicate selected items), it is recommended that you first make a copy. Iterating over a sequence does not implicitly make a copy. The slice notation makes this especially convenient:

>>>

**>>> for** w **in** words[:]: *# Loop over a slice copy of the entire list.*

**...**  **if** len(w) > 6:

**...**  words.insert(0, w)

**...**

**>>>** words

['defenestrate', 'cat', 'window', 'defenestrate']

## 4.3. The [range()](https://docs.python.org/3/library/stdtypes.html#range) Function

If you do need to iterate over a sequence of numbers, the built-in function [range()](https://docs.python.org/3/library/stdtypes.html#range) comes in handy. It generates arithmetic progressions:

>>>

**>>> for** i **in** range(5):

**...**  print(i)

**...**

0

1

2

3

4

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

range(5, 10)

5 through 9

range(0, 10, 3)

0, 3, 6, 9

range(-10, -100, -30)

-10, -40, -70

To iterate over the indices of a sequence, you can combine [range()](https://docs.python.org/3/library/stdtypes.html#range) and [len()](https://docs.python.org/3/library/functions.html#len) as follows:

>>>

**>>>** a = ['Mary', 'had', 'a', 'little', 'lamb']

**>>> for** i **in** range(len(a)):

**...**  print(i, a[i])

**...**

0 Mary

1 had

2 a

3 little

4 lamb

In most such cases, however, it is convenient to use the [enumerate()](https://docs.python.org/3/library/functions.html#enumerate) function, see [Looping Techniques](https://docs.python.org/3/tutorial/datastructures.html#tut-loopidioms).

A strange thing happens if you just print a range:

>>>

**>>>** print(range(10))

range(0, 10)

In many ways the object returned by [range()](https://docs.python.org/3/library/stdtypes.html#range) behaves as if it is a list, but in fact it isn’t. It is an object which returns the successive items of the desired sequence when you iterate over it, but it doesn’t really make the list, thus saving space.

We say such an object is iterable, that is, suitable as a target for functions and constructs that expect something from which they can obtain successive items until the supply is exhausted. We have seen that the [for](https://docs.python.org/3/reference/compound_stmts.html#for) statement is such an iterator. The function [list()](https://docs.python.org/3/library/stdtypes.html#list) is another; it creates lists from iterables:

>>>

**>>>** list(range(5))

[0, 1, 2, 3, 4]

Later we will see more functions that return iterables and take iterables as argument.

## 4.4. [break](https://docs.python.org/3/reference/simple_stmts.html#break) and [continue](https://docs.python.org/3/reference/simple_stmts.html#continue) Statements, and [else](https://docs.python.org/3/reference/compound_stmts.html#else) Clauses on Loops

The [break](https://docs.python.org/3/reference/simple_stmts.html#break) statement, like in C, breaks out of the smallest enclosing [for](https://docs.python.org/3/reference/compound_stmts.html#for) or [while](https://docs.python.org/3/reference/compound_stmts.html#while) loop.

Loop statements may have an else clause; it is executed when the loop terminates through exhaustion of the list (with [for](https://docs.python.org/3/reference/compound_stmts.html#for)) or when the condition becomes false (with [while](https://docs.python.org/3/reference/compound_stmts.html#while)), but not when the loop is terminated by a [break](https://docs.python.org/3/reference/simple_stmts.html#break) statement. This is exemplified by the following loop, which searches for prime numbers:

>>>

**>>> for** n **in** range(2, 10):

**...**  **for** x **in** range(2, n):

**...**  **if** n % x == 0:

**...**  print(n, 'equals', x, '\*', n//x)

**...**  **break**

**...**  **else**:

**...**  *# loop fell through without finding a factor*

**...**  print(n, 'is a prime number')

**...**

2 is a prime number

3 is a prime number

4 equals 2 \* 2

5 is a prime number

6 equals 2 \* 3

7 is a prime number

8 equals 2 \* 4

9 equals 3 \* 3

(Yes, this is the correct code. Look closely: the else clause belongs to the [for](https://docs.python.org/3/reference/compound_stmts.html#for) loop, **not** the [if](https://docs.python.org/3/reference/compound_stmts.html#if)statement.)

When used with a loop, the else clause has more in common with the else clause of a [try](https://docs.python.org/3/reference/compound_stmts.html#try)statement than it does that of [if](https://docs.python.org/3/reference/compound_stmts.html#if) statements: a [try](https://docs.python.org/3/reference/compound_stmts.html#try) statement’s else clause runs when no exception occurs, and a loop’s else clause runs when no break occurs. For more on the [try](https://docs.python.org/3/reference/compound_stmts.html#try) statement and exceptions, see [Handling Exceptions](https://docs.python.org/3/tutorial/errors.html#tut-handling).

The [continue](https://docs.python.org/3/reference/simple_stmts.html#continue) statement, also borrowed from C, continues with the next iteration of the loop:

>>>

**>>> for** num **in** range(2, 10):

**...**  **if** num % 2 == 0:

**...**  print("Found an even number", num)

**...**  **continue**

**...**  print("Found a number", num)

Found an even number 2

Found a number 3

Found an even number 4

Found a number 5

Found an even number 6

Found a number 7

Found an even number 8

Found a number 9

## 4.5. [pass](https://docs.python.org/3/reference/simple_stmts.html#pass) Statements

The [pass](https://docs.python.org/3/reference/simple_stmts.html#pass) statement does nothing. It can be used when a statement is required syntactically but the program requires no action. For example:

>>>

**>>> while** **True**:

**...**  **pass** *# Busy-wait for keyboard interrupt (Ctrl+C)*

**...**

This is commonly used for creating minimal classes:

>>>

**>>> class** **MyEmptyClass**:

**...**  **pass**

**...**

Another place [pass](https://docs.python.org/3/reference/simple_stmts.html#pass) can be used is as a place-holder for a function or conditional body when you are working on new code, allowing you to keep thinking at a more abstract level. The [pass](https://docs.python.org/3/reference/simple_stmts.html#pass) is silently ignored:

>>>

**>>> def** initlog(\*args):

**...**  **pass** *# Remember to implement this!*

**...**

## 4.6. Defining Functions

We can create a function that writes the Fibonacci series to an arbitrary boundary:

>>>

**>>> def** fib(n): *# write Fibonacci series up to n*

**...**  *"""Print a Fibonacci series up to n."""*

**...**  a, b = 0, 1

**...**  **while** a < n:

**...**  print(a, end=' ')

**...**  a, b = b, a+b

**...**  print()

**...**

**>>>** *# Now call the function we just defined:*

**...** fib(2000)

0 1 1 2 3 5 8 13 21 34 55 89 144 233 377 610 987 1597

The keyword [def](https://docs.python.org/3/reference/compound_stmts.html#def) introduces a function definition. It must be followed by the function name and the parenthesized list of formal parameters. The statements that form the body of the function start at the next line, and must be indented.

The first statement of the function body can optionally be a string literal; this string literal is the function’s documentation string, or docstring. (More about docstrings can be found in the section[Documentation Strings](https://docs.python.org/3/tutorial/controlflow.html#tut-docstrings).) There are tools which use docstrings to automatically produce online or printed documentation, or to let the user interactively browse through code; it’s good practice to include docstrings in code that you write, so make a habit of it.

The execution of a function introduces a new symbol table used for the local variables of the function. More precisely, all variable assignments in a function store the value in the local symbol table; whereas variable references first look in the local symbol table, then in the local symbol tables of enclosing functions, then in the global symbol table, and finally in the table of built-in names. Thus, global variables cannot be directly assigned a value within a function (unless named in a [global](https://docs.python.org/3/reference/simple_stmts.html#global)statement), although they may be referenced.

The actual parameters (arguments) to a function call are introduced in the local symbol table of the called function when it is called; thus, arguments are passed using call by value (where the value is always an object reference, not the value of the object). [[1]](https://docs.python.org/3/tutorial/controlflow.html#id2) When a function calls another function, a new local symbol table is created for that call.

A function definition introduces the function name in the current symbol table. The value of the function name has a type that is recognized by the interpreter as a user-defined function. This value can be assigned to another name which can then also be used as a function. This serves as a general renaming mechanism:

>>>

**>>>** fib

<function fib at 10042ed0>

**>>>** f = fib

**>>>** f(100)

0 1 1 2 3 5 8 13 21 34 55 89

Coming from other languages, you might object that fib is not a function but a procedure since it doesn’t return a value. In fact, even functions without a [return](https://docs.python.org/3/reference/simple_stmts.html#return) statement do return a value, albeit a rather boring one. This value is called None (it’s a built-in name). Writing the value None is normally suppressed by the interpreter if it would be the only value written. You can see it if you really want to using [print()](https://docs.python.org/3/library/functions.html#print):

>>>

**>>>** fib(0)

**>>>** print(fib(0))

None

It is simple to write a function that returns a list of the numbers of the Fibonacci series, instead of printing it:

>>>

**>>> def** fib2(n): *# return Fibonacci series up to n*

**...**  *"""Return a list containing the Fibonacci series up to n."""*

**...**  result = []

**...**  a, b = 0, 1

**...**  **while** a < n:

**...**  result.append(a) *# see below*

**...**  a, b = b, a+b

**...**  **return** result

**...**

**>>>** f100 = fib2(100) *# call it*

**>>>** f100 *# write the result*

[0, 1, 1, 2, 3, 5, 8, 13, 21, 34, 55, 89]

This example, as usual, demonstrates some new Python features:

* The [return](https://docs.python.org/3/reference/simple_stmts.html#return) statement returns with a value from a function. [return](https://docs.python.org/3/reference/simple_stmts.html#return) without an expression argument returns None. Falling off the end of a function also returns None.
* The statement result.append(a) calls a method of the list object result. A method is a function that ‘belongs’ to an object and is named obj.methodname, where obj is some object (this may be an expression), and methodname is the name of a method that is defined by the object’s type. Different types define different methods. Methods of different types may have the same name without causing ambiguity. (It is possible to define your own object types and methods, using classes, see [Classes](https://docs.python.org/3/tutorial/classes.html#tut-classes)) The method append() shown in the example is defined for list objects; it adds a new element at the end of the list. In this example it is equivalent toresult = result + [a], but more efficient.

## 4.7. More on Defining Functions

It is also possible to define functions with a variable number of arguments. There are three forms, which can be combined.

### 4.7.1. Default Argument Values

The most useful form is to specify a default value for one or more arguments. This creates a function that can be called with fewer arguments than it is defined to allow. For example:

**def** ask\_ok(prompt, retries=4, reminder='Please try again!'):

**while** **True**:

ok = input(prompt)

**if** ok **in** ('y', 'ye', 'yes'):

**return** **True**

**if** ok **in** ('n', 'no', 'nop', 'nope'):

**return** **False**

retries = retries - 1

**if** retries < 0:

**raise** ValueError('invalid user response')

print(reminder)

This function can be called in several ways:

* giving only the mandatory argument: ask\_ok('Do you really want to quit?')
* giving one of the optional arguments: ask\_ok('OK to overwrite the file?', 2)
* or even giving all arguments: ask\_ok('OK to overwrite the file?', 2, 'Come on, onlyyes or no!')

This example also introduces the [in](https://docs.python.org/3/reference/expressions.html#in) keyword. This tests whether or not a sequence contains a certain value.

The default values are evaluated at the point of function definition in the defining scope, so that

i = 5

**def** f(arg=i):

print(arg)

i = 6

f()

will print 5.

**Important warning:** The default value is evaluated only once. This makes a difference when the default is a mutable object such as a list, dictionary, or instances of most classes. For example, the following function accumulates the arguments passed to it on subsequent calls:

**def** f(a, L=[]):

L.append(a)

**return** L

print(f(1))

print(f(2))

print(f(3))

This will print

[1]

[1, 2]

[1, 2, 3]

If you don’t want the default to be shared between subsequent calls, you can write the function like this instead:

**def** f(a, L=**None**):

**if** L **is** **None**:

L = []

L.append(a)

**return** L

### 4.7.2. Keyword Arguments

Functions can also be called using [keyword arguments](https://docs.python.org/3/glossary.html#term-keyword-argument) of the form kwarg=value. For instance, the following function:

**def** parrot(voltage, state='a stiff', action='voom', type='Norwegian Blue'):

print("-- This parrot wouldn't", action, end=' ')

print("if you put", voltage, "volts through it.")

print("-- Lovely plumage, the", type)

print("-- It's", state, "!")

accepts one required argument (voltage) and three optional arguments (state, action, and type). This function can be called in any of the following ways:

parrot(1000) *# 1 positional argument*

parrot(voltage=1000) *# 1 keyword argument*

parrot(voltage=1000000, action='VOOOOOM') *# 2 keyword arguments*

parrot(action='VOOOOOM', voltage=1000000) *# 2 keyword arguments*

parrot('a million', 'bereft of life', 'jump') *# 3 positional arguments*

parrot('a thousand', state='pushing up the daisies') *# 1 positional, 1 keyword*

but all the following calls would be invalid:

parrot() *# required argument missing*

parrot(voltage=5.0, 'dead') *# non-keyword argument after a keyword argument*

parrot(110, voltage=220) *# duplicate value for the same argument*

parrot(actor='John Cleese') *# unknown keyword argument*

In a function call, keyword arguments must follow positional arguments. All the keyword arguments passed must match one of the arguments accepted by the function (e.g. actor is not a valid argument for the parrot function), and their order is not important. This also includes non-optional arguments (e.g. parrot(voltage=1000) is valid too). No argument may receive a value more than once. Here’s an example that fails due to this restriction:

>>>

**>>> def** function(a):

**...**  **pass**

**...**

**>>>** function(0, a=0)

Traceback (most recent call last):

File "<stdin>", line 1, in ?

TypeError: function() got multiple values for keyword argument 'a'

When a final formal parameter of the form \*\*name is present, it receives a dictionary (see [Mapping Types — dict](https://docs.python.org/3/library/stdtypes.html#typesmapping)) containing all keyword arguments except for those corresponding to a formal parameter. This may be combined with a formal parameter of the form \*name (described in the next subsection) which receives a tuple containing the positional arguments beyond the formal parameter list. (\*namemust occur before \*\*name.) For example, if we define a function like this:

**def** cheeseshop(kind, \*arguments, \*\*keywords):

print("-- Do you have any", kind, "?")

print("-- I'm sorry, we're all out of", kind)

**for** arg **in** arguments:

print(arg)

print("-" \* 40)

keys = sorted(keywords.keys())

**for** kw **in** keys:

print(kw, ":", keywords[kw])

It could be called like this:

cheeseshop("Limburger", "It's very runny, sir.",

"It's really very, VERY runny, sir.",

shopkeeper="Michael Palin",

client="John Cleese",

sketch="Cheese Shop Sketch")

and of course it would print:

-- Do you have any Limburger ?

-- I'm sorry, we're all out of Limburger

It's very runny, sir.

It's really very, VERY runny, sir.

----------------------------------------

client : John Cleese

shopkeeper : Michael Palin

sketch : Cheese Shop Sketch

Note that the list of keyword argument names is created by sorting the result of the keywords dictionary’s keys() method before printing its contents; if this is not done, the order in which the arguments are printed is undefined.

### 4.7.3. Arbitrary Argument Lists

Finally, the least frequently used option is to specify that a function can be called with an arbitrary number of arguments. These arguments will be wrapped up in a tuple (see [Tuples and Sequences](https://docs.python.org/3/tutorial/datastructures.html#tut-tuples)). Before the variable number of arguments, zero or more normal arguments may occur.

**def** write\_multiple\_items(file, separator, \*args):

file.write(separator.join(args))

Normally, these variadic arguments will be last in the list of formal parameters, because they scoop up all remaining input arguments that are passed to the function. Any formal parameters which occur after the \*args parameter are ‘keyword-only’ arguments, meaning that they can only be used as keywords rather than positional arguments.

>>>

**>>> def** concat(\*args, sep="/"):

**...**  **return** sep.join(args)

**...**

**>>>** concat("earth", "mars", "venus")

'earth/mars/venus'

**>>>** concat("earth", "mars", "venus", sep=".")

'earth.mars.venus'

### 4.7.4. Unpacking Argument Lists

The reverse situation occurs when the arguments are already in a list or tuple but need to be unpacked for a function call requiring separate positional arguments. For instance, the built-in [range()](https://docs.python.org/3/library/stdtypes.html#range)function expects separate start and stop arguments. If they are not available separately, write the function call with the \*-operator to unpack the arguments out of a list or tuple:

>>>

**>>>** list(range(3, 6)) *# normal call with separate arguments*

[3, 4, 5]

**>>>** args = [3, 6]

**>>>** list(range(\*args)) *# call with arguments unpacked from a list*

[3, 4, 5]

In the same fashion, dictionaries can deliver keyword arguments with the \*\*-operator:

>>>

**>>> def** parrot(voltage, state='a stiff', action='voom'):

**...**  print("-- This parrot wouldn't", action, end=' ')

**...**  print("if you put", voltage, "volts through it.", end=' ')

**...**  print("E's", state, "!")

**...**

**>>>** d = {"voltage": "four million", "state": "bleedin' demised", "action": "VOOM"}

**>>>** parrot(\*\*d)

-- This parrot wouldn't VOOM if you put four million volts through it. E's bleedin' demised !

### 4.7.5. Lambda Expressions

Small anonymous functions can be created with the [lambda](https://docs.python.org/3/reference/expressions.html#lambda) keyword. This function returns the sum of its two arguments: lambda a, b: a+b. Lambda functions can be used wherever function objects are required. They are syntactically restricted to a single expression. Semantically, they are just syntactic sugar for a normal function definition. Like nested function definitions, lambda functions can reference variables from the containing scope:

>>>

**>>> def** make\_incrementor(n):

**...**  **return** **lambda** x: x + n

**...**

**>>>** f = make\_incrementor(42)

**>>>** f(0)

42

**>>>** f(1)

43

The above example uses a lambda expression to return a function. Another use is to pass a small function as an argument:

>>>

**>>>** pairs = [(1, 'one'), (2, 'two'), (3, 'three'), (4, 'four')]

**>>>** pairs.sort(key=**lambda** pair: pair[1])

**>>>** pairs

[(4, 'four'), (1, 'one'), (3, 'three'), (2, 'two')]

### 4.7.6. Documentation Strings

Here are some conventions about the content and formatting of documentation strings.

The first line should always be a short, concise summary of the object’s purpose. For brevity, it should not explicitly state the object’s name or type, since these are available by other means (except if the name happens to be a verb describing a function’s operation). This line should begin with a capital letter and end with a period.

If there are more lines in the documentation string, the second line should be blank, visually separating the summary from the rest of the description. The following lines should be one or more paragraphs describing the object’s calling conventions, its side effects, etc.

The Python parser does not strip indentation from multi-line string literals in Python, so tools that process documentation have to strip indentation if desired. This is done using the following convention. The first non-blank line after the first line of the string determines the amount of indentation for the entire documentation string. (We can’t use the first line since it is generally adjacent to the string’s opening quotes so its indentation is not apparent in the string literal.) Whitespace “equivalent” to this indentation is then stripped from the start of all lines of the string. Lines that are indented less should not occur, but if they occur all their leading whitespace should be stripped. Equivalence of whitespace should be tested after expansion of tabs (to 8 spaces, normally).

Here is an example of a multi-line docstring:

>>>

**>>> def** my\_function():

**...**  *"""Do nothing, but document it.*

**...**

**...**  *No, really, it doesn't do anything.*

**...**  *"""*

**...**  **pass**

**...**

**>>>** print(my\_function.\_\_doc\_\_)

Do nothing, but document it.

No, really, it doesn't do anything.

### 4.7.7. Function Annotations

[Function annotations](https://docs.python.org/3/reference/compound_stmts.html#function) are completely optional metadata information about the types used by user-defined functions (see [**PEP 484**](https://www.python.org/dev/peps/pep-0484) for more information).

Annotations are stored in the \_\_annotations\_\_ attribute of the function as a dictionary and have no effect on any other part of the function. Parameter annotations are defined by a colon after the parameter name, followed by an expression evaluating to the value of the annotation. Return annotations are defined by a literal ->, followed by an expression, between the parameter list and the colon denoting the end of the [def](https://docs.python.org/3/reference/compound_stmts.html#def) statement. The following example has a positional argument, a keyword argument, and the return value annotated:

>>>

**>>> def** f(ham: str, eggs: str = 'eggs') -> str:

**...**  print("Annotations:", f.\_\_annotations\_\_)

**...**  print("Arguments:", ham, eggs)

**...**  **return** ham + ' and ' + eggs

**...**

**>>>** f('spam')

Annotations: {'ham': <class 'str'>, 'return': <class 'str'>, 'eggs': <class 'str'>}

Arguments: spam eggs

'spam and eggs'

## 4.8. Intermezzo: Coding Style

Now that you are about to write longer, more complex pieces of Python, it is a good time to talk aboutcoding style. Most languages can be written (or more concise, formatted) in different styles; some are more readable than others. Making it easy for others to read your code is always a good idea, and adopting a nice coding style helps tremendously for that.

For Python, [**PEP 8**](https://www.python.org/dev/peps/pep-0008) has emerged as the style guide that most projects adhere to; it promotes a very readable and eye-pleasing coding style. Every Python developer should read it at some point; here are the most important points extracted for you:

* Use 4-space indentation, and no tabs.

4 spaces are a good compromise between small indentation (allows greater nesting depth) and large indentation (easier to read). Tabs introduce confusion, and are best left out.

* Wrap lines so that they don’t exceed 79 characters.

This helps users with small displays and makes it possible to have several code files side-by-side on larger displays.

* Use blank lines to separate functions and classes, and larger blocks of code inside functions.
* When possible, put comments on a line of their own.
* Use docstrings.
* Use spaces around operators and after commas, but not directly inside bracketing constructs: a= f(1, 2) + g(3, 4).
* Name your classes and functions consistently; the convention is to use CamelCase for classes and lower\_case\_with\_underscores for functions and methods. Always use self as the name for the first method argument (see [A First Look at Classes](https://docs.python.org/3/tutorial/classes.html#tut-firstclasses) for more on classes and methods).
* Don’t use fancy encodings if your code is meant to be used in international environments. Python’s default, UTF-8, or even plain ASCII work best in any case.
* Likewise, don’t use non-ASCII characters in identifiers if there is only the slightest chance people speaking a different language will read or maintain the code.

**Footnotes**

|  |  |
| --- | --- |
| [[1]](https://docs.python.org/3/tutorial/controlflow.html#id1) | Actually, call by object reference would be a better description, since if a mutable object is passed, the caller will see any changes the callee makes to it (items inserted into a list). |

# 4. More Control Flow Tools

Besides the [while](https://docs.python.org/3/reference/compound_stmts.html#while) statement just introduced, Python knows the usual control flow statements known from other languages, with some twists.

## 4.1. [if](https://docs.python.org/3/reference/compound_stmts.html#if) Statements

Perhaps the most well-known statement type is the [if](https://docs.python.org/3/reference/compound_stmts.html#if) statement. For example:

>>>

**>>>** x = int(input("Please enter an integer: "))

Please enter an integer: 42

**>>> if** x < 0:

**...**  x = 0

**...**  print('Negative changed to zero')

**... elif** x == 0:

**...**  print('Zero')

**... elif** x == 1:

**...**  print('Single')

**... else**:

**...**  print('More')

**...**

More

There can be zero or more [elif](https://docs.python.org/3/reference/compound_stmts.html#elif) parts, and the [else](https://docs.python.org/3/reference/compound_stmts.html#else) part is optional. The keyword ‘[elif](https://docs.python.org/3/reference/compound_stmts.html#elif)‘ is short for ‘else if’, and is useful to avoid excessive indentation. An [if](https://docs.python.org/3/reference/compound_stmts.html#if) ... [elif](https://docs.python.org/3/reference/compound_stmts.html#elif) ... [elif](https://docs.python.org/3/reference/compound_stmts.html#elif) ... sequence is a substitute for the switch or case statements found in other languages.

## 4.2. [for](https://docs.python.org/3/reference/compound_stmts.html#for) Statements

The [for](https://docs.python.org/3/reference/compound_stmts.html#for) statement in Python differs a bit from what you may be used to in C or Pascal. Rather than always iterating over an arithmetic progression of numbers (like in Pascal), or giving the user the ability to define both the iteration step and halting condition (as C), Python’s [for](https://docs.python.org/3/reference/compound_stmts.html#for) statement iterates over the items of any sequence (a list or a string), in the order that they appear in the sequence. For example (no pun intended):

>>>

**>>>** *# Measure some strings:*

**...** words = ['cat', 'window', 'defenestrate']

**>>> for** w **in** words:

**...**  print(w, len(w))

**...**

cat 3

window 6

defenestrate 12

If you need to modify the sequence you are iterating over while inside the loop (for example to duplicate selected items), it is recommended that you first make a copy. Iterating over a sequence does not implicitly make a copy. The slice notation makes this especially convenient:

>>>

**>>> for** w **in** words[:]: *# Loop over a slice copy of the entire list.*

**...**  **if** len(w) > 6:

**...**  words.insert(0, w)

**...**

**>>>** words

['defenestrate', 'cat', 'window', 'defenestrate']

## 4.3. The [range()](https://docs.python.org/3/library/stdtypes.html#range) Function

If you do need to iterate over a sequence of numbers, the built-in function [range()](https://docs.python.org/3/library/stdtypes.html#range) comes in handy. It generates arithmetic progressions:

>>>

**>>> for** i **in** range(5):

**...**  print(i)

**...**

0

1

2

3

4

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

range(5, 10)

5 through 9

range(0, 10, 3)

0, 3, 6, 9

range(-10, -100, -30)

-10, -40, -70

To iterate over the indices of a sequence, you can combine [range()](https://docs.python.org/3/library/stdtypes.html#range) and [len()](https://docs.python.org/3/library/functions.html#len) as follows:

>>>

**>>>** a = ['Mary', 'had', 'a', 'little', 'lamb']

**>>> for** i **in** range(len(a)):

**...**  print(i, a[i])

**...**

0 Mary

1 had

2 a

3 little

4 lamb

In most such cases, however, it is convenient to use the [enumerate()](https://docs.python.org/3/library/functions.html#enumerate) function, see [Looping Techniques](https://docs.python.org/3/tutorial/datastructures.html#tut-loopidioms).

A strange thing happens if you just print a range:

>>>

**>>>** print(range(10))

range(0, 10)

In many ways the object returned by [range()](https://docs.python.org/3/library/stdtypes.html#range) behaves as if it is a list, but in fact it isn’t. It is an object which returns the successive items of the desired sequence when you iterate over it, but it doesn’t really make the list, thus saving space.

We say such an object is iterable, that is, suitable as a target for functions and constructs that expect something from which they can obtain successive items until the supply is exhausted. We have seen that the [for](https://docs.python.org/3/reference/compound_stmts.html#for) statement is such an iterator. The function [list()](https://docs.python.org/3/library/stdtypes.html#list) is another; it creates lists from iterables:

>>>

**>>>** list(range(5))

[0, 1, 2, 3, 4]

Later we will see more functions that return iterables and take iterables as argument.

## 4.4. [break](https://docs.python.org/3/reference/simple_stmts.html#break) and [continue](https://docs.python.org/3/reference/simple_stmts.html#continue) Statements, and [else](https://docs.python.org/3/reference/compound_stmts.html#else) Clauses on Loops

The [break](https://docs.python.org/3/reference/simple_stmts.html#break) statement, like in C, breaks out of the smallest enclosing [for](https://docs.python.org/3/reference/compound_stmts.html#for) or [while](https://docs.python.org/3/reference/compound_stmts.html#while) loop.

Loop statements may have an else clause; it is executed when the loop terminates through exhaustion of the list (with [for](https://docs.python.org/3/reference/compound_stmts.html#for)) or when the condition becomes false (with [while](https://docs.python.org/3/reference/compound_stmts.html#while)), but not when the loop is terminated by a [break](https://docs.python.org/3/reference/simple_stmts.html#break) statement. This is exemplified by the following loop, which searches for prime numbers:

>>>

**>>> for** n **in** range(2, 10):

**...**  **for** x **in** range(2, n):

**...**  **if** n % x == 0:

**...**  print(n, 'equals', x, '\*', n//x)

**...**  **break**

**...**  **else**:

**...**  *# loop fell through without finding a factor*

**...**  print(n, 'is a prime number')

**...**

2 is a prime number

3 is a prime number

4 equals 2 \* 2

5 is a prime number

6 equals 2 \* 3

7 is a prime number

8 equals 2 \* 4

9 equals 3 \* 3

(Yes, this is the correct code. Look closely: the else clause belongs to the [for](https://docs.python.org/3/reference/compound_stmts.html#for) loop, **not** the [if](https://docs.python.org/3/reference/compound_stmts.html#if)statement.)

When used with a loop, the else clause has more in common with the else clause of a [try](https://docs.python.org/3/reference/compound_stmts.html#try)statement than it does that of [if](https://docs.python.org/3/reference/compound_stmts.html#if) statements: a [try](https://docs.python.org/3/reference/compound_stmts.html#try) statement’s else clause runs when no exception occurs, and a loop’s else clause runs when no break occurs. For more on the [try](https://docs.python.org/3/reference/compound_stmts.html#try) statement and exceptions, see [Handling Exceptions](https://docs.python.org/3/tutorial/errors.html#tut-handling).

The [continue](https://docs.python.org/3/reference/simple_stmts.html#continue) statement, also borrowed from C, continues with the next iteration of the loop:

>>>

**>>> for** num **in** range(2, 10):

**...**  **if** num % 2 == 0:

**...**  print("Found an even number", num)

**...**  **continue**

**...**  print("Found a number", num)

Found an even number 2

Found a number 3

Found an even number 4

Found a number 5

Found an even number 6

Found a number 7

Found an even number 8

Found a number 9

## 4.5. [pass](https://docs.python.org/3/reference/simple_stmts.html#pass) Statements

The [pass](https://docs.python.org/3/reference/simple_stmts.html#pass) statement does nothing. It can be used when a statement is required syntactically but the program requires no action. For example:

>>>

**>>> while** **True**:

**...**  **pass** *# Busy-wait for keyboard interrupt (Ctrl+C)*

**...**

This is commonly used for creating minimal classes:

>>>

**>>> class** **MyEmptyClass**:

**...**  **pass**

**...**

Another place [pass](https://docs.python.org/3/reference/simple_stmts.html#pass) can be used is as a place-holder for a function or conditional body when you are working on new code, allowing you to keep thinking at a more abstract level. The [pass](https://docs.python.org/3/reference/simple_stmts.html#pass) is silently ignored:

>>>

**>>> def** initlog(\*args):

**...**  **pass** *# Remember to implement this!*

**...**

## 4.6. Defining Functions

We can create a function that writes the Fibonacci series to an arbitrary boundary:

>>>

**>>> def** fib(n): *# write Fibonacci series up to n*

**...**  *"""Print a Fibonacci series up to n."""*

**...**  a, b = 0, 1

**...**  **while** a < n:

**...**  print(a, end=' ')

**...**  a, b = b, a+b

**...**  print()

**...**

**>>>** *# Now call the function we just defined:*

**...** fib(2000)

0 1 1 2 3 5 8 13 21 34 55 89 144 233 377 610 987 1597

The keyword [def](https://docs.python.org/3/reference/compound_stmts.html#def) introduces a function definition. It must be followed by the function name and the parenthesized list of formal parameters. The statements that form the body of the function start at the next line, and must be indented.

The first statement of the function body can optionally be a string literal; this string literal is the function’s documentation string, or docstring. (More about docstrings can be found in the section[Documentation Strings](https://docs.python.org/3/tutorial/controlflow.html#tut-docstrings).) There are tools which use docstrings to automatically produce online or printed documentation, or to let the user interactively browse through code; it’s good practice to include docstrings in code that you write, so make a habit of it.

The execution of a function introduces a new symbol table used for the local variables of the function. More precisely, all variable assignments in a function store the value in the local symbol table; whereas variable references first look in the local symbol table, then in the local symbol tables of enclosing functions, then in the global symbol table, and finally in the table of built-in names. Thus, global variables cannot be directly assigned a value within a function (unless named in a [global](https://docs.python.org/3/reference/simple_stmts.html#global)statement), although they may be referenced.

The actual parameters (arguments) to a function call are introduced in the local symbol table of the called function when it is called; thus, arguments are passed using call by value (where the value is always an object reference, not the value of the object). [[1]](https://docs.python.org/3/tutorial/controlflow.html#id2) When a function calls another function, a new local symbol table is created for that call.

A function definition introduces the function name in the current symbol table. The value of the function name has a type that is recognized by the interpreter as a user-defined function. This value can be assigned to another name which can then also be used as a function. This serves as a general renaming mechanism:

>>>

**>>>** fib

<function fib at 10042ed0>

**>>>** f = fib

**>>>** f(100)

0 1 1 2 3 5 8 13 21 34 55 89

Coming from other languages, you might object that fib is not a function but a procedure since it doesn’t return a value. In fact, even functions without a [return](https://docs.python.org/3/reference/simple_stmts.html#return) statement do return a value, albeit a rather boring one. This value is called None (it’s a built-in name). Writing the value None is normally suppressed by the interpreter if it would be the only value written. You can see it if you really want to using [print()](https://docs.python.org/3/library/functions.html#print):

>>>

**>>>** fib(0)

**>>>** print(fib(0))

None

It is simple to write a function that returns a list of the numbers of the Fibonacci series, instead of printing it:

>>>

**>>> def** fib2(n): *# return Fibonacci series up to n*

**...**  *"""Return a list containing the Fibonacci series up to n."""*

**...**  result = []

**...**  a, b = 0, 1

**...**  **while** a < n:

**...**  result.append(a) *# see below*

**...**  a, b = b, a+b

**...**  **return** result

**...**

**>>>** f100 = fib2(100) *# call it*

**>>>** f100 *# write the result*

[0, 1, 1, 2, 3, 5, 8, 13, 21, 34, 55, 89]

This example, as usual, demonstrates some new Python features:

* The [return](https://docs.python.org/3/reference/simple_stmts.html#return) statement returns with a value from a function. [return](https://docs.python.org/3/reference/simple_stmts.html#return) without an expression argument returns None. Falling off the end of a function also returns None.
* The statement result.append(a) calls a method of the list object result. A method is a function that ‘belongs’ to an object and is named obj.methodname, where obj is some object (this may be an expression), and methodname is the name of a method that is defined by the object’s type. Different types define different methods. Methods of different types may have the same name without causing ambiguity. (It is possible to define your own object types and methods, using classes, see [Classes](https://docs.python.org/3/tutorial/classes.html#tut-classes)) The method append() shown in the example is defined for list objects; it adds a new element at the end of the list. In this example it is equivalent toresult = result + [a], but more efficient.

## 4.7. More on Defining Functions

It is also possible to define functions with a variable number of arguments. There are three forms, which can be combined.

### 4.7.1. Default Argument Values

The most useful form is to specify a default value for one or more arguments. This creates a function that can be called with fewer arguments than it is defined to allow. For example:

**def** ask\_ok(prompt, retries=4, reminder='Please try again!'):

**while** **True**:

ok = input(prompt)

**if** ok **in** ('y', 'ye', 'yes'):

**return** **True**

**if** ok **in** ('n', 'no', 'nop', 'nope'):

**return** **False**

retries = retries - 1

**if** retries < 0:

**raise** ValueError('invalid user response')

print(reminder)

This function can be called in several ways:

* giving only the mandatory argument: ask\_ok('Do you really want to quit?')
* giving one of the optional arguments: ask\_ok('OK to overwrite the file?', 2)
* or even giving all arguments: ask\_ok('OK to overwrite the file?', 2, 'Come on, onlyyes or no!')

This example also introduces the [in](https://docs.python.org/3/reference/expressions.html#in) keyword. This tests whether or not a sequence contains a certain value.

The default values are evaluated at the point of function definition in the defining scope, so that

i = 5

**def** f(arg=i):

print(arg)

i = 6

f()

will print 5.

**Important warning:** The default value is evaluated only once. This makes a difference when the default is a mutable object such as a list, dictionary, or instances of most classes. For example, the following function accumulates the arguments passed to it on subsequent calls:

**def** f(a, L=[]):

L.append(a)

**return** L

print(f(1))

print(f(2))

print(f(3))

This will print

[1]

[1, 2]

[1, 2, 3]

If you don’t want the default to be shared between subsequent calls, you can write the function like this instead:

**def** f(a, L=**None**):

**if** L **is** **None**:

L = []

L.append(a)

**return** L

### 4.7.2. Keyword Arguments

Functions can also be called using [keyword arguments](https://docs.python.org/3/glossary.html#term-keyword-argument) of the form kwarg=value. For instance, the following function:

**def** parrot(voltage, state='a stiff', action='voom', type='Norwegian Blue'):

print("-- This parrot wouldn't", action, end=' ')

print("if you put", voltage, "volts through it.")

print("-- Lovely plumage, the", type)

print("-- It's", state, "!")

accepts one required argument (voltage) and three optional arguments (state, action, and type). This function can be called in any of the following ways:

parrot(1000) *# 1 positional argument*

parrot(voltage=1000) *# 1 keyword argument*

parrot(voltage=1000000, action='VOOOOOM') *# 2 keyword arguments*

parrot(action='VOOOOOM', voltage=1000000) *# 2 keyword arguments*

parrot('a million', 'bereft of life', 'jump') *# 3 positional arguments*

parrot('a thousand', state='pushing up the daisies') *# 1 positional, 1 keyword*

but all the following calls would be invalid:

parrot() *# required argument missing*

parrot(voltage=5.0, 'dead') *# non-keyword argument after a keyword argument*

parrot(110, voltage=220) *# duplicate value for the same argument*

parrot(actor='John Cleese') *# unknown keyword argument*

In a function call, keyword arguments must follow positional arguments. All the keyword arguments passed must match one of the arguments accepted by the function (e.g. actor is not a valid argument for the parrot function), and their order is not important. This also includes non-optional arguments (e.g. parrot(voltage=1000) is valid too). No argument may receive a value more than once. Here’s an example that fails due to this restriction:

>>>

**>>> def** function(a):

**...**  **pass**

**...**

**>>>** function(0, a=0)

Traceback (most recent call last):

File "<stdin>", line 1, in ?

TypeError: function() got multiple values for keyword argument 'a'

When a final formal parameter of the form \*\*name is present, it receives a dictionary (see [Mapping Types — dict](https://docs.python.org/3/library/stdtypes.html#typesmapping)) containing all keyword arguments except for those corresponding to a formal parameter. This may be combined with a formal parameter of the form \*name (described in the next subsection) which receives a tuple containing the positional arguments beyond the formal parameter list. (\*namemust occur before \*\*name.) For example, if we define a function like this:

**def** cheeseshop(kind, \*arguments, \*\*keywords):

print("-- Do you have any", kind, "?")

print("-- I'm sorry, we're all out of", kind)

**for** arg **in** arguments:

print(arg)

print("-" \* 40)

keys = sorted(keywords.keys())

**for** kw **in** keys:

print(kw, ":", keywords[kw])

It could be called like this:

cheeseshop("Limburger", "It's very runny, sir.",

"It's really very, VERY runny, sir.",

shopkeeper="Michael Palin",

client="John Cleese",

sketch="Cheese Shop Sketch")

and of course it would print:

-- Do you have any Limburger ?

-- I'm sorry, we're all out of Limburger

It's very runny, sir.

It's really very, VERY runny, sir.

----------------------------------------

client : John Cleese

shopkeeper : Michael Palin

sketch : Cheese Shop Sketch

Note that the list of keyword argument names is created by sorting the result of the keywords dictionary’s keys() method before printing its contents; if this is not done, the order in which the arguments are printed is undefined.

### 4.7.3. Arbitrary Argument Lists

Finally, the least frequently used option is to specify that a function can be called with an arbitrary number of arguments. These arguments will be wrapped up in a tuple (see [Tuples and Sequences](https://docs.python.org/3/tutorial/datastructures.html#tut-tuples)). Before the variable number of arguments, zero or more normal arguments may occur.

**def** write\_multiple\_items(file, separator, \*args):

file.write(separator.join(args))

Normally, these variadic arguments will be last in the list of formal parameters, because they scoop up all remaining input arguments that are passed to the function. Any formal parameters which occur after the \*args parameter are ‘keyword-only’ arguments, meaning that they can only be used as keywords rather than positional arguments.

>>>

**>>> def** concat(\*args, sep="/"):

**...**  **return** sep.join(args)

**...**

**>>>** concat("earth", "mars", "venus")

'earth/mars/venus'

**>>>** concat("earth", "mars", "venus", sep=".")

'earth.mars.venus'

### 4.7.4. Unpacking Argument Lists

The reverse situation occurs when the arguments are already in a list or tuple but need to be unpacked for a function call requiring separate positional arguments. For instance, the built-in [range()](https://docs.python.org/3/library/stdtypes.html#range)function expects separate start and stop arguments. If they are not available separately, write the function call with the \*-operator to unpack the arguments out of a list or tuple:

>>>

**>>>** list(range(3, 6)) *# normal call with separate arguments*

[3, 4, 5]

**>>>** args = [3, 6]

**>>>** list(range(\*args)) *# call with arguments unpacked from a list*

[3, 4, 5]

In the same fashion, dictionaries can deliver keyword arguments with the \*\*-operator:

>>>

**>>> def** parrot(voltage, state='a stiff', action='voom'):

**...**  print("-- This parrot wouldn't", action, end=' ')

**...**  print("if you put", voltage, "volts through it.", end=' ')

**...**  print("E's", state, "!")

**...**

**>>>** d = {"voltage": "four million", "state": "bleedin' demised", "action": "VOOM"}

**>>>** parrot(\*\*d)

-- This parrot wouldn't VOOM if you put four million volts through it. E's bleedin' demised !

### 4.7.5. Lambda Expressions

Small anonymous functions can be created with the [lambda](https://docs.python.org/3/reference/expressions.html#lambda) keyword. This function returns the sum of its two arguments: lambda a, b: a+b. Lambda functions can be used wherever function objects are required. They are syntactically restricted to a single expression. Semantically, they are just syntactic sugar for a normal function definition. Like nested function definitions, lambda functions can reference variables from the containing scope:

>>>

**>>> def** make\_incrementor(n):

**...**  **return** **lambda** x: x + n

**...**

**>>>** f = make\_incrementor(42)

**>>>** f(0)

42

**>>>** f(1)

43

The above example uses a lambda expression to return a function. Another use is to pass a small function as an argument:

>>>

**>>>** pairs = [(1, 'one'), (2, 'two'), (3, 'three'), (4, 'four')]

**>>>** pairs.sort(key=**lambda** pair: pair[1])

**>>>** pairs

[(4, 'four'), (1, 'one'), (3, 'three'), (2, 'two')]

### 4.7.6. Documentation Strings

Here are some conventions about the content and formatting of documentation strings.

The first line should always be a short, concise summary of the object’s purpose. For brevity, it should not explicitly state the object’s name or type, since these are available by other means (except if the name happens to be a verb describing a function’s operation). This line should begin with a capital letter and end with a period.

If there are more lines in the documentation string, the second line should be blank, visually separating the summary from the rest of the description. The following lines should be one or more paragraphs describing the object’s calling conventions, its side effects, etc.

The Python parser does not strip indentation from multi-line string literals in Python, so tools that process documentation have to strip indentation if desired. This is done using the following convention. The first non-blank line after the first line of the string determines the amount of indentation for the entire documentation string. (We can’t use the first line since it is generally adjacent to the string’s opening quotes so its indentation is not apparent in the string literal.) Whitespace “equivalent” to this indentation is then stripped from the start of all lines of the string. Lines that are indented less should not occur, but if they occur all their leading whitespace should be stripped. Equivalence of whitespace should be tested after expansion of tabs (to 8 spaces, normally).

Here is an example of a multi-line docstring:

>>>

**>>> def** my\_function():

**...**  *"""Do nothing, but document it.*

**...**

**...**  *No, really, it doesn't do anything.*

**...**  *"""*

**...**  **pass**

**...**

**>>>** print(my\_function.\_\_doc\_\_)

Do nothing, but document it.

No, really, it doesn't do anything.

### 4.7.7. Function Annotations

[Function annotations](https://docs.python.org/3/reference/compound_stmts.html#function) are completely optional metadata information about the types used by user-defined functions (see [**PEP 484**](https://www.python.org/dev/peps/pep-0484) for more information).

Annotations are stored in the \_\_annotations\_\_ attribute of the function as a dictionary and have no effect on any other part of the function. Parameter annotations are defined by a colon after the parameter name, followed by an expression evaluating to the value of the annotation. Return annotations are defined by a literal ->, followed by an expression, between the parameter list and the colon denoting the end of the [def](https://docs.python.org/3/reference/compound_stmts.html#def) statement. The following example has a positional argument, a keyword argument, and the return value annotated:

>>>

**>>> def** f(ham: str, eggs: str = 'eggs') -> str:

**...**  print("Annotations:", f.\_\_annotations\_\_)

**...**  print("Arguments:", ham, eggs)

**...**  **return** ham + ' and ' + eggs

**...**

**>>>** f('spam')

Annotations: {'ham': <class 'str'>, 'return': <class 'str'>, 'eggs': <class 'str'>}

Arguments: spam eggs

'spam and eggs'

## 4.8. Intermezzo: Coding Style

Now that you are about to write longer, more complex pieces of Python, it is a good time to talk aboutcoding style. Most languages can be written (or more concise, formatted) in different styles; some are more readable than others. Making it easy for others to read your code is always a good idea, and adopting a nice coding style helps tremendously for that.

For Python, [**PEP 8**](https://www.python.org/dev/peps/pep-0008) has emerged as the style guide that most projects adhere to; it promotes a very readable and eye-pleasing coding style. Every Python developer should read it at some point; here are the most important points extracted for you:

* Use 4-space indentation, and no tabs.

4 spaces are a good compromise between small indentation (allows greater nesting depth) and large indentation (easier to read). Tabs introduce confusion, and are best left out.

* Wrap lines so that they don’t exceed 79 characters.

This helps users with small displays and makes it possible to have several code files side-by-side on larger displays.

* Use blank lines to separate functions and classes, and larger blocks of code inside functions.
* When possible, put comments on a line of their own.
* Use docstrings.
* Use spaces around operators and after commas, but not directly inside bracketing constructs: a= f(1, 2) + g(3, 4).
* Name your classes and functions consistently; the convention is to use CamelCase for classes and lower\_case\_with\_underscores for functions and methods. Always use self as the name for the first method argument (see [A First Look at Classes](https://docs.python.org/3/tutorial/classes.html#tut-firstclasses) for more on classes and methods).
* Don’t use fancy encodings if your code is meant to be used in international environments. Python’s default, UTF-8, or even plain ASCII work best in any case.
* Likewise, don’t use non-ASCII characters in identifiers if there is only the slightest chance people speaking a different language will read or maintain the code.

**Footnotes**

|  |  |
| --- | --- |
| [[1]](https://docs.python.org/3/tutorial/controlflow.html#id1) | Actually, call by object reference would be a better description, since if a mutable object is passed, the caller will see any changes the callee makes to it (items inserted into a list). |

# 4. More Control Flow Tools

Besides the [while](https://docs.python.org/3/reference/compound_stmts.html#while) statement just introduced, Python knows the usual control flow statements known from other languages, with some twists.

## 4.1. [if](https://docs.python.org/3/reference/compound_stmts.html#if) Statements

Perhaps the most well-known statement type is the [if](https://docs.python.org/3/reference/compound_stmts.html#if) statement. For example:

>>>

**>>>** x = int(input("Please enter an integer: "))

Please enter an integer: 42

**>>> if** x < 0:

**...**  x = 0

**...**  print('Negative changed to zero')

**... elif** x == 0:

**...**  print('Zero')

**... elif** x == 1:

**...**  print('Single')

**... else**:

**...**  print('More')

**...**

More

There can be zero or more [elif](https://docs.python.org/3/reference/compound_stmts.html#elif) parts, and the [else](https://docs.python.org/3/reference/compound_stmts.html#else) part is optional. The keyword ‘[elif](https://docs.python.org/3/reference/compound_stmts.html#elif)‘ is short for ‘else if’, and is useful to avoid excessive indentation. An [if](https://docs.python.org/3/reference/compound_stmts.html#if) ... [elif](https://docs.python.org/3/reference/compound_stmts.html#elif) ... [elif](https://docs.python.org/3/reference/compound_stmts.html#elif) ... sequence is a substitute for the switch or case statements found in other languages.

## 4.2. [for](https://docs.python.org/3/reference/compound_stmts.html#for) Statements

The [for](https://docs.python.org/3/reference/compound_stmts.html#for) statement in Python differs a bit from what you may be used to in C or Pascal. Rather than always iterating over an arithmetic progression of numbers (like in Pascal), or giving the user the ability to define both the iteration step and halting condition (as C), Python’s [for](https://docs.python.org/3/reference/compound_stmts.html#for) statement iterates over the items of any sequence (a list or a string), in the order that they appear in the sequence. For example (no pun intended):

>>>

**>>>** *# Measure some strings:*

**...** words = ['cat', 'window', 'defenestrate']

**>>> for** w **in** words:

**...**  print(w, len(w))

**...**

cat 3

window 6

defenestrate 12

If you need to modify the sequence you are iterating over while inside the loop (for example to duplicate selected items), it is recommended that you first make a copy. Iterating over a sequence does not implicitly make a copy. The slice notation makes this especially convenient:

>>>

**>>> for** w **in** words[:]: *# Loop over a slice copy of the entire list.*

**...**  **if** len(w) > 6:

**...**  words.insert(0, w)

**...**

**>>>** words

['defenestrate', 'cat', 'window', 'defenestrate']

## 4.3. The [range()](https://docs.python.org/3/library/stdtypes.html#range) Function

If you do need to iterate over a sequence of numbers, the built-in function [range()](https://docs.python.org/3/library/stdtypes.html#range) comes in handy. It generates arithmetic progressions:

>>>

**>>> for** i **in** range(5):

**...**  print(i)

**...**

0

1

2

3

4

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

range(5, 10)

5 through 9

range(0, 10, 3)

0, 3, 6, 9

range(-10, -100, -30)

-10, -40, -70

To iterate over the indices of a sequence, you can combine [range()](https://docs.python.org/3/library/stdtypes.html#range) and [len()](https://docs.python.org/3/library/functions.html#len) as follows:

>>>

**>>>** a = ['Mary', 'had', 'a', 'little', 'lamb']

**>>> for** i **in** range(len(a)):

**...**  print(i, a[i])

**...**

0 Mary

1 had

2 a

3 little

4 lamb

In most such cases, however, it is convenient to use the [enumerate()](https://docs.python.org/3/library/functions.html#enumerate) function, see [Looping Techniques](https://docs.python.org/3/tutorial/datastructures.html#tut-loopidioms).

A strange thing happens if you just print a range:

>>>

**>>>** print(range(10))

range(0, 10)

In many ways the object returned by [range()](https://docs.python.org/3/library/stdtypes.html#range) behaves as if it is a list, but in fact it isn’t. It is an object which returns the successive items of the desired sequence when you iterate over it, but it doesn’t really make the list, thus saving space.

We say such an object is iterable, that is, suitable as a target for functions and constructs that expect something from which they can obtain successive items until the supply is exhausted. We have seen that the [for](https://docs.python.org/3/reference/compound_stmts.html#for) statement is such an iterator. The function [list()](https://docs.python.org/3/library/stdtypes.html#list) is another; it creates lists from iterables:

>>>

**>>>** list(range(5))

[0, 1, 2, 3, 4]

Later we will see more functions that return iterables and take iterables as argument.

## 4.4. [break](https://docs.python.org/3/reference/simple_stmts.html#break) and [continue](https://docs.python.org/3/reference/simple_stmts.html#continue) Statements, and [else](https://docs.python.org/3/reference/compound_stmts.html#else) Clauses on Loops

The [break](https://docs.python.org/3/reference/simple_stmts.html#break) statement, like in C, breaks out of the smallest enclosing [for](https://docs.python.org/3/reference/compound_stmts.html#for) or [while](https://docs.python.org/3/reference/compound_stmts.html#while) loop.

Loop statements may have an else clause; it is executed when the loop terminates through exhaustion of the list (with [for](https://docs.python.org/3/reference/compound_stmts.html#for)) or when the condition becomes false (with [while](https://docs.python.org/3/reference/compound_stmts.html#while)), but not when the loop is terminated by a [break](https://docs.python.org/3/reference/simple_stmts.html#break) statement. This is exemplified by the following loop, which searches for prime numbers:

>>>

**>>> for** n **in** range(2, 10):

**...**  **for** x **in** range(2, n):

**...**  **if** n % x == 0:

**...**  print(n, 'equals', x, '\*', n//x)

**...**  **break**

**...**  **else**:

**...**  *# loop fell through without finding a factor*

**...**  print(n, 'is a prime number')

**...**

2 is a prime number

3 is a prime number

4 equals 2 \* 2

5 is a prime number

6 equals 2 \* 3

7 is a prime number

8 equals 2 \* 4

9 equals 3 \* 3

(Yes, this is the correct code. Look closely: the else clause belongs to the [for](https://docs.python.org/3/reference/compound_stmts.html#for) loop, **not** the [if](https://docs.python.org/3/reference/compound_stmts.html#if)statement.)

When used with a loop, the else clause has more in common with the else clause of a [try](https://docs.python.org/3/reference/compound_stmts.html#try)statement than it does that of [if](https://docs.python.org/3/reference/compound_stmts.html#if) statements: a [try](https://docs.python.org/3/reference/compound_stmts.html#try) statement’s else clause runs when no exception occurs, and a loop’s else clause runs when no break occurs. For more on the [try](https://docs.python.org/3/reference/compound_stmts.html#try) statement and exceptions, see [Handling Exceptions](https://docs.python.org/3/tutorial/errors.html#tut-handling).

The [continue](https://docs.python.org/3/reference/simple_stmts.html#continue) statement, also borrowed from C, continues with the next iteration of the loop:

>>>

**>>> for** num **in** range(2, 10):

**...**  **if** num % 2 == 0:

**...**  print("Found an even number", num)

**...**  **continue**

**...**  print("Found a number", num)

Found an even number 2

Found a number 3

Found an even number 4

Found a number 5

Found an even number 6

Found a number 7

Found an even number 8

Found a number 9

## 4.5. [pass](https://docs.python.org/3/reference/simple_stmts.html#pass) Statements

The [pass](https://docs.python.org/3/reference/simple_stmts.html#pass) statement does nothing. It can be used when a statement is required syntactically but the program requires no action. For example:

>>>

**>>> while** **True**:

**...**  **pass** *# Busy-wait for keyboard interrupt (Ctrl+C)*

**...**

This is commonly used for creating minimal classes:

>>>

**>>> class** **MyEmptyClass**:

**...**  **pass**

**...**

Another place [pass](https://docs.python.org/3/reference/simple_stmts.html#pass) can be used is as a place-holder for a function or conditional body when you are working on new code, allowing you to keep thinking at a more abstract level. The [pass](https://docs.python.org/3/reference/simple_stmts.html#pass) is silently ignored:

>>>

**>>> def** initlog(\*args):

**...**  **pass** *# Remember to implement this!*

**...**

## 4.6. Defining Functions

We can create a function that writes the Fibonacci series to an arbitrary boundary:

>>>

**>>> def** fib(n): *# write Fibonacci series up to n*

**...**  *"""Print a Fibonacci series up to n."""*

**...**  a, b = 0, 1

**...**  **while** a < n:

**...**  print(a, end=' ')

**...**  a, b = b, a+b

**...**  print()

**...**

**>>>** *# Now call the function we just defined:*

**...** fib(2000)

0 1 1 2 3 5 8 13 21 34 55 89 144 233 377 610 987 1597

The keyword [def](https://docs.python.org/3/reference/compound_stmts.html#def) introduces a function definition. It must be followed by the function name and the parenthesized list of formal parameters. The statements that form the body of the function start at the next line, and must be indented.

The first statement of the function body can optionally be a string literal; this string literal is the function’s documentation string, or docstring. (More about docstrings can be found in the section[Documentation Strings](https://docs.python.org/3/tutorial/controlflow.html#tut-docstrings).) There are tools which use docstrings to automatically produce online or printed documentation, or to let the user interactively browse through code; it’s good practice to include docstrings in code that you write, so make a habit of it.

The execution of a function introduces a new symbol table used for the local variables of the function. More precisely, all variable assignments in a function store the value in the local symbol table; whereas variable references first look in the local symbol table, then in the local symbol tables of enclosing functions, then in the global symbol table, and finally in the table of built-in names. Thus, global variables cannot be directly assigned a value within a function (unless named in a [global](https://docs.python.org/3/reference/simple_stmts.html#global)statement), although they may be referenced.

The actual parameters (arguments) to a function call are introduced in the local symbol table of the called function when it is called; thus, arguments are passed using call by value (where the value is always an object reference, not the value of the object). [[1]](https://docs.python.org/3/tutorial/controlflow.html#id2) When a function calls another function, a new local symbol table is created for that call.

A function definition introduces the function name in the current symbol table. The value of the function name has a type that is recognized by the interpreter as a user-defined function. This value can be assigned to another name which can then also be used as a function. This serves as a general renaming mechanism:

>>>

**>>>** fib

<function fib at 10042ed0>

**>>>** f = fib

**>>>** f(100)

0 1 1 2 3 5 8 13 21 34 55 89

Coming from other languages, you might object that fib is not a function but a procedure since it doesn’t return a value. In fact, even functions without a [return](https://docs.python.org/3/reference/simple_stmts.html#return) statement do return a value, albeit a rather boring one. This value is called None (it’s a built-in name). Writing the value None is normally suppressed by the interpreter if it would be the only value written. You can see it if you really want to using [print()](https://docs.python.org/3/library/functions.html#print):

>>>

**>>>** fib(0)

**>>>** print(fib(0))

None

It is simple to write a function that returns a list of the numbers of the Fibonacci series, instead of printing it:

>>>

**>>> def** fib2(n): *# return Fibonacci series up to n*

**...**  *"""Return a list containing the Fibonacci series up to n."""*

**...**  result = []

**...**  a, b = 0, 1

**...**  **while** a < n:

**...**  result.append(a) *# see below*

**...**  a, b = b, a+b

**...**  **return** result

**...**

**>>>** f100 = fib2(100) *# call it*

**>>>** f100 *# write the result*

[0, 1, 1, 2, 3, 5, 8, 13, 21, 34, 55, 89]

This example, as usual, demonstrates some new Python features:

* The [return](https://docs.python.org/3/reference/simple_stmts.html#return) statement returns with a value from a function. [return](https://docs.python.org/3/reference/simple_stmts.html#return) without an expression argument returns None. Falling off the end of a function also returns None.
* The statement result.append(a) calls a method of the list object result. A method is a function that ‘belongs’ to an object and is named obj.methodname, where obj is some object (this may be an expression), and methodname is the name of a method that is defined by the object’s type. Different types define different methods. Methods of different types may have the same name without causing ambiguity. (It is possible to define your own object types and methods, using classes, see [Classes](https://docs.python.org/3/tutorial/classes.html#tut-classes)) The method append() shown in the example is defined for list objects; it adds a new element at the end of the list. In this example it is equivalent toresult = result + [a], but more efficient.

## 4.7. More on Defining Functions

It is also possible to define functions with a variable number of arguments. There are three forms, which can be combined.

### 4.7.1. Default Argument Values

The most useful form is to specify a default value for one or more arguments. This creates a function that can be called with fewer arguments than it is defined to allow. For example:

**def** ask\_ok(prompt, retries=4, reminder='Please try again!'):

**while** **True**:

ok = input(prompt)

**if** ok **in** ('y', 'ye', 'yes'):

**return** **True**

**if** ok **in** ('n', 'no', 'nop', 'nope'):

**return** **False**

retries = retries - 1

**if** retries < 0:

**raise** ValueError('invalid user response')

print(reminder)

This function can be called in several ways:

* giving only the mandatory argument: ask\_ok('Do you really want to quit?')
* giving one of the optional arguments: ask\_ok('OK to overwrite the file?', 2)
* or even giving all arguments: ask\_ok('OK to overwrite the file?', 2, 'Come on, onlyyes or no!')

This example also introduces the [in](https://docs.python.org/3/reference/expressions.html#in) keyword. This tests whether or not a sequence contains a certain value.

The default values are evaluated at the point of function definition in the defining scope, so that

i = 5

**def** f(arg=i):

print(arg)

i = 6

f()

will print 5.

**Important warning:** The default value is evaluated only once. This makes a difference when the default is a mutable object such as a list, dictionary, or instances of most classes. For example, the following function accumulates the arguments passed to it on subsequent calls:

**def** f(a, L=[]):

L.append(a)

**return** L

print(f(1))

print(f(2))

print(f(3))

This will print

[1]

[1, 2]

[1, 2, 3]

If you don’t want the default to be shared between subsequent calls, you can write the function like this instead:

**def** f(a, L=**None**):

**if** L **is** **None**:

L = []

L.append(a)

**return** L

### 4.7.2. Keyword Arguments

Functions can also be called using [keyword arguments](https://docs.python.org/3/glossary.html#term-keyword-argument) of the form kwarg=value. For instance, the following function:

**def** parrot(voltage, state='a stiff', action='voom', type='Norwegian Blue'):

print("-- This parrot wouldn't", action, end=' ')

print("if you put", voltage, "volts through it.")

print("-- Lovely plumage, the", type)

print("-- It's", state, "!")

accepts one required argument (voltage) and three optional arguments (state, action, and type). This function can be called in any of the following ways:

parrot(1000) *# 1 positional argument*

parrot(voltage=1000) *# 1 keyword argument*

parrot(voltage=1000000, action='VOOOOOM') *# 2 keyword arguments*

parrot(action='VOOOOOM', voltage=1000000) *# 2 keyword arguments*

parrot('a million', 'bereft of life', 'jump') *# 3 positional arguments*

parrot('a thousand', state='pushing up the daisies') *# 1 positional, 1 keyword*

but all the following calls would be invalid:

parrot() *# required argument missing*

parrot(voltage=5.0, 'dead') *# non-keyword argument after a keyword argument*

parrot(110, voltage=220) *# duplicate value for the same argument*

parrot(actor='John Cleese') *# unknown keyword argument*

In a function call, keyword arguments must follow positional arguments. All the keyword arguments passed must match one of the arguments accepted by the function (e.g. actor is not a valid argument for the parrot function), and their order is not important. This also includes non-optional arguments (e.g. parrot(voltage=1000) is valid too). No argument may receive a value more than once. Here’s an example that fails due to this restriction:

>>>

**>>> def** function(a):

**...**  **pass**

**...**

**>>>** function(0, a=0)

Traceback (most recent call last):

File "<stdin>", line 1, in ?

TypeError: function() got multiple values for keyword argument 'a'

When a final formal parameter of the form \*\*name is present, it receives a dictionary (see [Mapping Types — dict](https://docs.python.org/3/library/stdtypes.html#typesmapping)) containing all keyword arguments except for those corresponding to a formal parameter. This may be combined with a formal parameter of the form \*name (described in the next subsection) which receives a tuple containing the positional arguments beyond the formal parameter list. (\*namemust occur before \*\*name.) For example, if we define a function like this:

**def** cheeseshop(kind, \*arguments, \*\*keywords):

print("-- Do you have any", kind, "?")

print("-- I'm sorry, we're all out of", kind)

**for** arg **in** arguments:

print(arg)

print("-" \* 40)

keys = sorted(keywords.keys())

**for** kw **in** keys:

print(kw, ":", keywords[kw])

It could be called like this:

cheeseshop("Limburger", "It's very runny, sir.",

"It's really very, VERY runny, sir.",

shopkeeper="Michael Palin",

client="John Cleese",

sketch="Cheese Shop Sketch")

and of course it would print:

-- Do you have any Limburger ?

-- I'm sorry, we're all out of Limburger

It's very runny, sir.

It's really very, VERY runny, sir.

----------------------------------------

client : John Cleese

shopkeeper : Michael Palin

sketch : Cheese Shop Sketch

Note that the list of keyword argument names is created by sorting the result of the keywords dictionary’s keys() method before printing its contents; if this is not done, the order in which the arguments are printed is undefined.

### 4.7.3. Arbitrary Argument Lists

Finally, the least frequently used option is to specify that a function can be called with an arbitrary number of arguments. These arguments will be wrapped up in a tuple (see [Tuples and Sequences](https://docs.python.org/3/tutorial/datastructures.html#tut-tuples)). Before the variable number of arguments, zero or more normal arguments may occur.

**def** write\_multiple\_items(file, separator, \*args):

file.write(separator.join(args))

Normally, these variadic arguments will be last in the list of formal parameters, because they scoop up all remaining input arguments that are passed to the function. Any formal parameters which occur after the \*args parameter are ‘keyword-only’ arguments, meaning that they can only be used as keywords rather than positional arguments.

>>>

**>>> def** concat(\*args, sep="/"):

**...**  **return** sep.join(args)

**...**

**>>>** concat("earth", "mars", "venus")

'earth/mars/venus'

**>>>** concat("earth", "mars", "venus", sep=".")

'earth.mars.venus'

### 4.7.4. Unpacking Argument Lists

The reverse situation occurs when the arguments are already in a list or tuple but need to be unpacked for a function call requiring separate positional arguments. For instance, the built-in [range()](https://docs.python.org/3/library/stdtypes.html#range)function expects separate start and stop arguments. If they are not available separately, write the function call with the \*-operator to unpack the arguments out of a list or tuple:

>>>

**>>>** list(range(3, 6)) *# normal call with separate arguments*

[3, 4, 5]

**>>>** args = [3, 6]

**>>>** list(range(\*args)) *# call with arguments unpacked from a list*

[3, 4, 5]

In the same fashion, dictionaries can deliver keyword arguments with the \*\*-operator:

>>>

**>>> def** parrot(voltage, state='a stiff', action='voom'):

**...**  print("-- This parrot wouldn't", action, end=' ')

**...**  print("if you put", voltage, "volts through it.", end=' ')

**...**  print("E's", state, "!")

**...**

**>>>** d = {"voltage": "four million", "state": "bleedin' demised", "action": "VOOM"}

**>>>** parrot(\*\*d)

-- This parrot wouldn't VOOM if you put four million volts through it. E's bleedin' demised !

### 4.7.5. Lambda Expressions

Small anonymous functions can be created with the [lambda](https://docs.python.org/3/reference/expressions.html#lambda) keyword. This function returns the sum of its two arguments: lambda a, b: a+b. Lambda functions can be used wherever function objects are required. They are syntactically restricted to a single expression. Semantically, they are just syntactic sugar for a normal function definition. Like nested function definitions, lambda functions can reference variables from the containing scope:

>>>

**>>> def** make\_incrementor(n):

**...**  **return** **lambda** x: x + n

**...**

**>>>** f = make\_incrementor(42)

**>>>** f(0)

42

**>>>** f(1)

43

The above example uses a lambda expression to return a function. Another use is to pass a small function as an argument:

>>>

**>>>** pairs = [(1, 'one'), (2, 'two'), (3, 'three'), (4, 'four')]

**>>>** pairs.sort(key=**lambda** pair: pair[1])

**>>>** pairs

[(4, 'four'), (1, 'one'), (3, 'three'), (2, 'two')]

### 4.7.6. Documentation Strings

Here are some conventions about the content and formatting of documentation strings.

The first line should always be a short, concise summary of the object’s purpose. For brevity, it should not explicitly state the object’s name or type, since these are available by other means (except if the name happens to be a verb describing a function’s operation). This line should begin with a capital letter and end with a period.

If there are more lines in the documentation string, the second line should be blank, visually separating the summary from the rest of the description. The following lines should be one or more paragraphs describing the object’s calling conventions, its side effects, etc.

The Python parser does not strip indentation from multi-line string literals in Python, so tools that process documentation have to strip indentation if desired. This is done using the following convention. The first non-blank line after the first line of the string determines the amount of indentation for the entire documentation string. (We can’t use the first line since it is generally adjacent to the string’s opening quotes so its indentation is not apparent in the string literal.) Whitespace “equivalent” to this indentation is then stripped from the start of all lines of the string. Lines that are indented less should not occur, but if they occur all their leading whitespace should be stripped. Equivalence of whitespace should be tested after expansion of tabs (to 8 spaces, normally).

Here is an example of a multi-line docstring:

>>>

**>>> def** my\_function():

**...**  *"""Do nothing, but document it.*

**...**

**...**  *No, really, it doesn't do anything.*

**...**  *"""*

**...**  **pass**

**...**

**>>>** print(my\_function.\_\_doc\_\_)

Do nothing, but document it.

No, really, it doesn't do anything.

### 4.7.7. Function Annotations

[Function annotations](https://docs.python.org/3/reference/compound_stmts.html#function) are completely optional metadata information about the types used by user-defined functions (see [**PEP 484**](https://www.python.org/dev/peps/pep-0484) for more information).

Annotations are stored in the \_\_annotations\_\_ attribute of the function as a dictionary and have no effect on any other part of the function. Parameter annotations are defined by a colon after the parameter name, followed by an expression evaluating to the value of the annotation. Return annotations are defined by a literal ->, followed by an expression, between the parameter list and the colon denoting the end of the [def](https://docs.python.org/3/reference/compound_stmts.html#def) statement. The following example has a positional argument, a keyword argument, and the return value annotated:

>>>

**>>> def** f(ham: str, eggs: str = 'eggs') -> str:

**...**  print("Annotations:", f.\_\_annotations\_\_)

**...**  print("Arguments:", ham, eggs)

**...**  **return** ham + ' and ' + eggs

**...**

**>>>** f('spam')

Annotations: {'ham': <class 'str'>, 'return': <class 'str'>, 'eggs': <class 'str'>}

Arguments: spam eggs

'spam and eggs'

## 4.8. Intermezzo: Coding Style

Now that you are about to write longer, more complex pieces of Python, it is a good time to talk aboutcoding style. Most languages can be written (or more concise, formatted) in different styles; some are more readable than others. Making it easy for others to read your code is always a good idea, and adopting a nice coding style helps tremendously for that.

For Python, [**PEP 8**](https://www.python.org/dev/peps/pep-0008) has emerged as the style guide that most projects adhere to; it promotes a very readable and eye-pleasing coding style. Every Python developer should read it at some point; here are the most important points extracted for you:

* Use 4-space indentation, and no tabs.

4 spaces are a good compromise between small indentation (allows greater nesting depth) and large indentation (easier to read). Tabs introduce confusion, and are best left out.

* Wrap lines so that they don’t exceed 79 characters.

This helps users with small displays and makes it possible to have several code files side-by-side on larger displays.

* Use blank lines to separate functions and classes, and larger blocks of code inside functions.
* When possible, put comments on a line of their own.
* Use docstrings.
* Use spaces around operators and after commas, but not directly inside bracketing constructs: a= f(1, 2) + g(3, 4).
* Name your classes and functions consistently; the convention is to use CamelCase for classes and lower\_case\_with\_underscores for functions and methods. Always use self as the name for the first method argument (see [A First Look at Classes](https://docs.python.org/3/tutorial/classes.html#tut-firstclasses) for more on classes and methods).
* Don’t use fancy encodings if your code is meant to be used in international environments. Python’s default, UTF-8, or even plain ASCII work best in any case.
* Likewise, don’t use non-ASCII characters in identifiers if there is only the slightest chance people speaking a different language will read or maintain the code.

**Footnotes**

|  |  |
| --- | --- |
| [[1]](https://docs.python.org/3/tutorial/controlflow.html#id1) | Actually, call by object reference would be a better description, since if a mutable object is passed, the caller will see any changes the callee makes to it (items inserted into a list). |

n with no duplicate elements. Basic uses include membership testing and eliminating duplicate entries. Set objects also support mathematical operations like union, intersection, difference, and symmetric difference.

Curly braces or the [set()](https://docs.python.org/3/library/stdtypes.html#set) function can be used to create sets. Note: to create an empty set you have to use set(), not {}; the latter creates an empty dictionary, a data structure that we discuss in the next section.

Here is a brief demonstration:

>>>

**>>>** basket = {'apple', 'orange', 'apple', 'pear', 'orange', 'banana'}

**>>>** print(basket) *# show that duplicates have been removed*

{'orange', 'banana', 'pear', 'apple'}

**>>>** 'orange' **in** basket *# fast membership testing*

True

**>>>** 'crabgrass' **in** basket

False

**>>>** *# Demonstrate set operations on unique letters from two words*

**...**

**>>>** a = set('abracadabra')

**>>>** b = set('alacazam')

**>>>** a *# unique letters in a*

{'a', 'r', 'b', 'c', 'd'}

**>>>** a - b *# letters in a but not in b*

{'r', 'd', 'b'}

**>>>** a | b *# letters in either a or b*

{'a', 'c', 'r', 'd', 'b', 'm', 'z', 'l'}

**>>>** a & b *# letters in both a and b*

{'a', 'c'}

**>>>** a ^ b *# letters in a or b but not both*

{'r', 'd', 'b', 'm', 'z', 'l'}

Similarly to [list comprehensions](https://docs.python.org/3/tutorial/datastructures.html#tut-listcomps), set comprehensions are also supported:

>>>

**>>>** a = {x **for** x **in** 'abracadabra' **if** x **not** **in** 'abc'}

**>>>** a

{'r', 'd'}

## 5.5. Dictionaries

Another useful data type built into Python is the dictionary (see [Mapping Types — dict](https://docs.python.org/3/library/stdtypes.html#typesmapping)). Dictionaries are sometimes found in other languages as “associative memories” or “associative arrays”. Unlike sequences, which are indexed by a range of numbers, dictionaries are indexed by keys, which can be any immutable type; strings and numbers can always be keys. Tuples can be used as keys if they contain only strings, numbers, or tuples; if a tuple contains any mutable object either directly or indirectly, it cannot be used as a key. You can’t use lists as keys, since lists can be modified in place using index assignments, slice assignments, or methods like append() and extend().

It is best to think of a dictionary as an unordered set of key: value pairs, with the requirement that the keys are unique (within one dictionary). A pair of braces creates an empty dictionary: {}. Placing a comma-separated list of key:value pairs within the braces adds initial key:value pairs to the dictionary; this is also the way dictionaries are written on output.

The main operations on a dictionary are storing a value with some key and extracting the value given the key. It is also possible to delete a key:value pair with del. If you store using a key that is already in use, the old value associated with that key is forgotten. It is an error to extract a value using a non-existent key.

Performing list(d.keys()) on a dictionary returns a list of all the keys used in the dictionary, in arbitrary order (if you want it sorted, just use sorted(d.keys()) instead). [[2]](https://docs.python.org/3/tutorial/datastructures.html#id4) To check whether a single key is in the dictionary, use the [in](https://docs.python.org/3/reference/expressions.html#in) keyword.

Here is a small example using a dictionary:

>>>

**>>>** tel = {'jack': 4098, 'sape': 4139}

**>>>** tel['guido'] = 4127

**>>>** tel

{'sape': 4139, 'guido': 4127, 'jack': 4098}

**>>>** tel['jack']

4098

**>>> del** tel['sape']

**>>>** tel['irv'] = 4127

**>>>** tel

{'guido': 4127, 'irv': 4127, 'jack': 4098}

**>>>** list(tel.keys())

['irv', 'guido', 'jack']

**>>>** sorted(tel.keys())

['guido', 'irv', 'jack']

**>>>** 'guido' **in** tel

True

**>>>** 'jack' **not** **in** tel

False

The [dict()](https://docs.python.org/3/library/stdtypes.html#dict) constructor builds dictionaries directly from sequences of key-value pairs:

>>>

**>>>** dict([('sape', 4139), ('guido', 4127), ('jack', 4098)])

{'sape': 4139, 'jack': 4098, 'guido': 4127}

In addition, dict comprehensions can be used to create dictionaries from arbitrary key and value expressions:

>>>

**>>>** {x: x\*\*2 **for** x **in** (2, 4, 6)}

{2: 4, 4: 16, 6: 36}

When the keys are simple strings, it is sometimes easier to specify pairs using keyword arguments:

>>>

**>>>** dict(sape=4139, guido=4127, jack=4098)

{'sape': 4139, 'jack': 4098, 'guido': 4127}

## 5.6. Looping Techniques

When looping through dictionaries, the key and corresponding value can be retrieved at the same time using the items() method.

>>>

**>>>** knights = {'gallahad': 'the pure', 'robin': 'the brave'}

**>>> for** k, v **in** knights.items():

**...**  print(k, v)

**...**

gallahad the pure

robin the brave

When looping through a sequence, the position index and corresponding value can be retrieved at the same time using the [enumerate()](https://docs.python.org/3/library/functions.html#enumerate) function.

>>>

**>>> for** i, v **in** enumerate(['tic', 'tac', 'toe']):

**...**  print(i, v)

**...**

0 tic

1 tac

2 toe

To loop over two or more sequences at the same time, the entries can be paired with the [zip()](https://docs.python.org/3/library/functions.html#zip)function.

>>>

**>>>** questions = ['name', 'quest', 'favorite color']

**>>>** answers = ['lancelot', 'the holy grail', 'blue']

**>>> for** q, a **in** zip(questions, answers):

**...**  print('What is your *{0}*? It is *{1}*.'.format(q, a))

**...**

What is your name? It is lancelot.

What is your quest? It is the holy grail.

What is your favorite color? It is blue.

To loop over a sequence in reverse, first specify the sequence in a forward direction and then call the[reversed()](https://docs.python.org/3/library/functions.html#reversed) function.

>>>

**>>> for** i **in** reversed(range(1, 10, 2)):

**...**  print(i)

**...**

9

7

5

3

1

To loop over a sequence in sorted order, use the [sorted()](https://docs.python.org/3/library/functions.html#sorted) function which returns a new sorted list while leaving the source unaltered.

>>>

**>>>** basket = ['apple', 'orange', 'apple', 'pear', 'orange', 'banana']

**>>> for** f **in** sorted(set(basket)):

**...**  print(f)

**...**

apple

banana

orange

pear

It is sometimes tempting to change a list while you are looping over it; however, it is often simpler and safer to create a new list instead.

>>>

**>>> import** **math**

**>>>** raw\_data = [56.2, float('NaN'), 51.7, 55.3, 52.5, float('NaN'), 47.8]

**>>>** filtered\_data = []

**>>> for** value **in** raw\_data:

**...**  **if** **not** math.isnan(value):

**...**  filtered\_data.append(value)

**...**

**>>>** filtered\_data

[56.2, 51.7, 55.3, 52.5, 47.8]

## 5.7. More on Conditions

The conditions used in while and if statements can contain any operators, not just comparisons.

The comparison operators in and not in check whether a value occurs (does not occur) in a sequence. The operators is and is not compare whether two objects are really the same object; this only matters for mutable objects like lists. All comparison operators have the same priority, which is lower than that of all numerical operators.

Comparisons can be chained. For example, a < b == c tests whether a is less than b and moreoverb equals c.

Comparisons may be combined using the Boolean operators and and or, and the outcome of a comparison (or of any other Boolean expression) may be negated with not. These have lower priorities than comparison operators; between them, not has the highest priority and or the lowest, so that A and not B or C is equivalent to (A and (not B)) or C. As always, parentheses can be used to express the desired composition.

The Boolean operators and and or are so-called short-circuit operators: their arguments are evaluated from left to right, and evaluation stops as soon as the outcome is determined. For example, if A and C are true but B is false, A and B and C does not evaluate the expression C. When used as a general value and not as a Boolean, the return value of a short-circuit operator is the last evaluated argument.

It is possible to assign the result of a comparison or other Boolean expression to a variable. For example,

>>>

**>>>** string1, string2, string3 = '', 'Trondheim', 'Hammer Dance'

**>>>** non\_null = string1 **or** string2 **or** string3

**>>>** non\_null

'Trondheim'

Note that in Python, unlike C, assignment cannot occur inside expressions. C programmers may grumble about this, but it avoids a common class of problems encountered in C programs: typing = in an expression when == was intended.

## 5.8. Comparing Sequences and Other Types

Sequence objects may be compared to other objects with the same sequence type. The comparison uses lexicographical ordering: first the first two items are compared, and if they differ this determines the outcome of the comparison; if they are equal, the next two items are compared, and so on, until either sequence is exhausted. If two items to be compared are themselves sequences of the same type, the lexicographical comparison is carried out recursively. If all items of two sequences compare equal, the sequences are considered equal. If one sequence is an initial sub-sequence of the other, the shorter sequence is the smaller (lesser) one. Lexicographical ordering for strings uses the Unicode code point number to order individual characters. Some examples of comparisons between sequences of the same type:

(1, 2, 3) < (1, 2, 4)

[1, 2, 3] < [1, 2, 4]

'ABC' < 'C' < 'Pascal' < 'Python'

(1, 2, 3, 4) < (1, 2, 4)

(1, 2) < (1, 2, -1)

(1, 2, 3) == (1.0, 2.0, 3.0)

(1, 2, ('aa', 'ab')) < (1, 2, ('abc', 'a'), 4)

Note that comparing objects of different types with < or > is legal provided that the objects have appropriate comparison methods. For example, mixed numeric types are compared according to their numeric value, so 0 equals 0.0, etc. Otherwise, rather than providing an arbitrary ordering, the interpreter will raise a [TypeError](https://docs.python.org/3/library/exceptions.html#TypeError) exception.

**Footnotes**

|  |  |
| --- | --- |
| [[1]](https://docs.python.org/3/tutorial/datastructures.html#id1) | Other languages may return the mutated object, which allows method chaining, such as d->insert("a")->remove("b")->sort();. |

|  |  |
| --- | --- |
| [[2]](https://docs.python.org/3/tutorial/datastructures.html#id2) | Calling d.keys() will return a *dictionary view* object. It supports operations like membership test and iteration, but its contents are not independent of the original dictionary – it is only a*view*. |

# 5. Data Structures

This chapter describes some things you’ve learned about already in more detail, and adds some new things as well.

## 5.1. More on Lists

The list data type has some more methods. Here are all of the methods of list objects:

list.**append**(x)

Add an item to the end of the list. Equivalent to a[len(a):] = [x].

list.**extend**(L)

Extend the list by appending all the items in the given list. Equivalent to a[len(a):] = L.

list.**insert**(i, x)

Insert an item at a given position. The first argument is the index of the element before which to insert, so a.insert(0, x) inserts at the front of the list, and a.insert(len(a), x) is equivalent to a.append(x).

list.**remove**(x)

Remove the first item from the list whose value is x. It is an error if there is no such item.

list.**pop**([i])

Remove the item at the given position in the list, and return it. If no index is specified, a.pop()removes and returns the last item in the list. (The square brackets around the i in the method signature denote that the parameter is optional, not that you should type square brackets at that position. You will see this notation frequently in the Python Library Reference.)

list.**clear**()

Remove all items from the list. Equivalent to del a[:].

list.**index**(x)

Return the index in the list of the first item whose value is x. It is an error if there is no such item.

list.**count**(x)

Return the number of times x appears in the list.

list.**sort**(key=None, reverse=False)

Sort the items of the list in place (the arguments can be used for sort customization, see[sorted()](https://docs.python.org/3/library/functions.html#sorted) for their explanation).

list.**reverse**()

Reverse the elements of the list in place.

list.**copy**()

Return a shallow copy of the list. Equivalent to a[:].

An example that uses most of the list methods:

>>>

**>>>** a = [66.25, 333, 333, 1, 1234.5]

**>>>** print(a.count(333), a.count(66.25), a.count('x'))

2 1 0

**>>>** a.insert(2, -1)

**>>>** a.append(333)

**>>>** a

[66.25, 333, -1, 333, 1, 1234.5, 333]

**>>>** a.index(333)

1

**>>>** a.remove(333)

**>>>** a

[66.25, -1, 333, 1, 1234.5, 333]

**>>>** a.reverse()

**>>>** a

[333, 1234.5, 1, 333, -1, 66.25]

**>>>** a.sort()

**>>>** a

[-1, 1, 66.25, 333, 333, 1234.5]

**>>>** a.pop()

1234.5

**>>>** a

[-1, 1, 66.25, 333, 333]

You might have noticed that methods like insert, remove or sort that only modify the list have no return value printed – they return the default None. [[1]](https://docs.python.org/3/tutorial/datastructures.html#id3) This is a design principle for all mutable data structures in Python.

### 5.1.1. Using Lists as Stacks

The list methods make it very easy to use a list as a stack, where the last element added is the first element retrieved (“last-in, first-out”). To add an item to the top of the stack, use append(). To retrieve an item from the top of the stack, use pop() without an explicit index. For example:

>>>

**>>>** stack = [3, 4, 5]

**>>>** stack.append(6)

**>>>** stack.append(7)

**>>>** stack

[3, 4, 5, 6, 7]

**>>>** stack.pop()

7

**>>>** stack

[3, 4, 5, 6]

**>>>** stack.pop()

6

**>>>** stack.pop()

5

**>>>** stack

[3, 4]

### 5.1.2. Using Lists as Queues

It is also possible to use a list as a queue, where the first element added is the first element retrieved (“first-in, first-out”); however, lists are not efficient for this purpose. While appends and pops from the end of list are fast, doing inserts or pops from the beginning of a list is slow (because all of the other elements have to be shifted by one).

To implement a queue, use [collections.deque](https://docs.python.org/3/library/collections.html#collections.deque) which was designed to have fast appends and pops from both ends. For example:

>>>

**>>> from** **collections** **import** deque

**>>>** queue = deque(["Eric", "John", "Michael"])

**>>>** queue.append("Terry") *# Terry arrives*

**>>>** queue.append("Graham") *# Graham arrives*

**>>>** queue.popleft() *# The first to arrive now leaves*

'Eric'

**>>>** queue.popleft() *# The second to arrive now leaves*

'John'

**>>>** queue *# Remaining queue in order of arrival*

deque(['Michael', 'Terry', 'Graham'])

### 5.1.3. List Comprehensions

List comprehensions provide a concise way to create lists. Common applications are to make new lists where each element is the result of some operations applied to each member of another sequence or iterable, or to create a subsequence of those elements that satisfy a certain condition.

For example, assume we want to create a list of squares, like:

>>>

**>>>** squares = []

**>>> for** x **in** range(10):

**...**  squares.append(x\*\*2)

**...**

**>>>** squares

[0, 1, 4, 9, 16, 25, 36, 49, 64, 81]

Note that this creates (or overwrites) a variable named x that still exists after the loop completes. We can calculate the list of squares without any side effects using:

squares = list(map(**lambda** x: x\*\*2, range(10)))

or, equivalently:

squares = [x\*\*2 **for** x **in** range(10)]

which is more concise and readable.

A list comprehension consists of brackets containing an expression followed by a [for](https://docs.python.org/3/reference/compound_stmts.html#for) clause, then zero or more [for](https://docs.python.org/3/reference/compound_stmts.html#for) or [if](https://docs.python.org/3/reference/compound_stmts.html#if) clauses. The result will be a new list resulting from evaluating the expression in the context of the [for](https://docs.python.org/3/reference/compound_stmts.html#for) and [if](https://docs.python.org/3/reference/compound_stmts.html#if) clauses which follow it. For example, this listcomp combines the elements of two lists if they are not equal:

>>>

**>>>** [(x, y) **for** x **in** [1,2,3] **for** y **in** [3,1,4] **if** x != y]

[(1, 3), (1, 4), (2, 3), (2, 1), (2, 4), (3, 1), (3, 4)]

and it’s equivalent to:

>>>

**>>>** combs = []

**>>> for** x **in** [1,2,3]:

**...**  **for** y **in** [3,1,4]:

**...**  **if** x != y:

**...**  combs.append((x, y))

**...**

**>>>** combs

[(1, 3), (1, 4), (2, 3), (2, 1), (2, 4), (3, 1), (3, 4)]

Note how the order of the [for](https://docs.python.org/3/reference/compound_stmts.html#for) and [if](https://docs.python.org/3/reference/compound_stmts.html#if) statements is the same in both these snippets.

If the expression is a tuple (e.g. the (x, y) in the previous example), it must be parenthesized.

>>>

**>>>** vec = [-4, -2, 0, 2, 4]

**>>>** *# create a new list with the values doubled*

**>>>** [x\*2 **for** x **in** vec]

[-8, -4, 0, 4, 8]

**>>>** *# filter the list to exclude negative numbers*

**>>>** [x **for** x **in** vec **if** x >= 0]

[0, 2, 4]

**>>>** *# apply a function to all the elements*

**>>>** [abs(x) **for** x **in** vec]

[4, 2, 0, 2, 4]

**>>>** *# call a method on each element*

**>>>** freshfruit = [' banana', ' loganberry ', 'passion fruit ']

**>>>** [weapon.strip() **for** weapon **in** freshfruit]

['banana', 'loganberry', 'passion fruit']

**>>>** *# create a list of 2-tuples like (number, square)*

**>>>** [(x, x\*\*2) **for** x **in** range(6)]

[(0, 0), (1, 1), (2, 4), (3, 9), (4, 16), (5, 25)]

**>>>** *# the tuple must be parenthesized, otherwise an error is raised*

**>>>** [x, x\*\*2 **for** x **in** range(6)]

File "<stdin>", line 1, in ?

[x, x\*\*2 for x in range(6)]

^

SyntaxError: invalid syntax

**>>>** *# flatten a list using a listcomp with two 'for'*

**>>>** vec = [[1,2,3], [4,5,6], [7,8,9]]

**>>>** [num **for** elem **in** vec **for** num **in** elem]

[1, 2, 3, 4, 5, 6, 7, 8, 9]

List comprehensions can contain complex expressions and nested functions:

>>>

**>>> from** **math** **import** pi

**>>>** [str(round(pi, i)) **for** i **in** range(1, 6)]

['3.1', '3.14', '3.142', '3.1416', '3.14159']

### 5.1.4. Nested List Comprehensions

The initial expression in a list comprehension can be any arbitrary expression, including another list comprehension.

Consider the following example of a 3x4 matrix implemented as a list of 3 lists of length 4:

>>>

**>>>** matrix = [

**...**  [1, 2, 3, 4],

**...**  [5, 6, 7, 8],

**...**  [9, 10, 11, 12],

**...** ]

The following list comprehension will transpose rows and columns:

>>>

**>>>** [[row[i] **for** row **in** matrix] **for** i **in** range(4)]

[[1, 5, 9], [2, 6, 10], [3, 7, 11], [4, 8, 12]]

As we saw in the previous section, the nested listcomp is evaluated in the context of the [for](https://docs.python.org/3/reference/compound_stmts.html#for) that follows it, so this example is equivalent to:

>>>

**>>>** transposed = []

**>>> for** i **in** range(4):

**...**  transposed.append([row[i] **for** row **in** matrix])

**...**

**>>>** transposed

[[1, 5, 9], [2, 6, 10], [3, 7, 11], [4, 8, 12]]

which, in turn, is the same as:

>>>

**>>>** transposed = []

**>>> for** i **in** range(4):

**...**  *# the following 3 lines implement the nested listcomp*

**...**  transposed\_row = []

**...**  **for** row **in** matrix:

**...**  transposed\_row.append(row[i])

**...**  transposed.append(transposed\_row)

**...**

**>>>** transposed

[[1, 5, 9], [2, 6, 10], [3, 7, 11], [4, 8, 12]]

In the real world, you should prefer built-in functions to complex flow statements. The [zip()](https://docs.python.org/3/library/functions.html#zip) function would do a great job for this use case:

>>>

**>>>** list(zip(\*matrix))

[(1, 5, 9), (2, 6, 10), (3, 7, 11), (4, 8, 12)]

See [Unpacking Argument Lists](https://docs.python.org/3/tutorial/controlflow.html#tut-unpacking-arguments) for details on the asterisk in this line.

## 5.2. The [del](https://docs.python.org/3/reference/simple_stmts.html#del) statement

There is a way to remove an item from a list given its index instead of its value: the [del](https://docs.python.org/3/reference/simple_stmts.html#del) statement. This differs from the pop() method which returns a value. The [del](https://docs.python.org/3/reference/simple_stmts.html#del) statement can also be used to remove slices from a list or clear the entire list (which we did earlier by assignment of an empty list to the slice). For example:

>>>

**>>>** a = [-1, 1, 66.25, 333, 333, 1234.5]

**>>> del** a[0]

**>>>** a

[1, 66.25, 333, 333, 1234.5]

**>>> del** a[2:4]

**>>>** a

[1, 66.25, 1234.5]

**>>> del** a[:]

**>>>** a

[]

[del](https://docs.python.org/3/reference/simple_stmts.html#del) can also be used to delete entire variables:

>>>

**>>> del** a

Referencing the name a hereafter is an error (at least until another value is assigned to it). We’ll find other uses for [del](https://docs.python.org/3/reference/simple_stmts.html#del) later.

## 5.3. Tuples and Sequences

We saw that lists and strings have many common properties, such as indexing and slicing operations. They are two examples of sequence data types (see [Sequence Types — list, tuple, range](https://docs.python.org/3/library/stdtypes.html#typesseq)). Since Python is an evolving language, other sequence data types may be added. There is also another standard sequence data type: the tuple.

A tuple consists of a number of values separated by commas, for instance:

>>>

**>>>** t = 12345, 54321, 'hello!'

**>>>** t[0]

12345

**>>>** t

(12345, 54321, 'hello!')

**>>>** *# Tuples may be nested:*

**...** u = t, (1, 2, 3, 4, 5)

**>>>** u

((12345, 54321, 'hello!'), (1, 2, 3, 4, 5))

**>>>** *# Tuples are immutable:*

**...** t[0] = 88888

Traceback (most recent call last):

File "<stdin>", line 1, in <module>

TypeError: 'tuple' object does not support item assignment

**>>>** *# but they can contain mutable objects:*

**...** v = ([1, 2, 3], [3, 2, 1])

**>>>** v

([1, 2, 3], [3, 2, 1])

As you see, on output tuples are always enclosed in parentheses, so that nested tuples are interpreted correctly; they may be input with or without surrounding parentheses, although often parentheses are necessary anyway (if the tuple is part of a larger expression). It is not possible to assign to the individual items of a tuple, however it is possible to create tuples which contain mutable objects, such as lists.

Though tuples may seem similar to lists, they are often used in different situations and for different purposes. Tuples are [immutable](https://docs.python.org/3/glossary.html#term-immutable), and usually contain a heterogeneous sequence of elements that are accessed via unpacking (see later in this section) or indexing (or even by attribute in the case of[namedtuples](https://docs.python.org/3/library/collections.html#collections.namedtuple)). Lists are [mutable](https://docs.python.org/3/glossary.html#term-mutable), and their elements are usually homogeneous and are accessed by iterating over the list.

A special problem is the construction of tuples containing 0 or 1 items: the syntax has some extra quirks to accommodate these. Empty tuples are constructed by an empty pair of parentheses; a tuple with one item is constructed by following a value with a comma (it is not sufficient to enclose a single value in parentheses). Ugly, but effective. For example:

>>>

**>>>** empty = ()

**>>>** singleton = 'hello', *# <-- note trailing comma*

**>>>** len(empty)

0

**>>>** len(singleton)

1

**>>>** singleton

('hello',)

The statement t = 12345, 54321, 'hello!' is an example of tuple packing: the values 12345,54321 and 'hello!' are packed together in a tuple. The reverse operation is also possible:

>>>

**>>>** x, y, z = t

This is called, appropriately enough, sequence unpacking and works for any sequence on the right-hand side. Sequence unpacking requires that there are as many variables on the left side of the equals sign as there are elements in the sequence. Note that multiple assignment is really just a combination of tuple packing and sequence unpacking.

## 5.4. Sets

Python also includes a data type for sets. A set is an unordered collection with no duplicate elements. Basic uses include membership testing and eliminating duplicate entries. Set objects also support mathematical operations like union, intersection, difference, and symmetric difference.

Curly braces or the [set()](https://docs.python.org/3/library/stdtypes.html#set) function can be used to create sets. Note: to create an empty set you have to use set(), not {}; the latter creates an empty dictionary, a data structure that we discuss in the next section.

Here is a brief demonstration:

>>>

**>>>** basket = {'apple', 'orange', 'apple', 'pear', 'orange', 'banana'}

**>>>** print(basket) *# show that duplicates have been removed*

{'orange', 'banana', 'pear', 'apple'}

**>>>** 'orange' **in** basket *# fast membership testing*

True

**>>>** 'crabgrass' **in** basket

False

**>>>** *# Demonstrate set operations on unique letters from two words*

**...**

**>>>** a = set('abracadabra')

**>>>** b = set('alacazam')

**>>>** a *# unique letters in a*

{'a', 'r', 'b', 'c', 'd'}

**>>>** a - b *# letters in a but not in b*

{'r', 'd', 'b'}

**>>>** a | b *# letters in either a or b*

{'a', 'c', 'r', 'd', 'b', 'm', 'z', 'l'}

**>>>** a & b *# letters in both a and b*

{'a', 'c'}

**>>>** a ^ b *# letters in a or b but not both*

{'r', 'd', 'b', 'm', 'z', 'l'}

Similarly to [list comprehensions](https://docs.python.org/3/tutorial/datastructures.html#tut-listcomps), set comprehensions are also supported:

>>>

**>>>** a = {x **for** x **in** 'abracadabra' **if** x **not** **in** 'abc'}

**>>>** a

{'r', 'd'}

## 5.5. Dictionaries

Another useful data type built into Python is the dictionary (see [Mapping Types — dict](https://docs.python.org/3/library/stdtypes.html#typesmapping)). Dictionaries are sometimes found in other languages as “associative memories” or “associative arrays”. Unlike sequences, which are indexed by a range of numbers, dictionaries are indexed by keys, which can be any immutable type; strings and numbers can always be keys. Tuples can be used as keys if they contain only strings, numbers, or tuples; if a tuple contains any mutable object either directly or indirectly, it cannot be used as a key. You can’t use lists as keys, since lists can be modified in place using index assignments, slice assignments, or methods like append() and extend().

It is best to think of a dictionary as an unordered set of key: value pairs, with the requirement that the keys are unique (within one dictionary). A pair of braces creates an empty dictionary: {}. Placing a comma-separated list of key:value pairs within the braces adds initial key:value pairs to the dictionary; this is also the way dictionaries are written on output.

The main operations on a dictionary are storing a value with some key and extracting the value given the key. It is also possible to delete a key:value pair with del. If you store using a key that is already in use, the old value associated with that key is forgotten. It is an error to extract a value using a non-existent key.

Performing list(d.keys()) on a dictionary returns a list of all the keys used in the dictionary, in arbitrary order (if you want it sorted, just use sorted(d.keys()) instead). [[2]](https://docs.python.org/3/tutorial/datastructures.html#id4) To check whether a single key is in the dictionary, use the [in](https://docs.python.org/3/reference/expressions.html#in) keyword.

Here is a small example using a dictionary:

>>>

**>>>** tel = {'jack': 4098, 'sape': 4139}

**>>>** tel['guido'] = 4127

**>>>** tel

{'sape': 4139, 'guido': 4127, 'jack': 4098}

**>>>** tel['jack']

4098

**>>> del** tel['sape']

**>>>** tel['irv'] = 4127

**>>>** tel

{'guido': 4127, 'irv': 4127, 'jack': 4098}

**>>>** list(tel.keys())

['irv', 'guido', 'jack']

**>>>** sorted(tel.keys())

['guido', 'irv', 'jack']

**>>>** 'guido' **in** tel

True

**>>>** 'jack' **not** **in** tel

False

The [dict()](https://docs.python.org/3/library/stdtypes.html#dict) constructor builds dictionaries directly from sequences of key-value pairs:

>>>

**>>>** dict([('sape', 4139), ('guido', 4127), ('jack', 4098)])

{'sape': 4139, 'jack': 4098, 'guido': 4127}

In addition, dict comprehensions can be used to create dictionaries from arbitrary key and value expressions:

>>>

**>>>** {x: x\*\*2 **for** x **in** (2, 4, 6)}

{2: 4, 4: 16, 6: 36}

When the keys are simple strings, it is sometimes easier to specify pairs using keyword arguments:

>>>

**>>>** dict(sape=4139, guido=4127, jack=4098)

{'sape': 4139, 'jack': 4098, 'guido': 4127}

## 5.6. Looping Techniques

When looping through dictionaries, the key and corresponding value can be retrieved at the same time using the items() method.

>>>

**>>>** knights = {'gallahad': 'the pure', 'robin': 'the brave'}

**>>> for** k, v **in** knights.items():

**...**  print(k, v)

**...**

gallahad the pure

robin the brave

When looping through a sequence, the position index and corresponding value can be retrieved at the same time using the [enumerate()](https://docs.python.org/3/library/functions.html#enumerate) function.

>>>

**>>> for** i, v **in** enumerate(['tic', 'tac', 'toe']):

**...**  print(i, v)

**...**

0 tic

1 tac

2 toe

To loop over two or more sequences at the same time, the entries can be paired with the [zip()](https://docs.python.org/3/library/functions.html#zip)function.

>>>

**>>>** questions = ['name', 'quest', 'favorite color']

**>>>** answers = ['lancelot', 'the holy grail', 'blue']

**>>> for** q, a **in** zip(questions, answers):

**...**  print('What is your *{0}*? It is *{1}*.'.format(q, a))

**...**

What is your name? It is lancelot.

What is your quest? It is the holy grail.

What is your favorite color? It is blue.

To loop over a sequence in reverse, first specify the sequence in a forward direction and then call the[reversed()](https://docs.python.org/3/library/functions.html#reversed) function.

>>>

**>>> for** i **in** reversed(range(1, 10, 2)):

**...**  print(i)

**...**

9

7

5

3

1

To loop over a sequence in sorted order, use the [sorted()](https://docs.python.org/3/library/functions.html#sorted) function which returns a new sorted list while leaving the source unaltered.

>>>

**>>>** basket = ['apple', 'orange', 'apple', 'pear', 'orange', 'banana']

**>>> for** f **in** sorted(set(basket)):

**...**  print(f)

**...**

apple

banana

orange

pear

It is sometimes tempting to change a list while you are looping over it; however, it is often simpler and safer to create a new list instead.

>>>

**>>> import** **math**

**>>>** raw\_data = [56.2, float('NaN'), 51.7, 55.3, 52.5, float('NaN'), 47.8]

**>>>** filtered\_data = []

**>>> for** value **in** raw\_data:

**...**  **if** **not** math.isnan(value):

**...**  filtered\_data.append(value)

**...**

**>>>** filtered\_data

[56.2, 51.7, 55.3, 52.5, 47.8]

## 5.7. More on Conditions

The conditions used in while and if statements can contain any operators, not just comparisons.

The comparison operators in and not in check whether a value occurs (does not occur) in a sequence. The operators is and is not compare whether two objects are really the same object; this only matters for mutable objects like lists. All comparison operators have the same priority, which is lower than that of all numerical operators.

Comparisons can be chained. For example, a < b == c tests whether a is less than b and moreoverb equals c.

Comparisons may be combined using the Boolean operators and and or, and the outcome of a comparison (or of any other Boolean expression) may be negated with not. These have lower priorities than comparison operators; between them, not has the highest priority and or the lowest, so that A and not B or C is equivalent to (A and (not B)) or C. As always, parentheses can be used to express the desired composition.

The Boolean operators and and or are so-called short-circuit operators: their arguments are evaluated from left to right, and evaluation stops as soon as the outcome is determined. For example, if A and C are true but B is false, A and B and C does not evaluate the expression C. When used as a general value and not as a Boolean, the return value of a short-circuit operator is the last evaluated argument.

It is possible to assign the result of a comparison or other Boolean expression to a variable. For example,

>>>

**>>>** string1, string2, string3 = '', 'Trondheim', 'Hammer Dance'

**>>>** non\_null = string1 **or** string2 **or** string3

**>>>** non\_null

'Trondheim'

Note that in Python, unlike C, assignment cannot occur inside expressions. C programmers may grumble about this, but it avoids a common class of problems encountered in C programs: typing = in an expression when == was intended.

## 5.8. Comparing Sequences and Other Types

Sequence objects may be compared to other objects with the same sequence type. The comparison uses lexicographical ordering: first the first two items are compared, and if they differ this determines the outcome of the comparison; if they are equal, the next two items are compared, and so on, until either sequence is exhausted. If two items to be compared are themselves sequences of the same type, the lexicographical comparison is carried out recursively. If all items of two sequences compare equal, the sequences are considered equal. If one sequence is an initial sub-sequence of the other, the shorter sequence is the smaller (lesser) one. Lexicographical ordering for strings uses the Unicode code point number to order individual characters. Some examples of comparisons between sequences of the same type:

(1, 2, 3) < (1, 2, 4)

[1, 2, 3] < [1, 2, 4]

'ABC' < 'C' < 'Pascal' < 'Python'

(1, 2, 3, 4) < (1, 2, 4)

(1, 2) < (1, 2, -1)

(1, 2, 3) == (1.0, 2.0, 3.0)

(1, 2, ('aa', 'ab')) < (1, 2, ('abc', 'a'), 4)

Note that comparing objects of different types with < or > is legal provided that the objects have appropriate comparison methods. For example, mixed numeric types are compared according to their numeric value, so 0 equals 0.0, etc. Otherwise, rather than providing an arbitrary ordering, the interpreter will raise a [TypeError](https://docs.python.org/3/library/exceptions.html#TypeError) exception.

**Footnotes**

|  |  |
| --- | --- |
| [[1]](https://docs.python.org/3/tutorial/datastructures.html#id1) | Other languages may return the mutated object, which allows method chaining, such as d->insert("a")->remove("b")->sort();. |

|  |  |
| --- | --- |
| [[2]](https://docs.python.org/3/tutorial/datastructures.html#id2) | Calling d.keys() will return a dictionary view object. It supports operations like membership test and iteration, but its contents are not independent of the original dictionary – it is only aview. |

# 5. Data Structures

This chapter describes some things you’ve learned about already in more detail, and adds some new things as well.

## 5.1. More on Lists

The list data type has some more methods. Here are all of the methods of list objects:

list.**append**(x)

Add an item to the end of the list. Equivalent to a[len(a):] = [x].

list.**extend**(L)

Extend the list by appending all the items in the given list. Equivalent to a[len(a):] = L.

list.**insert**(i, x)

Insert an item at a given position. The first argument is the index of the element before which to insert, so a.insert(0, x) inserts at the front of the list, and a.insert(len(a), x) is equivalent to a.append(x).

list.**remove**(x)

Remove the first item from the list whose value is x. It is an error if there is no such item.

list.**pop**([i])

Remove the item at the given position in the list, and return it. If no index is specified, a.pop()removes and returns the last item in the list. (The square brackets around the i in the method signature denote that the parameter is optional, not that you should type square brackets at that position. You will see this notation frequently in the Python Library Reference.)

list.**clear**()

Remove all items from the list. Equivalent to del a[:].

list.**index**(x)

Return the index in the list of the first item whose value is x. It is an error if there is no such item.

list.**count**(x)

Return the number of times x appears in the list.

list.**sort**(key=None, reverse=False)

Sort the items of the list in place (the arguments can be used for sort customization, see[sorted()](https://docs.python.org/3/library/functions.html#sorted) for their explanation).

list.**reverse**()

Reverse the elements of the list in place.

list.**copy**()

Return a shallow copy of the list. Equivalent to a[:].

An example that uses most of the list methods:

>>>

**>>>** a = [66.25, 333, 333, 1, 1234.5]

**>>>** print(a.count(333), a.count(66.25), a.count('x'))

2 1 0

**>>>** a.insert(2, -1)

**>>>** a.append(333)

**>>>** a

[66.25, 333, -1, 333, 1, 1234.5, 333]

**>>>** a.index(333)

1

**>>>** a.remove(333)

**>>>** a

[66.25, -1, 333, 1, 1234.5, 333]

**>>>** a.reverse()

**>>>** a

[333, 1234.5, 1, 333, -1, 66.25]

**>>>** a.sort()

**>>>** a

[-1, 1, 66.25, 333, 333, 1234.5]

**>>>** a.pop()

1234.5

**>>>** a

[-1, 1, 66.25, 333, 333]

You might have noticed that methods like insert, remove or sort that only modify the list have no return value printed – they return the default None. [[1]](https://docs.python.org/3/tutorial/datastructures.html#id3) This is a design principle for all mutable data structures in Python.

### 5.1.1. Using Lists as Stacks

The list methods make it very easy to use a list as a stack, where the last element added is the first element retrieved (“last-in, first-out”). To add an item to the top of the stack, use append(). To retrieve an item from the top of the stack, use pop() without an explicit index. For example:

>>>

**>>>** stack = [3, 4, 5]

**>>>** stack.append(6)

**>>>** stack.append(7)

**>>>** stack

[3, 4, 5, 6, 7]

**>>>** stack.pop()

7

**>>>** stack

[3, 4, 5, 6]

**>>>** stack.pop()

6

**>>>** stack.pop()

5

**>>>** stack

[3, 4]

### 5.1.2. Using Lists as Queues

It is also possible to use a list as a queue, where the first element added is the first element retrieved (“first-in, first-out”); however, lists are not efficient for this purpose. While appends and pops from the end of list are fast, doing inserts or pops from the beginning of a list is slow (because all of the other elements have to be shifted by one).

To implement a queue, use [collections.deque](https://docs.python.org/3/library/collections.html#collections.deque) which was designed to have fast appends and pops from both ends. For example:

>>>

**>>> from** **collections** **import** deque

**>>>** queue = deque(["Eric", "John", "Michael"])

**>>>** queue.append("Terry") *# Terry arrives*

**>>>** queue.append("Graham") *# Graham arrives*

**>>>** queue.popleft() *# The first to arrive now leaves*

'Eric'

**>>>** queue.popleft() *# The second to arrive now leaves*

'John'

**>>>** queue *# Remaining queue in order of arrival*

deque(['Michael', 'Terry', 'Graham'])

### 5.1.3. List Comprehensions

List comprehensions provide a concise way to create lists. Common applications are to make new lists where each element is the result of some operations applied to each member of another sequence or iterable, or to create a subsequence of those elements that satisfy a certain condition.

For example, assume we want to create a list of squares, like:

>>>

**>>>** squares = []

**>>> for** x **in** range(10):

**...**  squares.append(x\*\*2)

**...**

**>>>** squares

[0, 1, 4, 9, 16, 25, 36, 49, 64, 81]

Note that this creates (or overwrites) a variable named x that still exists after the loop completes. We can calculate the list of squares without any side effects using:

squares = list(map(**lambda** x: x\*\*2, range(10)))

or, equivalently:

squares = [x\*\*2 **for** x **in** range(10)]

which is more concise and readable.

A list comprehension consists of brackets containing an expression followed by a [for](https://docs.python.org/3/reference/compound_stmts.html#for) clause, then zero or more [for](https://docs.python.org/3/reference/compound_stmts.html#for) or [if](https://docs.python.org/3/reference/compound_stmts.html#if) clauses. The result will be a new list resulting from evaluating the expression in the context of the [for](https://docs.python.org/3/reference/compound_stmts.html#for) and [if](https://docs.python.org/3/reference/compound_stmts.html#if) clauses which follow it. For example, this listcomp combines the elements of two lists if they are not equal:

>>>

**>>>** [(x, y) **for** x **in** [1,2,3] **for** y **in** [3,1,4] **if** x != y]

[(1, 3), (1, 4), (2, 3), (2, 1), (2, 4), (3, 1), (3, 4)]

and it’s equivalent to:

>>>

**>>>** combs = []

**>>> for** x **in** [1,2,3]:

**...**  **for** y **in** [3,1,4]:

**...**  **if** x != y:

**...**  combs.append((x, y))

**...**

**>>>** combs

[(1, 3), (1, 4), (2, 3), (2, 1), (2, 4), (3, 1), (3, 4)]

Note how the order of the [for](https://docs.python.org/3/reference/compound_stmts.html#for) and [if](https://docs.python.org/3/reference/compound_stmts.html#if) statements is the same in both these snippets.

If the expression is a tuple (e.g. the (x, y) in the previous example), it must be parenthesized.

>>>

**>>>** vec = [-4, -2, 0, 2, 4]

**>>>** *# create a new list with the values doubled*

**>>>** [x\*2 **for** x **in** vec]

[-8, -4, 0, 4, 8]

**>>>** *# filter the list to exclude negative numbers*

**>>>** [x **for** x **in** vec **if** x >= 0]

[0, 2, 4]

**>>>** *# apply a function to all the elements*

**>>>** [abs(x) **for** x **in** vec]

[4, 2, 0, 2, 4]

**>>>** *# call a method on each element*

**>>>** freshfruit = [' banana', ' loganberry ', 'passion fruit ']

**>>>** [weapon.strip() **for** weapon **in** freshfruit]

['banana', 'loganberry', 'passion fruit']

**>>>** *# create a list of 2-tuples like (number, square)*

**>>>** [(x, x\*\*2) **for** x **in** range(6)]

[(0, 0), (1, 1), (2, 4), (3, 9), (4, 16), (5, 25)]

**>>>** *# the tuple must be parenthesized, otherwise an error is raised*

**>>>** [x, x\*\*2 **for** x **in** range(6)]

File "<stdin>", line 1, in ?

[x, x\*\*2 for x in range(6)]

^

SyntaxError: invalid syntax

**>>>** *# flatten a list using a listcomp with two 'for'*

**>>>** vec = [[1,2,3], [4,5,6], [7,8,9]]

**>>>** [num **for** elem **in** vec **for** num **in** elem]

[1, 2, 3, 4, 5, 6, 7, 8, 9]

List comprehensions can contain complex expressions and nested functions:

>>>

**>>> from** **math** **import** pi

**>>>** [str(round(pi, i)) **for** i **in** range(1, 6)]

['3.1', '3.14', '3.142', '3.1416', '3.14159']

### 5.1.4. Nested List Comprehensions

The initial expression in a list comprehension can be any arbitrary expression, including another list comprehension.

Consider the following example of a 3x4 matrix implemented as a list of 3 lists of length 4:

>>>

**>>>** matrix = [

**...**  [1, 2, 3, 4],

**...**  [5, 6, 7, 8],

**...**  [9, 10, 11, 12],

**...** ]

The following list comprehension will transpose rows and columns:

>>>

**>>>** [[row[i] **for** row **in** matrix] **for** i **in** range(4)]

[[1, 5, 9], [2, 6, 10], [3, 7, 11], [4, 8, 12]]

As we saw in the previous section, the nested listcomp is evaluated in the context of the [for](https://docs.python.org/3/reference/compound_stmts.html#for) that follows it, so this example is equivalent to:

>>>

**>>>** transposed = []

**>>> for** i **in** range(4):

**...**  transposed.append([row[i] **for** row **in** matrix])

**...**

**>>>** transposed

[[1, 5, 9], [2, 6, 10], [3, 7, 11], [4, 8, 12]]

which, in turn, is the same as:

>>>

**>>>** transposed = []

**>>> for** i **in** range(4):

**...**  *# the following 3 lines implement the nested listcomp*

**...**  transposed\_row = []

**...**  **for** row **in** matrix:

**...**  transposed\_row.append(row[i])

**...**  transposed.append(transposed\_row)

**...**

**>>>** transposed

[[1, 5, 9], [2, 6, 10], [3, 7, 11], [4, 8, 12]]

In the real world, you should prefer built-in functions to complex flow statements. The [zip()](https://docs.python.org/3/library/functions.html#zip) function would do a great job for this use case:

>>>

**>>>** list(zip(\*matrix))

[(1, 5, 9), (2, 6, 10), (3, 7, 11), (4, 8, 12)]

See [Unpacking Argument Lists](https://docs.python.org/3/tutorial/controlflow.html#tut-unpacking-arguments) for details on the asterisk in this line.

## 5.2. The [del](https://docs.python.org/3/reference/simple_stmts.html#del) statement

There is a way to remove an item from a list given its index instead of its value: the [del](https://docs.python.org/3/reference/simple_stmts.html#del) statement. This differs from the pop() method which returns a value. The [del](https://docs.python.org/3/reference/simple_stmts.html#del) statement can also be used to remove slices from a list or clear the entire list (which we did earlier by assignment of an empty list to the slice). For example:

>>>

**>>>** a = [-1, 1, 66.25, 333, 333, 1234.5]

**>>> del** a[0]

**>>>** a

[1, 66.25, 333, 333, 1234.5]

**>>> del** a[2:4]

**>>>** a

[1, 66.25, 1234.5]

**>>> del** a[:]

**>>>** a

[]

[del](https://docs.python.org/3/reference/simple_stmts.html#del) can also be used to delete entire variables:

>>>

**>>> del** a

Referencing the name a hereafter is an error (at least until another value is assigned to it). We’ll find other uses for [del](https://docs.python.org/3/reference/simple_stmts.html#del) later.

## 5.3. Tuples and Sequences

We saw that lists and strings have many common properties, such as indexing and slicing operations. They are two examples of sequence data types (see [Sequence Types — list, tuple, range](https://docs.python.org/3/library/stdtypes.html#typesseq)). Since Python is an evolving language, other sequence data types may be added. There is also another standard sequence data type: the tuple.

A tuple consists of a number of values separated by commas, for instance:

>>>

**>>>** t = 12345, 54321, 'hello!'

**>>>** t[0]

12345

**>>>** t

(12345, 54321, 'hello!')

**>>>** *# Tuples may be nested:*

**...** u = t, (1, 2, 3, 4, 5)

**>>>** u

((12345, 54321, 'hello!'), (1, 2, 3, 4, 5))

**>>>** *# Tuples are immutable:*

**...** t[0] = 88888

Traceback (most recent call last):

File "<stdin>", line 1, in <module>

TypeError: 'tuple' object does not support item assignment

**>>>** *# but they can contain mutable objects:*

**...** v = ([1, 2, 3], [3, 2, 1])

**>>>** v

([1, 2, 3], [3, 2, 1])

As you see, on output tuples are always enclosed in parentheses, so that nested tuples are interpreted correctly; they may be input with or without surrounding parentheses, although often parentheses are necessary anyway (if the tuple is part of a larger expression). It is not possible to assign to the individual items of a tuple, however it is possible to create tuples which contain mutable objects, such as lists.

Though tuples may seem similar to lists, they are often used in different situations and for different purposes. Tuples are [immutable](https://docs.python.org/3/glossary.html#term-immutable), and usually contain a heterogeneous sequence of elements that are accessed via unpacking (see later in this section) or indexing (or even by attribute in the case of[namedtuples](https://docs.python.org/3/library/collections.html#collections.namedtuple)). Lists are [mutable](https://docs.python.org/3/glossary.html#term-mutable), and their elements are usually homogeneous and are accessed by iterating over the list.

A special problem is the construction of tuples containing 0 or 1 items: the syntax has some extra quirks to accommodate these. Empty tuples are constructed by an empty pair of parentheses; a tuple with one item is constructed by following a value with a comma (it is not sufficient to enclose a single value in parentheses). Ugly, but effective. For example:

>>>

**>>>** empty = ()

**>>>** singleton = 'hello', *# <-- note trailing comma*

**>>>** len(empty)

0

**>>>** len(singleton)

1

**>>>** singleton

('hello',)

The statement t = 12345, 54321, 'hello!' is an example of tuple packing: the values 12345,54321 and 'hello!' are packed together in a tuple. The reverse operation is also possible:

>>>

**>>>** x, y, z = t

This is called, appropriately enough, sequence unpacking and works for any sequence on the right-hand side. Sequence unpacking requires that there are as many variables on the left side of the equals sign as there are elements in the sequence. Note that multiple assignment is really just a combination of tuple packing and sequence unpacking.

## 5.4. Sets

Python also includes a data type for sets. A set is an unordered collection with no duplicate elements. Basic uses include membership testing and eliminating duplicate entries. Set objects also support mathematical operations like union, intersection, difference, and symmetric difference.

Curly braces or the [set()](https://docs.python.org/3/library/stdtypes.html#set) function can be used to create sets. Note: to create an empty set you have to use set(), not {}; the latter creates an empty dictionary, a data structure that we discuss in the next section.

Here is a brief demonstration:

>>>

**>>>** basket = {'apple', 'orange', 'apple', 'pear', 'orange', 'banana'}

**>>>** print(basket) *# show that duplicates have been removed*

{'orange', 'banana', 'pear', 'apple'}

**>>>** 'orange' **in** basket *# fast membership testing*

True

**>>>** 'crabgrass' **in** basket

False

**>>>** *# Demonstrate set operations on unique letters from two words*

**...**

**>>>** a = set('abracadabra')

**>>>** b = set('alacazam')

**>>>** a *# unique letters in a*

{'a', 'r', 'b', 'c', 'd'}

**>>>** a - b *# letters in a but not in b*

{'r', 'd', 'b'}

**>>>** a | b *# letters in either a or b*

{'a', 'c', 'r', 'd', 'b', 'm', 'z', 'l'}

**>>>** a & b *# letters in both a and b*

{'a', 'c'}

**>>>** a ^ b *# letters in a or b but not both*

{'r', 'd', 'b', 'm', 'z', 'l'}

Similarly to [list comprehensions](https://docs.python.org/3/tutorial/datastructures.html#tut-listcomps), set comprehensions are also supported:

>>>

**>>>** a = {x **for** x **in** 'abracadabra' **if** x **not** **in** 'abc'}

**>>>** a

{'r', 'd'}

## 5.5. Dictionaries

Another useful data type built into Python is the dictionary (see [Mapping Types — dict](https://docs.python.org/3/library/stdtypes.html#typesmapping)). Dictionaries are sometimes found in other languages as “associative memories” or “associative arrays”. Unlike sequences, which are indexed by a range of numbers, dictionaries are indexed by keys, which can be any immutable type; strings and numbers can always be keys. Tuples can be used as keys if they contain only strings, numbers, or tuples; if a tuple contains any mutable object either directly or indirectly, it cannot be used as a key. You can’t use lists as keys, since lists can be modified in place using index assignments, slice assignments, or methods like append() and extend().

It is best to think of a dictionary as an unordered set of key: value pairs, with the requirement that the keys are unique (within one dictionary). A pair of braces creates an empty dictionary: {}. Placing a comma-separated list of key:value pairs within the braces adds initial key:value pairs to the dictionary; this is also the way dictionaries are written on output.

The main operations on a dictionary are storing a value with some key and extracting the value given the key. It is also possible to delete a key:value pair with del. If you store using a key that is already in use, the old value associated with that key is forgotten. It is an error to extract a value using a non-existent key.

Performing list(d.keys()) on a dictionary returns a list of all the keys used in the dictionary, in arbitrary order (if you want it sorted, just use sorted(d.keys()) instead). [[2]](https://docs.python.org/3/tutorial/datastructures.html#id4) To check whether a single key is in the dictionary, use the [in](https://docs.python.org/3/reference/expressions.html#in) keyword.

Here is a small example using a dictionary:

>>>

**>>>** tel = {'jack': 4098, 'sape': 4139}

**>>>** tel['guido'] = 4127

**>>>** tel

{'sape': 4139, 'guido': 4127, 'jack': 4098}

**>>>** tel['jack']

4098

**>>> del** tel['sape']

**>>>** tel['irv'] = 4127

**>>>** tel

{'guido': 4127, 'irv': 4127, 'jack': 4098}

**>>>** list(tel.keys())

['irv', 'guido', 'jack']

**>>>** sorted(tel.keys())

['guido', 'irv', 'jack']

**>>>** 'guido' **in** tel

True

**>>>** 'jack' **not** **in** tel

False

The [dict()](https://docs.python.org/3/library/stdtypes.html#dict) constructor builds dictionaries directly from sequences of key-value pairs:

>>>

**>>>** dict([('sape', 4139), ('guido', 4127), ('jack', 4098)])

{'sape': 4139, 'jack': 4098, 'guido': 4127}

In addition, dict comprehensions can be used to create dictionaries from arbitrary key and value expressions:

>>>

**>>>** {x: x\*\*2 **for** x **in** (2, 4, 6)}

{2: 4, 4: 16, 6: 36}

When the keys are simple strings, it is sometimes easier to specify pairs using keyword arguments:

>>>

**>>>** dict(sape=4139, guido=4127, jack=4098)

{'sape': 4139, 'jack': 4098, 'guido': 4127}

## 5.6. Looping Techniques

When looping through dictionaries, the key and corresponding value can be retrieved at the same time using the items() method.

>>>

**>>>** knights = {'gallahad': 'the pure', 'robin': 'the brave'}

**>>> for** k, v **in** knights.items():

**...**  print(k, v)

**...**

gallahad the pure

robin the brave

When looping through a sequence, the position index and corresponding value can be retrieved at the same time using the [enumerate()](https://docs.python.org/3/library/functions.html#enumerate) function.

>>>

**>>> for** i, v **in** enumerate(['tic', 'tac', 'toe']):

**...**  print(i, v)

**...**

0 tic

1 tac

2 toe

To loop over two or more sequences at the same time, the entries can be paired with the [zip()](https://docs.python.org/3/library/functions.html#zip)function.

>>>

**>>>** questions = ['name', 'quest', 'favorite color']

**>>>** answers = ['lancelot', 'the holy grail', 'blue']

**>>> for** q, a **in** zip(questions, answers):

**...**  print('What is your *{0}*? It is *{1}*.'.format(q, a))

**...**

What is your name? It is lancelot.

What is your quest? It is the holy grail.

What is your favorite color? It is blue.

To loop over a sequence in reverse, first specify the sequence in a forward direction and then call the[reversed()](https://docs.python.org/3/library/functions.html#reversed) function.

>>>

**>>> for** i **in** reversed(range(1, 10, 2)):

**...**  print(i)

**...**

9

7

5

3

1

To loop over a sequence in sorted order, use the [sorted()](https://docs.python.org/3/library/functions.html#sorted) function which returns a new sorted list while leaving the source unaltered.

>>>

**>>>** basket = ['apple', 'orange', 'apple', 'pear', 'orange', 'banana']

**>>> for** f **in** sorted(set(basket)):

**...**  print(f)

**...**

apple

banana

orange

pear

It is sometimes tempting to change a list while you are looping over it; however, it is often simpler and safer to create a new list instead.

>>>

**>>> import** **math**

**>>>** raw\_data = [56.2, float('NaN'), 51.7, 55.3, 52.5, float('NaN'), 47.8]

**>>>** filtered\_data = []

**>>> for** value **in** raw\_data:

**...**  **if** **not** math.isnan(value):

**...**  filtered\_data.append(value)

**...**

**>>>** filtered\_data

[56.2, 51.7, 55.3, 52.5, 47.8]

## 5.7. More on Conditions

The conditions used in while and if statements can contain any operators, not just comparisons.

The comparison operators in and not in check whether a value occurs (does not occur) in a sequence. The operators is and is not compare whether two objects are really the same object; this only matters for mutable objects like lists. All comparison operators have the same priority, which is lower than that of all numerical operators.

Comparisons can be chained. For example, a < b == c tests whether a is less than b and moreoverb equals c.

Comparisons may be combined using the Boolean operators and and or, and the outcome of a comparison (or of any other Boolean expression) may be negated with not. These have lower priorities than comparison operators; between them, not has the highest priority and or the lowest, so that A and not B or C is equivalent to (A and (not B)) or C. As always, parentheses can be used to express the desired composition.

The Boolean operators and and or are so-called short-circuit operators: their arguments are evaluated from left to right, and evaluation stops as soon as the outcome is determined. For example, if A and C are true but B is false, A and B and C does not evaluate the expression C. When used as a general value and not as a Boolean, the return value of a short-circuit operator is the last evaluated argument.

It is possible to assign the result of a comparison or other Boolean expression to a variable. For example,

>>>

**>>>** string1, string2, string3 = '', 'Trondheim', 'Hammer Dance'

**>>>** non\_null = string1 **or** string2 **or** string3

**>>>** non\_null

'Trondheim'

Note that in Python, unlike C, assignment cannot occur inside expressions. C programmers may grumble about this, but it avoids a common class of problems encountered in C programs: typing = in an expression when == was intended.

## 5.8. Comparing Sequences and Other Types

Sequence objects may be compared to other objects with the same sequence type. The comparison uses lexicographical ordering: first the first two items are compared, and if they differ this determines the outcome of the comparison; if they are equal, the next two items are compared, and so on, until either sequence is exhausted. If two items to be compared are themselves sequences of the same type, the lexicographical comparison is carried out recursively. If all items of two sequences compare equal, the sequences are considered equal. If one sequence is an initial sub-sequence of the other, the shorter sequence is the smaller (lesser) one. Lexicographical ordering for strings uses the Unicode code point number to order individual characters. Some examples of comparisons between sequences of the same type:

(1, 2, 3) < (1, 2, 4)

[1, 2, 3] < [1, 2, 4]

'ABC' < 'C' < 'Pascal' < 'Python'

(1, 2, 3, 4) < (1, 2, 4)

(1, 2) < (1, 2, -1)

(1, 2, 3) == (1.0, 2.0, 3.0)

(1, 2, ('aa', 'ab')) < (1, 2, ('abc', 'a'), 4)

Note that comparing objects of different types with < or > is legal provided that the objects have appropriate comparison methods. For example, mixed numeric types are compared according to their numeric value, so 0 equals 0.0, etc. Otherwise, rather than providing an arbitrary ordering, the interpreter will raise a [TypeError](https://docs.python.org/3/library/exceptions.html#TypeError) exception.

**Footnotes**

|  |  |
| --- | --- |
| [[1]](https://docs.python.org/3/tutorial/datastructures.html#id1) | Other languages may return the mutated object, which allows method chaining, such as d->insert("a")->remove("b")->sort();. |

|  |  |
| --- | --- |
| [[2]](https://docs.python.org/3/tutorial/datastructures.html#id2) | Calling d.keys() will return a dictionary view object. It supports operations like membership test and iteration, but its contents are not independent of the original dictionary – it is only aview. |

# 5. Data Structures

This chapter describes some things you’ve learned about already in more detail, and adds some new things as well.

## 5.1. More on Lists

The list data type has some more methods. Here are all of the methods of list objects:

list.**append**(x)

Add an item to the end of the list. Equivalent to a[len(a):] = [x].

list.**extend**(L)

Extend the list by appending all the items in the given list. Equivalent to a[len(a):] = L.

list.**insert**(i, x)

Insert an item at a given position. The first argument is the index of the element before which to insert, so a.insert(0, x) inserts at the front of the list, and a.insert(len(a), x) is equivalent to a.append(x).

list.**remove**(x)

Remove the first item from the list whose value is x. It is an error if there is no such item.

list.**pop**([i])

Remove the item at the given position in the list, and return it. If no index is specified, a.pop()removes and returns the last item in the list. (The square brackets around the i in the method signature denote that the parameter is optional, not that you should type square brackets at that position. You will see this notation frequently in the Python Library Reference.)

list.**clear**()

Remove all items from the list. Equivalent to del a[:].

list.**index**(x)

Return the index in the list of the first item whose value is x. It is an error if there is no such item.

list.**count**(x)

Return the number of times x appears in the list.

list.**sort**(key=None, reverse=False)

Sort the items of the list in place (the arguments can be used for sort customization, see[sorted()](https://docs.python.org/3/library/functions.html#sorted) for their explanation).

list.**reverse**()

Reverse the elements of the list in place.

list.**copy**()

Return a shallow copy of the list. Equivalent to a[:].

An example that uses most of the list methods:

>>>

**>>>** a = [66.25, 333, 333, 1, 1234.5]

**>>>** print(a.count(333), a.count(66.25), a.count('x'))

2 1 0

**>>>** a.insert(2, -1)

**>>>** a.append(333)

**>>>** a

[66.25, 333, -1, 333, 1, 1234.5, 333]

**>>>** a.index(333)

1

**>>>** a.remove(333)

**>>>** a

[66.25, -1, 333, 1, 1234.5, 333]

**>>>** a.reverse()

**>>>** a

[333, 1234.5, 1, 333, -1, 66.25]

**>>>** a.sort()

**>>>** a

[-1, 1, 66.25, 333, 333, 1234.5]

**>>>** a.pop()

1234.5

**>>>** a

[-1, 1, 66.25, 333, 333]

You might have noticed that methods like insert, remove or sort that only modify the list have no return value printed – they return the default None. [[1]](https://docs.python.org/3/tutorial/datastructures.html#id3) This is a design principle for all mutable data structures in Python.

### 5.1.1. Using Lists as Stacks

The list methods make it very easy to use a list as a stack, where the last element added is the first element retrieved (“last-in, first-out”). To add an item to the top of the stack, use append(). To retrieve an item from the top of the stack, use pop() without an explicit index. For example:

>>>

**>>>** stack = [3, 4, 5]

**>>>** stack.append(6)

**>>>** stack.append(7)

**>>>** stack

[3, 4, 5, 6, 7]

**>>>** stack.pop()

7

**>>>** stack

[3, 4, 5, 6]

**>>>** stack.pop()

6

**>>>** stack.pop()

5

**>>>** stack

[3, 4]

### 5.1.2. Using Lists as Queues

It is also possible to use a list as a queue, where the first element added is the first element retrieved (“first-in, first-out”); however, lists are not efficient for this purpose. While appends and pops from the end of list are fast, doing inserts or pops from the beginning of a list is slow (because all of the other elements have to be shifted by one).

To implement a queue, use [collections.deque](https://docs.python.org/3/library/collections.html#collections.deque) which was designed to have fast appends and pops from both ends. For example:

>>>

**>>> from** **collections** **import** deque

**>>>** queue = deque(["Eric", "John", "Michael"])

**>>>** queue.append("Terry") *# Terry arrives*

**>>>** queue.append("Graham") *# Graham arrives*

**>>>** queue.popleft() *# The first to arrive now leaves*

'Eric'

**>>>** queue.popleft() *# The second to arrive now leaves*

'John'

**>>>** queue *# Remaining queue in order of arrival*

deque(['Michael', 'Terry', 'Graham'])

### 5.1.3. List Comprehensions

List comprehensions provide a concise way to create lists. Common applications are to make new lists where each element is the result of some operations applied to each member of another sequence or iterable, or to create a subsequence of those elements that satisfy a certain condition.

For example, assume we want to create a list of squares, like:

>>>

**>>>** squares = []

**>>> for** x **in** range(10):

**...**  squares.append(x\*\*2)

**...**

**>>>** squares

[0, 1, 4, 9, 16, 25, 36, 49, 64, 81]

Note that this creates (or overwrites) a variable named x that still exists after the loop completes. We can calculate the list of squares without any side effects using:

squares = list(map(**lambda** x: x\*\*2, range(10)))

or, equivalently:

squares = [x\*\*2 **for** x **in** range(10)]

which is more concise and readable.

A list comprehension consists of brackets containing an expression followed by a [for](https://docs.python.org/3/reference/compound_stmts.html#for) clause, then zero or more [for](https://docs.python.org/3/reference/compound_stmts.html#for) or [if](https://docs.python.org/3/reference/compound_stmts.html#if) clauses. The result will be a new list resulting from evaluating the expression in the context of the [for](https://docs.python.org/3/reference/compound_stmts.html#for) and [if](https://docs.python.org/3/reference/compound_stmts.html#if) clauses which follow it. For example, this listcomp combines the elements of two lists if they are not equal:

>>>

**>>>** [(x, y) **for** x **in** [1,2,3] **for** y **in** [3,1,4] **if** x != y]

[(1, 3), (1, 4), (2, 3), (2, 1), (2, 4), (3, 1), (3, 4)]

and it’s equivalent to:

>>>

**>>>** combs = []

**>>> for** x **in** [1,2,3]:

**...**  **for** y **in** [3,1,4]:

**...**  **if** x != y:

**...**  combs.append((x, y))

**...**

**>>>** combs

[(1, 3), (1, 4), (2, 3), (2, 1), (2, 4), (3, 1), (3, 4)]

Note how the order of the [for](https://docs.python.org/3/reference/compound_stmts.html#for) and [if](https://docs.python.org/3/reference/compound_stmts.html#if) statements is the same in both these snippets.

If the expression is a tuple (e.g. the (x, y) in the previous example), it must be parenthesized.

>>>

**>>>** vec = [-4, -2, 0, 2, 4]

**>>>** *# create a new list with the values doubled*

**>>>** [x\*2 **for** x **in** vec]

[-8, -4, 0, 4, 8]

**>>>** *# filter the list to exclude negative numbers*

**>>>** [x **for** x **in** vec **if** x >= 0]

[0, 2, 4]

**>>>** *# apply a function to all the elements*

**>>>** [abs(x) **for** x **in** vec]

[4, 2, 0, 2, 4]

**>>>** *# call a method on each element*

**>>>** freshfruit = [' banana', ' loganberry ', 'passion fruit ']

**>>>** [weapon.strip() **for** weapon **in** freshfruit]

['banana', 'loganberry', 'passion fruit']

**>>>** *# create a list of 2-tuples like (number, square)*

**>>>** [(x, x\*\*2) **for** x **in** range(6)]

[(0, 0), (1, 1), (2, 4), (3, 9), (4, 16), (5, 25)]

**>>>** *# the tuple must be parenthesized, otherwise an error is raised*

**>>>** [x, x\*\*2 **for** x **in** range(6)]

File "<stdin>", line 1, in ?

[x, x\*\*2 for x in range(6)]

^

SyntaxError: invalid syntax

**>>>** *# flatten a list using a listcomp with two 'for'*

**>>>** vec = [[1,2,3], [4,5,6], [7,8,9]]

**>>>** [num **for** elem **in** vec **for** num **in** elem]

[1, 2, 3, 4, 5, 6, 7, 8, 9]

List comprehensions can contain complex expressions and nested functions:

>>>

**>>> from** **math** **import** pi

**>>>** [str(round(pi, i)) **for** i **in** range(1, 6)]

['3.1', '3.14', '3.142', '3.1416', '3.14159']

### 5.1.4. Nested List Comprehensions

The initial expression in a list comprehension can be any arbitrary expression, including another list comprehension.

Consider the following example of a 3x4 matrix implemented as a list of 3 lists of length 4:

>>>

**>>>** matrix = [

**...**  [1, 2, 3, 4],

**...**  [5, 6, 7, 8],

**...**  [9, 10, 11, 12],

**...** ]

The following list comprehension will transpose rows and columns:

>>>

**>>>** [[row[i] **for** row **in** matrix] **for** i **in** range(4)]

[[1, 5, 9], [2, 6, 10], [3, 7, 11], [4, 8, 12]]

As we saw in the previous section, the nested listcomp is evaluated in the context of the [for](https://docs.python.org/3/reference/compound_stmts.html#for) that follows it, so this example is equivalent to:

>>>

**>>>** transposed = []

**>>> for** i **in** range(4):

**...**  transposed.append([row[i] **for** row **in** matrix])

**...**

**>>>** transposed

[[1, 5, 9], [2, 6, 10], [3, 7, 11], [4, 8, 12]]

which, in turn, is the same as:

>>>

**>>>** transposed = []

**>>> for** i **in** range(4):

**...**  *# the following 3 lines implement the nested listcomp*

**...**  transposed\_row = []

**...**  **for** row **in** matrix:

**...**  transposed\_row.append(row[i])

**...**  transposed.append(transposed\_row)

**...**

**>>>** transposed

[[1, 5, 9], [2, 6, 10], [3, 7, 11], [4, 8, 12]]

In the real world, you should prefer built-in functions to complex flow statements. The [zip()](https://docs.python.org/3/library/functions.html#zip) function would do a great job for this use case:

>>>

**>>>** list(zip(\*matrix))

[(1, 5, 9), (2, 6, 10), (3, 7, 11), (4, 8, 12)]

See [Unpacking Argument Lists](https://docs.python.org/3/tutorial/controlflow.html#tut-unpacking-arguments) for details on the asterisk in this line.

## 5.2. The [del](https://docs.python.org/3/reference/simple_stmts.html#del) statement

There is a way to remove an item from a list given its index instead of its value: the [del](https://docs.python.org/3/reference/simple_stmts.html#del) statement. This differs from the pop() method which returns a value. The [del](https://docs.python.org/3/reference/simple_stmts.html#del) statement can also be used to remove slices from a list or clear the entire list (which we did earlier by assignment of an empty list to the slice). For example:

>>>

**>>>** a = [-1, 1, 66.25, 333, 333, 1234.5]

**>>> del** a[0]

**>>>** a

[1, 66.25, 333, 333, 1234.5]

**>>> del** a[2:4]

**>>>** a

[1, 66.25, 1234.5]

**>>> del** a[:]

**>>>** a

[]

[del](https://docs.python.org/3/reference/simple_stmts.html#del) can also be used to delete entire variables:

>>>

**>>> del** a

Referencing the name a hereafter is an error (at least until another value is assigned to it). We’ll find other uses for [del](https://docs.python.org/3/reference/simple_stmts.html#del) later.

## 5.3. Tuples and Sequences

We saw that lists and strings have many common properties, such as indexing and slicing operations. They are two examples of sequence data types (see [Sequence Types — list, tuple, range](https://docs.python.org/3/library/stdtypes.html#typesseq)). Since Python is an evolving language, other sequence data types may be added. There is also another standard sequence data type: the tuple.

A tuple consists of a number of values separated by commas, for instance:

>>>

**>>>** t = 12345, 54321, 'hello!'

**>>>** t[0]

12345

**>>>** t

(12345, 54321, 'hello!')

**>>>** *# Tuples may be nested:*

**...** u = t, (1, 2, 3, 4, 5)

**>>>** u

((12345, 54321, 'hello!'), (1, 2, 3, 4, 5))

**>>>** *# Tuples are immutable:*

**...** t[0] = 88888

Traceback (most recent call last):

File "<stdin>", line 1, in <module>

TypeError: 'tuple' object does not support item assignment

**>>>** *# but they can contain mutable objects:*

**...** v = ([1, 2, 3], [3, 2, 1])

**>>>** v

([1, 2, 3], [3, 2, 1])

As you see, on output tuples are always enclosed in parentheses, so that nested tuples are interpreted correctly; they may be input with or without surrounding parentheses, although often parentheses are necessary anyway (if the tuple is part of a larger expression). It is not possible to assign to the individual items of a tuple, however it is possible to create tuples which contain mutable objects, such as lists.

Though tuples may seem similar to lists, they are often used in different situations and for different purposes. Tuples are [immutable](https://docs.python.org/3/glossary.html#term-immutable), and usually contain a heterogeneous sequence of elements that are accessed via unpacking (see later in this section) or indexing (or even by attribute in the case of[namedtuples](https://docs.python.org/3/library/collections.html#collections.namedtuple)). Lists are [mutable](https://docs.python.org/3/glossary.html#term-mutable), and their elements are usually homogeneous and are accessed by iterating over the list.

A special problem is the construction of tuples containing 0 or 1 items: the syntax has some extra quirks to accommodate these. Empty tuples are constructed by an empty pair of parentheses; a tuple with one item is constructed by following a value with a comma (it is not sufficient to enclose a single value in parentheses). Ugly, but effective. For example:

>>>

**>>>** empty = ()

**>>>** singleton = 'hello', *# <-- note trailing comma*

**>>>** len(empty)

0

**>>>** len(singleton)

1

**>>>** singleton

('hello',)

The statement t = 12345, 54321, 'hello!' is an example of tuple packing: the values 12345,54321 and 'hello!' are packed together in a tuple. The reverse operation is also possible:

>>>

**>>>** x, y, z = t

This is called, appropriately enough, sequence unpacking and works for any sequence on the right-hand side. Sequence unpacking requires that there are as many variables on the left side of the equals sign as there are elements in the sequence. Note that multiple assignment is really just a combination of tuple packing and sequence unpacking.

## 5.4. Sets

Python also includes a data type for sets. A set is an unordered collection with no duplicate elements. Basic uses include membership testing and eliminating duplicate entries. Set objects also support mathematical operations like union, intersection, difference, and symmetric difference.

Curly braces or the [set()](https://docs.python.org/3/library/stdtypes.html#set) function can be used to create sets. Note: to create an empty set you have to use set(), not {}; the latter creates an empty dictionary, a data structure that we discuss in the next section.

Here is a brief demonstration:

>>>

**>>>** basket = {'apple', 'orange', 'apple', 'pear', 'orange', 'banana'}

**>>>** print(basket) *# show that duplicates have been removed*

{'orange', 'banana', 'pear', 'apple'}

**>>>** 'orange' **in** basket *# fast membership testing*

True

**>>>** 'crabgrass' **in** basket

False

**>>>** *# Demonstrate set operations on unique letters from two words*

**...**

**>>>** a = set('abracadabra')

**>>>** b = set('alacazam')

**>>>** a *# unique letters in a*

{'a', 'r', 'b', 'c', 'd'}

**>>>** a - b *# letters in a but not in b*

{'r', 'd', 'b'}

**>>>** a | b *# letters in either a or b*

{'a', 'c', 'r', 'd', 'b', 'm', 'z', 'l'}

**>>>** a & b *# letters in both a and b*

{'a', 'c'}

**>>>** a ^ b *# letters in a or b but not both*

{'r', 'd', 'b', 'm', 'z', 'l'}

Similarly to [list comprehensions](https://docs.python.org/3/tutorial/datastructures.html#tut-listcomps), set comprehensions are also supported:

>>>

**>>>** a = {x **for** x **in** 'abracadabra' **if** x **not** **in** 'abc'}

**>>>** a

{'r', 'd'}

## 5.5. Dictionaries

Another useful data type built into Python is the dictionary (see [Mapping Types — dict](https://docs.python.org/3/library/stdtypes.html#typesmapping)). Dictionaries are sometimes found in other languages as “associative memories” or “associative arrays”. Unlike sequences, which are indexed by a range of numbers, dictionaries are indexed by keys, which can be any immutable type; strings and numbers can always be keys. Tuples can be used as keys if they contain only strings, numbers, or tuples; if a tuple contains any mutable object either directly or indirectly, it cannot be used as a key. You can’t use lists as keys, since lists can be modified in place using index assignments, slice assignments, or methods like append() and extend().

It is best to think of a dictionary as an unordered set of key: value pairs, with the requirement that the keys are unique (within one dictionary). A pair of braces creates an empty dictionary: {}. Placing a comma-separated list of key:value pairs within the braces adds initial key:value pairs to the dictionary; this is also the way dictionaries are written on output.

The main operations on a dictionary are storing a value with some key and extracting the value given the key. It is also possible to delete a key:value pair with del. If you store using a key that is already in use, the old value associated with that key is forgotten. It is an error to extract a value using a non-existent key.

Performing list(d.keys()) on a dictionary returns a list of all the keys used in the dictionary, in arbitrary order (if you want it sorted, just use sorted(d.keys()) instead). [[2]](https://docs.python.org/3/tutorial/datastructures.html#id4) To check whether a single key is in the dictionary, use the [in](https://docs.python.org/3/reference/expressions.html#in) keyword.

Here is a small example using a dictionary:

>>>

**>>>** tel = {'jack': 4098, 'sape': 4139}

**>>>** tel['guido'] = 4127

**>>>** tel

{'sape': 4139, 'guido': 4127, 'jack': 4098}

**>>>** tel['jack']

4098

**>>> del** tel['sape']

**>>>** tel['irv'] = 4127

**>>>** tel

{'guido': 4127, 'irv': 4127, 'jack': 4098}

**>>>** list(tel.keys())

['irv', 'guido', 'jack']

**>>>** sorted(tel.keys())

['guido', 'irv', 'jack']

**>>>** 'guido' **in** tel

True

**>>>** 'jack' **not** **in** tel

False

The [dict()](https://docs.python.org/3/library/stdtypes.html#dict) constructor builds dictionaries directly from sequences of key-value pairs:

>>>

**>>>** dict([('sape', 4139), ('guido', 4127), ('jack', 4098)])

{'sape': 4139, 'jack': 4098, 'guido': 4127}

In addition, dict comprehensions can be used to create dictionaries from arbitrary key and value expressions:

>>>

**>>>** {x: x\*\*2 **for** x **in** (2, 4, 6)}

{2: 4, 4: 16, 6: 36}

When the keys are simple strings, it is sometimes easier to specify pairs using keyword arguments:

>>>

**>>>** dict(sape=4139, guido=4127, jack=4098)

{'sape': 4139, 'jack': 4098, 'guido': 4127}

## 5.6. Looping Techniques

When looping through dictionaries, the key and corresponding value can be retrieved at the same time using the items() method.

>>>

**>>>** knights = {'gallahad': 'the pure', 'robin': 'the brave'}

**>>> for** k, v **in** knights.items():

**...**  print(k, v)

**...**

gallahad the pure

robin the brave

When looping through a sequence, the position index and corresponding value can be retrieved at the same time using the [enumerate()](https://docs.python.org/3/library/functions.html#enumerate) function.

>>>

**>>> for** i, v **in** enumerate(['tic', 'tac', 'toe']):

**...**  print(i, v)

**...**

0 tic

1 tac

2 toe

To loop over two or more sequences at the same time, the entries can be paired with the [zip()](https://docs.python.org/3/library/functions.html#zip)function.

>>>

**>>>** questions = ['name', 'quest', 'favorite color']

**>>>** answers = ['lancelot', 'the holy grail', 'blue']

**>>> for** q, a **in** zip(questions, answers):

**...**  print('What is your *{0}*? It is *{1}*.'.format(q, a))

**...**

What is your name? It is lancelot.

What is your quest? It is the holy grail.

What is your favorite color? It is blue.

To loop over a sequence in reverse, first specify the sequence in a forward direction and then call the[reversed()](https://docs.python.org/3/library/functions.html#reversed) function.

>>>

**>>> for** i **in** reversed(range(1, 10, 2)):

**...**  print(i)

**...**

9

7

5

3

1

To loop over a sequence in sorted order, use the [sorted()](https://docs.python.org/3/library/functions.html#sorted) function which returns a new sorted list while leaving the source unaltered.

>>>

**>>>** basket = ['apple', 'orange', 'apple', 'pear', 'orange', 'banana']

**>>> for** f **in** sorted(set(basket)):

**...**  print(f)

**...**

apple

banana

orange

pear

It is sometimes tempting to change a list while you are looping over it; however, it is often simpler and safer to create a new list instead.

>>>

**>>> import** **math**

**>>>** raw\_data = [56.2, float('NaN'), 51.7, 55.3, 52.5, float('NaN'), 47.8]

**>>>** filtered\_data = []

**>>> for** value **in** raw\_data:

**...**  **if** **not** math.isnan(value):

**...**  filtered\_data.append(value)

**...**

**>>>** filtered\_data

[56.2, 51.7, 55.3, 52.5, 47.8]

## 5.7. More on Conditions

The conditions used in while and if statements can contain any operators, not just comparisons.

The comparison operators in and not in check whether a value occurs (does not occur) in a sequence. The operators is and is not compare whether two objects are really the same object; this only matters for mutable objects like lists. All comparison operators have the same priority, which is lower than that of all numerical operators.

Comparisons can be chained. For example, a < b == c tests whether a is less than b and moreoverb equals c.

Comparisons may be combined using the Boolean operators and and or, and the outcome of a comparison (or of any other Boolean expression) may be negated with not. These have lower priorities than comparison operators; between them, not has the highest priority and or the lowest, so that A and not B or C is equivalent to (A and (not B)) or C. As always, parentheses can be used to express the desired composition.

The Boolean operators and and or are so-called short-circuit operators: their arguments are evaluated from left to right, and evaluation stops as soon as the outcome is determined. For example, if A and C are true but B is false, A and B and C does not evaluate the expression C. When used as a general value and not as a Boolean, the return value of a short-circuit operator is the last evaluated argument.

It is possible to assign the result of a comparison or other Boolean expression to a variable. For example,

>>>

**>>>** string1, string2, string3 = '', 'Trondheim', 'Hammer Dance'

**>>>** non\_null = string1 **or** string2 **or** string3

**>>>** non\_null

'Trondheim'

Note that in Python, unlike C, assignment cannot occur inside expressions. C programmers may grumble about this, but it avoids a common class of problems encountered in C programs: typing = in an expression when == was intended.

## 5.8. Comparing Sequences and Other Types

Sequence objects may be compared to other objects with the same sequence type. The comparison uses lexicographical ordering: first the first two items are compared, and if they differ this determines the outcome of the comparison; if they are equal, the next two items are compared, and so on, until either sequence is exhausted. If two items to be compared are themselves sequences of the same type, the lexicographical comparison is carried out recursively. If all items of two sequences compare equal, the sequences are considered equal. If one sequence is an initial sub-sequence of the other, the shorter sequence is the smaller (lesser) one. Lexicographical ordering for strings uses the Unicode code point number to order individual characters. Some examples of comparisons between sequences of the same type:

(1, 2, 3) < (1, 2, 4)

[1, 2, 3] < [1, 2, 4]

'ABC' < 'C' < 'Pascal' < 'Python'

(1, 2, 3, 4) < (1, 2, 4)

(1, 2) < (1, 2, -1)

(1, 2, 3) == (1.0, 2.0, 3.0)

(1, 2, ('aa', 'ab')) < (1, 2, ('abc', 'a'), 4)

Note that comparing objects of different types with < or > is legal provided that the objects have appropriate comparison methods. For example, mixed numeric types are compared according to their numeric value, so 0 equals 0.0, etc. Otherwise, rather than providing an arbitrary ordering, the interpreter will raise a [TypeError](https://docs.python.org/3/library/exceptions.html#TypeError) exception.

**Footnotes**

|  |  |
| --- | --- |
| [[1]](https://docs.python.org/3/tutorial/datastructures.html#id1) | Other languages may return the mutated object, which allows method chaining, such as d->insert("a")->remove("b")->sort();. |

|  |  |
| --- | --- |
| [[2]](https://docs.python.org/3/tutorial/datastructures.html#id2) | Calling d.keys() will return a dictionary view object. It supports operations like membership test and iteration, but its contents are not independent of the original dictionary – it is only aview. |

# 5. Data Structures

This chapter describes some things you’ve learned about already in more detail, and adds some new things as well.

## 5.1. More on Lists

The list data type has some more methods. Here are all of the methods of list objects:

list.**append**(x)

Add an item to the end of the list. Equivalent to a[len(a):] = [x].

list.**extend**(L)

Extend the list by appending all the items in the given list. Equivalent to a[len(a):] = L.

list.**insert**(i, x)

Insert an item at a given position. The first argument is the index of the element before which to insert, so a.insert(0, x) inserts at the front of the list, and a.insert(len(a), x) is equivalent to a.append(x).

list.**remove**(x)

Remove the first item from the list whose value is x. It is an error if there is no such item.

list.**pop**([i])

Remove the item at the given position in the list, and return it. If no index is specified, a.pop()removes and returns the last item in the list. (The square brackets around the i in the method signature denote that the parameter is optional, not that you should type square brackets at that position. You will see this notation frequently in the Python Library Reference.)

list.**clear**()

Remove all items from the list. Equivalent to del a[:].

list.**index**(x)

Return the index in the list of the first item whose value is x. It is an error if there is no such item.

list.**count**(x)

Return the number of times x appears in the list.

list.**sort**(key=None, reverse=False)

Sort the items of the list in place (the arguments can be used for sort customization, see[sorted()](https://docs.python.org/3/library/functions.html#sorted) for their explanation).

list.**reverse**()

Reverse the elements of the list in place.

list.**copy**()

Return a shallow copy of the list. Equivalent to a[:].

An example that uses most of the list methods:

>>>

**>>>** a = [66.25, 333, 333, 1, 1234.5]

**>>>** print(a.count(333), a.count(66.25), a.count('x'))

2 1 0

**>>>** a.insert(2, -1)

**>>>** a.append(333)

**>>>** a

[66.25, 333, -1, 333, 1, 1234.5, 333]

**>>>** a.index(333)

1

**>>>** a.remove(333)

**>>>** a

[66.25, -1, 333, 1, 1234.5, 333]

**>>>** a.reverse()

**>>>** a

[333, 1234.5, 1, 333, -1, 66.25]

**>>>** a.sort()

**>>>** a

[-1, 1, 66.25, 333, 333, 1234.5]

**>>>** a.pop()

1234.5

**>>>** a

[-1, 1, 66.25, 333, 333]

You might have noticed that methods like insert, remove or sort that only modify the list have no return value printed – they return the default None. [[1]](https://docs.python.org/3/tutorial/datastructures.html#id3) This is a design principle for all mutable data structures in Python.

### 5.1.1. Using Lists as Stacks

The list methods make it very easy to use a list as a stack, where the last element added is the first element retrieved (“last-in, first-out”). To add an item to the top of the stack, use append(). To retrieve an item from the top of the stack, use pop() without an explicit index. For example:

>>>

**>>>** stack = [3, 4, 5]

**>>>** stack.append(6)

**>>>** stack.append(7)

**>>>** stack

[3, 4, 5, 6, 7]

**>>>** stack.pop()

7

**>>>** stack

[3, 4, 5, 6]

**>>>** stack.pop()

6

**>>>** stack.pop()

5

**>>>** stack

[3, 4]

### 5.1.2. Using Lists as Queues

It is also possible to use a list as a queue, where the first element added is the first element retrieved (“first-in, first-out”); however, lists are not efficient for this purpose. While appends and pops from the end of list are fast, doing inserts or pops from the beginning of a list is slow (because all of the other elements have to be shifted by one).

To implement a queue, use [collections.deque](https://docs.python.org/3/library/collections.html#collections.deque) which was designed to have fast appends and pops from both ends. For example:

>>>

**>>> from** **collections** **import** deque

**>>>** queue = deque(["Eric", "John", "Michael"])

**>>>** queue.append("Terry") *# Terry arrives*

**>>>** queue.append("Graham") *# Graham arrives*

**>>>** queue.popleft() *# The first to arrive now leaves*

'Eric'

**>>>** queue.popleft() *# The second to arrive now leaves*

'John'

**>>>** queue *# Remaining queue in order of arrival*

deque(['Michael', 'Terry', 'Graham'])

### 5.1.3. List Comprehensions

List comprehensions provide a concise way to create lists. Common applications are to make new lists where each element is the result of some operations applied to each member of another sequence or iterable, or to create a subsequence of those elements that satisfy a certain condition.

For example, assume we want to create a list of squares, like:

>>>

**>>>** squares = []

**>>> for** x **in** range(10):

**...**  squares.append(x\*\*2)

**...**

**>>>** squares

[0, 1, 4, 9, 16, 25, 36, 49, 64, 81]

Note that this creates (or overwrites) a variable named x that still exists after the loop completes. We can calculate the list of squares without any side effects using:

squares = list(map(**lambda** x: x\*\*2, range(10)))

or, equivalently:

squares = [x\*\*2 **for** x **in** range(10)]

which is more concise and readable.

A list comprehension consists of brackets containing an expression followed by a [for](https://docs.python.org/3/reference/compound_stmts.html#for) clause, then zero or more [for](https://docs.python.org/3/reference/compound_stmts.html#for) or [if](https://docs.python.org/3/reference/compound_stmts.html#if) clauses. The result will be a new list resulting from evaluating the expression in the context of the [for](https://docs.python.org/3/reference/compound_stmts.html#for) and [if](https://docs.python.org/3/reference/compound_stmts.html#if) clauses which follow it. For example, this listcomp combines the elements of two lists if they are not equal:

>>>

**>>>** [(x, y) **for** x **in** [1,2,3] **for** y **in** [3,1,4] **if** x != y]

[(1, 3), (1, 4), (2, 3), (2, 1), (2, 4), (3, 1), (3, 4)]

and it’s equivalent to:

>>>

**>>>** combs = []

**>>> for** x **in** [1,2,3]:

**...**  **for** y **in** [3,1,4]:

**...**  **if** x != y:

**...**  combs.append((x, y))

**...**

**>>>** combs

[(1, 3), (1, 4), (2, 3), (2, 1), (2, 4), (3, 1), (3, 4)]

Note how the order of the [for](https://docs.python.org/3/reference/compound_stmts.html#for) and [if](https://docs.python.org/3/reference/compound_stmts.html#if) statements is the same in both these snippets.

If the expression is a tuple (e.g. the (x, y) in the previous example), it must be parenthesized.

>>>

**>>>** vec = [-4, -2, 0, 2, 4]

**>>>** *# create a new list with the values doubled*

**>>>** [x\*2 **for** x **in** vec]

[-8, -4, 0, 4, 8]

**>>>** *# filter the list to exclude negative numbers*

**>>>** [x **for** x **in** vec **if** x >= 0]

[0, 2, 4]

**>>>** *# apply a function to all the elements*

**>>>** [abs(x) **for** x **in** vec]

[4, 2, 0, 2, 4]

**>>>** *# call a method on each element*

**>>>** freshfruit = [' banana', ' loganberry ', 'passion fruit ']

**>>>** [weapon.strip() **for** weapon **in** freshfruit]

['banana', 'loganberry', 'passion fruit']

**>>>** *# create a list of 2-tuples like (number, square)*

**>>>** [(x, x\*\*2) **for** x **in** range(6)]

[(0, 0), (1, 1), (2, 4), (3, 9), (4, 16), (5, 25)]

**>>>** *# the tuple must be parenthesized, otherwise an error is raised*

**>>>** [x, x\*\*2 **for** x **in** range(6)]

File "<stdin>", line 1, in ?

[x, x\*\*2 for x in range(6)]

^

SyntaxError: invalid syntax

**>>>** *# flatten a list using a listcomp with two 'for'*

**>>>** vec = [[1,2,3], [4,5,6], [7,8,9]]

**>>>** [num **for** elem **in** vec **for** num **in** elem]

[1, 2, 3, 4, 5, 6, 7, 8, 9]

List comprehensions can contain complex expressions and nested functions:

>>>

**>>> from** **math** **import** pi

**>>>** [str(round(pi, i)) **for** i **in** range(1, 6)]

['3.1', '3.14', '3.142', '3.1416', '3.14159']

### 5.1.4. Nested List Comprehensions

The initial expression in a list comprehension can be any arbitrary expression, including another list comprehension.

Consider the following example of a 3x4 matrix implemented as a list of 3 lists of length 4:

>>>

**>>>** matrix = [

**...**  [1, 2, 3, 4],

**...**  [5, 6, 7, 8],

**...**  [9, 10, 11, 12],

**...** ]

The following list comprehension will transpose rows and columns:

>>>

**>>>** [[row[i] **for** row **in** matrix] **for** i **in** range(4)]

[[1, 5, 9], [2, 6, 10], [3, 7, 11], [4, 8, 12]]

As we saw in the previous section, the nested listcomp is evaluated in the context of the [for](https://docs.python.org/3/reference/compound_stmts.html#for) that follows it, so this example is equivalent to:

>>>

**>>>** transposed = []

**>>> for** i **in** range(4):

**...**  transposed.append([row[i] **for** row **in** matrix])

**...**

**>>>** transposed

[[1, 5, 9], [2, 6, 10], [3, 7, 11], [4, 8, 12]]

which, in turn, is the same as:

>>>

**>>>** transposed = []

**>>> for** i **in** range(4):

**...**  *# the following 3 lines implement the nested listcomp*

**...**  transposed\_row = []

**...**  **for** row **in** matrix:

**...**  transposed\_row.append(row[i])

**...**  transposed.append(transposed\_row)

**...**

**>>>** transposed

[[1, 5, 9], [2, 6, 10], [3, 7, 11], [4, 8, 12]]

In the real world, you should prefer built-in functions to complex flow statements. The [zip()](https://docs.python.org/3/library/functions.html#zip) function would do a great job for this use case:

>>>

**>>>** list(zip(\*matrix))

[(1, 5, 9), (2, 6, 10), (3, 7, 11), (4, 8, 12)]

See [Unpacking Argument Lists](https://docs.python.org/3/tutorial/controlflow.html#tut-unpacking-arguments) for details on the asterisk in this line.

## 5.2. The [del](https://docs.python.org/3/reference/simple_stmts.html#del) statement

There is a way to remove an item from a list given its index instead of its value: the [del](https://docs.python.org/3/reference/simple_stmts.html#del) statement. This differs from the pop() method which returns a value. The [del](https://docs.python.org/3/reference/simple_stmts.html#del) statement can also be used to remove slices from a list or clear the entire list (which we did earlier by assignment of an empty list to the slice). For example:

>>>

**>>>** a = [-1, 1, 66.25, 333, 333, 1234.5]

**>>> del** a[0]

**>>>** a

[1, 66.25, 333, 333, 1234.5]

**>>> del** a[2:4]

**>>>** a

[1, 66.25, 1234.5]

**>>> del** a[:]

**>>>** a

[]

[del](https://docs.python.org/3/reference/simple_stmts.html#del) can also be used to delete entire variables:

>>>

**>>> del** a

Referencing the name a hereafter is an error (at least until another value is assigned to it). We’ll find other uses for [del](https://docs.python.org/3/reference/simple_stmts.html#del) later.

## 5.3. Tuples and Sequences

We saw that lists and strings have many common properties, such as indexing and slicing operations. They are two examples of sequence data types (see [Sequence Types — list, tuple, range](https://docs.python.org/3/library/stdtypes.html#typesseq)). Since Python is an evolving language, other sequence data types may be added. There is also another standard sequence data type: the tuple.

A tuple consists of a number of values separated by commas, for instance:

>>>

**>>>** t = 12345, 54321, 'hello!'

**>>>** t[0]

12345

**>>>** t

(12345, 54321, 'hello!')

**>>>** *# Tuples may be nested:*

**...** u = t, (1, 2, 3, 4, 5)

**>>>** u

((12345, 54321, 'hello!'), (1, 2, 3, 4, 5))

**>>>** *# Tuples are immutable:*

**...** t[0] = 88888

Traceback (most recent call last):

File "<stdin>", line 1, in <module>

TypeError: 'tuple' object does not support item assignment

**>>>** *# but they can contain mutable objects:*

**...** v = ([1, 2, 3], [3, 2, 1])

**>>>** v

([1, 2, 3], [3, 2, 1])

As you see, on output tuples are always enclosed in parentheses, so that nested tuples are interpreted correctly; they may be input with or without surrounding parentheses, although often parentheses are necessary anyway (if the tuple is part of a larger expression). It is not possible to assign to the individual items of a tuple, however it is possible to create tuples which contain mutable objects, such as lists.

Though tuples may seem similar to lists, they are often used in different situations and for different purposes. Tuples are [immutable](https://docs.python.org/3/glossary.html#term-immutable), and usually contain a heterogeneous sequence of elements that are accessed via unpacking (see later in this section) or indexing (or even by attribute in the case of[namedtuples](https://docs.python.org/3/library/collections.html#collections.namedtuple)). Lists are [mutable](https://docs.python.org/3/glossary.html#term-mutable), and their elements are usually homogeneous and are accessed by iterating over the list.

A special problem is the construction of tuples containing 0 or 1 items: the syntax has some extra quirks to accommodate these. Empty tuples are constructed by an empty pair of parentheses; a tuple with one item is constructed by following a value with a comma (it is not sufficient to enclose a single value in parentheses). Ugly, but effective. For example:

>>>

**>>>** empty = ()

**>>>** singleton = 'hello', *# <-- note trailing comma*

**>>>** len(empty)

0

**>>>** len(singleton)

1

**>>>** singleton

('hello',)

The statement t = 12345, 54321, 'hello!' is an example of tuple packing: the values 12345,54321 and 'hello!' are packed together in a tuple. The reverse operation is also possible:

>>>

**>>>** x, y, z = t

This is called, appropriately enough, sequence unpacking and works for any sequence on the right-hand side. Sequence unpacking requires that there are as many variables on the left side of the equals sign as there are elements in the sequence. Note that multiple assignment is really just a combination of tuple packing and sequence unpacking.

## 5.4. Sets

Python also includes a data type for sets. A set is an unordered collection with no duplicate elements. Basic uses include membership testing and eliminating duplicate entries. Set objects also support mathematical operations like union, intersection, difference, and symmetric difference.

Curly braces or the [set()](https://docs.python.org/3/library/stdtypes.html#set) function can be used to create sets. Note: to create an empty set you have to use set(), not {}; the latter creates an empty dictionary, a data structure that we discuss in the next section.

Here is a brief demonstration:

>>>

**>>>** basket = {'apple', 'orange', 'apple', 'pear', 'orange', 'banana'}

**>>>** print(basket) *# show that duplicates have been removed*

{'orange', 'banana', 'pear', 'apple'}

**>>>** 'orange' **in** basket *# fast membership testing*

True

**>>>** 'crabgrass' **in** basket

False

**>>>** *# Demonstrate set operations on unique letters from two words*

**...**

**>>>** a = set('abracadabra')

**>>>** b = set('alacazam')

**>>>** a *# unique letters in a*

{'a', 'r', 'b', 'c', 'd'}

**>>>** a - b *# letters in a but not in b*

{'r', 'd', 'b'}

**>>>** a | b *# letters in either a or b*

{'a', 'c', 'r', 'd', 'b', 'm', 'z', 'l'}

**>>>** a & b *# letters in both a and b*

{'a', 'c'}

**>>>** a ^ b *# letters in a or b but not both*

{'r', 'd', 'b', 'm', 'z', 'l'}

Similarly to [list comprehensions](https://docs.python.org/3/tutorial/datastructures.html#tut-listcomps), set comprehensions are also supported:

>>>

**>>>** a = {x **for** x **in** 'abracadabra' **if** x **not** **in** 'abc'}

**>>>** a

{'r', 'd'}

## 5.5. Dictionaries

Another useful data type built into Python is the dictionary (see [Mapping Types — dict](https://docs.python.org/3/library/stdtypes.html#typesmapping)). Dictionaries are sometimes found in other languages as “associative memories” or “associative arrays”. Unlike sequences, which are indexed by a range of numbers, dictionaries are indexed by keys, which can be any immutable type; strings and numbers can always be keys. Tuples can be used as keys if they contain only strings, numbers, or tuples; if a tuple contains any mutable object either directly or indirectly, it cannot be used as a key. You can’t use lists as keys, since lists can be modified in place using index assignments, slice assignments, or methods like append() and extend().

It is best to think of a dictionary as an unordered set of key: value pairs, with the requirement that the keys are unique (within one dictionary). A pair of braces creates an empty dictionary: {}. Placing a comma-separated list of key:value pairs within the braces adds initial key:value pairs to the dictionary; this is also the way dictionaries are written on output.

The main operations on a dictionary are storing a value with some key and extracting the value given the key. It is also possible to delete a key:value pair with del. If you store using a key that is already in use, the old value associated with that key is forgotten. It is an error to extract a value using a non-existent key.

Performing list(d.keys()) on a dictionary returns a list of all the keys used in the dictionary, in arbitrary order (if you want it sorted, just use sorted(d.keys()) instead). [[2]](https://docs.python.org/3/tutorial/datastructures.html#id4) To check whether a single key is in the dictionary, use the [in](https://docs.python.org/3/reference/expressions.html#in) keyword.

Here is a small example using a dictionary:

>>>

**>>>** tel = {'jack': 4098, 'sape': 4139}

**>>>** tel['guido'] = 4127

**>>>** tel

{'sape': 4139, 'guido': 4127, 'jack': 4098}

**>>>** tel['jack']

4098

**>>> del** tel['sape']

**>>>** tel['irv'] = 4127

**>>>** tel

{'guido': 4127, 'irv': 4127, 'jack': 4098}

**>>>** list(tel.keys())

['irv', 'guido', 'jack']

**>>>** sorted(tel.keys())

['guido', 'irv', 'jack']

**>>>** 'guido' **in** tel

True

**>>>** 'jack' **not** **in** tel

False

The [dict()](https://docs.python.org/3/library/stdtypes.html#dict) constructor builds dictionaries directly from sequences of key-value pairs:

>>>

**>>>** dict([('sape', 4139), ('guido', 4127), ('jack', 4098)])

{'sape': 4139, 'jack': 4098, 'guido': 4127}

In addition, dict comprehensions can be used to create dictionaries from arbitrary key and value expressions:

>>>

**>>>** {x: x\*\*2 **for** x **in** (2, 4, 6)}

{2: 4, 4: 16, 6: 36}

When the keys are simple strings, it is sometimes easier to specify pairs using keyword arguments:

>>>

**>>>** dict(sape=4139, guido=4127, jack=4098)

{'sape': 4139, 'jack': 4098, 'guido': 4127}

## 5.6. Looping Techniques

When looping through dictionaries, the key and corresponding value can be retrieved at the same time using the items() method.

>>>

**>>>** knights = {'gallahad': 'the pure', 'robin': 'the brave'}

**>>> for** k, v **in** knights.items():

**...**  print(k, v)

**...**

gallahad the pure

robin the brave

When looping through a sequence, the position index and corresponding value can be retrieved at the same time using the [enumerate()](https://docs.python.org/3/library/functions.html#enumerate) function.

>>>

**>>> for** i, v **in** enumerate(['tic', 'tac', 'toe']):

**...**  print(i, v)

**...**

0 tic

1 tac

2 toe

To loop over two or more sequences at the same time, the entries can be paired with the [zip()](https://docs.python.org/3/library/functions.html#zip)function.

>>>

**>>>** questions = ['name', 'quest', 'favorite color']

**>>>** answers = ['lancelot', 'the holy grail', 'blue']

**>>> for** q, a **in** zip(questions, answers):

**...**  print('What is your *{0}*? It is *{1}*.'.format(q, a))

**...**

What is your name? It is lancelot.

What is your quest? It is the holy grail.

What is your favorite color? It is blue.

To loop over a sequence in reverse, first specify the sequence in a forward direction and then call the[reversed()](https://docs.python.org/3/library/functions.html#reversed) function.

>>>

**>>> for** i **in** reversed(range(1, 10, 2)):

**...**  print(i)

**...**

9

7

5

3

1

To loop over a sequence in sorted order, use the [sorted()](https://docs.python.org/3/library/functions.html#sorted) function which returns a new sorted list while leaving the source unaltered.

>>>

**>>>** basket = ['apple', 'orange', 'apple', 'pear', 'orange', 'banana']

**>>> for** f **in** sorted(set(basket)):

**...**  print(f)

**...**

apple

banana

orange

pear

It is sometimes tempting to change a list while you are looping over it; however, it is often simpler and safer to create a new list instead.

>>>

**>>> import** **math**

**>>>** raw\_data = [56.2, float('NaN'), 51.7, 55.3, 52.5, float('NaN'), 47.8]

**>>>** filtered\_data = []

**>>> for** value **in** raw\_data:

**...**  **if** **not** math.isnan(value):

**...**  filtered\_data.append(value)

**...**

**>>>** filtered\_data

[56.2, 51.7, 55.3, 52.5, 47.8]

## 5.7. More on Conditions

The conditions used in while and if statements can contain any operators, not just comparisons.

The comparison operators in and not in check whether a value occurs (does not occur) in a sequence. The operators is and is not compare whether two objects are really the same object; this only matters for mutable objects like lists. All comparison operators have the same priority, which is lower than that of all numerical operators.

Comparisons can be chained. For example, a < b == c tests whether a is less than b and moreoverb equals c.

Comparisons may be combined using the Boolean operators and and or, and the outcome of a comparison (or of any other Boolean expression) may be negated with not. These have lower priorities than comparison operators; between them, not has the highest priority and or the lowest, so that A and not B or C is equivalent to (A and (not B)) or C. As always, parentheses can be used to express the desired composition.

The Boolean operators and and or are so-called short-circuit operators: their arguments are evaluated from left to right, and evaluation stops as soon as the outcome is determined. For example, if A and C are true but B is false, A and B and C does not evaluate the expression C. When used as a general value and not as a Boolean, the return value of a short-circuit operator is the last evaluated argument.

It is possible to assign the result of a comparison or other Boolean expression to a variable. For example,

>>>

**>>>** string1, string2, string3 = '', 'Trondheim', 'Hammer Dance'

**>>>** non\_null = string1 **or** string2 **or** string3

**>>>** non\_null

'Trondheim'

Note that in Python, unlike C, assignment cannot occur inside expressions. C programmers may grumble about this, but it avoids a common class of problems encountered in C programs: typing = in an expression when == was intended.

## 5.8. Comparing Sequences and Other Types

Sequence objects may be compared to other objects with the same sequence type. The comparison uses lexicographical ordering: first the first two items are compared, and if they differ this determines the outcome of the comparison; if they are equal, the next two items are compared, and so on, until either sequence is exhausted. If two items to be compared are themselves sequences of the same type, the lexicographical comparison is carried out recursively. If all items of two sequences compare equal, the sequences are considered equal. If one sequence is an initial sub-sequence of the other, the shorter sequence is the smaller (lesser) one. Lexicographical ordering for strings uses the Unicode code point number to order individual characters. Some examples of comparisons between sequences of the same type:

(1, 2, 3) < (1, 2, 4)

[1, 2, 3] < [1, 2, 4]

'ABC' < 'C' < 'Pascal' < 'Python'

(1, 2, 3, 4) < (1, 2, 4)

(1, 2) < (1, 2, -1)

(1, 2, 3) == (1.0, 2.0, 3.0)

(1, 2, ('aa', 'ab')) < (1, 2, ('abc', 'a'), 4)

Note that comparing objects of different types with < or > is legal provided that the objects have appropriate comparison methods. For example, mixed numeric types are compared according to their numeric value, so 0 equals 0.0, etc. Otherwise, rather than providing an arbitrary ordering, the interpreter will raise a [TypeError](https://docs.python.org/3/library/exceptions.html#TypeError) exception.

**Footnotes**

|  |  |
| --- | --- |
| [[1]](https://docs.python.org/3/tutorial/datastructures.html#id1) | Other languages may return the mutated object, which allows method chaining, such as d->insert("a")->remove("b")->sort();. |

|  |  |
| --- | --- |
| [[2]](https://docs.python.org/3/tutorial/datastructures.html#id2) | Calling d.keys() will return a *dictionary view* object. It supports operations like membership test and iteration, but its contents are not independent of the original dictionary – it is only a*view*. |

# 5. Data Structures

This chapter describes some things you’ve learned about already in more detail, and adds some new things as well.

## 5.1. More on Lists

The list data type has some more methods. Here are all of the methods of list objects:

list.**append**(x)

Add an item to the end of the list. Equivalent to a[len(a):] = [x].

list.**extend**(L)

Extend the list by appending all the items in the given list. Equivalent to a[len(a):] = L.

list.**insert**(i, x)

Insert an item at a given position. The first argument is the index of the element before which to insert, so a.insert(0, x) inserts at the front of the list, and a.insert(len(a), x) is equivalent to a.append(x).

list.**remove**(x)

Remove the first item from the list whose value is x. It is an error if there is no such item.

list.**pop**([i])

Remove the item at the given position in the list, and return it. If no index is specified, a.pop()removes and returns the last item in the list. (The square brackets around the i in the method signature denote that the parameter is optional, not that you should type square brackets at that position. You will see this notation frequently in the Python Library Reference.)

list.**clear**()

Remove all items from the list. Equivalent to del a[:].

list.**index**(x)

Return the index in the list of the first item whose value is x. It is an error if there is no such item.

list.**count**(x)

Return the number of times x appears in the list.

list.**sort**(key=None, reverse=False)

Sort the items of the list in place (the arguments can be used for sort customization, see[sorted()](https://docs.python.org/3/library/functions.html#sorted) for their explanation).

list.**reverse**()

Reverse the elements of the list in place.

list.**copy**()

Return a shallow copy of the list. Equivalent to a[:].

An example that uses most of the list methods:

>>>

**>>>** a = [66.25, 333, 333, 1, 1234.5]

**>>>** print(a.count(333), a.count(66.25), a.count('x'))

2 1 0

**>>>** a.insert(2, -1)

**>>>** a.append(333)

**>>>** a

[66.25, 333, -1, 333, 1, 1234.5, 333]

**>>>** a.index(333)

1

**>>>** a.remove(333)

**>>>** a

[66.25, -1, 333, 1, 1234.5, 333]

**>>>** a.reverse()

**>>>** a

[333, 1234.5, 1, 333, -1, 66.25]

**>>>** a.sort()

**>>>** a

[-1, 1, 66.25, 333, 333, 1234.5]

**>>>** a.pop()

1234.5

**>>>** a

[-1, 1, 66.25, 333, 333]

You might have noticed that methods like insert, remove or sort that only modify the list have no return value printed – they return the default None. [[1]](https://docs.python.org/3/tutorial/datastructures.html#id3) This is a design principle for all mutable data structures in Python.

### 5.1.1. Using Lists as Stacks

The list methods make it very easy to use a list as a stack, where the last element added is the first element retrieved (“last-in, first-out”). To add an item to the top of the stack, use append(). To retrieve an item from the top of the stack, use pop() without an explicit index. For example:

>>>

**>>>** stack = [3, 4, 5]

**>>>** stack.append(6)

**>>>** stack.append(7)

**>>>** stack

[3, 4, 5, 6, 7]

**>>>** stack.pop()

7

**>>>** stack

[3, 4, 5, 6]

**>>>** stack.pop()

6

**>>>** stack.pop()

5

**>>>** stack

[3, 4]

### 5.1.2. Using Lists as Queues

It is also possible to use a list as a queue, where the first element added is the first element retrieved (“first-in, first-out”); however, lists are not efficient for this purpose. While appends and pops from the end of list are fast, doing inserts or pops from the beginning of a list is slow (because all of the other elements have to be shifted by one).

To implement a queue, use [collections.deque](https://docs.python.org/3/library/collections.html#collections.deque) which was designed to have fast appends and pops from both ends. For example:

>>>

**>>> from** **collections** **import** deque

**>>>** queue = deque(["Eric", "John", "Michael"])

**>>>** queue.append("Terry") *# Terry arrives*

**>>>** queue.append("Graham") *# Graham arrives*

**>>>** queue.popleft() *# The first to arrive now leaves*

'Eric'

**>>>** queue.popleft() *# The second to arrive now leaves*

'John'

**>>>** queue *# Remaining queue in order of arrival*

deque(['Michael', 'Terry', 'Graham'])

### 5.1.3. List Comprehensions

List comprehensions provide a concise way to create lists. Common applications are to make new lists where each element is the result of some operations applied to each member of another sequence or iterable, or to create a subsequence of those elements that satisfy a certain condition.

For example, assume we want to create a list of squares, like:

>>>

**>>>** squares = []

**>>> for** x **in** range(10):

**...**  squares.append(x\*\*2)

**...**

**>>>** squares

[0, 1, 4, 9, 16, 25, 36, 49, 64, 81]

Note that this creates (or overwrites) a variable named x that still exists after the loop completes. We can calculate the list of squares without any side effects using:

squares = list(map(**lambda** x: x\*\*2, range(10)))

or, equivalently:

squares = [x\*\*2 **for** x **in** range(10)]

which is more concise and readable.

A list comprehension consists of brackets containing an expression followed by a [for](https://docs.python.org/3/reference/compound_stmts.html#for) clause, then zero or more [for](https://docs.python.org/3/reference/compound_stmts.html#for) or [if](https://docs.python.org/3/reference/compound_stmts.html#if) clauses. The result will be a new list resulting from evaluating the expression in the context of the [for](https://docs.python.org/3/reference/compound_stmts.html#for) and [if](https://docs.python.org/3/reference/compound_stmts.html#if) clauses which follow it. For example, this listcomp combines the elements of two lists if they are not equal:

>>>

**>>>** [(x, y) **for** x **in** [1,2,3] **for** y **in** [3,1,4] **if** x != y]

[(1, 3), (1, 4), (2, 3), (2, 1), (2, 4), (3, 1), (3, 4)]

and it’s equivalent to:

>>>

**>>>** combs = []

**>>> for** x **in** [1,2,3]:

**...**  **for** y **in** [3,1,4]:

**...**  **if** x != y:

**...**  combs.append((x, y))

**...**

**>>>** combs

[(1, 3), (1, 4), (2, 3), (2, 1), (2, 4), (3, 1), (3, 4)]

Note how the order of the [for](https://docs.python.org/3/reference/compound_stmts.html#for) and [if](https://docs.python.org/3/reference/compound_stmts.html#if) statements is the same in both these snippets.

If the expression is a tuple (e.g. the (x, y) in the previous example), it must be parenthesized.

>>>

**>>>** vec = [-4, -2, 0, 2, 4]

**>>>** *# create a new list with the values doubled*

**>>>** [x\*2 **for** x **in** vec]

[-8, -4, 0, 4, 8]

**>>>** *# filter the list to exclude negative numbers*

**>>>** [x **for** x **in** vec **if** x >= 0]

[0, 2, 4]

**>>>** *# apply a function to all the elements*

**>>>** [abs(x) **for** x **in** vec]

[4, 2, 0, 2, 4]

**>>>** *# call a method on each element*

**>>>** freshfruit = [' banana', ' loganberry ', 'passion fruit ']

**>>>** [weapon.strip() **for** weapon **in** freshfruit]

['banana', 'loganberry', 'passion fruit']

**>>>** *# create a list of 2-tuples like (number, square)*

**>>>** [(x, x\*\*2) **for** x **in** range(6)]

[(0, 0), (1, 1), (2, 4), (3, 9), (4, 16), (5, 25)]

**>>>** *# the tuple must be parenthesized, otherwise an error is raised*

**>>>** [x, x\*\*2 **for** x **in** range(6)]

File "<stdin>", line 1, in ?

[x, x\*\*2 for x in range(6)]

^

SyntaxError: invalid syntax

**>>>** *# flatten a list using a listcomp with two 'for'*

**>>>** vec = [[1,2,3], [4,5,6], [7,8,9]]

**>>>** [num **for** elem **in** vec **for** num **in** elem]

[1, 2, 3, 4, 5, 6, 7, 8, 9]

List comprehensions can contain complex expressions and nested functions:

>>>

**>>> from** **math** **import** pi

**>>>** [str(round(pi, i)) **for** i **in** range(1, 6)]

['3.1', '3.14', '3.142', '3.1416', '3.14159']

### 5.1.4. Nested List Comprehensions

The initial expression in a list comprehension can be any arbitrary expression, including another list comprehension.

Consider the following example of a 3x4 matrix implemented as a list of 3 lists of length 4:

>>>

**>>>** matrix = [

**...**  [1, 2, 3, 4],

**...**  [5, 6, 7, 8],

**...**  [9, 10, 11, 12],

**...** ]

The following list comprehension will transpose rows and columns:

>>>

**>>>** [[row[i] **for** row **in** matrix] **for** i **in** range(4)]

[[1, 5, 9], [2, 6, 10], [3, 7, 11], [4, 8, 12]]

As we saw in the previous section, the nested listcomp is evaluated in the context of the [for](https://docs.python.org/3/reference/compound_stmts.html#for) that follows it, so this example is equivalent to:

>>>

**>>>** transposed = []

**>>> for** i **in** range(4):

**...**  transposed.append([row[i] **for** row **in** matrix])

**...**

**>>>** transposed

[[1, 5, 9], [2, 6, 10], [3, 7, 11], [4, 8, 12]]

which, in turn, is the same as:

>>>

**>>>** transposed = []

**>>> for** i **in** range(4):

**...**  *# the following 3 lines implement the nested listcomp*

**...**  transposed\_row = []

**...**  **for** row **in** matrix:

**...**  transposed\_row.append(row[i])

**...**  transposed.append(transposed\_row)

**...**

**>>>** transposed

[[1, 5, 9], [2, 6, 10], [3, 7, 11], [4, 8, 12]]

In the real world, you should prefer built-in functions to complex flow statements. The [zip()](https://docs.python.org/3/library/functions.html#zip) function would do a great job for this use case:

>>>

**>>>** list(zip(\*matrix))

[(1, 5, 9), (2, 6, 10), (3, 7, 11), (4, 8, 12)]

See [Unpacking Argument Lists](https://docs.python.org/3/tutorial/controlflow.html#tut-unpacking-arguments) for details on the asterisk in this line.

## 5.2. The [del](https://docs.python.org/3/reference/simple_stmts.html#del) statement

There is a way to remove an item from a list given its index instead of its value: the [del](https://docs.python.org/3/reference/simple_stmts.html#del) statement. This differs from the pop() method which returns a value. The [del](https://docs.python.org/3/reference/simple_stmts.html#del) statement can also be used to remove slices from a list or clear the entire list (which we did earlier by assignment of an empty list to the slice). For example:

>>>

**>>>** a = [-1, 1, 66.25, 333, 333, 1234.5]

**>>> del** a[0]

**>>>** a

[1, 66.25, 333, 333, 1234.5]

**>>> del** a[2:4]

**>>>** a

[1, 66.25, 1234.5]

**>>> del** a[:]

**>>>** a

[]

[del](https://docs.python.org/3/reference/simple_stmts.html#del) can also be used to delete entire variables:

>>>

**>>> del** a

Referencing the name a hereafter is an error (at least until another value is assigned to it). We’ll find other uses for [del](https://docs.python.org/3/reference/simple_stmts.html#del) later.

## 5.3. Tuples and Sequences

We saw that lists and strings have many common properties, such as indexing and slicing operations. They are two examples of sequence data types (see [Sequence Types — list, tuple, range](https://docs.python.org/3/library/stdtypes.html#typesseq)). Since Python is an evolving language, other sequence data types may be added. There is also another standard sequence data type: the tuple.

A tuple consists of a number of values separated by commas, for instance:

>>>

**>>>** t = 12345, 54321, 'hello!'

**>>>** t[0]

12345

**>>>** t

(12345, 54321, 'hello!')

**>>>** *# Tuples may be nested:*

**...** u = t, (1, 2, 3, 4, 5)

**>>>** u

((12345, 54321, 'hello!'), (1, 2, 3, 4, 5))

**>>>** *# Tuples are immutable:*

**...** t[0] = 88888

Traceback (most recent call last):

File "<stdin>", line 1, in <module>

TypeError: 'tuple' object does not support item assignment

**>>>** *# but they can contain mutable objects:*

**...** v = ([1, 2, 3], [3, 2, 1])

**>>>** v

([1, 2, 3], [3, 2, 1])

As you see, on output tuples are always enclosed in parentheses, so that nested tuples are interpreted correctly; they may be input with or without surrounding parentheses, although often parentheses are necessary anyway (if the tuple is part of a larger expression). It is not possible to assign to the individual items of a tuple, however it is possible to create tuples which contain mutable objects, such as lists.

Though tuples may seem similar to lists, they are often used in different situations and for different purposes. Tuples are [immutable](https://docs.python.org/3/glossary.html#term-immutable), and usually contain a heterogeneous sequence of elements that are accessed via unpacking (see later in this section) or indexing (or even by attribute in the case of[namedtuples](https://docs.python.org/3/library/collections.html#collections.namedtuple)). Lists are [mutable](https://docs.python.org/3/glossary.html#term-mutable), and their elements are usually homogeneous and are accessed by iterating over the list.

A special problem is the construction of tuples containing 0 or 1 items: the syntax has some extra quirks to accommodate these. Empty tuples are constructed by an empty pair of parentheses; a tuple with one item is constructed by following a value with a comma (it is not sufficient to enclose a single value in parentheses). Ugly, but effective. For example:

>>>

**>>>** empty = ()

**>>>** singleton = 'hello', *# <-- note trailing comma*

**>>>** len(empty)

0

**>>>** len(singleton)

1

**>>>** singleton

('hello',)

The statement t = 12345, 54321, 'hello!' is an example of tuple packing: the values 12345,54321 and 'hello!' are packed together in a tuple. The reverse operation is also possible:

>>>

**>>>** x, y, z = t

This is called, appropriately enough, sequence unpacking and works for any sequence on the right-hand side. Sequence unpacking requires that there are as many variables on the left side of the equals sign as there are elements in the sequence. Note that multiple assignment is really just a combination of tuple packing and sequence unpacking.

## 5.4. Sets

Python also includes a data type for sets. A set is an unordered collection with no duplicate elements. Basic uses include membership testing and eliminating duplicate entries. Set objects also support mathematical operations like union, intersection, difference, and symmetric difference.

Curly braces or the [set()](https://docs.python.org/3/library/stdtypes.html#set) function can be used to create sets. Note: to create an empty set you have to use set(), not {}; the latter creates an empty dictionary, a data structure that we discuss in the next section.

Here is a brief demonstration:

>>>

**>>>** basket = {'apple', 'orange', 'apple', 'pear', 'orange', 'banana'}

**>>>** print(basket) *# show that duplicates have been removed*

{'orange', 'banana', 'pear', 'apple'}

**>>>** 'orange' **in** basket *# fast membership testing*

True

**>>>** 'crabgrass' **in** basket

False

**>>>** *# Demonstrate set operations on unique letters from two words*

**...**

**>>>** a = set('abracadabra')

**>>>** b = set('alacazam')

**>>>** a *# unique letters in a*

{'a', 'r', 'b', 'c', 'd'}

**>>>** a - b *# letters in a but not in b*

{'r', 'd', 'b'}

**>>>** a | b *# letters in either a or b*

{'a', 'c', 'r', 'd', 'b', 'm', 'z', 'l'}

**>>>** a & b *# letters in both a and b*

{'a', 'c'}

**>>>** a ^ b *# letters in a or b but not both*

{'r', 'd', 'b', 'm', 'z', 'l'}

Similarly to [list comprehensions](https://docs.python.org/3/tutorial/datastructures.html#tut-listcomps), set comprehensions are also supported:

>>>

**>>>** a = {x **for** x **in** 'abracadabra' **if** x **not** **in** 'abc'}

**>>>** a

{'r', 'd'}

## 5.5. Dictionaries

Another useful data type built into Python is the dictionary (see [Mapping Types — dict](https://docs.python.org/3/library/stdtypes.html#typesmapping)). Dictionaries are sometimes found in other languages as “associative memories” or “associative arrays”. Unlike sequences, which are indexed by a range of numbers, dictionaries are indexed by keys, which can be any immutable type; strings and numbers can always be keys. Tuples can be used as keys if they contain only strings, numbers, or tuples; if a tuple contains any mutable object either directly or indirectly, it cannot be used as a key. You can’t use lists as keys, since lists can be modified in place using index assignments, slice assignments, or methods like append() and extend().

It is best to think of a dictionary as an unordered set of key: value pairs, with the requirement that the keys are unique (within one dictionary). A pair of braces creates an empty dictionary: {}. Placing a comma-separated list of key:value pairs within the braces adds initial key:value pairs to the dictionary; this is also the way dictionaries are written on output.

The main operations on a dictionary are storing a value with some key and extracting the value given the key. It is also possible to delete a key:value pair with del. If you store using a key that is already in use, the old value associated with that key is forgotten. It is an error to extract a value using a non-existent key.

Performing list(d.keys()) on a dictionary returns a list of all the keys used in the dictionary, in arbitrary order (if you want it sorted, just use sorted(d.keys()) instead). [[2]](https://docs.python.org/3/tutorial/datastructures.html#id4) To check whether a single key is in the dictionary, use the [in](https://docs.python.org/3/reference/expressions.html#in) keyword.

Here is a small example using a dictionary:

>>>

**>>>** tel = {'jack': 4098, 'sape': 4139}

**>>>** tel['guido'] = 4127

**>>>** tel

{'sape': 4139, 'guido': 4127, 'jack': 4098}

**>>>** tel['jack']

4098

**>>> del** tel['sape']

**>>>** tel['irv'] = 4127

**>>>** tel

{'guido': 4127, 'irv': 4127, 'jack': 4098}

**>>>** list(tel.keys())

['irv', 'guido', 'jack']

**>>>** sorted(tel.keys())

['guido', 'irv', 'jack']

**>>>** 'guido' **in** tel

True

**>>>** 'jack' **not** **in** tel

False

The [dict()](https://docs.python.org/3/library/stdtypes.html#dict) constructor builds dictionaries directly from sequences of key-value pairs:

>>>

**>>>** dict([('sape', 4139), ('guido', 4127), ('jack', 4098)])

{'sape': 4139, 'jack': 4098, 'guido': 4127}

In addition, dict comprehensions can be used to create dictionaries from arbitrary key and value expressions:

>>>

**>>>** {x: x\*\*2 **for** x **in** (2, 4, 6)}

{2: 4, 4: 16, 6: 36}

When the keys are simple strings, it is sometimes easier to specify pairs using keyword arguments:

>>>

**>>>** dict(sape=4139, guido=4127, jack=4098)

{'sape': 4139, 'jack': 4098, 'guido': 4127}

## 5.6. Looping Techniques

When looping through dictionaries, the key and corresponding value can be retrieved at the same time using the items() method.

>>>

**>>>** knights = {'gallahad': 'the pure', 'robin': 'the brave'}

**>>> for** k, v **in** knights.items():

**...**  print(k, v)

**...**

gallahad the pure

robin the brave

When looping through a sequence, the position index and corresponding value can be retrieved at the same time using the [enumerate()](https://docs.python.org/3/library/functions.html#enumerate) function.

>>>

**>>> for** i, v **in** enumerate(['tic', 'tac', 'toe']):

**...**  print(i, v)

**...**

0 tic

1 tac

2 toe

To loop over two or more sequences at the same time, the entries can be paired with the [zip()](https://docs.python.org/3/library/functions.html#zip)function.

>>>

**>>>** questions = ['name', 'quest', 'favorite color']

**>>>** answers = ['lancelot', 'the holy grail', 'blue']

**>>> for** q, a **in** zip(questions, answers):

**...**  print('What is your *{0}*? It is *{1}*.'.format(q, a))

**...**

What is your name? It is lancelot.

What is your quest? It is the holy grail.

What is your favorite color? It is blue.

To loop over a sequence in reverse, first specify the sequence in a forward direction and then call the[reversed()](https://docs.python.org/3/library/functions.html#reversed) function.

>>>

**>>> for** i **in** reversed(range(1, 10, 2)):

**...**  print(i)

**...**

9

7

5

3

1

To loop over a sequence in sorted order, use the [sorted()](https://docs.python.org/3/library/functions.html#sorted) function which returns a new sorted list while leaving the source unaltered.

>>>

**>>>** basket = ['apple', 'orange', 'apple', 'pear', 'orange', 'banana']

**>>> for** f **in** sorted(set(basket)):

**...**  print(f)

**...**

apple

banana

orange

pear

It is sometimes tempting to change a list while you are looping over it; however, it is often simpler and safer to create a new list instead.

>>>

**>>> import** **math**

**>>>** raw\_data = [56.2, float('NaN'), 51.7, 55.3, 52.5, float('NaN'), 47.8]

**>>>** filtered\_data = []

**>>> for** value **in** raw\_data:

**...**  **if** **not** math.isnan(value):

**...**  filtered\_data.append(value)

**...**

**>>>** filtered\_data

[56.2, 51.7, 55.3, 52.5, 47.8]

## 5.7. More on Conditions

The conditions used in while and if statements can contain any operators, not just comparisons.

The comparison operators in and not in check whether a value occurs (does not occur) in a sequence. The operators is and is not compare whether two objects are really the same object; this only matters for mutable objects like lists. All comparison operators have the same priority, which is lower than that of all numerical operators.

Comparisons can be chained. For example, a < b == c tests whether a is less than b and moreoverb equals c.

Comparisons may be combined using the Boolean operators and and or, and the outcome of a comparison (or of any other Boolean expression) may be negated with not. These have lower priorities than comparison operators; between them, not has the highest priority and or the lowest, so that A and not B or C is equivalent to (A and (not B)) or C. As always, parentheses can be used to express the desired composition.

The Boolean operators and and or are so-called short-circuit operators: their arguments are evaluated from left to right, and evaluation stops as soon as the outcome is determined. For example, if A and C are true but B is false, A and B and C does not evaluate the expression C. When used as a general value and not as a Boolean, the return value of a short-circuit operator is the last evaluated argument.

It is possible to assign the result of a comparison or other Boolean expression to a variable. For example,

>>>

**>>>** string1, string2, string3 = '', 'Trondheim', 'Hammer Dance'

**>>>** non\_null = string1 **or** string2 **or** string3

**>>>** non\_null

'Trondheim'

Note that in Python, unlike C, assignment cannot occur inside expressions. C programmers may grumble about this, but it avoids a common class of problems encountered in C programs: typing = in an expression when == was intended.

## 5.8. Comparing Sequences and Other Types

Sequence objects may be compared to other objects with the same sequence type. The comparison uses lexicographical ordering: first the first two items are compared, and if they differ this determines the outcome of the comparison; if they are equal, the next two items are compared, and so on, until either sequence is exhausted. If two items to be compared are themselves sequences of the same type, the lexicographical comparison is carried out recursively. If all items of two sequences compare equal, the sequences are considered equal. If one sequence is an initial sub-sequence of the other, the shorter sequence is the smaller (lesser) one. Lexicographical ordering for strings uses the Unicode code point number to order individual characters. Some examples of comparisons between sequences of the same type:

(1, 2, 3) < (1, 2, 4)

[1, 2, 3] < [1, 2, 4]

'ABC' < 'C' < 'Pascal' < 'Python'

(1, 2, 3, 4) < (1, 2, 4)

(1, 2) < (1, 2, -1)

(1, 2, 3) == (1.0, 2.0, 3.0)

(1, 2, ('aa', 'ab')) < (1, 2, ('abc', 'a'), 4)

Note that comparing objects of different types with < or > is legal provided that the objects have appropriate comparison methods. For example, mixed numeric types are compared according to their numeric value, so 0 equals 0.0, etc. Otherwise, rather than providing an arbitrary ordering, the interpreter will raise a [TypeError](https://docs.python.org/3/library/exceptions.html#TypeError) exception.

**Footnotes**

|  |  |
| --- | --- |
| [[1]](https://docs.python.org/3/tutorial/datastructures.html#id1) | Other languages may return the mutated object, which allows method chaining, such as d->insert("a")->remove("b")->sort();. |

|  |  |
| --- | --- |
| [[2]](https://docs.python.org/3/tutorial/datastructures.html#id2) | Calling d.keys() will return a dictionary view object. It supports operations like membership test and iteration, but its contents are not independent of the original dictionary – it is only aview. |

# 5. Data Structures

This chapter describes some things you’ve learned about already in more detail, and adds some new things as well.

## 5.1. More on Lists

The list data type has some more methods. Here are all of the methods of list objects:

list.**append**(x)

Add an item to the end of the list. Equivalent to a[len(a):] = [x].

list.**extend**(L)

Extend the list by appending all the items in the given list. Equivalent to a[len(a):] = L.

list.**insert**(i, x)

Insert an item at a given position. The first argument is the index of the element before which to insert, so a.insert(0, x) inserts at the front of the list, and a.insert(len(a), x) is equivalent to a.append(x).

list.**remove**(x)

Remove the first item from the list whose value is x. It is an error if there is no such item.

list.**pop**([i])

Remove the item at the given position in the list, and return it. If no index is specified, a.pop()removes and returns the last item in the list. (The square brackets around the i in the method signature denote that the parameter is optional, not that you should type square brackets at that position. You will see this notation frequently in the Python Library Reference.)

list.**clear**()

Remove all items from the list. Equivalent to del a[:].

list.**index**(x)

Return the index in the list of the first item whose value is x. It is an error if there is no such item.

list.**count**(x)

Return the number of times x appears in the list.

list.**sort**(key=None, reverse=False)

Sort the items of the list in place (the arguments can be used for sort customization, see[sorted()](https://docs.python.org/3/library/functions.html#sorted) for their explanation).

list.**reverse**()

Reverse the elements of the list in place.

list.**copy**()

Return a shallow copy of the list. Equivalent to a[:].

An example that uses most of the list methods:

>>>

**>>>** a = [66.25, 333, 333, 1, 1234.5]

**>>>** print(a.count(333), a.count(66.25), a.count('x'))

2 1 0

**>>>** a.insert(2, -1)

**>>>** a.append(333)

**>>>** a

[66.25, 333, -1, 333, 1, 1234.5, 333]

**>>>** a.index(333)

1

**>>>** a.remove(333)

**>>>** a

[66.25, -1, 333, 1, 1234.5, 333]

**>>>** a.reverse()

**>>>** a

[333, 1234.5, 1, 333, -1, 66.25]

**>>>** a.sort()

**>>>** a

[-1, 1, 66.25, 333, 333, 1234.5]

**>>>** a.pop()

1234.5

**>>>** a

[-1, 1, 66.25, 333, 333]

You might have noticed that methods like insert, remove or sort that only modify the list have no return value printed – they return the default None. [[1]](https://docs.python.org/3/tutorial/datastructures.html#id3) This is a design principle for all mutable data structures in Python.

### 5.1.1. Using Lists as Stacks

The list methods make it very easy to use a list as a stack, where the last element added is the first element retrieved (“last-in, first-out”). To add an item to the top of the stack, use append(). To retrieve an item from the top of the stack, use pop() without an explicit index. For example:

>>>

**>>>** stack = [3, 4, 5]

**>>>** stack.append(6)

**>>>** stack.append(7)

**>>>** stack

[3, 4, 5, 6, 7]

**>>>** stack.pop()

7

**>>>** stack

[3, 4, 5, 6]

**>>>** stack.pop()

6

**>>>** stack.pop()

5

**>>>** stack

[3, 4]

### 5.1.2. Using Lists as Queues

It is also possible to use a list as a queue, where the first element added is the first element retrieved (“first-in, first-out”); however, lists are not efficient for this purpose. While appends and pops from the end of list are fast, doing inserts or pops from the beginning of a list is slow (because all of the other elements have to be shifted by one).

To implement a queue, use [collections.deque](https://docs.python.org/3/library/collections.html#collections.deque) which was designed to have fast appends and pops from both ends. For example:

>>>

**>>> from** **collections** **import** deque

**>>>** queue = deque(["Eric", "John", "Michael"])

**>>>** queue.append("Terry") *# Terry arrives*

**>>>** queue.append("Graham") *# Graham arrives*

**>>>** queue.popleft() *# The first to arrive now leaves*

'Eric'

**>>>** queue.popleft() *# The second to arrive now leaves*

'John'

**>>>** queue *# Remaining queue in order of arrival*

deque(['Michael', 'Terry', 'Graham'])

### 5.1.3. List Comprehensions

List comprehensions provide a concise way to create lists. Common applications are to make new lists where each element is the result of some operations applied to each member of another sequence or iterable, or to create a subsequence of those elements that satisfy a certain condition.

For example, assume we want to create a list of squares, like:

>>>

**>>>** squares = []

**>>> for** x **in** range(10):

**...**  squares.append(x\*\*2)

**...**

**>>>** squares

[0, 1, 4, 9, 16, 25, 36, 49, 64, 81]

Note that this creates (or overwrites) a variable named x that still exists after the loop completes. We can calculate the list of squares without any side effects using:

squares = list(map(**lambda** x: x\*\*2, range(10)))

or, equivalently:

squares = [x\*\*2 **for** x **in** range(10)]

which is more concise and readable.

A list comprehension consists of brackets containing an expression followed by a [for](https://docs.python.org/3/reference/compound_stmts.html#for) clause, then zero or more [for](https://docs.python.org/3/reference/compound_stmts.html#for) or [if](https://docs.python.org/3/reference/compound_stmts.html#if) clauses. The result will be a new list resulting from evaluating the expression in the context of the [for](https://docs.python.org/3/reference/compound_stmts.html#for) and [if](https://docs.python.org/3/reference/compound_stmts.html#if) clauses which follow it. For example, this listcomp combines the elements of two lists if they are not equal:

>>>

**>>>** [(x, y) **for** x **in** [1,2,3] **for** y **in** [3,1,4] **if** x != y]

[(1, 3), (1, 4), (2, 3), (2, 1), (2, 4), (3, 1), (3, 4)]

and it’s equivalent to:

>>>

**>>>** combs = []

**>>> for** x **in** [1,2,3]:

**...**  **for** y **in** [3,1,4]:

**...**  **if** x != y:

**...**  combs.append((x, y))

**...**

**>>>** combs

[(1, 3), (1, 4), (2, 3), (2, 1), (2, 4), (3, 1), (3, 4)]

Note how the order of the [for](https://docs.python.org/3/reference/compound_stmts.html#for) and [if](https://docs.python.org/3/reference/compound_stmts.html#if) statements is the same in both these snippets.

If the expression is a tuple (e.g. the (x, y) in the previous example), it must be parenthesized.

>>>

**>>>** vec = [-4, -2, 0, 2, 4]

**>>>** *# create a new list with the values doubled*

**>>>** [x\*2 **for** x **in** vec]

[-8, -4, 0, 4, 8]

**>>>** *# filter the list to exclude negative numbers*

**>>>** [x **for** x **in** vec **if** x >= 0]

[0, 2, 4]

**>>>** *# apply a function to all the elements*

**>>>** [abs(x) **for** x **in** vec]

[4, 2, 0, 2, 4]

**>>>** *# call a method on each element*

**>>>** freshfruit = [' banana', ' loganberry ', 'passion fruit ']

**>>>** [weapon.strip() **for** weapon **in** freshfruit]

['banana', 'loganberry', 'passion fruit']

**>>>** *# create a list of 2-tuples like (number, square)*

**>>>** [(x, x\*\*2) **for** x **in** range(6)]

[(0, 0), (1, 1), (2, 4), (3, 9), (4, 16), (5, 25)]

**>>>** *# the tuple must be parenthesized, otherwise an error is raised*

**>>>** [x, x\*\*2 **for** x **in** range(6)]

File "<stdin>", line 1, in ?

[x, x\*\*2 for x in range(6)]

^

SyntaxError: invalid syntax

**>>>** *# flatten a list using a listcomp with two 'for'*

**>>>** vec = [[1,2,3], [4,5,6], [7,8,9]]

**>>>** [num **for** elem **in** vec **for** num **in** elem]

[1, 2, 3, 4, 5, 6, 7, 8, 9]

List comprehensions can contain complex expressions and nested functions:

>>>

**>>> from** **math** **import** pi

**>>>** [str(round(pi, i)) **for** i **in** range(1, 6)]

['3.1', '3.14', '3.142', '3.1416', '3.14159']

### 5.1.4. Nested List Comprehensions

The initial expression in a list comprehension can be any arbitrary expression, including another list comprehension.

Consider the following example of a 3x4 matrix implemented as a list of 3 lists of length 4:

>>>

**>>>** matrix = [

**...**  [1, 2, 3, 4],

**...**  [5, 6, 7, 8],

**...**  [9, 10, 11, 12],

**...** ]

The following list comprehension will transpose rows and columns:

>>>

**>>>** [[row[i] **for** row **in** matrix] **for** i **in** range(4)]

[[1, 5, 9], [2, 6, 10], [3, 7, 11], [4, 8, 12]]

As we saw in the previous section, the nested listcomp is evaluated in the context of the [for](https://docs.python.org/3/reference/compound_stmts.html#for) that follows it, so this example is equivalent to:

>>>

**>>>** transposed = []

**>>> for** i **in** range(4):

**...**  transposed.append([row[i] **for** row **in** matrix])

**...**

**>>>** transposed

[[1, 5, 9], [2, 6, 10], [3, 7, 11], [4, 8, 12]]

which, in turn, is the same as:

>>>

**>>>** transposed = []

**>>> for** i **in** range(4):

**...**  *# the following 3 lines implement the nested listcomp*

**...**  transposed\_row = []

**...**  **for** row **in** matrix:

**...**  transposed\_row.append(row[i])

**...**  transposed.append(transposed\_row)

**...**

**>>>** transposed

[[1, 5, 9], [2, 6, 10], [3, 7, 11], [4, 8, 12]]

In the real world, you should prefer built-in functions to complex flow statements. The [zip()](https://docs.python.org/3/library/functions.html#zip) function would do a great job for this use case:

>>>

**>>>** list(zip(\*matrix))

[(1, 5, 9), (2, 6, 10), (3, 7, 11), (4, 8, 12)]

See [Unpacking Argument Lists](https://docs.python.org/3/tutorial/controlflow.html#tut-unpacking-arguments) for details on the asterisk in this line.

## 5.2. The [del](https://docs.python.org/3/reference/simple_stmts.html#del) statement

There is a way to remove an item from a list given its index instead of its value: the [del](https://docs.python.org/3/reference/simple_stmts.html#del) statement. This differs from the pop() method which returns a value. The [del](https://docs.python.org/3/reference/simple_stmts.html#del) statement can also be used to remove slices from a list or clear the entire list (which we did earlier by assignment of an empty list to the slice). For example:

>>>

**>>>** a = [-1, 1, 66.25, 333, 333, 1234.5]

**>>> del** a[0]

**>>>** a

[1, 66.25, 333, 333, 1234.5]

**>>> del** a[2:4]

**>>>** a

[1, 66.25, 1234.5]

**>>> del** a[:]

**>>>** a

[]

[del](https://docs.python.org/3/reference/simple_stmts.html#del) can also be used to delete entire variables:

>>>

**>>> del** a

Referencing the name a hereafter is an error (at least until another value is assigned to it). We’ll find other uses for [del](https://docs.python.org/3/reference/simple_stmts.html#del) later.

## 5.3. Tuples and Sequences

We saw that lists and strings have many common properties, such as indexing and slicing operations. They are two examples of sequence data types (see [Sequence Types — list, tuple, range](https://docs.python.org/3/library/stdtypes.html#typesseq)). Since Python is an evolving language, other sequence data types may be added. There is also another standard sequence data type: the tuple.

A tuple consists of a number of values separated by commas, for instance:

>>>

**>>>** t = 12345, 54321, 'hello!'

**>>>** t[0]

12345

**>>>** t

(12345, 54321, 'hello!')

**>>>** *# Tuples may be nested:*

**...** u = t, (1, 2, 3, 4, 5)

**>>>** u

((12345, 54321, 'hello!'), (1, 2, 3, 4, 5))

**>>>** *# Tuples are immutable:*

**...** t[0] = 88888

Traceback (most recent call last):

File "<stdin>", line 1, in <module>

TypeError: 'tuple' object does not support item assignment

**>>>** *# but they can contain mutable objects:*

**...** v = ([1, 2, 3], [3, 2, 1])

**>>>** v

([1, 2, 3], [3, 2, 1])

As you see, on output tuples are always enclosed in parentheses, so that nested tuples are interpreted correctly; they may be input with or without surrounding parentheses, although often parentheses are necessary anyway (if the tuple is part of a larger expression). It is not possible to assign to the individual items of a tuple, however it is possible to create tuples which contain mutable objects, such as lists.

Though tuples may seem similar to lists, they are often used in different situations and for different purposes. Tuples are [immutable](https://docs.python.org/3/glossary.html#term-immutable), and usually contain a heterogeneous sequence of elements that are accessed via unpacking (see later in this section) or indexing (or even by attribute in the case of[namedtuples](https://docs.python.org/3/library/collections.html#collections.namedtuple)). Lists are [mutable](https://docs.python.org/3/glossary.html#term-mutable), and their elements are usually homogeneous and are accessed by iterating over the list.

A special problem is the construction of tuples containing 0 or 1 items: the syntax has some extra quirks to accommodate these. Empty tuples are constructed by an empty pair of parentheses; a tuple with one item is constructed by following a value with a comma (it is not sufficient to enclose a single value in parentheses). Ugly, but effective. For example:

>>>

**>>>** empty = ()

**>>>** singleton = 'hello', *# <-- note trailing comma*

**>>>** len(empty)

0

**>>>** len(singleton)

1

**>>>** singleton

('hello',)

The statement t = 12345, 54321, 'hello!' is an example of tuple packing: the values 12345,54321 and 'hello!' are packed together in a tuple. The reverse operation is also possible:

>>>

**>>>** x, y, z = t

This is called, appropriately enough, sequence unpacking and works for any sequence on the right-hand side. Sequence unpacking requires that there are as many variables on the left side of the equals sign as there are elements in the sequence. Note that multiple assignment is really just a combination of tuple packing and sequence unpacking.

## 5.4. Sets

Python also includes a data type for sets. A set is an unordered collection with no duplicate elements. Basic uses include membership testing and eliminating duplicate entries. Set objects also support mathematical operations like union, intersection, difference, and symmetric difference.

Curly braces or the [set()](https://docs.python.org/3/library/stdtypes.html#set) function can be used to create sets. Note: to create an empty set you have to use set(), not {}; the latter creates an empty dictionary, a data structure that we discuss in the next section.

Here is a brief demonstration:

>>>

**>>>** basket = {'apple', 'orange', 'apple', 'pear', 'orange', 'banana'}

**>>>** print(basket) *# show that duplicates have been removed*

{'orange', 'banana', 'pear', 'apple'}

**>>>** 'orange' **in** basket *# fast membership testing*

True

**>>>** 'crabgrass' **in** basket

False

**>>>** *# Demonstrate set operations on unique letters from two words*

**...**

**>>>** a = set('abracadabra')

**>>>** b = set('alacazam')

**>>>** a *# unique letters in a*

{'a', 'r', 'b', 'c', 'd'}

**>>>** a - b *# letters in a but not in b*

{'r', 'd', 'b'}

**>>>** a | b *# letters in either a or b*

{'a', 'c', 'r', 'd', 'b', 'm', 'z', 'l'}

**>>>** a & b *# letters in both a and b*

{'a', 'c'}

**>>>** a ^ b *# letters in a or b but not both*

{'r', 'd', 'b', 'm', 'z', 'l'}

Similarly to [list comprehensions](https://docs.python.org/3/tutorial/datastructures.html#tut-listcomps), set comprehensions are also supported:

>>>

**>>>** a = {x **for** x **in** 'abracadabra' **if** x **not** **in** 'abc'}

**>>>** a

{'r', 'd'}

## 5.5. Dictionaries

Another useful data type built into Python is the dictionary (see [Mapping Types — dict](https://docs.python.org/3/library/stdtypes.html#typesmapping)). Dictionaries are sometimes found in other languages as “associative memories” or “associative arrays”. Unlike sequences, which are indexed by a range of numbers, dictionaries are indexed by keys, which can be any immutable type; strings and numbers can always be keys. Tuples can be used as keys if they contain only strings, numbers, or tuples; if a tuple contains any mutable object either directly or indirectly, it cannot be used as a key. You can’t use lists as keys, since lists can be modified in place using index assignments, slice assignments, or methods like append() and extend().

It is best to think of a dictionary as an unordered set of key: value pairs, with the requirement that the keys are unique (within one dictionary). A pair of braces creates an empty dictionary: {}. Placing a comma-separated list of key:value pairs within the braces adds initial key:value pairs to the dictionary; this is also the way dictionaries are written on output.

The main operations on a dictionary are storing a value with some key and extracting the value given the key. It is also possible to delete a key:value pair with del. If you store using a key that is already in use, the old value associated with that key is forgotten. It is an error to extract a value using a non-existent key.

Performing list(d.keys()) on a dictionary returns a list of all the keys used in the dictionary, in arbitrary order (if you want it sorted, just use sorted(d.keys()) instead). [[2]](https://docs.python.org/3/tutorial/datastructures.html#id4) To check whether a single key is in the dictionary, use the [in](https://docs.python.org/3/reference/expressions.html#in) keyword.

Here is a small example using a dictionary:

>>>

**>>>** tel = {'jack': 4098, 'sape': 4139}

**>>>** tel['guido'] = 4127

**>>>** tel

{'sape': 4139, 'guido': 4127, 'jack': 4098}

**>>>** tel['jack']

4098

**>>> del** tel['sape']

**>>>** tel['irv'] = 4127

**>>>** tel

{'guido': 4127, 'irv': 4127, 'jack': 4098}

**>>>** list(tel.keys())

['irv', 'guido', 'jack']

**>>>** sorted(tel.keys())

['guido', 'irv', 'jack']

**>>>** 'guido' **in** tel

True

**>>>** 'jack' **not** **in** tel

False

The [dict()](https://docs.python.org/3/library/stdtypes.html#dict) constructor builds dictionaries directly from sequences of key-value pairs:

>>>

**>>>** dict([('sape', 4139), ('guido', 4127), ('jack', 4098)])

{'sape': 4139, 'jack': 4098, 'guido': 4127}

In addition, dict comprehensions can be used to create dictionaries from arbitrary key and value expressions:

>>>

**>>>** {x: x\*\*2 **for** x **in** (2, 4, 6)}

{2: 4, 4: 16, 6: 36}

When the keys are simple strings, it is sometimes easier to specify pairs using keyword arguments:

>>>

**>>>** dict(sape=4139, guido=4127, jack=4098)

{'sape': 4139, 'jack': 4098, 'guido': 4127}

## 5.6. Looping Techniques

When looping through dictionaries, the key and corresponding value can be retrieved at the same time using the items() method.

>>>

**>>>** knights = {'gallahad': 'the pure', 'robin': 'the brave'}

**>>> for** k, v **in** knights.items():

**...**  print(k, v)

**...**

gallahad the pure

robin the brave

When looping through a sequence, the position index and corresponding value can be retrieved at the same time using the [enumerate()](https://docs.python.org/3/library/functions.html#enumerate) function.

>>>

**>>> for** i, v **in** enumerate(['tic', 'tac', 'toe']):

**...**  print(i, v)

**...**

0 tic

1 tac

2 toe

To loop over two or more sequences at the same time, the entries can be paired with the [zip()](https://docs.python.org/3/library/functions.html#zip)function.

>>>

**>>>** questions = ['name', 'quest', 'favorite color']

**>>>** answers = ['lancelot', 'the holy grail', 'blue']

**>>> for** q, a **in** zip(questions, answers):

**...**  print('What is your *{0}*? It is *{1}*.'.format(q, a))

**...**

What is your name? It is lancelot.

What is your quest? It is the holy grail.

What is your favorite color? It is blue.

To loop over a sequence in reverse, first specify the sequence in a forward direction and then call the[reversed()](https://docs.python.org/3/library/functions.html#reversed) function.

>>>

**>>> for** i **in** reversed(range(1, 10, 2)):

**...**  print(i)

**...**

9

7

5

3

1

To loop over a sequence in sorted order, use the [sorted()](https://docs.python.org/3/library/functions.html#sorted) function which returns a new sorted list while leaving the source unaltered.

>>>

**>>>** basket = ['apple', 'orange', 'apple', 'pear', 'orange', 'banana']

**>>> for** f **in** sorted(set(basket)):

**...**  print(f)

**...**

apple

banana

orange

pear

It is sometimes tempting to change a list while you are looping over it; however, it is often simpler and safer to create a new list instead.

>>>

**>>> import** **math**

**>>>** raw\_data = [56.2, float('NaN'), 51.7, 55.3, 52.5, float('NaN'), 47.8]

**>>>** filtered\_data = []

**>>> for** value **in** raw\_data:

**...**  **if** **not** math.isnan(value):

**...**  filtered\_data.append(value)

**...**

**>>>** filtered\_data

[56.2, 51.7, 55.3, 52.5, 47.8]

## 5.7. More on Conditions

The conditions used in while and if statements can contain any operators, not just comparisons.

The comparison operators in and not in check whether a value occurs (does not occur) in a sequence. The operators is and is not compare whether two objects are really the same object; this only matters for mutable objects like lists. All comparison operators have the same priority, which is lower than that of all numerical operators.

Comparisons can be chained. For example, a < b == c tests whether a is less than b and moreoverb equals c.

Comparisons may be combined using the Boolean operators and and or, and the outcome of a comparison (or of any other Boolean expression) may be negated with not. These have lower priorities than comparison operators; between them, not has the highest priority and or the lowest, so that A and not B or C is equivalent to (A and (not B)) or C. As always, parentheses can be used to express the desired composition.

The Boolean operators and and or are so-called short-circuit operators: their arguments are evaluated from left to right, and evaluation stops as soon as the outcome is determined. For example, if A and C are true but B is false, A and B and C does not evaluate the expression C. When used as a general value and not as a Boolean, the return value of a short-circuit operator is the last evaluated argument.

It is possible to assign the result of a comparison or other Boolean expression to a variable. For example,

>>>

**>>>** string1, string2, string3 = '', 'Trondheim', 'Hammer Dance'

**>>>** non\_null = string1 **or** string2 **or** string3

**>>>** non\_null

'Trondheim'

Note that in Python, unlike C, assignment cannot occur inside expressions. C programmers may grumble about this, but it avoids a common class of problems encountered in C programs: typing = in an expression when == was intended.

## 5.8. Comparing Sequences and Other Types

Sequence objects may be compared to other objects with the same sequence type. The comparison uses lexicographical ordering: first the first two items are compared, and if they differ this determines the outcome of the comparison; if they are equal, the next two items are compared, and so on, until either sequence is exhausted. If two items to be compared are themselves sequences of the same type, the lexicographical comparison is carried out recursively. If all items of two sequences compare equal, the sequences are considered equal. If one sequence is an initial sub-sequence of the other, the shorter sequence is the smaller (lesser) one. Lexicographical ordering for strings uses the Unicode code point number to order individual characters. Some examples of comparisons between sequences of the same type:

(1, 2, 3) < (1, 2, 4)

[1, 2, 3] < [1, 2, 4]

'ABC' < 'C' < 'Pascal' < 'Python'

(1, 2, 3, 4) < (1, 2, 4)

(1, 2) < (1, 2, -1)

(1, 2, 3) == (1.0, 2.0, 3.0)

(1, 2, ('aa', 'ab')) < (1, 2, ('abc', 'a'), 4)

Note that comparing objects of different types with < or > is legal provided that the objects have appropriate comparison methods. For example, mixed numeric types are compared according to their numeric value, so 0 equals 0.0, etc. Otherwise, rather than providing an arbitrary ordering, the interpreter will raise a [TypeError](https://docs.python.org/3/library/exceptions.html#TypeError) exception.

**Footnotes**

|  |  |
| --- | --- |
| [[1]](https://docs.python.org/3/tutorial/datastructures.html#id1) | Other languages may return the mutated object, which allows method chaining, such as d->insert("a")->remove("b")->sort();. |

|  |  |
| --- | --- |
| [[2]](https://docs.python.org/3/tutorial/datastructures.html#id2) | Calling d.keys() will return a dictionary view object. It supports operations like membership test and iteration, but its contents are not independent of the original dictionary – it is only aview. |

# 5. Data Structures

This chapter describes some things you’ve learned about already in more detail, and adds some new things as well.

## 5.1. More on Lists

The list data type has some more methods. Here are all of the methods of list objects:

list.**append**(x)

Add an item to the end of the list. Equivalent to a[len(a):] = [x].

list.**extend**(L)

Extend the list by appending all the items in the given list. Equivalent to a[len(a):] = L.

list.**insert**(i, x)

Insert an item at a given position. The first argument is the index of the element before which to insert, so a.insert(0, x) inserts at the front of the list, and a.insert(len(a), x) is equivalent to a.append(x).

list.**remove**(x)

Remove the first item from the list whose value is x. It is an error if there is no such item.

list.**pop**([i])

Remove the item at the given position in the list, and return it. If no index is specified, a.pop()removes and returns the last item in the list. (The square brackets around the i in the method signature denote that the parameter is optional, not that you should type square brackets at that position. You will see this notation frequently in the Python Library Reference.)

list.**clear**()

Remove all items from the list. Equivalent to del a[:].

list.**index**(x)

Return the index in the list of the first item whose value is x. It is an error if there is no such item.

list.**count**(x)

Return the number of times x appears in the list.

list.**sort**(key=None, reverse=False)

Sort the items of the list in place (the arguments can be used for sort customization, see[sorted()](https://docs.python.org/3/library/functions.html#sorted) for their explanation).

list.**reverse**()

Reverse the elements of the list in place.

list.**copy**()

Return a shallow copy of the list. Equivalent to a[:].

An example that uses most of the list methods:

>>>

**>>>** a = [66.25, 333, 333, 1, 1234.5]

**>>>** print(a.count(333), a.count(66.25), a.count('x'))

2 1 0

**>>>** a.insert(2, -1)

**>>>** a.append(333)

**>>>** a

[66.25, 333, -1, 333, 1, 1234.5, 333]

**>>>** a.index(333)

1

**>>>** a.remove(333)

**>>>** a

[66.25, -1, 333, 1, 1234.5, 333]

**>>>** a.reverse()

**>>>** a

[333, 1234.5, 1, 333, -1, 66.25]

**>>>** a.sort()

**>>>** a

[-1, 1, 66.25, 333, 333, 1234.5]

**>>>** a.pop()

1234.5

**>>>** a

[-1, 1, 66.25, 333, 333]

You might have noticed that methods like insert, remove or sort that only modify the list have no return value printed – they return the default None. [[1]](https://docs.python.org/3/tutorial/datastructures.html#id3) This is a design principle for all mutable data structures in Python.

### 5.1.1. Using Lists as Stacks

The list methods make it very easy to use a list as a stack, where the last element added is the first element retrieved (“last-in, first-out”). To add an item to the top of the stack, use append(). To retrieve an item from the top of the stack, use pop() without an explicit index. For example:

>>>

**>>>** stack = [3, 4, 5]

**>>>** stack.append(6)

**>>>** stack.append(7)

**>>>** stack

[3, 4, 5, 6, 7]

**>>>** stack.pop()

7

**>>>** stack

[3, 4, 5, 6]

**>>>** stack.pop()

6

**>>>** stack.pop()

5

**>>>** stack

[3, 4]

### 5.1.2. Using Lists as Queues

It is also possible to use a list as a queue, where the first element added is the first element retrieved (“first-in, first-out”); however, lists are not efficient for this purpose. While appends and pops from the end of list are fast, doing inserts or pops from the beginning of a list is slow (because all of the other elements have to be shifted by one).

To implement a queue, use [collections.deque](https://docs.python.org/3/library/collections.html#collections.deque) which was designed to have fast appends and pops from both ends. For example:

>>>

**>>> from** **collections** **import** deque

**>>>** queue = deque(["Eric", "John", "Michael"])

**>>>** queue.append("Terry") *# Terry arrives*

**>>>** queue.append("Graham") *# Graham arrives*

**>>>** queue.popleft() *# The first to arrive now leaves*

'Eric'

**>>>** queue.popleft() *# The second to arrive now leaves*

'John'

**>>>** queue *# Remaining queue in order of arrival*

deque(['Michael', 'Terry', 'Graham'])

### 5.1.3. List Comprehensions

List comprehensions provide a concise way to create lists. Common applications are to make new lists where each element is the result of some operations applied to each member of another sequence or iterable, or to create a subsequence of those elements that satisfy a certain condition.

For example, assume we want to create a list of squares, like:

>>>

**>>>** squares = []

**>>> for** x **in** range(10):

**...**  squares.append(x\*\*2)

**...**

**>>>** squares

[0, 1, 4, 9, 16, 25, 36, 49, 64, 81]

Note that this creates (or overwrites) a variable named x that still exists after the loop completes. We can calculate the list of squares without any side effects using:

squares = list(map(**lambda** x: x\*\*2, range(10)))

or, equivalently:

squares = [x\*\*2 **for** x **in** range(10)]

which is more concise and readable.

A list comprehension consists of brackets containing an expression followed by a [for](https://docs.python.org/3/reference/compound_stmts.html#for) clause, then zero or more [for](https://docs.python.org/3/reference/compound_stmts.html#for) or [if](https://docs.python.org/3/reference/compound_stmts.html#if) clauses. The result will be a new list resulting from evaluating the expression in the context of the [for](https://docs.python.org/3/reference/compound_stmts.html#for) and [if](https://docs.python.org/3/reference/compound_stmts.html#if) clauses which follow it. For example, this listcomp combines the elements of two lists if they are not equal:

>>>

**>>>** [(x, y) **for** x **in** [1,2,3] **for** y **in** [3,1,4] **if** x != y]

[(1, 3), (1, 4), (2, 3), (2, 1), (2, 4), (3, 1), (3, 4)]

and it’s equivalent to:

>>>

**>>>** combs = []

**>>> for** x **in** [1,2,3]:

**...**  **for** y **in** [3,1,4]:

**...**  **if** x != y:

**...**  combs.append((x, y))

**...**

**>>>** combs

[(1, 3), (1, 4), (2, 3), (2, 1), (2, 4), (3, 1), (3, 4)]

Note how the order of the [for](https://docs.python.org/3/reference/compound_stmts.html#for) and [if](https://docs.python.org/3/reference/compound_stmts.html#if) statements is the same in both these snippets.

If the expression is a tuple (e.g. the (x, y) in the previous example), it must be parenthesized.

>>>

**>>>** vec = [-4, -2, 0, 2, 4]

**>>>** *# create a new list with the values doubled*

**>>>** [x\*2 **for** x **in** vec]

[-8, -4, 0, 4, 8]

**>>>** *# filter the list to exclude negative numbers*

**>>>** [x **for** x **in** vec **if** x >= 0]

[0, 2, 4]

**>>>** *# apply a function to all the elements*

**>>>** [abs(x) **for** x **in** vec]

[4, 2, 0, 2, 4]

**>>>** *# call a method on each element*

**>>>** freshfruit = [' banana', ' loganberry ', 'passion fruit ']

**>>>** [weapon.strip() **for** weapon **in** freshfruit]

['banana', 'loganberry', 'passion fruit']

**>>>** *# create a list of 2-tuples like (number, square)*

**>>>** [(x, x\*\*2) **for** x **in** range(6)]

[(0, 0), (1, 1), (2, 4), (3, 9), (4, 16), (5, 25)]

**>>>** *# the tuple must be parenthesized, otherwise an error is raised*

**>>>** [x, x\*\*2 **for** x **in** range(6)]

File "<stdin>", line 1, in ?

[x, x\*\*2 for x in range(6)]

^

SyntaxError: invalid syntax

**>>>** *# flatten a list using a listcomp with two 'for'*

**>>>** vec = [[1,2,3], [4,5,6], [7,8,9]]

**>>>** [num **for** elem **in** vec **for** num **in** elem]

[1, 2, 3, 4, 5, 6, 7, 8, 9]

List comprehensions can contain complex expressions and nested functions:

>>>

**>>> from** **math** **import** pi

**>>>** [str(round(pi, i)) **for** i **in** range(1, 6)]

['3.1', '3.14', '3.142', '3.1416', '3.14159']

### 5.1.4. Nested List Comprehensions

The initial expression in a list comprehension can be any arbitrary expression, including another list comprehension.

Consider the following example of a 3x4 matrix implemented as a list of 3 lists of length 4:

>>>

**>>>** matrix = [

**...**  [1, 2, 3, 4],

**...**  [5, 6, 7, 8],

**...**  [9, 10, 11, 12],

**...** ]

The following list comprehension will transpose rows and columns:

>>>

**>>>** [[row[i] **for** row **in** matrix] **for** i **in** range(4)]

[[1, 5, 9], [2, 6, 10], [3, 7, 11], [4, 8, 12]]

As we saw in the previous section, the nested listcomp is evaluated in the context of the [for](https://docs.python.org/3/reference/compound_stmts.html#for) that follows it, so this example is equivalent to:

>>>

**>>>** transposed = []

**>>> for** i **in** range(4):

**...**  transposed.append([row[i] **for** row **in** matrix])

**...**

**>>>** transposed

[[1, 5, 9], [2, 6, 10], [3, 7, 11], [4, 8, 12]]

which, in turn, is the same as:

>>>

**>>>** transposed = []

**>>> for** i **in** range(4):

**...**  *# the following 3 lines implement the nested listcomp*

**...**  transposed\_row = []

**...**  **for** row **in** matrix:

**...**  transposed\_row.append(row[i])

**...**  transposed.append(transposed\_row)

**...**

**>>>** transposed

[[1, 5, 9], [2, 6, 10], [3, 7, 11], [4, 8, 12]]

In the real world, you should prefer built-in functions to complex flow statements. The [zip()](https://docs.python.org/3/library/functions.html#zip) function would do a great job for this use case:

>>>

**>>>** list(zip(\*matrix))

[(1, 5, 9), (2, 6, 10), (3, 7, 11), (4, 8, 12)]

See [Unpacking Argument Lists](https://docs.python.org/3/tutorial/controlflow.html#tut-unpacking-arguments) for details on the asterisk in this line.

## 5.2. The [del](https://docs.python.org/3/reference/simple_stmts.html#del) statement

There is a way to remove an item from a list given its index instead of its value: the [del](https://docs.python.org/3/reference/simple_stmts.html#del) statement. This differs from the pop() method which returns a value. The [del](https://docs.python.org/3/reference/simple_stmts.html#del) statement can also be used to remove slices from a list or clear the entire list (which we did earlier by assignment of an empty list to the slice). For example:

>>>

**>>>** a = [-1, 1, 66.25, 333, 333, 1234.5]

**>>> del** a[0]

**>>>** a

[1, 66.25, 333, 333, 1234.5]

**>>> del** a[2:4]

**>>>** a

[1, 66.25, 1234.5]

**>>> del** a[:]

**>>>** a

[]

[del](https://docs.python.org/3/reference/simple_stmts.html#del) can also be used to delete entire variables:

>>>

**>>> del** a

Referencing the name a hereafter is an error (at least until another value is assigned to it). We’ll find other uses for [del](https://docs.python.org/3/reference/simple_stmts.html#del) later.

## 5.3. Tuples and Sequences

We saw that lists and strings have many common properties, such as indexing and slicing operations. They are two examples of sequence data types (see [Sequence Types — list, tuple, range](https://docs.python.org/3/library/stdtypes.html#typesseq)). Since Python is an evolving language, other sequence data types may be added. There is also another standard sequence data type: the tuple.

A tuple consists of a number of values separated by commas, for instance:

>>>

**>>>** t = 12345, 54321, 'hello!'

**>>>** t[0]

12345

**>>>** t

(12345, 54321, 'hello!')

**>>>** *# Tuples may be nested:*

**...** u = t, (1, 2, 3, 4, 5)

**>>>** u

((12345, 54321, 'hello!'), (1, 2, 3, 4, 5))

**>>>** *# Tuples are immutable:*

**...** t[0] = 88888

Traceback (most recent call last):

File "<stdin>", line 1, in <module>

TypeError: 'tuple' object does not support item assignment

**>>>** *# but they can contain mutable objects:*

**...** v = ([1, 2, 3], [3, 2, 1])

**>>>** v

([1, 2, 3], [3, 2, 1])

As you see, on output tuples are always enclosed in parentheses, so that nested tuples are interpreted correctly; they may be input with or without surrounding parentheses, although often parentheses are necessary anyway (if the tuple is part of a larger expression). It is not possible to assign to the individual items of a tuple, however it is possible to create tuples which contain mutable objects, such as lists.

Though tuples may seem similar to lists, they are often used in different situations and for different purposes. Tuples are [immutable](https://docs.python.org/3/glossary.html#term-immutable), and usually contain a heterogeneous sequence of elements that are accessed via unpacking (see later in this section) or indexing (or even by attribute in the case of[namedtuples](https://docs.python.org/3/library/collections.html#collections.namedtuple)). Lists are [mutable](https://docs.python.org/3/glossary.html#term-mutable), and their elements are usually homogeneous and are accessed by iterating over the list.

A special problem is the construction of tuples containing 0 or 1 items: the syntax has some extra quirks to accommodate these. Empty tuples are constructed by an empty pair of parentheses; a tuple with one item is constructed by following a value with a comma (it is not sufficient to enclose a single value in parentheses). Ugly, but effective. For example:

>>>

**>>>** empty = ()

**>>>** singleton = 'hello', *# <-- note trailing comma*

**>>>** len(empty)

0

**>>>** len(singleton)

1

**>>>** singleton

('hello',)

The statement t = 12345, 54321, 'hello!' is an example of tuple packing: the values 12345,54321 and 'hello!' are packed together in a tuple. The reverse operation is also possible:

>>>

**>>>** x, y, z = t

This is called, appropriately enough, sequence unpacking and works for any sequence on the right-hand side. Sequence unpacking requires that there are as many variables on the left side of the equals sign as there are elements in the sequence. Note that multiple assignment is really just a combination of tuple packing and sequence unpacking.

## 5.4. Sets

Python also includes a data type for sets. A set is an unordered collection with no duplicate elements. Basic uses include membership testing and eliminating duplicate entries. Set objects also support mathematical operations like union, intersection, difference, and symmetric difference.

Curly braces or the [set()](https://docs.python.org/3/library/stdtypes.html#set) function can be used to create sets. Note: to create an empty set you have to use set(), not {}; the latter creates an empty dictionary, a data structure that we discuss in the next section.

Here is a brief demonstration:

>>>

**>>>** basket = {'apple', 'orange', 'apple', 'pear', 'orange', 'banana'}

**>>>** print(basket) *# show that duplicates have been removed*

{'orange', 'banana', 'pear', 'apple'}

**>>>** 'orange' **in** basket *# fast membership testing*

True

**>>>** 'crabgrass' **in** basket

False

**>>>** *# Demonstrate set operations on unique letters from two words*

**...**

**>>>** a = set('abracadabra')

**>>>** b = set('alacazam')

**>>>** a *# unique letters in a*

{'a', 'r', 'b', 'c', 'd'}

**>>>** a - b *# letters in a but not in b*

{'r', 'd', 'b'}

**>>>** a | b *# letters in either a or b*

{'a', 'c', 'r', 'd', 'b', 'm', 'z', 'l'}

**>>>** a & b *# letters in both a and b*

{'a', 'c'}

**>>>** a ^ b *# letters in a or b but not both*

{'r', 'd', 'b', 'm', 'z', 'l'}

Similarly to [list comprehensions](https://docs.python.org/3/tutorial/datastructures.html#tut-listcomps), set comprehensions are also supported:

>>>

**>>>** a = {x **for** x **in** 'abracadabra' **if** x **not** **in** 'abc'}

**>>>** a

{'r', 'd'}

## 5.5. Dictionaries

Another useful data type built into Python is the dictionary (see [Mapping Types — dict](https://docs.python.org/3/library/stdtypes.html#typesmapping)). Dictionaries are sometimes found in other languages as “associative memories” or “associative arrays”. Unlike sequences, which are indexed by a range of numbers, dictionaries are indexed by keys, which can be any immutable type; strings and numbers can always be keys. Tuples can be used as keys if they contain only strings, numbers, or tuples; if a tuple contains any mutable object either directly or indirectly, it cannot be used as a key. You can’t use lists as keys, since lists can be modified in place using index assignments, slice assignments, or methods like append() and extend().

It is best to think of a dictionary as an unordered set of key: value pairs, with the requirement that the keys are unique (within one dictionary). A pair of braces creates an empty dictionary: {}. Placing a comma-separated list of key:value pairs within the braces adds initial key:value pairs to the dictionary; this is also the way dictionaries are written on output.

The main operations on a dictionary are storing a value with some key and extracting the value given the key. It is also possible to delete a key:value pair with del. If you store using a key that is already in use, the old value associated with that key is forgotten. It is an error to extract a value using a non-existent key.

Performing list(d.keys()) on a dictionary returns a list of all the keys used in the dictionary, in arbitrary order (if you want it sorted, just use sorted(d.keys()) instead). [[2]](https://docs.python.org/3/tutorial/datastructures.html#id4) To check whether a single key is in the dictionary, use the [in](https://docs.python.org/3/reference/expressions.html#in) keyword.

Here is a small example using a dictionary:

>>>

**>>>** tel = {'jack': 4098, 'sape': 4139}

**>>>** tel['guido'] = 4127

**>>>** tel

{'sape': 4139, 'guido': 4127, 'jack': 4098}

**>>>** tel['jack']

4098

**>>> del** tel['sape']

**>>>** tel['irv'] = 4127

**>>>** tel

{'guido': 4127, 'irv': 4127, 'jack': 4098}

**>>>** list(tel.keys())

['irv', 'guido', 'jack']

**>>>** sorted(tel.keys())

['guido', 'irv', 'jack']

**>>>** 'guido' **in** tel

True

**>>>** 'jack' **not** **in** tel

False

The [dict()](https://docs.python.org/3/library/stdtypes.html#dict) constructor builds dictionaries directly from sequences of key-value pairs:

>>>

**>>>** dict([('sape', 4139), ('guido', 4127), ('jack', 4098)])

{'sape': 4139, 'jack': 4098, 'guido': 4127}

In addition, dict comprehensions can be used to create dictionaries from arbitrary key and value expressions:

>>>

**>>>** {x: x\*\*2 **for** x **in** (2, 4, 6)}

{2: 4, 4: 16, 6: 36}

When the keys are simple strings, it is sometimes easier to specify pairs using keyword arguments:

>>>

**>>>** dict(sape=4139, guido=4127, jack=4098)

{'sape': 4139, 'jack': 4098, 'guido': 4127}

## 5.6. Looping Techniques

When looping through dictionaries, the key and corresponding value can be retrieved at the same time using the items() method.

>>>

**>>>** knights = {'gallahad': 'the pure', 'robin': 'the brave'}

**>>> for** k, v **in** knights.items():

**...**  print(k, v)

**...**

gallahad the pure

robin the brave

When looping through a sequence, the position index and corresponding value can be retrieved at the same time using the [enumerate()](https://docs.python.org/3/library/functions.html#enumerate) function.

>>>

**>>> for** i, v **in** enumerate(['tic', 'tac', 'toe']):

**...**  print(i, v)

**...**

0 tic

1 tac

2 toe

To loop over two or more sequences at the same time, the entries can be paired with the [zip()](https://docs.python.org/3/library/functions.html#zip)function.

>>>

**>>>** questions = ['name', 'quest', 'favorite color']

**>>>** answers = ['lancelot', 'the holy grail', 'blue']

**>>> for** q, a **in** zip(questions, answers):

**...**  print('What is your *{0}*? It is *{1}*.'.format(q, a))

**...**

What is your name? It is lancelot.

What is your quest? It is the holy grail.

What is your favorite color? It is blue.

To loop over a sequence in reverse, first specify the sequence in a forward direction and then call the[reversed()](https://docs.python.org/3/library/functions.html#reversed) function.

>>>

**>>> for** i **in** reversed(range(1, 10, 2)):

**...**  print(i)

**...**

9

7

5

3

1

To loop over a sequence in sorted order, use the [sorted()](https://docs.python.org/3/library/functions.html#sorted) function which returns a new sorted list while leaving the source unaltered.

>>>

**>>>** basket = ['apple', 'orange', 'apple', 'pear', 'orange', 'banana']

**>>> for** f **in** sorted(set(basket)):

**...**  print(f)

**...**

apple

banana

orange

pear

It is sometimes tempting to change a list while you are looping over it; however, it is often simpler and safer to create a new list instead.

>>>

**>>> import** **math**

**>>>** raw\_data = [56.2, float('NaN'), 51.7, 55.3, 52.5, float('NaN'), 47.8]

**>>>** filtered\_data = []

**>>> for** value **in** raw\_data:

**...**  **if** **not** math.isnan(value):

**...**  filtered\_data.append(value)

**...**

**>>>** filtered\_data

[56.2, 51.7, 55.3, 52.5, 47.8]

## 5.7. More on Conditions

The conditions used in while and if statements can contain any operators, not just comparisons.

The comparison operators in and not in check whether a value occurs (does not occur) in a sequence. The operators is and is not compare whether two objects are really the same object; this only matters for mutable objects like lists. All comparison operators have the same priority, which is lower than that of all numerical operators.

Comparisons can be chained. For example, a < b == c tests whether a is less than b and moreoverb equals c.

Comparisons may be combined using the Boolean operators and and or, and the outcome of a comparison (or of any other Boolean expression) may be negated with not. These have lower priorities than comparison operators; between them, not has the highest priority and or the lowest, so that A and not B or C is equivalent to (A and (not B)) or C. As always, parentheses can be used to express the desired composition.

The Boolean operators and and or are so-called short-circuit operators: their arguments are evaluated from left to right, and evaluation stops as soon as the outcome is determined. For example, if A and C are true but B is false, A and B and C does not evaluate the expression C. When used as a general value and not as a Boolean, the return value of a short-circuit operator is the last evaluated argument.

It is possible to assign the result of a comparison or other Boolean expression to a variable. For example,

>>>

**>>>** string1, string2, string3 = '', 'Trondheim', 'Hammer Dance'

**>>>** non\_null = string1 **or** string2 **or** string3

**>>>** non\_null

'Trondheim'

Note that in Python, unlike C, assignment cannot occur inside expressions. C programmers may grumble about this, but it avoids a common class of problems encountered in C programs: typing = in an expression when == was intended.

## 5.8. Comparing Sequences and Other Types

Sequence objects may be compared to other objects with the same sequence type. The comparison uses lexicographical ordering: first the first two items are compared, and if they differ this determines the outcome of the comparison; if they are equal, the next two items are compared, and so on, until either sequence is exhausted. If two items to be compared are themselves sequences of the same type, the lexicographical comparison is carried out recursively. If all items of two sequences compare equal, the sequences are considered equal. If one sequence is an initial sub-sequence of the other, the shorter sequence is the smaller (lesser) one. Lexicographical ordering for strings uses the Unicode code point number to order individual characters. Some examples of comparisons between sequences of the same type:

(1, 2, 3) < (1, 2, 4)

[1, 2, 3] < [1, 2, 4]

'ABC' < 'C' < 'Pascal' < 'Python'

(1, 2, 3, 4) < (1, 2, 4)

(1, 2) < (1, 2, -1)

(1, 2, 3) == (1.0, 2.0, 3.0)

(1, 2, ('aa', 'ab')) < (1, 2, ('abc', 'a'), 4)

Note that comparing objects of different types with < or > is legal provided that the objects have appropriate comparison methods. For example, mixed numeric types are compared according to their numeric value, so 0 equals 0.0, etc. Otherwise, rather than providing an arbitrary ordering, the interpreter will raise a [TypeError](https://docs.python.org/3/library/exceptions.html#TypeError) exception.

**Footnotes**

|  |  |
| --- | --- |
| [[1]](https://docs.python.org/3/tutorial/datastructures.html#id1) | Other languages may return the mutated object, which allows method chaining, such as d->insert("a")->remove("b")->sort();. |

|  |  |
| --- | --- |
| [[2]](https://docs.python.org/3/tutorial/datastructures.html#id2) | Calling d.keys() will return a dictionary view object. It supports operations like membership test and iteration, but its contents are not independent of the original dictionary – it is only aview. |

# 5. Data Structures

This chapter describes some things you’ve learned about already in more detail, and adds some new things as well.

## 5.1. More on Lists

The list data type has some more methods. Here are all of the methods of list objects:

list.**append**(x)

Add an item to the end of the list. Equivalent to a[len(a):] = [x].

list.**extend**(L)

Extend the list by appending all the items in the given list. Equivalent to a[len(a):] = L.

list.**insert**(i, x)

Insert an item at a given position. The first argument is the index of the element before which to insert, so a.insert(0, x) inserts at the front of the list, and a.insert(len(a), x) is equivalent to a.append(x).

list.**remove**(x)

Remove the first item from the list whose value is x. It is an error if there is no such item.

list.**pop**([i])

Remove the item at the given position in the list, and return it. If no index is specified, a.pop()removes and returns the last item in the list. (The square brackets around the i in the method signature denote that the parameter is optional, not that you should type square brackets at that position. You will see this notation frequently in the Python Library Reference.)

list.**clear**()

Remove all items from the list. Equivalent to del a[:].

list.**index**(x)

Return the index in the list of the first item whose value is x. It is an error if there is no such item.

list.**count**(x)

Return the number of times x appears in the list.

list.**sort**(key=None, reverse=False)

Sort the items of the list in place (the arguments can be used for sort customization, see[sorted()](https://docs.python.org/3/library/functions.html#sorted) for their explanation).

list.**reverse**()

Reverse the elements of the list in place.

list.**copy**()

Return a shallow copy of the list. Equivalent to a[:].

An example that uses most of the list methods:

>>>

**>>>** a = [66.25, 333, 333, 1, 1234.5]

**>>>** print(a.count(333), a.count(66.25), a.count('x'))

2 1 0

**>>>** a.insert(2, -1)

**>>>** a.append(333)

**>>>** a

[66.25, 333, -1, 333, 1, 1234.5, 333]

**>>>** a.index(333)

1

**>>>** a.remove(333)

**>>>** a

[66.25, -1, 333, 1, 1234.5, 333]

**>>>** a.reverse()

**>>>** a

[333, 1234.5, 1, 333, -1, 66.25]

**>>>** a.sort()

**>>>** a

[-1, 1, 66.25, 333, 333, 1234.5]

**>>>** a.pop()

1234.5

**>>>** a

[-1, 1, 66.25, 333, 333]

You might have noticed that methods like insert, remove or sort that only modify the list have no return value printed – they return the default None. [[1]](https://docs.python.org/3/tutorial/datastructures.html#id3) This is a design principle for all mutable data structures in Python.

### 5.1.1. Using Lists as Stacks

The list methods make it very easy to use a list as a stack, where the last element added is the first element retrieved (“last-in, first-out”). To add an item to the top of the stack, use append(). To retrieve an item from the top of the stack, use pop() without an explicit index. For example:

>>>

**>>>** stack = [3, 4, 5]

**>>>** stack.append(6)

**>>>** stack.append(7)

**>>>** stack

[3, 4, 5, 6, 7]

**>>>** stack.pop()

7

**>>>** stack

[3, 4, 5, 6]

**>>>** stack.pop()

6

**>>>** stack.pop()

5

**>>>** stack

[3, 4]

### 5.1.2. Using Lists as Queues

It is also possible to use a list as a queue, where the first element added is the first element retrieved (“first-in, first-out”); however, lists are not efficient for this purpose. While appends and pops from the end of list are fast, doing inserts or pops from the beginning of a list is slow (because all of the other elements have to be shifted by one).

To implement a queue, use [collections.deque](https://docs.python.org/3/library/collections.html#collections.deque) which was designed to have fast appends and pops from both ends. For example:

>>>

**>>> from** **collections** **import** deque

**>>>** queue = deque(["Eric", "John", "Michael"])

**>>>** queue.append("Terry") *# Terry arrives*

**>>>** queue.append("Graham") *# Graham arrives*

**>>>** queue.popleft() *# The first to arrive now leaves*

'Eric'

**>>>** queue.popleft() *# The second to arrive now leaves*

'John'

**>>>** queue *# Remaining queue in order of arrival*

deque(['Michael', 'Terry', 'Graham'])

### 5.1.3. List Comprehensions

List comprehensions provide a concise way to create lists. Common applications are to make new lists where each element is the result of some operations applied to each member of another sequence or iterable, or to create a subsequence of those elements that satisfy a certain condition.

For example, assume we want to create a list of squares, like:

>>>

**>>>** squares = []

**>>> for** x **in** range(10):

**...**  squares.append(x\*\*2)

**...**

**>>>** squares

[0, 1, 4, 9, 16, 25, 36, 49, 64, 81]

Note that this creates (or overwrites) a variable named x that still exists after the loop completes. We can calculate the list of squares without any side effects using:

squares = list(map(**lambda** x: x\*\*2, range(10)))

or, equivalently:

squares = [x\*\*2 **for** x **in** range(10)]

which is more concise and readable.

A list comprehension consists of brackets containing an expression followed by a [for](https://docs.python.org/3/reference/compound_stmts.html#for) clause, then zero or more [for](https://docs.python.org/3/reference/compound_stmts.html#for) or [if](https://docs.python.org/3/reference/compound_stmts.html#if) clauses. The result will be a new list resulting from evaluating the expression in the context of the [for](https://docs.python.org/3/reference/compound_stmts.html#for) and [if](https://docs.python.org/3/reference/compound_stmts.html#if) clauses which follow it. For example, this listcomp combines the elements of two lists if they are not equal:

>>>

**>>>** [(x, y) **for** x **in** [1,2,3] **for** y **in** [3,1,4] **if** x != y]

[(1, 3), (1, 4), (2, 3), (2, 1), (2, 4), (3, 1), (3, 4)]

and it’s equivalent to:

>>>

**>>>** combs = []

**>>> for** x **in** [1,2,3]:

**...**  **for** y **in** [3,1,4]:

**...**  **if** x != y:

**...**  combs.append((x, y))

**...**

**>>>** combs

[(1, 3), (1, 4), (2, 3), (2, 1), (2, 4), (3, 1), (3, 4)]

Note how the order of the [for](https://docs.python.org/3/reference/compound_stmts.html#for) and [if](https://docs.python.org/3/reference/compound_stmts.html#if) statements is the same in both these snippets.

If the expression is a tuple (e.g. the (x, y) in the previous example), it must be parenthesized.

>>>

**>>>** vec = [-4, -2, 0, 2, 4]

**>>>** *# create a new list with the values doubled*

**>>>** [x\*2 **for** x **in** vec]

[-8, -4, 0, 4, 8]

**>>>** *# filter the list to exclude negative numbers*

**>>>** [x **for** x **in** vec **if** x >= 0]

[0, 2, 4]

**>>>** *# apply a function to all the elements*

**>>>** [abs(x) **for** x **in** vec]

[4, 2, 0, 2, 4]

**>>>** *# call a method on each element*

**>>>** freshfruit = [' banana', ' loganberry ', 'passion fruit ']

**>>>** [weapon.strip() **for** weapon **in** freshfruit]

['banana', 'loganberry', 'passion fruit']

**>>>** *# create a list of 2-tuples like (number, square)*

**>>>** [(x, x\*\*2) **for** x **in** range(6)]

[(0, 0), (1, 1), (2, 4), (3, 9), (4, 16), (5, 25)]

**>>>** *# the tuple must be parenthesized, otherwise an error is raised*

**>>>** [x, x\*\*2 **for** x **in** range(6)]

File "<stdin>", line 1, in ?

[x, x\*\*2 for x in range(6)]

^

SyntaxError: invalid syntax

**>>>** *# flatten a list using a listcomp with two 'for'*

**>>>** vec = [[1,2,3], [4,5,6], [7,8,9]]

**>>>** [num **for** elem **in** vec **for** num **in** elem]

[1, 2, 3, 4, 5, 6, 7, 8, 9]

List comprehensions can contain complex expressions and nested functions:

>>>

**>>> from** **math** **import** pi

**>>>** [str(round(pi, i)) **for** i **in** range(1, 6)]

['3.1', '3.14', '3.142', '3.1416', '3.14159']

### 5.1.4. Nested List Comprehensions

The initial expression in a list comprehension can be any arbitrary expression, including another list comprehension.

Consider the following example of a 3x4 matrix implemented as a list of 3 lists of length 4:

>>>

**>>>** matrix = [

**...**  [1, 2, 3, 4],

**...**  [5, 6, 7, 8],

**...**  [9, 10, 11, 12],

**...** ]

The following list comprehension will transpose rows and columns:

>>>

**>>>** [[row[i] **for** row **in** matrix] **for** i **in** range(4)]

[[1, 5, 9], [2, 6, 10], [3, 7, 11], [4, 8, 12]]

As we saw in the previous section, the nested listcomp is evaluated in the context of the [for](https://docs.python.org/3/reference/compound_stmts.html#for) that follows it, so this example is equivalent to:

>>>

**>>>** transposed = []

**>>> for** i **in** range(4):

**...**  transposed.append([row[i] **for** row **in** matrix])

**...**

**>>>** transposed

[[1, 5, 9], [2, 6, 10], [3, 7, 11], [4, 8, 12]]

which, in turn, is the same as:

>>>

**>>>** transposed = []

**>>> for** i **in** range(4):

**...**  *# the following 3 lines implement the nested listcomp*

**...**  transposed\_row = []

**...**  **for** row **in** matrix:

**...**  transposed\_row.append(row[i])

**...**  transposed.append(transposed\_row)

**...**

**>>>** transposed

[[1, 5, 9], [2, 6, 10], [3, 7, 11], [4, 8, 12]]

In the real world, you should prefer built-in functions to complex flow statements. The [zip()](https://docs.python.org/3/library/functions.html#zip) function would do a great job for this use case:

>>>

**>>>** list(zip(\*matrix))

[(1, 5, 9), (2, 6, 10), (3, 7, 11), (4, 8, 12)]

See [Unpacking Argument Lists](https://docs.python.org/3/tutorial/controlflow.html#tut-unpacking-arguments) for details on the asterisk in this line.

## 5.2. The [del](https://docs.python.org/3/reference/simple_stmts.html#del) statement

There is a way to remove an item from a list given its index instead of its value: the [del](https://docs.python.org/3/reference/simple_stmts.html#del) statement. This differs from the pop() method which returns a value. The [del](https://docs.python.org/3/reference/simple_stmts.html#del) statement can also be used to remove slices from a list or clear the entire list (which we did earlier by assignment of an empty list to the slice). For example:

>>>

**>>>** a = [-1, 1, 66.25, 333, 333, 1234.5]

**>>> del** a[0]

**>>>** a

[1, 66.25, 333, 333, 1234.5]

**>>> del** a[2:4]

**>>>** a

[1, 66.25, 1234.5]

**>>> del** a[:]

**>>>** a

[]

[del](https://docs.python.org/3/reference/simple_stmts.html#del) can also be used to delete entire variables:

>>>

**>>> del** a

Referencing the name a hereafter is an error (at least until another value is assigned to it). We’ll find other uses for [del](https://docs.python.org/3/reference/simple_stmts.html#del) later.

## 5.3. Tuples and Sequences

We saw that lists and strings have many common properties, such as indexing and slicing operations. They are two examples of sequence data types (see [Sequence Types — list, tuple, range](https://docs.python.org/3/library/stdtypes.html#typesseq)). Since Python is an evolving language, other sequence data types may be added. There is also another standard sequence data type: the tuple.

A tuple consists of a number of values separated by commas, for instance:

>>>

**>>>** t = 12345, 54321, 'hello!'

**>>>** t[0]

12345

**>>>** t

(12345, 54321, 'hello!')

**>>>** *# Tuples may be nested:*

**...** u = t, (1, 2, 3, 4, 5)

**>>>** u

((12345, 54321, 'hello!'), (1, 2, 3, 4, 5))

**>>>** *# Tuples are immutable:*

**...** t[0] = 88888

Traceback (most recent call last):

File "<stdin>", line 1, in <module>

TypeError: 'tuple' object does not support item assignment

**>>>** *# but they can contain mutable objects:*

**...** v = ([1, 2, 3], [3, 2, 1])

**>>>** v

([1, 2, 3], [3, 2, 1])

As you see, on output tuples are always enclosed in parentheses, so that nested tuples are interpreted correctly; they may be input with or without surrounding parentheses, although often parentheses are necessary anyway (if the tuple is part of a larger expression). It is not possible to assign to the individual items of a tuple, however it is possible to create tuples which contain mutable objects, such as lists.

Though tuples may seem similar to lists, they are often used in different situations and for different purposes. Tuples are [immutable](https://docs.python.org/3/glossary.html#term-immutable), and usually contain a heterogeneous sequence of elements that are accessed via unpacking (see later in this section) or indexing (or even by attribute in the case of[namedtuples](https://docs.python.org/3/library/collections.html#collections.namedtuple)). Lists are [mutable](https://docs.python.org/3/glossary.html#term-mutable), and their elements are usually homogeneous and are accessed by iterating over the list.

A special problem is the construction of tuples containing 0 or 1 items: the syntax has some extra quirks to accommodate these. Empty tuples are constructed by an empty pair of parentheses; a tuple with one item is constructed by following a value with a comma (it is not sufficient to enclose a single value in parentheses). Ugly, but effective. For example:

>>>

**>>>** empty = ()

**>>>** singleton = 'hello', *# <-- note trailing comma*

**>>>** len(empty)

0

**>>>** len(singleton)

1

**>>>** singleton

('hello',)

The statement t = 12345, 54321, 'hello!' is an example of tuple packing: the values 12345,54321 and 'hello!' are packed together in a tuple. The reverse operation is also possible:

>>>

**>>>** x, y, z = t

This is called, appropriately enough, sequence unpacking and works for any sequence on the right-hand side. Sequence unpacking requires that there are as many variables on the left side of the equals sign as there are elements in the sequence. Note that multiple assignment is really just a combination of tuple packing and sequence unpacking.

## 5.4. Sets

Python also includes a data type for sets. A set is an unordered collection with no duplicate elements. Basic uses include membership testing and eliminating duplicate entries. Set objects also support mathematical operations like union, intersection, difference, and symmetric difference.

Curly braces or the [set()](https://docs.python.org/3/library/stdtypes.html#set) function can be used to create sets. Note: to create an empty set you have to use set(), not {}; the latter creates an empty dictionary, a data structure that we discuss in the next section.

Here is a brief demonstration:

>>>

**>>>** basket = {'apple', 'orange', 'apple', 'pear', 'orange', 'banana'}

**>>>** print(basket) *# show that duplicates have been removed*

{'orange', 'banana', 'pear', 'apple'}

**>>>** 'orange' **in** basket *# fast membership testing*

True

**>>>** 'crabgrass' **in** basket

False

**>>>** *# Demonstrate set operations on unique letters from two words*

**...**

**>>>** a = set('abracadabra')

**>>>** b = set('alacazam')

**>>>** a *# unique letters in a*

{'a', 'r', 'b', 'c', 'd'}

**>>>** a - b *# letters in a but not in b*

{'r', 'd', 'b'}

**>>>** a | b *# letters in either a or b*

{'a', 'c', 'r', 'd', 'b', 'm', 'z', 'l'}

**>>>** a & b *# letters in both a and b*

{'a', 'c'}

**>>>** a ^ b *# letters in a or b but not both*

{'r', 'd', 'b', 'm', 'z', 'l'}

Similarly to [list comprehensions](https://docs.python.org/3/tutorial/datastructures.html#tut-listcomps), set comprehensions are also supported:

>>>

**>>>** a = {x **for** x **in** 'abracadabra' **if** x **not** **in** 'abc'}

**>>>** a

{'r', 'd'}

## 5.5. Dictionaries

Another useful data type built into Python is the dictionary (see [Mapping Types — dict](https://docs.python.org/3/library/stdtypes.html#typesmapping)). Dictionaries are sometimes found in other languages as “associative memories” or “associative arrays”. Unlike sequences, which are indexed by a range of numbers, dictionaries are indexed by keys, which can be any immutable type; strings and numbers can always be keys. Tuples can be used as keys if they contain only strings, numbers, or tuples; if a tuple contains any mutable object either directly or indirectly, it cannot be used as a key. You can’t use lists as keys, since lists can be modified in place using index assignments, slice assignments, or methods like append() and extend().

It is best to think of a dictionary as an unordered set of key: value pairs, with the requirement that the keys are unique (within one dictionary). A pair of braces creates an empty dictionary: {}. Placing a comma-separated list of key:value pairs within the braces adds initial key:value pairs to the dictionary; this is also the way dictionaries are written on output.

The main operations on a dictionary are storing a value with some key and extracting the value given the key. It is also possible to delete a key:value pair with del. If you store using a key that is already in use, the old value associated with that key is forgotten. It is an error to extract a value using a non-existent key.

Performing list(d.keys()) on a dictionary returns a list of all the keys used in the dictionary, in arbitrary order (if you want it sorted, just use sorted(d.keys()) instead). [[2]](https://docs.python.org/3/tutorial/datastructures.html#id4) To check whether a single key is in the dictionary, use the [in](https://docs.python.org/3/reference/expressions.html#in) keyword.

Here is a small example using a dictionary:

>>>

**>>>** tel = {'jack': 4098, 'sape': 4139}

**>>>** tel['guido'] = 4127

**>>>** tel

{'sape': 4139, 'guido': 4127, 'jack': 4098}

**>>>** tel['jack']

4098

**>>> del** tel['sape']

**>>>** tel['irv'] = 4127

**>>>** tel

{'guido': 4127, 'irv': 4127, 'jack': 4098}

**>>>** list(tel.keys())

['irv', 'guido', 'jack']

**>>>** sorted(tel.keys())

['guido', 'irv', 'jack']

**>>>** 'guido' **in** tel

True

**>>>** 'jack' **not** **in** tel

False

The [dict()](https://docs.python.org/3/library/stdtypes.html#dict) constructor builds dictionaries directly from sequences of key-value pairs:

>>>

**>>>** dict([('sape', 4139), ('guido', 4127), ('jack', 4098)])

{'sape': 4139, 'jack': 4098, 'guido': 4127}

In addition, dict comprehensions can be used to create dictionaries from arbitrary key and value expressions:

>>>

**>>>** {x: x\*\*2 **for** x **in** (2, 4, 6)}

{2: 4, 4: 16, 6: 36}

When the keys are simple strings, it is sometimes easier to specify pairs using keyword arguments:

>>>

**>>>** dict(sape=4139, guido=4127, jack=4098)

{'sape': 4139, 'jack': 4098, 'guido': 4127}

## 5.6. Looping Techniques

When looping through dictionaries, the key and corresponding value can be retrieved at the same time using the items() method.

>>>

**>>>** knights = {'gallahad': 'the pure', 'robin': 'the brave'}

**>>> for** k, v **in** knights.items():

**...**  print(k, v)

**...**

gallahad the pure

robin the brave

When looping through a sequence, the position index and corresponding value can be retrieved at the same time using the [enumerate()](https://docs.python.org/3/library/functions.html#enumerate) function.

>>>

**>>> for** i, v **in** enumerate(['tic', 'tac', 'toe']):

**...**  print(i, v)

**...**

0 tic

1 tac

2 toe

To loop over two or more sequences at the same time, the entries can be paired with the [zip()](https://docs.python.org/3/library/functions.html#zip)function.

>>>

**>>>** questions = ['name', 'quest', 'favorite color']

**>>>** answers = ['lancelot', 'the holy grail', 'blue']

**>>> for** q, a **in** zip(questions, answers):

**...**  print('What is your *{0}*? It is *{1}*.'.format(q, a))

**...**

What is your name? It is lancelot.

What is your quest? It is the holy grail.

What is your favorite color? It is blue.

To loop over a sequence in reverse, first specify the sequence in a forward direction and then call the[reversed()](https://docs.python.org/3/library/functions.html#reversed) function.

>>>

**>>> for** i **in** reversed(range(1, 10, 2)):

**...**  print(i)

**...**

9

7

5

3

1

To loop over a sequence in sorted order, use the [sorted()](https://docs.python.org/3/library/functions.html#sorted) function which returns a new sorted list while leaving the source unaltered.

>>>

**>>>** basket = ['apple', 'orange', 'apple', 'pear', 'orange', 'banana']

**>>> for** f **in** sorted(set(basket)):

**...**  print(f)

**...**

apple

banana

orange

pear

It is sometimes tempting to change a list while you are looping over it; however, it is often simpler and safer to create a new list instead.

>>>

**>>> import** **math**

**>>>** raw\_data = [56.2, float('NaN'), 51.7, 55.3, 52.5, float('NaN'), 47.8]

**>>>** filtered\_data = []

**>>> for** value **in** raw\_data:

**...**  **if** **not** math.isnan(value):

**...**  filtered\_data.append(value)

**...**

**>>>** filtered\_data

[56.2, 51.7, 55.3, 52.5, 47.8]

## 5.7. More on Conditions

The conditions used in while and if statements can contain any operators, not just comparisons.

The comparison operators in and not in check whether a value occurs (does not occur) in a sequence. The operators is and is not compare whether two objects are really the same object; this only matters for mutable objects like lists. All comparison operators have the same priority, which is lower than that of all numerical operators.

Comparisons can be chained. For example, a < b == c tests whether a is less than b and moreoverb equals c.

Comparisons may be combined using the Boolean operators and and or, and the outcome of a comparison (or of any other Boolean expression) may be negated with not. These have lower priorities than comparison operators; between them, not has the highest priority and or the lowest, so that A and not B or C is equivalent to (A and (not B)) or C. As always, parentheses can be used to express the desired composition.

The Boolean operators and and or are so-called short-circuit operators: their arguments are evaluated from left to right, and evaluation stops as soon as the outcome is determined. For example, if A and C are true but B is false, A and B and C does not evaluate the expression C. When used as a general value and not as a Boolean, the return value of a short-circuit operator is the last evaluated argument.

It is possible to assign the result of a comparison or other Boolean expression to a variable. For example,

>>>

**>>>** string1, string2, string3 = '', 'Trondheim', 'Hammer Dance'

**>>>** non\_null = string1 **or** string2 **or** string3

**>>>** non\_null

'Trondheim'

Note that in Python, unlike C, assignment cannot occur inside expressions. C programmers may grumble about this, but it avoids a common class of problems encountered in C programs: typing = in an expression when == was intended.

## 5.8. Comparing Sequences and Other Types

Sequence objects may be compared to other objects with the same sequence type. The comparison uses lexicographical ordering: first the first two items are compared, and if they differ this determines the outcome of the comparison; if they are equal, the next two items are compared, and so on, until either sequence is exhausted. If two items to be compared are themselves sequences of the same type, the lexicographical comparison is carried out recursively. If all items of two sequences compare equal, the sequences are considered equal. If one sequence is an initial sub-sequence of the other, the shorter sequence is the smaller (lesser) one. Lexicographical ordering for strings uses the Unicode code point number to order individual characters. Some examples of comparisons between sequences of the same type:

(1, 2, 3) < (1, 2, 4)

[1, 2, 3] < [1, 2, 4]

'ABC' < 'C' < 'Pascal' < 'Python'

(1, 2, 3, 4) < (1, 2, 4)

(1, 2) < (1, 2, -1)

(1, 2, 3) == (1.0, 2.0, 3.0)

(1, 2, ('aa', 'ab')) < (1, 2, ('abc', 'a'), 4)

Note that comparing objects of different types with < or > is legal provided that the objects have appropriate comparison methods. For example, mixed numeric types are compared according to their numeric value, so 0 equals 0.0, etc. Otherwise, rather than providing an arbitrary ordering, the interpreter will raise a [TypeError](https://docs.python.org/3/library/exceptions.html#TypeError) exception.

**Footnotes**

|  |  |
| --- | --- |
| [[1]](https://docs.python.org/3/tutorial/datastructures.html#id1) | Other languages may return the mutated object, which allows method chaining, such as d->insert("a")->remove("b")->sort();. |

|  |  |
| --- | --- |
| [[2]](https://docs.python.org/3/tutorial/datastructures.html#id2) | Calling d.keys() will return a dictionary view object. It supports operations like membership test and iteration, but its contents are not independent of the original dictionary – it is only aview. |

# 5. Data Structures

This chapter describes some things you’ve learned about already in more detail, and adds some new things as well.

## 5.1. More on Lists

The list data type has some more methods. Here are all of the methods of list objects:

list.**append**(x)

Add an item to the end of the list. Equivalent to a[len(a):] = [x].

list.**extend**(L)

Extend the list by appending all the items in the given list. Equivalent to a[len(a):] = L.

list.**insert**(i, x)

Insert an item at a given position. The first argument is the index of the element before which to insert, so a.insert(0, x) inserts at the front of the list, and a.insert(len(a), x) is equivalent to a.append(x).

list.**remove**(x)

Remove the first item from the list whose value is x. It is an error if there is no such item.

list.**pop**([i])

Remove the item at the given position in the list, and return it. If no index is specified, a.pop()removes and returns the last item in the list. (The square brackets around the i in the method signature denote that the parameter is optional, not that you should type square brackets at that position. You will see this notation frequently in the Python Library Reference.)

list.**clear**()

Remove all items from the list. Equivalent to del a[:].

list.**index**(x)

Return the index in the list of the first item whose value is x. It is an error if there is no such item.

list.**count**(x)

Return the number of times x appears in the list.

list.**sort**(key=None, reverse=False)

Sort the items of the list in place (the arguments can be used for sort customization, see[sorted()](https://docs.python.org/3/library/functions.html#sorted) for their explanation).

list.**reverse**()

Reverse the elements of the list in place.

list.**copy**()

Return a shallow copy of the list. Equivalent to a[:].

An example that uses most of the list methods:

>>>

**>>>** a = [66.25, 333, 333, 1, 1234.5]

**>>>** print(a.count(333), a.count(66.25), a.count('x'))

2 1 0

**>>>** a.insert(2, -1)

**>>>** a.append(333)

**>>>** a

[66.25, 333, -1, 333, 1, 1234.5, 333]

**>>>** a.index(333)

1

**>>>** a.remove(333)

**>>>** a

[66.25, -1, 333, 1, 1234.5, 333]

**>>>** a.reverse()

**>>>** a

[333, 1234.5, 1, 333, -1, 66.25]

**>>>** a.sort()

**>>>** a

[-1, 1, 66.25, 333, 333, 1234.5]

**>>>** a.pop()

1234.5

**>>>** a

[-1, 1, 66.25, 333, 333]

You might have noticed that methods like insert, remove or sort that only modify the list have no return value printed – they return the default None. [[1]](https://docs.python.org/3/tutorial/datastructures.html#id3) This is a design principle for all mutable data structures in Python.

### 5.1.1. Using Lists as Stacks

The list methods make it very easy to use a list as a stack, where the last element added is the first element retrieved (“last-in, first-out”). To add an item to the top of the stack, use append(). To retrieve an item from the top of the stack, use pop() without an explicit index. For example:

>>>

**>>>** stack = [3, 4, 5]

**>>>** stack.append(6)

**>>>** stack.append(7)

**>>>** stack

[3, 4, 5, 6, 7]

**>>>** stack.pop()

7

**>>>** stack

[3, 4, 5, 6]

**>>>** stack.pop()

6

**>>>** stack.pop()

5

**>>>** stack

[3, 4]

### 5.1.2. Using Lists as Queues

It is also possible to use a list as a queue, where the first element added is the first element retrieved (“first-in, first-out”); however, lists are not efficient for this purpose. While appends and pops from the end of list are fast, doing inserts or pops from the beginning of a list is slow (because all of the other elements have to be shifted by one).

To implement a queue, use [collections.deque](https://docs.python.org/3/library/collections.html#collections.deque) which was designed to have fast appends and pops from both ends. For example:

>>>

**>>> from** **collections** **import** deque

**>>>** queue = deque(["Eric", "John", "Michael"])

**>>>** queue.append("Terry") *# Terry arrives*

**>>>** queue.append("Graham") *# Graham arrives*

**>>>** queue.popleft() *# The first to arrive now leaves*

'Eric'

**>>>** queue.popleft() *# The second to arrive now leaves*

'John'

**>>>** queue *# Remaining queue in order of arrival*

deque(['Michael', 'Terry', 'Graham'])

### 5.1.3. List Comprehensions

List comprehensions provide a concise way to create lists. Common applications are to make new lists where each element is the result of some operations applied to each member of another sequence or iterable, or to create a subsequence of those elements that satisfy a certain condition.

For example, assume we want to create a list of squares, like:

>>>

**>>>** squares = []

**>>> for** x **in** range(10):

**...**  squares.append(x\*\*2)

**...**

**>>>** squares

[0, 1, 4, 9, 16, 25, 36, 49, 64, 81]

Note that this creates (or overwrites) a variable named x that still exists after the loop completes. We can calculate the list of squares without any side effects using:

squares = list(map(**lambda** x: x\*\*2, range(10)))

or, equivalently:

squares = [x\*\*2 **for** x **in** range(10)]

which is more concise and readable.

A list comprehension consists of brackets containing an expression followed by a [for](https://docs.python.org/3/reference/compound_stmts.html#for) clause, then zero or more [for](https://docs.python.org/3/reference/compound_stmts.html#for) or [if](https://docs.python.org/3/reference/compound_stmts.html#if) clauses. The result will be a new list resulting from evaluating the expression in the context of the [for](https://docs.python.org/3/reference/compound_stmts.html#for) and [if](https://docs.python.org/3/reference/compound_stmts.html#if) clauses which follow it. For example, this listcomp combines the elements of two lists if they are not equal:

>>>

**>>>** [(x, y) **for** x **in** [1,2,3] **for** y **in** [3,1,4] **if** x != y]

[(1, 3), (1, 4), (2, 3), (2, 1), (2, 4), (3, 1), (3, 4)]

and it’s equivalent to:

>>>

**>>>** combs = []

**>>> for** x **in** [1,2,3]:

**...**  **for** y **in** [3,1,4]:

**...**  **if** x != y:

**...**  combs.append((x, y))

**...**

**>>>** combs

[(1, 3), (1, 4), (2, 3), (2, 1), (2, 4), (3, 1), (3, 4)]

Note how the order of the [for](https://docs.python.org/3/reference/compound_stmts.html#for) and [if](https://docs.python.org/3/reference/compound_stmts.html#if) statements is the same in both these snippets.

If the expression is a tuple (e.g. the (x, y) in the previous example), it must be parenthesized.

>>>

**>>>** vec = [-4, -2, 0, 2, 4]

**>>>** *# create a new list with the values doubled*

**>>>** [x\*2 **for** x **in** vec]

[-8, -4, 0, 4, 8]

**>>>** *# filter the list to exclude negative numbers*

**>>>** [x **for** x **in** vec **if** x >= 0]

[0, 2, 4]

**>>>** *# apply a function to all the elements*

**>>>** [abs(x) **for** x **in** vec]

[4, 2, 0, 2, 4]

**>>>** *# call a method on each element*

**>>>** freshfruit = [' banana', ' loganberry ', 'passion fruit ']

**>>>** [weapon.strip() **for** weapon **in** freshfruit]

['banana', 'loganberry', 'passion fruit']

**>>>** *# create a list of 2-tuples like (number, square)*

**>>>** [(x, x\*\*2) **for** x **in** range(6)]

[(0, 0), (1, 1), (2, 4), (3, 9), (4, 16), (5, 25)]

**>>>** *# the tuple must be parenthesized, otherwise an error is raised*

**>>>** [x, x\*\*2 **for** x **in** range(6)]

File "<stdin>", line 1, in ?

[x, x\*\*2 for x in range(6)]

^

SyntaxError: invalid syntax

**>>>** *# flatten a list using a listcomp with two 'for'*

**>>>** vec = [[1,2,3], [4,5,6], [7,8,9]]

**>>>** [num **for** elem **in** vec **for** num **in** elem]

[1, 2, 3, 4, 5, 6, 7, 8, 9]

List comprehensions can contain complex expressions and nested functions:

>>>

**>>> from** **math** **import** pi

**>>>** [str(round(pi, i)) **for** i **in** range(1, 6)]

['3.1', '3.14', '3.142', '3.1416', '3.14159']

### 5.1.4. Nested List Comprehensions

The initial expression in a list comprehension can be any arbitrary expression, including another list comprehension.

Consider the following example of a 3x4 matrix implemented as a list of 3 lists of length 4:

>>>

**>>>** matrix = [

**...**  [1, 2, 3, 4],

**...**  [5, 6, 7, 8],

**...**  [9, 10, 11, 12],

**...** ]

The following list comprehension will transpose rows and columns:

>>>

**>>>** [[row[i] **for** row **in** matrix] **for** i **in** range(4)]

[[1, 5, 9], [2, 6, 10], [3, 7, 11], [4, 8, 12]]

As we saw in the previous section, the nested listcomp is evaluated in the context of the [for](https://docs.python.org/3/reference/compound_stmts.html#for) that follows it, so this example is equivalent to:

>>>

**>>>** transposed = []

**>>> for** i **in** range(4):

**...**  transposed.append([row[i] **for** row **in** matrix])

**...**

**>>>** transposed

[[1, 5, 9], [2, 6, 10], [3, 7, 11], [4, 8, 12]]

which, in turn, is the same as:

>>>

**>>>** transposed = []

**>>> for** i **in** range(4):

**...**  *# the following 3 lines implement the nested listcomp*

**...**  transposed\_row = []

**...**  **for** row **in** matrix:

**...**  transposed\_row.append(row[i])

**...**  transposed.append(transposed\_row)

**...**

**>>>** transposed

[[1, 5, 9], [2, 6, 10], [3, 7, 11], [4, 8, 12]]

In the real world, you should prefer built-in functions to complex flow statements. The [zip()](https://docs.python.org/3/library/functions.html#zip) function would do a great job for this use case:

>>>

**>>>** list(zip(\*matrix))

[(1, 5, 9), (2, 6, 10), (3, 7, 11), (4, 8, 12)]

See [Unpacking Argument Lists](https://docs.python.org/3/tutorial/controlflow.html#tut-unpacking-arguments) for details on the asterisk in this line.

## 5.2. The [del](https://docs.python.org/3/reference/simple_stmts.html#del) statement

There is a way to remove an item from a list given its index instead of its value: the [del](https://docs.python.org/3/reference/simple_stmts.html#del) statement. This differs from the pop() method which returns a value. The [del](https://docs.python.org/3/reference/simple_stmts.html#del) statement can also be used to remove slices from a list or clear the entire list (which we did earlier by assignment of an empty list to the slice). For example:

>>>

**>>>** a = [-1, 1, 66.25, 333, 333, 1234.5]

**>>> del** a[0]

**>>>** a

[1, 66.25, 333, 333, 1234.5]

**>>> del** a[2:4]

**>>>** a

[1, 66.25, 1234.5]

**>>> del** a[:]

**>>>** a

[]

[del](https://docs.python.org/3/reference/simple_stmts.html#del) can also be used to delete entire variables:

>>>

**>>> del** a

Referencing the name a hereafter is an error (at least until another value is assigned to it). We’ll find other uses for [del](https://docs.python.org/3/reference/simple_stmts.html#del) later.

## 5.3. Tuples and Sequences

We saw that lists and strings have many common properties, such as indexing and slicing operations. They are two examples of sequence data types (see [Sequence Types — list, tuple, range](https://docs.python.org/3/library/stdtypes.html#typesseq)). Since Python is an evolving language, other sequence data types may be added. There is also another standard sequence data type: the tuple.

A tuple consists of a number of values separated by commas, for instance:

>>>

**>>>** t = 12345, 54321, 'hello!'

**>>>** t[0]

12345

**>>>** t

(12345, 54321, 'hello!')

**>>>** *# Tuples may be nested:*

**...** u = t, (1, 2, 3, 4, 5)

**>>>** u

((12345, 54321, 'hello!'), (1, 2, 3, 4, 5))

**>>>** *# Tuples are immutable:*

**...** t[0] = 88888

Traceback (most recent call last):

File "<stdin>", line 1, in <module>

TypeError: 'tuple' object does not support item assignment

**>>>** *# but they can contain mutable objects:*

**...** v = ([1, 2, 3], [3, 2, 1])

**>>>** v

([1, 2, 3], [3, 2, 1])

As you see, on output tuples are always enclosed in parentheses, so that nested tuples are interpreted correctly; they may be input with or without surrounding parentheses, although often parentheses are necessary anyway (if the tuple is part of a larger expression). It is not possible to assign to the individual items of a tuple, however it is possible to create tuples which contain mutable objects, such as lists.

Though tuples may seem similar to lists, they are often used in different situations and for different purposes. Tuples are [immutable](https://docs.python.org/3/glossary.html#term-immutable), and usually contain a heterogeneous sequence of elements that are accessed via unpacking (see later in this section) or indexing (or even by attribute in the case of[namedtuples](https://docs.python.org/3/library/collections.html#collections.namedtuple)). Lists are [mutable](https://docs.python.org/3/glossary.html#term-mutable), and their elements are usually homogeneous and are accessed by iterating over the list.

A special problem is the construction of tuples containing 0 or 1 items: the syntax has some extra quirks to accommodate these. Empty tuples are constructed by an empty pair of parentheses; a tuple with one item is constructed by following a value with a comma (it is not sufficient to enclose a single value in parentheses). Ugly, but effective. For example:

>>>

**>>>** empty = ()

**>>>** singleton = 'hello', *# <-- note trailing comma*

**>>>** len(empty)

0

**>>>** len(singleton)

1

**>>>** singleton

('hello',)

The statement t = 12345, 54321, 'hello!' is an example of tuple packing: the values 12345,54321 and 'hello!' are packed together in a tuple. The reverse operation is also possible:

>>>

**>>>** x, y, z = t

This is called, appropriately enough, sequence unpacking and works for any sequence on the right-hand side. Sequence unpacking requires that there are as many variables on the left side of the equals sign as there are elements in the sequence. Note that multiple assignment is really just a combination of tuple packing and sequence unpacking.

## 5.4. Sets

Python also includes a data type for sets. A set is an unordered collection with no duplicate elements. Basic uses include membership testing and eliminating duplicate entries. Set objects also support mathematical operations like union, intersection, difference, and symmetric difference.

Curly braces or the [set()](https://docs.python.org/3/library/stdtypes.html#set) function can be used to create sets. Note: to create an empty set you have to use set(), not {}; the latter creates an empty dictionary, a data structure that we discuss in the next section.

Here is a brief demonstration:

>>>

**>>>** basket = {'apple', 'orange', 'apple', 'pear', 'orange', 'banana'}

**>>>** print(basket) *# show that duplicates have been removed*

{'orange', 'banana', 'pear', 'apple'}

**>>>** 'orange' **in** basket *# fast membership testing*

True

**>>>** 'crabgrass' **in** basket

False

**>>>** *# Demonstrate set operations on unique letters from two words*

**...**

**>>>** a = set('abracadabra')

**>>>** b = set('alacazam')

**>>>** a *# unique letters in a*

{'a', 'r', 'b', 'c', 'd'}

**>>>** a - b *# letters in a but not in b*

{'r', 'd', 'b'}

**>>>** a | b *# letters in either a or b*

{'a', 'c', 'r', 'd', 'b', 'm', 'z', 'l'}

**>>>** a & b *# letters in both a and b*

{'a', 'c'}

**>>>** a ^ b *# letters in a or b but not both*

{'r', 'd', 'b', 'm', 'z', 'l'}

Similarly to [list comprehensions](https://docs.python.org/3/tutorial/datastructures.html#tut-listcomps), set comprehensions are also supported:

>>>

**>>>** a = {x **for** x **in** 'abracadabra' **if** x **not** **in** 'abc'}

**>>>** a

{'r', 'd'}

## 5.5. Dictionaries

Another useful data type built into Python is the dictionary (see [Mapping Types — dict](https://docs.python.org/3/library/stdtypes.html#typesmapping)). Dictionaries are sometimes found in other languages as “associative memories” or “associative arrays”. Unlike sequences, which are indexed by a range of numbers, dictionaries are indexed by keys, which can be any immutable type; strings and numbers can always be keys. Tuples can be used as keys if they contain only strings, numbers, or tuples; if a tuple contains any mutable object either directly or indirectly, it cannot be used as a key. You can’t use lists as keys, since lists can be modified in place using index assignments, slice assignments, or methods like append() and extend().

It is best to think of a dictionary as an unordered set of key: value pairs, with the requirement that the keys are unique (within one dictionary). A pair of braces creates an empty dictionary: {}. Placing a comma-separated list of key:value pairs within the braces adds initial key:value pairs to the dictionary; this is also the way dictionaries are written on output.

The main operations on a dictionary are storing a value with some key and extracting the value given the key. It is also possible to delete a key:value pair with del. If you store using a key that is already in use, the old value associated with that key is forgotten. It is an error to extract a value using a non-existent key.

Performing list(d.keys()) on a dictionary returns a list of all the keys used in the dictionary, in arbitrary order (if you want it sorted, just use sorted(d.keys()) instead). [[2]](https://docs.python.org/3/tutorial/datastructures.html#id4) To check whether a single key is in the dictionary, use the [in](https://docs.python.org/3/reference/expressions.html#in) keyword.

Here is a small example using a dictionary:

>>>

**>>>** tel = {'jack': 4098, 'sape': 4139}

**>>>** tel['guido'] = 4127

**>>>** tel

{'sape': 4139, 'guido': 4127, 'jack': 4098}

**>>>** tel['jack']

4098

**>>> del** tel['sape']

**>>>** tel['irv'] = 4127

**>>>** tel

{'guido': 4127, 'irv': 4127, 'jack': 4098}

**>>>** list(tel.keys())

['irv', 'guido', 'jack']

**>>>** sorted(tel.keys())

['guido', 'irv', 'jack']

**>>>** 'guido' **in** tel

True

**>>>** 'jack' **not** **in** tel

False

The [dict()](https://docs.python.org/3/library/stdtypes.html#dict) constructor builds dictionaries directly from sequences of key-value pairs:

>>>

**>>>** dict([('sape', 4139), ('guido', 4127), ('jack', 4098)])

{'sape': 4139, 'jack': 4098, 'guido': 4127}

In addition, dict comprehensions can be used to create dictionaries from arbitrary key and value expressions:

>>>

**>>>** {x: x\*\*2 **for** x **in** (2, 4, 6)}

{2: 4, 4: 16, 6: 36}

When the keys are simple strings, it is sometimes easier to specify pairs using keyword arguments:

>>>

**>>>** dict(sape=4139, guido=4127, jack=4098)

{'sape': 4139, 'jack': 4098, 'guido': 4127}

## 5.6. Looping Techniques

When looping through dictionaries, the key and corresponding value can be retrieved at the same time using the items() method.

>>>

**>>>** knights = {'gallahad': 'the pure', 'robin': 'the brave'}

**>>> for** k, v **in** knights.items():

**...**  print(k, v)

**...**

gallahad the pure

robin the brave

When looping through a sequence, the position index and corresponding value can be retrieved at the same time using the [enumerate()](https://docs.python.org/3/library/functions.html#enumerate) function.

>>>

**>>> for** i, v **in** enumerate(['tic', 'tac', 'toe']):

**...**  print(i, v)

**...**

0 tic

1 tac

2 toe

To loop over two or more sequences at the same time, the entries can be paired with the [zip()](https://docs.python.org/3/library/functions.html#zip)function.

>>>

**>>>** questions = ['name', 'quest', 'favorite color']

**>>>** answers = ['lancelot', 'the holy grail', 'blue']

**>>> for** q, a **in** zip(questions, answers):

**...**  print('What is your *{0}*? It is *{1}*.'.format(q, a))

**...**

What is your name? It is lancelot.

What is your quest? It is the holy grail.

What is your favorite color? It is blue.

To loop over a sequence in reverse, first specify the sequence in a forward direction and then call the[reversed()](https://docs.python.org/3/library/functions.html#reversed) function.

>>>

**>>> for** i **in** reversed(range(1, 10, 2)):

**...**  print(i)

**...**

9

7

5

3

1

To loop over a sequence in sorted order, use the [sorted()](https://docs.python.org/3/library/functions.html#sorted) function which returns a new sorted list while leaving the source unaltered.

>>>

**>>>** basket = ['apple', 'orange', 'apple', 'pear', 'orange', 'banana']

**>>> for** f **in** sorted(set(basket)):

**...**  print(f)

**...**

apple

banana

orange

pear

It is sometimes tempting to change a list while you are looping over it; however, it is often simpler and safer to create a new list instead.

>>>

**>>> import** **math**

**>>>** raw\_data = [56.2, float('NaN'), 51.7, 55.3, 52.5, float('NaN'), 47.8]

**>>>** filtered\_data = []

**>>> for** value **in** raw\_data:

**...**  **if** **not** math.isnan(value):

**...**  filtered\_data.append(value)

**...**

**>>>** filtered\_data

[56.2, 51.7, 55.3, 52.5, 47.8]

## 5.7. More on Conditions

The conditions used in while and if statements can contain any operators, not just comparisons.

The comparison operators in and not in check whether a value occurs (does not occur) in a sequence. The operators is and is not compare whether two objects are really the same object; this only matters for mutable objects like lists. All comparison operators have the same priority, which is lower than that of all numerical operators.

Comparisons can be chained. For example, a < b == c tests whether a is less than b and moreoverb equals c.

Comparisons may be combined using the Boolean operators and and or, and the outcome of a comparison (or of any other Boolean expression) may be negated with not. These have lower priorities than comparison operators; between them, not has the highest priority and or the lowest, so that A and not B or C is equivalent to (A and (not B)) or C. As always, parentheses can be used to express the desired composition.

The Boolean operators and and or are so-called short-circuit operators: their arguments are evaluated from left to right, and evaluation stops as soon as the outcome is determined. For example, if A and C are true but B is false, A and B and C does not evaluate the expression C. When used as a general value and not as a Boolean, the return value of a short-circuit operator is the last evaluated argument.

It is possible to assign the result of a comparison or other Boolean expression to a variable. For example,

>>>

**>>>** string1, string2, string3 = '', 'Trondheim', 'Hammer Dance'

**>>>** non\_null = string1 **or** string2 **or** string3

**>>>** non\_null

'Trondheim'

Note that in Python, unlike C, assignment cannot occur inside expressions. C programmers may grumble about this, but it avoids a common class of problems encountered in C programs: typing = in an expression when == was intended.

## 5.8. Comparing Sequences and Other Types

Sequence objects may be compared to other objects with the same sequence type. The comparison uses lexicographical ordering: first the first two items are compared, and if they differ this determines the outcome of the comparison; if they are equal, the next two items are compared, and so on, until either sequence is exhausted. If two items to be compared are themselves sequences of the same type, the lexicographical comparison is carried out recursively. If all items of two sequences compare equal, the sequences are considered equal. If one sequence is an initial sub-sequence of the other, the shorter sequence is the smaller (lesser) one. Lexicographical ordering for strings uses the Unicode code point number to order individual characters. Some examples of comparisons between sequences of the same type:

(1, 2, 3) < (1, 2, 4)

[1, 2, 3] < [1, 2, 4]

'ABC' < 'C' < 'Pascal' < 'Python'

(1, 2, 3, 4) < (1, 2, 4)

(1, 2) < (1, 2, -1)

(1, 2, 3) == (1.0, 2.0, 3.0)

(1, 2, ('aa', 'ab')) < (1, 2, ('abc', 'a'), 4)

Note that comparing objects of different types with < or > is legal provided that the objects have appropriate comparison methods. For example, mixed numeric types are compared according to their numeric value, so 0 equals 0.0, etc. Otherwise, rather than providing an arbitrary ordering, the interpreter will raise a [TypeError](https://docs.python.org/3/library/exceptions.html#TypeError) exception.

**Footnotes**

|  |  |
| --- | --- |
| [[1]](https://docs.python.org/3/tutorial/datastructures.html#id1) | Other languages may return the mutated object, which allows method chaining, such as d->insert("a")->remove("b")->sort();. |

|  |  |
| --- | --- |
| [[2]](https://docs.python.org/3/tutorial/datastructures.html#id2) | Calling d.keys() will return a dictionary view object. It supports operations like membership test and iteration, but its contents are not independent of the original dictionary – it is only aview. |

# 5. Data Structures

This chapter describes some things you’ve learned about already in more detail, and adds some new things as well.

## 5.1. More on Lists

The list data type has some more methods. Here are all of the methods of list objects:

list.**append**(x)

Add an item to the end of the list. Equivalent to a[len(a):] = [x].

list.**extend**(L)

Extend the list by appending all the items in the given list. Equivalent to a[len(a):] = L.

list.**insert**(i, x)

Insert an item at a given position. The first argument is the index of the element before which to insert, so a.insert(0, x) inserts at the front of the list, and a.insert(len(a), x) is equivalent to a.append(x).

list.**remove**(x)

Remove the first item from the list whose value is x. It is an error if there is no such item.

list.**pop**([i])

Remove the item at the given position in the list, and return it. If no index is specified, a.pop()removes and returns the last item in the list. (The square brackets around the i in the method signature denote that the parameter is optional, not that you should type square brackets at that position. You will see this notation frequently in the Python Library Reference.)

list.**clear**()

Remove all items from the list. Equivalent to del a[:].

list.**index**(x)

Return the index in the list of the first item whose value is x. It is an error if there is no such item.

list.**count**(x)

Return the number of times x appears in the list.

list.**sort**(key=None, reverse=False)

Sort the items of the list in place (the arguments can be used for sort customization, see[sorted()](https://docs.python.org/3/library/functions.html#sorted) for their explanation).

list.**reverse**()

Reverse the elements of the list in place.

list.**copy**()

Return a shallow copy of the list. Equivalent to a[:].

An example that uses most of the list methods:

>>>

**>>>** a = [66.25, 333, 333, 1, 1234.5]

**>>>** print(a.count(333), a.count(66.25), a.count('x'))

2 1 0

**>>>** a.insert(2, -1)

**>>>** a.append(333)

**>>>** a

[66.25, 333, -1, 333, 1, 1234.5, 333]

**>>>** a.index(333)

1

**>>>** a.remove(333)

**>>>** a

[66.25, -1, 333, 1, 1234.5, 333]

**>>>** a.reverse()

**>>>** a

[333, 1234.5, 1, 333, -1, 66.25]

**>>>** a.sort()

**>>>** a

[-1, 1, 66.25, 333, 333, 1234.5]

**>>>** a.pop()

1234.5

**>>>** a

[-1, 1, 66.25, 333, 333]

You might have noticed that methods like insert, remove or sort that only modify the list have no return value printed – they return the default None. [[1]](https://docs.python.org/3/tutorial/datastructures.html#id3) This is a design principle for all mutable data structures in Python.

### 5.1.1. Using Lists as Stacks

The list methods make it very easy to use a list as a stack, where the last element added is the first element retrieved (“last-in, first-out”). To add an item to the top of the stack, use append(). To retrieve an item from the top of the stack, use pop() without an explicit index. For example:

>>>

**>>>** stack = [3, 4, 5]

**>>>** stack.append(6)

**>>>** stack.append(7)

**>>>** stack

[3, 4, 5, 6, 7]

**>>>** stack.pop()

7

**>>>** stack

[3, 4, 5, 6]

**>>>** stack.pop()

6

**>>>** stack.pop()

5

**>>>** stack

[3, 4]

### 5.1.2. Using Lists as Queues

It is also possible to use a list as a queue, where the first element added is the first element retrieved (“first-in, first-out”); however, lists are not efficient for this purpose. While appends and pops from the end of list are fast, doing inserts or pops from the beginning of a list is slow (because all of the other elements have to be shifted by one).

To implement a queue, use [collections.deque](https://docs.python.org/3/library/collections.html#collections.deque) which was designed to have fast appends and pops from both ends. For example:

>>>

**>>> from** **collections** **import** deque

**>>>** queue = deque(["Eric", "John", "Michael"])

**>>>** queue.append("Terry") *# Terry arrives*

**>>>** queue.append("Graham") *# Graham arrives*

**>>>** queue.popleft() *# The first to arrive now leaves*

'Eric'

**>>>** queue.popleft() *# The second to arrive now leaves*

'John'

**>>>** queue *# Remaining queue in order of arrival*

deque(['Michael', 'Terry', 'Graham'])

### 5.1.3. List Comprehensions

List comprehensions provide a concise way to create lists. Common applications are to make new lists where each element is the result of some operations applied to each member of another sequence or iterable, or to create a subsequence of those elements that satisfy a certain condition.

For example, assume we want to create a list of squares, like:

>>>

**>>>** squares = []

**>>> for** x **in** range(10):

**...**  squares.append(x\*\*2)

**...**

**>>>** squares

[0, 1, 4, 9, 16, 25, 36, 49, 64, 81]

Note that this creates (or overwrites) a variable named x that still exists after the loop completes. We can calculate the list of squares without any side effects using:

squares = list(map(**lambda** x: x\*\*2, range(10)))

or, equivalently:

squares = [x\*\*2 **for** x **in** range(10)]

which is more concise and readable.

A list comprehension consists of brackets containing an expression followed by a [for](https://docs.python.org/3/reference/compound_stmts.html#for) clause, then zero or more [for](https://docs.python.org/3/reference/compound_stmts.html#for) or [if](https://docs.python.org/3/reference/compound_stmts.html#if) clauses. The result will be a new list resulting from evaluating the expression in the context of the [for](https://docs.python.org/3/reference/compound_stmts.html#for) and [if](https://docs.python.org/3/reference/compound_stmts.html#if) clauses which follow it. For example, this listcomp combines the elements of two lists if they are not equal:

>>>

**>>>** [(x, y) **for** x **in** [1,2,3] **for** y **in** [3,1,4] **if** x != y]

[(1, 3), (1, 4), (2, 3), (2, 1), (2, 4), (3, 1), (3, 4)]

and it’s equivalent to:

>>>

**>>>** combs = []

**>>> for** x **in** [1,2,3]:

**...**  **for** y **in** [3,1,4]:

**...**  **if** x != y:

**...**  combs.append((x, y))

**...**

**>>>** combs

[(1, 3), (1, 4), (2, 3), (2, 1), (2, 4), (3, 1), (3, 4)]

Note how the order of the [for](https://docs.python.org/3/reference/compound_stmts.html#for) and [if](https://docs.python.org/3/reference/compound_stmts.html#if) statements is the same in both these snippets.

If the expression is a tuple (e.g. the (x, y) in the previous example), it must be parenthesized.

>>>

**>>>** vec = [-4, -2, 0, 2, 4]

**>>>** *# create a new list with the values doubled*

**>>>** [x\*2 **for** x **in** vec]

[-8, -4, 0, 4, 8]

**>>>** *# filter the list to exclude negative numbers*

**>>>** [x **for** x **in** vec **if** x >= 0]

[0, 2, 4]

**>>>** *# apply a function to all the elements*

**>>>** [abs(x) **for** x **in** vec]

[4, 2, 0, 2, 4]

**>>>** *# call a method on each element*

**>>>** freshfruit = [' banana', ' loganberry ', 'passion fruit ']

**>>>** [weapon.strip() **for** weapon **in** freshfruit]

['banana', 'loganberry', 'passion fruit']

**>>>** *# create a list of 2-tuples like (number, square)*

**>>>** [(x, x\*\*2) **for** x **in** range(6)]

[(0, 0), (1, 1), (2, 4), (3, 9), (4, 16), (5, 25)]

**>>>** *# the tuple must be parenthesized, otherwise an error is raised*

**>>>** [x, x\*\*2 **for** x **in** range(6)]

File "<stdin>", line 1, in ?

[x, x\*\*2 for x in range(6)]

^

SyntaxError: invalid syntax

**>>>** *# flatten a list using a listcomp with two 'for'*

**>>>** vec = [[1,2,3], [4,5,6], [7,8,9]]

**>>>** [num **for** elem **in** vec **for** num **in** elem]

[1, 2, 3, 4, 5, 6, 7, 8, 9]

List comprehensions can contain complex expressions and nested functions:

>>>

**>>> from** **math** **import** pi

**>>>** [str(round(pi, i)) **for** i **in** range(1, 6)]

['3.1', '3.14', '3.142', '3.1416', '3.14159']

### 5.1.4. Nested List Comprehensions

The initial expression in a list comprehension can be any arbitrary expression, including another list comprehension.

Consider the following example of a 3x4 matrix implemented as a list of 3 lists of length 4:

>>>

**>>>** matrix = [

**...**  [1, 2, 3, 4],

**...**  [5, 6, 7, 8],

**...**  [9, 10, 11, 12],

**...** ]

The following list comprehension will transpose rows and columns:

>>>

**>>>** [[row[i] **for** row **in** matrix] **for** i **in** range(4)]

[[1, 5, 9], [2, 6, 10], [3, 7, 11], [4, 8, 12]]

As we saw in the previous section, the nested listcomp is evaluated in the context of the [for](https://docs.python.org/3/reference/compound_stmts.html#for) that follows it, so this example is equivalent to:

>>>

**>>>** transposed = []

**>>> for** i **in** range(4):

**...**  transposed.append([row[i] **for** row **in** matrix])

**...**

**>>>** transposed

[[1, 5, 9], [2, 6, 10], [3, 7, 11], [4, 8, 12]]

which, in turn, is the same as:

>>>

**>>>** transposed = []

**>>> for** i **in** range(4):

**...**  *# the following 3 lines implement the nested listcomp*

**...**  transposed\_row = []

**...**  **for** row **in** matrix:

**...**  transposed\_row.append(row[i])

**...**  transposed.append(transposed\_row)

**...**

**>>>** transposed

[[1, 5, 9], [2, 6, 10], [3, 7, 11], [4, 8, 12]]

In the real world, you should prefer built-in functions to complex flow statements. The [zip()](https://docs.python.org/3/library/functions.html#zip) function would do a great job for this use case:

>>>

**>>>** list(zip(\*matrix))

[(1, 5, 9), (2, 6, 10), (3, 7, 11), (4, 8, 12)]

See [Unpacking Argument Lists](https://docs.python.org/3/tutorial/controlflow.html#tut-unpacking-arguments) for details on the asterisk in this line.

## 5.2. The [del](https://docs.python.org/3/reference/simple_stmts.html#del) statement

There is a way to remove an item from a list given its index instead of its value: the [del](https://docs.python.org/3/reference/simple_stmts.html#del) statement. This differs from the pop() method which returns a value. The [del](https://docs.python.org/3/reference/simple_stmts.html#del) statement can also be used to remove slices from a list or clear the entire list (which we did earlier by assignment of an empty list to the slice). For example:

>>>

**>>>** a = [-1, 1, 66.25, 333, 333, 1234.5]

**>>> del** a[0]

**>>>** a

[1, 66.25, 333, 333, 1234.5]

**>>> del** a[2:4]

**>>>** a

[1, 66.25, 1234.5]

**>>> del** a[:]

**>>>** a

[]

[del](https://docs.python.org/3/reference/simple_stmts.html#del) can also be used to delete entire variables:

>>>

**>>> del** a

Referencing the name a hereafter is an error (at least until another value is assigned to it). We’ll find other uses for [del](https://docs.python.org/3/reference/simple_stmts.html#del) later.

## 5.3. Tuples and Sequences

We saw that lists and strings have many common properties, such as indexing and slicing operations. They are two examples of sequence data types (see [Sequence Types — list, tuple, range](https://docs.python.org/3/library/stdtypes.html#typesseq)). Since Python is an evolving language, other sequence data types may be added. There is also another standard sequence data type: the tuple.

A tuple consists of a number of values separated by commas, for instance:

>>>

**>>>** t = 12345, 54321, 'hello!'

**>>>** t[0]

12345

**>>>** t

(12345, 54321, 'hello!')

**>>>** *# Tuples may be nested:*

**...** u = t, (1, 2, 3, 4, 5)

**>>>** u

((12345, 54321, 'hello!'), (1, 2, 3, 4, 5))

**>>>** *# Tuples are immutable:*

**...** t[0] = 88888

Traceback (most recent call last):

File "<stdin>", line 1, in <module>

TypeError: 'tuple' object does not support item assignment

**>>>** *# but they can contain mutable objects:*

**...** v = ([1, 2, 3], [3, 2, 1])

**>>>** v

([1, 2, 3], [3, 2, 1])

As you see, on output tuples are always enclosed in parentheses, so that nested tuples are interpreted correctly; they may be input with or without surrounding parentheses, although often parentheses are necessary anyway (if the tuple is part of a larger expression). It is not possible to assign to the individual items of a tuple, however it is possible to create tuples which contain mutable objects, such as lists.

Though tuples may seem similar to lists, they are often used in different situations and for different purposes. Tuples are [immutable](https://docs.python.org/3/glossary.html#term-immutable), and usually contain a heterogeneous sequence of elements that are accessed via unpacking (see later in this section) or indexing (or even by attribute in the case of[namedtuples](https://docs.python.org/3/library/collections.html#collections.namedtuple)). Lists are [mutable](https://docs.python.org/3/glossary.html#term-mutable), and their elements are usually homogeneous and are accessed by iterating over the list.

A special problem is the construction of tuples containing 0 or 1 items: the syntax has some extra quirks to accommodate these. Empty tuples are constructed by an empty pair of parentheses; a tuple with one item is constructed by following a value with a comma (it is not sufficient to enclose a single value in parentheses). Ugly, but effective. For example:

>>>

**>>>** empty = ()

**>>>** singleton = 'hello', *# <-- note trailing comma*

**>>>** len(empty)

0

**>>>** len(singleton)

1

**>>>** singleton

('hello',)

The statement t = 12345, 54321, 'hello!' is an example of tuple packing: the values 12345,54321 and 'hello!' are packed together in a tuple. The reverse operation is also possible:

>>>

**>>>** x, y, z = t

This is called, appropriately enough, sequence unpacking and works for any sequence on the right-hand side. Sequence unpacking requires that there are as many variables on the left side of the equals sign as there are elements in the sequence. Note that multiple assignment is really just a combination of tuple packing and sequence unpacking.

## 5.4. Sets

Python also includes a data type for sets. A set is an unordered collection with no duplicate elements. Basic uses include membership testing and eliminating duplicate entries. Set objects also support mathematical operations like union, intersection, difference, and symmetric difference.

Curly braces or the [set()](https://docs.python.org/3/library/stdtypes.html#set) function can be used to create sets. Note: to create an empty set you have to use set(), not {}; the latter creates an empty dictionary, a data structure that we discuss in the next section.

Here is a brief demonstration:

>>>

**>>>** basket = {'apple', 'orange', 'apple', 'pear', 'orange', 'banana'}

**>>>** print(basket) *# show that duplicates have been removed*

{'orange', 'banana', 'pear', 'apple'}

**>>>** 'orange' **in** basket *# fast membership testing*

True

**>>>** 'crabgrass' **in** basket

False

**>>>** *# Demonstrate set operations on unique letters from two words*

**...**

**>>>** a = set('abracadabra')

**>>>** b = set('alacazam')

**>>>** a *# unique letters in a*

{'a', 'r', 'b', 'c', 'd'}

**>>>** a - b *# letters in a but not in b*

{'r', 'd', 'b'}

**>>>** a | b *# letters in either a or b*

{'a', 'c', 'r', 'd', 'b', 'm', 'z', 'l'}

**>>>** a & b *# letters in both a and b*

{'a', 'c'}

**>>>** a ^ b *# letters in a or b but not both*

{'r', 'd', 'b', 'm', 'z', 'l'}

Similarly to [list comprehensions](https://docs.python.org/3/tutorial/datastructures.html#tut-listcomps), set comprehensions are also supported:

>>>

**>>>** a = {x **for** x **in** 'abracadabra' **if** x **not** **in** 'abc'}

**>>>** a

{'r', 'd'}

## 5.5. Dictionaries

Another useful data type built into Python is the dictionary (see [Mapping Types — dict](https://docs.python.org/3/library/stdtypes.html#typesmapping)). Dictionaries are sometimes found in other languages as “associative memories” or “associative arrays”. Unlike sequences, which are indexed by a range of numbers, dictionaries are indexed by keys, which can be any immutable type; strings and numbers can always be keys. Tuples can be used as keys if they contain only strings, numbers, or tuples; if a tuple contains any mutable object either directly or indirectly, it cannot be used as a key. You can’t use lists as keys, since lists can be modified in place using index assignments, slice assignments, or methods like append() and extend().

It is best to think of a dictionary as an unordered set of key: value pairs, with the requirement that the keys are unique (within one dictionary). A pair of braces creates an empty dictionary: {}. Placing a comma-separated list of key:value pairs within the braces adds initial key:value pairs to the dictionary; this is also the way dictionaries are written on output.

The main operations on a dictionary are storing a value with some key and extracting the value given the key. It is also possible to delete a key:value pair with del. If you store using a key that is already in use, the old value associated with that key is forgotten. It is an error to extract a value using a non-existent key.

Performing list(d.keys()) on a dictionary returns a list of all the keys used in the dictionary, in arbitrary order (if you want it sorted, just use sorted(d.keys()) instead). [[2]](https://docs.python.org/3/tutorial/datastructures.html#id4) To check whether a single key is in the dictionary, use the [in](https://docs.python.org/3/reference/expressions.html#in) keyword.

Here is a small example using a dictionary:

>>>

**>>>** tel = {'jack': 4098, 'sape': 4139}

**>>>** tel['guido'] = 4127

**>>>** tel

{'sape': 4139, 'guido': 4127, 'jack': 4098}

**>>>** tel['jack']

4098

**>>> del** tel['sape']

**>>>** tel['irv'] = 4127

**>>>** tel

{'guido': 4127, 'irv': 4127, 'jack': 4098}

**>>>** list(tel.keys())

['irv', 'guido', 'jack']

**>>>** sorted(tel.keys())

['guido', 'irv', 'jack']

**>>>** 'guido' **in** tel

True

**>>>** 'jack' **not** **in** tel

False

The [dict()](https://docs.python.org/3/library/stdtypes.html#dict) constructor builds dictionaries directly from sequences of key-value pairs:

>>>

**>>>** dict([('sape', 4139), ('guido', 4127), ('jack', 4098)])

{'sape': 4139, 'jack': 4098, 'guido': 4127}

In addition, dict comprehensions can be used to create dictionaries from arbitrary key and value expressions:

>>>

**>>>** {x: x\*\*2 **for** x **in** (2, 4, 6)}

{2: 4, 4: 16, 6: 36}

When the keys are simple strings, it is sometimes easier to specify pairs using keyword arguments:

>>>

**>>>** dict(sape=4139, guido=4127, jack=4098)

{'sape': 4139, 'jack': 4098, 'guido': 4127}

## 5.6. Looping Techniques

When looping through dictionaries, the key and corresponding value can be retrieved at the same time using the items() method.

>>>

**>>>** knights = {'gallahad': 'the pure', 'robin': 'the brave'}

**>>> for** k, v **in** knights.items():

**...**  print(k, v)

**...**

gallahad the pure

robin the brave

When looping through a sequence, the position index and corresponding value can be retrieved at the same time using the [enumerate()](https://docs.python.org/3/library/functions.html#enumerate) function.

>>>

**>>> for** i, v **in** enumerate(['tic', 'tac', 'toe']):

**...**  print(i, v)

**...**

0 tic

1 tac

2 toe

To loop over two or more sequences at the same time, the entries can be paired with the [zip()](https://docs.python.org/3/library/functions.html#zip)function.

>>>

**>>>** questions = ['name', 'quest', 'favorite color']

**>>>** answers = ['lancelot', 'the holy grail', 'blue']

**>>> for** q, a **in** zip(questions, answers):

**...**  print('What is your *{0}*? It is *{1}*.'.format(q, a))

**...**

What is your name? It is lancelot.

What is your quest? It is the holy grail.

What is your favorite color? It is blue.

To loop over a sequence in reverse, first specify the sequence in a forward direction and then call the[reversed()](https://docs.python.org/3/library/functions.html#reversed) function.

>>>

**>>> for** i **in** reversed(range(1, 10, 2)):

**...**  print(i)

**...**

9

7

5

3

1

To loop over a sequence in sorted order, use the [sorted()](https://docs.python.org/3/library/functions.html#sorted) function which returns a new sorted list while leaving the source unaltered.

>>>

**>>>** basket = ['apple', 'orange', 'apple', 'pear', 'orange', 'banana']

**>>> for** f **in** sorted(set(basket)):

**...**  print(f)

**...**

apple

banana

orange

pear

It is sometimes tempting to change a list while you are looping over it; however, it is often simpler and safer to create a new list instead.

>>>

**>>> import** **math**

**>>>** raw\_data = [56.2, float('NaN'), 51.7, 55.3, 52.5, float('NaN'), 47.8]

**>>>** filtered\_data = []

**>>> for** value **in** raw\_data:

**...**  **if** **not** math.isnan(value):

**...**  filtered\_data.append(value)

**...**

**>>>** filtered\_data

[56.2, 51.7, 55.3, 52.5, 47.8]

## 5.7. More on Conditions

The conditions used in while and if statements can contain any operators, not just comparisons.

The comparison operators in and not in check whether a value occurs (does not occur) in a sequence. The operators is and is not compare whether two objects are really the same object; this only matters for mutable objects like lists. All comparison operators have the same priority, which is lower than that of all numerical operators.

Comparisons can be chained. For example, a < b == c tests whether a is less than b and moreoverb equals c.

Comparisons may be combined using the Boolean operators and and or, and the outcome of a comparison (or of any other Boolean expression) may be negated with not. These have lower priorities than comparison operators; between them, not has the highest priority and or the lowest, so that A and not B or C is equivalent to (A and (not B)) or C. As always, parentheses can be used to express the desired composition.

The Boolean operators and and or are so-called short-circuit operators: their arguments are evaluated from left to right, and evaluation stops as soon as the outcome is determined. For example, if A and C are true but B is false, A and B and C does not evaluate the expression C. When used as a general value and not as a Boolean, the return value of a short-circuit operator is the last evaluated argument.

It is possible to assign the result of a comparison or other Boolean expression to a variable. For example,

>>>

**>>>** string1, string2, string3 = '', 'Trondheim', 'Hammer Dance'

**>>>** non\_null = string1 **or** string2 **or** string3

**>>>** non\_null

'Trondheim'

Note that in Python, unlike C, assignment cannot occur inside expressions. C programmers may grumble about this, but it avoids a common class of problems encountered in C programs: typing = in an expression when == was intended.

## 5.8. Comparing Sequences and Other Types

Sequence objects may be compared to other objects with the same sequence type. The comparison uses lexicographical ordering: first the first two items are compared, and if they differ this determines the outcome of the comparison; if they are equal, the next two items are compared, and so on, until either sequence is exhausted. If two items to be compared are themselves sequences of the same type, the lexicographical comparison is carried out recursively. If all items of two sequences compare equal, the sequences are considered equal. If one sequence is an initial sub-sequence of the other, the shorter sequence is the smaller (lesser) one. Lexicographical ordering for strings uses the Unicode code point number to order individual characters. Some examples of comparisons between sequences of the same type:

(1, 2, 3) < (1, 2, 4)

[1, 2, 3] < [1, 2, 4]

'ABC' < 'C' < 'Pascal' < 'Python'

(1, 2, 3, 4) < (1, 2, 4)

(1, 2) < (1, 2, -1)

(1, 2, 3) == (1.0, 2.0, 3.0)

(1, 2, ('aa', 'ab')) < (1, 2, ('abc', 'a'), 4)

Note that comparing objects of different types with < or > is legal provided that the objects have appropriate comparison methods. For example, mixed numeric types are compared according to their numeric value, so 0 equals 0.0, etc. Otherwise, rather than providing an arbitrary ordering, the interpreter will raise a [TypeError](https://docs.python.org/3/library/exceptions.html#TypeError) exception.

**Footnotes**

|  |  |
| --- | --- |
| [[1]](https://docs.python.org/3/tutorial/datastructures.html#id1) | Other languages may return the mutated object, which allows method chaining, such as d->insert("a")->remove("b")->sort();. |

|  |  |
| --- | --- |
| [[2]](https://docs.python.org/3/tutorial/datastructures.html#id2) | Calling d.keys() will return a dictionary view object. It supports operations like membership test and iteration, but its contents are not independent of the original dictionary – it is only aview. |

# 5. Data Structures

This chapter describes some things you’ve learned about already in more detail, and adds some new things as well.

## 5.1. More on Lists

The list data type has some more methods. Here are all of the methods of list objects:

list.**append**(x)

Add an item to the end of the list. Equivalent to a[len(a):] = [x].

list.**extend**(L)

Extend the list by appending all the items in the given list. Equivalent to a[len(a):] = L.

list.**insert**(i, x)

Insert an item at a given position. The first argument is the index of the element before which to insert, so a.insert(0, x) inserts at the front of the list, and a.insert(len(a), x) is equivalent to a.append(x).

list.**remove**(x)

Remove the first item from the list whose value is x. It is an error if there is no such item.

list.**pop**([i])

Remove the item at the given position in the list, and return it. If no index is specified, a.pop()removes and returns the last item in the list. (The square brackets around the i in the method signature denote that the parameter is optional, not that you should type square brackets at that position. You will see this notation frequently in the Python Library Reference.)

list.**clear**()

Remove all items from the list. Equivalent to del a[:].

list.**index**(x)

Return the index in the list of the first item whose value is x. It is an error if there is no such item.

list.**count**(x)

Return the number of times x appears in the list.

list.**sort**(key=None, reverse=False)

Sort the items of the list in place (the arguments can be used for sort customization, see[sorted()](https://docs.python.org/3/library/functions.html#sorted) for their explanation).

list.**reverse**()

Reverse the elements of the list in place.

list.**copy**()

Return a shallow copy of the list. Equivalent to a[:].

An example that uses most of the list methods:

>>>

**>>>** a = [66.25, 333, 333, 1, 1234.5]

**>>>** print(a.count(333), a.count(66.25), a.count('x'))

2 1 0

**>>>** a.insert(2, -1)

**>>>** a.append(333)

**>>>** a

[66.25, 333, -1, 333, 1, 1234.5, 333]

**>>>** a.index(333)

1

**>>>** a.remove(333)

**>>>** a

[66.25, -1, 333, 1, 1234.5, 333]

**>>>** a.reverse()

**>>>** a

[333, 1234.5, 1, 333, -1, 66.25]

**>>>** a.sort()

**>>>** a

[-1, 1, 66.25, 333, 333, 1234.5]

**>>>** a.pop()

1234.5

**>>>** a

[-1, 1, 66.25, 333, 333]

You might have noticed that methods like insert, remove or sort that only modify the list have no return value printed – they return the default None. [[1]](https://docs.python.org/3/tutorial/datastructures.html#id3) This is a design principle for all mutable data structures in Python.

### 5.1.1. Using Lists as Stacks

The list methods make it very easy to use a list as a stack, where the last element added is the first element retrieved (“last-in, first-out”). To add an item to the top of the stack, use append(). To retrieve an item from the top of the stack, use pop() without an explicit index. For example:

>>>

**>>>** stack = [3, 4, 5]

**>>>** stack.append(6)

**>>>** stack.append(7)

**>>>** stack

[3, 4, 5, 6, 7]

**>>>** stack.pop()

7

**>>>** stack

[3, 4, 5, 6]

**>>>** stack.pop()

6

**>>>** stack.pop()

5

**>>>** stack

[3, 4]

### 5.1.2. Using Lists as Queues

It is also possible to use a list as a queue, where the first element added is the first element retrieved (“first-in, first-out”); however, lists are not efficient for this purpose. While appends and pops from the end of list are fast, doing inserts or pops from the beginning of a list is slow (because all of the other elements have to be shifted by one).

To implement a queue, use [collections.deque](https://docs.python.org/3/library/collections.html#collections.deque) which was designed to have fast appends and pops from both ends. For example:

>>>

**>>> from** **collections** **import** deque

**>>>** queue = deque(["Eric", "John", "Michael"])

**>>>** queue.append("Terry") *# Terry arrives*

**>>>** queue.append("Graham") *# Graham arrives*

**>>>** queue.popleft() *# The first to arrive now leaves*

'Eric'

**>>>** queue.popleft() *# The second to arrive now leaves*

'John'

**>>>** queue *# Remaining queue in order of arrival*

deque(['Michael', 'Terry', 'Graham'])

### 5.1.3. List Comprehensions

List comprehensions provide a concise way to create lists. Common applications are to make new lists where each element is the result of some operations applied to each member of another sequence or iterable, or to create a subsequence of those elements that satisfy a certain condition.

For example, assume we want to create a list of squares, like:

>>>

**>>>** squares = []

**>>> for** x **in** range(10):

**...**  squares.append(x\*\*2)

**...**

**>>>** squares

[0, 1, 4, 9, 16, 25, 36, 49, 64, 81]

Note that this creates (or overwrites) a variable named x that still exists after the loop completes. We can calculate the list of squares without any side effects using:

squares = list(map(**lambda** x: x\*\*2, range(10)))

or, equivalently:

squares = [x\*\*2 **for** x **in** range(10)]

which is more concise and readable.

A list comprehension consists of brackets containing an expression followed by a [for](https://docs.python.org/3/reference/compound_stmts.html#for) clause, then zero or more [for](https://docs.python.org/3/reference/compound_stmts.html#for) or [if](https://docs.python.org/3/reference/compound_stmts.html#if) clauses. The result will be a new list resulting from evaluating the expression in the context of the [for](https://docs.python.org/3/reference/compound_stmts.html#for) and [if](https://docs.python.org/3/reference/compound_stmts.html#if) clauses which follow it. For example, this listcomp combines the elements of two lists if they are not equal:

>>>

**>>>** [(x, y) **for** x **in** [1,2,3] **for** y **in** [3,1,4] **if** x != y]

[(1, 3), (1, 4), (2, 3), (2, 1), (2, 4), (3, 1), (3, 4)]

and it’s equivalent to:

>>>

**>>>** combs = []

**>>> for** x **in** [1,2,3]:

**...**  **for** y **in** [3,1,4]:

**...**  **if** x != y:

**...**  combs.append((x, y))

**...**

**>>>** combs

[(1, 3), (1, 4), (2, 3), (2, 1), (2, 4), (3, 1), (3, 4)]

Note how the order of the [for](https://docs.python.org/3/reference/compound_stmts.html#for) and [if](https://docs.python.org/3/reference/compound_stmts.html#if) statements is the same in both these snippets.

If the expression is a tuple (e.g. the (x, y) in the previous example), it must be parenthesized.

>>>

**>>>** vec = [-4, -2, 0, 2, 4]

**>>>** *# create a new list with the values doubled*

**>>>** [x\*2 **for** x **in** vec]

[-8, -4, 0, 4, 8]

**>>>** *# filter the list to exclude negative numbers*

**>>>** [x **for** x **in** vec **if** x >= 0]

[0, 2, 4]

**>>>** *# apply a function to all the elements*

**>>>** [abs(x) **for** x **in** vec]

[4, 2, 0, 2, 4]

**>>>** *# call a method on each element*

**>>>** freshfruit = [' banana', ' loganberry ', 'passion fruit ']

**>>>** [weapon.strip() **for** weapon **in** freshfruit]

['banana', 'loganberry', 'passion fruit']

**>>>** *# create a list of 2-tuples like (number, square)*

**>>>** [(x, x\*\*2) **for** x **in** range(6)]

[(0, 0), (1, 1), (2, 4), (3, 9), (4, 16), (5, 25)]

**>>>** *# the tuple must be parenthesized, otherwise an error is raised*

**>>>** [x, x\*\*2 **for** x **in** range(6)]

File "<stdin>", line 1, in ?

[x, x\*\*2 for x in range(6)]

^

SyntaxError: invalid syntax

**>>>** *# flatten a list using a listcomp with two 'for'*

**>>>** vec = [[1,2,3], [4,5,6], [7,8,9]]

**>>>** [num **for** elem **in** vec **for** num **in** elem]

[1, 2, 3, 4, 5, 6, 7, 8, 9]

List comprehensions can contain complex expressions and nested functions:

>>>

**>>> from** **math** **import** pi

**>>>** [str(round(pi, i)) **for** i **in** range(1, 6)]

['3.1', '3.14', '3.142', '3.1416', '3.14159']

### 5.1.4. Nested List Comprehensions

The initial expression in a list comprehension can be any arbitrary expression, including another list comprehension.

Consider the following example of a 3x4 matrix implemented as a list of 3 lists of length 4:

>>>

**>>>** matrix = [

**...**  [1, 2, 3, 4],

**...**  [5, 6, 7, 8],

**...**  [9, 10, 11, 12],

**...** ]

The following list comprehension will transpose rows and columns:

>>>

**>>>** [[row[i] **for** row **in** matrix] **for** i **in** range(4)]

[[1, 5, 9], [2, 6, 10], [3, 7, 11], [4, 8, 12]]

As we saw in the previous section, the nested listcomp is evaluated in the context of the [for](https://docs.python.org/3/reference/compound_stmts.html#for) that follows it, so this example is equivalent to:

>>>

**>>>** transposed = []

**>>> for** i **in** range(4):

**...**  transposed.append([row[i] **for** row **in** matrix])

**...**

**>>>** transposed

[[1, 5, 9], [2, 6, 10], [3, 7, 11], [4, 8, 12]]

which, in turn, is the same as:

>>>

**>>>** transposed = []

**>>> for** i **in** range(4):

**...**  *# the following 3 lines implement the nested listcomp*

**...**  transposed\_row = []

**...**  **for** row **in** matrix:

**...**  transposed\_row.append(row[i])

**...**  transposed.append(transposed\_row)

**...**

**>>>** transposed

[[1, 5, 9], [2, 6, 10], [3, 7, 11], [4, 8, 12]]

In the real world, you should prefer built-in functions to complex flow statements. The [zip()](https://docs.python.org/3/library/functions.html#zip) function would do a great job for this use case:

>>>

**>>>** list(zip(\*matrix))

[(1, 5, 9), (2, 6, 10), (3, 7, 11), (4, 8, 12)]

See [Unpacking Argument Lists](https://docs.python.org/3/tutorial/controlflow.html#tut-unpacking-arguments) for details on the asterisk in this line.

## 5.2. The [del](https://docs.python.org/3/reference/simple_stmts.html#del) statement

There is a way to remove an item from a list given its index instead of its value: the [del](https://docs.python.org/3/reference/simple_stmts.html#del) statement. This differs from the pop() method which returns a value. The [del](https://docs.python.org/3/reference/simple_stmts.html#del) statement can also be used to remove slices from a list or clear the entire list (which we did earlier by assignment of an empty list to the slice). For example:

>>>

**>>>** a = [-1, 1, 66.25, 333, 333, 1234.5]

**>>> del** a[0]

**>>>** a

[1, 66.25, 333, 333, 1234.5]

**>>> del** a[2:4]

**>>>** a

[1, 66.25, 1234.5]

**>>> del** a[:]

**>>>** a

[]

[del](https://docs.python.org/3/reference/simple_stmts.html#del) can also be used to delete entire variables:

>>>

**>>> del** a

Referencing the name a hereafter is an error (at least until another value is assigned to it). We’ll find other uses for [del](https://docs.python.org/3/reference/simple_stmts.html#del) later.

## 5.3. Tuples and Sequences

We saw that lists and strings have many common properties, such as indexing and slicing operations. They are two examples of sequence data types (see [Sequence Types — list, tuple, range](https://docs.python.org/3/library/stdtypes.html#typesseq)). Since Python is an evolving language, other sequence data types may be added. There is also another standard sequence data type: the tuple.

A tuple consists of a number of values separated by commas, for instance:

>>>

**>>>** t = 12345, 54321, 'hello!'

**>>>** t[0]

12345

**>>>** t

(12345, 54321, 'hello!')

**>>>** *# Tuples may be nested:*

**...** u = t, (1, 2, 3, 4, 5)

**>>>** u

((12345, 54321, 'hello!'), (1, 2, 3, 4, 5))

**>>>** *# Tuples are immutable:*

**...** t[0] = 88888

Traceback (most recent call last):

File "<stdin>", line 1, in <module>

TypeError: 'tuple' object does not support item assignment

**>>>** *# but they can contain mutable objects:*

**...** v = ([1, 2, 3], [3, 2, 1])

**>>>** v

([1, 2, 3], [3, 2, 1])

As you see, on output tuples are always enclosed in parentheses, so that nested tuples are interpreted correctly; they may be input with or without surrounding parentheses, although often parentheses are necessary anyway (if the tuple is part of a larger expression). It is not possible to assign to the individual items of a tuple, however it is possible to create tuples which contain mutable objects, such as lists.

Though tuples may seem similar to lists, they are often used in different situations and for different purposes. Tuples are [immutable](https://docs.python.org/3/glossary.html#term-immutable), and usually contain a heterogeneous sequence of elements that are accessed via unpacking (see later in this section) or indexing (or even by attribute in the case of[namedtuples](https://docs.python.org/3/library/collections.html#collections.namedtuple)). Lists are [mutable](https://docs.python.org/3/glossary.html#term-mutable), and their elements are usually homogeneous and are accessed by iterating over the list.

A special problem is the construction of tuples containing 0 or 1 items: the syntax has some extra quirks to accommodate these. Empty tuples are constructed by an empty pair of parentheses; a tuple with one item is constructed by following a value with a comma (it is not sufficient to enclose a single value in parentheses). Ugly, but effective. For example:

>>>

**>>>** empty = ()

**>>>** singleton = 'hello', *# <-- note trailing comma*

**>>>** len(empty)

0

**>>>** len(singleton)

1

**>>>** singleton

('hello',)

The statement t = 12345, 54321, 'hello!' is an example of tuple packing: the values 12345,54321 and 'hello!' are packed together in a tuple. The reverse operation is also possible:

>>>

**>>>** x, y, z = t

This is called, appropriately enough, sequence unpacking and works for any sequence on the right-hand side. Sequence unpacking requires that there are as many variables on the left side of the equals sign as there are elements in the sequence. Note that multiple assignment is really just a combination of tuple packing and sequence unpacking.

## 5.4. Sets

Python also includes a data type for sets. A set is an unordered collection with no duplicate elements. Basic uses include membership testing and eliminating duplicate entries. Set objects also support mathematical operations like union, intersection, difference, and symmetric difference.

Curly braces or the [set()](https://docs.python.org/3/library/stdtypes.html#set) function can be used to create sets. Note: to create an empty set you have to use set(), not {}; the latter creates an empty dictionary, a data structure that we discuss in the next section.

Here is a brief demonstration:

>>>

**>>>** basket = {'apple', 'orange', 'apple', 'pear', 'orange', 'banana'}

**>>>** print(basket) *# show that duplicates have been removed*

{'orange', 'banana', 'pear', 'apple'}

**>>>** 'orange' **in** basket *# fast membership testing*

True

**>>>** 'crabgrass' **in** basket

False

**>>>** *# Demonstrate set operations on unique letters from two words*

**...**

**>>>** a = set('abracadabra')

**>>>** b = set('alacazam')

**>>>** a *# unique letters in a*

{'a', 'r', 'b', 'c', 'd'}

**>>>** a - b *# letters in a but not in b*

{'r', 'd', 'b'}

**>>>** a | b *# letters in either a or b*

{'a', 'c', 'r', 'd', 'b', 'm', 'z', 'l'}

**>>>** a & b *# letters in both a and b*

{'a', 'c'}

**>>>** a ^ b *# letters in a or b but not both*

{'r', 'd', 'b', 'm', 'z', 'l'}

Similarly to [list comprehensions](https://docs.python.org/3/tutorial/datastructures.html#tut-listcomps), set comprehensions are also supported:

>>>

**>>>** a = {x **for** x **in** 'abracadabra' **if** x **not** **in** 'abc'}

**>>>** a

{'r', 'd'}

## 5.5. Dictionaries

Another useful data type built into Python is the dictionary (see [Mapping Types — dict](https://docs.python.org/3/library/stdtypes.html#typesmapping)). Dictionaries are sometimes found in other languages as “associative memories” or “associative arrays”. Unlike sequences, which are indexed by a range of numbers, dictionaries are indexed by keys, which can be any immutable type; strings and numbers can always be keys. Tuples can be used as keys if they contain only strings, numbers, or tuples; if a tuple contains any mutable object either directly or indirectly, it cannot be used as a key. You can’t use lists as keys, since lists can be modified in place using index assignments, slice assignments, or methods like append() and extend().

It is best to think of a dictionary as an unordered set of key: value pairs, with the requirement that the keys are unique (within one dictionary). A pair of braces creates an empty dictionary: {}. Placing a comma-separated list of key:value pairs within the braces adds initial key:value pairs to the dictionary; this is also the way dictionaries are written on output.

The main operations on a dictionary are storing a value with some key and extracting the value given the key. It is also possible to delete a key:value pair with del. If you store using a key that is already in use, the old value associated with that key is forgotten. It is an error to extract a value using a non-existent key.

Performing list(d.keys()) on a dictionary returns a list of all the keys used in the dictionary, in arbitrary order (if you want it sorted, just use sorted(d.keys()) instead). [[2]](https://docs.python.org/3/tutorial/datastructures.html#id4) To check whether a single key is in the dictionary, use the [in](https://docs.python.org/3/reference/expressions.html#in) keyword.

Here is a small example using a dictionary:

>>>

**>>>** tel = {'jack': 4098, 'sape': 4139}

**>>>** tel['guido'] = 4127

**>>>** tel

{'sape': 4139, 'guido': 4127, 'jack': 4098}

**>>>** tel['jack']

4098

**>>> del** tel['sape']

**>>>** tel['irv'] = 4127

**>>>** tel

{'guido': 4127, 'irv': 4127, 'jack': 4098}

**>>>** list(tel.keys())

['irv', 'guido', 'jack']

**>>>** sorted(tel.keys())

['guido', 'irv', 'jack']

**>>>** 'guido' **in** tel

True

**>>>** 'jack' **not** **in** tel

False

The [dict()](https://docs.python.org/3/library/stdtypes.html#dict) constructor builds dictionaries directly from sequences of key-value pairs:

>>>

**>>>** dict([('sape', 4139), ('guido', 4127), ('jack', 4098)])

{'sape': 4139, 'jack': 4098, 'guido': 4127}

In addition, dict comprehensions can be used to create dictionaries from arbitrary key and value expressions:

>>>

**>>>** {x: x\*\*2 **for** x **in** (2, 4, 6)}

{2: 4, 4: 16, 6: 36}

When the keys are simple strings, it is sometimes easier to specify pairs using keyword arguments:

>>>

**>>>** dict(sape=4139, guido=4127, jack=4098)

{'sape': 4139, 'jack': 4098, 'guido': 4127}

## 5.6. Looping Techniques

When looping through dictionaries, the key and corresponding value can be retrieved at the same time using the items() method.

>>>

**>>>** knights = {'gallahad': 'the pure', 'robin': 'the brave'}

**>>> for** k, v **in** knights.items():

**...**  print(k, v)

**...**

gallahad the pure

robin the brave

When looping through a sequence, the position index and corresponding value can be retrieved at the same time using the [enumerate()](https://docs.python.org/3/library/functions.html#enumerate) function.

>>>

**>>> for** i, v **in** enumerate(['tic', 'tac', 'toe']):

**...**  print(i, v)

**...**

0 tic

1 tac

2 toe

To loop over two or more sequences at the same time, the entries can be paired with the [zip()](https://docs.python.org/3/library/functions.html#zip)function.

>>>

**>>>** questions = ['name', 'quest', 'favorite color']

**>>>** answers = ['lancelot', 'the holy grail', 'blue']

**>>> for** q, a **in** zip(questions, answers):

**...**  print('What is your *{0}*? It is *{1}*.'.format(q, a))

**...**

What is your name? It is lancelot.

What is your quest? It is the holy grail.

What is your favorite color? It is blue.

To loop over a sequence in reverse, first specify the sequence in a forward direction and then call the[reversed()](https://docs.python.org/3/library/functions.html#reversed) function.

>>>

**>>> for** i **in** reversed(range(1, 10, 2)):

**...**  print(i)

**...**

9

7

5

3

1

To loop over a sequence in sorted order, use the [sorted()](https://docs.python.org/3/library/functions.html#sorted) function which returns a new sorted list while leaving the source unaltered.

>>>

**>>>** basket = ['apple', 'orange', 'apple', 'pear', 'orange', 'banana']

**>>> for** f **in** sorted(set(basket)):

**...**  print(f)

**...**

apple

banana

orange

pear

It is sometimes tempting to change a list while you are looping over it; however, it is often simpler and safer to create a new list instead.

>>>

**>>> import** **math**

**>>>** raw\_data = [56.2, float('NaN'), 51.7, 55.3, 52.5, float('NaN'), 47.8]

**>>>** filtered\_data = []

**>>> for** value **in** raw\_data:

**...**  **if** **not** math.isnan(value):

**...**  filtered\_data.append(value)

**...**

**>>>** filtered\_data

[56.2, 51.7, 55.3, 52.5, 47.8]

## 5.7. More on Conditions

The conditions used in while and if statements can contain any operators, not just comparisons.

The comparison operators in and not in check whether a value occurs (does not occur) in a sequence. The operators is and is not compare whether two objects are really the same object; this only matters for mutable objects like lists. All comparison operators have the same priority, which is lower than that of all numerical operators.

Comparisons can be chained. For example, a < b == c tests whether a is less than b and moreoverb equals c.

Comparisons may be combined using the Boolean operators and and or, and the outcome of a comparison (or of any other Boolean expression) may be negated with not. These have lower priorities than comparison operators; between them, not has the highest priority and or the lowest, so that A and not B or C is equivalent to (A and (not B)) or C. As always, parentheses can be used to express the desired composition.

The Boolean operators and and or are so-called short-circuit operators: their arguments are evaluated from left to right, and evaluation stops as soon as the outcome is determined. For example, if A and C are true but B is false, A and B and C does not evaluate the expression C. When used as a general value and not as a Boolean, the return value of a short-circuit operator is the last evaluated argument.

It is possible to assign the result of a comparison or other Boolean expression to a variable. For example,

>>>

**>>>** string1, string2, string3 = '', 'Trondheim', 'Hammer Dance'

**>>>** non\_null = string1 **or** string2 **or** string3

**>>>** non\_null

'Trondheim'

Note that in Python, unlike C, assignment cannot occur inside expressions. C programmers may grumble about this, but it avoids a common class of problems encountered in C programs: typing = in an expression when == was intended.

## 5.8. Comparing Sequences and Other Types

Sequence objects may be compared to other objects with the same sequence type. The comparison uses lexicographical ordering: first the first two items are compared, and if they differ this determines the outcome of the comparison; if they are equal, the next two items are compared, and so on, until either sequence is exhausted. If two items to be compared are themselves sequences of the same type, the lexicographical comparison is carried out recursively. If all items of two sequences compare equal, the sequences are considered equal. If one sequence is an initial sub-sequence of the other, the shorter sequence is the smaller (lesser) one. Lexicographical ordering for strings uses the Unicode code point number to order individual characters. Some examples of comparisons between sequences of the same type:

(1, 2, 3) < (1, 2, 4)

[1, 2, 3] < [1, 2, 4]

'ABC' < 'C' < 'Pascal' < 'Python'

(1, 2, 3, 4) < (1, 2, 4)

(1, 2) < (1, 2, -1)

(1, 2, 3) == (1.0, 2.0, 3.0)

(1, 2, ('aa', 'ab')) < (1, 2, ('abc', 'a'), 4)

Note that comparing objects of different types with < or > is legal provided that the objects have appropriate comparison methods. For example, mixed numeric types are compared according to their numeric value, so 0 equals 0.0, etc. Otherwise, rather than providing an arbitrary ordering, the interpreter will raise a [TypeError](https://docs.python.org/3/library/exceptions.html#TypeError) exception.

**Footnotes**

|  |  |
| --- | --- |
| [[1]](https://docs.python.org/3/tutorial/datastructures.html#id1) | Other languages may return the mutated object, which allows method chaining, such as d->insert("a")->remove("b")->sort();. |

|  |  |
| --- | --- |
| [[2]](https://docs.python.org/3/tutorial/datastructures.html#id2) | Calling d.keys() will return a dictionary view object. It supports operations like membership test and iteration, but its contents are not independent of the original dictionary – it is only aview. |

# 6. Modules

If you quit from the Python interpreter and enter it again, the definitions you have made (functions and variables) are lost. Therefore, if you want to write a somewhat longer program, you are better off using a text editor to prepare the input for the interpreter and running it with that file as input instead. This is known as creating a script. As your program gets longer, you may want to split it into several files for easier maintenance. You may also want to use a handy function that you’ve written in several programs without copying its definition into each program.

To support this, Python has a way to put definitions in a file and use them in a script or in an interactive instance of the interpreter. Such a file is called a module; definitions from a module can be importedinto other modules or into the main module (the collection of variables that you have access to in a script executed at the top level and in calculator mode).

A module is a file containing Python definitions and statements. The file name is the module name with the suffix .py appended. Within a module, the module’s name (as a string) is available as the value of the global variable \_\_name\_\_. For instance, use your favorite text editor to create a file calledfibo.py in the current directory with the following contents:

*# Fibonacci numbers module*

**def** fib(n): *# write Fibonacci series up to n*

a, b = 0, 1

**while** b < n:

print(b, end=' ')

a, b = b, a+b

print()

**def** fib2(n): *# return Fibonacci series up to n*

result = []

a, b = 0, 1

**while** b < n:

result.append(b)

a, b = b, a+b

**return** result

Now enter the Python interpreter and import this module with the following command:

>>>

**>>> import** **fibo**

This does not enter the names of the functions defined in fibo directly in the current symbol table; it only enters the module name fibo there. Using the module name you can access the functions:

>>>

**>>>** fibo.fib(1000)

1 1 2 3 5 8 13 21 34 55 89 144 233 377 610 987

**>>>** fibo.fib2(100)

[1, 1, 2, 3, 5, 8, 13, 21, 34, 55, 89]

**>>>** fibo.\_\_name\_\_

'fibo'

If you intend to use a function often you can assign it to a local name:

>>>

**>>>** fib = fibo.fib

**>>>** fib(500)

1 1 2 3 5 8 13 21 34 55 89 144 233 377

## 6.1. More on Modules

A module can contain executable statements as well as function definitions. These statements are intended to initialize the module. They are executed only the first time the module name is encountered in an import statement. [[1]](https://docs.python.org/3/tutorial/modules.html#id2) (They are also run if the file is executed as a script.)

Each module has its own private symbol table, which is used as the global symbol table by all functions defined in the module. Thus, the author of a module can use global variables in the module without worrying about accidental clashes with a user’s global variables. On the other hand, if you know what you are doing you can touch a module’s global variables with the same notation used to refer to its functions, modname.itemname.

Modules can import other modules. It is customary but not required to place all [import](https://docs.python.org/3/reference/simple_stmts.html#import) statements at the beginning of a module (or script, for that matter). The imported module names are placed in the importing module’s global symbol table.

There is a variant of the [import](https://docs.python.org/3/reference/simple_stmts.html#import) statement that imports names from a module directly into the importing module’s symbol table. For example:

>>>

**>>> from** **fibo** **import** fib, fib2

**>>>** fib(500)

1 1 2 3 5 8 13 21 34 55 89 144 233 377

This does not introduce the module name from which the imports are taken in the local symbol table (so in the example, fibo is not defined).

There is even a variant to import all names that a module defines:

>>>

**>>> from** **fibo** **import** \*

**>>>** fib(500)

1 1 2 3 5 8 13 21 34 55 89 144 233 377

This imports all names except those beginning with an underscore (\_). In most cases Python programmers do not use this facility since it introduces an unknown set of names into the interpreter, possibly hiding some things you have already defined.

Note that in general the practice of importing \* from a module or package is frowned upon, since it often causes poorly readable code. However, it is okay to use it to save typing in interactive sessions.

**Note**

For efficiency reasons, each module is only imported once per interpreter session. Therefore, if you change your modules, you must restart the interpreter – or, if it’s just one module you want to test interactively, use [importlib.reload()](https://docs.python.org/3/library/importlib.html#importlib.reload), e.g. import importlib;importlib.reload(modulename).

### 6.1.1. Executing modules as scripts

When you run a Python module with

python fibo.py <arguments>

the code in the module will be executed, just as if you imported it, but with the \_\_name\_\_ set to"\_\_main\_\_". That means that by adding this code at the end of your module:

**if** \_\_name\_\_ == "\_\_main\_\_":

**import** **sys**

fib(int(sys.argv[1]))

you can make the file usable as a script as well as an importable module, because the code that parses the command line only runs if the module is executed as the “main” file:

$ python fibo.py 50

1 1 2 3 5 8 13 21 34

If the module is imported, the code is not run:

>>>

**>>> import** **fibo**

>>>

This is often used either to provide a convenient user interface to a module, or for testing purposes (running the module as a script executes a test suite).

### 6.1.2. The Module Search Path

When a module named spam is imported, the interpreter first searches for a built-in module with that name. If not found, it then searches for a file named spam.py in a list of directories given by the variable [sys.path](https://docs.python.org/3/library/sys.html#sys.path). [sys.path](https://docs.python.org/3/library/sys.html#sys.path) is initialized from these locations:

* The directory containing the input script (or the current directory when no file is specified).
* [PYTHONPATH](https://docs.python.org/3/using/cmdline.html#envvar-PYTHONPATH) (a list of directory names, with the same syntax as the shell variable PATH).
* The installation-dependent default.

**Note**

On file systems which support symlinks, the directory containing the input script is calculated after the symlink is followed. In other words the directory containing the symlink is **not** added to the module search path.

After initialization, Python programs can modify [sys.path](https://docs.python.org/3/library/sys.html#sys.path). The directory containing the script being run is placed at the beginning of the search path, ahead of the standard library path. This means that scripts in that directory will be loaded instead of modules of the same name in the library directory. This is an error unless the replacement is intended. See section [Standard Modules](https://docs.python.org/3/tutorial/modules.html#tut-standardmodules) for more information.

### 6.1.3. “Compiled” Python files

To speed up loading modules, Python caches the compiled version of each module in the\_\_pycache\_\_ directory under the name module.*version*.pyc, where the version encodes the format of the compiled file; it generally contains the Python version number. For example, in CPython release 3.3 the compiled version of spam.py would be cached as \_\_pycache\_\_/spam.cpython-33.pyc. This naming convention allows compiled modules from different releases and different versions of Python to coexist.

Python checks the modification date of the source against the compiled version to see if it’s out of date and needs to be recompiled. This is a completely automatic process. Also, the compiled modules are platform-independent, so the same library can be shared among systems with different architectures.

Python does not check the cache in two circumstances. First, it always recompiles and does not store the result for the module that’s loaded directly from the command line. Second, it does not check the cache if there is no source module. To support a non-source (compiled only) distribution, the compiled module must be in the source directory, and there must not be a source module.

Some tips for experts:

* You can use the [-O](https://docs.python.org/3/using/cmdline.html#cmdoption-O) or [-OO](https://docs.python.org/3/using/cmdline.html#cmdoption-OO) switches on the Python command to reduce the size of a compiled module. The -O switch removes assert statements, the -OO switch removes both assert statements and \_\_doc\_\_ strings. Since some programs may rely on having these available, you should only use this option if you know what you’re doing. “Optimized” modules have an opt-tag and are usually smaller. Future releases may change the effects of optimization.
* A program doesn’t run any faster when it is read from a .pyc file than when it is read from a .pyfile; the only thing that’s faster about .pyc files is the speed with which they are loaded.
* The module [compileall](https://docs.python.org/3/library/compileall.html#module-compileall) can create .pyc files for all modules in a directory.
* There is more detail on this process, including a flow chart of the decisions, in PEP 3147.

## 6.2. Standard Modules

Python comes with a library of standard modules, described in a separate document, the Python Library Reference (“Library Reference” hereafter). Some modules are built into the interpreter; these provide access to operations that are not part of the core of the language but are nevertheless built in, either for efficiency or to provide access to operating system primitives such as system calls. The set of such modules is a configuration option which also depends on the underlying platform. For example, the [winreg](https://docs.python.org/3/library/winreg.html#module-winreg) module is only provided on Windows systems. One particular module deserves some attention: [sys](https://docs.python.org/3/library/sys.html#module-sys), which is built into every Python interpreter. The variables sys.ps1 and sys.ps2define the strings used as primary and secondary prompts:

>>>

**>>> import** **sys**

**>>>** sys.ps1

'>>> '

**>>>** sys.ps2

'... '

**>>>** sys.ps1 = 'C> '

C> print('Yuck!')

Yuck!

C>

These two variables are only defined if the interpreter is in interactive mode.

The variable sys.path is a list of strings that determines the interpreter’s search path for modules. It is initialized to a default path taken from the environment variable [PYTHONPATH](https://docs.python.org/3/using/cmdline.html#envvar-PYTHONPATH), or from a built-in default if[PYTHONPATH](https://docs.python.org/3/using/cmdline.html#envvar-PYTHONPATH) is not set. You can modify it using standard list operations:

>>>

**>>> import** **sys**

**>>>** sys.path.append('/ufs/guido/lib/python')

## 6.3. The [dir()](https://docs.python.org/3/library/functions.html#dir) Function

The built-in function [dir()](https://docs.python.org/3/library/functions.html#dir) is used to find out which names a module defines. It returns a sorted list of strings:

>>>

**>>> import** **fibo**, **sys**

**>>>** dir(fibo)

['\_\_name\_\_', 'fib', 'fib2']

**>>>** dir(sys)

['\_\_displayhook\_\_', '\_\_doc\_\_', '\_\_excepthook\_\_', '\_\_loader\_\_', '\_\_name\_\_',

'\_\_package\_\_', '\_\_stderr\_\_', '\_\_stdin\_\_', '\_\_stdout\_\_',

'\_clear\_type\_cache', '\_current\_frames', '\_debugmallocstats', '\_getframe',

'\_home', '\_mercurial', '\_xoptions', 'abiflags', 'api\_version', 'argv',

'base\_exec\_prefix', 'base\_prefix', 'builtin\_module\_names', 'byteorder',

'call\_tracing', 'callstats', 'copyright', 'displayhook',

'dont\_write\_bytecode', 'exc\_info', 'excepthook', 'exec\_prefix',

'executable', 'exit', 'flags', 'float\_info', 'float\_repr\_style',

'getcheckinterval', 'getdefaultencoding', 'getdlopenflags',

'getfilesystemencoding', 'getobjects', 'getprofile', 'getrecursionlimit',

'getrefcount', 'getsizeof', 'getswitchinterval', 'gettotalrefcount',

'gettrace', 'hash\_info', 'hexversion', 'implementation', 'int\_info',

'intern', 'maxsize', 'maxunicode', 'meta\_path', 'modules', 'path',

'path\_hooks', 'path\_importer\_cache', 'platform', 'prefix', 'ps1',

'setcheckinterval', 'setdlopenflags', 'setprofile', 'setrecursionlimit',

'setswitchinterval', 'settrace', 'stderr', 'stdin', 'stdout',

'thread\_info', 'version', 'version\_info', 'warnoptions']

Without arguments, [dir()](https://docs.python.org/3/library/functions.html#dir) lists the names you have defined currently:

>>>

**>>>** a = [1, 2, 3, 4, 5]

**>>> import** **fibo**

**>>>** fib = fibo.fib

**>>>** dir()

['\_\_builtins\_\_', '\_\_name\_\_', 'a', 'fib', 'fibo', 'sys']

Note that it lists all types of names: variables, modules, functions, etc.

[dir()](https://docs.python.org/3/library/functions.html#dir) does not list the names of built-in functions and variables. If you want a list of those, they are defined in the standard module [builtins](https://docs.python.org/3/library/builtins.html#module-builtins):

>>>

**>>> import** **builtins**

**>>>** dir(builtins)

['ArithmeticError', 'AssertionError', 'AttributeError', 'BaseException',

'BlockingIOError', 'BrokenPipeError', 'BufferError', 'BytesWarning',

'ChildProcessError', 'ConnectionAbortedError', 'ConnectionError',

'ConnectionRefusedError', 'ConnectionResetError', 'DeprecationWarning',

'EOFError', 'Ellipsis', 'EnvironmentError', 'Exception', 'False',

'FileExistsError', 'FileNotFoundError', 'FloatingPointError',

'FutureWarning', 'GeneratorExit', 'IOError', 'ImportError',

'ImportWarning', 'IndentationError', 'IndexError', 'InterruptedError',

'IsADirectoryError', 'KeyError', 'KeyboardInterrupt', 'LookupError',

'MemoryError', 'NameError', 'None', 'NotADirectoryError', 'NotImplemented',

'NotImplementedError', 'OSError', 'OverflowError',

'PendingDeprecationWarning', 'PermissionError', 'ProcessLookupError',

'ReferenceError', 'ResourceWarning', 'RuntimeError', 'RuntimeWarning',

'StopIteration', 'SyntaxError', 'SyntaxWarning', 'SystemError',

'SystemExit', 'TabError', 'TimeoutError', 'True', 'TypeError',

'UnboundLocalError', 'UnicodeDecodeError', 'UnicodeEncodeError',

'UnicodeError', 'UnicodeTranslateError', 'UnicodeWarning', 'UserWarning',

'ValueError', 'Warning', 'ZeroDivisionError', '\_', '\_\_build\_class\_\_',

'\_\_debug\_\_', '\_\_doc\_\_', '\_\_import\_\_', '\_\_name\_\_', '\_\_package\_\_', 'abs',

'all', 'any', 'ascii', 'bin', 'bool', 'bytearray', 'bytes', 'callable',

'chr', 'classmethod', 'compile', 'complex', 'copyright', 'credits',

'delattr', 'dict', 'dir', 'divmod', 'enumerate', 'eval', 'exec', 'exit',

'filter', 'float', 'format', 'frozenset', 'getattr', 'globals', 'hasattr',

'hash', 'help', 'hex', 'id', 'input', 'int', 'isinstance', 'issubclass',

'iter', 'len', 'license', 'list', 'locals', 'map', 'max', 'memoryview',

'min', 'next', 'object', 'oct', 'open', 'ord', 'pow', 'print', 'property',

'quit', 'range', 'repr', 'reversed', 'round', 'set', 'setattr', 'slice',

'sorted', 'staticmethod', 'str', 'sum', 'super', 'tuple', 'type', 'vars',

'zip']

## 6.4. Packages

Packages are a way of structuring Python’s module namespace by using “dotted module names”. For example, the module name A.B designates a submodule named B in a package named A. Just like the use of modules saves the authors of different modules from having to worry about each other’s global variable names, the use of dotted module names saves the authors of multi-module packages like NumPy or the Python Imaging Library from having to worry about each other’s module names.

Suppose you want to design a collection of modules (a “package”) for the uniform handling of sound files and sound data. There are many different sound file formats (usually recognized by their extension, for example: .wav, .aiff, .au), so you may need to create and maintain a growing collection of modules for the conversion between the various file formats. There are also many different operations you might want to perform on sound data (such as mixing, adding echo, applying an equalizer function, creating an artificial stereo effect), so in addition you will be writing a never-ending stream of modules to perform these operations. Here’s a possible structure for your package (expressed in terms of a hierarchical filesystem):

sound/ Top-level package

\_\_init\_\_.py Initialize the sound package

formats/ Subpackage for file format conversions

\_\_init\_\_.py

wavread.py

wavwrite.py

aiffread.py

aiffwrite.py

auread.py

auwrite.py

...

effects/ Subpackage for sound effects

\_\_init\_\_.py

echo.py

surround.py

reverse.py

...

filters/ Subpackage for filters

\_\_init\_\_.py

equalizer.py

vocoder.py

karaoke.py

...

When importing the package, Python searches through the directories on sys.path looking for the package subdirectory.

The \_\_init\_\_.py files are required to make Python treat the directories as containing packages; this is done to prevent directories with a common name, such as string, from unintentionally hiding valid modules that occur later on the module search path. In the simplest case, \_\_init\_\_.py can just be an empty file, but it can also execute initialization code for the package or set the \_\_all\_\_ variable, described later.

Users of the package can import individual modules from the package, for example:

**import** **sound.effects.echo**

This loads the submodule sound.effects.echo. It must be referenced with its full name.

sound.effects.echo.echofilter(input, output, delay=0.7, atten=4)

An alternative way of importing the submodule is:

**from** **sound.effects** **import** echo

This also loads the submodule echo, and makes it available without its package prefix, so it can be used as follows:

echo.echofilter(input, output, delay=0.7, atten=4)

Yet another variation is to import the desired function or variable directly:

**from** **sound.effects.echo** **import** echofilter

Again, this loads the submodule echo, but this makes its function echofilter() directly available:

echofilter(input, output, delay=0.7, atten=4)

Note that when using from package import item, the item can be either a submodule (or subpackage) of the package, or some other name defined in the package, like a function, class or variable. The import statement first tests whether the item is defined in the package; if not, it assumes it is a module and attempts to load it. If it fails to find it, an [ImportError](https://docs.python.org/3/library/exceptions.html#ImportError) exception is raised.

Contrarily, when using syntax like import item.subitem.subsubitem, each item except for the last must be a package; the last item can be a module or a package but can’t be a class or function or variable defined in the previous item.

### 6.4.1. Importing \* From a Package

Now what happens when the user writes from sound.effects import \*? Ideally, one would hope that this somehow goes out to the filesystem, finds which submodules are present in the package, and imports them all. This could take a long time and importing sub-modules might have unwanted side-effects that should only happen when the sub-module is explicitly imported.

The only solution is for the package author to provide an explicit index of the package. The [import](https://docs.python.org/3/reference/simple_stmts.html#import)statement uses the following convention: if a package’s \_\_init\_\_.py code defines a list named\_\_all\_\_, it is taken to be the list of module names that should be imported when from packageimport \* is encountered. It is up to the package author to keep this list up-to-date when a new version of the package is released. Package authors may also decide not to support it, if they don’t see a use for importing \* from their package. For example, the file sound/effects/\_\_init\_\_.py could contain the following code:

\_\_all\_\_ = ["echo", "surround", "reverse"]

This would mean that from sound.effects import \* would import the three named submodules of the sound package.

If \_\_all\_\_ is not defined, the statement from sound.effects import \* does not import all submodules from the package sound.effects into the current namespace; it only ensures that the package sound.effects has been imported (possibly running any initialization code in \_\_init\_\_.py) and then imports whatever names are defined in the package. This includes any names defined (and submodules explicitly loaded) by \_\_init\_\_.py. It also includes any submodules of the package that were explicitly loaded by previous [import](https://docs.python.org/3/reference/simple_stmts.html#import) statements. Consider this code:

**import** **sound.effects.echo**

**import** **sound.effects.surround**

**from** **sound.effects** **import** \*

In this example, the echo and surround modules are imported in the current namespace because they are defined in the sound.effects package when the from...import statement is executed. (This also works when \_\_all\_\_ is defined.)

Although certain modules are designed to export only names that follow certain patterns when you useimport \*, it is still considered bad practise in production code.

Remember, there is nothing wrong with using from Package import specific\_submodule! In fact, this is the recommended notation unless the importing module needs to use submodules with the same name from different packages.

### 6.4.2. Intra-package References

When packages are structured into subpackages (as with the sound package in the example), you can use absolute imports to refer to submodules of siblings packages. For example, if the modulesound.filters.vocoder needs to use the echo module in the sound.effects package, it can usefrom sound.effects import echo.

You can also write relative imports, with the from module import name form of import statement. These imports use leading dots to indicate the current and parent packages involved in the relative import. From the surround module for example, you might use:

**from** **.** **import** echo

**from** **..** **import** formats

**from** **..filters** **import** equalizer

Note that relative imports are based on the name of the current module. Since the name of the main module is always "\_\_main\_\_", modules intended for use as the main module of a Python application must always use absolute imports.

### 6.4.3. Packages in Multiple Directories

Packages support one more special attribute, [\_\_path\_\_](https://docs.python.org/3/reference/import.html#__path__). This is initialized to be a list containing the name of the directory holding the package’s \_\_init\_\_.py before the code in that file is executed. This variable can be modified; doing so affects future searches for modules and subpackages contained in the package.

While this feature is not often needed, it can be used to extend the set of modules found in a package.

**Footnotes**

|  |  |
| --- | --- |
| [[1]](https://docs.python.org/3/tutorial/modules.html#id1) | In fact function definitions are also ‘statements’ that are ‘executed’; the execution of a module-level function definition enters the function name in the module’s global symbol table. |

# 6. Modules

If you quit from the Python interpreter and enter it again, the definitions you have made (functions and variables) are lost. Therefore, if you want to write a somewhat longer program, you are better off using a text editor to prepare the input for the interpreter and running it with that file as input instead. This is known as creating a script. As your program gets longer, you may want to split it into several files for easier maintenance. You may also want to use a handy function that you’ve written in several programs without copying its definition into each program.

To support this, Python has a way to put definitions in a file and use them in a script or in an interactive instance of the interpreter. Such a file is called a module; definitions from a module can be importedinto other modules or into the main module (the collection of variables that you have access to in a script executed at the top level and in calculator mode).

A module is a file containing Python definitions and statements. The file name is the module name with the suffix .py appended. Within a module, the module’s name (as a string) is available as the value of the global variable \_\_name\_\_. For instance, use your favorite text editor to create a file calledfibo.py in the current directory with the following contents:

*# Fibonacci numbers module*

**def** fib(n): *# write Fibonacci series up to n*

a, b = 0, 1

**while** b < n:

print(b, end=' ')

a, b = b, a+b

print()

**def** fib2(n): *# return Fibonacci series up to n*

result = []

a, b = 0, 1

**while** b < n:

result.append(b)

a, b = b, a+b

**return** result

Now enter the Python interpreter and import this module with the following command:

>>>

**>>> import** **fibo**

This does not enter the names of the functions defined in fibo directly in the current symbol table; it only enters the module name fibo there. Using the module name you can access the functions:

>>>

**>>>** fibo.fib(1000)

1 1 2 3 5 8 13 21 34 55 89 144 233 377 610 987

**>>>** fibo.fib2(100)

[1, 1, 2, 3, 5, 8, 13, 21, 34, 55, 89]

**>>>** fibo.\_\_name\_\_

'fibo'

If you intend to use a function often you can assign it to a local name:

>>>

**>>>** fib = fibo.fib

**>>>** fib(500)

1 1 2 3 5 8 13 21 34 55 89 144 233 377

## 6.1. More on Modules

A module can contain executable statements as well as function definitions. These statements are intended to initialize the module. They are executed only the first time the module name is encountered in an import statement. [[1]](https://docs.python.org/3/tutorial/modules.html#id2) (They are also run if the file is executed as a script.)

Each module has its own private symbol table, which is used as the global symbol table by all functions defined in the module. Thus, the author of a module can use global variables in the module without worrying about accidental clashes with a user’s global variables. On the other hand, if you know what you are doing you can touch a module’s global variables with the same notation used to refer to its functions, modname.itemname.

Modules can import other modules. It is customary but not required to place all [import](https://docs.python.org/3/reference/simple_stmts.html#import) statements at the beginning of a module (or script, for that matter). The imported module names are placed in the importing module’s global symbol table.

There is a variant of the [import](https://docs.python.org/3/reference/simple_stmts.html#import) statement that imports names from a module directly into the importing module’s symbol table. For example:

>>>

**>>> from** **fibo** **import** fib, fib2

**>>>** fib(500)

1 1 2 3 5 8 13 21 34 55 89 144 233 377

This does not introduce the module name from which the imports are taken in the local symbol table (so in the example, fibo is not defined).

There is even a variant to import all names that a module defines:

>>>

**>>> from** **fibo** **import** \*

**>>>** fib(500)

1 1 2 3 5 8 13 21 34 55 89 144 233 377

This imports all names except those beginning with an underscore (\_). In most cases Python programmers do not use this facility since it introduces an unknown set of names into the interpreter, possibly hiding some things you have already defined.

Note that in general the practice of importing \* from a module or package is frowned upon, since it often causes poorly readable code. However, it is okay to use it to save typing in interactive sessions.

**Note**

For efficiency reasons, each module is only imported once per interpreter session. Therefore, if you change your modules, you must restart the interpreter – or, if it’s just one module you want to test interactively, use [importlib.reload()](https://docs.python.org/3/library/importlib.html#importlib.reload), e.g. import importlib;importlib.reload(modulename).

### 6.1.1. Executing modules as scripts

When you run a Python module with

python fibo.py <arguments>

the code in the module will be executed, just as if you imported it, but with the \_\_name\_\_ set to"\_\_main\_\_". That means that by adding this code at the end of your module:

**if** \_\_name\_\_ == "\_\_main\_\_":

**import** **sys**

fib(int(sys.argv[1]))

you can make the file usable as a script as well as an importable module, because the code that parses the command line only runs if the module is executed as the “main” file:

$ python fibo.py 50

1 1 2 3 5 8 13 21 34

If the module is imported, the code is not run:

>>>

**>>> import** **fibo**

>>>

This is often used either to provide a convenient user interface to a module, or for testing purposes (running the module as a script executes a test suite).

### 6.1.2. The Module Search Path

When a module named spam is imported, the interpreter first searches for a built-in module with that name. If not found, it then searches for a file named spam.py in a list of directories given by the variable [sys.path](https://docs.python.org/3/library/sys.html#sys.path). [sys.path](https://docs.python.org/3/library/sys.html#sys.path) is initialized from these locations:

* The directory containing the input script (or the current directory when no file is specified).
* [PYTHONPATH](https://docs.python.org/3/using/cmdline.html#envvar-PYTHONPATH) (a list of directory names, with the same syntax as the shell variable PATH).
* The installation-dependent default.

**Note**

On file systems which support symlinks, the directory containing the input script is calculated after the symlink is followed. In other words the directory containing the symlink is **not** added to the module search path.

After initialization, Python programs can modify [sys.path](https://docs.python.org/3/library/sys.html#sys.path). The directory containing the script being run is placed at the beginning of the search path, ahead of the standard library path. This means that scripts in that directory will be loaded instead of modules of the same name in the library directory. This is an error unless the replacement is intended. See section [Standard Modules](https://docs.python.org/3/tutorial/modules.html#tut-standardmodules) for more information.

### 6.1.3. “Compiled” Python files

To speed up loading modules, Python caches the compiled version of each module in the\_\_pycache\_\_ directory under the name module.*version*.pyc, where the version encodes the format of the compiled file; it generally contains the Python version number. For example, in CPython release 3.3 the compiled version of spam.py would be cached as \_\_pycache\_\_/spam.cpython-33.pyc. This naming convention allows compiled modules from different releases and different versions of Python to coexist.

Python checks the modification date of the source against the compiled version to see if it’s out of date and needs to be recompiled. This is a completely automatic process. Also, the compiled modules are platform-independent, so the same library can be shared among systems with different architectures.

Python does not check the cache in two circumstances. First, it always recompiles and does not store the result for the module that’s loaded directly from the command line. Second, it does not check the cache if there is no source module. To support a non-source (compiled only) distribution, the compiled module must be in the source directory, and there must not be a source module.

Some tips for experts:

* You can use the [-O](https://docs.python.org/3/using/cmdline.html#cmdoption-O) or [-OO](https://docs.python.org/3/using/cmdline.html#cmdoption-OO) switches on the Python command to reduce the size of a compiled module. The -O switch removes assert statements, the -OO switch removes both assert statements and \_\_doc\_\_ strings. Since some programs may rely on having these available, you should only use this option if you know what you’re doing. “Optimized” modules have an opt-tag and are usually smaller. Future releases may change the effects of optimization.
* A program doesn’t run any faster when it is read from a .pyc file than when it is read from a .pyfile; the only thing that’s faster about .pyc files is the speed with which they are loaded.
* The module [compileall](https://docs.python.org/3/library/compileall.html#module-compileall) can create .pyc files for all modules in a directory.
* There is more detail on this process, including a flow chart of the decisions, in PEP 3147.

## 6.2. Standard Modules

Python comes with a library of standard modules, described in a separate document, the Python Library Reference (“Library Reference” hereafter). Some modules are built into the interpreter; these provide access to operations that are not part of the core of the language but are nevertheless built in, either for efficiency or to provide access to operating system primitives such as system calls. The set of such modules is a configuration option which also depends on the underlying platform. For example, the [winreg](https://docs.python.org/3/library/winreg.html#module-winreg) module is only provided on Windows systems. One particular module deserves some attention: [sys](https://docs.python.org/3/library/sys.html#module-sys), which is built into every Python interpreter. The variables sys.ps1 and sys.ps2define the strings used as primary and secondary prompts:

>>>

**>>> import** **sys**

**>>>** sys.ps1

'>>> '

**>>>** sys.ps2

'... '

**>>>** sys.ps1 = 'C> '

C> print('Yuck!')

Yuck!

C>

These two variables are only defined if the interpreter is in interactive mode.

The variable sys.path is a list of strings that determines the interpreter’s search path for modules. It is initialized to a default path taken from the environment variable [PYTHONPATH](https://docs.python.org/3/using/cmdline.html#envvar-PYTHONPATH), or from a built-in default if[PYTHONPATH](https://docs.python.org/3/using/cmdline.html#envvar-PYTHONPATH) is not set. You can modify it using standard list operations:

>>>

**>>> import** **sys**

**>>>** sys.path.append('/ufs/guido/lib/python')

## 6.3. The [dir()](https://docs.python.org/3/library/functions.html#dir) Function

The built-in function [dir()](https://docs.python.org/3/library/functions.html#dir) is used to find out which names a module defines. It returns a sorted list of strings:

>>>

**>>> import** **fibo**, **sys**

**>>>** dir(fibo)

['\_\_name\_\_', 'fib', 'fib2']

**>>>** dir(sys)

['\_\_displayhook\_\_', '\_\_doc\_\_', '\_\_excepthook\_\_', '\_\_loader\_\_', '\_\_name\_\_',

'\_\_package\_\_', '\_\_stderr\_\_', '\_\_stdin\_\_', '\_\_stdout\_\_',

'\_clear\_type\_cache', '\_current\_frames', '\_debugmallocstats', '\_getframe',

'\_home', '\_mercurial', '\_xoptions', 'abiflags', 'api\_version', 'argv',

'base\_exec\_prefix', 'base\_prefix', 'builtin\_module\_names', 'byteorder',

'call\_tracing', 'callstats', 'copyright', 'displayhook',

'dont\_write\_bytecode', 'exc\_info', 'excepthook', 'exec\_prefix',

'executable', 'exit', 'flags', 'float\_info', 'float\_repr\_style',

'getcheckinterval', 'getdefaultencoding', 'getdlopenflags',

'getfilesystemencoding', 'getobjects', 'getprofile', 'getrecursionlimit',

'getrefcount', 'getsizeof', 'getswitchinterval', 'gettotalrefcount',

'gettrace', 'hash\_info', 'hexversion', 'implementation', 'int\_info',

'intern', 'maxsize', 'maxunicode', 'meta\_path', 'modules', 'path',

'path\_hooks', 'path\_importer\_cache', 'platform', 'prefix', 'ps1',

'setcheckinterval', 'setdlopenflags', 'setprofile', 'setrecursionlimit',

'setswitchinterval', 'settrace', 'stderr', 'stdin', 'stdout',

'thread\_info', 'version', 'version\_info', 'warnoptions']

Without arguments, [dir()](https://docs.python.org/3/library/functions.html#dir) lists the names you have defined currently:

>>>

**>>>** a = [1, 2, 3, 4, 5]

**>>> import** **fibo**

**>>>** fib = fibo.fib

**>>>** dir()

['\_\_builtins\_\_', '\_\_name\_\_', 'a', 'fib', 'fibo', 'sys']

Note that it lists all types of names: variables, modules, functions, etc.

[dir()](https://docs.python.org/3/library/functions.html#dir) does not list the names of built-in functions and variables. If you want a list of those, they are defined in the standard module [builtins](https://docs.python.org/3/library/builtins.html#module-builtins):

>>>

**>>> import** **builtins**

**>>>** dir(builtins)

['ArithmeticError', 'AssertionError', 'AttributeError', 'BaseException',

'BlockingIOError', 'BrokenPipeError', 'BufferError', 'BytesWarning',

'ChildProcessError', 'ConnectionAbortedError', 'ConnectionError',

'ConnectionRefusedError', 'ConnectionResetError', 'DeprecationWarning',

'EOFError', 'Ellipsis', 'EnvironmentError', 'Exception', 'False',

'FileExistsError', 'FileNotFoundError', 'FloatingPointError',

'FutureWarning', 'GeneratorExit', 'IOError', 'ImportError',

'ImportWarning', 'IndentationError', 'IndexError', 'InterruptedError',

'IsADirectoryError', 'KeyError', 'KeyboardInterrupt', 'LookupError',

'MemoryError', 'NameError', 'None', 'NotADirectoryError', 'NotImplemented',

'NotImplementedError', 'OSError', 'OverflowError',

'PendingDeprecationWarning', 'PermissionError', 'ProcessLookupError',

'ReferenceError', 'ResourceWarning', 'RuntimeError', 'RuntimeWarning',

'StopIteration', 'SyntaxError', 'SyntaxWarning', 'SystemError',

'SystemExit', 'TabError', 'TimeoutError', 'True', 'TypeError',

'UnboundLocalError', 'UnicodeDecodeError', 'UnicodeEncodeError',

'UnicodeError', 'UnicodeTranslateError', 'UnicodeWarning', 'UserWarning',

'ValueError', 'Warning', 'ZeroDivisionError', '\_', '\_\_build\_class\_\_',

'\_\_debug\_\_', '\_\_doc\_\_', '\_\_import\_\_', '\_\_name\_\_', '\_\_package\_\_', 'abs',

'all', 'any', 'ascii', 'bin', 'bool', 'bytearray', 'bytes', 'callable',

'chr', 'classmethod', 'compile', 'complex', 'copyright', 'credits',

'delattr', 'dict', 'dir', 'divmod', 'enumerate', 'eval', 'exec', 'exit',

'filter', 'float', 'format', 'frozenset', 'getattr', 'globals', 'hasattr',

'hash', 'help', 'hex', 'id', 'input', 'int', 'isinstance', 'issubclass',

'iter', 'len', 'license', 'list', 'locals', 'map', 'max', 'memoryview',

'min', 'next', 'object', 'oct', 'open', 'ord', 'pow', 'print', 'property',

'quit', 'range', 'repr', 'reversed', 'round', 'set', 'setattr', 'slice',

'sorted', 'staticmethod', 'str', 'sum', 'super', 'tuple', 'type', 'vars',

'zip']

## 6.4. Packages

Packages are a way of structuring Python’s module namespace by using “dotted module names”. For example, the module name A.B designates a submodule named B in a package named A. Just like the use of modules saves the authors of different modules from having to worry about each other’s global variable names, the use of dotted module names saves the authors of multi-module packages like NumPy or the Python Imaging Library from having to worry about each other’s module names.

Suppose you want to design a collection of modules (a “package”) for the uniform handling of sound files and sound data. There are many different sound file formats (usually recognized by their extension, for example: .wav, .aiff, .au), so you may need to create and maintain a growing collection of modules for the conversion between the various file formats. There are also many different operations you might want to perform on sound data (such as mixing, adding echo, applying an equalizer function, creating an artificial stereo effect), so in addition you will be writing a never-ending stream of modules to perform these operations. Here’s a possible structure for your package (expressed in terms of a hierarchical filesystem):

sound/ Top-level package

\_\_init\_\_.py Initialize the sound package

formats/ Subpackage for file format conversions

\_\_init\_\_.py

wavread.py

wavwrite.py

aiffread.py

aiffwrite.py

auread.py

auwrite.py

...

effects/ Subpackage for sound effects

\_\_init\_\_.py

echo.py

surround.py

reverse.py

...

filters/ Subpackage for filters

\_\_init\_\_.py

equalizer.py

vocoder.py

karaoke.py

...

When importing the package, Python searches through the directories on sys.path looking for the package subdirectory.

The \_\_init\_\_.py files are required to make Python treat the directories as containing packages; this is done to prevent directories with a common name, such as string, from unintentionally hiding valid modules that occur later on the module search path. In the simplest case, \_\_init\_\_.py can just be an empty file, but it can also execute initialization code for the package or set the \_\_all\_\_ variable, described later.

Users of the package can import individual modules from the package, for example:

**import** **sound.effects.echo**

This loads the submodule sound.effects.echo. It must be referenced with its full name.

sound.effects.echo.echofilter(input, output, delay=0.7, atten=4)

An alternative way of importing the submodule is:

**from** **sound.effects** **import** echo

This also loads the submodule echo, and makes it available without its package prefix, so it can be used as follows:

echo.echofilter(input, output, delay=0.7, atten=4)

Yet another variation is to import the desired function or variable directly:

**from** **sound.effects.echo** **import** echofilter

Again, this loads the submodule echo, but this makes its function echofilter() directly available:

echofilter(input, output, delay=0.7, atten=4)

Note that when using from package import item, the item can be either a submodule (or subpackage) of the package, or some other name defined in the package, like a function, class or variable. The import statement first tests whether the item is defined in the package; if not, it assumes it is a module and attempts to load it. If it fails to find it, an [ImportError](https://docs.python.org/3/library/exceptions.html#ImportError) exception is raised.

Contrarily, when using syntax like import item.subitem.subsubitem, each item except for the last must be a package; the last item can be a module or a package but can’t be a class or function or variable defined in the previous item.

### 6.4.1. Importing \* From a Package

Now what happens when the user writes from sound.effects import \*? Ideally, one would hope that this somehow goes out to the filesystem, finds which submodules are present in the package, and imports them all. This could take a long time and importing sub-modules might have unwanted side-effects that should only happen when the sub-module is explicitly imported.

The only solution is for the package author to provide an explicit index of the package. The [import](https://docs.python.org/3/reference/simple_stmts.html#import)statement uses the following convention: if a package’s \_\_init\_\_.py code defines a list named\_\_all\_\_, it is taken to be the list of module names that should be imported when from packageimport \* is encountered. It is up to the package author to keep this list up-to-date when a new version of the package is released. Package authors may also decide not to support it, if they don’t see a use for importing \* from their package. For example, the file sound/effects/\_\_init\_\_.py could contain the following code:

\_\_all\_\_ = ["echo", "surround", "reverse"]

This would mean that from sound.effects import \* would import the three named submodules of the sound package.

If \_\_all\_\_ is not defined, the statement from sound.effects import \* does not import all submodules from the package sound.effects into the current namespace; it only ensures that the package sound.effects has been imported (possibly running any initialization code in \_\_init\_\_.py) and then imports whatever names are defined in the package. This includes any names defined (and submodules explicitly loaded) by \_\_init\_\_.py. It also includes any submodules of the package that were explicitly loaded by previous [import](https://docs.python.org/3/reference/simple_stmts.html#import) statements. Consider this code:

**import** **sound.effects.echo**

**import** **sound.effects.surround**

**from** **sound.effects** **import** \*

In this example, the echo and surround modules are imported in the current namespace because they are defined in the sound.effects package when the from...import statement is executed. (This also works when \_\_all\_\_ is defined.)

Although certain modules are designed to export only names that follow certain patterns when you useimport \*, it is still considered bad practise in production code.

Remember, there is nothing wrong with using from Package import specific\_submodule! In fact, this is the recommended notation unless the importing module needs to use submodules with the same name from different packages.

### 6.4.2. Intra-package References

When packages are structured into subpackages (as with the sound package in the example), you can use absolute imports to refer to submodules of siblings packages. For example, if the modulesound.filters.vocoder needs to use the echo module in the sound.effects package, it can usefrom sound.effects import echo.

You can also write relative imports, with the from module import name form of import statement. These imports use leading dots to indicate the current and parent packages involved in the relative import. From the surround module for example, you might use:

**from** **.** **import** echo

**from** **..** **import** formats

**from** **..filters** **import** equalizer

Note that relative imports are based on the name of the current module. Since the name of the main module is always "\_\_main\_\_", modules intended for use as the main module of a Python application must always use absolute imports.

### 6.4.3. Packages in Multiple Directories

Packages support one more special attribute, [\_\_path\_\_](https://docs.python.org/3/reference/import.html#__path__). This is initialized to be a list containing the name of the directory holding the package’s \_\_init\_\_.py before the code in that file is executed. This variable can be modified; doing so affects future searches for modules and subpackages contained in the package.

While this feature is not often needed, it can be used to extend the set of modules found in a package.

**Footnotes**

|  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| [[1]](https://docs.python.org/3/tutorial/modules.html#id1) | 6. Modules If you quit from the Python interpreter and enter it again, the definitions you have made (functions and variables) are lost. Therefore, if you want to write a somewhat longer program, you are better off using a text editor to prepare the input for the interpreter and running it with that file as input instead. This is known as creating a script. As your program gets longer, you may want to split it into several files for easier maintenance. You may also want to use a handy function that you’ve written in several programs without copying its definition into each program.  To support this, Python has a way to put definitions in a file and use them in a script or in an interactive instance of the interpreter. Such a file is called a module; definitions from a module can be importedinto other modules or into the main module (the collection of variables that you have access to in a script executed at the top level and in calculator mode).  A module is a file containing Python definitions and statements. The file name is the module name with the suffix .py appended. Within a module, the module’s name (as a string) is available as the value of the global variable \_\_name\_\_. For instance, use your favorite text editor to create a file calledfibo.py in the current directory with the following contents:  *# Fibonacci numbers module*  **def** fib(n): *# write Fibonacci series up to n*  a, b = 0, 1  **while** b < n:  print(b, end=' ')  a, b = b, a+b  print()  **def** fib2(n): *# return Fibonacci series up to n*  result = []  a, b = 0, 1  **while** b < n:  result.append(b)  a, b = b, a+b  **return** result  Now enter the Python interpreter and import this module with the following command:  >>>  **>>> import** **fibo**  This does not enter the names of the functions defined in fibo directly in the current symbol table; it only enters the module name fibo there. Using the module name you can access the functions:  >>>  **>>>** fibo.fib(1000)  1 1 2 3 5 8 13 21 34 55 89 144 233 377 610 987  **>>>** fibo.fib2(100)  [1, 1, 2, 3, 5, 8, 13, 21, 34, 55, 89]  **>>>** fibo.\_\_name\_\_  'fibo'  If you intend to use a function often you can assign it to a local name:  >>>  **>>>** fib = fibo.fib  **>>>** fib(500)  1 1 2 3 5 8 13 21 34 55 89 144 233 377 6.1. More on Modules A module can contain executable statements as well as function definitions. These statements are intended to initialize the module. They are executed only the first time the module name is encountered in an import statement. [[1]](https://docs.python.org/3/tutorial/modules.html#id2) (They are also run if the file is executed as a script.)  Each module has its own private symbol table, which is used as the global symbol table by all functions defined in the module. Thus, the author of a module can use global variables in the module without worrying about accidental clashes with a user’s global variables. On the other hand, if you know what you are doing you can touch a module’s global variables with the same notation used to refer to its functions, modname.itemname.  Modules can import other modules. It is customary but not required to place all [import](https://docs.python.org/3/reference/simple_stmts.html#import) statements at the beginning of a module (or script, for that matter). The imported module names are placed in the importing module’s global symbol table.  There is a variant of the [import](https://docs.python.org/3/reference/simple_stmts.html#import) statement that imports names from a module directly into the importing module’s symbol table. For example:  >>>  **>>> from** **fibo** **import** fib, fib2  **>>>** fib(500)  1 1 2 3 5 8 13 21 34 55 89 144 233 377  This does not introduce the module name from which the imports are taken in the local symbol table (so in the example, fibo is not defined).  There is even a variant to import all names that a module defines:  >>>  **>>> from** **fibo** **import** \*  **>>>** fib(500)  1 1 2 3 5 8 13 21 34 55 89 144 233 377  This imports all names except those beginning with an underscore (\_). In most cases Python programmers do not use this facility since it introduces an unknown set of names into the interpreter, possibly hiding some things you have already defined.  Note that in general the practice of importing \* from a module or package is frowned upon, since it often causes poorly readable code. However, it is okay to use it to save typing in interactive sessions.  **Note**    For efficiency reasons, each module is only imported once per interpreter session. Therefore, if you change your modules, you must restart the interpreter – or, if it’s just one module you want to test interactively, use [importlib.reload()](https://docs.python.org/3/library/importlib.html#importlib.reload), e.g. import importlib;importlib.reload(modulename). 6.1.1. Executing modules as scripts When you run a Python module with  python fibo.py <arguments>  the code in the module will be executed, just as if you imported it, but with the \_\_name\_\_ set to"\_\_main\_\_". That means that by adding this code at the end of your module:  **if** \_\_name\_\_ == "\_\_main\_\_":  **import** **sys**  fib(int(sys.argv[1]))  you can make the file usable as a script as well as an importable module, because the code that parses the command line only runs if the module is executed as the “main” file:  $ python fibo.py 50  1 1 2 3 5 8 13 21 34  If the module is imported, the code is not run:  >>>  **>>> import** **fibo**  >>>  This is often used either to provide a convenient user interface to a module, or for testing purposes (running the module as a script executes a test suite). 6.1.2. The Module Search Path When a module named spam is imported, the interpreter first searches for a built-in module with that name. If not found, it then searches for a file named spam.py in a list of directories given by the variable [sys.path](https://docs.python.org/3/library/sys.html#sys.path). [sys.path](https://docs.python.org/3/library/sys.html#sys.path) is initialized from these locations:   * The directory containing the input script (or the current directory when no file is specified). * [PYTHONPATH](https://docs.python.org/3/using/cmdline.html#envvar-PYTHONPATH) (a list of directory names, with the same syntax as the shell variable PATH). * The installation-dependent default.   **Note**    On file systems which support symlinks, the directory containing the input script is calculated after the symlink is followed. In other words the directory containing the symlink is **not** added to the module search path.  After initialization, Python programs can modify [sys.path](https://docs.python.org/3/library/sys.html#sys.path). The directory containing the script being run is placed at the beginning of the search path, ahead of the standard library path. This means that scripts in that directory will be loaded instead of modules of the same name in the library directory. This is an error unless the replacement is intended. See section [Standard Modules](https://docs.python.org/3/tutorial/modules.html#tut-standardmodules) for more information. 6.1.3. “Compiled” Python files To speed up loading modules, Python caches the compiled version of each module in the\_\_pycache\_\_ directory under the name module.*version*.pyc, where the version encodes the format of the compiled file; it generally contains the Python version number. For example, in CPython release 3.3 the compiled version of spam.py would be cached as \_\_pycache\_\_/spam.cpython-33.pyc. This naming convention allows compiled modules from different releases and different versions of Python to coexist.  Python checks the modification date of the source against the compiled version to see if it’s out of date and needs to be recompiled. This is a completely automatic process. Also, the compiled modules are platform-independent, so the same library can be shared among systems with different architectures.  Python does not check the cache in two circumstances. First, it always recompiles and does not store the result for the module that’s loaded directly from the command line. Second, it does not check the cache if there is no source module. To support a non-source (compiled only) distribution, the compiled module must be in the source directory, and there must not be a source module.  Some tips for experts:   * You can use the [-O](https://docs.python.org/3/using/cmdline.html#cmdoption-O) or [-OO](https://docs.python.org/3/using/cmdline.html#cmdoption-OO) switches on the Python command to reduce the size of a compiled module. The -O switch removes assert statements, the -OO switch removes both assert statements and \_\_doc\_\_ strings. Since some programs may rely on having these available, you should only use this option if you know what you’re doing. “Optimized” modules have an opt-tag and are usually smaller. Future releases may change the effects of optimization. * A program doesn’t run any faster when it is read from a .pyc file than when it is read from a .pyfile; the only thing that’s faster about .pyc files is the speed with which they are loaded. * The module [compileall](https://docs.python.org/3/library/compileall.html#module-compileall) can create .pyc files for all modules in a directory. * There is more detail on this process, including a flow chart of the decisions, in PEP 3147.  6.2. Standard Modules Python comes with a library of standard modules, described in a separate document, the Python Library Reference (“Library Reference” hereafter). Some modules are built into the interpreter; these provide access to operations that are not part of the core of the language but are nevertheless built in, either for efficiency or to provide access to operating system primitives such as system calls. The set of such modules is a configuration option which also depends on the underlying platform. For example, the [winreg](https://docs.python.org/3/library/winreg.html#module-winreg) module is only provided on Windows systems. One particular module deserves some attention: [sys](https://docs.python.org/3/library/sys.html#module-sys), which is built into every Python interpreter. The variables sys.ps1 and sys.ps2define the strings used as primary and secondary prompts:  >>>  **>>> import** **sys**  **>>>** sys.ps1  '>>> '  **>>>** sys.ps2  '... '  **>>>** sys.ps1 = 'C> '  C> print('Yuck!')  Yuck!  C>  These two variables are only defined if the interpreter is in interactive mode.  The variable sys.path is a list of strings that determines the interpreter’s search path for modules. It is initialized to a default path taken from the environment variable [PYTHONPATH](https://docs.python.org/3/using/cmdline.html#envvar-PYTHONPATH), or from a built-in default if[PYTHONPATH](https://docs.python.org/3/using/cmdline.html#envvar-PYTHONPATH) is not set. You can modify it using standard list operations:  >>>  **>>> import** **sys**  **>>>** sys.path.append('/ufs/guido/lib/python') 6.3. The [dir()](https://docs.python.org/3/library/functions.html#dir) Function The built-in function [dir()](https://docs.python.org/3/library/functions.html#dir) is used to find out which names a module defines. It returns a sorted list of strings:  >>>  **>>> import** **fibo**, **sys**  **>>>** dir(fibo)  ['\_\_name\_\_', 'fib', 'fib2']  **>>>** dir(sys)  ['\_\_displayhook\_\_', '\_\_doc\_\_', '\_\_excepthook\_\_', '\_\_loader\_\_', '\_\_name\_\_',  '\_\_package\_\_', '\_\_stderr\_\_', '\_\_stdin\_\_', '\_\_stdout\_\_',  '\_clear\_type\_cache', '\_current\_frames', '\_debugmallocstats', '\_getframe',  '\_home', '\_mercurial', '\_xoptions', 'abiflags', 'api\_version', 'argv',  'base\_exec\_prefix', 'base\_prefix', 'builtin\_module\_names', 'byteorder',  'call\_tracing', 'callstats', 'copyright', 'displayhook',  'dont\_write\_bytecode', 'exc\_info', 'excepthook', 'exec\_prefix',  'executable', 'exit', 'flags', 'float\_info', 'float\_repr\_style',  'getcheckinterval', 'getdefaultencoding', 'getdlopenflags',  'getfilesystemencoding', 'getobjects', 'getprofile', 'getrecursionlimit',  'getrefcount', 'getsizeof', 'getswitchinterval', 'gettotalrefcount',  'gettrace', 'hash\_info', 'hexversion', 'implementation', 'int\_info',  'intern', 'maxsize', 'maxunicode', 'meta\_path', 'modules', 'path',  'path\_hooks', 'path\_importer\_cache', 'platform', 'prefix', 'ps1',  'setcheckinterval', 'setdlopenflags', 'setprofile', 'setrecursionlimit',  'setswitchinterval', 'settrace', 'stderr', 'stdin', 'stdout',  'thread\_info', 'version', 'version\_info', 'warnoptions']  Without arguments, [dir()](https://docs.python.org/3/library/functions.html#dir) lists the names you have defined currently:  >>>  **>>>** a = [1, 2, 3, 4, 5]  **>>> import** **fibo**  **>>>** fib = fibo.fib  **>>>** dir()  ['\_\_builtins\_\_', '\_\_name\_\_', 'a', 'fib', 'fibo', 'sys']  Note that it lists all types of names: variables, modules, functions, etc.  [dir()](https://docs.python.org/3/library/functions.html#dir) does not list the names of built-in functions and variables. If you want a list of those, they are defined in the standard module [builtins](https://docs.python.org/3/library/builtins.html#module-builtins):  >>>  **>>> import** **builtins**  **>>>** dir(builtins)  ['ArithmeticError', 'AssertionError', 'AttributeError', 'BaseException',  'BlockingIOError', 'BrokenPipeError', 'BufferError', 'BytesWarning',  'ChildProcessError', 'ConnectionAbortedError', 'ConnectionError',  'ConnectionRefusedError', 'ConnectionResetError', 'DeprecationWarning',  'EOFError', 'Ellipsis', 'EnvironmentError', 'Exception', 'False',  'FileExistsError', 'FileNotFoundError', 'FloatingPointError',  'FutureWarning', 'GeneratorExit', 'IOError', 'ImportError',  'ImportWarning', 'IndentationError', 'IndexError', 'InterruptedError',  'IsADirectoryError', 'KeyError', 'KeyboardInterrupt', 'LookupError',  'MemoryError', 'NameError', 'None', 'NotADirectoryError', 'NotImplemented',  'NotImplementedError', 'OSError', 'OverflowError',  'PendingDeprecationWarning', 'PermissionError', 'ProcessLookupError',  'ReferenceError', 'ResourceWarning', 'RuntimeError', 'RuntimeWarning',  'StopIteration', 'SyntaxError', 'SyntaxWarning', 'SystemError',  'SystemExit', 'TabError', 'TimeoutError', 'True', 'TypeError',  'UnboundLocalError', 'UnicodeDecodeError', 'UnicodeEncodeError',  'UnicodeError', 'UnicodeTranslateError', 'UnicodeWarning', 'UserWarning',  'ValueError', 'Warning', 'ZeroDivisionError', '\_', '\_\_build\_class\_\_',  '\_\_debug\_\_', '\_\_doc\_\_', '\_\_import\_\_', '\_\_name\_\_', '\_\_package\_\_', 'abs',  'all', 'any', 'ascii', 'bin', 'bool', 'bytearray', 'bytes', 'callable',  'chr', 'classmethod', 'compile', 'complex', 'copyright', 'credits',  'delattr', 'dict', 'dir', 'divmod', 'enumerate', 'eval', 'exec', 'exit',  'filter', 'float', 'format', 'frozenset', 'getattr', 'globals', 'hasattr',  'hash', 'help', 'hex', 'id', 'input', 'int', 'isinstance', 'issubclass',  'iter', 'len', 'license', 'list', 'locals', 'map', 'max', 'memoryview',  'min', 'next', 'object', 'oct', 'open', 'ord', 'pow', 'print', 'property',  'quit', 'range', 'repr', 'reversed', 'round', 'set', 'setattr', 'slice',  'sorted', 'staticmethod', 'str', 'sum', 'super', 'tuple', 'type', 'vars',  'zip'] 6.4. Packages Packages are a way of structuring Python’s module namespace by using “dotted module names”. For example, the module name A.B designates a submodule named B in a package named A. Just like the use of modules saves the authors of different modules from having to worry about each other’s global variable names, the use of dotted module names saves the authors of multi-module packages like NumPy or the Python Imaging Library from having to worry about each other’s module names.  Suppose you want to design a collection of modules (a “package”) for the uniform handling of sound files and sound data. There are many different sound file formats (usually recognized by their extension, for example: .wav, .aiff, .au), so you may need to create and maintain a growing collection of modules for the conversion between the various file formats. There are also many different operations you might want to perform on sound data (such as mixing, adding echo, applying an equalizer function, creating an artificial stereo effect), so in addition you will be writing a never-ending stream of modules to perform these operations. Here’s a possible structure for your package (expressed in terms of a hierarchical filesystem):  sound/ Top-level package  \_\_init\_\_.py Initialize the sound package  formats/ Subpackage for file format conversions  \_\_init\_\_.py  wavread.py  wavwrite.py  aiffread.py  aiffwrite.py  auread.py  auwrite.py  ...  effects/ Subpackage for sound effects  \_\_init\_\_.py  echo.py  surround.py  reverse.py  ...  filters/ Subpackage for filters  \_\_init\_\_.py  equalizer.py  vocoder.py  karaoke.py  ...  When importing the package, Python searches through the directories on sys.path looking for the package subdirectory.  The \_\_init\_\_.py files are required to make Python treat the directories as containing packages; this is done to prevent directories with a common name, such as string, from unintentionally hiding valid modules that occur later on the module search path. In the simplest case, \_\_init\_\_.py can just be an empty file, but it can also execute initialization code for the package or set the \_\_all\_\_ variable, described later.  Users of the package can import individual modules from the package, for example:  **import** **sound.effects.echo**  This loads the submodule sound.effects.echo. It must be referenced with its full name.  sound.effects.echo.echofilter(input, output, delay=0.7, atten=4)  An alternative way of importing the submodule is:  **from** **sound.effects** **import** echo  This also loads the submodule echo, and makes it available without its package prefix, so it can be used as follows:  echo.echofilter(input, output, delay=0.7, atten=4)  Yet another variation is to import the desired function or variable directly:  **from** **sound.effects.echo** **import** echofilter  Again, this loads the submodule echo, but this makes its function echofilter() directly available:  echofilter(input, output, delay=0.7, atten=4)  Note that when using from package import item, the item can be either a submodule (or subpackage) of the package, or some other name defined in the package, like a function, class or variable. The import statement first tests whether the item is defined in the package; if not, it assumes it is a module and attempts to load it. If it fails to find it, an [ImportError](https://docs.python.org/3/library/exceptions.html#ImportError) exception is raised.  Contrarily, when using syntax like import item.subitem.subsubitem, each item except for the last must be a package; the last item can be a module or a package but can’t be a class or function or variable defined in the previous item. 6.4.1. Importing \* From a Package Now what happens when the user writes from sound.effects import \*? Ideally, one would hope that this somehow goes out to the filesystem, finds which submodules are present in the package, and imports them all. This could take a long time and importing sub-modules might have unwanted side-effects that should only happen when the sub-module is explicitly imported.  The only solution is for the package author to provide an explicit index of the package. The [import](https://docs.python.org/3/reference/simple_stmts.html#import)statement uses the following convention: if a package’s \_\_init\_\_.py code defines a list named\_\_all\_\_, it is taken to be the list of module names that should be imported when from packageimport \* is encountered. It is up to the package author to keep this list up-to-date when a new version of the package is released. Package authors may also decide not to support it, if they don’t see a use for importing \* from their package. For example, the file sound/effects/\_\_init\_\_.py could contain the following code:  \_\_all\_\_ = ["echo", "surround", "reverse"]  This would mean that from sound.effects import \* would import the three named submodules of the sound package.  If \_\_all\_\_ is not defined, the statement from sound.effects import \* does not import all submodules from the package sound.effects into the current namespace; it only ensures that the package sound.effects has been imported (possibly running any initialization code in \_\_init\_\_.py) and then imports whatever names are defined in the package. This includes any names defined (and submodules explicitly loaded) by \_\_init\_\_.py. It also includes any submodules of the package that were explicitly loaded by previous [import](https://docs.python.org/3/reference/simple_stmts.html#import) statements. Consider this code:  **import** **sound.effects.echo**  **import** **sound.effects.surround**  **from** **sound.effects** **import** \*  In this example, the echo and surround modules are imported in the current namespace because they are defined in the sound.effects package when the from...import statement is executed. (This also works when \_\_all\_\_ is defined.)  Although certain modules are designed to export only names that follow certain patterns when you useimport \*, it is still considered bad practise in production code.  Remember, there is nothing wrong with using from Package import specific\_submodule! In fact, this is the recommended notation unless the importing module needs to use submodules with the same name from different packages. 6.4.2. Intra-package References When packages are structured into subpackages (as with the sound package in the example), you can use absolute imports to refer to submodules of siblings packages. For example, if the modulesound.filters.vocoder needs to use the echo module in the sound.effects package, it can usefrom sound.effects import echo.  You can also write relative imports, with the from module import name form of import statement. These imports use leading dots to indicate the current and parent packages involved in the relative import. From the surround module for example, you might use:  **from** **.** **import** echo  **from** **..** **import** formats  **from** **..filters** **import** equalizer  Note that relative imports are based on the name of the current module. Since the name of the main module is always "\_\_main\_\_", modules intended for use as the main module of a Python application must always use absolute imports. 6.4.3. Packages in Multiple Directories Packages support one more special attribute, [\_\_path\_\_](https://docs.python.org/3/reference/import.html#__path__). This is initialized to be a list containing the name of the directory holding the package’s \_\_init\_\_.py before the code in that file is executed. This variable can be modified; doing so affects future searches for modules and subpackages contained in the package.  While this feature is not often needed, it can be used to extend the set of modules found in a package.  **Footnotes**   |  |  | | --- | --- | | [[1]](https://docs.python.org/3/tutorial/modules.html#id1) | In fact function definitions are also ‘statements’ that are ‘executed’; the execution of a module-level function definition enters the function name in the module’s global symbol table. |  6. Modules If you quit from the Python interpreter and enter it again, the definitions you have made (functions and variables) are lost. Therefore, if you want to write a somewhat longer program, you are better off using a text editor to prepare the input for the interpreter and running it with that file as input instead. This is known as creating a script. As your program gets longer, you may want to split it into several files for easier maintenance. You may also want to use a handy function that you’ve written in several programs without copying its definition into each program.  To support this, Python has a way to put definitions in a file and use them in a script or in an interactive instance of the interpreter. Such a file is called a module; definitions from a module can be importedinto other modules or into the main module (the collection of variables that you have access to in a script executed at the top level and in calculator mode).  A module is a file containing Python definitions and statements. The file name is the module name with the suffix .py appended. Within a module, the module’s name (as a string) is available as the value of the global variable \_\_name\_\_. For instance, use your favorite text editor to create a file calledfibo.py in the current directory with the following contents:  *# Fibonacci numbers module*  **def** fib(n): *# write Fibonacci series up to n*  a, b = 0, 1  **while** b < n:  print(b, end=' ')  a, b = b, a+b  print()  **def** fib2(n): *# return Fibonacci series up to n*  result = []  a, b = 0, 1  **while** b < n:  result.append(b)  a, b = b, a+b  **return** result  Now enter the Python interpreter and import this module with the following command:  >>>  **>>> import** **fibo**  This does not enter the names of the functions defined in fibo directly in the current symbol table; it only enters the module name fibo there. Using the module name you can access the functions:  >>>  **>>>** fibo.fib(1000)  1 1 2 3 5 8 13 21 34 55 89 144 233 377 610 987  **>>>** fibo.fib2(100)  [1, 1, 2, 3, 5, 8, 13, 21, 34, 55, 89]  **>>>** fibo.\_\_name\_\_  'fibo'  If you intend to use a function often you can assign it to a local name:  >>>  **>>>** fib = fibo.fib  **>>>** fib(500)  1 1 2 3 5 8 13 21 34 55 89 144 233 377 6.1. More on Modules A module can contain executable statements as well as function definitions. These statements are intended to initialize the module. They are executed only the first time the module name is encountered in an import statement. [[1]](https://docs.python.org/3/tutorial/modules.html#id2) (They are also run if the file is executed as a script.)  Each module has its own private symbol table, which is used as the global symbol table by all functions defined in the module. Thus, the author of a module can use global variables in the module without worrying about accidental clashes with a user’s global variables. On the other hand, if you know what you are doing you can touch a module’s global variables with the same notation used to refer to its functions, modname.itemname.  Modules can import other modules. It is customary but not required to place all [import](https://docs.python.org/3/reference/simple_stmts.html#import) statements at the beginning of a module (or script, for that matter). The imported module names are placed in the importing module’s global symbol table.  There is a variant of the [import](https://docs.python.org/3/reference/simple_stmts.html#import) statement that imports names from a module directly into the importing module’s symbol table. For example:  >>>  **>>> from** **fibo** **import** fib, fib2  **>>>** fib(500)  1 1 2 3 5 8 13 21 34 55 89 144 233 377  This does not introduce the module name from which the imports are taken in the local symbol table (so in the example, fibo is not defined).  There is even a variant to import all names that a module defines:  >>>  **>>> from** **fibo** **import** \*  **>>>** fib(500)  1 1 2 3 5 8 13 21 34 55 89 144 233 377  This imports all names except those beginning with an underscore (\_). In most cases Python programmers do not use this facility since it introduces an unknown set of names into the interpreter, possibly hiding some things you have already defined.  Note that in general the practice of importing \* from a module or package is frowned upon, since it often causes poorly readable code. However, it is okay to use it to save typing in interactive sessions.  **Note**    For efficiency reasons, each module is only imported once per interpreter session. Therefore, if you change your modules, you must restart the interpreter – or, if it’s just one module you want to test interactively, use [importlib.reload()](https://docs.python.org/3/library/importlib.html#importlib.reload), e.g. import importlib;importlib.reload(modulename). 6.1.1. Executing modules as scripts When you run a Python module with  python fibo.py <arguments>  the code in the module will be executed, just as if you imported it, but with the \_\_name\_\_ set to"\_\_main\_\_". That means that by adding this code at the end of your module:  **if** \_\_name\_\_ == "\_\_main\_\_":  **import** **sys**  fib(int(sys.argv[1]))  you can make the file usable as a script as well as an importable module, because the code that parses the command line only runs if the module is executed as the “main” file:  $ python fibo.py 50  1 1 2 3 5 8 13 21 34  If the module is imported, the code is not run:  >>>  **>>> import** **fibo**  >>>  This is often used either to provide a convenient user interface to a module, or for testing purposes (running the module as a script executes a test suite). 6.1.2. The Module Search Path When a module named spam is imported, the interpreter first searches for a built-in module with that name. If not found, it then searches for a file named spam.py in a list of directories given by the variable [sys.path](https://docs.python.org/3/library/sys.html#sys.path). [sys.path](https://docs.python.org/3/library/sys.html#sys.path) is initialized from these locations:   * The directory containing the input script (or the current directory when no file is specified). * [PYTHONPATH](https://docs.python.org/3/using/cmdline.html#envvar-PYTHONPATH) (a list of directory names, with the same syntax as the shell variable PATH). * The installation-dependent default.   **Note**    On file systems which support symlinks, the directory containing the input script is calculated after the symlink is followed. In other words the directory containing the symlink is **not** added to the module search path.  After initialization, Python programs can modify [sys.path](https://docs.python.org/3/library/sys.html#sys.path). The directory containing the script being run is placed at the beginning of the search path, ahead of the standard library path. This means that scripts in that directory will be loaded instead of modules of the same name in the library directory. This is an error unless the replacement is intended. See section [Standard Modules](https://docs.python.org/3/tutorial/modules.html#tut-standardmodules) for more information. 6.1.3. “Compiled” Python files To speed up loading modules, Python caches the compiled version of each module in the\_\_pycache\_\_ directory under the name module.*version*.pyc, where the version encodes the format of the compiled file; it generally contains the Python version number. For example, in CPython release 3.3 the compiled version of spam.py would be cached as \_\_pycache\_\_/spam.cpython-33.pyc. This naming convention allows compiled modules from different releases and different versions of Python to coexist.  Python checks the modification date of the source against the compiled version to see if it’s out of date and needs to be recompiled. This is a completely automatic process. Also, the compiled modules are platform-independent, so the same library can be shared among systems with different architectures.  Python does not check the cache in two circumstances. First, it always recompiles and does not store the result for the module that’s loaded directly from the command line. Second, it does not check the cache if there is no source module. To support a non-source (compiled only) distribution, the compiled module must be in the source directory, and there must not be a source module.  Some tips for experts:   * You can use the [-O](https://docs.python.org/3/using/cmdline.html#cmdoption-O) or [-OO](https://docs.python.org/3/using/cmdline.html#cmdoption-OO) switches on the Python command to reduce the size of a compiled module. The -O switch removes assert statements, the -OO switch removes both assert statements and \_\_doc\_\_ strings. Since some programs may rely on having these available, you should only use this option if you know what you’re doing. “Optimized” modules have an opt-tag and are usually smaller. Future releases may change the effects of optimization. * A program doesn’t run any faster when it is read from a .pyc file than when it is read from a .pyfile; the only thing that’s faster about .pyc files is the speed with which they are loaded. * The module [compileall](https://docs.python.org/3/library/compileall.html#module-compileall) can create .pyc files for all modules in a directory. * There is more detail on this process, including a flow chart of the decisions, in PEP 3147.  6.2. Standard Modules Python comes with a library of standard modules, described in a separate document, the Python Library Reference (“Library Reference” hereafter). Some modules are built into the interpreter; these provide access to operations that are not part of the core of the language but are nevertheless built in, either for efficiency or to provide access to operating system primitives such as system calls. The set of such modules is a configuration option which also depends on the underlying platform. For example, the [winreg](https://docs.python.org/3/library/winreg.html#module-winreg) module is only provided on Windows systems. One particular module deserves some attention: [sys](https://docs.python.org/3/library/sys.html#module-sys), which is built into every Python interpreter. The variables sys.ps1 and sys.ps2define the strings used as primary and secondary prompts:  >>>  **>>> import** **sys**  **>>>** sys.ps1  '>>> '  **>>>** sys.ps2  '... '  **>>>** sys.ps1 = 'C> '  C> print('Yuck!')  Yuck!  C>  These two variables are only defined if the interpreter is in interactive mode.  The variable sys.path is a list of strings that determines the interpreter’s search path for modules. It is initialized to a default path taken from the environment variable [PYTHONPATH](https://docs.python.org/3/using/cmdline.html#envvar-PYTHONPATH), or from a built-in default if[PYTHONPATH](https://docs.python.org/3/using/cmdline.html#envvar-PYTHONPATH) is not set. You can modify it using standard list operations:  >>>  **>>> import** **sys**  **>>>** sys.path.append('/ufs/guido/lib/python') 6.3. The [dir()](https://docs.python.org/3/library/functions.html#dir) Function The built-in function [dir()](https://docs.python.org/3/library/functions.html#dir) is used to find out which names a module defines. It returns a sorted list of strings:  >>>  **>>> import** **fibo**, **sys**  **>>>** dir(fibo)  ['\_\_name\_\_', 'fib', 'fib2']  **>>>** dir(sys)  ['\_\_displayhook\_\_', '\_\_doc\_\_', '\_\_excepthook\_\_', '\_\_loader\_\_', '\_\_name\_\_',  '\_\_package\_\_', '\_\_stderr\_\_', '\_\_stdin\_\_', '\_\_stdout\_\_',  '\_clear\_type\_cache', '\_current\_frames', '\_debugmallocstats', '\_getframe',  '\_home', '\_mercurial', '\_xoptions', 'abiflags', 'api\_version', 'argv',  'base\_exec\_prefix', 'base\_prefix', 'builtin\_module\_names', 'byteorder',  'call\_tracing', 'callstats', 'copyright', 'displayhook',  'dont\_write\_bytecode', 'exc\_info', 'excepthook', 'exec\_prefix',  'executable', 'exit', 'flags', 'float\_info', 'float\_repr\_style',  'getcheckinterval', 'getdefaultencoding', 'getdlopenflags',  'getfilesystemencoding', 'getobjects', 'getprofile', 'getrecursionlimit',  'getrefcount', 'getsizeof', 'getswitchinterval', 'gettotalrefcount',  'gettrace', 'hash\_info', 'hexversion', 'implementation', 'int\_info',  'intern', 'maxsize', 'maxunicode', 'meta\_path', 'modules', 'path',  'path\_hooks', 'path\_importer\_cache', 'platform', 'prefix', 'ps1',  'setcheckinterval', 'setdlopenflags', 'setprofile', 'setrecursionlimit',  'setswitchinterval', 'settrace', 'stderr', 'stdin', 'stdout',  'thread\_info', 'version', 'version\_info', 'warnoptions']  Without arguments, [dir()](https://docs.python.org/3/library/functions.html#dir) lists the names you have defined currently:  >>>  **>>>** a = [1, 2, 3, 4, 5]  **>>> import** **fibo**  **>>>** fib = fibo.fib  **>>>** dir()  ['\_\_builtins\_\_', '\_\_name\_\_', 'a', 'fib', 'fibo', 'sys']  Note that it lists all types of names: variables, modules, functions, etc.  [dir()](https://docs.python.org/3/library/functions.html#dir) does not list the names of built-in functions and variables. If you want a list of those, they are defined in the standard module [builtins](https://docs.python.org/3/library/builtins.html#module-builtins):  >>>  **>>> import** **builtins**  **>>>** dir(builtins)  ['ArithmeticError', 'AssertionError', 'AttributeError', 'BaseException',  'BlockingIOError', 'BrokenPipeError', 'BufferError', 'BytesWarning',  'ChildProcessError', 'ConnectionAbortedError', 'ConnectionError',  'ConnectionRefusedError', 'ConnectionResetError', 'DeprecationWarning',  'EOFError', 'Ellipsis', 'EnvironmentError', 'Exception', 'False',  'FileExistsError', 'FileNotFoundError', 'FloatingPointError',  'FutureWarning', 'GeneratorExit', 'IOError', 'ImportError',  'ImportWarning', 'IndentationError', 'IndexError', 'InterruptedError',  'IsADirectoryError', 'KeyError', 'KeyboardInterrupt', 'LookupError',  'MemoryError', 'NameError', 'None', 'NotADirectoryError', 'NotImplemented',  'NotImplementedError', 'OSError', 'OverflowError',  'PendingDeprecationWarning', 'PermissionError', 'ProcessLookupError',  'ReferenceError', 'ResourceWarning', 'RuntimeError', 'RuntimeWarning',  'StopIteration', 'SyntaxError', 'SyntaxWarning', 'SystemError',  'SystemExit', 'TabError', 'TimeoutError', 'True', 'TypeError',  'UnboundLocalError', 'UnicodeDecodeError', 'UnicodeEncodeError',  'UnicodeError', 'UnicodeTranslateError', 'UnicodeWarning', 'UserWarning',  'ValueError', 'Warning', 'ZeroDivisionError', '\_', '\_\_build\_class\_\_',  '\_\_debug\_\_', '\_\_doc\_\_', '\_\_import\_\_', '\_\_name\_\_', '\_\_package\_\_', 'abs',  'all', 'any', 'ascii', 'bin', 'bool', 'bytearray', 'bytes', 'callable',  'chr', 'classmethod', 'compile', 'complex', 'copyright', 'credits',  'delattr', 'dict', 'dir', 'divmod', 'enumerate', 'eval', 'exec', 'exit',  'filter', 'float', 'format', 'frozenset', 'getattr', 'globals', 'hasattr',  'hash', 'help', 'hex', 'id', 'input', 'int', 'isinstance', 'issubclass',  'iter', 'len', 'license', 'list', 'locals', 'map', 'max', 'memoryview',  'min', 'next', 'object', 'oct', 'open', 'ord', 'pow', 'print', 'property',  'quit', 'range', 'repr', 'reversed', 'round', 'set', 'setattr', 'slice',  'sorted', 'staticmethod', 'str', 'sum', 'super', 'tuple', 'type', 'vars',  'zip'] 6.4. Packages Packages are a way of structuring Python’s module namespace by using “dotted module names”. For example, the module name A.B designates a submodule named B in a package named A. Just like the use of modules saves the authors of different modules from having to worry about each other’s global variable names, the use of dotted module names saves the authors of multi-module packages like NumPy or the Python Imaging Library from having to worry about each other’s module names.  Suppose you want to design a collection of modules (a “package”) for the uniform handling of sound files and sound data. There are many different sound file formats (usually recognized by their extension, for example: .wav, .aiff, .au), so you may need to create and maintain a growing collection of modules for the conversion between the various file formats. There are also many different operations you might want to perform on sound data (such as mixing, adding echo, applying an equalizer function, creating an artificial stereo effect), so in addition you will be writing a never-ending stream of modules to perform these operations. Here’s a possible structure for your package (expressed in terms of a hierarchical filesystem):  sound/ Top-level package  \_\_init\_\_.py Initialize the sound package  formats/ Subpackage for file format conversions  \_\_init\_\_.py  wavread.py  wavwrite.py  aiffread.py  aiffwrite.py  auread.py  auwrite.py  ...  effects/ Subpackage for sound effects  \_\_init\_\_.py  echo.py  surround.py  reverse.py  ...  filters/ Subpackage for filters  \_\_init\_\_.py  equalizer.py  vocoder.py  karaoke.py  ...  When importing the package, Python searches through the directories on sys.path looking for the package subdirectory.  The \_\_init\_\_.py files are required to make Python treat the directories as containing packages; this is done to prevent directories with a common name, such as string, from unintentionally hiding valid modules that occur later on the module search path. In the simplest case, \_\_init\_\_.py can just be an empty file, but it can also execute initialization code for the package or set the \_\_all\_\_ variable, described later.  Users of the package can import individual modules from the package, for example:  **import** **sound.effects.echo**  This loads the submodule sound.effects.echo. It must be referenced with its full name.  sound.effects.echo.echofilter(input, output, delay=0.7, atten=4)  An alternative way of importing the submodule is:  **from** **sound.effects** **import** echo  This also loads the submodule echo, and makes it available without its package prefix, so it can be used as follows:  echo.echofilter(input, output, delay=0.7, atten=4)  Yet another variation is to import the desired function or variable directly:  **from** **sound.effects.echo** **import** echofilter  Again, this loads the submodule echo, but this makes its function echofilter() directly available:  echofilter(input, output, delay=0.7, atten=4)  Note that when using from package import item, the item can be either a submodule (or subpackage) of the package, or some other name defined in the package, like a function, class or variable. The import statement first tests whether the item is defined in the package; if not, it assumes it is a module and attempts to load it. If it fails to find it, an [ImportError](https://docs.python.org/3/library/exceptions.html#ImportError) exception is raised.  Contrarily, when using syntax like import item.subitem.subsubitem, each item except for the last must be a package; the last item can be a module or a package but can’t be a class or function or variable defined in the previous item. 6.4.1. Importing \* From a Package Now what happens when the user writes from sound.effects import \*? Ideally, one would hope that this somehow goes out to the filesystem, finds which submodules are present in the package, and imports them all. This could take a long time and importing sub-modules might have unwanted side-effects that should only happen when the sub-module is explicitly imported.  The only solution is for the package author to provide an explicit index of the package. The [import](https://docs.python.org/3/reference/simple_stmts.html#import)statement uses the following convention: if a package’s \_\_init\_\_.py code defines a list named\_\_all\_\_, it is taken to be the list of module names that should be imported when from packageimport \* is encountered. It is up to the package author to keep this list up-to-date when a new version of the package is released. Package authors may also decide not to support it, if they don’t see a use for importing \* from their package. For example, the file sound/effects/\_\_init\_\_.py could contain the following code:  \_\_all\_\_ = ["echo", "surround", "reverse"]  This would mean that from sound.effects import \* would import the three named submodules of the sound package.  If \_\_all\_\_ is not defined, the statement from sound.effects import \* does not import all submodules from the package sound.effects into the current namespace; it only ensures that the package sound.effects has been imported (possibly running any initialization code in \_\_init\_\_.py) and then imports whatever names are defined in the package. This includes any names defined (and submodules explicitly loaded) by \_\_init\_\_.py. It also includes any submodules of the package that were explicitly loaded by previous [import](https://docs.python.org/3/reference/simple_stmts.html#import) statements. Consider this code:  **import** **sound.effects.echo**  **import** **sound.effects.surround**  **from** **sound.effects** **import** \*  In this example, the echo and surround modules are imported in the current namespace because they are defined in the sound.effects package when the from...import statement is executed. (This also works when \_\_all\_\_ is defined.)  Although certain modules are designed to export only names that follow certain patterns when you useimport \*, it is still considered bad practise in production code.  Remember, there is nothing wrong with using from Package import specific\_submodule! In fact, this is the recommended notation unless the importing module needs to use submodules with the same name from different packages. 6.4.2. Intra-package References When packages are structured into subpackages (as with the sound package in the example), you can use absolute imports to refer to submodules of siblings packages. For example, if the modulesound.filters.vocoder needs to use the echo module in the sound.effects package, it can usefrom sound.effects import echo.  You can also write relative imports, with the from module import name form of import statement. These imports use leading dots to indicate the current and parent packages involved in the relative import. From the surround module for example, you might use:  **from** **.** **import** echo  **from** **..** **import** formats  **from** **..filters** **import** equalizer  Note that relative imports are based on the name of the current module. Since the name of the main module is always "\_\_main\_\_", modules intended for use as the main module of a Python application must always use absolute imports. 6.4.3. Packages in Multiple Directories Packages support one more special attribute, [\_\_path\_\_](https://docs.python.org/3/reference/import.html#__path__). This is initialized to be a list containing the name of the directory holding the package’s \_\_init\_\_.py before the code in that file is executed. This variable can be modified; doing so affects future searches for modules and subpackages contained in the package.  While this feature is not often needed, it can be used to extend the set of modules found in a package.  **Footnotes**   |  |  | | --- | --- | | [[1]](https://docs.python.org/3/tutorial/modules.html#id1) | In fact function definitions are also ‘statements’ that are ‘executed’; the execution of a module-level function definition enters the function name in the module’s global symbol table. |  6. Modules If you quit from the Python interpreter and enter it again, the definitions you have made (functions and variables) are lost. Therefore, if you want to write a somewhat longer program, you are better off using a text editor to prepare the input for the interpreter and running it with that file as input instead. This is known as creating a script. As your program gets longer, you may want to split it into several files for easier maintenance. You may also want to use a handy function that you’ve written in several programs without copying its definition into each program.  To support this, Python has a way to put definitions in a file and use them in a script or in an interactive instance of the interpreter. Such a file is called a module; definitions from a module can be importedinto other modules or into the main module (the collection of variables that you have access to in a script executed at the top level and in calculator mode).  A module is a file containing Python definitions and statements. The file name is the module name with the suffix .py appended. Within a module, the module’s name (as a string) is available as the value of the global variable \_\_name\_\_. For instance, use your favorite text editor to create a file calledfibo.py in the current directory with the following contents:  *# Fibonacci numbers module*  **def** fib(n): *# write Fibonacci series up to n*  a, b = 0, 1  **while** b < n:  print(b, end=' ')  a, b = b, a+b  print()  **def** fib2(n): *# return Fibonacci series up to n*  result = []  a, b = 0, 1  **while** b < n:  result.append(b)  a, b = b, a+b  **return** result  Now enter the Python interpreter and import this module with the following command:  >>>  **>>> import** **fibo**  This does not enter the names of the functions defined in fibo directly in the current symbol table; it only enters the module name fibo there. Using the module name you can access the functions:  >>>  **>>>** fibo.fib(1000)  1 1 2 3 5 8 13 21 34 55 89 144 233 377 610 987  **>>>** fibo.fib2(100)  [1, 1, 2, 3, 5, 8, 13, 21, 34, 55, 89]  **>>>** fibo.\_\_name\_\_  'fibo'  If you intend to use a function often you can assign it to a local name:  >>>  **>>>** fib = fibo.fib  **>>>** fib(500)  1 1 2 3 5 8 13 21 34 55 89 144 233 377 6.1. More on Modules A module can contain executable statements as well as function definitions. These statements are intended to initialize the module. They are executed only the first time the module name is encountered in an import statement. [[1]](https://docs.python.org/3/tutorial/modules.html#id2) (They are also run if the file is executed as a script.)  Each module has its own private symbol table, which is used as the global symbol table by all functions defined in the module. Thus, the author of a module can use global variables in the module without worrying about accidental clashes with a user’s global variables. On the other hand, if you know what you are doing you can touch a module’s global variables with the same notation used to refer to its functions, modname.itemname.  Modules can import other modules. It is customary but not required to place all [import](https://docs.python.org/3/reference/simple_stmts.html#import) statements at the beginning of a module (or script, for that matter). The imported module names are placed in the importing module’s global symbol table.  There is a variant of the [import](https://docs.python.org/3/reference/simple_stmts.html#import) statement that imports names from a module directly into the importing module’s symbol table. For example:  >>>  **>>> from** **fibo** **import** fib, fib2  **>>>** fib(500)  1 1 2 3 5 8 13 21 34 55 89 144 233 377  This does not introduce the module name from which the imports are taken in the local symbol table (so in the example, fibo is not defined).  There is even a variant to import all names that a module defines:  >>>  **>>> from** **fibo** **import** \*  **>>>** fib(500)  1 1 2 3 5 8 13 21 34 55 89 144 233 377  This imports all names except those beginning with an underscore (\_). In most cases Python programmers do not use this facility since it introduces an unknown set of names into the interpreter, possibly hiding some things you have already defined.  Note that in general the practice of importing \* from a module or package is frowned upon, since it often causes poorly readable code. However, it is okay to use it to save typing in interactive sessions.  **Note**    For efficiency reasons, each module is only imported once per interpreter session. Therefore, if you change your modules, you must restart the interpreter – or, if it’s just one module you want to test interactively, use [importlib.reload()](https://docs.python.org/3/library/importlib.html#importlib.reload), e.g. import importlib;importlib.reload(modulename). 6.1.1. Executing modules as scripts When you run a Python module with  python fibo.py <arguments>  the code in the module will be executed, just as if you imported it, but with the \_\_name\_\_ set to"\_\_main\_\_". That means that by adding this code at the end of your module:  **if** \_\_name\_\_ == "\_\_main\_\_":  **import** **sys**  fib(int(sys.argv[1]))  you can make the file usable as a script as well as an importable module, because the code that parses the command line only runs if the module is executed as the “main” file:  $ python fibo.py 50  1 1 2 3 5 8 13 21 34  If the module is imported, the code is not run:  >>>  **>>> import** **fibo**  >>>  This is often used either to provide a convenient user interface to a module, or for testing purposes (running the module as a script executes a test suite). 6.1.2. The Module Search Path When a module named spam is imported, the interpreter first searches for a built-in module with that name. If not found, it then searches for a file named spam.py in a list of directories given by the variable [sys.path](https://docs.python.org/3/library/sys.html#sys.path). [sys.path](https://docs.python.org/3/library/sys.html#sys.path) is initialized from these locations:   * The directory containing the input script (or the current directory when no file is specified). * [PYTHONPATH](https://docs.python.org/3/using/cmdline.html#envvar-PYTHONPATH) (a list of directory names, with the same syntax as the shell variable PATH). * The installation-dependent default.   **Note**    On file systems which support symlinks, the directory containing the input script is calculated after the symlink is followed. In other words the directory containing the symlink is **not** added to the module search path.  After initialization, Python programs can modify [sys.path](https://docs.python.org/3/library/sys.html#sys.path). The directory containing the script being run is placed at the beginning of the search path, ahead of the standard library path. This means that scripts in that directory will be loaded instead of modules of the same name in the library directory. This is an error unless the replacement is intended. See section [Standard Modules](https://docs.python.org/3/tutorial/modules.html#tut-standardmodules) for more information. 6.1.3. “Compiled” Python files To speed up loading modules, Python caches the compiled version of each module in the\_\_pycache\_\_ directory under the name module.*version*.pyc, where the version encodes the format of the compiled file; it generally contains the Python version number. For example, in CPython release 3.3 the compiled version of spam.py would be cached as \_\_pycache\_\_/spam.cpython-33.pyc. This naming convention allows compiled modules from different releases and different versions of Python to coexist.  Python checks the modification date of the source against the compiled version to see if it’s out of date and needs to be recompiled. This is a completely automatic process. Also, the compiled modules are platform-independent, so the same library can be shared among systems with different architectures.  Python does not check the cache in two circumstances. First, it always recompiles and does not store the result for the module that’s loaded directly from the command line. Second, it does not check the cache if there is no source module. To support a non-source (compiled only) distribution, the compiled module must be in the source directory, and there must not be a source module.  Some tips for experts:   * You can use the [-O](https://docs.python.org/3/using/cmdline.html#cmdoption-O) or [-OO](https://docs.python.org/3/using/cmdline.html#cmdoption-OO) switches on the Python command to reduce the size of a compiled module. The -O switch removes assert statements, the -OO switch removes both assert statements and \_\_doc\_\_ strings. Since some programs may rely on having these available, you should only use this option if you know what you’re doing. “Optimized” modules have an opt-tag and are usually smaller. Future releases may change the effects of optimization. * A program doesn’t run any faster when it is read from a .pyc file than when it is read from a .pyfile; the only thing that’s faster about .pyc files is the speed with which they are loaded. * The module [compileall](https://docs.python.org/3/library/compileall.html#module-compileall) can create .pyc files for all modules in a directory. * There is more detail on this process, including a flow chart of the decisions, in PEP 3147.  6.2. Standard Modules Python comes with a library of standard modules, described in a separate document, the Python Library Reference (“Library Reference” hereafter). Some modules are built into the interpreter; these provide access to operations that are not part of the core of the language but are nevertheless built in, either for efficiency or to provide access to operating system primitives such as system calls. The set of such modules is a configuration option which also depends on the underlying platform. For example, the [winreg](https://docs.python.org/3/library/winreg.html#module-winreg) module is only provided on Windows systems. One particular module deserves some attention: [sys](https://docs.python.org/3/library/sys.html#module-sys), which is built into every Python interpreter. The variables sys.ps1 and sys.ps2define the strings used as primary and secondary prompts:  >>>  **>>> import** **sys**  **>>>** sys.ps1  '>>> '  **>>>** sys.ps2  '... '  **>>>** sys.ps1 = 'C> '  C> print('Yuck!')  Yuck!  C>  These two variables are only defined if the interpreter is in interactive mode.  The variable sys.path is a list of strings that determines the interpreter’s search path for modules. It is initialized to a default path taken from the environment variable [PYTHONPATH](https://docs.python.org/3/using/cmdline.html#envvar-PYTHONPATH), or from a built-in default if[PYTHONPATH](https://docs.python.org/3/using/cmdline.html#envvar-PYTHONPATH) is not set. You can modify it using standard list operations:  >>>  **>>> import** **sys**  **>>>** sys.path.append('/ufs/guido/lib/python') 6.3. The [dir()](https://docs.python.org/3/library/functions.html#dir) Function The built-in function [dir()](https://docs.python.org/3/library/functions.html#dir) is used to find out which names a module defines. It returns a sorted list of strings:  >>>  **>>> import** **fibo**, **sys**  **>>>** dir(fibo)  ['\_\_name\_\_', 'fib', 'fib2']  **>>>** dir(sys)  ['\_\_displayhook\_\_', '\_\_doc\_\_', '\_\_excepthook\_\_', '\_\_loader\_\_', '\_\_name\_\_',  '\_\_package\_\_', '\_\_stderr\_\_', '\_\_stdin\_\_', '\_\_stdout\_\_',  '\_clear\_type\_cache', '\_current\_frames', '\_debugmallocstats', '\_getframe',  '\_home', '\_mercurial', '\_xoptions', 'abiflags', 'api\_version', 'argv',  'base\_exec\_prefix', 'base\_prefix', 'builtin\_module\_names', 'byteorder',  'call\_tracing', 'callstats', 'copyright', 'displayhook',  'dont\_write\_bytecode', 'exc\_info', 'excepthook', 'exec\_prefix',  'executable', 'exit', 'flags', 'float\_info', 'float\_repr\_style',  'getcheckinterval', 'getdefaultencoding', 'getdlopenflags',  'getfilesystemencoding', 'getobjects', 'getprofile', 'getrecursionlimit',  'getrefcount', 'getsizeof', 'getswitchinterval', 'gettotalrefcount',  'gettrace', 'hash\_info', 'hexversion', 'implementation', 'int\_info',  'intern', 'maxsize', 'maxunicode', 'meta\_path', 'modules', 'path',  'path\_hooks', 'path\_importer\_cache', 'platform', 'prefix', 'ps1',  'setcheckinterval', 'setdlopenflags', 'setprofile', 'setrecursionlimit',  'setswitchinterval', 'settrace', 'stderr', 'stdin', 'stdout',  'thread\_info', 'version', 'version\_info', 'warnoptions']  Without arguments, [dir()](https://docs.python.org/3/library/functions.html#dir) lists the names you have defined currently:  >>>  **>>>** a = [1, 2, 3, 4, 5]  **>>> import** **fibo**  **>>>** fib = fibo.fib  **>>>** dir()  ['\_\_builtins\_\_', '\_\_name\_\_', 'a', 'fib', 'fibo', 'sys']  Note that it lists all types of names: variables, modules, functions, etc.  [dir()](https://docs.python.org/3/library/functions.html#dir) does not list the names of built-in functions and variables. If you want a list of those, they are defined in the standard module [builtins](https://docs.python.org/3/library/builtins.html#module-builtins):  >>>  **>>> import** **builtins**  **>>>** dir(builtins)  ['ArithmeticError', 'AssertionError', 'AttributeError', 'BaseException',  'BlockingIOError', 'BrokenPipeError', 'BufferError', 'BytesWarning',  'ChildProcessError', 'ConnectionAbortedError', 'ConnectionError',  'ConnectionRefusedError', 'ConnectionResetError', 'DeprecationWarning',  'EOFError', 'Ellipsis', 'EnvironmentError', 'Exception', 'False',  'FileExistsError', 'FileNotFoundError', 'FloatingPointError',  'FutureWarning', 'GeneratorExit', 'IOError', 'ImportError',  'ImportWarning', 'IndentationError', 'IndexError', 'InterruptedError',  'IsADirectoryError', 'KeyError', 'KeyboardInterrupt', 'LookupError',  'MemoryError', 'NameError', 'None', 'NotADirectoryError', 'NotImplemented',  'NotImplementedError', 'OSError', 'OverflowError',  'PendingDeprecationWarning', 'PermissionError', 'ProcessLookupError',  'ReferenceError', 'ResourceWarning', 'RuntimeError', 'RuntimeWarning',  'StopIteration', 'SyntaxError', 'SyntaxWarning', 'SystemError',  'SystemExit', 'TabError', 'TimeoutError', 'True', 'TypeError',  'UnboundLocalError', 'UnicodeDecodeError', 'UnicodeEncodeError',  'UnicodeError', 'UnicodeTranslateError', 'UnicodeWarning', 'UserWarning',  'ValueError', 'Warning', 'ZeroDivisionError', '\_', '\_\_build\_class\_\_',  '\_\_debug\_\_', '\_\_doc\_\_', '\_\_import\_\_', '\_\_name\_\_', '\_\_package\_\_', 'abs',  'all', 'any', 'ascii', 'bin', 'bool', 'bytearray', 'bytes', 'callable',  'chr', 'classmethod', 'compile', 'complex', 'copyright', 'credits',  'delattr', 'dict', 'dir', 'divmod', 'enumerate', 'eval', 'exec', 'exit',  'filter', 'float', 'format', 'frozenset', 'getattr', 'globals', 'hasattr',  'hash', 'help', 'hex', 'id', 'input', 'int', 'isinstance', 'issubclass',  'iter', 'len', 'license', 'list', 'locals', 'map', 'max', 'memoryview',  'min', 'next', 'object', 'oct', 'open', 'ord', 'pow', 'print', 'property',  'quit', 'range', 'repr', 'reversed', 'round', 'set', 'setattr', 'slice',  'sorted', 'staticmethod', 'str', 'sum', 'super', 'tuple', 'type', 'vars',  'zip'] 6.4. Packages Packages are a way of structuring Python’s module namespace by using “dotted module names”. For example, the module name A.B designates a submodule named B in a package named A. Just like the use of modules saves the authors of different modules from having to worry about each other’s global variable names, the use of dotted module names saves the authors of multi-module packages like NumPy or the Python Imaging Library from having to worry about each other’s module names.  Suppose you want to design a collection of modules (a “package”) for the uniform handling of sound files and sound data. There are many different sound file formats (usually recognized by their extension, for example: .wav, .aiff, .au), so you may need to create and maintain a growing collection of modules for the conversion between the various file formats. There are also many different operations you might want to perform on sound data (such as mixing, adding echo, applying an equalizer function, creating an artificial stereo effect), so in addition you will be writing a never-ending stream of modules to perform these operations. Here’s a possible structure for your package (expressed in terms of a hierarchical filesystem):  sound/ Top-level package  \_\_init\_\_.py Initialize the sound package  formats/ Subpackage for file format conversions  \_\_init\_\_.py  wavread.py  wavwrite.py  aiffread.py  aiffwrite.py  auread.py  auwrite.py  ...  effects/ Subpackage for sound effects  \_\_init\_\_.py  echo.py  surround.py  reverse.py  ...  filters/ Subpackage for filters  \_\_init\_\_.py  equalizer.py  vocoder.py  karaoke.py  ...  When importing the package, Python searches through the directories on sys.path looking for the package subdirectory.  The \_\_init\_\_.py files are required to make Python treat the directories as containing packages; this is done to prevent directories with a common name, such as string, from unintentionally hiding valid modules that occur later on the module search path. In the simplest case, \_\_init\_\_.py can just be an empty file, but it can also execute initialization code for the package or set the \_\_all\_\_ variable, described later.  Users of the package can import individual modules from the package, for example:  **import** **sound.effects.echo**  This loads the submodule sound.effects.echo. It must be referenced with its full name.  sound.effects.echo.echofilter(input, output, delay=0.7, atten=4)  An alternative way of importing the submodule is:  **from** **sound.effects** **import** echo  This also loads the submodule echo, and makes it available without its package prefix, so it can be used as follows:  echo.echofilter(input, output, delay=0.7, atten=4)  Yet another variation is to import the desired function or variable directly:  **from** **sound.effects.echo** **import** echofilter  Again, this loads the submodule echo, but this makes its function echofilter() directly available:  echofilter(input, output, delay=0.7, atten=4)  Note that when using from package import item, the item can be either a submodule (or subpackage) of the package, or some other name defined in the package, like a function, class or variable. The import statement first tests whether the item is defined in the package; if not, it assumes it is a module and attempts to load it. If it fails to find it, an [ImportError](https://docs.python.org/3/library/exceptions.html#ImportError) exception is raised.  Contrarily, when using syntax like import item.subitem.subsubitem, each item except for the last must be a package; the last item can be a module or a package but can’t be a class or function or variable defined in the previous item. 6.4.1. Importing \* From a Package Now what happens when the user writes from sound.effects import \*? Ideally, one would hope that this somehow goes out to the filesystem, finds which submodules are present in the package, and imports them all. This could take a long time and importing sub-modules might have unwanted side-effects that should only happen when the sub-module is explicitly imported.  The only solution is for the package author to provide an explicit index of the package. The [import](https://docs.python.org/3/reference/simple_stmts.html#import)statement uses the following convention: if a package’s \_\_init\_\_.py code defines a list named\_\_all\_\_, it is taken to be the list of module names that should be imported when from packageimport \* is encountered. It is up to the package author to keep this list up-to-date when a new version of the package is released. Package authors may also decide not to support it, if they don’t see a use for importing \* from their package. For example, the file sound/effects/\_\_init\_\_.py could contain the following code:  \_\_all\_\_ = ["echo", "surround", "reverse"]  This would mean that from sound.effects import \* would import the three named submodules of the sound package.  If \_\_all\_\_ is not defined, the statement from sound.effects import \* does not import all submodules from the package sound.effects into the current namespace; it only ensures that the package sound.effects has been imported (possibly running any initialization code in \_\_init\_\_.py) and then imports whatever names are defined in the package. This includes any names defined (and submodules explicitly loaded) by \_\_init\_\_.py. It also includes any submodules of the package that were explicitly loaded by previous [import](https://docs.python.org/3/reference/simple_stmts.html#import) statements. Consider this code:  **import** **sound.effects.echo**  **import** **sound.effects.surround**  **from** **sound.effects** **import** \*  In this example, the echo and surround modules are imported in the current namespace because they are defined in the sound.effects package when the from...import statement is executed. (This also works when \_\_all\_\_ is defined.)  Although certain modules are designed to export only names that follow certain patterns when you useimport \*, it is still considered bad practise in production code.  Remember, there is nothing wrong with using from Package import specific\_submodule! In fact, this is the recommended notation unless the importing module needs to use submodules with the same name from different packages. 6.4.2. Intra-package References When packages are structured into subpackages (as with the sound package in the example), you can use absolute imports to refer to submodules of siblings packages. For example, if the modulesound.filters.vocoder needs to use the echo module in the sound.effects package, it can usefrom sound.effects import echo.  You can also write relative imports, with the from module import name form of import statement. These imports use leading dots to indicate the current and parent packages involved in the relative import. From the surround module for example, you might use:  **from** **.** **import** echo  **from** **..** **import** formats  **from** **..filters** **import** equalizer  Note that relative imports are based on the name of the current module. Since the name of the main module is always "\_\_main\_\_", modules intended for use as the main module of a Python application must always use absolute imports. 6.4.3. Packages in Multiple Directories Packages support one more special attribute, [\_\_path\_\_](https://docs.python.org/3/reference/import.html#__path__). This is initialized to be a list containing the name of the directory holding the package’s \_\_init\_\_.py before the code in that file is executed. This variable can be modified; doing so affects future searches for modules and subpackages contained in the package.  While this feature is not often needed, it can be used to extend the set of modules found in a package.  **Footnotes**   |  |  | | --- | --- | | [[1]](https://docs.python.org/3/tutorial/modules.html#id1) | In fact function definitions are also ‘statements’ that are ‘executed’; the execution of a module-level function definition enters the function name in the module’s global symbol table. |  6. Modules If you quit from the Python interpreter and enter it again, the definitions you have made (functions and variables) are lost. Therefore, if you want to write a somewhat longer program, you are better off using a text editor to prepare the input for the interpreter and running it with that file as input instead. This is known as creating a script. As your program gets longer, you may want to split it into several files for easier maintenance. You may also want to use a handy function that you’ve written in several programs without copying its definition into each program.  To support this, Python has a way to put definitions in a file and use them in a script or in an interactive instance of the interpreter. Such a file is called a module; definitions from a module can be importedinto other modules or into the main module (the collection of variables that you have access to in a script executed at the top level and in calculator mode).  A module is a file containing Python definitions and statements. The file name is the module name with the suffix .py appended. Within a module, the module’s name (as a string) is available as the value of the global variable \_\_name\_\_. For instance, use your favorite text editor to create a file calledfibo.py in the current directory with the following contents:  *# Fibonacci numbers module*  **def** fib(n): *# write Fibonacci series up to n*  a, b = 0, 1  **while** b < n:  print(b, end=' ')  a, b = b, a+b  print()  **def** fib2(n): *# return Fibonacci series up to n*  result = []  a, b = 0, 1  **while** b < n:  result.append(b)  a, b = b, a+b  **return** result  Now enter the Python interpreter and import this module with the following command:  >>>  **>>> import** **fibo**  This does not enter the names of the functions defined in fibo directly in the current symbol table; it only enters the module name fibo there. Using the module name you can access the functions:  >>>  **>>>** fibo.fib(1000)  1 1 2 3 5 8 13 21 34 55 89 144 233 377 610 987  **>>>** fibo.fib2(100)  [1, 1, 2, 3, 5, 8, 13, 21, 34, 55, 89]  **>>>** fibo.\_\_name\_\_  'fibo'  If you intend to use a function often you can assign it to a local name:  >>>  **>>>** fib = fibo.fib  **>>>** fib(500)  1 1 2 3 5 8 13 21 34 55 89 144 233 377 6.1. More on Modules A module can contain executable statements as well as function definitions. These statements are intended to initialize the module. They are executed only the first time the module name is encountered in an import statement. [[1]](https://docs.python.org/3/tutorial/modules.html#id2) (They are also run if the file is executed as a script.)  Each module has its own private symbol table, which is used as the global symbol table by all functions defined in the module. Thus, the author of a module can use global variables in the module without worrying about accidental clashes with a user’s global variables. On the other hand, if you know what you are doing you can touch a module’s global variables with the same notation used to refer to its functions, modname.itemname.  Modules can import other modules. It is customary but not required to place all [import](https://docs.python.org/3/reference/simple_stmts.html#import) statements at the beginning of a module (or script, for that matter). The imported module names are placed in the importing module’s global symbol table.  There is a variant of the [import](https://docs.python.org/3/reference/simple_stmts.html#import) statement that imports names from a module directly into the importing module’s symbol table. For example:  >>>  **>>> from** **fibo** **import** fib, fib2  **>>>** fib(500)  1 1 2 3 5 8 13 21 34 55 89 144 233 377  This does not introduce the module name from which the imports are taken in the local symbol table (so in the example, fibo is not defined).  There is even a variant to import all names that a module defines:  >>>  **>>> from** **fibo** **import** \*  **>>>** fib(500)  1 1 2 3 5 8 13 21 34 55 89 144 233 377  This imports all names except those beginning with an underscore (\_). In most cases Python programmers do not use this facility since it introduces an unknown set of names into the interpreter, possibly hiding some things you have already defined.  Note that in general the practice of importing \* from a module or package is frowned upon, since it often causes poorly readable code. However, it is okay to use it to save typing in interactive sessions.  **Note**    For efficiency reasons, each module is only imported once per interpreter session. Therefore, if you change your modules, you must restart the interpreter – or, if it’s just one module you want to test interactively, use [importlib.reload()](https://docs.python.org/3/library/importlib.html#importlib.reload), e.g. import importlib;importlib.reload(modulename). 6.1.1. Executing modules as scripts When you run a Python module with  python fibo.py <arguments>  the code in the module will be executed, just as if you imported it, but with the \_\_name\_\_ set to"\_\_main\_\_". That means that by adding this code at the end of your module:  **if** \_\_name\_\_ == "\_\_main\_\_":  **import** **sys**  fib(int(sys.argv[1]))  you can make the file usable as a script as well as an importable module, because the code that parses the command line only runs if the module is executed as the “main” file:  $ python fibo.py 50  1 1 2 3 5 8 13 21 34  If the module is imported, the code is not run:  >>>  **>>> import** **fibo**  >>>  This is often used either to provide a convenient user interface to a module, or for testing purposes (running the module as a script executes a test suite). 6.1.2. The Module Search Path When a module named spam is imported, the interpreter first searches for a built-in module with that name. If not found, it then searches for a file named spam.py in a list of directories given by the variable [sys.path](https://docs.python.org/3/library/sys.html#sys.path). [sys.path](https://docs.python.org/3/library/sys.html#sys.path) is initialized from these locations:   * The directory containing the input script (or the current directory when no file is specified). * [PYTHONPATH](https://docs.python.org/3/using/cmdline.html#envvar-PYTHONPATH) (a list of directory names, with the same syntax as the shell variable PATH). * The installation-dependent default.   **Note**    On file systems which support symlinks, the directory containing the input script is calculated after the symlink is followed. In other words the directory containing the symlink is **not** added to the module search path.  After initialization, Python programs can modify [sys.path](https://docs.python.org/3/library/sys.html#sys.path). The directory containing the script being run is placed at the beginning of the search path, ahead of the standard library path. This means that scripts in that directory will be loaded instead of modules of the same name in the library directory. This is an error unless the replacement is intended. See section [Standard Modules](https://docs.python.org/3/tutorial/modules.html#tut-standardmodules) for more information. 6.1.3. “Compiled” Python files To speed up loading modules, Python caches the compiled version of each module in the\_\_pycache\_\_ directory under the name module.*version*.pyc, where the version encodes the format of the compiled file; it generally contains the Python version number. For example, in CPython release 3.3 the compiled version of spam.py would be cached as \_\_pycache\_\_/spam.cpython-33.pyc. This naming convention allows compiled modules from different releases and different versions of Python to coexist.  Python checks the modification date of the source against the compiled version to see if it’s out of date and needs to be recompiled. This is a completely automatic process. Also, the compiled modules are platform-independent, so the same library can be shared among systems with different architectures.  Python does not check the cache in two circumstances. First, it always recompiles and does not store the result for the module that’s loaded directly from the command line. Second, it does not check the cache if there is no source module. To support a non-source (compiled only) distribution, the compiled module must be in the source directory, and there must not be a source module.  Some tips for experts:   * You can use the [-O](https://docs.python.org/3/using/cmdline.html#cmdoption-O) or [-OO](https://docs.python.org/3/using/cmdline.html#cmdoption-OO) switches on the Python command to reduce the size of a compiled module. The -O switch removes assert statements, the -OO switch removes both assert statements and \_\_doc\_\_ strings. Since some programs may rely on having these available, you should only use this option if you know what you’re doing. “Optimized” modules have an opt-tag and are usually smaller. Future releases may change the effects of optimization. * A program doesn’t run any faster when it is read from a .pyc file than when it is read from a .pyfile; the only thing that’s faster about .pyc files is the speed with which they are loaded. * The module [compileall](https://docs.python.org/3/library/compileall.html#module-compileall) can create .pyc files for all modules in a directory. * There is more detail on this process, including a flow chart of the decisions, in PEP 3147.  6.2. Standard Modules Python comes with a library of standard modules, described in a separate document, the Python Library Reference (“Library Reference” hereafter). Some modules are built into the interpreter; these provide access to operations that are not part of the core of the language but are nevertheless built in, either for efficiency or to provide access to operating system primitives such as system calls. The set of such modules is a configuration option which also depends on the underlying platform. For example, the [winreg](https://docs.python.org/3/library/winreg.html#module-winreg) module is only provided on Windows systems. One particular module deserves some attention: [sys](https://docs.python.org/3/library/sys.html#module-sys), which is built into every Python interpreter. The variables sys.ps1 and sys.ps2define the strings used as primary and secondary prompts:  >>>  **>>> import** **sys**  **>>>** sys.ps1  '>>> '  **>>>** sys.ps2  '... '  **>>>** sys.ps1 = 'C> '  C> print('Yuck!')  Yuck!  C>  These two variables are only defined if the interpreter is in interactive mode.  The variable sys.path is a list of strings that determines the interpreter’s search path for modules. It is initialized to a default path taken from the environment variable [PYTHONPATH](https://docs.python.org/3/using/cmdline.html#envvar-PYTHONPATH), or from a built-in default if[PYTHONPATH](https://docs.python.org/3/using/cmdline.html#envvar-PYTHONPATH) is not set. You can modify it using standard list operations:  >>>  **>>> import** **sys**  **>>>** sys.path.append('/ufs/guido/lib/python') 6.3. The [dir()](https://docs.python.org/3/library/functions.html#dir) Function The built-in function [dir()](https://docs.python.org/3/library/functions.html#dir) is used to find out which names a module defines. It returns a sorted list of strings:  >>>  **>>> import** **fibo**, **sys**  **>>>** dir(fibo)  ['\_\_name\_\_', 'fib', 'fib2']  **>>>** dir(sys)  ['\_\_displayhook\_\_', '\_\_doc\_\_', '\_\_excepthook\_\_', '\_\_loader\_\_', '\_\_name\_\_',  '\_\_package\_\_', '\_\_stderr\_\_', '\_\_stdin\_\_', '\_\_stdout\_\_',  '\_clear\_type\_cache', '\_current\_frames', '\_debugmallocstats', '\_getframe',  '\_home', '\_mercurial', '\_xoptions', 'abiflags', 'api\_version', 'argv',  'base\_exec\_prefix', 'base\_prefix', 'builtin\_module\_names', 'byteorder',  'call\_tracing', 'callstats', 'copyright', 'displayhook',  'dont\_write\_bytecode', 'exc\_info', 'excepthook', 'exec\_prefix',  'executable', 'exit', 'flags', 'float\_info', 'float\_repr\_style',  'getcheckinterval', 'getdefaultencoding', 'getdlopenflags',  'getfilesystemencoding', 'getobjects', 'getprofile', 'getrecursionlimit',  'getrefcount', 'getsizeof', 'getswitchinterval', 'gettotalrefcount',  'gettrace', 'hash\_info', 'hexversion', 'implementation', 'int\_info',  'intern', 'maxsize', 'maxunicode', 'meta\_path', 'modules', 'path',  'path\_hooks', 'path\_importer\_cache', 'platform', 'prefix', 'ps1',  'setcheckinterval', 'setdlopenflags', 'setprofile', 'setrecursionlimit',  'setswitchinterval', 'settrace', 'stderr', 'stdin', 'stdout',  'thread\_info', 'version', 'version\_info', 'warnoptions']  Without arguments, [dir()](https://docs.python.org/3/library/functions.html#dir) lists the names you have defined currently:  >>>  **>>>** a = [1, 2, 3, 4, 5]  **>>> import** **fibo**  **>>>** fib = fibo.fib  **>>>** dir()  ['\_\_builtins\_\_', '\_\_name\_\_', 'a', 'fib', 'fibo', 'sys']  Note that it lists all types of names: variables, modules, functions, etc.  [dir()](https://docs.python.org/3/library/functions.html#dir) does not list the names of built-in functions and variables. If you want a list of those, they are defined in the standard module [builtins](https://docs.python.org/3/library/builtins.html#module-builtins):  >>>  **>>> import** **builtins**  **>>>** dir(builtins)  ['ArithmeticError', 'AssertionError', 'AttributeError', 'BaseException',  'BlockingIOError', 'BrokenPipeError', 'BufferError', 'BytesWarning',  'ChildProcessError', 'ConnectionAbortedError', 'ConnectionError',  'ConnectionRefusedError', 'ConnectionResetError', 'DeprecationWarning',  'EOFError', 'Ellipsis', 'EnvironmentError', 'Exception', 'False',  'FileExistsError', 'FileNotFoundError', 'FloatingPointError',  'FutureWarning', 'GeneratorExit', 'IOError', 'ImportError',  'ImportWarning', 'IndentationError', 'IndexError', 'InterruptedError',  'IsADirectoryError', 'KeyError', 'KeyboardInterrupt', 'LookupError',  'MemoryError', 'NameError', 'None', 'NotADirectoryError', 'NotImplemented',  'NotImplementedError', 'OSError', 'OverflowError',  'PendingDeprecationWarning', 'PermissionError', 'ProcessLookupError',  'ReferenceError', 'ResourceWarning', 'RuntimeError', 'RuntimeWarning',  'StopIteration', 'SyntaxError', 'SyntaxWarning', 'SystemError',  'SystemExit', 'TabError', 'TimeoutError', 'True', 'TypeError',  'UnboundLocalError', 'UnicodeDecodeError', 'UnicodeEncodeError',  'UnicodeError', 'UnicodeTranslateError', 'UnicodeWarning', 'UserWarning',  'ValueError', 'Warning', 'ZeroDivisionError', '\_', '\_\_build\_class\_\_',  '\_\_debug\_\_', '\_\_doc\_\_', '\_\_import\_\_', '\_\_name\_\_', '\_\_package\_\_', 'abs',  'all', 'any', 'ascii', 'bin', 'bool', 'bytearray', 'bytes', 'callable',  'chr', 'classmethod', 'compile', 'complex', 'copyright', 'credits',  'delattr', 'dict', 'dir', 'divmod', 'enumerate', 'eval', 'exec', 'exit',  'filter', 'float', 'format', 'frozenset', 'getattr', 'globals', 'hasattr',  'hash', 'help', 'hex', 'id', 'input', 'int', 'isinstance', 'issubclass',  'iter', 'len', 'license', 'list', 'locals', 'map', 'max', 'memoryview',  'min', 'next', 'object', 'oct', 'open', 'ord', 'pow', 'print', 'property',  'quit', 'range', 'repr', 'reversed', 'round', 'set', 'setattr', 'slice',  'sorted', 'staticmethod', 'str', 'sum', 'super', 'tuple', 'type', 'vars',  'zip'] 6.4. Packages Packages are a way of structuring Python’s module namespace by using “dotted module names”. For example, the module name A.B designates a submodule named B in a package named A. Just like the use of modules saves the authors of different modules from having to worry about each other’s global variable names, the use of dotted module names saves the authors of multi-module packages like NumPy or the Python Imaging Library from having to worry about each other’s module names.  Suppose you want to design a collection of modules (a “package”) for the uniform handling of sound files and sound data. There are many different sound file formats (usually recognized by their extension, for example: .wav, .aiff, .au), so you may need to create and maintain a growing collection of modules for the conversion between the various file formats. There are also many different operations you might want to perform on sound data (such as mixing, adding echo, applying an equalizer function, creating an artificial stereo effect), so in addition you will be writing a never-ending stream of modules to perform these operations. Here’s a possible structure for your package (expressed in terms of a hierarchical filesystem):  sound/ Top-level package  \_\_init\_\_.py Initialize the sound package  formats/ Subpackage for file format conversions  \_\_init\_\_.py  wavread.py  wavwrite.py  aiffread.py  aiffwrite.py  auread.py  auwrite.py  ...  effects/ Subpackage for sound effects  \_\_init\_\_.py  echo.py  surround.py  reverse.py  ...  filters/ Subpackage for filters  \_\_init\_\_.py  equalizer.py  vocoder.py  karaoke.py  ...  When importing the package, Python searches through the directories on sys.path looking for the package subdirectory.  The \_\_init\_\_.py files are required to make Python treat the directories as containing packages; this is done to prevent directories with a common name, such as string, from unintentionally hiding valid modules that occur later on the module search path. In the simplest case, \_\_init\_\_.py can just be an empty file, but it can also execute initialization code for the package or set the \_\_all\_\_ variable, described later.  Users of the package can import individual modules from the package, for example:  **import** **sound.effects.echo**  This loads the submodule sound.effects.echo. It must be referenced with its full name.  sound.effects.echo.echofilter(input, output, delay=0.7, atten=4)  An alternative way of importing the submodule is:  **from** **sound.effects** **import** echo  This also loads the submodule echo, and makes it available without its package prefix, so it can be used as follows:  echo.echofilter(input, output, delay=0.7, atten=4)  Yet another variation is to import the desired function or variable directly:  **from** **sound.effects.echo** **import** echofilter  Again, this loads the submodule echo, but this makes its function echofilter() directly available:  echofilter(input, output, delay=0.7, atten=4)  Note that when using from package import item, the item can be either a submodule (or subpackage) of the package, or some other name defined in the package, like a function, class or variable. The import statement first tests whether the item is defined in the package; if not, it assumes it is a module and attempts to load it. If it fails to find it, an [ImportError](https://docs.python.org/3/library/exceptions.html#ImportError) exception is raised.  Contrarily, when using syntax like import item.subitem.subsubitem, each item except for the last must be a package; the last item can be a module or a package but can’t be a class or function or variable defined in the previous item. 6.4.1. Importing \* From a Package Now what happens when the user writes from sound.effects import \*? Ideally, one would hope that this somehow goes out to the filesystem, finds which submodules are present in the package, and imports them all. This could take a long time and importing sub-modules might have unwanted side-effects that should only happen when the sub-module is explicitly imported.  The only solution is for the package author to provide an explicit index of the package. The [import](https://docs.python.org/3/reference/simple_stmts.html#import)statement uses the following convention: if a package’s \_\_init\_\_.py code defines a list named\_\_all\_\_, it is taken to be the list of module names that should be imported when from packageimport \* is encountered. It is up to the package author to keep this list up-to-date when a new version of the package is released. Package authors may also decide not to support it, if they don’t see a use for importing \* from their package. For example, the file sound/effects/\_\_init\_\_.py could contain the following code:  \_\_all\_\_ = ["echo", "surround", "reverse"]  This would mean that from sound.effects import \* would import the three named submodules of the sound package.  If \_\_all\_\_ is not defined, the statement from sound.effects import \* does not import all submodules from the package sound.effects into the current namespace; it only ensures that the package sound.effects has been imported (possibly running any initialization code in \_\_init\_\_.py) and then imports whatever names are defined in the package. This includes any names defined (and submodules explicitly loaded) by \_\_init\_\_.py. It also includes any submodules of the package that were explicitly loaded by previous [import](https://docs.python.org/3/reference/simple_stmts.html#import) statements. Consider this code:  **import** **sound.effects.echo**  **import** **sound.effects.surround**  **from** **sound.effects** **import** \*  In this example, the echo and surround modules are imported in the current namespace because they are defined in the sound.effects package when the from...import statement is executed. (This also works when \_\_all\_\_ is defined.)  Although certain modules are designed to export only names that follow certain patterns when you useimport \*, it is still considered bad practise in production code.  Remember, there is nothing wrong with using from Package import specific\_submodule! In fact, this is the recommended notation unless the importing module needs to use submodules with the same name from different packages. 6.4.2. Intra-package References When packages are structured into subpackages (as with the sound package in the example), you can use absolute imports to refer to submodules of siblings packages. For example, if the modulesound.filters.vocoder needs to use the echo module in the sound.effects package, it can usefrom sound.effects import echo.  You can also write relative imports, with the from module import name form of import statement. These imports use leading dots to indicate the current and parent packages involved in the relative import. From the surround module for example, you might use:  **from** **.** **import** echo  **from** **..** **import** formats  **from** **..filters** **import** equalizer  Note that relative imports are based on the name of the current module. Since the name of the main module is always "\_\_main\_\_", modules intended for use as the main module of a Python application must always use absolute imports. 6.4.3. Packages in Multiple Directories Packages support one more special attribute, [\_\_path\_\_](https://docs.python.org/3/reference/import.html#__path__). This is initialized to be a list containing the name of the directory holding the package’s \_\_init\_\_.py before the code in that file is executed. This variable can be modified; doing so affects future searches for modules and subpackages contained in the package.  While this feature is not often needed, it can be used to extend the set of modules found in a package.  **Footnotes**   |  |  | | --- | --- | | [[1]](https://docs.python.org/3/tutorial/modules.html#id1) | In fact function definitions are also ‘statements’ that are ‘executed’; the execution of a module-level function definition enters the function name in the module’s global symbol table. |  6. Modules If you quit from the Python interpreter and enter it again, the definitions you have made (functions and variables) are lost. Therefore, if you want to write a somewhat longer program, you are better off using a text editor to prepare the input for the interpreter and running it with that file as input instead. This is known as creating a script. As your program gets longer, you may want to split it into several files for easier maintenance. You may also want to use a handy function that you’ve written in several programs without copying its definition into each program.  To support this, Python has a way to put definitions in a file and use them in a script or in an interactive instance of the interpreter. Such a file is called a module; definitions from a module can be importedinto other modules or into the main module (the collection of variables that you have access to in a script executed at the top level and in calculator mode).  A module is a file containing Python definitions and statements. The file name is the module name with the suffix .py appended. Within a module, the module’s name (as a string) is available as the value of the global variable \_\_name\_\_. For instance, use your favorite text editor to create a file calledfibo.py in the current directory with the following contents:  *# Fibonacci numbers module*  **def** fib(n): *# write Fibonacci series up to n*  a, b = 0, 1  **while** b < n:  print(b, end=' ')  a, b = b, a+b  print()  **def** fib2(n): *# return Fibonacci series up to n*  result = []  a, b = 0, 1  **while** b < n:  result.append(b)  a, b = b, a+b  **return** result  Now enter the Python interpreter and import this module with the following command:  >>>  **>>> import** **fibo**  This does not enter the names of the functions defined in fibo directly in the current symbol table; it only enters the module name fibo there. Using the module name you can access the functions:  >>>  **>>>** fibo.fib(1000)  1 1 2 3 5 8 13 21 34 55 89 144 233 377 610 987  **>>>** fibo.fib2(100)  [1, 1, 2, 3, 5, 8, 13, 21, 34, 55, 89]  **>>>** fibo.\_\_name\_\_  'fibo'  If you intend to use a function often you can assign it to a local name:  >>>  **>>>** fib = fibo.fib  **>>>** fib(500)  1 1 2 3 5 8 13 21 34 55 89 144 233 377 6.1. More on Modules A module can contain executable statements as well as function definitions. These statements are intended to initialize the module. They are executed only the first time the module name is encountered in an import statement. [[1]](https://docs.python.org/3/tutorial/modules.html#id2) (They are also run if the file is executed as a script.)  Each module has its own private symbol table, which is used as the global symbol table by all functions defined in the module. Thus, the author of a module can use global variables in the module without worrying about accidental clashes with a user’s global variables. On the other hand, if you know what you are doing you can touch a module’s global variables with the same notation used to refer to its functions, modname.itemname.  Modules can import other modules. It is customary but not required to place all [import](https://docs.python.org/3/reference/simple_stmts.html#import) statements at the beginning of a module (or script, for that matter). The imported module names are placed in the importing module’s global symbol table.  There is a variant of the [import](https://docs.python.org/3/reference/simple_stmts.html#import) statement that imports names from a module directly into the importing module’s symbol table. For example:  >>>  **>>> from** **fibo** **import** fib, fib2  **>>>** fib(500)  1 1 2 3 5 8 13 21 34 55 89 144 233 377  This does not introduce the module name from which the imports are taken in the local symbol table (so in the example, fibo is not defined).  There is even a variant to import all names that a module defines:  >>>  **>>> from** **fibo** **import** \*  **>>>** fib(500)  1 1 2 3 5 8 13 21 34 55 89 144 233 377  This imports all names except those beginning with an underscore (\_). In most cases Python programmers do not use this facility since it introduces an unknown set of names into the interpreter, possibly hiding some things you have already defined.  Note that in general the practice of importing \* from a module or package is frowned upon, since it often causes poorly readable code. However, it is okay to use it to save typing in interactive sessions.  **Note**    For efficiency reasons, each module is only imported once per interpreter session. Therefore, if you change your modules, you must restart the interpreter – or, if it’s just one module you want to test interactively, use [importlib.reload()](https://docs.python.org/3/library/importlib.html#importlib.reload), e.g. import importlib;importlib.reload(modulename). 6.1.1. Executing modules as scripts When you run a Python module with  python fibo.py <arguments>  the code in the module will be executed, just as if you imported it, but with the \_\_name\_\_ set to"\_\_main\_\_". That means that by adding this code at the end of your module:  **if** \_\_name\_\_ == "\_\_main\_\_":  **import** **sys**  fib(int(sys.argv[1]))  you can make the file usable as a script as well as an importable module, because the code that parses the command line only runs if the module is executed as the “main” file:  $ python fibo.py 50  1 1 2 3 5 8 13 21 34  If the module is imported, the code is not run:  >>>  **>>> import** **fibo**  >>>  This is often used either to provide a convenient user interface to a module, or for testing purposes (running the module as a script executes a test suite). 6.1.2. The Module Search Path When a module named spam is imported, the interpreter first searches for a built-in module with that name. If not found, it then searches for a file named spam.py in a list of directories given by the variable [sys.path](https://docs.python.org/3/library/sys.html#sys.path). [sys.path](https://docs.python.org/3/library/sys.html#sys.path) is initialized from these locations:   * The directory containing the input script (or the current directory when no file is specified). * [PYTHONPATH](https://docs.python.org/3/using/cmdline.html#envvar-PYTHONPATH) (a list of directory names, with the same syntax as the shell variable PATH). * The installation-dependent default.   **Note**    On file systems which support symlinks, the directory containing the input script is calculated after the symlink is followed. In other words the directory containing the symlink is **not** added to the module search path.  After initialization, Python programs can modify [sys.path](https://docs.python.org/3/library/sys.html#sys.path). The directory containing the script being run is placed at the beginning of the search path, ahead of the standard library path. This means that scripts in that directory will be loaded instead of modules of the same name in the library directory. This is an error unless the replacement is intended. See section [Standard Modules](https://docs.python.org/3/tutorial/modules.html#tut-standardmodules) for more information. 6.1.3. “Compiled” Python files To speed up loading modules, Python caches the compiled version of each module in the\_\_pycache\_\_ directory under the name module.*version*.pyc, where the version encodes the format of the compiled file; it generally contains the Python version number. For example, in CPython release 3.3 the compiled version of spam.py would be cached as \_\_pycache\_\_/spam.cpython-33.pyc. This naming convention allows compiled modules from different releases and different versions of Python to coexist.  Python checks the modification date of the source against the compiled version to see if it’s out of date and needs to be recompiled. This is a completely automatic process. Also, the compiled modules are platform-independent, so the same library can be shared among systems with different architectures.  Python does not check the cache in two circumstances. First, it always recompiles and does not store the result for the module that’s loaded directly from the command line. Second, it does not check the cache if there is no source module. To support a non-source (compiled only) distribution, the compiled module must be in the source directory, and there must not be a source module.  Some tips for experts:   * You can use the [-O](https://docs.python.org/3/using/cmdline.html#cmdoption-O) or [-OO](https://docs.python.org/3/using/cmdline.html#cmdoption-OO) switches on the Python command to reduce the size of a compiled module. The -O switch removes assert statements, the -OO switch removes both assert statements and \_\_doc\_\_ strings. Since some programs may rely on having these available, you should only use this option if you know what you’re doing. “Optimized” modules have an opt-tag and are usually smaller. Future releases may change the effects of optimization. * A program doesn’t run any faster when it is read from a .pyc file than when it is read from a .pyfile; the only thing that’s faster about .pyc files is the speed with which they are loaded. * The module [compileall](https://docs.python.org/3/library/compileall.html#module-compileall) can create .pyc files for all modules in a directory. * There is more detail on this process, including a flow chart of the decisions, in PEP 3147.  6.2. Standard Modules Python comes with a library of standard modules, described in a separate document, the Python Library Reference (“Library Reference” hereafter). Some modules are built into the interpreter; these provide access to operations that are not part of the core of the language but are nevertheless built in, either for efficiency or to provide access to operating system primitives such as system calls. The set of such modules is a configuration option which also depends on the underlying platform. For example, the [winreg](https://docs.python.org/3/library/winreg.html#module-winreg) module is only provided on Windows systems. One particular module deserves some attention: [sys](https://docs.python.org/3/library/sys.html#module-sys), which is built into every Python interpreter. The variables sys.ps1 and sys.ps2define the strings used as primary and secondary prompts:  >>>  **>>> import** **sys**  **>>>** sys.ps1  '>>> '  **>>>** sys.ps2  '... '  **>>>** sys.ps1 = 'C> '  C> print('Yuck!')  Yuck!  C>  These two variables are only defined if the interpreter is in interactive mode.  The variable sys.path is a list of strings that determines the interpreter’s search path for modules. It is initialized to a default path taken from the environment variable [PYTHONPATH](https://docs.python.org/3/using/cmdline.html#envvar-PYTHONPATH), or from a built-in default if[PYTHONPATH](https://docs.python.org/3/using/cmdline.html#envvar-PYTHONPATH) is not set. You can modify it using standard list operations:  >>>  **>>> import** **sys**  **>>>** sys.path.append('/ufs/guido/lib/python') 6.3. The [dir()](https://docs.python.org/3/library/functions.html#dir) Function The built-in function [dir()](https://docs.python.org/3/library/functions.html#dir) is used to find out which names a module defines. It returns a sorted list of strings:  >>>  **>>> import** **fibo**, **sys**  **>>>** dir(fibo)  ['\_\_name\_\_', 'fib', 'fib2']  **>>>** dir(sys)  ['\_\_displayhook\_\_', '\_\_doc\_\_', '\_\_excepthook\_\_', '\_\_loader\_\_', '\_\_name\_\_',  '\_\_package\_\_', '\_\_stderr\_\_', '\_\_stdin\_\_', '\_\_stdout\_\_',  '\_clear\_type\_cache', '\_current\_frames', '\_debugmallocstats', '\_getframe',  '\_home', '\_mercurial', '\_xoptions', 'abiflags', 'api\_version', 'argv',  'base\_exec\_prefix', 'base\_prefix', 'builtin\_module\_names', 'byteorder',  'call\_tracing', 'callstats', 'copyright', 'displayhook',  'dont\_write\_bytecode', 'exc\_info', 'excepthook', 'exec\_prefix',  'executable', 'exit', 'flags', 'float\_info', 'float\_repr\_style',  'getcheckinterval', 'getdefaultencoding', 'getdlopenflags',  'getfilesystemencoding', 'getobjects', 'getprofile', 'getrecursionlimit',  'getrefcount', 'getsizeof', 'getswitchinterval', 'gettotalrefcount',  'gettrace', 'hash\_info', 'hexversion', 'implementation', 'int\_info',  'intern', 'maxsize', 'maxunicode', 'meta\_path', 'modules', 'path',  'path\_hooks', 'path\_importer\_cache', 'platform', 'prefix', 'ps1',  'setcheckinterval', 'setdlopenflags', 'setprofile', 'setrecursionlimit',  'setswitchinterval', 'settrace', 'stderr', 'stdin', 'stdout',  'thread\_info', 'version', 'version\_info', 'warnoptions']  Without arguments, [dir()](https://docs.python.org/3/library/functions.html#dir) lists the names you have defined currently:  >>>  **>>>** a = [1, 2, 3, 4, 5]  **>>> import** **fibo**  **>>>** fib = fibo.fib  **>>>** dir()  ['\_\_builtins\_\_', '\_\_name\_\_', 'a', 'fib', 'fibo', 'sys']  Note that it lists all types of names: variables, modules, functions, etc.  [dir()](https://docs.python.org/3/library/functions.html#dir) does not list the names of built-in functions and variables. If you want a list of those, they are defined in the standard module [builtins](https://docs.python.org/3/library/builtins.html#module-builtins):  >>>  **>>> import** **builtins**  **>>>** dir(builtins)  ['ArithmeticError', 'AssertionError', 'AttributeError', 'BaseException',  'BlockingIOError', 'BrokenPipeError', 'BufferError', 'BytesWarning',  'ChildProcessError', 'ConnectionAbortedError', 'ConnectionError',  'ConnectionRefusedError', 'ConnectionResetError', 'DeprecationWarning',  'EOFError', 'Ellipsis', 'EnvironmentError', 'Exception', 'False',  'FileExistsError', 'FileNotFoundError', 'FloatingPointError',  'FutureWarning', 'GeneratorExit', 'IOError', 'ImportError',  'ImportWarning', 'IndentationError', 'IndexError', 'InterruptedError',  'IsADirectoryError', 'KeyError', 'KeyboardInterrupt', 'LookupError',  'MemoryError', 'NameError', 'None', 'NotADirectoryError', 'NotImplemented',  'NotImplementedError', 'OSError', 'OverflowError',  'PendingDeprecationWarning', 'PermissionError', 'ProcessLookupError',  'ReferenceError', 'ResourceWarning', 'RuntimeError', 'RuntimeWarning',  'StopIteration', 'SyntaxError', 'SyntaxWarning', 'SystemError',  'SystemExit', 'TabError', 'TimeoutError', 'True', 'TypeError',  'UnboundLocalError', 'UnicodeDecodeError', 'UnicodeEncodeError',  'UnicodeError', 'UnicodeTranslateError', 'UnicodeWarning', 'UserWarning',  'ValueError', 'Warning', 'ZeroDivisionError', '\_', '\_\_build\_class\_\_',  '\_\_debug\_\_', '\_\_doc\_\_', '\_\_import\_\_', '\_\_name\_\_', '\_\_package\_\_', 'abs',  'all', 'any', 'ascii', 'bin', 'bool', 'bytearray', 'bytes', 'callable',  'chr', 'classmethod', 'compile', 'complex', 'copyright', 'credits',  'delattr', 'dict', 'dir', 'divmod', 'enumerate', 'eval', 'exec', 'exit',  'filter', 'float', 'format', 'frozenset', 'getattr', 'globals', 'hasattr',  'hash', 'help', 'hex', 'id', 'input', 'int', 'isinstance', 'issubclass',  'iter', 'len', 'license', 'list', 'locals', 'map', 'max', 'memoryview',  'min', 'next', 'object', 'oct', 'open', 'ord', 'pow', 'print', 'property',  'quit', 'range', 'repr', 'reversed', 'round', 'set', 'setattr', 'slice',  'sorted', 'staticmethod', 'str', 'sum', 'super', 'tuple', 'type', 'vars',  'zip'] 6.4. Packages Packages are a way of structuring Python’s module namespace by using “dotted module names”. For example, the module name A.B designates a submodule named B in a package named A. Just like the use of modules saves the authors of different modules from having to worry about each other’s global variable names, the use of dotted module names saves the authors of multi-module packages like NumPy or the Python Imaging Library from having to worry about each other’s module names.  Suppose you want to design a collection of modules (a “package”) for the uniform handling of sound files and sound data. There are many different sound file formats (usually recognized by their extension, for example: .wav, .aiff, .au), so you may need to create and maintain a growing collection of modules for the conversion between the various file formats. 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It must be referenced with its full name.  sound.effects.echo.echofilter(input, output, delay=0.7, atten=4)  An alternative way of importing the submodule is:  **from** **sound.effects** **import** echo  This also loads the submodule echo, and makes it available without its package prefix, so it can be used as follows:  echo.echofilter(input, output, delay=0.7, atten=4)  Yet another variation is to import the desired function or variable directly:  **from** **sound.effects.echo** **import** echofilter  Again, this loads the submodule echo, but this makes its function echofilter() directly available:  echofilter(input, output, delay=0.7, atten=4)  Note that when using from package import item, the item can be either a submodule (or subpackage) of the package, or some other name defined in the package, like a function, class or variable. The import statement first tests whether the item is defined in the package; if not, it assumes it is a module and attempts to load it. If it fails to find it, an [ImportError](https://docs.python.org/3/library/exceptions.html#ImportError) exception is raised.  Contrarily, when using syntax like import item.subitem.subsubitem, each item except for the last must be a package; the last item can be a module or a package but can’t be a class or function or variable defined in the previous item. 6.4.1. Importing \* From a Package Now what happens when the user writes from sound.effects import \*? Ideally, one would hope that this somehow goes out to the filesystem, finds which submodules are present in the package, and imports them all. This could take a long time and importing sub-modules might have unwanted side-effects that should only happen when the sub-module is explicitly imported.  The only solution is for the package author to provide an explicit index of the package. The [import](https://docs.python.org/3/reference/simple_stmts.html#import)statement uses the following convention: if a package’s \_\_init\_\_.py code defines a list named\_\_all\_\_, it is taken to be the list of module names that should be imported when from packageimport \* is encountered. It is up to the package author to keep this list up-to-date when a new version of the package is released. Package authors may also decide not to support it, if they don’t see a use for importing \* from their package. For example, the file sound/effects/\_\_init\_\_.py could contain the following code:  \_\_all\_\_ = ["echo", "surround", "reverse"]  This would mean that from sound.effects import \* would import the three named submodules of the sound package.  If \_\_all\_\_ is not defined, the statement from sound.effects import \* does not import all submodules from the package sound.effects into the current namespace; it only ensures that the package sound.effects has been imported (possibly running any initialization code in \_\_init\_\_.py) and then imports whatever names are defined in the package. This includes any names defined (and submodules explicitly loaded) by \_\_init\_\_.py. It also includes any submodules of the package that were explicitly loaded by previous [import](https://docs.python.org/3/reference/simple_stmts.html#import) statements. Consider this code:  **import** **sound.effects.echo**  **import** **sound.effects.surround**  **from** **sound.effects** **import** \*  In this example, the echo and surround modules are imported in the current namespace because they are defined in the sound.effects package when the from...import statement is executed. (This also works when \_\_all\_\_ is defined.)  Although certain modules are designed to export only names that follow certain patterns when you useimport \*, it is still considered bad practise in production code.  Remember, there is nothing wrong with using from Package import specific\_submodule! In fact, this is the recommended notation unless the importing module needs to use submodules with the same name from different packages. 6.4.2. Intra-package References When packages are structured into subpackages (as with the sound package in the example), you can use absolute imports to refer to submodules of siblings packages. For example, if the modulesound.filters.vocoder needs to use the echo module in the sound.effects package, it can usefrom sound.effects import echo.  You can also write relative imports, with the from module import name form of import statement. These imports use leading dots to indicate the current and parent packages involved in the relative import. From the surround module for example, you might use:  **from** **.** **import** echo  **from** **..** **import** formats  **from** **..filters** **import** equalizer  Note that relative imports are based on the name of the current module. Since the name of the main module is always "\_\_main\_\_", modules intended for use as the main module of a Python application must always use absolute imports. 6.4.3. Packages in Multiple Directories Packages support one more special attribute, [\_\_path\_\_](https://docs.python.org/3/reference/import.html#__path__). This is initialized to be a list containing the name of the directory holding the package’s \_\_init\_\_.py before the code in that file is executed. This variable can be modified; doing so affects future searches for modules and subpackages contained in the package.  While this feature is not often needed, it can be used to extend the set of modules found in a package.  **Footnotes**   |  |  | | --- | --- | | [[1]](https://docs.python.org/3/tutorial/modules.html#id1) | In fact function definitions are also ‘statements’ that are ‘executed’; the execution of a module-level function definition enters the function name in the module’s global symbol table. | |

# 6. Modules

If you quit from the Python interpreter and enter it again, the definitions you have made (functions and variables) are lost. Therefore, if you want to write a somewhat longer program, you are better off using a text editor to prepare the input for the interpreter and running it with that file as input instead. This is known as creating a script. As your program gets longer, you may want to split it into several files for easier maintenance. You may also want to use a handy function that you’ve written in several programs without copying its definition into each program.

To support this, Python has a way to put definitions in a file and use them in a script or in an interactive instance of the interpreter. Such a file is called a module; definitions from a module can be importedinto other modules or into the main module (the collection of variables that you have access to in a script executed at the top level and in calculator mode).

A module is a file containing Python definitions and statements. The file name is the module name with the suffix .py appended. Within a module, the module’s name (as a string) is available as the value of the global variable \_\_name\_\_. For instance, use your favorite text editor to create a file calledfibo.py in the current directory with the following contents:

*# Fibonacci numbers module*

**def** fib(n): *# write Fibonacci series up to n*

a, b = 0, 1

**while** b < n:

print(b, end=' ')

a, b = b, a+b

print()

**def** fib2(n): *# return Fibonacci series up to n*

result = []

a, b = 0, 1

**while** b < n:

result.append(b)

a, b = b, a+b

**return** result

Now enter the Python interpreter and import this module with the following command:

>>>

**>>> import** **fibo**

This does not enter the names of the functions defined in fibo directly in the current symbol table; it only enters the module name fibo there. Using the module name you can access the functions:

>>>

**>>>** fibo.fib(1000)

1 1 2 3 5 8 13 21 34 55 89 144 233 377 610 987

**>>>** fibo.fib2(100)

[1, 1, 2, 3, 5, 8, 13, 21, 34, 55, 89]

**>>>** fibo.\_\_name\_\_

'fibo'

If you intend to use a function often you can assign it to a local name:

>>>

**>>>** fib = fibo.fib

**>>>** fib(500)

1 1 2 3 5 8 13 21 34 55 89 144 233 377

## 6.1. More on Modules

A module can contain executable statements as well as function definitions. These statements are intended to initialize the module. They are executed only the first time the module name is encountered in an import statement. [[1]](https://docs.python.org/3/tutorial/modules.html#id2) (They are also run if the file is executed as a script.)

Each module has its own private symbol table, which is used as the global symbol table by all functions defined in the module. Thus, the author of a module can use global variables in the module without worrying about accidental clashes with a user’s global variables. On the other hand, if you know what you are doing you can touch a module’s global variables with the same notation used to refer to its functions, modname.itemname.

Modules can import other modules. It is customary but not required to place all [import](https://docs.python.org/3/reference/simple_stmts.html#import) statements at the beginning of a module (or script, for that matter). The imported module names are placed in the importing module’s global symbol table.

There is a variant of the [import](https://docs.python.org/3/reference/simple_stmts.html#import) statement that imports names from a module directly into the importing module’s symbol table. For example:

>>>

**>>> from** **fibo** **import** fib, fib2

**>>>** fib(500)

1 1 2 3 5 8 13 21 34 55 89 144 233 377

This does not introduce the module name from which the imports are taken in the local symbol table (so in the example, fibo is not defined).

There is even a variant to import all names that a module defines:

>>>

**>>> from** **fibo** **import** \*

**>>>** fib(500)

1 1 2 3 5 8 13 21 34 55 89 144 233 377

This imports all names except those beginning with an underscore (\_). In most cases Python programmers do not use this facility since it introduces an unknown set of names into the interpreter, possibly hiding some things you have already defined.

Note that in general the practice of importing \* from a module or package is frowned upon, since it often causes poorly readable code. However, it is okay to use it to save typing in interactive sessions.

**Note**

For efficiency reasons, each module is only imported once per interpreter session. Therefore, if you change your modules, you must restart the interpreter – or, if it’s just one module you want to test interactively, use [importlib.reload()](https://docs.python.org/3/library/importlib.html#importlib.reload), e.g. import importlib;importlib.reload(modulename).

### 6.1.1. Executing modules as scripts

When you run a Python module with

python fibo.py <arguments>

the code in the module will be executed, just as if you imported it, but with the \_\_name\_\_ set to"\_\_main\_\_". That means that by adding this code at the end of your module:

**if** \_\_name\_\_ == "\_\_main\_\_":

**import** **sys**

fib(int(sys.argv[1]))

you can make the file usable as a script as well as an importable module, because the code that parses the command line only runs if the module is executed as the “main” file:

$ python fibo.py 50

1 1 2 3 5 8 13 21 34

If the module is imported, the code is not run:

>>>

**>>> import** **fibo**

>>>

This is often used either to provide a convenient user interface to a module, or for testing purposes (running the module as a script executes a test suite).

### 6.1.2. The Module Search Path

When a module named spam is imported, the interpreter first searches for a built-in module with that name. If not found, it then searches for a file named spam.py in a list of directories given by the variable [sys.path](https://docs.python.org/3/library/sys.html#sys.path). [sys.path](https://docs.python.org/3/library/sys.html#sys.path) is initialized from these locations:

* The directory containing the input script (or the current directory when no file is specified).
* [PYTHONPATH](https://docs.python.org/3/using/cmdline.html#envvar-PYTHONPATH) (a list of directory names, with the same syntax as the shell variable PATH).
* The installation-dependent default.

**Note**

On file systems which support symlinks, the directory containing the input script is calculated after the symlink is followed. In other words the directory containing the symlink is **not** added to the module search path.

After initialization, Python programs can modify [sys.path](https://docs.python.org/3/library/sys.html#sys.path). The directory containing the script being run is placed at the beginning of the search path, ahead of the standard library path. This means that scripts in that directory will be loaded instead of modules of the same name in the library directory. This is an error unless the replacement is intended. See section [Standard Modules](https://docs.python.org/3/tutorial/modules.html#tut-standardmodules) for more information.

### 6.1.3. “Compiled” Python files

To speed up loading modules, Python caches the compiled version of each module in the\_\_pycache\_\_ directory under the name module.*version*.pyc, where the version encodes the format of the compiled file; it generally contains the Python version number. For example, in CPython release 3.3 the compiled version of spam.py would be cached as \_\_pycache\_\_/spam.cpython-33.pyc. This naming convention allows compiled modules from different releases and different versions of Python to coexist.

Python checks the modification date of the source against the compiled version to see if it’s out of date and needs to be recompiled. This is a completely automatic process. Also, the compiled modules are platform-independent, so the same library can be shared among systems with different architectures.

Python does not check the cache in two circumstances. First, it always recompiles and does not store the result for the module that’s loaded directly from the command line. Second, it does not check the cache if there is no source module. To support a non-source (compiled only) distribution, the compiled module must be in the source directory, and there must not be a source module.

Some tips for experts:

* You can use the [-O](https://docs.python.org/3/using/cmdline.html#cmdoption-O) or [-OO](https://docs.python.org/3/using/cmdline.html#cmdoption-OO) switches on the Python command to reduce the size of a compiled module. The -O switch removes assert statements, the -OO switch removes both assert statements and \_\_doc\_\_ strings. Since some programs may rely on having these available, you should only use this option if you know what you’re doing. “Optimized” modules have an opt-tag and are usually smaller. Future releases may change the effects of optimization.
* A program doesn’t run any faster when it is read from a .pyc file than when it is read from a .pyfile; the only thing that’s faster about .pyc files is the speed with which they are loaded.
* The module [compileall](https://docs.python.org/3/library/compileall.html#module-compileall) can create .pyc files for all modules in a directory.
* There is more detail on this process, including a flow chart of the decisions, in PEP 3147.

## 6.2. Standard Modules

Python comes with a library of standard modules, described in a separate document, the Python Library Reference (“Library Reference” hereafter). Some modules are built into the interpreter; these provide access to operations that are not part of the core of the language but are nevertheless built in, either for efficiency or to provide access to operating system primitives such as system calls. The set of such modules is a configuration option which also depends on the underlying platform. For example, the [winreg](https://docs.python.org/3/library/winreg.html#module-winreg) module is only provided on Windows systems. One particular module deserves some attention: [sys](https://docs.python.org/3/library/sys.html#module-sys), which is built into every Python interpreter. The variables sys.ps1 and sys.ps2define the strings used as primary and secondary prompts:

>>>

**>>> import** **sys**

**>>>** sys.ps1

'>>> '

**>>>** sys.ps2

'... '

**>>>** sys.ps1 = 'C> '

C> print('Yuck!')

Yuck!

C>

These two variables are only defined if the interpreter is in interactive mode.

The variable sys.path is a list of strings that determines the interpreter’s search path for modules. It is initialized to a default path taken from the environment variable [PYTHONPATH](https://docs.python.org/3/using/cmdline.html#envvar-PYTHONPATH), or from a built-in default if[PYTHONPATH](https://docs.python.org/3/using/cmdline.html#envvar-PYTHONPATH) is not set. You can modify it using standard list operations:

>>>

**>>> import** **sys**

**>>>** sys.path.append('/ufs/guido/lib/python')

## 6.3. The [dir()](https://docs.python.org/3/library/functions.html#dir) Function

The built-in function [dir()](https://docs.python.org/3/library/functions.html#dir) is used to find out which names a module defines. It returns a sorted list of strings:

>>>

**>>> import** **fibo**, **sys**

**>>>** dir(fibo)

['\_\_name\_\_', 'fib', 'fib2']

**>>>** dir(sys)

['\_\_displayhook\_\_', '\_\_doc\_\_', '\_\_excepthook\_\_', '\_\_loader\_\_', '\_\_name\_\_',

'\_\_package\_\_', '\_\_stderr\_\_', '\_\_stdin\_\_', '\_\_stdout\_\_',

'\_clear\_type\_cache', '\_current\_frames', '\_debugmallocstats', '\_getframe',

'\_home', '\_mercurial', '\_xoptions', 'abiflags', 'api\_version', 'argv',

'base\_exec\_prefix', 'base\_prefix', 'builtin\_module\_names', 'byteorder',

'call\_tracing', 'callstats', 'copyright', 'displayhook',

'dont\_write\_bytecode', 'exc\_info', 'excepthook', 'exec\_prefix',

'executable', 'exit', 'flags', 'float\_info', 'float\_repr\_style',

'getcheckinterval', 'getdefaultencoding', 'getdlopenflags',

'getfilesystemencoding', 'getobjects', 'getprofile', 'getrecursionlimit',

'getrefcount', 'getsizeof', 'getswitchinterval', 'gettotalrefcount',

'gettrace', 'hash\_info', 'hexversion', 'implementation', 'int\_info',

'intern', 'maxsize', 'maxunicode', 'meta\_path', 'modules', 'path',

'path\_hooks', 'path\_importer\_cache', 'platform', 'prefix', 'ps1',

'setcheckinterval', 'setdlopenflags', 'setprofile', 'setrecursionlimit',

'setswitchinterval', 'settrace', 'stderr', 'stdin', 'stdout',

'thread\_info', 'version', 'version\_info', 'warnoptions']

Without arguments, [dir()](https://docs.python.org/3/library/functions.html#dir) lists the names you have defined currently:

>>>

**>>>** a = [1, 2, 3, 4, 5]

**>>> import** **fibo**

**>>>** fib = fibo.fib

**>>>** dir()

['\_\_builtins\_\_', '\_\_name\_\_', 'a', 'fib', 'fibo', 'sys']

Note that it lists all types of names: variables, modules, functions, etc.

[dir()](https://docs.python.org/3/library/functions.html#dir) does not list the names of built-in functions and variables. If you want a list of those, they are defined in the standard module [builtins](https://docs.python.org/3/library/builtins.html#module-builtins):

>>>

**>>> import** **builtins**

**>>>** dir(builtins)

['ArithmeticError', 'AssertionError', 'AttributeError', 'BaseException',

'BlockingIOError', 'BrokenPipeError', 'BufferError', 'BytesWarning',

'ChildProcessError', 'ConnectionAbortedError', 'ConnectionError',

'ConnectionRefusedError', 'ConnectionResetError', 'DeprecationWarning',

'EOFError', 'Ellipsis', 'EnvironmentError', 'Exception', 'False',

'FileExistsError', 'FileNotFoundError', 'FloatingPointError',

'FutureWarning', 'GeneratorExit', 'IOError', 'ImportError',

'ImportWarning', 'IndentationError', 'IndexError', 'InterruptedError',

'IsADirectoryError', 'KeyError', 'KeyboardInterrupt', 'LookupError',

'MemoryError', 'NameError', 'None', 'NotADirectoryError', 'NotImplemented',

'NotImplementedError', 'OSError', 'OverflowError',

'PendingDeprecationWarning', 'PermissionError', 'ProcessLookupError',

'ReferenceError', 'ResourceWarning', 'RuntimeError', 'RuntimeWarning',

'StopIteration', 'SyntaxError', 'SyntaxWarning', 'SystemError',

'SystemExit', 'TabError', 'TimeoutError', 'True', 'TypeError',

'UnboundLocalError', 'UnicodeDecodeError', 'UnicodeEncodeError',

'UnicodeError', 'UnicodeTranslateError', 'UnicodeWarning', 'UserWarning',

'ValueError', 'Warning', 'ZeroDivisionError', '\_', '\_\_build\_class\_\_',

'\_\_debug\_\_', '\_\_doc\_\_', '\_\_import\_\_', '\_\_name\_\_', '\_\_package\_\_', 'abs',

'all', 'any', 'ascii', 'bin', 'bool', 'bytearray', 'bytes', 'callable',

'chr', 'classmethod', 'compile', 'complex', 'copyright', 'credits',

'delattr', 'dict', 'dir', 'divmod', 'enumerate', 'eval', 'exec', 'exit',

'filter', 'float', 'format', 'frozenset', 'getattr', 'globals', 'hasattr',

'hash', 'help', 'hex', 'id', 'input', 'int', 'isinstance', 'issubclass',

'iter', 'len', 'license', 'list', 'locals', 'map', 'max', 'memoryview',

'min', 'next', 'object', 'oct', 'open', 'ord', 'pow', 'print', 'property',

'quit', 'range', 'repr', 'reversed', 'round', 'set', 'setattr', 'slice',

'sorted', 'staticmethod', 'str', 'sum', 'super', 'tuple', 'type', 'vars',

'zip']

## 6.4. Packages

Packages are a way of structuring Python’s module namespace by using “dotted module names”. For example, the module name A.B designates a submodule named B in a package named A. Just like the use of modules saves the authors of different modules from having to worry about each other’s global variable names, the use of dotted module names saves the authors of multi-module packages like NumPy or the Python Imaging Library from having to worry about each other’s module names.

Suppose you want to design a collection of modules (a “package”) for the uniform handling of sound files and sound data. There are many different sound file formats (usually recognized by their extension, for example: .wav, .aiff, .au), so you may need to create and maintain a growing collection of modules for the conversion between the various file formats. There are also many different operations you might want to perform on sound data (such as mixing, adding echo, applying an equalizer function, creating an artificial stereo effect), so in addition you will be writing a never-ending stream of modules to perform these operations. Here’s a possible structure for your package (expressed in terms of a hierarchical filesystem):

sound/ Top-level package

\_\_init\_\_.py Initialize the sound package

formats/ Subpackage for file format conversions

\_\_init\_\_.py

wavread.py

wavwrite.py

aiffread.py

aiffwrite.py

auread.py

auwrite.py

...

effects/ Subpackage for sound effects

\_\_init\_\_.py

echo.py

surround.py

reverse.py

...

filters/ Subpackage for filters

\_\_init\_\_.py

equalizer.py

vocoder.py

karaoke.py

...

When importing the package, Python searches through the directories on sys.path looking for the package subdirectory.

The \_\_init\_\_.py files are required to make Python treat the directories as containing packages; this is done to prevent directories with a common name, such as string, from unintentionally hiding valid modules that occur later on the module search path. In the simplest case, \_\_init\_\_.py can just be an empty file, but it can also execute initialization code for the package or set the \_\_all\_\_ variable, described later.

Users of the package can import individual modules from the package, for example:

**import** **sound.effects.echo**

This loads the submodule sound.effects.echo. It must be referenced with its full name.

sound.effects.echo.echofilter(input, output, delay=0.7, atten=4)

An alternative way of importing the submodule is:

**from** **sound.effects** **import** echo

This also loads the submodule echo, and makes it available without its package prefix, so it can be used as follows:

echo.echofilter(input, output, delay=0.7, atten=4)

Yet another variation is to import the desired function or variable directly:

**from** **sound.effects.echo** **import** echofilter

Again, this loads the submodule echo, but this makes its function echofilter() directly available:

echofilter(input, output, delay=0.7, atten=4)

Note that when using from package import item, the item can be either a submodule (or subpackage) of the package, or some other name defined in the package, like a function, class or variable. The import statement first tests whether the item is defined in the package; if not, it assumes it is a module and attempts to load it. If it fails to find it, an [ImportError](https://docs.python.org/3/library/exceptions.html#ImportError) exception is raised.

Contrarily, when using syntax like import item.subitem.subsubitem, each item except for the last must be a package; the last item can be a module or a package but can’t be a class or function or variable defined in the previous item.

### 6.4.1. Importing \* From a Package

Now what happens when the user writes from sound.effects import \*? Ideally, one would hope that this somehow goes out to the filesystem, finds which submodules are present in the package, and imports them all. This could take a long time and importing sub-modules might have unwanted side-effects that should only happen when the sub-module is explicitly imported.

The only solution is for the package author to provide an explicit index of the package. The [import](https://docs.python.org/3/reference/simple_stmts.html#import)statement uses the following convention: if a package’s \_\_init\_\_.py code defines a list named\_\_all\_\_, it is taken to be the list of module names that should be imported when from packageimport \* is encountered. It is up to the package author to keep this list up-to-date when a new version of the package is released. Package authors may also decide not to support it, if they don’t see a use for importing \* from their package. For example, the file sound/effects/\_\_init\_\_.py could contain the following code:

\_\_all\_\_ = ["echo", "surround", "reverse"]

This would mean that from sound.effects import \* would import the three named submodules of the sound package.

If \_\_all\_\_ is not defined, the statement from sound.effects import \* does not import all submodules from the package sound.effects into the current namespace; it only ensures that the package sound.effects has been imported (possibly running any initialization code in \_\_init\_\_.py) and then imports whatever names are defined in the package. This includes any names defined (and submodules explicitly loaded) by \_\_init\_\_.py. It also includes any submodules of the package that were explicitly loaded by previous [import](https://docs.python.org/3/reference/simple_stmts.html#import) statements. Consider this code:

**import** **sound.effects.echo**

**import** **sound.effects.surround**

**from** **sound.effects** **import** \*

In this example, the echo and surround modules are imported in the current namespace because they are defined in the sound.effects package when the from...import statement is executed. (This also works when \_\_all\_\_ is defined.)

Although certain modules are designed to export only names that follow certain patterns when you useimport \*, it is still considered bad practise in production code.

Remember, there is nothing wrong with using from Package import specific\_submodule! In fact, this is the recommended notation unless the importing module needs to use submodules with the same name from different packages.

### 6.4.2. Intra-package References

When packages are structured into subpackages (as with the sound package in the example), you can use absolute imports to refer to submodules of siblings packages. For example, if the modulesound.filters.vocoder needs to use the echo module in the sound.effects package, it can usefrom sound.effects import echo.

You can also write relative imports, with the from module import name form of import statement. These imports use leading dots to indicate the current and parent packages involved in the relative import. From the surround module for example, you might use:

**from** **.** **import** echo

**from** **..** **import** formats

**from** **..filters** **import** equalizer

Note that relative imports are based on the name of the current module. Since the name of the main module is always "\_\_main\_\_", modules intended for use as the main module of a Python application must always use absolute imports.

### 6.4.3. Packages in Multiple Directories

Packages support one more special attribute, [\_\_path\_\_](https://docs.python.org/3/reference/import.html#__path__). This is initialized to be a list containing the name of the directory holding the package’s \_\_init\_\_.py before the code in that file is executed. This variable can be modified; doing so affects future searches for modules and subpackages contained in the package.

While this feature is not often needed, it can be used to extend the set of modules found in a package.

**Footnotes**

|  |  |
| --- | --- |
| [[1]](https://docs.python.org/3/tutorial/modules.html#id1) | In fact function definitions are also ‘statements’ that are ‘executed’; the execution of a module-level function definition enters the function name in the module’s global symbol table. |

# 6. Modules

If you quit from the Python interpreter and enter it again, the definitions you have made (functions and variables) are lost. Therefore, if you want to write a somewhat longer program, you are better off using a text editor to prepare the input for the interpreter and running it with that file as input instead. This is known as creating a script. As your program gets longer, you may want to split it into several files for easier maintenance. You may also want to use a handy function that you’ve written in several programs without copying its definition into each program.

To support this, Python has a way to put definitions in a file and use them in a script or in an interactive instance of the interpreter. Such a file is called a module; definitions from a module can be importedinto other modules or into the main module (the collection of variables that you have access to in a script executed at the top level and in calculator mode).

A module is a file containing Python definitions and statements. The file name is the module name with the suffix .py appended. Within a module, the module’s name (as a string) is available as the value of the global variable \_\_name\_\_. For instance, use your favorite text editor to create a file calledfibo.py in the current directory with the following contents:

*# Fibonacci numbers module*

**def** fib(n): *# write Fibonacci series up to n*

a, b = 0, 1

**while** b < n:

print(b, end=' ')

a, b = b, a+b

print()

**def** fib2(n): *# return Fibonacci series up to n*

result = []

a, b = 0, 1

**while** b < n:

result.append(b)

a, b = b, a+b

**return** result

Now enter the Python interpreter and import this module with the following command:

>>>

**>>> import** **fibo**

This does not enter the names of the functions defined in fibo directly in the current symbol table; it only enters the module name fibo there. Using the module name you can access the functions:

>>>

**>>>** fibo.fib(1000)

1 1 2 3 5 8 13 21 34 55 89 144 233 377 610 987

**>>>** fibo.fib2(100)

[1, 1, 2, 3, 5, 8, 13, 21, 34, 55, 89]

**>>>** fibo.\_\_name\_\_

'fibo'

If you intend to use a function often you can assign it to a local name:

>>>

**>>>** fib = fibo.fib

**>>>** fib(500)

1 1 2 3 5 8 13 21 34 55 89 144 233 377

## 6.1. More on Modules

A module can contain executable statements as well as function definitions. These statements are intended to initialize the module. They are executed only the first time the module name is encountered in an import statement. [[1]](https://docs.python.org/3/tutorial/modules.html#id2) (They are also run if the file is executed as a script.)

Each module has its own private symbol table, which is used as the global symbol table by all functions defined in the module. Thus, the author of a module can use global variables in the module without worrying about accidental clashes with a user’s global variables. On the other hand, if you know what you are doing you can touch a module’s global variables with the same notation used to refer to its functions, modname.itemname.

Modules can import other modules. It is customary but not required to place all [import](https://docs.python.org/3/reference/simple_stmts.html#import) statements at the beginning of a module (or script, for that matter). The imported module names are placed in the importing module’s global symbol table.

There is a variant of the [import](https://docs.python.org/3/reference/simple_stmts.html#import) statement that imports names from a module directly into the importing module’s symbol table. For example:

>>>

**>>> from** **fibo** **import** fib, fib2

**>>>** fib(500)

1 1 2 3 5 8 13 21 34 55 89 144 233 377

This does not introduce the module name from which the imports are taken in the local symbol table (so in the example, fibo is not defined).

There is even a variant to import all names that a module defines:

>>>

**>>> from** **fibo** **import** \*

**>>>** fib(500)

1 1 2 3 5 8 13 21 34 55 89 144 233 377

This imports all names except those beginning with an underscore (\_). In most cases Python programmers do not use this facility since it introduces an unknown set of names into the interpreter, possibly hiding some things you have already defined.

Note that in general the practice of importing \* from a module or package is frowned upon, since it often causes poorly readable code. However, it is okay to use it to save typing in interactive sessions.

**Note**

For efficiency reasons, each module is only imported once per interpreter session. Therefore, if you change your modules, you must restart the interpreter – or, if it’s just one module you want to test interactively, use [importlib.reload()](https://docs.python.org/3/library/importlib.html#importlib.reload), e.g. import importlib;importlib.reload(modulename).

### 6.1.1. Executing modules as scripts

When you run a Python module with

python fibo.py <arguments>

the code in the module will be executed, just as if you imported it, but with the \_\_name\_\_ set to"\_\_main\_\_". That means that by adding this code at the end of your module:

**if** \_\_name\_\_ == "\_\_main\_\_":

**import** **sys**

fib(int(sys.argv[1]))

you can make the file usable as a script as well as an importable module, because the code that parses the command line only runs if the module is executed as the “main” file:

$ python fibo.py 50

1 1 2 3 5 8 13 21 34

If the module is imported, the code is not run:

>>>

**>>> import** **fibo**

>>>

This is often used either to provide a convenient user interface to a module, or for testing purposes (running the module as a script executes a test suite).

### 6.1.2. The Module Search Path

When a module named spam is imported, the interpreter first searches for a built-in module with that name. If not found, it then searches for a file named spam.py in a list of directories given by the variable [sys.path](https://docs.python.org/3/library/sys.html#sys.path). [sys.path](https://docs.python.org/3/library/sys.html#sys.path) is initialized from these locations:

* The directory containing the input script (or the current directory when no file is specified).
* [PYTHONPATH](https://docs.python.org/3/using/cmdline.html#envvar-PYTHONPATH) (a list of directory names, with the same syntax as the shell variable PATH).
* The installation-dependent default.

**Note**

On file systems which support symlinks, the directory containing the input script is calculated after the symlink is followed. In other words the directory containing the symlink is **not** added to the module search path.

After initialization, Python programs can modify [sys.path](https://docs.python.org/3/library/sys.html#sys.path). The directory containing the script being run is placed at the beginning of the search path, ahead of the standard library path. This means that scripts in that directory will be loaded instead of modules of the same name in the library directory. This is an error unless the replacement is intended. See section [Standard Modules](https://docs.python.org/3/tutorial/modules.html#tut-standardmodules) for more information.

### 6.1.3. “Compiled” Python files

To speed up loading modules, Python caches the compiled version of each module in the\_\_pycache\_\_ directory under the name module.*version*.pyc, where the version encodes the format of the compiled file; it generally contains the Python version number. For example, in CPython release 3.3 the compiled version of spam.py would be cached as \_\_pycache\_\_/spam.cpython-33.pyc. This naming convention allows compiled modules from different releases and different versions of Python to coexist.

Python checks the modification date of the source against the compiled version to see if it’s out of date and needs to be recompiled. This is a completely automatic process. Also, the compiled modules are platform-independent, so the same library can be shared among systems with different architectures.

Python does not check the cache in two circumstances. First, it always recompiles and does not store the result for the module that’s loaded directly from the command line. Second, it does not check the cache if there is no source module. To support a non-source (compiled only) distribution, the compiled module must be in the source directory, and there must not be a source module.

Some tips for experts:

* You can use the [-O](https://docs.python.org/3/using/cmdline.html#cmdoption-O) or [-OO](https://docs.python.org/3/using/cmdline.html#cmdoption-OO) switches on the Python command to reduce the size of a compiled module. The -O switch removes assert statements, the -OO switch removes both assert statements and \_\_doc\_\_ strings. Since some programs may rely on having these available, you should only use this option if you know what you’re doing. “Optimized” modules have an opt-tag and are usually smaller. Future releases may change the effects of optimization.
* A program doesn’t run any faster when it is read from a .pyc file than when it is read from a .pyfile; the only thing that’s faster about .pyc files is the speed with which they are loaded.
* The module [compileall](https://docs.python.org/3/library/compileall.html#module-compileall) can create .pyc files for all modules in a directory.
* There is more detail on this process, including a flow chart of the decisions, in PEP 3147.

## 6.2. Standard Modules

Python comes with a library of standard modules, described in a separate document, the Python Library Reference (“Library Reference” hereafter). Some modules are built into the interpreter; these provide access to operations that are not part of the core of the language but are nevertheless built in, either for efficiency or to provide access to operating system primitives such as system calls. The set of such modules is a configuration option which also depends on the underlying platform. For example, the [winreg](https://docs.python.org/3/library/winreg.html#module-winreg) module is only provided on Windows systems. One particular module deserves some attention: [sys](https://docs.python.org/3/library/sys.html#module-sys), which is built into every Python interpreter. The variables sys.ps1 and sys.ps2define the strings used as primary and secondary prompts:

>>>

**>>> import** **sys**

**>>>** sys.ps1

'>>> '

**>>>** sys.ps2

'... '

**>>>** sys.ps1 = 'C> '

C> print('Yuck!')

Yuck!

C>

These two variables are only defined if the interpreter is in interactive mode.

The variable sys.path is a list of strings that determines the interpreter’s search path for modules. It is initialized to a default path taken from the environment variable [PYTHONPATH](https://docs.python.org/3/using/cmdline.html#envvar-PYTHONPATH), or from a built-in default if[PYTHONPATH](https://docs.python.org/3/using/cmdline.html#envvar-PYTHONPATH) is not set. You can modify it using standard list operations:

>>>

**>>> import** **sys**

**>>>** sys.path.append('/ufs/guido/lib/python')

## 6.3. The [dir()](https://docs.python.org/3/library/functions.html#dir) Function

The built-in function [dir()](https://docs.python.org/3/library/functions.html#dir) is used to find out which names a module defines. It returns a sorted list of strings:

>>>

**>>> import** **fibo**, **sys**

**>>>** dir(fibo)

['\_\_name\_\_', 'fib', 'fib2']

**>>>** dir(sys)

['\_\_displayhook\_\_', '\_\_doc\_\_', '\_\_excepthook\_\_', '\_\_loader\_\_', '\_\_name\_\_',

'\_\_package\_\_', '\_\_stderr\_\_', '\_\_stdin\_\_', '\_\_stdout\_\_',

'\_clear\_type\_cache', '\_current\_frames', '\_debugmallocstats', '\_getframe',

'\_home', '\_mercurial', '\_xoptions', 'abiflags', 'api\_version', 'argv',

'base\_exec\_prefix', 'base\_prefix', 'builtin\_module\_names', 'byteorder',

'call\_tracing', 'callstats', 'copyright', 'displayhook',

'dont\_write\_bytecode', 'exc\_info', 'excepthook', 'exec\_prefix',

'executable', 'exit', 'flags', 'float\_info', 'float\_repr\_style',

'getcheckinterval', 'getdefaultencoding', 'getdlopenflags',

'getfilesystemencoding', 'getobjects', 'getprofile', 'getrecursionlimit',

'getrefcount', 'getsizeof', 'getswitchinterval', 'gettotalrefcount',

'gettrace', 'hash\_info', 'hexversion', 'implementation', 'int\_info',

'intern', 'maxsize', 'maxunicode', 'meta\_path', 'modules', 'path',

'path\_hooks', 'path\_importer\_cache', 'platform', 'prefix', 'ps1',

'setcheckinterval', 'setdlopenflags', 'setprofile', 'setrecursionlimit',

'setswitchinterval', 'settrace', 'stderr', 'stdin', 'stdout',

'thread\_info', 'version', 'version\_info', 'warnoptions']

Without arguments, [dir()](https://docs.python.org/3/library/functions.html#dir) lists the names you have defined currently:

>>>

**>>>** a = [1, 2, 3, 4, 5]

**>>> import** **fibo**

**>>>** fib = fibo.fib

**>>>** dir()

['\_\_builtins\_\_', '\_\_name\_\_', 'a', 'fib', 'fibo', 'sys']

Note that it lists all types of names: variables, modules, functions, etc.

[dir()](https://docs.python.org/3/library/functions.html#dir) does not list the names of built-in functions and variables. If you want a list of those, they are defined in the standard module [builtins](https://docs.python.org/3/library/builtins.html#module-builtins):

>>>

**>>> import** **builtins**

**>>>** dir(builtins)

['ArithmeticError', 'AssertionError', 'AttributeError', 'BaseException',

'BlockingIOError', 'BrokenPipeError', 'BufferError', 'BytesWarning',

'ChildProcessError', 'ConnectionAbortedError', 'ConnectionError',

'ConnectionRefusedError', 'ConnectionResetError', 'DeprecationWarning',

'EOFError', 'Ellipsis', 'EnvironmentError', 'Exception', 'False',

'FileExistsError', 'FileNotFoundError', 'FloatingPointError',

'FutureWarning', 'GeneratorExit', 'IOError', 'ImportError',

'ImportWarning', 'IndentationError', 'IndexError', 'InterruptedError',

'IsADirectoryError', 'KeyError', 'KeyboardInterrupt', 'LookupError',

'MemoryError', 'NameError', 'None', 'NotADirectoryError', 'NotImplemented',

'NotImplementedError', 'OSError', 'OverflowError',

'PendingDeprecationWarning', 'PermissionError', 'ProcessLookupError',

'ReferenceError', 'ResourceWarning', 'RuntimeError', 'RuntimeWarning',

'StopIteration', 'SyntaxError', 'SyntaxWarning', 'SystemError',

'SystemExit', 'TabError', 'TimeoutError', 'True', 'TypeError',

'UnboundLocalError', 'UnicodeDecodeError', 'UnicodeEncodeError',

'UnicodeError', 'UnicodeTranslateError', 'UnicodeWarning', 'UserWarning',

'ValueError', 'Warning', 'ZeroDivisionError', '\_', '\_\_build\_class\_\_',

'\_\_debug\_\_', '\_\_doc\_\_', '\_\_import\_\_', '\_\_name\_\_', '\_\_package\_\_', 'abs',

'all', 'any', 'ascii', 'bin', 'bool', 'bytearray', 'bytes', 'callable',

'chr', 'classmethod', 'compile', 'complex', 'copyright', 'credits',

'delattr', 'dict', 'dir', 'divmod', 'enumerate', 'eval', 'exec', 'exit',

'filter', 'float', 'format', 'frozenset', 'getattr', 'globals', 'hasattr',

'hash', 'help', 'hex', 'id', 'input', 'int', 'isinstance', 'issubclass',

'iter', 'len', 'license', 'list', 'locals', 'map', 'max', 'memoryview',

'min', 'next', 'object', 'oct', 'open', 'ord', 'pow', 'print', 'property',

'quit', 'range', 'repr', 'reversed', 'round', 'set', 'setattr', 'slice',

'sorted', 'staticmethod', 'str', 'sum', 'super', 'tuple', 'type', 'vars',

'zip']

## 6.4. Packages

Packages are a way of structuring Python’s module namespace by using “dotted module names”. For example, the module name A.B designates a submodule named B in a package named A. Just like the use of modules saves the authors of different modules from having to worry about each other’s global variable names, the use of dotted module names saves the authors of multi-module packages like NumPy or the Python Imaging Library from having to worry about each other’s module names.

Suppose you want to design a collection of modules (a “package”) for the uniform handling of sound files and sound data. There are many different sound file formats (usually recognized by their extension, for example: .wav, .aiff, .au), so you may need to create and maintain a growing collection of modules for the conversion between the various file formats. There are also many different operations you might want to perform on sound data (such as mixing, adding echo, applying an equalizer function, creating an artificial stereo effect), so in addition you will be writing a never-ending stream of modules to perform these operations. Here’s a possible structure for your package (expressed in terms of a hierarchical filesystem):

sound/ Top-level package

\_\_init\_\_.py Initialize the sound package

formats/ Subpackage for file format conversions

\_\_init\_\_.py

wavread.py

wavwrite.py

aiffread.py

aiffwrite.py

auread.py

auwrite.py

...

effects/ Subpackage for sound effects

\_\_init\_\_.py

echo.py

surround.py

reverse.py

...

filters/ Subpackage for filters

\_\_init\_\_.py

equalizer.py

vocoder.py

karaoke.py

...

When importing the package, Python searches through the directories on sys.path looking for the package subdirectory.

The \_\_init\_\_.py files are required to make Python treat the directories as containing packages; this is done to prevent directories with a common name, such as string, from unintentionally hiding valid modules that occur later on the module search path. In the simplest case, \_\_init\_\_.py can just be an empty file, but it can also execute initialization code for the package or set the \_\_all\_\_ variable, described later.

Users of the package can import individual modules from the package, for example:

**import** **sound.effects.echo**

This loads the submodule sound.effects.echo. It must be referenced with its full name.

sound.effects.echo.echofilter(input, output, delay=0.7, atten=4)

An alternative way of importing the submodule is:

**from** **sound.effects** **import** echo

This also loads the submodule echo, and makes it available without its package prefix, so it can be used as follows:

echo.echofilter(input, output, delay=0.7, atten=4)

Yet another variation is to import the desired function or variable directly:

**from** **sound.effects.echo** **import** echofilter

Again, this loads the submodule echo, but this makes its function echofilter() directly available:

echofilter(input, output, delay=0.7, atten=4)

Note that when using from package import item, the item can be either a submodule (or subpackage) of the package, or some other name defined in the package, like a function, class or variable. The import statement first tests whether the item is defined in the package; if not, it assumes it is a module and attempts to load it. If it fails to find it, an [ImportError](https://docs.python.org/3/library/exceptions.html#ImportError) exception is raised.

Contrarily, when using syntax like import item.subitem.subsubitem, each item except for the last must be a package; the last item can be a module or a package but can’t be a class or function or variable defined in the previous item.

### 6.4.1. Importing \* From a Package

Now what happens when the user writes from sound.effects import \*? Ideally, one would hope that this somehow goes out to the filesystem, finds which submodules are present in the package, and imports them all. This could take a long time and importing sub-modules might have unwanted side-effects that should only happen when the sub-module is explicitly imported.

The only solution is for the package author to provide an explicit index of the package. The [import](https://docs.python.org/3/reference/simple_stmts.html#import)statement uses the following convention: if a package’s \_\_init\_\_.py code defines a list named\_\_all\_\_, it is taken to be the list of module names that should be imported when from packageimport \* is encountered. It is up to the package author to keep this list up-to-date when a new version of the package is released. Package authors may also decide not to support it, if they don’t see a use for importing \* from their package. For example, the file sound/effects/\_\_init\_\_.py could contain the following code:

\_\_all\_\_ = ["echo", "surround", "reverse"]

This would mean that from sound.effects import \* would import the three named submodules of the sound package.

If \_\_all\_\_ is not defined, the statement from sound.effects import \* does not import all submodules from the package sound.effects into the current namespace; it only ensures that the package sound.effects has been imported (possibly running any initialization code in \_\_init\_\_.py) and then imports whatever names are defined in the package. This includes any names defined (and submodules explicitly loaded) by \_\_init\_\_.py. It also includes any submodules of the package that were explicitly loaded by previous [import](https://docs.python.org/3/reference/simple_stmts.html#import) statements. Consider this code:

**import** **sound.effects.echo**

**import** **sound.effects.surround**

**from** **sound.effects** **import** \*

In this example, the echo and surround modules are imported in the current namespace because they are defined in the sound.effects package when the from...import statement is executed. (This also works when \_\_all\_\_ is defined.)

Although certain modules are designed to export only names that follow certain patterns when you useimport \*, it is still considered bad practise in production code.

Remember, there is nothing wrong with using from Package import specific\_submodule! In fact, this is the recommended notation unless the importing module needs to use submodules with the same name from different packages.

### 6.4.2. Intra-package References

When packages are structured into subpackages (as with the sound package in the example), you can use absolute imports to refer to submodules of siblings packages. For example, if the modulesound.filters.vocoder needs to use the echo module in the sound.effects package, it can usefrom sound.effects import echo.

You can also write relative imports, with the from module import name form of import statement. These imports use leading dots to indicate the current and parent packages involved in the relative import. From the surround module for example, you might use:

**from** **.** **import** echo

**from** **..** **import** formats

**from** **..filters** **import** equalizer

Note that relative imports are based on the name of the current module. Since the name of the main module is always "\_\_main\_\_", modules intended for use as the main module of a Python application must always use absolute imports.

### 6.4.3. Packages in Multiple Directories

Packages support one more special attribute, [\_\_path\_\_](https://docs.python.org/3/reference/import.html#__path__). This is initialized to be a list containing the name of the directory holding the package’s \_\_init\_\_.py before the code in that file is executed. This variable can be modified; doing so affects future searches for modules and subpackages contained in the package.

While this feature is not often needed, it can be used to extend the set of modules found in a package.

**Footnotes**

|  |  |
| --- | --- |
| [[1]](https://docs.python.org/3/tutorial/modules.html#id1) | In fact function definitions are also ‘statements’ that are ‘executed’; the execution of a module-level function definition enters the function name in the module’s global symbol table. |

# 6. Modules

If you quit from the Python interpreter and enter it again, the definitions you have made (functions and variables) are lost. Therefore, if you want to write a somewhat longer program, you are better off using a text editor to prepare the input for the interpreter and running it with that file as input instead. This is known as creating a script. As your program gets longer, you may want to split it into several files for easier maintenance. You may also want to use a handy function that you’ve written in several programs without copying its definition into each program.

To support this, Python has a way to put definitions in a file and use them in a script or in an interactive instance of the interpreter. Such a file is called a module; definitions from a module can be importedinto other modules or into the main module (the collection of variables that you have access to in a script executed at the top level and in calculator mode).

A module is a file containing Python definitions and statements. The file name is the module name with the suffix .py appended. Within a module, the module’s name (as a string) is available as the value of the global variable \_\_name\_\_. For instance, use your favorite text editor to create a file calledfibo.py in the current directory with the following contents:

*# Fibonacci numbers module*

**def** fib(n): *# write Fibonacci series up to n*

a, b = 0, 1

**while** b < n:

print(b, end=' ')

a, b = b, a+b

print()

**def** fib2(n): *# return Fibonacci series up to n*

result = []

a, b = 0, 1

**while** b < n:

result.append(b)

a, b = b, a+b

**return** result

Now enter the Python interpreter and import this module with the following command:

>>>

**>>> import** **fibo**

This does not enter the names of the functions defined in fibo directly in the current symbol table; it only enters the module name fibo there. Using the module name you can access the functions:

>>>

**>>>** fibo.fib(1000)

1 1 2 3 5 8 13 21 34 55 89 144 233 377 610 987

**>>>** fibo.fib2(100)

[1, 1, 2, 3, 5, 8, 13, 21, 34, 55, 89]

**>>>** fibo.\_\_name\_\_

'fibo'

If you intend to use a function often you can assign it to a local name:

>>>

**>>>** fib = fibo.fib

**>>>** fib(500)

1 1 2 3 5 8 13 21 34 55 89 144 233 377

## 6.1. More on Modules

A module can contain executable statements as well as function definitions. These statements are intended to initialize the module. They are executed only the first time the module name is encountered in an import statement. [[1]](https://docs.python.org/3/tutorial/modules.html#id2) (They are also run if the file is executed as a script.)

Each module has its own private symbol table, which is used as the global symbol table by all functions defined in the module. Thus, the author of a module can use global variables in the module without worrying about accidental clashes with a user’s global variables. On the other hand, if you know what you are doing you can touch a module’s global variables with the same notation used to refer to its functions, modname.itemname.

Modules can import other modules. It is customary but not required to place all [import](https://docs.python.org/3/reference/simple_stmts.html#import) statements at the beginning of a module (or script, for that matter). The imported module names are placed in the importing module’s global symbol table.

There is a variant of the [import](https://docs.python.org/3/reference/simple_stmts.html#import) statement that imports names from a module directly into the importing module’s symbol table. For example:

>>>

**>>> from** **fibo** **import** fib, fib2

**>>>** fib(500)

1 1 2 3 5 8 13 21 34 55 89 144 233 377

This does not introduce the module name from which the imports are taken in the local symbol table (so in the example, fibo is not defined).

There is even a variant to import all names that a module defines:

>>>

**>>> from** **fibo** **import** \*

**>>>** fib(500)

1 1 2 3 5 8 13 21 34 55 89 144 233 377

This imports all names except those beginning with an underscore (\_). In most cases Python programmers do not use this facility since it introduces an unknown set of names into the interpreter, possibly hiding some things you have already defined.

Note that in general the practice of importing \* from a module or package is frowned upon, since it often causes poorly readable code. However, it is okay to use it to save typing in interactive sessions.

**Note**

For efficiency reasons, each module is only imported once per interpreter session. Therefore, if you change your modules, you must restart the interpreter – or, if it’s just one module you want to test interactively, use [importlib.reload()](https://docs.python.org/3/library/importlib.html#importlib.reload), e.g. import importlib;importlib.reload(modulename).

### 6.1.1. Executing modules as scripts

When you run a Python module with

python fibo.py <arguments>

the code in the module will be executed, just as if you imported it, but with the \_\_name\_\_ set to"\_\_main\_\_". That means that by adding this code at the end of your module:

**if** \_\_name\_\_ == "\_\_main\_\_":

**import** **sys**

fib(int(sys.argv[1]))

you can make the file usable as a script as well as an importable module, because the code that parses the command line only runs if the module is executed as the “main” file:

$ python fibo.py 50

1 1 2 3 5 8 13 21 34

If the module is imported, the code is not run:

>>>

**>>> import** **fibo**

>>>

This is often used either to provide a convenient user interface to a module, or for testing purposes (running the module as a script executes a test suite).

### 6.1.2. The Module Search Path

When a module named spam is imported, the interpreter first searches for a built-in module with that name. If not found, it then searches for a file named spam.py in a list of directories given by the variable [sys.path](https://docs.python.org/3/library/sys.html#sys.path). [sys.path](https://docs.python.org/3/library/sys.html#sys.path) is initialized from these locations:

* The directory containing the input script (or the current directory when no file is specified).
* [PYTHONPATH](https://docs.python.org/3/using/cmdline.html#envvar-PYTHONPATH) (a list of directory names, with the same syntax as the shell variable PATH).
* The installation-dependent default.

**Note**

On file systems which support symlinks, the directory containing the input script is calculated after the symlink is followed. In other words the directory containing the symlink is **not** added to the module search path.

After initialization, Python programs can modify [sys.path](https://docs.python.org/3/library/sys.html#sys.path). The directory containing the script being run is placed at the beginning of the search path, ahead of the standard library path. This means that scripts in that directory will be loaded instead of modules of the same name in the library directory. This is an error unless the replacement is intended. See section [Standard Modules](https://docs.python.org/3/tutorial/modules.html#tut-standardmodules) for more information.

### 6.1.3. “Compiled” Python files

To speed up loading modules, Python caches the compiled version of each module in the\_\_pycache\_\_ directory under the name module.*version*.pyc, where the version encodes the format of the compiled file; it generally contains the Python version number. For example, in CPython release 3.3 the compiled version of spam.py would be cached as \_\_pycache\_\_/spam.cpython-33.pyc. This naming convention allows compiled modules from different releases and different versions of Python to coexist.

Python checks the modification date of the source against the compiled version to see if it’s out of date and needs to be recompiled. This is a completely automatic process. Also, the compiled modules are platform-independent, so the same library can be shared among systems with different architectures.

Python does not check the cache in two circumstances. First, it always recompiles and does not store the result for the module that’s loaded directly from the command line. Second, it does not check the cache if there is no source module. To support a non-source (compiled only) distribution, the compiled module must be in the source directory, and there must not be a source module.

Some tips for experts:

* You can use the [-O](https://docs.python.org/3/using/cmdline.html#cmdoption-O) or [-OO](https://docs.python.org/3/using/cmdline.html#cmdoption-OO) switches on the Python command to reduce the size of a compiled module. The -O switch removes assert statements, the -OO switch removes both assert statements and \_\_doc\_\_ strings. Since some programs may rely on having these available, you should only use this option if you know what you’re doing. “Optimized” modules have an opt-tag and are usually smaller. Future releases may change the effects of optimization.
* A program doesn’t run any faster when it is read from a .pyc file than when it is read from a .pyfile; the only thing that’s faster about .pyc files is the speed with which they are loaded.
* The module [compileall](https://docs.python.org/3/library/compileall.html#module-compileall) can create .pyc files for all modules in a directory.
* There is more detail on this process, including a flow chart of the decisions, in PEP 3147.

## 6.2. Standard Modules

Python comes with a library of standard modules, described in a separate document, the Python Library Reference (“Library Reference” hereafter). Some modules are built into the interpreter; these provide access to operations that are not part of the core of the language but are nevertheless built in, either for efficiency or to provide access to operating system primitives such as system calls. The set of such modules is a configuration option which also depends on the underlying platform. For example, the [winreg](https://docs.python.org/3/library/winreg.html#module-winreg) module is only provided on Windows systems. One particular module deserves some attention: [sys](https://docs.python.org/3/library/sys.html#module-sys), which is built into every Python interpreter. The variables sys.ps1 and sys.ps2define the strings used as primary and secondary prompts:

>>>

**>>> import** **sys**

**>>>** sys.ps1

'>>> '

**>>>** sys.ps2

'... '

**>>>** sys.ps1 = 'C> '

C> print('Yuck!')

Yuck!

C>

These two variables are only defined if the interpreter is in interactive mode.

The variable sys.path is a list of strings that determines the interpreter’s search path for modules. It is initialized to a default path taken from the environment variable [PYTHONPATH](https://docs.python.org/3/using/cmdline.html#envvar-PYTHONPATH), or from a built-in default if[PYTHONPATH](https://docs.python.org/3/using/cmdline.html#envvar-PYTHONPATH) is not set. You can modify it using standard list operations:

>>>

**>>> import** **sys**

**>>>** sys.path.append('/ufs/guido/lib/python')

## 6.3. The [dir()](https://docs.python.org/3/library/functions.html#dir) Function

The built-in function [dir()](https://docs.python.org/3/library/functions.html#dir) is used to find out which names a module defines. It returns a sorted list of strings:

>>>

**>>> import** **fibo**, **sys**

**>>>** dir(fibo)

['\_\_name\_\_', 'fib', 'fib2']

**>>>** dir(sys)

['\_\_displayhook\_\_', '\_\_doc\_\_', '\_\_excepthook\_\_', '\_\_loader\_\_', '\_\_name\_\_',

'\_\_package\_\_', '\_\_stderr\_\_', '\_\_stdin\_\_', '\_\_stdout\_\_',

'\_clear\_type\_cache', '\_current\_frames', '\_debugmallocstats', '\_getframe',

'\_home', '\_mercurial', '\_xoptions', 'abiflags', 'api\_version', 'argv',

'base\_exec\_prefix', 'base\_prefix', 'builtin\_module\_names', 'byteorder',

'call\_tracing', 'callstats', 'copyright', 'displayhook',

'dont\_write\_bytecode', 'exc\_info', 'excepthook', 'exec\_prefix',

'executable', 'exit', 'flags', 'float\_info', 'float\_repr\_style',

'getcheckinterval', 'getdefaultencoding', 'getdlopenflags',

'getfilesystemencoding', 'getobjects', 'getprofile', 'getrecursionlimit',

'getrefcount', 'getsizeof', 'getswitchinterval', 'gettotalrefcount',

'gettrace', 'hash\_info', 'hexversion', 'implementation', 'int\_info',

'intern', 'maxsize', 'maxunicode', 'meta\_path', 'modules', 'path',

'path\_hooks', 'path\_importer\_cache', 'platform', 'prefix', 'ps1',

'setcheckinterval', 'setdlopenflags', 'setprofile', 'setrecursionlimit',

'setswitchinterval', 'settrace', 'stderr', 'stdin', 'stdout',

'thread\_info', 'version', 'version\_info', 'warnoptions']

Without arguments, [dir()](https://docs.python.org/3/library/functions.html#dir) lists the names you have defined currently:

>>>

**>>>** a = [1, 2, 3, 4, 5]

**>>> import** **fibo**

**>>>** fib = fibo.fib

**>>>** dir()

['\_\_builtins\_\_', '\_\_name\_\_', 'a', 'fib', 'fibo', 'sys']

Note that it lists all types of names: variables, modules, functions, etc.

[dir()](https://docs.python.org/3/library/functions.html#dir) does not list the names of built-in functions and variables. If you want a list of those, they are defined in the standard module [builtins](https://docs.python.org/3/library/builtins.html#module-builtins):

>>>

**>>> import** **builtins**

**>>>** dir(builtins)

['ArithmeticError', 'AssertionError', 'AttributeError', 'BaseException',

'BlockingIOError', 'BrokenPipeError', 'BufferError', 'BytesWarning',

'ChildProcessError', 'ConnectionAbortedError', 'ConnectionError',

'ConnectionRefusedError', 'ConnectionResetError', 'DeprecationWarning',

'EOFError', 'Ellipsis', 'EnvironmentError', 'Exception', 'False',

'FileExistsError', 'FileNotFoundError', 'FloatingPointError',

'FutureWarning', 'GeneratorExit', 'IOError', 'ImportError',

'ImportWarning', 'IndentationError', 'IndexError', 'InterruptedError',

'IsADirectoryError', 'KeyError', 'KeyboardInterrupt', 'LookupError',

'MemoryError', 'NameError', 'None', 'NotADirectoryError', 'NotImplemented',

'NotImplementedError', 'OSError', 'OverflowError',

'PendingDeprecationWarning', 'PermissionError', 'ProcessLookupError',

'ReferenceError', 'ResourceWarning', 'RuntimeError', 'RuntimeWarning',

'StopIteration', 'SyntaxError', 'SyntaxWarning', 'SystemError',

'SystemExit', 'TabError', 'TimeoutError', 'True', 'TypeError',

'UnboundLocalError', 'UnicodeDecodeError', 'UnicodeEncodeError',

'UnicodeError', 'UnicodeTranslateError', 'UnicodeWarning', 'UserWarning',

'ValueError', 'Warning', 'ZeroDivisionError', '\_', '\_\_build\_class\_\_',

'\_\_debug\_\_', '\_\_doc\_\_', '\_\_import\_\_', '\_\_name\_\_', '\_\_package\_\_', 'abs',

'all', 'any', 'ascii', 'bin', 'bool', 'bytearray', 'bytes', 'callable',

'chr', 'classmethod', 'compile', 'complex', 'copyright', 'credits',

'delattr', 'dict', 'dir', 'divmod', 'enumerate', 'eval', 'exec', 'exit',

'filter', 'float', 'format', 'frozenset', 'getattr', 'globals', 'hasattr',

'hash', 'help', 'hex', 'id', 'input', 'int', 'isinstance', 'issubclass',

'iter', 'len', 'license', 'list', 'locals', 'map', 'max', 'memoryview',

'min', 'next', 'object', 'oct', 'open', 'ord', 'pow', 'print', 'property',

'quit', 'range', 'repr', 'reversed', 'round', 'set', 'setattr', 'slice',

'sorted', 'staticmethod', 'str', 'sum', 'super', 'tuple', 'type', 'vars',

'zip']

## 6.4. Packages

Packages are a way of structuring Python’s module namespace by using “dotted module names”. For example, the module name A.B designates a submodule named B in a package named A. Just like the use of modules saves the authors of different modules from having to worry about each other’s global variable names, the use of dotted module names saves the authors of multi-module packages like NumPy or the Python Imaging Library from having to worry about each other’s module names.

Suppose you want to design a collection of modules (a “package”) for the uniform handling of sound files and sound data. There are many different sound file formats (usually recognized by their extension, for example: .wav, .aiff, .au), so you may need to create and maintain a growing collection of modules for the conversion between the various file formats. There are also many different operations you might want to perform on sound data (such as mixing, adding echo, applying an equalizer function, creating an artificial stereo effect), so in addition you will be writing a never-ending stream of modules to perform these operations. Here’s a possible structure for your package (expressed in terms of a hierarchical filesystem):

sound/ Top-level package

\_\_init\_\_.py Initialize the sound package

formats/ Subpackage for file format conversions

\_\_init\_\_.py

wavread.py

wavwrite.py

aiffread.py

aiffwrite.py

auread.py

auwrite.py

...

effects/ Subpackage for sound effects

\_\_init\_\_.py

echo.py

surround.py

reverse.py

...

filters/ Subpackage for filters

\_\_init\_\_.py

equalizer.py

vocoder.py

karaoke.py

...

When importing the package, Python searches through the directories on sys.path looking for the package subdirectory.

The \_\_init\_\_.py files are required to make Python treat the directories as containing packages; this is done to prevent directories with a common name, such as string, from unintentionally hiding valid modules that occur later on the module search path. In the simplest case, \_\_init\_\_.py can just be an empty file, but it can also execute initialization code for the package or set the \_\_all\_\_ variable, described later.

Users of the package can import individual modules from the package, for example:

**import** **sound.effects.echo**

This loads the submodule sound.effects.echo. It must be referenced with its full name.

sound.effects.echo.echofilter(input, output, delay=0.7, atten=4)

An alternative way of importing the submodule is:

**from** **sound.effects** **import** echo

This also loads the submodule echo, and makes it available without its package prefix, so it can be used as follows:

echo.echofilter(input, output, delay=0.7, atten=4)

Yet another variation is to import the desired function or variable directly:

**from** **sound.effects.echo** **import** echofilter

Again, this loads the submodule echo, but this makes its function echofilter() directly available:

echofilter(input, output, delay=0.7, atten=4)

Note that when using from package import item, the item can be either a submodule (or subpackage) of the package, or some other name defined in the package, like a function, class or variable. The import statement first tests whether the item is defined in the package; if not, it assumes it is a module and attempts to load it. If it fails to find it, an [ImportError](https://docs.python.org/3/library/exceptions.html#ImportError) exception is raised.

Contrarily, when using syntax like import item.subitem.subsubitem, each item except for the last must be a package; the last item can be a module or a package but can’t be a class or function or variable defined in the previous item.

### 6.4.1. Importing \* From a Package

Now what happens when the user writes from sound.effects import \*? Ideally, one would hope that this somehow goes out to the filesystem, finds which submodules are present in the package, and imports them all. This could take a long time and importing sub-modules might have unwanted side-effects that should only happen when the sub-module is explicitly imported.

The only solution is for the package author to provide an explicit index of the package. The [import](https://docs.python.org/3/reference/simple_stmts.html#import)statement uses the following convention: if a package’s \_\_init\_\_.py code defines a list named\_\_all\_\_, it is taken to be the list of module names that should be imported when from packageimport \* is encountered. It is up to the package author to keep this list up-to-date when a new version of the package is released. Package authors may also decide not to support it, if they don’t see a use for importing \* from their package. For example, the file sound/effects/\_\_init\_\_.py could contain the following code:

\_\_all\_\_ = ["echo", "surround", "reverse"]

This would mean that from sound.effects import \* would import the three named submodules of the sound package.

If \_\_all\_\_ is not defined, the statement from sound.effects import \* does not import all submodules from the package sound.effects into the current namespace; it only ensures that the package sound.effects has been imported (possibly running any initialization code in \_\_init\_\_.py) and then imports whatever names are defined in the package. This includes any names defined (and submodules explicitly loaded) by \_\_init\_\_.py. It also includes any submodules of the package that were explicitly loaded by previous [import](https://docs.python.org/3/reference/simple_stmts.html#import) statements. Consider this code:

**import** **sound.effects.echo**

**import** **sound.effects.surround**

**from** **sound.effects** **import** \*

In this example, the echo and surround modules are imported in the current namespace because they are defined in the sound.effects package when the from...import statement is executed. (This also works when \_\_all\_\_ is defined.)

Although certain modules are designed to export only names that follow certain patterns when you useimport \*, it is still considered bad practise in production code.

Remember, there is nothing wrong with using from Package import specific\_submodule! In fact, this is the recommended notation unless the importing module needs to use submodules with the same name from different packages.

### 6.4.2. Intra-package References

When packages are structured into subpackages (as with the sound package in the example), you can use absolute imports to refer to submodules of siblings packages. For example, if the modulesound.filters.vocoder needs to use the echo module in the sound.effects package, it can usefrom sound.effects import echo.

You can also write relative imports, with the from module import name form of import statement. These imports use leading dots to indicate the current and parent packages involved in the relative import. From the surround module for example, you might use:

**from** **.** **import** echo

**from** **..** **import** formats

**from** **..filters** **import** equalizer

Note that relative imports are based on the name of the current module. Since the name of the main module is always "\_\_main\_\_", modules intended for use as the main module of a Python application must always use absolute imports.

### 6.4.3. Packages in Multiple Directories

Packages support one more special attribute, [\_\_path\_\_](https://docs.python.org/3/reference/import.html#__path__). This is initialized to be a list containing the name of the directory holding the package’s \_\_init\_\_.py before the code in that file is executed. This variable can be modified; doing so affects future searches for modules and subpackages contained in the package.

While this feature is not often needed, it can be used to extend the set of modules found in a package.

**Footnotes**

|  |  |
| --- | --- |
| [[1]](https://docs.python.org/3/tutorial/modules.html#id1) | In fact function definitions are also ‘statements’ that are ‘executed’; the execution of a module-level function definition enters the function name in the module’s global symbol table. |

# 6. Modules

If you quit from the Python interpreter and enter it again, the definitions you have made (functions and variables) are lost. Therefore, if you want to write a somewhat longer program, you are better off using a text editor to prepare the input for the interpreter and running it with that file as input instead. This is known as creating a script. As your program gets longer, you may want to split it into several files for easier maintenance. You may also want to use a handy function that you’ve written in several programs without copying its definition into each program.

To support this, Python has a way to put definitions in a file and use them in a script or in an interactive instance of the interpreter. Such a file is called a module; definitions from a module can be importedinto other modules or into the main module (the collection of variables that you have access to in a script executed at the top level and in calculator mode).

A module is a file containing Python definitions and statements. The file name is the module name with the suffix .py appended. Within a module, the module’s name (as a string) is available as the value of the global variable \_\_name\_\_. For instance, use your favorite text editor to create a file calledfibo.py in the current directory with the following contents:

*# Fibonacci numbers module*

**def** fib(n): *# write Fibonacci series up to n*

a, b = 0, 1

**while** b < n:

print(b, end=' ')

a, b = b, a+b

print()

**def** fib2(n): *# return Fibonacci series up to n*

result = []

a, b = 0, 1

**while** b < n:

result.append(b)

a, b = b, a+b

**return** result

Now enter the Python interpreter and import this module with the following command:

>>>

**>>> import** **fibo**

This does not enter the names of the functions defined in fibo directly in the current symbol table; it only enters the module name fibo there. Using the module name you can access the functions:

>>>

**>>>** fibo.fib(1000)

1 1 2 3 5 8 13 21 34 55 89 144 233 377 610 987

**>>>** fibo.fib2(100)

[1, 1, 2, 3, 5, 8, 13, 21, 34, 55, 89]

**>>>** fibo.\_\_name\_\_

'fibo'

If you intend to use a function often you can assign it to a local name:

>>>

**>>>** fib = fibo.fib

**>>>** fib(500)

1 1 2 3 5 8 13 21 34 55 89 144 233 377

## 6.1. More on Modules

A module can contain executable statements as well as function definitions. These statements are intended to initialize the module. They are executed only the first time the module name is encountered in an import statement. [[1]](https://docs.python.org/3/tutorial/modules.html#id2) (They are also run if the file is executed as a script.)

Each module has its own private symbol table, which is used as the global symbol table by all functions defined in the module. Thus, the author of a module can use global variables in the module without worrying about accidental clashes with a user’s global variables. On the other hand, if you know what you are doing you can touch a module’s global variables with the same notation used to refer to its functions, modname.itemname.

Modules can import other modules. It is customary but not required to place all [import](https://docs.python.org/3/reference/simple_stmts.html#import) statements at the beginning of a module (or script, for that matter). The imported module names are placed in the importing module’s global symbol table.

There is a variant of the [import](https://docs.python.org/3/reference/simple_stmts.html#import) statement that imports names from a module directly into the importing module’s symbol table. For example:

>>>

**>>> from** **fibo** **import** fib, fib2

**>>>** fib(500)

1 1 2 3 5 8 13 21 34 55 89 144 233 377

This does not introduce the module name from which the imports are taken in the local symbol table (so in the example, fibo is not defined).

There is even a variant to import all names that a module defines:

>>>

**>>> from** **fibo** **import** \*

**>>>** fib(500)

1 1 2 3 5 8 13 21 34 55 89 144 233 377

This imports all names except those beginning with an underscore (\_). In most cases Python programmers do not use this facility since it introduces an unknown set of names into the interpreter, possibly hiding some things you have already defined.

Note that in general the practice of importing \* from a module or package is frowned upon, since it often causes poorly readable code. However, it is okay to use it to save typing in interactive sessions.

**Note**

For efficiency reasons, each module is only imported once per interpreter session. Therefore, if you change your modules, you must restart the interpreter – or, if it’s just one module you want to test interactively, use [importlib.reload()](https://docs.python.org/3/library/importlib.html#importlib.reload), e.g. import importlib;importlib.reload(modulename).

### 6.1.1. Executing modules as scripts

When you run a Python module with

python fibo.py <arguments>

the code in the module will be executed, just as if you imported it, but with the \_\_name\_\_ set to"\_\_main\_\_". That means that by adding this code at the end of your module:

**if** \_\_name\_\_ == "\_\_main\_\_":

**import** **sys**

fib(int(sys.argv[1]))

you can make the file usable as a script as well as an importable module, because the code that parses the command line only runs if the module is executed as the “main” file:

$ python fibo.py 50

1 1 2 3 5 8 13 21 34

If the module is imported, the code is not run:

>>>

**>>> import** **fibo**

>>>

This is often used either to provide a convenient user interface to a module, or for testing purposes (running the module as a script executes a test suite).

### 6.1.2. The Module Search Path

When a module named spam is imported, the interpreter first searches for a built-in module with that name. If not found, it then searches for a file named spam.py in a list of directories given by the variable [sys.path](https://docs.python.org/3/library/sys.html#sys.path). [sys.path](https://docs.python.org/3/library/sys.html#sys.path) is initialized from these locations:

* The directory containing the input script (or the current directory when no file is specified).
* [PYTHONPATH](https://docs.python.org/3/using/cmdline.html#envvar-PYTHONPATH) (a list of directory names, with the same syntax as the shell variable PATH).
* The installation-dependent default.

**Note**

On file systems which support symlinks, the directory containing the input script is calculated after the symlink is followed. In other words the directory containing the symlink is **not** added to the module search path.

After initialization, Python programs can modify [sys.path](https://docs.python.org/3/library/sys.html#sys.path). The directory containing the script being run is placed at the beginning of the search path, ahead of the standard library path. This means that scripts in that directory will be loaded instead of modules of the same name in the library directory. This is an error unless the replacement is intended. See section [Standard Modules](https://docs.python.org/3/tutorial/modules.html#tut-standardmodules) for more information.

### 6.1.3. “Compiled” Python files

To speed up loading modules, Python caches the compiled version of each module in the\_\_pycache\_\_ directory under the name module.*version*.pyc, where the version encodes the format of the compiled file; it generally contains the Python version number. For example, in CPython release 3.3 the compiled version of spam.py would be cached as \_\_pycache\_\_/spam.cpython-33.pyc. This naming convention allows compiled modules from different releases and different versions of Python to coexist.

Python checks the modification date of the source against the compiled version to see if it’s out of date and needs to be recompiled. This is a completely automatic process. Also, the compiled modules are platform-independent, so the same library can be shared among systems with different architectures.

Python does not check the cache in two circumstances. First, it always recompiles and does not store the result for the module that’s loaded directly from the command line. Second, it does not check the cache if there is no source module. To support a non-source (compiled only) distribution, the compiled module must be in the source directory, and there must not be a source module.

Some tips for experts:

* You can use the [-O](https://docs.python.org/3/using/cmdline.html#cmdoption-O) or [-OO](https://docs.python.org/3/using/cmdline.html#cmdoption-OO) switches on the Python command to reduce the size of a compiled module. The -O switch removes assert statements, the -OO switch removes both assert statements and \_\_doc\_\_ strings. Since some programs may rely on having these available, you should only use this option if you know what you’re doing. “Optimized” modules have an opt-tag and are usually smaller. Future releases may change the effects of optimization.
* A program doesn’t run any faster when it is read from a .pyc file than when it is read from a .pyfile; the only thing that’s faster about .pyc files is the speed with which they are loaded.
* The module [compileall](https://docs.python.org/3/library/compileall.html#module-compileall) can create .pyc files for all modules in a directory.
* There is more detail on this process, including a flow chart of the decisions, in PEP 3147.

## 6.2. Standard Modules

Python comes with a library of standard modules, described in a separate document, the Python Library Reference (“Library Reference” hereafter). Some modules are built into the interpreter; these provide access to operations that are not part of the core of the language but are nevertheless built in, either for efficiency or to provide access to operating system primitives such as system calls. The set of such modules is a configuration option which also depends on the underlying platform. For example, the [winreg](https://docs.python.org/3/library/winreg.html#module-winreg) module is only provided on Windows systems. One particular module deserves some attention: [sys](https://docs.python.org/3/library/sys.html#module-sys), which is built into every Python interpreter. The variables sys.ps1 and sys.ps2define the strings used as primary and secondary prompts:

>>>

**>>> import** **sys**

**>>>** sys.ps1

'>>> '

**>>>** sys.ps2

'... '

**>>>** sys.ps1 = 'C> '

C> print('Yuck!')

Yuck!

C>

These two variables are only defined if the interpreter is in interactive mode.

The variable sys.path is a list of strings that determines the interpreter’s search path for modules. It is initialized to a default path taken from the environment variable [PYTHONPATH](https://docs.python.org/3/using/cmdline.html#envvar-PYTHONPATH), or from a built-in default if[PYTHONPATH](https://docs.python.org/3/using/cmdline.html#envvar-PYTHONPATH) is not set. You can modify it using standard list operations:

>>>

**>>> import** **sys**

**>>>** sys.path.append('/ufs/guido/lib/python')

## 6.3. The [dir()](https://docs.python.org/3/library/functions.html#dir) Function

The built-in function [dir()](https://docs.python.org/3/library/functions.html#dir) is used to find out which names a module defines. It returns a sorted list of strings:

>>>

**>>> import** **fibo**, **sys**

**>>>** dir(fibo)

['\_\_name\_\_', 'fib', 'fib2']

**>>>** dir(sys)

['\_\_displayhook\_\_', '\_\_doc\_\_', '\_\_excepthook\_\_', '\_\_loader\_\_', '\_\_name\_\_',

'\_\_package\_\_', '\_\_stderr\_\_', '\_\_stdin\_\_', '\_\_stdout\_\_',

'\_clear\_type\_cache', '\_current\_frames', '\_debugmallocstats', '\_getframe',

'\_home', '\_mercurial', '\_xoptions', 'abiflags', 'api\_version', 'argv',

'base\_exec\_prefix', 'base\_prefix', 'builtin\_module\_names', 'byteorder',

'call\_tracing', 'callstats', 'copyright', 'displayhook',

'dont\_write\_bytecode', 'exc\_info', 'excepthook', 'exec\_prefix',

'executable', 'exit', 'flags', 'float\_info', 'float\_repr\_style',

'getcheckinterval', 'getdefaultencoding', 'getdlopenflags',

'getfilesystemencoding', 'getobjects', 'getprofile', 'getrecursionlimit',

'getrefcount', 'getsizeof', 'getswitchinterval', 'gettotalrefcount',

'gettrace', 'hash\_info', 'hexversion', 'implementation', 'int\_info',

'intern', 'maxsize', 'maxunicode', 'meta\_path', 'modules', 'path',

'path\_hooks', 'path\_importer\_cache', 'platform', 'prefix', 'ps1',

'setcheckinterval', 'setdlopenflags', 'setprofile', 'setrecursionlimit',

'setswitchinterval', 'settrace', 'stderr', 'stdin', 'stdout',

'thread\_info', 'version', 'version\_info', 'warnoptions']

Without arguments, [dir()](https://docs.python.org/3/library/functions.html#dir) lists the names you have defined currently:

>>>

**>>>** a = [1, 2, 3, 4, 5]

**>>> import** **fibo**

**>>>** fib = fibo.fib

**>>>** dir()

['\_\_builtins\_\_', '\_\_name\_\_', 'a', 'fib', 'fibo', 'sys']

Note that it lists all types of names: variables, modules, functions, etc.

[dir()](https://docs.python.org/3/library/functions.html#dir) does not list the names of built-in functions and variables. If you want a list of those, they are defined in the standard module [builtins](https://docs.python.org/3/library/builtins.html#module-builtins):

>>>

**>>> import** **builtins**

**>>>** dir(builtins)

['ArithmeticError', 'AssertionError', 'AttributeError', 'BaseException',

'BlockingIOError', 'BrokenPipeError', 'BufferError', 'BytesWarning',

'ChildProcessError', 'ConnectionAbortedError', 'ConnectionError',

'ConnectionRefusedError', 'ConnectionResetError', 'DeprecationWarning',

'EOFError', 'Ellipsis', 'EnvironmentError', 'Exception', 'False',

'FileExistsError', 'FileNotFoundError', 'FloatingPointError',

'FutureWarning', 'GeneratorExit', 'IOError', 'ImportError',

'ImportWarning', 'IndentationError', 'IndexError', 'InterruptedError',

'IsADirectoryError', 'KeyError', 'KeyboardInterrupt', 'LookupError',

'MemoryError', 'NameError', 'None', 'NotADirectoryError', 'NotImplemented',

'NotImplementedError', 'OSError', 'OverflowError',

'PendingDeprecationWarning', 'PermissionError', 'ProcessLookupError',

'ReferenceError', 'ResourceWarning', 'RuntimeError', 'RuntimeWarning',

'StopIteration', 'SyntaxError', 'SyntaxWarning', 'SystemError',

'SystemExit', 'TabError', 'TimeoutError', 'True', 'TypeError',

'UnboundLocalError', 'UnicodeDecodeError', 'UnicodeEncodeError',

'UnicodeError', 'UnicodeTranslateError', 'UnicodeWarning', 'UserWarning',

'ValueError', 'Warning', 'ZeroDivisionError', '\_', '\_\_build\_class\_\_',

'\_\_debug\_\_', '\_\_doc\_\_', '\_\_import\_\_', '\_\_name\_\_', '\_\_package\_\_', 'abs',

'all', 'any', 'ascii', 'bin', 'bool', 'bytearray', 'bytes', 'callable',

'chr', 'classmethod', 'compile', 'complex', 'copyright', 'credits',

'delattr', 'dict', 'dir', 'divmod', 'enumerate', 'eval', 'exec', 'exit',

'filter', 'float', 'format', 'frozenset', 'getattr', 'globals', 'hasattr',

'hash', 'help', 'hex', 'id', 'input', 'int', 'isinstance', 'issubclass',

'iter', 'len', 'license', 'list', 'locals', 'map', 'max', 'memoryview',

'min', 'next', 'object', 'oct', 'open', 'ord', 'pow', 'print', 'property',

'quit', 'range', 'repr', 'reversed', 'round', 'set', 'setattr', 'slice',

'sorted', 'staticmethod', 'str', 'sum', 'super', 'tuple', 'type', 'vars',

'zip']

## 6.4. Packages

Packages are a way of structuring Python’s module namespace by using “dotted module names”. For example, the module name A.B designates a submodule named B in a package named A. Just like the use of modules saves the authors of different modules from having to worry about each other’s global variable names, the use of dotted module names saves the authors of multi-module packages like NumPy or the Python Imaging Library from having to worry about each other’s module names.

Suppose you want to design a collection of modules (a “package”) for the uniform handling of sound files and sound data. There are many different sound file formats (usually recognized by their extension, for example: .wav, .aiff, .au), so you may need to create and maintain a growing collection of modules for the conversion between the various file formats. There are also many different operations you might want to perform on sound data (such as mixing, adding echo, applying an equalizer function, creating an artificial stereo effect), so in addition you will be writing a never-ending stream of modules to perform these operations. Here’s a possible structure for your package (expressed in terms of a hierarchical filesystem):

sound/ Top-level package

\_\_init\_\_.py Initialize the sound package

formats/ Subpackage for file format conversions

\_\_init\_\_.py

wavread.py

wavwrite.py

aiffread.py

aiffwrite.py

auread.py

auwrite.py

...

effects/ Subpackage for sound effects

\_\_init\_\_.py

echo.py

surround.py

reverse.py

...

filters/ Subpackage for filters

\_\_init\_\_.py

equalizer.py

vocoder.py

karaoke.py

...

When importing the package, Python searches through the directories on sys.path looking for the package subdirectory.

The \_\_init\_\_.py files are required to make Python treat the directories as containing packages; this is done to prevent directories with a common name, such as string, from unintentionally hiding valid modules that occur later on the module search path. In the simplest case, \_\_init\_\_.py can just be an empty file, but it can also execute initialization code for the package or set the \_\_all\_\_ variable, described later.

Users of the package can import individual modules from the package, for example:

**import** **sound.effects.echo**

This loads the submodule sound.effects.echo. It must be referenced with its full name.

sound.effects.echo.echofilter(input, output, delay=0.7, atten=4)

An alternative way of importing the submodule is:

**from** **sound.effects** **import** echo

This also loads the submodule echo, and makes it available without its package prefix, so it can be used as follows:

echo.echofilter(input, output, delay=0.7, atten=4)

Yet another variation is to import the desired function or variable directly:

**from** **sound.effects.echo** **import** echofilter

Again, this loads the submodule echo, but this makes its function echofilter() directly available:

echofilter(input, output, delay=0.7, atten=4)

Note that when using from package import item, the item can be either a submodule (or subpackage) of the package, or some other name defined in the package, like a function, class or variable. The import statement first tests whether the item is defined in the package; if not, it assumes it is a module and attempts to load it. If it fails to find it, an [ImportError](https://docs.python.org/3/library/exceptions.html#ImportError) exception is raised.

Contrarily, when using syntax like import item.subitem.subsubitem, each item except for the last must be a package; the last item can be a module or a package but can’t be a class or function or variable defined in the previous item.

### 6.4.1. Importing \* From a Package

Now what happens when the user writes from sound.effects import \*? Ideally, one would hope that this somehow goes out to the filesystem, finds which submodules are present in the package, and imports them all. This could take a long time and importing sub-modules might have unwanted side-effects that should only happen when the sub-module is explicitly imported.

The only solution is for the package author to provide an explicit index of the package. The [import](https://docs.python.org/3/reference/simple_stmts.html#import)statement uses the following convention: if a package’s \_\_init\_\_.py code defines a list named\_\_all\_\_, it is taken to be the list of module names that should be imported when from packageimport \* is encountered. It is up to the package author to keep this list up-to-date when a new version of the package is released. Package authors may also decide not to support it, if they don’t see a use for importing \* from their package. For example, the file sound/effects/\_\_init\_\_.py could contain the following code:

\_\_all\_\_ = ["echo", "surround", "reverse"]

This would mean that from sound.effects import \* would import the three named submodules of the sound package.

If \_\_all\_\_ is not defined, the statement from sound.effects import \* does not import all submodules from the package sound.effects into the current namespace; it only ensures that the package sound.effects has been imported (possibly running any initialization code in \_\_init\_\_.py) and then imports whatever names are defined in the package. This includes any names defined (and submodules explicitly loaded) by \_\_init\_\_.py. It also includes any submodules of the package that were explicitly loaded by previous [import](https://docs.python.org/3/reference/simple_stmts.html#import) statements. Consider this code:

**import** **sound.effects.echo**

**import** **sound.effects.surround**

**from** **sound.effects** **import** \*

In this example, the echo and surround modules are imported in the current namespace because they are defined in the sound.effects package when the from...import statement is executed. (This also works when \_\_all\_\_ is defined.)

Although certain modules are designed to export only names that follow certain patterns when you useimport \*, it is still considered bad practise in production code.

Remember, there is nothing wrong with using from Package import specific\_submodule! In fact, this is the recommended notation unless the importing module needs to use submodules with the same name from different packages.

### 6.4.2. Intra-package References

When packages are structured into subpackages (as with the sound package in the example), you can use absolute imports to refer to submodules of siblings packages. For example, if the modulesound.filters.vocoder needs to use the echo module in the sound.effects package, it can usefrom sound.effects import echo.

You can also write relative imports, with the from module import name form of import statement. These imports use leading dots to indicate the current and parent packages involved in the relative import. From the surround module for example, you might use:

**from** **.** **import** echo

**from** **..** **import** formats

**from** **..filters** **import** equalizer

Note that relative imports are based on the name of the current module. Since the name of the main module is always "\_\_main\_\_", modules intended for use as the main module of a Python application must always use absolute imports.

### 6.4.3. Packages in Multiple Directories

Packages support one more special attribute, [\_\_path\_\_](https://docs.python.org/3/reference/import.html#__path__). This is initialized to be a list containing the name of the directory holding the package’s \_\_init\_\_.py before the code in that file is executed. This variable can be modified; doing so affects future searches for modules and subpackages contained in the package.

While this feature is not often needed, it can be used to extend the set of modules found in a package.

**Footnotes**

|  |  |
| --- | --- |
| [[1]](https://docs.python.org/3/tutorial/modules.html#id1) | 7. Input and Output There are several ways to present the output of a program; data can be printed in a human-readable form, or written to a file for future use. This chapter will discuss some of the possibilities. 7.1. Fancier Output Formatting So far we’ve encountered two ways of writing values: expression statements and the [print()](https://docs.python.org/3/library/functions.html#print)function. (A third way is using the write() method of file objects; the standard output file can be referenced as sys.stdout. See the Library Reference for more information on this.)  Often you’ll want more control over the formatting of your output than simply printing space-separated values. There are two ways to format your output; the first way is to do all the string handling yourself; using string slicing and concatenation operations you can create any layout you can imagine. The string type has some methods that perform useful operations for padding strings to a given column width; these will be discussed shortly. The second way is to use the [str.format()](https://docs.python.org/3/library/stdtypes.html#str.format) method.  The [string](https://docs.python.org/3/library/string.html#module-string) module contains a [Template](https://docs.python.org/3/library/string.html#string.Template) class which offers yet another way to substitute values into strings.  One question remains, of course: how do you convert values to strings? Luckily, Python has ways to convert any value to a string: pass it to the [repr()](https://docs.python.org/3/library/functions.html#repr) or [str()](https://docs.python.org/3/library/stdtypes.html#str) functions.  The [str()](https://docs.python.org/3/library/stdtypes.html#str) function is meant to return representations of values which are fairly human-readable, while [repr()](https://docs.python.org/3/library/functions.html#repr) is meant to generate representations which can be read by the interpreter (or will force a[SyntaxError](https://docs.python.org/3/library/exceptions.html#SyntaxError) if there is no equivalent syntax). For objects which don’t have a particular representation for human consumption, [str()](https://docs.python.org/3/library/stdtypes.html#str) will return the same value as [repr()](https://docs.python.org/3/library/functions.html#repr). Many values, such as numbers or structures like lists and dictionaries, have the same representation using either function. Strings, in particular, have two distinct representations.  Some examples:  >>>  **>>>** s = 'Hello, world.'  **>>>** str(s)  'Hello, world.'  **>>>** repr(s)  "'Hello, world.'"  **>>>** str(1/7)  '0.14285714285714285'  **>>>** x = 10 \* 3.25  **>>>** y = 200 \* 200  **>>>** s = 'The value of x is ' + repr(x) + ', and y is ' + repr(y) + '...'  **>>>** print(s)  The value of x is 32.5, and y is 40000...  **>>>** *# The repr() of a string adds string quotes and backslashes:*  **...** hello = 'hello, world**\n**'  **>>>** hellos = repr(hello)  **>>>** print(hellos)  'hello, world\n'  **>>>** *# The argument to repr() may be any Python object:*  **...** repr((x, y, ('spam', 'eggs')))  "(32.5, 40000, ('spam', 'eggs'))"  Here are two ways to write a table of squares and cubes:  >>>  **>>> for** x **in** range(1, 11):  **...**  print(repr(x).rjust(2), repr(x\*x).rjust(3), end=' ')  **...**  *# Note use of 'end' on previous line*  **...**  print(repr(x\*x\*x).rjust(4))  **...**  1 1 1  2 4 8  3 9 27  4 16 64  5 25 125  6 36 216  7 49 343  8 64 512  9 81 729  10 100 1000  **>>> for** x **in** range(1, 11):  **...**  print('*{0:2d}* *{1:3d}* *{2:4d}*'.format(x, x\*x, x\*x\*x))  **...**  1 1 1  2 4 8  3 9 27  4 16 64  5 25 125  6 36 216  7 49 343  8 64 512  9 81 729  10 100 1000  (Note that in the first example, one space between each column was added by the way [print()](https://docs.python.org/3/library/functions.html#print)works: it always adds spaces between its arguments.)  This example demonstrates the [str.rjust()](https://docs.python.org/3/library/stdtypes.html#str.rjust) method of string objects, which right-justifies a string in a field of a given width by padding it with spaces on the left. There are similar methods [str.ljust()](https://docs.python.org/3/library/stdtypes.html#str.ljust)and [str.center()](https://docs.python.org/3/library/stdtypes.html#str.center). These methods do not write anything, they just return a new string. If the input string is too long, they don’t truncate it, but return it unchanged; this will mess up your column lay-out but that’s usually better than the alternative, which would be lying about a value. (If you really want truncation you can always add a slice operation, as in x.ljust(n)[:n].)  There is another method, [str.zfill()](https://docs.python.org/3/library/stdtypes.html#str.zfill), which pads a numeric string on the left with zeros. It understands about plus and minus signs:  >>>  **>>>** '12'.zfill(5)  '00012'  **>>>** '-3.14'.zfill(7)  '-003.14'  **>>>** '3.14159265359'.zfill(5)  '3.14159265359'  Basic usage of the [str.format()](https://docs.python.org/3/library/stdtypes.html#str.format) method looks like this:  >>>  **>>>** print('We are the *{}* who say "*{}*!"'.format('knights', 'Ni'))  We are the knights who say "Ni!"  The brackets and characters within them (called format fields) are replaced with the objects passed into the [str.format()](https://docs.python.org/3/library/stdtypes.html#str.format) method. A number in the brackets can be used to refer to the position of the object passed into the [str.format()](https://docs.python.org/3/library/stdtypes.html#str.format) method.  >>>  **>>>** print('*{0}* and *{1}*'.format('spam', 'eggs'))  spam and eggs  **>>>** print('*{1}* and *{0}*'.format('spam', 'eggs'))  eggs and spam  If keyword arguments are used in the [str.format()](https://docs.python.org/3/library/stdtypes.html#str.format) method, their values are referred to by using the name of the argument.  >>>  **>>>** print('This *{food}* is *{adjective}*.'.format(  **...**  food='spam', adjective='absolutely horrible'))  This spam is absolutely horrible.  Positional and keyword arguments can be arbitrarily combined:  >>>  **>>>** print('The story of *{0}*, *{1}*, and *{other}*.'.format('Bill', 'Manfred',  other='Georg'))  The story of Bill, Manfred, and Georg.  '!a' (apply [ascii()](https://docs.python.org/3/library/functions.html#ascii)), '!s' (apply [str()](https://docs.python.org/3/library/stdtypes.html#str)) and '!r' (apply [repr()](https://docs.python.org/3/library/functions.html#repr)) can be used to convert the value before it is formatted:  >>>  **>>>** contents = 'eels'  **>>>** print('My hovercraft is full of *{}*.'.format(contents))  My hovercraft is full of eels.  **>>>** print('My hovercraft is full of *{!r}*.'.format(contents))  My hovercraft is full of 'eels'.  An optional ':' and format specifier can follow the field name. This allows greater control over how the value is formatted. The following example rounds Pi to three places after the decimal.  >>>  **>>> import** **math**  **>>>** print('The value of PI is approximately *{0:.3f}*.'.format(math.pi))  The value of PI is approximately 3.142.  Passing an integer after the ':' will cause that field to be a minimum number of characters wide. This is useful for making tables pretty.  >>>  **>>>** table = {'Sjoerd': 4127, 'Jack': 4098, 'Dcab': 7678}  **>>> for** name, phone **in** table.items():  **...**  print('*{0:10}* ==> *{1:10d}*'.format(name, phone))  **...**  Jack ==> 4098  Dcab ==> 7678  Sjoerd ==> 4127  If you have a really long format string that you don’t want to split up, it would be nice if you could reference the variables to be formatted by name instead of by position. This can be done by simply passing the dict and using square brackets '[]' to access the keys  >>>  **>>>** table = {'Sjoerd': 4127, 'Jack': 4098, 'Dcab': 8637678}  **>>>** print('Jack: *{0[Jack]:d}*; Sjoerd: *{0[Sjoerd]:d}*; '  **...**  'Dcab: *{0[Dcab]:d}*'.format(table))  Jack: 4098; Sjoerd: 4127; Dcab: 8637678  This could also be done by passing the table as keyword arguments with the ‘\*\*’ notation.  >>>  **>>>** table = {'Sjoerd': 4127, 'Jack': 4098, 'Dcab': 8637678}  **>>>** print('Jack: *{Jack:d}*; Sjoerd: *{Sjoerd:d}*; Dcab: *{Dcab:d}*'.format(\*\*table))  Jack: 4098; Sjoerd: 4127; Dcab: 8637678  This is particularly useful in combination with the built-in function [vars()](https://docs.python.org/3/library/functions.html#vars), which returns a dictionary containing all local variables.  For a complete overview of string formatting with [str.format()](https://docs.python.org/3/library/stdtypes.html#str.format), see [Format String Syntax](https://docs.python.org/3/library/string.html#formatstrings). 7.1.1. Old string formatting The % operator can also be used for string formatting. It interprets the left argument much like asprintf()-style format string to be applied to the right argument, and returns the string resulting from this formatting operation. For example:  >>>  **>>> import** **math**  **>>>** print('The value of PI is approximately *%5.3f*.' % math.pi)  The value of PI is approximately 3.142.  More information can be found in the [printf-style String Formatting](https://docs.python.org/3/library/stdtypes.html#old-string-formatting) section. 7.2. Reading and Writing Files [open()](https://docs.python.org/3/library/functions.html#open) returns a [file object](https://docs.python.org/3/glossary.html#term-file-object), and is most commonly used with two arguments: open(filename,mode).  >>>  **>>>** f = open('workfile', 'w')  The first argument is a string containing the filename. The second argument is another string containing a few characters describing the way in which the file will be used. mode can be 'r' when the file will only be read, 'w' for only writing (an existing file with the same name will be erased), and'a' opens the file for appending; any data written to the file is automatically added to the end. 'r+'opens the file for both reading and writing. The mode argument is optional; 'r' will be assumed if it’s omitted.  Normally, files are opened in text mode, that means, you read and write strings from and to the file, which are encoded in a specific encoding. If encoding is not specified, the default is platform dependent (see [open()](https://docs.python.org/3/library/functions.html#open)). 'b' appended to the mode opens the file in binary mode: now the data is read and written in the form of bytes objects. This mode should be used for all files that don’t contain text.  In text mode, the default when reading is to convert platform-specific line endings (\n on Unix, \r\non Windows) to just \n. When writing in text mode, the default is to convert occurrences of \n back to platform-specific line endings. This behind-the-scenes modification to file data is fine for text files, but will corrupt binary data like that in JPEG or EXE files. Be very careful to use binary mode when reading and writing such files. 7.2.1. Methods of File Objects The rest of the examples in this section will assume that a file object called f has already been created.  To read a file’s contents, call f.read(size), which reads some quantity of data and returns it as a string (in text mode) or bytes object (in binary mode). size is an optional numeric argument. When sizeis omitted or negative, the entire contents of the file will be read and returned; it’s your problem if the file is twice as large as your machine’s memory. Otherwise, at most size bytes are read and returned. If the end of the file has been reached, f.read() will return an empty string ('').  >>>  **>>>** f.read()  'This is the entire file.\n'  **>>>** f.read()  ''  f.readline() reads a single line from the file; a newline character (\n) is left at the end of the string, and is only omitted on the last line of the file if the file doesn’t end in a newline. This makes the return value unambiguous; if f.readline() returns an empty string, the end of the file has been reached, while a blank line is represented by '\n', a string containing only a single newline.  >>>  **>>>** f.readline()  'This is the first line of the file.\n'  **>>>** f.readline()  'Second line of the file\n'  **>>>** f.readline()  ''  For reading lines from a file, you can loop over the file object. This is memory efficient, fast, and leads to simple code:  >>>  **>>> for** line **in** f:  **...**  print(line, end='')  **...**  This is the first line of the file.  Second line of the file  If you want to read all the lines of a file in a list you can also use list(f) or f.readlines().  f.write(string) writes the contents of string to the file, returning the number of characters written.  >>>  **>>>** f.write('This is a test**\n**')  15  Other types of objects need to be converted – either to a string (in text mode) or a bytes object (in binary mode) – before writing them:  >>>  **>>>** value = ('the answer', 42)  **>>>** s = str(value) *# convert the tuple to string*  **>>>** f.write(s)  18  f.tell() returns an integer giving the file object’s current position in the file represented as number of bytes from the beginning of the file when in binary mode and an opaque number when in text mode.  To change the file object’s position, use f.seek(offset, from\_what). The position is computed from adding offset to a reference point; the reference point is selected by the from\_what argument. Afrom\_what value of 0 measures from the beginning of the file, 1 uses the current file position, and 2 uses the end of the file as the reference point. from\_what can be omitted and defaults to 0, using the beginning of the file as the reference point.  >>>  **>>>** f = open('workfile', 'rb+')  **>>>** f.write(b'0123456789abcdef')  16  **>>>** f.seek(5) *# Go to the 6th byte in the file*  5  **>>>** f.read(1)  b'5'  **>>>** f.seek(-3, 2) *# Go to the 3rd byte before the end*  13  **>>>** f.read(1)  b'd'  In text files (those opened without a b in the mode string), only seeks relative to the beginning of the file are allowed (the exception being seeking to the very file end with seek(0, 2)) and the only validoffset values are those returned from the f.tell(), or zero. Any other offset value produces undefined behaviour.  When you’re done with a file, call f.close() to close it and free up any system resources taken up by the open file. After calling f.close(), attempts to use the file object will automatically fail.  >>>  **>>>** f.close()  **>>>** f.read()  Traceback (most recent call last):  File "<stdin>", line 1, in ?  ValueError: I/O operation on closed file  It is good practice to use the [with](https://docs.python.org/3/reference/compound_stmts.html#with) keyword when dealing with file objects. This has the advantage that the file is properly closed after its suite finishes, even if an exception is raised on the way. It is also much shorter than writing equivalent [try](https://docs.python.org/3/reference/compound_stmts.html#try)-[finally](https://docs.python.org/3/reference/compound_stmts.html#finally) blocks:  >>>  **>>> with** open('workfile', 'r') **as** f:  **...**  read\_data = f.read()  **>>>** f.closed  True  File objects have some additional methods, such as isatty() and truncate() which are less frequently used; consult the Library Reference for a complete guide to file objects. 7.2.2. Saving structured data with [json](https://docs.python.org/3/library/json.html#module-json) Strings can easily be written to and read from a file. Numbers take a bit more effort, since the read()method only returns strings, which will have to be passed to a function like [int()](https://docs.python.org/3/library/functions.html#int), which takes a string like '123' and returns its numeric value 123. When you want to save more complex data types like nested lists and dictionaries, parsing and serializing by hand becomes complicated.  Rather than having users constantly writing and debugging code to save complicated data types to files, Python allows you to use the popular data interchange format called [JSON (JavaScript Object Notation)](http://json.org/). The standard module called [json](https://docs.python.org/3/library/json.html#module-json) can take Python data hierarchies, and convert them to string representations; this process is called serializing. Reconstructing the data from the string representation is called deserializing. Between serializing and deserializing, the string representing the object may have been stored in a file or data, or sent over a network connection to some distant machine.  **Note**    The JSON format is commonly used by modern applications to allow for data exchange. Many programmers are already familiar with it, which makes it a good choice for interoperability.  If you have an object x, you can view its JSON string representation with a simple line of code:  >>>  **>>>** json.dumps([1, 'simple', 'list'])  '[1, "simple", "list"]'  Another variant of the [dumps()](https://docs.python.org/3/library/json.html#json.dumps) function, called [dump()](https://docs.python.org/3/library/json.html#json.dump), simply serializes the object to a [text file](https://docs.python.org/3/glossary.html#term-text-file). So iff is a [text file](https://docs.python.org/3/glossary.html#term-text-file) object opened for writing, we can do this:  json.dump(x, f)  To decode the object again, if f is a [text file](https://docs.python.org/3/glossary.html#term-text-file) object which has been opened for reading:  x = json.load(f)  This simple serialization technique can handle lists and dictionaries, but serializing arbitrary class instances in JSON requires a bit of extra effort. The reference for the [json](https://docs.python.org/3/library/json.html#module-json) module contains an explanation of this.  **See also**    [pickle](https://docs.python.org/3/library/pickle.html#module-pickle) - the pickle module  Contrary to [JSON](https://docs.python.org/3/tutorial/inputoutput.html#tut-json), pickle is a protocol which allows the serialization of arbitrarily complex Python objects. As such, it is specific to Python and cannot be used to communicate with applications written in other languages. It is also insecure by default: deserializing pickle data coming from an untrusted source can execute arbitrary code, if the data was crafted by a skilled attacker. 7. Input and Output There are several ways to present the output of a program; data can be printed in a human-readable form, or written to a file for future use. This chapter will discuss some of the possibilities. 7.1. Fancier Output Formatting So far we’ve encountered two ways of writing values: expression statements and the [print()](https://docs.python.org/3/library/functions.html#print)function. (A third way is using the write() method of file objects; the standard output file can be referenced as sys.stdout. See the Library Reference for more information on this.)  Often you’ll want more control over the formatting of your output than simply printing space-separated values. There are two ways to format your output; the first way is to do all the string handling yourself; using string slicing and concatenation operations you can create any layout you can imagine. The string type has some methods that perform useful operations for padding strings to a given column width; these will be discussed shortly. The second way is to use the [str.format()](https://docs.python.org/3/library/stdtypes.html#str.format) method.  The [string](https://docs.python.org/3/library/string.html#module-string) module contains a [Template](https://docs.python.org/3/library/string.html#string.Template) class which offers yet another way to substitute values into strings.  One question remains, of course: how do you convert values to strings? Luckily, Python has ways to convert any value to a string: pass it to the [repr()](https://docs.python.org/3/library/functions.html#repr) or [str()](https://docs.python.org/3/library/stdtypes.html#str) functions.  The [str()](https://docs.python.org/3/library/stdtypes.html#str) function is meant to return representations of values which are fairly human-readable, while [repr()](https://docs.python.org/3/library/functions.html#repr) is meant to generate representations which can be read by the interpreter (or will force a[SyntaxError](https://docs.python.org/3/library/exceptions.html#SyntaxError) if there is no equivalent syntax). For objects which don’t have a particular representation for human consumption, [str()](https://docs.python.org/3/library/stdtypes.html#str) will return the same value as [repr()](https://docs.python.org/3/library/functions.html#repr). Many values, such as numbers or structures like lists and dictionaries, have the same representation using either function. Strings, in particular, have two distinct representations.  Some examples:  >>>  **>>>** s = 'Hello, world.'  **>>>** str(s)  'Hello, world.'  **>>>** repr(s)  "'Hello, world.'"  **>>>** str(1/7)  '0.14285714285714285'  **>>>** x = 10 \* 3.25  **>>>** y = 200 \* 200  **>>>** s = 'The value of x is ' + repr(x) + ', and y is ' + repr(y) + '...'  **>>>** print(s)  The value of x is 32.5, and y is 40000...  **>>>** *# The repr() of a string adds string quotes and backslashes:*  **...** hello = 'hello, world**\n**'  **>>>** hellos = repr(hello)  **>>>** print(hellos)  'hello, world\n'  **>>>** *# The argument to repr() may be any Python object:*  **...** repr((x, y, ('spam', 'eggs')))  "(32.5, 40000, ('spam', 'eggs'))"  Here are two ways to write a table of squares and cubes:  >>>  **>>> for** x **in** range(1, 11):  **...**  print(repr(x).rjust(2), repr(x\*x).rjust(3), end=' ')  **...**  *# Note use of 'end' on previous line*  **...**  print(repr(x\*x\*x).rjust(4))  **...**  1 1 1  2 4 8  3 9 27  4 16 64  5 25 125  6 36 216  7 49 343  8 64 512  9 81 729  10 100 1000  **>>> for** x **in** range(1, 11):  **...**  print('*{0:2d}* *{1:3d}* *{2:4d}*'.format(x, x\*x, x\*x\*x))  **...**  1 1 1  2 4 8  3 9 27  4 16 64  5 25 125  6 36 216  7 49 343  8 64 512  9 81 729  10 100 1000  (Note that in the first example, one space between each column was added by the way [print()](https://docs.python.org/3/library/functions.html#print)works: it always adds spaces between its arguments.)  This example demonstrates the [str.rjust()](https://docs.python.org/3/library/stdtypes.html#str.rjust) method of string objects, which right-justifies a string in a field of a given width by padding it with spaces on the left. There are similar methods [str.ljust()](https://docs.python.org/3/library/stdtypes.html#str.ljust)and [str.center()](https://docs.python.org/3/library/stdtypes.html#str.center). These methods do not write anything, they just return a new string. If the input string is too long, they don’t truncate it, but return it unchanged; this will mess up your column lay-out but that’s usually better than the alternative, which would be lying about a value. (If you really want truncation you can always add a slice operation, as in x.ljust(n)[:n].)  There is another method, [str.zfill()](https://docs.python.org/3/library/stdtypes.html#str.zfill), which pads a numeric string on the left with zeros. It understands about plus and minus signs:  >>>  **>>>** '12'.zfill(5)  '00012'  **>>>** '-3.14'.zfill(7)  '-003.14'  **>>>** '3.14159265359'.zfill(5)  '3.14159265359'  Basic usage of the [str.format()](https://docs.python.org/3/library/stdtypes.html#str.format) method looks like this:  >>>  **>>>** print('We are the *{}* who say "*{}*!"'.format('knights', 'Ni'))  We are the knights who say "Ni!"  The brackets and characters within them (called format fields) are replaced with the objects passed into the [str.format()](https://docs.python.org/3/library/stdtypes.html#str.format) method. A number in the brackets can be used to refer to the position of the object passed into the [str.format()](https://docs.python.org/3/library/stdtypes.html#str.format) method.  >>>  **>>>** print('*{0}* and *{1}*'.format('spam', 'eggs'))  spam and eggs  **>>>** print('*{1}* and *{0}*'.format('spam', 'eggs'))  eggs and spam  If keyword arguments are used in the [str.format()](https://docs.python.org/3/library/stdtypes.html#str.format) method, their values are referred to by using the name of the argument.  >>>  **>>>** print('This *{food}* is *{adjective}*.'.format(  **...**  food='spam', adjective='absolutely horrible'))  This spam is absolutely horrible.  Positional and keyword arguments can be arbitrarily combined:  >>>  **>>>** print('The story of *{0}*, *{1}*, and *{other}*.'.format('Bill', 'Manfred',  other='Georg'))  The story of Bill, Manfred, and Georg.  '!a' (apply [ascii()](https://docs.python.org/3/library/functions.html#ascii)), '!s' (apply [str()](https://docs.python.org/3/library/stdtypes.html#str)) and '!r' (apply [repr()](https://docs.python.org/3/library/functions.html#repr)) can be used to convert the value before it is formatted:  >>>  **>>>** contents = 'eels'  **>>>** print('My hovercraft is full of *{}*.'.format(contents))  My hovercraft is full of eels.  **>>>** print('My hovercraft is full of *{!r}*.'.format(contents))  My hovercraft is full of 'eels'.  An optional ':' and format specifier can follow the field name. This allows greater control over how the value is formatted. The following example rounds Pi to three places after the decimal.  >>>  **>>> import** **math**  **>>>** print('The value of PI is approximately *{0:.3f}*.'.format(math.pi))  The value of PI is approximately 3.142.  Passing an integer after the ':' will cause that field to be a minimum number of characters wide. This is useful for making tables pretty.  >>>  **>>>** table = {'Sjoerd': 4127, 'Jack': 4098, 'Dcab': 7678}  **>>> for** name, phone **in** table.items():  **...**  print('*{0:10}* ==> *{1:10d}*'.format(name, phone))  **...**  Jack ==> 4098  Dcab ==> 7678  Sjoerd ==> 4127  If you have a really long format string that you don’t want to split up, it would be nice if you could reference the variables to be formatted by name instead of by position. This can be done by simply passing the dict and using square brackets '[]' to access the keys  >>>  **>>>** table = {'Sjoerd': 4127, 'Jack': 4098, 'Dcab': 8637678}  **>>>** print('Jack: *{0[Jack]:d}*; Sjoerd: *{0[Sjoerd]:d}*; '  **...**  'Dcab: *{0[Dcab]:d}*'.format(table))  Jack: 4098; Sjoerd: 4127; Dcab: 8637678  This could also be done by passing the table as keyword arguments with the ‘\*\*’ notation.  >>>  **>>>** table = {'Sjoerd': 4127, 'Jack': 4098, 'Dcab': 8637678}  **>>>** print('Jack: *{Jack:d}*; Sjoerd: *{Sjoerd:d}*; Dcab: *{Dcab:d}*'.format(\*\*table))  Jack: 4098; Sjoerd: 4127; Dcab: 8637678  This is particularly useful in combination with the built-in function [vars()](https://docs.python.org/3/library/functions.html#vars), which returns a dictionary containing all local variables.  For a complete overview of string formatting with [str.format()](https://docs.python.org/3/library/stdtypes.html#str.format), see [Format String Syntax](https://docs.python.org/3/library/string.html#formatstrings). 7.1.1. Old string formatting The % operator can also be used for string formatting. It interprets the left argument much like asprintf()-style format string to be applied to the right argument, and returns the string resulting from this formatting operation. For example:  >>>  **>>> import** **math**  **>>>** print('The value of PI is approximately *%5.3f*.' % math.pi)  The value of PI is approximately 3.142.  More information can be found in the [printf-style String Formatting](https://docs.python.org/3/library/stdtypes.html#old-string-formatting) section. 7.2. Reading and Writing Files [open()](https://docs.python.org/3/library/functions.html#open) returns a [file object](https://docs.python.org/3/glossary.html#term-file-object), and is most commonly used with two arguments: open(filename,mode).  >>>  **>>>** f = open('workfile', 'w')  The first argument is a string containing the filename. The second argument is another string containing a few characters describing the way in which the file will be used. mode can be 'r' when the file will only be read, 'w' for only writing (an existing file with the same name will be erased), and'a' opens the file for appending; any data written to the file is automatically added to the end. 'r+'opens the file for both reading and writing. The mode argument is optional; 'r' will be assumed if it’s omitted.  Normally, files are opened in text mode, that means, you read and write strings from and to the file, which are encoded in a specific encoding. If encoding is not specified, the default is platform dependent (see [open()](https://docs.python.org/3/library/functions.html#open)). 'b' appended to the mode opens the file in binary mode: now the data is read and written in the form of bytes objects. This mode should be used for all files that don’t contain text.  In text mode, the default when reading is to convert platform-specific line endings (\n on Unix, \r\non Windows) to just \n. When writing in text mode, the default is to convert occurrences of \n back to platform-specific line endings. This behind-the-scenes modification to file data is fine for text files, but will corrupt binary data like that in JPEG or EXE files. Be very careful to use binary mode when reading and writing such files. 7.2.1. Methods of File Objects The rest of the examples in this section will assume that a file object called f has already been created.  To read a file’s contents, call f.read(size), which reads some quantity of data and returns it as a string (in text mode) or bytes object (in binary mode). size is an optional numeric argument. When sizeis omitted or negative, the entire contents of the file will be read and returned; it’s your problem if the file is twice as large as your machine’s memory. Otherwise, at most size bytes are read and returned. If the end of the file has been reached, f.read() will return an empty string ('').  >>>  **>>>** f.read()  'This is the entire file.\n'  **>>>** f.read()  ''  f.readline() reads a single line from the file; a newline character (\n) is left at the end of the string, and is only omitted on the last line of the file if the file doesn’t end in a newline. This makes the return value unambiguous; if f.readline() returns an empty string, the end of the file has been reached, while a blank line is represented by '\n', a string containing only a single newline.  >>>  **>>>** f.readline()  'This is the first line of the file.\n'  **>>>** f.readline()  'Second line of the file\n'  **>>>** f.readline()  ''  For reading lines from a file, you can loop over the file object. This is memory efficient, fast, and leads to simple code:  >>>  **>>> for** line **in** f:  **...**  print(line, end='')  **...**  This is the first line of the file.  Second line of the file  If you want to read all the lines of a file in a list you can also use list(f) or f.readlines().  f.write(string) writes the contents of string to the file, returning the number of characters written.  >>>  **>>>** f.write('This is a test**\n**')  15  Other types of objects need to be converted – either to a string (in text mode) or a bytes object (in binary mode) – before writing them:  >>>  **>>>** value = ('the answer', 42)  **>>>** s = str(value) *# convert the tuple to string*  **>>>** f.write(s)  18  f.tell() returns an integer giving the file object’s current position in the file represented as number of bytes from the beginning of the file when in binary mode and an opaque number when in text mode.  To change the file object’s position, use f.seek(offset, from\_what). The position is computed from adding offset to a reference point; the reference point is selected by the from\_what argument. Afrom\_what value of 0 measures from the beginning of the file, 1 uses the current file position, and 2 uses the end of the file as the reference point. from\_what can be omitted and defaults to 0, using the beginning of the file as the reference point.  >>>  **>>>** f = open('workfile', 'rb+')  **>>>** f.write(b'0123456789abcdef')  16  **>>>** f.seek(5) *# Go to the 6th byte in the file*  5  **>>>** f.read(1)  b'5'  **>>>** f.seek(-3, 2) *# Go to the 3rd byte before the end*  13  **>>>** f.read(1)  b'd'  In text files (those opened without a b in the mode string), only seeks relative to the beginning of the file are allowed (the exception being seeking to the very file end with seek(0, 2)) and the only validoffset values are those returned from the f.tell(), or zero. Any other offset value produces undefined behaviour.  When you’re done with a file, call f.close() to close it and free up any system resources taken up by the open file. After calling f.close(), attempts to use the file object will automatically fail.  >>>  **>>>** f.close()  **>>>** f.read()  Traceback (most recent call last):  File "<stdin>", line 1, in ?  ValueError: I/O operation on closed file  It is good practice to use the [with](https://docs.python.org/3/reference/compound_stmts.html#with) keyword when dealing with file objects. This has the advantage that the file is properly closed after its suite finishes, even if an exception is raised on the way. It is also much shorter than writing equivalent [try](https://docs.python.org/3/reference/compound_stmts.html#try)-[finally](https://docs.python.org/3/reference/compound_stmts.html#finally) blocks:  >>>  **>>> with** open('workfile', 'r') **as** f:  **...**  read\_data = f.read()  **>>>** f.closed  True  File objects have some additional methods, such as isatty() and truncate() which are less frequently used; consult the Library Reference for a complete guide to file objects. 7.2.2. Saving structured data with [json](https://docs.python.org/3/library/json.html#module-json) Strings can easily be written to and read from a file. Numbers take a bit more effort, since the read()method only returns strings, which will have to be passed to a function like [int()](https://docs.python.org/3/library/functions.html#int), which takes a string like '123' and returns its numeric value 123. When you want to save more complex data types like nested lists and dictionaries, parsing and serializing by hand becomes complicated.  Rather than having users constantly writing and debugging code to save complicated data types to files, Python allows you to use the popular data interchange format called [JSON (JavaScript Object Notation)](http://json.org/). The standard module called [json](https://docs.python.org/3/library/json.html#module-json) can take Python data hierarchies, and convert them to string representations; this process is called serializing. Reconstructing the data from the string representation is called deserializing. Between serializing and deserializing, the string representing the object may have been stored in a file or data, or sent over a network connection to some distant machine.  **Note**    The JSON format is commonly used by modern applications to allow for data exchange. Many programmers are already familiar with it, which makes it a good choice for interoperability.  If you have an object x, you can view its JSON string representation with a simple line of code:  >>>  **>>>** json.dumps([1, 'simple', 'list'])  '[1, "simple", "list"]'  Another variant of the [dumps()](https://docs.python.org/3/library/json.html#json.dumps) function, called [dump()](https://docs.python.org/3/library/json.html#json.dump), simply serializes the object to a [text file](https://docs.python.org/3/glossary.html#term-text-file). So iff is a [text file](https://docs.python.org/3/glossary.html#term-text-file) object opened for writing, we can do this:  json.dump(x, f)  To decode the object again, if f is a [text file](https://docs.python.org/3/glossary.html#term-text-file) object which has been opened for reading:  x = json.load(f)  This simple serialization technique can handle lists and dictionaries, but serializing arbitrary class instances in JSON requires a bit of extra effort. The reference for the [json](https://docs.python.org/3/library/json.html#module-json) module contains an explanation of this.  **See also**    [pickle](https://docs.python.org/3/library/pickle.html#module-pickle) - the pickle module  Contrary to [JSON](https://docs.python.org/3/tutorial/inputoutput.html#tut-json), pickle is a protocol which allows the serialization of arbitrarily complex Python objects. As such, it is specific to Python and cannot be used to communicate with applications written in other languages. It is also insecure by default: deserializing pickle data coming from an untrusted source can execute arbitrary code, if the data was crafted by a skilled attacker. 7. Input and Output There are several ways to present the output of a program; data can be printed in a human-readable form, or written to a file for future use. This chapter will discuss some of the possibilities. 7.1. Fancier Output Formatting So far we’ve encountered two ways of writing values: expression statements and the [print()](https://docs.python.org/3/library/functions.html#print)function. (A third way is using the write() method of file objects; the standard output file can be referenced as sys.stdout. See the Library Reference for more information on this.)  Often you’ll want more control over the formatting of your output than simply printing space-separated values. There are two ways to format your output; the first way is to do all the string handling yourself; using string slicing and concatenation operations you can create any layout you can imagine. The string type has some methods that perform useful operations for padding strings to a given column width; these will be discussed shortly. The second way is to use the [str.format()](https://docs.python.org/3/library/stdtypes.html#str.format) method.  The [string](https://docs.python.org/3/library/string.html#module-string) module contains a [Template](https://docs.python.org/3/library/string.html#string.Template) class which offers yet another way to substitute values into strings.  One question remains, of course: how do you convert values to strings? Luckily, Python has ways to convert any value to a string: pass it to the [repr()](https://docs.python.org/3/library/functions.html#repr) or [str()](https://docs.python.org/3/library/stdtypes.html#str) functions.  The [str()](https://docs.python.org/3/library/stdtypes.html#str) function is meant to return representations of values which are fairly human-readable, while [repr()](https://docs.python.org/3/library/functions.html#repr) is meant to generate representations which can be read by the interpreter (or will force a[SyntaxError](https://docs.python.org/3/library/exceptions.html#SyntaxError) if there is no equivalent syntax). For objects which don’t have a particular representation for human consumption, [str()](https://docs.python.org/3/library/stdtypes.html#str) will return the same value as [repr()](https://docs.python.org/3/library/functions.html#repr). Many values, such as numbers or structures like lists and dictionaries, have the same representation using either function. Strings, in particular, have two distinct representations.  Some examples:  >>>  **>>>** s = 'Hello, world.'  **>>>** str(s)  'Hello, world.'  **>>>** repr(s)  "'Hello, world.'"  **>>>** str(1/7)  '0.14285714285714285'  **>>>** x = 10 \* 3.25  **>>>** y = 200 \* 200  **>>>** s = 'The value of x is ' + repr(x) + ', and y is ' + repr(y) + '...'  **>>>** print(s)  The value of x is 32.5, and y is 40000...  **>>>** *# The repr() of a string adds string quotes and backslashes:*  **...** hello = 'hello, world**\n**'  **>>>** hellos = repr(hello)  **>>>** print(hellos)  'hello, world\n'  **>>>** *# The argument to repr() may be any Python object:*  **...** repr((x, y, ('spam', 'eggs')))  "(32.5, 40000, ('spam', 'eggs'))"  Here are two ways to write a table of squares and cubes:  >>>  **>>> for** x **in** range(1, 11):  **...**  print(repr(x).rjust(2), repr(x\*x).rjust(3), end=' ')  **...**  *# Note use of 'end' on previous line*  **...**  print(repr(x\*x\*x).rjust(4))  **...**  1 1 1  2 4 8  3 9 27  4 16 64  5 25 125  6 36 216  7 49 343  8 64 512  9 81 729  10 100 1000  **>>> for** x **in** range(1, 11):  **...**  print('*{0:2d}* *{1:3d}* *{2:4d}*'.format(x, x\*x, x\*x\*x))  **...**  1 1 1  2 4 8  3 9 27  4 16 64  5 25 125  6 36 216  7 49 343  8 64 512  9 81 729  10 100 1000  (Note that in the first example, one space between each column was added by the way [print()](https://docs.python.org/3/library/functions.html#print)works: it always adds spaces between its arguments.)  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It understands about plus and minus signs:  >>>  **>>>** '12'.zfill(5)  '00012'  **>>>** '-3.14'.zfill(7)  '-003.14'  **>>>** '3.14159265359'.zfill(5)  '3.14159265359'  Basic usage of the [str.format()](https://docs.python.org/3/library/stdtypes.html#str.format) method looks like this:  >>>  **>>>** print('We are the *{}* who say "*{}*!"'.format('knights', 'Ni'))  We are the knights who say "Ni!"  The brackets and characters within them (called format fields) are replaced with the objects passed into the [str.format()](https://docs.python.org/3/library/stdtypes.html#str.format) method. A number in the brackets can be used to refer to the position of the object passed into the [str.format()](https://docs.python.org/3/library/stdtypes.html#str.format) method.  >>>  **>>>** print('*{0}* and *{1}*'.format('spam', 'eggs'))  spam and eggs  **>>>** print('*{1}* and *{0}*'.format('spam', 'eggs'))  eggs and spam  If keyword arguments are used in the [str.format()](https://docs.python.org/3/library/stdtypes.html#str.format) method, their values are referred to by using the name of the argument.  >>>  **>>>** print('This *{food}* is *{adjective}*.'.format(  **...**  food='spam', adjective='absolutely horrible'))  This spam is absolutely horrible.  Positional and keyword arguments can be arbitrarily combined:  >>>  **>>>** print('The story of *{0}*, *{1}*, and *{other}*.'.format('Bill', 'Manfred',  other='Georg'))  The story of Bill, Manfred, and Georg.  '!a' (apply [ascii()](https://docs.python.org/3/library/functions.html#ascii)), '!s' (apply [str()](https://docs.python.org/3/library/stdtypes.html#str)) and '!r' (apply [repr()](https://docs.python.org/3/library/functions.html#repr)) can be used to convert the value before it is formatted:  >>>  **>>>** contents = 'eels'  **>>>** print('My hovercraft is full of *{}*.'.format(contents))  My hovercraft is full of eels.  **>>>** print('My hovercraft is full of *{!r}*.'.format(contents))  My hovercraft is full of 'eels'.  An optional ':' and format specifier can follow the field name. This allows greater control over how the value is formatted. The following example rounds Pi to three places after the decimal.  >>>  **>>> import** **math**  **>>>** print('The value of PI is approximately *{0:.3f}*.'.format(math.pi))  The value of PI is approximately 3.142.  Passing an integer after the ':' will cause that field to be a minimum number of characters wide. This is useful for making tables pretty.  >>>  **>>>** table = {'Sjoerd': 4127, 'Jack': 4098, 'Dcab': 7678}  **>>> for** name, phone **in** table.items():  **...**  print('*{0:10}* ==> *{1:10d}*'.format(name, phone))  **...**  Jack ==> 4098  Dcab ==> 7678  Sjoerd ==> 4127  If you have a really long format string that you don’t want to split up, it would be nice if you could reference the variables to be formatted by name instead of by position. This can be done by simply passing the dict and using square brackets '[]' to access the keys  >>>  **>>>** table = {'Sjoerd': 4127, 'Jack': 4098, 'Dcab': 8637678}  **>>>** print('Jack: *{0[Jack]:d}*; Sjoerd: *{0[Sjoerd]:d}*; '  **...**  'Dcab: *{0[Dcab]:d}*'.format(table))  Jack: 4098; Sjoerd: 4127; Dcab: 8637678  This could also be done by passing the table as keyword arguments with the ‘\*\*’ notation.  >>>  **>>>** table = {'Sjoerd': 4127, 'Jack': 4098, 'Dcab': 8637678}  **>>>** print('Jack: *{Jack:d}*; Sjoerd: *{Sjoerd:d}*; Dcab: *{Dcab:d}*'.format(\*\*table))  Jack: 4098; Sjoerd: 4127; Dcab: 8637678  This is particularly useful in combination with the built-in function [vars()](https://docs.python.org/3/library/functions.html#vars), which returns a dictionary containing all local variables.  For a complete overview of string formatting with [str.format()](https://docs.python.org/3/library/stdtypes.html#str.format), see [Format String Syntax](https://docs.python.org/3/library/string.html#formatstrings). 7.1.1. Old string formatting The % operator can also be used for string formatting. It interprets the left argument much like asprintf()-style format string to be applied to the right argument, and returns the string resulting from this formatting operation. For example:  >>>  **>>> import** **math**  **>>>** print('The value of PI is approximately *%5.3f*.' % math.pi)  The value of PI is approximately 3.142.  More information can be found in the [printf-style String Formatting](https://docs.python.org/3/library/stdtypes.html#old-string-formatting) section. 7.2. Reading and Writing Files [open()](https://docs.python.org/3/library/functions.html#open) returns a [file object](https://docs.python.org/3/glossary.html#term-file-object), and is most commonly used with two arguments: open(filename,mode).  >>>  **>>>** f = open('workfile', 'w')  The first argument is a string containing the filename. The second argument is another string containing a few characters describing the way in which the file will be used. mode can be 'r' when the file will only be read, 'w' for only writing (an existing file with the same name will be erased), and'a' opens the file for appending; any data written to the file is automatically added to the end. 'r+'opens the file for both reading and writing. The mode argument is optional; 'r' will be assumed if it’s omitted.  Normally, files are opened in text mode, that means, you read and write strings from and to the file, which are encoded in a specific encoding. If encoding is not specified, the default is platform dependent (see [open()](https://docs.python.org/3/library/functions.html#open)). 'b' appended to the mode opens the file in binary mode: now the data is read and written in the form of bytes objects. This mode should be used for all files that don’t contain text.  In text mode, the default when reading is to convert platform-specific line endings (\n on Unix, \r\non Windows) to just \n. When writing in text mode, the default is to convert occurrences of \n back to platform-specific line endings. This behind-the-scenes modification to file data is fine for text files, but will corrupt binary data like that in JPEG or EXE files. Be very careful to use binary mode when reading and writing such files. 7.2.1. Methods of File Objects The rest of the examples in this section will assume that a file object called f has already been created.  To read a file’s contents, call f.read(size), which reads some quantity of data and returns it as a string (in text mode) or bytes object (in binary mode). size is an optional numeric argument. When sizeis omitted or negative, the entire contents of the file will be read and returned; it’s your problem if the file is twice as large as your machine’s memory. Otherwise, at most size bytes are read and returned. If the end of the file has been reached, f.read() will return an empty string ('').  >>>  **>>>** f.read()  'This is the entire file.\n'  **>>>** f.read()  ''  f.readline() reads a single line from the file; a newline character (\n) is left at the end of the string, and is only omitted on the last line of the file if the file doesn’t end in a newline. This makes the return value unambiguous; if f.readline() returns an empty string, the end of the file has been reached, while a blank line is represented by '\n', a string containing only a single newline.  >>>  **>>>** f.readline()  'This is the first line of the file.\n'  **>>>** f.readline()  'Second line of the file\n'  **>>>** f.readline()  ''  For reading lines from a file, you can loop over the file object. This is memory efficient, fast, and leads to simple code:  >>>  **>>> for** line **in** f:  **...**  print(line, end='')  **...**  This is the first line of the file.  Second line of the file  If you want to read all the lines of a file in a list you can also use list(f) or f.readlines().  f.write(string) writes the contents of string to the file, returning the number of characters written.  >>>  **>>>** f.write('This is a test**\n**')  15  Other types of objects need to be converted – either to a string (in text mode) or a bytes object (in binary mode) – before writing them:  >>>  **>>>** value = ('the answer', 42)  **>>>** s = str(value) *# convert the tuple to string*  **>>>** f.write(s)  18  f.tell() returns an integer giving the file object’s current position in the file represented as number of bytes from the beginning of the file when in binary mode and an opaque number when in text mode.  To change the file object’s position, use f.seek(offset, from\_what). The position is computed from adding offset to a reference point; the reference point is selected by the from\_what argument. Afrom\_what value of 0 measures from the beginning of the file, 1 uses the current file position, and 2 uses the end of the file as the reference point. from\_what can be omitted and defaults to 0, using the beginning of the file as the reference point.  >>>  **>>>** f = open('workfile', 'rb+')  **>>>** f.write(b'0123456789abcdef')  16  **>>>** f.seek(5) *# Go to the 6th byte in the file*  5  **>>>** f.read(1)  b'5'  **>>>** f.seek(-3, 2) *# Go to the 3rd byte before the end*  13  **>>>** f.read(1)  b'd'  In text files (those opened without a b in the mode string), only seeks relative to the beginning of the file are allowed (the exception being seeking to the very file end with seek(0, 2)) and the only validoffset values are those returned from the f.tell(), or zero. Any other offset value produces undefined behaviour.  When you’re done with a file, call f.close() to close it and free up any system resources taken up by the open file. After calling f.close(), attempts to use the file object will automatically fail.  >>>  **>>>** f.close()  **>>>** f.read()  Traceback (most recent call last):  File "<stdin>", line 1, in ?  ValueError: I/O operation on closed file  It is good practice to use the [with](https://docs.python.org/3/reference/compound_stmts.html#with) keyword when dealing with file objects. This has the advantage that the file is properly closed after its suite finishes, even if an exception is raised on the way. It is also much shorter than writing equivalent [try](https://docs.python.org/3/reference/compound_stmts.html#try)-[finally](https://docs.python.org/3/reference/compound_stmts.html#finally) blocks:  >>>  **>>> with** open('workfile', 'r') **as** f:  **...**  read\_data = f.read()  **>>>** f.closed  True  File objects have some additional methods, such as isatty() and truncate() which are less frequently used; consult the Library Reference for a complete guide to file objects. 7.2.2. Saving structured data with [json](https://docs.python.org/3/library/json.html#module-json) Strings can easily be written to and read from a file. Numbers take a bit more effort, since the read()method only returns strings, which will have to be passed to a function like [int()](https://docs.python.org/3/library/functions.html#int), which takes a string like '123' and returns its numeric value 123. When you want to save more complex data types like nested lists and dictionaries, parsing and serializing by hand becomes complicated.  Rather than having users constantly writing and debugging code to save complicated data types to files, Python allows you to use the popular data interchange format called [JSON (JavaScript Object Notation)](http://json.org/). The standard module called [json](https://docs.python.org/3/library/json.html#module-json) can take Python data hierarchies, and convert them to string representations; this process is called serializing. Reconstructing the data from the string representation is called deserializing. Between serializing and deserializing, the string representing the object may have been stored in a file or data, or sent over a network connection to some distant machine.  **Note**    The JSON format is commonly used by modern applications to allow for data exchange. Many programmers are already familiar with it, which makes it a good choice for interoperability.  If you have an object x, you can view its JSON string representation with a simple line of code:  >>>  **>>>** json.dumps([1, 'simple', 'list'])  '[1, "simple", "list"]'  Another variant of the [dumps()](https://docs.python.org/3/library/json.html#json.dumps) function, called [dump()](https://docs.python.org/3/library/json.html#json.dump), simply serializes the object to a [text file](https://docs.python.org/3/glossary.html#term-text-file). So iff is a [text file](https://docs.python.org/3/glossary.html#term-text-file) object opened for writing, we can do this:  json.dump(x, f)  To decode the object again, if f is a [text file](https://docs.python.org/3/glossary.html#term-text-file) object which has been opened for reading:  x = json.load(f)  This simple serialization technique can handle lists and dictionaries, but serializing arbitrary class instances in JSON requires a bit of extra effort. The reference for the [json](https://docs.python.org/3/library/json.html#module-json) module contains an explanation of this.  **See also**    [pickle](https://docs.python.org/3/library/pickle.html#module-pickle) - the pickle module  Contrary to [JSON](https://docs.python.org/3/tutorial/inputoutput.html#tut-json), pickle is a protocol which allows the serialization of arbitrarily complex Python objects. As such, it is specific to Python and cannot be used to communicate with applications written in other languages. It is also insecure by default: deserializing pickle data coming from an untrusted source can execute arbitrary code, if the data was crafted by a skilled attacker. 7. Input and Output There are several ways to present the output of a program; data can be printed in a human-readable form, or written to a file for future use. This chapter will discuss some of the possibilities. 7.1. Fancier Output Formatting So far we’ve encountered two ways of writing values: expression statements and the [print()](https://docs.python.org/3/library/functions.html#print)function. (A third way is using the write() method of file objects; the standard output file can be referenced as sys.stdout. See the Library Reference for more information on this.)  Often you’ll want more control over the formatting of your output than simply printing space-separated values. There are two ways to format your output; the first way is to do all the string handling yourself; using string slicing and concatenation operations you can create any layout you can imagine. The string type has some methods that perform useful operations for padding strings to a given column width; these will be discussed shortly. The second way is to use the [str.format()](https://docs.python.org/3/library/stdtypes.html#str.format) method.  The [string](https://docs.python.org/3/library/string.html#module-string) module contains a [Template](https://docs.python.org/3/library/string.html#string.Template) class which offers yet another way to substitute values into strings.  One question remains, of course: how do you convert values to strings? Luckily, Python has ways to convert any value to a string: pass it to the [repr()](https://docs.python.org/3/library/functions.html#repr) or [str()](https://docs.python.org/3/library/stdtypes.html#str) functions.  The [str()](https://docs.python.org/3/library/stdtypes.html#str) function is meant to return representations of values which are fairly human-readable, while [repr()](https://docs.python.org/3/library/functions.html#repr) is meant to generate representations which can be read by the interpreter (or will force a[SyntaxError](https://docs.python.org/3/library/exceptions.html#SyntaxError) if there is no equivalent syntax). For objects which don’t have a particular representation for human consumption, [str()](https://docs.python.org/3/library/stdtypes.html#str) will return the same value as [repr()](https://docs.python.org/3/library/functions.html#repr). Many values, such as numbers or structures like lists and dictionaries, have the same representation using either function. Strings, in particular, have two distinct representations.  Some examples:  >>>  **>>>** s = 'Hello, world.'  **>>>** str(s)  'Hello, world.'  **>>>** repr(s)  "'Hello, world.'"  **>>>** str(1/7)  '0.14285714285714285'  **>>>** x = 10 \* 3.25  **>>>** y = 200 \* 200  **>>>** s = 'The value of x is ' + repr(x) + ', and y is ' + repr(y) + '...'  **>>>** print(s)  The value of x is 32.5, and y is 40000...  **>>>** *# The repr() of a string adds string quotes and backslashes:*  **...** hello = 'hello, world**\n**'  **>>>** hellos = repr(hello)  **>>>** print(hellos)  'hello, world\n'  **>>>** *# The argument to repr() may be any Python object:*  **...** repr((x, y, ('spam', 'eggs')))  "(32.5, 40000, ('spam', 'eggs'))"  Here are two ways to write a table of squares and cubes:  >>>  **>>> for** x **in** range(1, 11):  **...**  print(repr(x).rjust(2), repr(x\*x).rjust(3), end=' ')  **...**  *# Note use of 'end' on previous line*  **...**  print(repr(x\*x\*x).rjust(4))  **...**  1 1 1  2 4 8  3 9 27  4 16 64  5 25 125  6 36 216  7 49 343  8 64 512  9 81 729  10 100 1000  **>>> for** x **in** range(1, 11):  **...**  print('*{0:2d}* *{1:3d}* *{2:4d}*'.format(x, x\*x, x\*x\*x))  **...**  1 1 1  2 4 8  3 9 27  4 16 64  5 25 125  6 36 216  7 49 343  8 64 512  9 81 729  10 100 1000  (Note that in the first example, one space between each column was added by the way [print()](https://docs.python.org/3/library/functions.html#print)works: it always adds spaces between its arguments.)  This example demonstrates the [str.rjust()](https://docs.python.org/3/library/stdtypes.html#str.rjust) method of string objects, which right-justifies a string in a field of a given width by padding it with spaces on the left. There are similar methods [str.ljust()](https://docs.python.org/3/library/stdtypes.html#str.ljust)and [str.center()](https://docs.python.org/3/library/stdtypes.html#str.center). These methods do not write anything, they just return a new string. If the input string is too long, they don’t truncate it, but return it unchanged; this will mess up your column lay-out but that’s usually better than the alternative, which would be lying about a value. (If you really want truncation you can always add a slice operation, as in x.ljust(n)[:n].)  There is another method, [str.zfill()](https://docs.python.org/3/library/stdtypes.html#str.zfill), which pads a numeric string on the left with zeros. It understands about plus and minus signs:  >>>  **>>>** '12'.zfill(5)  '00012'  **>>>** '-3.14'.zfill(7)  '-003.14'  **>>>** '3.14159265359'.zfill(5)  '3.14159265359'  Basic usage of the [str.format()](https://docs.python.org/3/library/stdtypes.html#str.format) method looks like this:  >>>  **>>>** print('We are the *{}* who say "*{}*!"'.format('knights', 'Ni'))  We are the knights who say "Ni!"  The brackets and characters within them (called format fields) are replaced with the objects passed into the [str.format()](https://docs.python.org/3/library/stdtypes.html#str.format) method. A number in the brackets can be used to refer to the position of the object passed into the [str.format()](https://docs.python.org/3/library/stdtypes.html#str.format) method.  >>>  **>>>** print('*{0}* and *{1}*'.format('spam', 'eggs'))  spam and eggs  **>>>** print('*{1}* and *{0}*'.format('spam', 'eggs'))  eggs and spam  If keyword arguments are used in the [str.format()](https://docs.python.org/3/library/stdtypes.html#str.format) method, their values are referred to by using the name of the argument.  >>>  **>>>** print('This *{food}* is *{adjective}*.'.format(  **...**  food='spam', adjective='absolutely horrible'))  This spam is absolutely horrible.  Positional and keyword arguments can be arbitrarily combined:  >>>  **>>>** print('The story of *{0}*, *{1}*, and *{other}*.'.format('Bill', 'Manfred',  other='Georg'))  The story of Bill, Manfred, and Georg.  '!a' (apply [ascii()](https://docs.python.org/3/library/functions.html#ascii)), '!s' (apply [str()](https://docs.python.org/3/library/stdtypes.html#str)) and '!r' (apply [repr()](https://docs.python.org/3/library/functions.html#repr)) can be used to convert the value before it is formatted:  >>>  **>>>** contents = 'eels'  **>>>** print('My hovercraft is full of *{}*.'.format(contents))  My hovercraft is full of eels.  **>>>** print('My hovercraft is full of *{!r}*.'.format(contents))  My hovercraft is full of 'eels'.  An optional ':' and format specifier can follow the field name. This allows greater control over how the value is formatted. The following example rounds Pi to three places after the decimal.  >>>  **>>> import** **math**  **>>>** print('The value of PI is approximately *{0:.3f}*.'.format(math.pi))  The value of PI is approximately 3.142.  Passing an integer after the ':' will cause that field to be a minimum number of characters wide. This is useful for making tables pretty.  >>>  **>>>** table = {'Sjoerd': 4127, 'Jack': 4098, 'Dcab': 7678}  **>>> for** name, phone **in** table.items():  **...**  print('*{0:10}* ==> *{1:10d}*'.format(name, phone))  **...**  Jack ==> 4098  Dcab ==> 7678  Sjoerd ==> 4127  If you have a really long format string that you don’t want to split up, it would be nice if you could reference the variables to be formatted by name instead of by position. This can be done by simply passing the dict and using square brackets '[]' to access the keys  >>>  **>>>** table = {'Sjoerd': 4127, 'Jack': 4098, 'Dcab': 8637678}  **>>>** print('Jack: *{0[Jack]:d}*; Sjoerd: *{0[Sjoerd]:d}*; '  **...**  'Dcab: *{0[Dcab]:d}*'.format(table))  Jack: 4098; Sjoerd: 4127; Dcab: 8637678  This could also be done by passing the table as keyword arguments with the ‘\*\*’ notation.  >>>  **>>>** table = {'Sjoerd': 4127, 'Jack': 4098, 'Dcab': 8637678}  **>>>** print('Jack: *{Jack:d}*; Sjoerd: *{Sjoerd:d}*; Dcab: *{Dcab:d}*'.format(\*\*table))  Jack: 4098; Sjoerd: 4127; Dcab: 8637678  This is particularly useful in combination with the built-in function [vars()](https://docs.python.org/3/library/functions.html#vars), which returns a dictionary containing all local variables.  For a complete overview of string formatting with [str.format()](https://docs.python.org/3/library/stdtypes.html#str.format), see [Format String Syntax](https://docs.python.org/3/library/string.html#formatstrings). 7.1.1. Old string formatting The % operator can also be used for string formatting. It interprets the left argument much like asprintf()-style format string to be applied to the right argument, and returns the string resulting from this formatting operation. For example:  >>>  **>>> import** **math**  **>>>** print('The value of PI is approximately *%5.3f*.' % math.pi)  The value of PI is approximately 3.142.  More information can be found in the [printf-style String Formatting](https://docs.python.org/3/library/stdtypes.html#old-string-formatting) section. 7.2. Reading and Writing Files [open()](https://docs.python.org/3/library/functions.html#open) returns a [file object](https://docs.python.org/3/glossary.html#term-file-object), and is most commonly used with two arguments: open(filename,mode).  >>>  **>>>** f = open('workfile', 'w')  The first argument is a string containing the filename. The second argument is another string containing a few characters describing the way in which the file will be used. mode can be 'r' when the file will only be read, 'w' for only writing (an existing file with the same name will be erased), and'a' opens the file for appending; any data written to the file is automatically added to the end. 'r+'opens the file for both reading and writing. The mode argument is optional; 'r' will be assumed if it’s omitted.  Normally, files are opened in text mode, that means, you read and write strings from and to the file, which are encoded in a specific encoding. If encoding is not specified, the default is platform dependent (see [open()](https://docs.python.org/3/library/functions.html#open)). 'b' appended to the mode opens the file in binary mode: now the data is read and written in the form of bytes objects. This mode should be used for all files that don’t contain text.  In text mode, the default when reading is to convert platform-specific line endings (\n on Unix, \r\non Windows) to just \n. When writing in text mode, the default is to convert occurrences of \n back to platform-specific line endings. This behind-the-scenes modification to file data is fine for text files, but will corrupt binary data like that in JPEG or EXE files. Be very careful to use binary mode when reading and writing such files. 7.2.1. Methods of File Objects The rest of the examples in this section will assume that a file object called f has already been created.  To read a file’s contents, call f.read(size), which reads some quantity of data and returns it as a string (in text mode) or bytes object (in binary mode). size is an optional numeric argument. When sizeis omitted or negative, the entire contents of the file will be read and returned; it’s your problem if the file is twice as large as your machine’s memory. Otherwise, at most size bytes are read and returned. If the end of the file has been reached, f.read() will return an empty string ('').  >>>  **>>>** f.read()  'This is the entire file.\n'  **>>>** f.read()  ''  f.readline() reads a single line from the file; a newline character (\n) is left at the end of the string, and is only omitted on the last line of the file if the file doesn’t end in a newline. This makes the return value unambiguous; if f.readline() returns an empty string, the end of the file has been reached, while a blank line is represented by '\n', a string containing only a single newline.  >>>  **>>>** f.readline()  'This is the first line of the file.\n'  **>>>** f.readline()  'Second line of the file\n'  **>>>** f.readline()  ''  For reading lines from a file, you can loop over the file object. This is memory efficient, fast, and leads to simple code:  >>>  **>>> for** line **in** f:  **...**  print(line, end='')  **...**  This is the first line of the file.  Second line of the file  If you want to read all the lines of a file in a list you can also use list(f) or f.readlines().  f.write(string) writes the contents of string to the file, returning the number of characters written.  >>>  **>>>** f.write('This is a test**\n**')  15  Other types of objects need to be converted – either to a string (in text mode) or a bytes object (in binary mode) – before writing them:  >>>  **>>>** value = ('the answer', 42)  **>>>** s = str(value) *# convert the tuple to string*  **>>>** f.write(s)  18  f.tell() returns an integer giving the file object’s current position in the file represented as number of bytes from the beginning of the file when in binary mode and an opaque number when in text mode.  To change the file object’s position, use f.seek(offset, from\_what). The position is computed from adding offset to a reference point; the reference point is selected by the from\_what argument. Afrom\_what value of 0 measures from the beginning of the file, 1 uses the current file position, and 2 uses the end of the file as the reference point. from\_what can be omitted and defaults to 0, using the beginning of the file as the reference point.  >>>  **>>>** f = open('workfile', 'rb+')  **>>>** f.write(b'0123456789abcdef')  16  **>>>** f.seek(5) *# Go to the 6th byte in the file*  5  **>>>** f.read(1)  b'5'  **>>>** f.seek(-3, 2) *# Go to the 3rd byte before the end*  13  **>>>** f.read(1)  b'd'  In text files (those opened without a b in the mode string), only seeks relative to the beginning of the file are allowed (the exception being seeking to the very file end with seek(0, 2)) and the only validoffset values are those returned from the f.tell(), or zero. Any other offset value produces undefined behaviour.  When you’re done with a file, call f.close() to close it and free up any system resources taken up by the open file. After calling f.close(), attempts to use the file object will automatically fail.  >>>  **>>>** f.close()  **>>>** f.read()  Traceback (most recent call last):  File "<stdin>", line 1, in ?  ValueError: I/O operation on closed file  It is good practice to use the [with](https://docs.python.org/3/reference/compound_stmts.html#with) keyword when dealing with file objects. This has the advantage that the file is properly closed after its suite finishes, even if an exception is raised on the way. It is also much shorter than writing equivalent [try](https://docs.python.org/3/reference/compound_stmts.html#try)-[finally](https://docs.python.org/3/reference/compound_stmts.html#finally) blocks:  >>>  **>>> with** open('workfile', 'r') **as** f:  **...**  read\_data = f.read()  **>>>** f.closed  True  File objects have some additional methods, such as isatty() and truncate() which are less frequently used; consult the Library Reference for a complete guide to file objects. 7.2.2. Saving structured data with [json](https://docs.python.org/3/library/json.html#module-json) Strings can easily be written to and read from a file. Numbers take a bit more effort, since the read()method only returns strings, which will have to be passed to a function like [int()](https://docs.python.org/3/library/functions.html#int), which takes a string like '123' and returns its numeric value 123. When you want to save more complex data types like nested lists and dictionaries, parsing and serializing by hand becomes complicated.  Rather than having users constantly writing and debugging code to save complicated data types to files, Python allows you to use the popular data interchange format called [JSON (JavaScript Object Notation)](http://json.org/). The standard module called [json](https://docs.python.org/3/library/json.html#module-json) can take Python data hierarchies, and convert them to string representations; this process is called serializing. Reconstructing the data from the string representation is called deserializing. Between serializing and deserializing, the string representing the object may have been stored in a file or data, or sent over a network connection to some distant machine.  **Note**    The JSON format is commonly used by modern applications to allow for data exchange. Many programmers are already familiar with it, which makes it a good choice for interoperability.  If you have an object x, you can view its JSON string representation with a simple line of code:  >>>  **>>>** json.dumps([1, 'simple', 'list'])  '[1, "simple", "list"]'  Another variant of the [dumps()](https://docs.python.org/3/library/json.html#json.dumps) function, called [dump()](https://docs.python.org/3/library/json.html#json.dump), simply serializes the object to a [text file](https://docs.python.org/3/glossary.html#term-text-file). So iff is a [text file](https://docs.python.org/3/glossary.html#term-text-file) object opened for writing, we can do this:  json.dump(x, f)  To decode the object again, if f is a [text file](https://docs.python.org/3/glossary.html#term-text-file) object which has been opened for reading:  x = json.load(f)  This simple serialization technique can handle lists and dictionaries, but serializing arbitrary class instances in JSON requires a bit of extra effort. The reference for the [json](https://docs.python.org/3/library/json.html#module-json) module contains an explanation of this.  **See also**    [pickle](https://docs.python.org/3/library/pickle.html#module-pickle) - the pickle module  Contrary to [JSON](https://docs.python.org/3/tutorial/inputoutput.html#tut-json), pickle is a protocol which allows the serialization of arbitrarily complex Python objects. As such, it is specific to Python and cannot be used to communicate with applications written in other languages. It is also insecure by default: deserializing pickle data coming from an untrusted source can execute arbitrary code, if the data was crafted by a skilled attacker. |

# 7. Input and Output

There are several ways to present the output of a program; data can be printed in a human-readable form, or written to a file for future use. This chapter will discuss some of the possibilities.

## 7.1. Fancier Output Formatting

So far we’ve encountered two ways of writing values: expression statements and the [print()](https://docs.python.org/3/library/functions.html#print)function. (A third way is using the write() method of file objects; the standard output file can be referenced as sys.stdout. See the Library Reference for more information on this.)

Often you’ll want more control over the formatting of your output than simply printing space-separated values. There are two ways to format your output; the first way is to do all the string handling yourself; using string slicing and concatenation operations you can create any layout you can imagine. The string type has some methods that perform useful operations for padding strings to a given column width; these will be discussed shortly. The second way is to use the [str.format()](https://docs.python.org/3/library/stdtypes.html#str.format) method.

The [string](https://docs.python.org/3/library/string.html#module-string) module contains a [Template](https://docs.python.org/3/library/string.html#string.Template) class which offers yet another way to substitute values into strings.

One question remains, of course: how do you convert values to strings? Luckily, Python has ways to convert any value to a string: pass it to the [repr()](https://docs.python.org/3/library/functions.html#repr) or [str()](https://docs.python.org/3/library/stdtypes.html#str) functions.

The [str()](https://docs.python.org/3/library/stdtypes.html#str) function is meant to return representations of values which are fairly human-readable, while [repr()](https://docs.python.org/3/library/functions.html#repr) is meant to generate representations which can be read by the interpreter (or will force a[SyntaxError](https://docs.python.org/3/library/exceptions.html#SyntaxError) if there is no equivalent syntax). For objects which don’t have a particular representation for human consumption, [str()](https://docs.python.org/3/library/stdtypes.html#str) will return the same value as [repr()](https://docs.python.org/3/library/functions.html#repr). Many values, such as numbers or structures like lists and dictionaries, have the same representation using either function. Strings, in particular, have two distinct representations.

Some examples:

>>>

**>>>** s = 'Hello, world.'

**>>>** str(s)

'Hello, world.'

**>>>** repr(s)

"'Hello, world.'"

**>>>** str(1/7)

'0.14285714285714285'

**>>>** x = 10 \* 3.25

**>>>** y = 200 \* 200

**>>>** s = 'The value of x is ' + repr(x) + ', and y is ' + repr(y) + '...'

**>>>** print(s)

The value of x is 32.5, and y is 40000...

**>>>** *# The repr() of a string adds string quotes and backslashes:*

**...** hello = 'hello, world**\n**'

**>>>** hellos = repr(hello)

**>>>** print(hellos)

'hello, world\n'

**>>>** *# The argument to repr() may be any Python object:*

**...** repr((x, y, ('spam', 'eggs')))

"(32.5, 40000, ('spam', 'eggs'))"

Here are two ways to write a table of squares and cubes:

>>>

**>>> for** x **in** range(1, 11):

**...**  print(repr(x).rjust(2), repr(x\*x).rjust(3), end=' ')

**...**  *# Note use of 'end' on previous line*

**...**  print(repr(x\*x\*x).rjust(4))

**...**

1 1 1

2 4 8

3 9 27

4 16 64

5 25 125

6 36 216

7 49 343

8 64 512

9 81 729

10 100 1000

**>>> for** x **in** range(1, 11):

**...**  print('*{0:2d}* *{1:3d}* *{2:4d}*'.format(x, x\*x, x\*x\*x))

**...**

1 1 1

2 4 8

3 9 27

4 16 64

5 25 125

6 36 216

7 49 343

8 64 512

9 81 729

10 100 1000

(Note that in the first example, one space between each column was added by the way [print()](https://docs.python.org/3/library/functions.html#print)works: it always adds spaces between its arguments.)

This example demonstrates the [str.rjust()](https://docs.python.org/3/library/stdtypes.html#str.rjust) method of string objects, which right-justifies a string in a field of a given width by padding it with spaces on the left. There are similar methods [str.ljust()](https://docs.python.org/3/library/stdtypes.html#str.ljust)and [str.center()](https://docs.python.org/3/library/stdtypes.html#str.center). These methods do not write anything, they just return a new string. If the input string is too long, they don’t truncate it, but return it unchanged; this will mess up your column lay-out but that’s usually better than the alternative, which would be lying about a value. (If you really want truncation you can always add a slice operation, as in x.ljust(n)[:n].)

There is another method, [str.zfill()](https://docs.python.org/3/library/stdtypes.html#str.zfill), which pads a numeric string on the left with zeros. It understands about plus and minus signs:

>>>

**>>>** '12'.zfill(5)

'00012'

**>>>** '-3.14'.zfill(7)

'-003.14'

**>>>** '3.14159265359'.zfill(5)

'3.14159265359'

Basic usage of the [str.format()](https://docs.python.org/3/library/stdtypes.html#str.format) method looks like this:

>>>

**>>>** print('We are the *{}* who say "*{}*!"'.format('knights', 'Ni'))

We are the knights who say "Ni!"

The brackets and characters within them (called format fields) are replaced with the objects passed into the [str.format()](https://docs.python.org/3/library/stdtypes.html#str.format) method. A number in the brackets can be used to refer to the position of the object passed into the [str.format()](https://docs.python.org/3/library/stdtypes.html#str.format) method.

>>>

**>>>** print('*{0}* and *{1}*'.format('spam', 'eggs'))

spam and eggs

**>>>** print('*{1}* and *{0}*'.format('spam', 'eggs'))

eggs and spam

If keyword arguments are used in the [str.format()](https://docs.python.org/3/library/stdtypes.html#str.format) method, their values are referred to by using the name of the argument.

>>>

**>>>** print('This *{food}* is *{adjective}*.'.format(

**...**  food='spam', adjective='absolutely horrible'))

This spam is absolutely horrible.

Positional and keyword arguments can be arbitrarily combined:

>>>

**>>>** print('The story of *{0}*, *{1}*, and *{other}*.'.format('Bill', 'Manfred',

other='Georg'))

The story of Bill, Manfred, and Georg.

'!a' (apply [ascii()](https://docs.python.org/3/library/functions.html#ascii)), '!s' (apply [str()](https://docs.python.org/3/library/stdtypes.html#str)) and '!r' (apply [repr()](https://docs.python.org/3/library/functions.html#repr)) can be used to convert the value before it is formatted:

>>>

**>>>** contents = 'eels'

**>>>** print('My hovercraft is full of *{}*.'.format(contents))

My hovercraft is full of eels.

**>>>** print('My hovercraft is full of *{!r}*.'.format(contents))

My hovercraft is full of 'eels'.

An optional ':' and format specifier can follow the field name. This allows greater control over how the value is formatted. The following example rounds Pi to three places after the decimal.

>>>

**>>> import** **math**

**>>>** print('The value of PI is approximately *{0:.3f}*.'.format(math.pi))

The value of PI is approximately 3.142.

Passing an integer after the ':' will cause that field to be a minimum number of characters wide. This is useful for making tables pretty.

>>>

**>>>** table = {'Sjoerd': 4127, 'Jack': 4098, 'Dcab': 7678}

**>>> for** name, phone **in** table.items():

**...**  print('*{0:10}* ==> *{1:10d}*'.format(name, phone))

**...**

Jack ==> 4098

Dcab ==> 7678

Sjoerd ==> 4127

If you have a really long format string that you don’t want to split up, it would be nice if you could reference the variables to be formatted by name instead of by position. This can be done by simply passing the dict and using square brackets '[]' to access the keys

>>>

**>>>** table = {'Sjoerd': 4127, 'Jack': 4098, 'Dcab': 8637678}

**>>>** print('Jack: *{0[Jack]:d}*; Sjoerd: *{0[Sjoerd]:d}*; '

**...**  'Dcab: *{0[Dcab]:d}*'.format(table))

Jack: 4098; Sjoerd: 4127; Dcab: 8637678

This could also be done by passing the table as keyword arguments with the ‘\*\*’ notation.

>>>

**>>>** table = {'Sjoerd': 4127, 'Jack': 4098, 'Dcab': 8637678}

**>>>** print('Jack: *{Jack:d}*; Sjoerd: *{Sjoerd:d}*; Dcab: *{Dcab:d}*'.format(\*\*table))

Jack: 4098; Sjoerd: 4127; Dcab: 8637678

This is particularly useful in combination with the built-in function [vars()](https://docs.python.org/3/library/functions.html#vars), which returns a dictionary containing all local variables.

For a complete overview of string formatting with [str.format()](https://docs.python.org/3/library/stdtypes.html#str.format), see [Format String Syntax](https://docs.python.org/3/library/string.html#formatstrings).

### 7.1.1. Old string formatting

The % operator can also be used for string formatting. It interprets the left argument much like asprintf()-style format string to be applied to the right argument, and returns the string resulting from this formatting operation. For example:

>>>

**>>> import** **math**

**>>>** print('The value of PI is approximately *%5.3f*.' % math.pi)

The value of PI is approximately 3.142.

More information can be found in the [printf-style String Formatting](https://docs.python.org/3/library/stdtypes.html#old-string-formatting) section.

## 7.2. Reading and Writing Files

[open()](https://docs.python.org/3/library/functions.html#open) returns a [file object](https://docs.python.org/3/glossary.html#term-file-object), and is most commonly used with two arguments: open(filename,mode).

>>>

**>>>** f = open('workfile', 'w')

The first argument is a string containing the filename. The second argument is another string containing a few characters describing the way in which the file will be used. mode can be 'r' when the file will only be read, 'w' for only writing (an existing file with the same name will be erased), and'a' opens the file for appending; any data written to the file is automatically added to the end. 'r+'opens the file for both reading and writing. The mode argument is optional; 'r' will be assumed if it’s omitted.

Normally, files are opened in text mode, that means, you read and write strings from and to the file, which are encoded in a specific encoding. If encoding is not specified, the default is platform dependent (see [open()](https://docs.python.org/3/library/functions.html#open)). 'b' appended to the mode opens the file in binary mode: now the data is read and written in the form of bytes objects. This mode should be used for all files that don’t contain text.

In text mode, the default when reading is to convert platform-specific line endings (\n on Unix, \r\non Windows) to just \n. When writing in text mode, the default is to convert occurrences of \n back to platform-specific line endings. This behind-the-scenes modification to file data is fine for text files, but will corrupt binary data like that in JPEG or EXE files. Be very careful to use binary mode when reading and writing such files.

### 7.2.1. Methods of File Objects

The rest of the examples in this section will assume that a file object called f has already been created.

To read a file’s contents, call f.read(size), which reads some quantity of data and returns it as a string (in text mode) or bytes object (in binary mode). size is an optional numeric argument. When sizeis omitted or negative, the entire contents of the file will be read and returned; it’s your problem if the file is twice as large as your machine’s memory. Otherwise, at most size bytes are read and returned. If the end of the file has been reached, f.read() will return an empty string ('').

>>>

**>>>** f.read()

'This is the entire file.\n'

**>>>** f.read()

''

f.readline() reads a single line from the file; a newline character (\n) is left at the end of the string, and is only omitted on the last line of the file if the file doesn’t end in a newline. This makes the return value unambiguous; if f.readline() returns an empty string, the end of the file has been reached, while a blank line is represented by '\n', a string containing only a single newline.

>>>

**>>>** f.readline()

'This is the first line of the file.\n'

**>>>** f.readline()

'Second line of the file\n'

**>>>** f.readline()

''

For reading lines from a file, you can loop over the file object. This is memory efficient, fast, and leads to simple code:

>>>

**>>> for** line **in** f:

**...**  print(line, end='')

**...**

This is the first line of the file.

Second line of the file

If you want to read all the lines of a file in a list you can also use list(f) or f.readlines().

f.write(string) writes the contents of string to the file, returning the number of characters written.

>>>

**>>>** f.write('This is a test**\n**')

15

Other types of objects need to be converted – either to a string (in text mode) or a bytes object (in binary mode) – before writing them:

>>>

**>>>** value = ('the answer', 42)

**>>>** s = str(value) *# convert the tuple to string*

**>>>** f.write(s)

18

f.tell() returns an integer giving the file object’s current position in the file represented as number of bytes from the beginning of the file when in binary mode and an opaque number when in text mode.

To change the file object’s position, use f.seek(offset, from\_what). The position is computed from adding offset to a reference point; the reference point is selected by the from\_what argument. Afrom\_what value of 0 measures from the beginning of the file, 1 uses the current file position, and 2 uses the end of the file as the reference point. from\_what can be omitted and defaults to 0, using the beginning of the file as the reference point.

>>>

**>>>** f = open('workfile', 'rb+')

**>>>** f.write(b'0123456789abcdef')

16

**>>>** f.seek(5) *# Go to the 6th byte in the file*

5

**>>>** f.read(1)

b'5'

**>>>** f.seek(-3, 2) *# Go to the 3rd byte before the end*

13

**>>>** f.read(1)

b'd'

In text files (those opened without a b in the mode string), only seeks relative to the beginning of the file are allowed (the exception being seeking to the very file end with seek(0, 2)) and the only validoffset values are those returned from the f.tell(), or zero. Any other offset value produces undefined behaviour.

When you’re done with a file, call f.close() to close it and free up any system resources taken up by the open file. After calling f.close(), attempts to use the file object will automatically fail.

>>>

**>>>** f.close()

**>>>** f.read()

Traceback (most recent call last):

File "<stdin>", line 1, in ?

ValueError: I/O operation on closed file

It is good practice to use the [with](https://docs.python.org/3/reference/compound_stmts.html#with) keyword when dealing with file objects. This has the advantage that the file is properly closed after its suite finishes, even if an exception is raised on the way. It is also much shorter than writing equivalent [try](https://docs.python.org/3/reference/compound_stmts.html#try)-[finally](https://docs.python.org/3/reference/compound_stmts.html#finally) blocks:

>>>

**>>> with** open('workfile', 'r') **as** f:

**...**  read\_data = f.read()

**>>>** f.closed

True

File objects have some additional methods, such as isatty() and truncate() which are less frequently used; consult the Library Reference for a complete guide to file objects.

### 7.2.2. Saving structured data with [json](https://docs.python.org/3/library/json.html#module-json)

Strings can easily be written to and read from a file. Numbers take a bit more effort, since the read()method only returns strings, which will have to be passed to a function like [int()](https://docs.python.org/3/library/functions.html#int), which takes a string like '123' and returns its numeric value 123. When you want to save more complex data types like nested lists and dictionaries, parsing and serializing by hand becomes complicated.

Rather than having users constantly writing and debugging code to save complicated data types to files, Python allows you to use the popular data interchange format called [JSON (JavaScript Object Notation)](http://json.org/). The standard module called [json](https://docs.python.org/3/library/json.html#module-json) can take Python data hierarchies, and convert them to string representations; this process is called serializing. Reconstructing the data from the string representation is called deserializing. Between serializing and deserializing, the string representing the object may have been stored in a file or data, or sent over a network connection to some distant machine.

**Note**

The JSON format is commonly used by modern applications to allow for data exchange. Many programmers are already familiar with it, which makes it a good choice for interoperability.

If you have an object x, you can view its JSON string representation with a simple line of code:

>>>

**>>>** json.dumps([1, 'simple', 'list'])

'[1, "simple", "list"]'

Another variant of the [dumps()](https://docs.python.org/3/library/json.html#json.dumps) function, called [dump()](https://docs.python.org/3/library/json.html#json.dump), simply serializes the object to a [text file](https://docs.python.org/3/glossary.html#term-text-file). So iff is a [text file](https://docs.python.org/3/glossary.html#term-text-file) object opened for writing, we can do this:

json.dump(x, f)

To decode the object again, if f is a [text file](https://docs.python.org/3/glossary.html#term-text-file) object which has been opened for reading:

x = json.load(f)

This simple serialization technique can handle lists and dictionaries, but serializing arbitrary class instances in JSON requires a bit of extra effort. The reference for the [json](https://docs.python.org/3/library/json.html#module-json) module contains an explanation of this.

**See also**

[pickle](https://docs.python.org/3/library/pickle.html#module-pickle) - the pickle module

Contrary to [JSON](https://docs.python.org/3/tutorial/inputoutput.html#tut-json), pickle is a protocol which allows the serialization of arbitrarily complex Python objects. As such, it is specific to Python and cannot be used to communicate with applications written in other languages. It is also insecure by default: deserializing pickle data coming from an untrusted source can execute arbitrary code, if the data was crafted by a skilled attacker.

# 7. Input and Output

There are several ways to present the output of a program; data can be printed in a human-readable form, or written to a file for future use. This chapter will discuss some of the possibilities.

## 7.1. Fancier Output Formatting

So far we’ve encountered two ways of writing values: expression statements and the [print()](https://docs.python.org/3/library/functions.html#print)function. (A third way is using the write() method of file objects; the standard output file can be referenced as sys.stdout. See the Library Reference for more information on this.)

Often you’ll want more control over the formatting of your output than simply printing space-separated values. There are two ways to format your output; the first way is to do all the string handling yourself; using string slicing and concatenation operations you can create any layout you can imagine. The string type has some methods that perform useful operations for padding strings to a given column width; these will be discussed shortly. The second way is to use the [str.format()](https://docs.python.org/3/library/stdtypes.html#str.format) method.

The [string](https://docs.python.org/3/library/string.html#module-string) module contains a [Template](https://docs.python.org/3/library/string.html#string.Template) class which offers yet another way to substitute values into strings.

One question remains, of course: how do you convert values to strings? Luckily, Python has ways to convert any value to a string: pass it to the [repr()](https://docs.python.org/3/library/functions.html#repr) or [str()](https://docs.python.org/3/library/stdtypes.html#str) functions.

The [str()](https://docs.python.org/3/library/stdtypes.html#str) function is meant to return representations of values which are fairly human-readable, while [repr()](https://docs.python.org/3/library/functions.html#repr) is meant to generate representations which can be read by the interpreter (or will force a[SyntaxError](https://docs.python.org/3/library/exceptions.html#SyntaxError) if there is no equivalent syntax). For objects which don’t have a particular representation for human consumption, [str()](https://docs.python.org/3/library/stdtypes.html#str) will return the same value as [repr()](https://docs.python.org/3/library/functions.html#repr). Many values, such as numbers or structures like lists and dictionaries, have the same representation using either function. Strings, in particular, have two distinct representations.

Some examples:

>>>

**>>>** s = 'Hello, world.'

**>>>** str(s)

'Hello, world.'

**>>>** repr(s)

"'Hello, world.'"

**>>>** str(1/7)

'0.14285714285714285'

**>>>** x = 10 \* 3.25

**>>>** y = 200 \* 200

**>>>** s = 'The value of x is ' + repr(x) + ', and y is ' + repr(y) + '...'

**>>>** print(s)

The value of x is 32.5, and y is 40000...

**>>>** *# The repr() of a string adds string quotes and backslashes:*

**...** hello = 'hello, world**\n**'

**>>>** hellos = repr(hello)

**>>>** print(hellos)

'hello, world\n'

**>>>** *# The argument to repr() may be any Python object:*

**...** repr((x, y, ('spam', 'eggs')))

"(32.5, 40000, ('spam', 'eggs'))"

Here are two ways to write a table of squares and cubes:

>>>

**>>> for** x **in** range(1, 11):

**...**  print(repr(x).rjust(2), repr(x\*x).rjust(3), end=' ')

**...**  *# Note use of 'end' on previous line*

**...**  print(repr(x\*x\*x).rjust(4))

**...**

1 1 1

2 4 8

3 9 27

4 16 64

5 25 125

6 36 216

7 49 343

8 64 512

9 81 729

10 100 1000

**>>> for** x **in** range(1, 11):

**...**  print('*{0:2d}* *{1:3d}* *{2:4d}*'.format(x, x\*x, x\*x\*x))

**...**

1 1 1

2 4 8

3 9 27

4 16 64

5 25 125

6 36 216

7 49 343

8 64 512

9 81 729

10 100 1000

(Note that in the first example, one space between each column was added by the way [print()](https://docs.python.org/3/library/functions.html#print)works: it always adds spaces between its arguments.)

This example demonstrates the [str.rjust()](https://docs.python.org/3/library/stdtypes.html#str.rjust) method of string objects, which right-justifies a string in a field of a given width by padding it with spaces on the left. There are similar methods [str.ljust()](https://docs.python.org/3/library/stdtypes.html#str.ljust)and [str.center()](https://docs.python.org/3/library/stdtypes.html#str.center). These methods do not write anything, they just return a new string. If the input string is too long, they don’t truncate it, but return it unchanged; this will mess up your column lay-out but that’s usually better than the alternative, which would be lying about a value. (If you really want truncation you can always add a slice operation, as in x.ljust(n)[:n].)

There is another method, [str.zfill()](https://docs.python.org/3/library/stdtypes.html#str.zfill), which pads a numeric string on the left with zeros. It understands about plus and minus signs:

>>>

**>>>** '12'.zfill(5)

'00012'

**>>>** '-3.14'.zfill(7)

'-003.14'

**>>>** '3.14159265359'.zfill(5)

'3.14159265359'

Basic usage of the [str.format()](https://docs.python.org/3/library/stdtypes.html#str.format) method looks like this:

>>>

**>>>** print('We are the *{}* who say "*{}*!"'.format('knights', 'Ni'))

We are the knights who say "Ni!"

The brackets and characters within them (called format fields) are replaced with the objects passed into the [str.format()](https://docs.python.org/3/library/stdtypes.html#str.format) method. A number in the brackets can be used to refer to the position of the object passed into the [str.format()](https://docs.python.org/3/library/stdtypes.html#str.format) method.

>>>

**>>>** print('*{0}* and *{1}*'.format('spam', 'eggs'))

spam and eggs

**>>>** print('*{1}* and *{0}*'.format('spam', 'eggs'))

eggs and spam

If keyword arguments are used in the [str.format()](https://docs.python.org/3/library/stdtypes.html#str.format) method, their values are referred to by using the name of the argument.

>>>

**>>>** print('This *{food}* is *{adjective}*.'.format(

**...**  food='spam', adjective='absolutely horrible'))

This spam is absolutely horrible.

Positional and keyword arguments can be arbitrarily combined:

>>>

**>>>** print('The story of *{0}*, *{1}*, and *{other}*.'.format('Bill', 'Manfred',

other='Georg'))

The story of Bill, Manfred, and Georg.

'!a' (apply [ascii()](https://docs.python.org/3/library/functions.html#ascii)), '!s' (apply [str()](https://docs.python.org/3/library/stdtypes.html#str)) and '!r' (apply [repr()](https://docs.python.org/3/library/functions.html#repr)) can be used to convert the value before it is formatted:

>>>

**>>>** contents = 'eels'

**>>>** print('My hovercraft is full of *{}*.'.format(contents))

My hovercraft is full of eels.

**>>>** print('My hovercraft is full of *{!r}*.'.format(contents))

My hovercraft is full of 'eels'.

An optional ':' and format specifier can follow the field name. This allows greater control over how the value is formatted. The following example rounds Pi to three places after the decimal.

>>>

**>>> import** **math**

**>>>** print('The value of PI is approximately *{0:.3f}*.'.format(math.pi))

The value of PI is approximately 3.142.

Passing an integer after the ':' will cause that field to be a minimum number of characters wide. This is useful for making tables pretty.

>>>

**>>>** table = {'Sjoerd': 4127, 'Jack': 4098, 'Dcab': 7678}

**>>> for** name, phone **in** table.items():

**...**  print('*{0:10}* ==> *{1:10d}*'.format(name, phone))

**...**

Jack ==> 4098

Dcab ==> 7678

Sjoerd ==> 4127

If you have a really long format string that you don’t want to split up, it would be nice if you could reference the variables to be formatted by name instead of by position. This can be done by simply passing the dict and using square brackets '[]' to access the keys

>>>

**>>>** table = {'Sjoerd': 4127, 'Jack': 4098, 'Dcab': 8637678}

**>>>** print('Jack: *{0[Jack]:d}*; Sjoerd: *{0[Sjoerd]:d}*; '

**...**  'Dcab: *{0[Dcab]:d}*'.format(table))

Jack: 4098; Sjoerd: 4127; Dcab: 8637678

This could also be done by passing the table as keyword arguments with the ‘\*\*’ notation.

>>>

**>>>** table = {'Sjoerd': 4127, 'Jack': 4098, 'Dcab': 8637678}

**>>>** print('Jack: *{Jack:d}*; Sjoerd: *{Sjoerd:d}*; Dcab: *{Dcab:d}*'.format(\*\*table))

Jack: 4098; Sjoerd: 4127; Dcab: 8637678

This is particularly useful in combination with the built-in function [vars()](https://docs.python.org/3/library/functions.html#vars), which returns a dictionary containing all local variables.

For a complete overview of string formatting with [str.format()](https://docs.python.org/3/library/stdtypes.html#str.format), see [Format String Syntax](https://docs.python.org/3/library/string.html#formatstrings).

### 7.1.1. Old string formatting

The % operator can also be used for string formatting. It interprets the left argument much like asprintf()-style format string to be applied to the right argument, and returns the string resulting from this formatting operation. For example:

>>>

**>>> import** **math**

**>>>** print('The value of PI is approximately *%5.3f*.' % math.pi)

The value of PI is approximately 3.142.

More information can be found in the [printf-style String Formatting](https://docs.python.org/3/library/stdtypes.html#old-string-formatting) section.

## 7.2. Reading and Writing Files

[open()](https://docs.python.org/3/library/functions.html#open) returns a [file object](https://docs.python.org/3/glossary.html#term-file-object), and is most commonly used with two arguments: open(filename,mode).

>>>

**>>>** f = open('workfile', 'w')

The first argument is a string containing the filename. The second argument is another string containing a few characters describing the way in which the file will be used. mode can be 'r' when the file will only be read, 'w' for only writing (an existing file with the same name will be erased), and'a' opens the file for appending; any data written to the file is automatically added to the end. 'r+'opens the file for both reading and writing. The mode argument is optional; 'r' will be assumed if it’s omitted.

Normally, files are opened in text mode, that means, you read and write strings from and to the file, which are encoded in a specific encoding. If encoding is not specified, the default is platform dependent (see [open()](https://docs.python.org/3/library/functions.html#open)). 'b' appended to the mode opens the file in binary mode: now the data is read and written in the form of bytes objects. This mode should be used for all files that don’t contain text.

In text mode, the default when reading is to convert platform-specific line endings (\n on Unix, \r\non Windows) to just \n. When writing in text mode, the default is to convert occurrences of \n back to platform-specific line endings. This behind-the-scenes modification to file data is fine for text files, but will corrupt binary data like that in JPEG or EXE files. Be very careful to use binary mode when reading and writing such files.

### 7.2.1. Methods of File Objects

The rest of the examples in this section will assume that a file object called f has already been created.

To read a file’s contents, call f.read(size), which reads some quantity of data and returns it as a string (in text mode) or bytes object (in binary mode). size is an optional numeric argument. When sizeis omitted or negative, the entire contents of the file will be read and returned; it’s your problem if the file is twice as large as your machine’s memory. Otherwise, at most size bytes are read and returned. If the end of the file has been reached, f.read() will return an empty string ('').

>>>

**>>>** f.read()

'This is the entire file.\n'

**>>>** f.read()

''

f.readline() reads a single line from the file; a newline character (\n) is left at the end of the string, and is only omitted on the last line of the file if the file doesn’t end in a newline. This makes the return value unambiguous; if f.readline() returns an empty string, the end of the file has been reached, while a blank line is represented by '\n', a string containing only a single newline.

>>>

**>>>** f.readline()

'This is the first line of the file.\n'

**>>>** f.readline()

'Second line of the file\n'

**>>>** f.readline()

''

For reading lines from a file, you can loop over the file object. This is memory efficient, fast, and leads to simple code:

>>>

**>>> for** line **in** f:

**...**  print(line, end='')

**...**

This is the first line of the file.

Second line of the file

If you want to read all the lines of a file in a list you can also use list(f) or f.readlines().

f.write(string) writes the contents of string to the file, returning the number of characters written.

>>>

**>>>** f.write('This is a test**\n**')

15

Other types of objects need to be converted – either to a string (in text mode) or a bytes object (in binary mode) – before writing them:

>>>

**>>>** value = ('the answer', 42)

**>>>** s = str(value) *# convert the tuple to string*

**>>>** f.write(s)

18

f.tell() returns an integer giving the file object’s current position in the file represented as number of bytes from the beginning of the file when in binary mode and an opaque number when in text mode.

To change the file object’s position, use f.seek(offset, from\_what). The position is computed from adding offset to a reference point; the reference point is selected by the from\_what argument. Afrom\_what value of 0 measures from the beginning of the file, 1 uses the current file position, and 2 uses the end of the file as the reference point. from\_what can be omitted and defaults to 0, using the beginning of the file as the reference point.

>>>

**>>>** f = open('workfile', 'rb+')

**>>>** f.write(b'0123456789abcdef')

16

**>>>** f.seek(5) *# Go to the 6th byte in the file*

5

**>>>** f.read(1)

b'5'

**>>>** f.seek(-3, 2) *# Go to the 3rd byte before the end*

13

**>>>** f.read(1)

b'd'

In text files (those opened without a b in the mode string), only seeks relative to the beginning of the file are allowed (the exception being seeking to the very file end with seek(0, 2)) and the only validoffset values are those returned from the f.tell(), or zero. Any other offset value produces undefined behaviour.

When you’re done with a file, call f.close() to close it and free up any system resources taken up by the open file. After calling f.close(), attempts to use the file object will automatically fail.

>>>

**>>>** f.close()

**>>>** f.read()

Traceback (most recent call last):

File "<stdin>", line 1, in ?

ValueError: I/O operation on closed file

It is good practice to use the [with](https://docs.python.org/3/reference/compound_stmts.html#with) keyword when dealing with file objects. This has the advantage that the file is properly closed after its suite finishes, even if an exception is raised on the way. It is also much shorter than writing equivalent [try](https://docs.python.org/3/reference/compound_stmts.html#try)-[finally](https://docs.python.org/3/reference/compound_stmts.html#finally) blocks:

>>>

**>>> with** open('workfile', 'r') **as** f:

**...**  read\_data = f.read()

**>>>** f.closed

True

File objects have some additional methods, such as isatty() and truncate() which are less frequently used; consult the Library Reference for a complete guide to file objects.

### 7.2.2. Saving structured data with [json](https://docs.python.org/3/library/json.html#module-json)

Strings can easily be written to and read from a file. Numbers take a bit more effort, since the read()method only returns strings, which will have to be passed to a function like [int()](https://docs.python.org/3/library/functions.html#int), which takes a string like '123' and returns its numeric value 123. When you want to save more complex data types like nested lists and dictionaries, parsing and serializing by hand becomes complicated.

Rather than having users constantly writing and debugging code to save complicated data types to files, Python allows you to use the popular data interchange format called [JSON (JavaScript Object Notation)](http://json.org/). The standard module called [json](https://docs.python.org/3/library/json.html#module-json) can take Python data hierarchies, and convert them to string representations; this process is called serializing. Reconstructing the data from the string representation is called deserializing. Between serializing and deserializing, the string representing the object may have been stored in a file or data, or sent over a network connection to some distant machine.

**Note**

The JSON format is commonly used by modern applications to allow for data exchange. Many programmers are already familiar with it, which makes it a good choice for interoperability.

If you have an object x, you can view its JSON string representation with a simple line of code:

>>>

**>>>** json.dumps([1, 'simple', 'list'])

'[1, "simple", "list"]'

Another variant of the [dumps()](https://docs.python.org/3/library/json.html#json.dumps) function, called [dump()](https://docs.python.org/3/library/json.html#json.dump), simply serializes the object to a [text file](https://docs.python.org/3/glossary.html#term-text-file). So iff is a [text file](https://docs.python.org/3/glossary.html#term-text-file) object opened for writing, we can do this:

json.dump(x, f)

To decode the object again, if f is a [text file](https://docs.python.org/3/glossary.html#term-text-file) object which has been opened for reading:

x = json.load(f)

This simple serialization technique can handle lists and dictionaries, but serializing arbitrary class instances in JSON requires a bit of extra effort. The reference for the [json](https://docs.python.org/3/library/json.html#module-json) module contains an explanation of this.

**See also**

[pickle](https://docs.python.org/3/library/pickle.html#module-pickle) - the pickle module

Contrary to [JSON](https://docs.python.org/3/tutorial/inputoutput.html#tut-json), pickle is a protocol which allows the serialization of arbitrarily complex Python objects. As such, it is specific to Python and cannot be used to communicate with applications written in other languages. It is also insecure by default: deserializing pickle data coming from an untrusted source can execute arbitrary code, if the data was crafted by a skilled attacker.

# 8. Errors and Exceptions

Until now error messages haven’t been more than mentioned, but if you have tried out the examples you have probably seen some. There are (at least) two distinguishable kinds of errors: syntax errorsand exceptions.

## 8.1. Syntax Errors

Syntax errors, also known as parsing errors, are perhaps the most common kind of complaint you get while you are still learning Python:

>>>

**>>> while** **True** print('Hello world')

File "<stdin>", line 1, in ?

while True print('Hello world')

^

SyntaxError: invalid syntax

The parser repeats the offending line and displays a little ‘arrow’ pointing at the earliest point in the line where the error was detected. The error is caused by (or at least detected at) the token preceding the arrow: in the example, the error is detected at the function [print()](https://docs.python.org/3/library/functions.html#print), since a colon (':') is missing before it. File name and line number are printed so you know where to look in case the input came from a script.

## 8.2. Exceptions

Even if a statement or expression is syntactically correct, it may cause an error when an attempt is made to execute it. Errors detected during execution are called exceptions and are not unconditionally fatal: you will soon learn how to handle them in Python programs. Most exceptions are not handled by programs, however, and result in error messages as shown here:

>>>

**>>>** 10 \* (1/0)

Traceback (most recent call last):

File "<stdin>", line 1, in ?

ZeroDivisionError: division by zero

**>>>** 4 + spam\*3

Traceback (most recent call last):

File "<stdin>", line 1, in ?

NameError: name 'spam' is not defined

**>>>** '2' + 2

Traceback (most recent call last):

File "<stdin>", line 1, in ?

TypeError: Can't convert 'int' object to str implicitly

The last line of the error message indicates what happened. Exceptions come in different types, and the type is printed as part of the message: the types in the example are [ZeroDivisionError](https://docs.python.org/3/library/exceptions.html#ZeroDivisionError),[NameError](https://docs.python.org/3/library/exceptions.html#NameError) and [TypeError](https://docs.python.org/3/library/exceptions.html#TypeError). The string printed as the exception type is the name of the built-in exception that occurred. This is true for all built-in exceptions, but need not be true for user-defined exceptions (although it is a useful convention). Standard exception names are built-in identifiers (not reserved keywords).

The rest of the line provides detail based on the type of exception and what caused it.

The preceding part of the error message shows the context where the exception happened, in the form of a stack traceback. In general it contains a stack traceback listing source lines; however, it will not display lines read from standard input.

[Built-in Exceptions](https://docs.python.org/3/library/exceptions.html#bltin-exceptions) lists the built-in exceptions and their meanings.

## 8.3. Handling Exceptions

It is possible to write programs that handle selected exceptions. Look at the following example, which asks the user for input until a valid integer has been entered, but allows the user to interrupt the program (using Control-C or whatever the operating system supports); note that a user-generated interruption is signalled by raising the [KeyboardInterrupt](https://docs.python.org/3/library/exceptions.html#KeyboardInterrupt) exception.

>>>

**>>> while** **True**:

**...**  **try**:

**...**  x = int(input("Please enter a number: "))

**...**  **break**

**...**  **except** ValueError:

**...**  print("Oops! That was no valid number. Try again...")

**...**

The [try](https://docs.python.org/3/reference/compound_stmts.html#try) statement works as follows.

* First, the try clause (the statement(s) between the [try](https://docs.python.org/3/reference/compound_stmts.html#try) and [except](https://docs.python.org/3/reference/compound_stmts.html#except) keywords) is executed.
* If no exception occurs, the except clause is skipped and execution of the [try](https://docs.python.org/3/reference/compound_stmts.html#try) statement is finished.
* If an exception occurs during execution of the try clause, the rest of the clause is skipped. Then if its type matches the exception named after the [except](https://docs.python.org/3/reference/compound_stmts.html#except) keyword, the except clause is executed, and then execution continues after the [try](https://docs.python.org/3/reference/compound_stmts.html#try) statement.
* If an exception occurs which does not match the exception named in the except clause, it is passed on to outer [try](https://docs.python.org/3/reference/compound_stmts.html#try) statements; if no handler is found, it is an unhandled exception and execution stops with a message as shown above.

A [try](https://docs.python.org/3/reference/compound_stmts.html#try) statement may have more than one except clause, to specify handlers for different exceptions. At most one handler will be executed. Handlers only handle exceptions that occur in the corresponding try clause, not in other handlers of the same [try](https://docs.python.org/3/reference/compound_stmts.html#try) statement. An except clause may name multiple exceptions as a parenthesized tuple, for example:

... **except** (RuntimeError, TypeError, NameError):

... **pass**

The last except clause may omit the exception name(s), to serve as a wildcard. Use this with extreme caution, since it is easy to mask a real programming error in this way! It can also be used to print an error message and then re-raise the exception (allowing a caller to handle the exception as well):

**import** **sys**

**try**:

f = open('myfile.txt')

s = f.readline()

i = int(s.strip())

**except** OSError **as** err:

print("OS error: *{0}*".format(err))

**except** ValueError:

print("Could not convert data to an integer.")

**except**:

print("Unexpected error:", sys.exc\_info()[0])

**raise**

The [try](https://docs.python.org/3/reference/compound_stmts.html#try) ... [except](https://docs.python.org/3/reference/compound_stmts.html#except) statement has an optional else clause, which, when present, must follow all except clauses. It is useful for code that must be executed if the try clause does not raise an exception. For example:

**for** arg **in** sys.argv[1:]:

**try**:

f = open(arg, 'r')

**except** IOError:

print('cannot open', arg)

**else**:

print(arg, 'has', len(f.readlines()), 'lines')

f.close()

The use of the [else](https://docs.python.org/3/reference/compound_stmts.html#else) clause is better than adding additional code to the [try](https://docs.python.org/3/reference/compound_stmts.html#try) clause because it avoids accidentally catching an exception that wasn’t raised by the code being protected by the [try](https://docs.python.org/3/reference/compound_stmts.html#try) ...[except](https://docs.python.org/3/reference/compound_stmts.html#except) statement.

When an exception occurs, it may have an associated value, also known as the exception’s argument. The presence and type of the argument depend on the exception type.

The except clause may specify a variable after the exception name. The variable is bound to an exception instance with the arguments stored in instance.args. For convenience, the exception instance defines [\_\_str\_\_()](https://docs.python.org/3/reference/datamodel.html#object.__str__) so the arguments can be printed directly without having to reference.args. One may also instantiate an exception first before raising it and add any attributes to it as desired.

>>>

**>>> try**:

**...**  **raise** Exception('spam', 'eggs')

**... except** Exception **as** inst:

**...**  print(type(inst)) *# the exception instance*

**...**  print(inst.args) *# arguments stored in .args*

**...**  print(inst) *# \_\_str\_\_ allows args to be printed directly,*

**...**  *# but may be overridden in exception subclasses*

**...**  x, y = inst.args *# unpack args*

**...**  print('x =', x)

**...**  print('y =', y)

**...**

<class 'Exception'>

('spam', 'eggs')

('spam', 'eggs')

x = spam

y = eggs

If an exception has arguments, they are printed as the last part (‘detail’) of the message for unhandled exceptions.

Exception handlers don’t just handle exceptions if they occur immediately in the try clause, but also if they occur inside functions that are called (even indirectly) in the try clause. For example:

>>>

**>>> def** this\_fails():

**...**  x = 1/0

**...**

**>>> try**:

**...**  this\_fails()

**... except** ZeroDivisionError **as** err:

**...**  print('Handling run-time error:', err)

**...**

Handling run-time error: int division or modulo by zero

## 8.4. Raising Exceptions

The [raise](https://docs.python.org/3/reference/simple_stmts.html#raise) statement allows the programmer to force a specified exception to occur. For example:

>>>

**>>> raise** NameError('HiThere')

Traceback (most recent call last):

File "<stdin>", line 1, in ?

NameError: HiThere

The sole argument to [raise](https://docs.python.org/3/reference/simple_stmts.html#raise) indicates the exception to be raised. This must be either an exception instance or an exception class (a class that derives from [Exception](https://docs.python.org/3/library/exceptions.html#Exception)).

If you need to determine whether an exception was raised but don’t intend to handle it, a simpler form of the [raise](https://docs.python.org/3/reference/simple_stmts.html#raise) statement allows you to re-raise the exception:

>>>

**>>> try**:

**...**  **raise** NameError('HiThere')

**... except** NameError:

**...**  print('An exception flew by!')

**...**  **raise**

**...**

An exception flew by!

Traceback (most recent call last):

File "<stdin>", line 2, in ?

NameError: HiThere

## 8.5. User-defined Exceptions

Programs may name their own exceptions by creating a new exception class (see [Classes](https://docs.python.org/3/tutorial/classes.html#tut-classes) for more about Python classes). Exceptions should typically be derived from the [Exception](https://docs.python.org/3/library/exceptions.html#Exception) class, either directly or indirectly. For example:

>>>

**>>> class** **MyError**(Exception):

**...**  **def** \_\_init\_\_(self, value):

**...**  self.value = value

**...**  **def** \_\_str\_\_(self):

**...**  **return** repr(self.value)

**...**

**>>> try**:

**...**  **raise** MyError(2\*2)

**... except** MyError **as** e:

**...**  print('My exception occurred, value:', e.value)

**...**

My exception occurred, value: 4

**>>> raise** MyError('oops!')

Traceback (most recent call last):

File "<stdin>", line 1, in ?

\_\_main\_\_.MyError: 'oops!'

In this example, the default [\_\_init\_\_()](https://docs.python.org/3/reference/datamodel.html#object.__init__) of [Exception](https://docs.python.org/3/library/exceptions.html#Exception) has been overridden. The new behavior simply creates the value attribute. This replaces the default behavior of creating the args attribute.

Exception classes can be defined which do anything any other class can do, but are usually kept simple, often only offering a number of attributes that allow information about the error to be extracted by handlers for the exception. When creating a module that can raise several distinct errors, a common practice is to create a base class for exceptions defined by that module, and subclass that to create specific exception classes for different error conditions:

**class** **Error**(Exception):

*"""Base class for exceptions in this module."""*

**pass**

**class** **InputError**(Error):

*"""Exception raised for errors in the input.*

*Attributes:*

*expression -- input expression in which the error occurred*

*message -- explanation of the error*

*"""*

**def** \_\_init\_\_(self, expression, message):

self.expression = expression

self.message = message

**class** **TransitionError**(Error):

*"""Raised when an operation attempts a state transition that's not*

*allowed.*

*Attributes:*

*previous -- state at beginning of transition*

*next -- attempted new state*

*message -- explanation of why the specific transition is not allowed*

*"""*

**def** \_\_init\_\_(self, previous, next, message):

self.previous = previous

self.next = next

self.message = message

Most exceptions are defined with names that end in “Error,” similar to the naming of the standard exceptions.

Many standard modules define their own exceptions to report errors that may occur in functions they define. More information on classes is presented in chapter [Classes](https://docs.python.org/3/tutorial/classes.html#tut-classes).

## 8.6. Defining Clean-up Actions

The [try](https://docs.python.org/3/reference/compound_stmts.html#try) statement has another optional clause which is intended to define clean-up actions that must be executed under all circumstances. For example:

>>>

**>>> try**:

**...**  **raise** KeyboardInterrupt

**... finally**:

**...**  print('Goodbye, world!')

**...**

Goodbye, world!

**KeyboardInterrupt**

Traceback (most recent call last):

File "<stdin>", line 2, in ?

A finally clause is always executed before leaving the [try](https://docs.python.org/3/reference/compound_stmts.html#try) statement, whether an exception has occurred or not. When an exception has occurred in the [try](https://docs.python.org/3/reference/compound_stmts.html#try) clause and has not been handled by an[except](https://docs.python.org/3/reference/compound_stmts.html#except) clause (or it has occurred in an [except](https://docs.python.org/3/reference/compound_stmts.html#except) or [else](https://docs.python.org/3/reference/compound_stmts.html#else) clause), it is re-raised after the [finally](https://docs.python.org/3/reference/compound_stmts.html#finally)clause has been executed. The [finally](https://docs.python.org/3/reference/compound_stmts.html#finally) clause is also executed “on the way out” when any other clause of the [try](https://docs.python.org/3/reference/compound_stmts.html#try) statement is left via a [break](https://docs.python.org/3/reference/simple_stmts.html#break), [continue](https://docs.python.org/3/reference/simple_stmts.html#continue) or [return](https://docs.python.org/3/reference/simple_stmts.html#return) statement. A more complicated example:

>>>

**>>> def** divide(x, y):

**...**  **try**:

**...**  result = x / y

**...**  **except** ZeroDivisionError:

**...**  print("division by zero!")

**...**  **else**:

**...**  print("result is", result)

**...**  **finally**:

**...**  print("executing finally clause")

**...**

**>>>** divide(2, 1)

result is 2.0

executing finally clause

**>>>** divide(2, 0)

division by zero!

executing finally clause

**>>>** divide("2", "1")

executing finally clause

Traceback (most recent call last):

File "<stdin>", line 1, in ?

File "<stdin>", line 3, in divide

TypeError: unsupported operand type(s) for /: 'str' and 'str'

As you can see, the [finally](https://docs.python.org/3/reference/compound_stmts.html#finally) clause is executed in any event. The [TypeError](https://docs.python.org/3/library/exceptions.html#TypeError) raised by dividing two strings is not handled by the [except](https://docs.python.org/3/reference/compound_stmts.html#except) clause and therefore re-raised after the [finally](https://docs.python.org/3/reference/compound_stmts.html#finally) clause has been executed.

In real world applications, the [finally](https://docs.python.org/3/reference/compound_stmts.html#finally) clause is useful for releasing external resources (such as files or network connections), regardless of whether the use of the resource was successful.

## 8.7. Predefined Clean-up Actions

Some objects define standard clean-up actions to be undertaken when the object is no longer needed, regardless of whether or not the operation using the object succeeded or failed. Look at the following example, which tries to open a file and print its contents to the screen.

**for** line **in** open("myfile.txt"):

print(line, end="")

The problem with this code is that it leaves the file open for an indeterminate amount of time after this part of the code has finished executing. This is not an issue in simple scripts, but can be a problem for larger applications. The [with](https://docs.python.org/3/reference/compound_stmts.html#with) statement allows objects like files to be used in a way that ensures they are always cleaned up promptly and correctly.

**with** open("myfile.txt") **as** f:

**for** line **in** f:

print(line, end="")

After the statement is executed, the file f is always closed, even if a problem was encountered while processing the lines. Objects which, like files, provide predefined clean-up actions will indicate this in their documentation.

# 8. Errors and Exceptions

Until now error messages haven’t been more than mentioned, but if you have tried out the examples you have probably seen some. There are (at least) two distinguishable kinds of errors: syntax errorsand exceptions.

## 8.1. Syntax Errors

Syntax errors, also known as parsing errors, are perhaps the most common kind of complaint you get while you are still learning Python:

>>>

**>>> while** **True** print('Hello world')

File "<stdin>", line 1, in ?

while True print('Hello world')

^

SyntaxError: invalid syntax

The parser repeats the offending line and displays a little ‘arrow’ pointing at the earliest point in the line where the error was detected. The error is caused by (or at least detected at) the token preceding the arrow: in the example, the error is detected at the function [print()](https://docs.python.org/3/library/functions.html#print), since a colon (':') is missing before it. File name and line number are printed so you know where to look in case the input came from a script.

## 8.2. Exceptions

Even if a statement or expression is syntactically correct, it may cause an error when an attempt is made to execute it. Errors detected during execution are called exceptions and are not unconditionally fatal: you will soon learn how to handle them in Python programs. Most exceptions are not handled by programs, however, and result in error messages as shown here:

>>>

**>>>** 10 \* (1/0)

Traceback (most recent call last):

File "<stdin>", line 1, in ?

ZeroDivisionError: division by zero

**>>>** 4 + spam\*3

Traceback (most recent call last):

File "<stdin>", line 1, in ?

NameError: name 'spam' is not defined

**>>>** '2' + 2

Traceback (most recent call last):

File "<stdin>", line 1, in ?

TypeError: Can't convert 'int' object to str implicitly

The last line of the error message indicates what happened. Exceptions come in different types, and the type is printed as part of the message: the types in the example are [ZeroDivisionError](https://docs.python.org/3/library/exceptions.html#ZeroDivisionError),[NameError](https://docs.python.org/3/library/exceptions.html#NameError) and [TypeError](https://docs.python.org/3/library/exceptions.html#TypeError). The string printed as the exception type is the name of the built-in exception that occurred. This is true for all built-in exceptions, but need not be true for user-defined exceptions (although it is a useful convention). Standard exception names are built-in identifiers (not reserved keywords).

The rest of the line provides detail based on the type of exception and what caused it.

The preceding part of the error message shows the context where the exception happened, in the form of a stack traceback. In general it contains a stack traceback listing source lines; however, it will not display lines read from standard input.

[Built-in Exceptions](https://docs.python.org/3/library/exceptions.html#bltin-exceptions) lists the built-in exceptions and their meanings.

## 8.3. Handling Exceptions

It is possible to write programs that handle selected exceptions. Look at the following example, which asks the user for input until a valid integer has been entered, but allows the user to interrupt the program (using Control-C or whatever the operating system supports); note that a user-generated interruption is signalled by raising the [KeyboardInterrupt](https://docs.python.org/3/library/exceptions.html#KeyboardInterrupt) exception.

>>>

**>>> while** **True**:

**...**  **try**:

**...**  x = int(input("Please enter a number: "))

**...**  **break**

**...**  **except** ValueError:

**...**  print("Oops! That was no valid number. Try again...")

**...**

The [try](https://docs.python.org/3/reference/compound_stmts.html#try) statement works as follows.

* First, the try clause (the statement(s) between the [try](https://docs.python.org/3/reference/compound_stmts.html#try) and [except](https://docs.python.org/3/reference/compound_stmts.html#except) keywords) is executed.
* If no exception occurs, the except clause is skipped and execution of the [try](https://docs.python.org/3/reference/compound_stmts.html#try) statement is finished.
* If an exception occurs during execution of the try clause, the rest of the clause is skipped. Then if its type matches the exception named after the [except](https://docs.python.org/3/reference/compound_stmts.html#except) keyword, the except clause is executed, and then execution continues after the [try](https://docs.python.org/3/reference/compound_stmts.html#try) statement.
* If an exception occurs which does not match the exception named in the except clause, it is passed on to outer [try](https://docs.python.org/3/reference/compound_stmts.html#try) statements; if no handler is found, it is an unhandled exception and execution stops with a message as shown above.

A [try](https://docs.python.org/3/reference/compound_stmts.html#try) statement may have more than one except clause, to specify handlers for different exceptions. At most one handler will be executed. Handlers only handle exceptions that occur in the corresponding try clause, not in other handlers of the same [try](https://docs.python.org/3/reference/compound_stmts.html#try) statement. An except clause may name multiple exceptions as a parenthesized tuple, for example:

... **except** (RuntimeError, TypeError, NameError):

... **pass**

The last except clause may omit the exception name(s), to serve as a wildcard. Use this with extreme caution, since it is easy to mask a real programming error in this way! It can also be used to print an error message and then re-raise the exception (allowing a caller to handle the exception as well):

**import** **sys**

**try**:

f = open('myfile.txt')

s = f.readline()

i = int(s.strip())

**except** OSError **as** err:

print("OS error: *{0}*".format(err))

**except** ValueError:

print("Could not convert data to an integer.")

**except**:

print("Unexpected error:", sys.exc\_info()[0])

**raise**

The [try](https://docs.python.org/3/reference/compound_stmts.html#try) ... [except](https://docs.python.org/3/reference/compound_stmts.html#except) statement has an optional else clause, which, when present, must follow all except clauses. It is useful for code that must be executed if the try clause does not raise an exception. For example:

**for** arg **in** sys.argv[1:]:

**try**:

f = open(arg, 'r')

**except** IOError:

print('cannot open', arg)

**else**:

print(arg, 'has', len(f.readlines()), 'lines')

f.close()

The use of the [else](https://docs.python.org/3/reference/compound_stmts.html#else) clause is better than adding additional code to the [try](https://docs.python.org/3/reference/compound_stmts.html#try) clause because it avoids accidentally catching an exception that wasn’t raised by the code being protected by the [try](https://docs.python.org/3/reference/compound_stmts.html#try) ...[except](https://docs.python.org/3/reference/compound_stmts.html#except) statement.

When an exception occurs, it may have an associated value, also known as the exception’s argument. The presence and type of the argument depend on the exception type.

The except clause may specify a variable after the exception name. The variable is bound to an exception instance with the arguments stored in instance.args. For convenience, the exception instance defines [\_\_str\_\_()](https://docs.python.org/3/reference/datamodel.html#object.__str__) so the arguments can be printed directly without having to reference.args. One may also instantiate an exception first before raising it and add any attributes to it as desired.

>>>

**>>> try**:

**...**  **raise** Exception('spam', 'eggs')

**... except** Exception **as** inst:

**...**  print(type(inst)) *# the exception instance*

**...**  print(inst.args) *# arguments stored in .args*

**...**  print(inst) *# \_\_str\_\_ allows args to be printed directly,*

**...**  *# but may be overridden in exception subclasses*

**...**  x, y = inst.args *# unpack args*

**...**  print('x =', x)

**...**  print('y =', y)

**...**

<class 'Exception'>

('spam', 'eggs')

('spam', 'eggs')

x = spam

y = eggs

If an exception has arguments, they are printed as the last part (‘detail’) of the message for unhandled exceptions.

Exception handlers don’t just handle exceptions if they occur immediately in the try clause, but also if they occur inside functions that are called (even indirectly) in the try clause. For example:

>>>

**>>> def** this\_fails():

**...**  x = 1/0

**...**

**>>> try**:

**...**  this\_fails()

**... except** ZeroDivisionError **as** err:

**...**  print('Handling run-time error:', err)

**...**

Handling run-time error: int division or modulo by zero

## 8.4. Raising Exceptions

The [raise](https://docs.python.org/3/reference/simple_stmts.html#raise) statement allows the programmer to force a specified exception to occur. For example:

>>>

**>>> raise** NameError('HiThere')

Traceback (most recent call last):

File "<stdin>", line 1, in ?

NameError: HiThere

The sole argument to [raise](https://docs.python.org/3/reference/simple_stmts.html#raise) indicates the exception to be raised. This must be either an exception instance or an exception class (a class that derives from [Exception](https://docs.python.org/3/library/exceptions.html#Exception)).

If you need to determine whether an exception was raised but don’t intend to handle it, a simpler form of the [raise](https://docs.python.org/3/reference/simple_stmts.html#raise) statement allows you to re-raise the exception:

>>>

**>>> try**:

**...**  **raise** NameError('HiThere')

**... except** NameError:

**...**  print('An exception flew by!')

**...**  **raise**

**...**

An exception flew by!

Traceback (most recent call last):

File "<stdin>", line 2, in ?

NameError: HiThere

## 8.5. User-defined Exceptions

Programs may name their own exceptions by creating a new exception class (see [Classes](https://docs.python.org/3/tutorial/classes.html#tut-classes) for more about Python classes). Exceptions should typically be derived from the [Exception](https://docs.python.org/3/library/exceptions.html#Exception) class, either directly or indirectly. For example:

>>>

**>>> class** **MyError**(Exception):

**...**  **def** \_\_init\_\_(self, value):

**...**  self.value = value

**...**  **def** \_\_str\_\_(self):

**...**  **return** repr(self.value)

**...**

**>>> try**:

**...**  **raise** MyError(2\*2)

**... except** MyError **as** e:

**...**  print('My exception occurred, value:', e.value)

**...**

My exception occurred, value: 4

**>>> raise** MyError('oops!')

Traceback (most recent call last):

File "<stdin>", line 1, in ?

\_\_main\_\_.MyError: 'oops!'

In this example, the default [\_\_init\_\_()](https://docs.python.org/3/reference/datamodel.html#object.__init__) of [Exception](https://docs.python.org/3/library/exceptions.html#Exception) has been overridden. The new behavior simply creates the value attribute. This replaces the default behavior of creating the args attribute.

Exception classes can be defined which do anything any other class can do, but are usually kept simple, often only offering a number of attributes that allow information about the error to be extracted by handlers for the exception. When creating a module that can raise several distinct errors, a common practice is to create a base class for exceptions defined by that module, and subclass that to create specific exception classes for different error conditions:

**class** **Error**(Exception):

*"""Base class for exceptions in this module."""*

**pass**

**class** **InputError**(Error):

*"""Exception raised for errors in the input.*

*Attributes:*

*expression -- input expression in which the error occurred*

*message -- explanation of the error*

*"""*

**def** \_\_init\_\_(self, expression, message):

self.expression = expression

self.message = message

**class** **TransitionError**(Error):

*"""Raised when an operation attempts a state transition that's not*

*allowed.*

*Attributes:*

*previous -- state at beginning of transition*

*next -- attempted new state*

*message -- explanation of why the specific transition is not allowed*

*"""*

**def** \_\_init\_\_(self, previous, next, message):

self.previous = previous

self.next = next

self.message = message

Most exceptions are defined with names that end in “Error,” similar to the naming of the standard exceptions.

Many standard modules define their own exceptions to report errors that may occur in functions they define. More information on classes is presented in chapter [Classes](https://docs.python.org/3/tutorial/classes.html#tut-classes).

## 8.6. Defining Clean-up Actions

The [try](https://docs.python.org/3/reference/compound_stmts.html#try) statement has another optional clause which is intended to define clean-up actions that must be executed under all circumstances. For example:

>>>

**>>> try**:

**...**  **raise** KeyboardInterrupt

**... finally**:

**...**  print('Goodbye, world!')

**...**

Goodbye, world!

**KeyboardInterrupt**

Traceback (most recent call last):

File "<stdin>", line 2, in ?

A finally clause is always executed before leaving the [try](https://docs.python.org/3/reference/compound_stmts.html#try) statement, whether an exception has occurred or not. When an exception has occurred in the [try](https://docs.python.org/3/reference/compound_stmts.html#try) clause and has not been handled by an[except](https://docs.python.org/3/reference/compound_stmts.html#except) clause (or it has occurred in an [except](https://docs.python.org/3/reference/compound_stmts.html#except) or [else](https://docs.python.org/3/reference/compound_stmts.html#else) clause), it is re-raised after the [finally](https://docs.python.org/3/reference/compound_stmts.html#finally)clause has been executed. The [finally](https://docs.python.org/3/reference/compound_stmts.html#finally) clause is also executed “on the way out” when any other clause of the [try](https://docs.python.org/3/reference/compound_stmts.html#try) statement is left via a [break](https://docs.python.org/3/reference/simple_stmts.html#break), [continue](https://docs.python.org/3/reference/simple_stmts.html#continue) or [return](https://docs.python.org/3/reference/simple_stmts.html#return) statement. A more complicated example:

>>>

**>>> def** divide(x, y):

**...**  **try**:

**...**  result = x / y

**...**  **except** ZeroDivisionError:

**...**  print("division by zero!")

**...**  **else**:

**...**  print("result is", result)

**...**  **finally**:

**...**  print("executing finally clause")

**...**

**>>>** divide(2, 1)

result is 2.0

executing finally clause

**>>>** divide(2, 0)

division by zero!

executing finally clause

**>>>** divide("2", "1")

executing finally clause

Traceback (most recent call last):

File "<stdin>", line 1, in ?

File "<stdin>", line 3, in divide

TypeError: unsupported operand type(s) for /: 'str' and 'str'

As you can see, the [finally](https://docs.python.org/3/reference/compound_stmts.html#finally) clause is executed in any event. The [TypeError](https://docs.python.org/3/library/exceptions.html#TypeError) raised by dividing two strings is not handled by the [except](https://docs.python.org/3/reference/compound_stmts.html#except) clause and therefore re-raised after the [finally](https://docs.python.org/3/reference/compound_stmts.html#finally) clause has been executed.

In real world applications, the [finally](https://docs.python.org/3/reference/compound_stmts.html#finally) clause is useful for releasing external resources (such as files or network connections), regardless of whether the use of the resource was successful.

## 8.7. Predefined Clean-up Actions

Some objects define standard clean-up actions to be undertaken when the object is no longer needed, regardless of whether or not the operation using the object succeeded or failed. Look at the following example, which tries to open a file and print its contents to the screen.

**for** line **in** open("myfile.txt"):

print(line, end="")

The problem with this code is that it leaves the file open for an indeterminate amount of time after this part of the code has finished executing. This is not an issue in simple scripts, but can be a problem for larger applications. The [with](https://docs.python.org/3/reference/compound_stmts.html#with) statement allows objects like files to be used in a way that ensures they are always cleaned up promptly and correctly.

**with** open("myfile.txt") **as** f:

**for** line **in** f:

print(line, end="")

After the statement is executed, the file f is always closed, even if a problem was encountered while processing the lines. Objects which, like files, provide predefined clean-up actions will indicate this in their documentation.

# 8. Errors and Exceptions

Until now error messages haven’t been more than mentioned, but if you have tried out the examples you have probably seen some. There are (at least) two distinguishable kinds of errors: syntax errorsand exceptions.

## 8.1. Syntax Errors

Syntax errors, also known as parsing errors, are perhaps the most common kind of complaint you get while you are still learning Python:

>>>

**>>> while** **True** print('Hello world')

File "<stdin>", line 1, in ?

while True print('Hello world')

^

SyntaxError: invalid syntax

The parser repeats the offending line and displays a little ‘arrow’ pointing at the earliest point in the line where the error was detected. The error is caused by (or at least detected at) the token preceding the arrow: in the example, the error is detected at the function [print()](https://docs.python.org/3/library/functions.html#print), since a colon (':') is missing before it. File name and line number are printed so you know where to look in case the input came from a script.

## 8.2. Exceptions

Even if a statement or expression is syntactically correct, it may cause an error when an attempt is made to execute it. Errors detected during execution are called exceptions and are not unconditionally fatal: you will soon learn how to handle them in Python programs. Most exceptions are not handled by programs, however, and result in error messages as shown here:

>>>

**>>>** 10 \* (1/0)

Traceback (most recent call last):

File "<stdin>", line 1, in ?

ZeroDivisionError: division by zero

**>>>** 4 + spam\*3

Traceback (most recent call last):

File "<stdin>", line 1, in ?

NameError: name 'spam' is not defined

**>>>** '2' + 2

Traceback (most recent call last):

File "<stdin>", line 1, in ?

TypeError: Can't convert 'int' object to str implicitly

The last line of the error message indicates what happened. Exceptions come in different types, and the type is printed as part of the message: the types in the example are [ZeroDivisionError](https://docs.python.org/3/library/exceptions.html#ZeroDivisionError),[NameError](https://docs.python.org/3/library/exceptions.html#NameError) and [TypeError](https://docs.python.org/3/library/exceptions.html#TypeError). The string printed as the exception type is the name of the built-in exception that occurred. This is true for all built-in exceptions, but need not be true for user-defined exceptions (although it is a useful convention). Standard exception names are built-in identifiers (not reserved keywords).

The rest of the line provides detail based on the type of exception and what caused it.

The preceding part of the error message shows the context where the exception happened, in the form of a stack traceback. In general it contains a stack traceback listing source lines; however, it will not display lines read from standard input.

[Built-in Exceptions](https://docs.python.org/3/library/exceptions.html#bltin-exceptions) lists the built-in exceptions and their meanings.

## 8.3. Handling Exceptions

It is possible to write programs that handle selected exceptions. Look at the following example, which asks the user for input until a valid integer has been entered, but allows the user to interrupt the program (using Control-C or whatever the operating system supports); note that a user-generated interruption is signalled by raising the [KeyboardInterrupt](https://docs.python.org/3/library/exceptions.html#KeyboardInterrupt) exception.

>>>

**>>> while** **True**:

**...**  **try**:

**...**  x = int(input("Please enter a number: "))

**...**  **break**

**...**  **except** ValueError:

**...**  print("Oops! That was no valid number. Try again...")

**...**

The [try](https://docs.python.org/3/reference/compound_stmts.html#try) statement works as follows.

* First, the try clause (the statement(s) between the [try](https://docs.python.org/3/reference/compound_stmts.html#try) and [except](https://docs.python.org/3/reference/compound_stmts.html#except) keywords) is executed.
* If no exception occurs, the except clause is skipped and execution of the [try](https://docs.python.org/3/reference/compound_stmts.html#try) statement is finished.
* If an exception occurs during execution of the try clause, the rest of the clause is skipped. Then if its type matches the exception named after the [except](https://docs.python.org/3/reference/compound_stmts.html#except) keyword, the except clause is executed, and then execution continues after the [try](https://docs.python.org/3/reference/compound_stmts.html#try) statement.
* If an exception occurs which does not match the exception named in the except clause, it is passed on to outer [try](https://docs.python.org/3/reference/compound_stmts.html#try) statements; if no handler is found, it is an unhandled exception and execution stops with a message as shown above.

A [try](https://docs.python.org/3/reference/compound_stmts.html#try) statement may have more than one except clause, to specify handlers for different exceptions. At most one handler will be executed. Handlers only handle exceptions that occur in the corresponding try clause, not in other handlers of the same [try](https://docs.python.org/3/reference/compound_stmts.html#try) statement. An except clause may name multiple exceptions as a parenthesized tuple, for example:

... **except** (RuntimeError, TypeError, NameError):

... **pass**

The last except clause may omit the exception name(s), to serve as a wildcard. Use this with extreme caution, since it is easy to mask a real programming error in this way! It can also be used to print an error message and then re-raise the exception (allowing a caller to handle the exception as well):

**import** **sys**

**try**:

f = open('myfile.txt')

s = f.readline()

i = int(s.strip())

**except** OSError **as** err:

print("OS error: *{0}*".format(err))

**except** ValueError:

print("Could not convert data to an integer.")

**except**:

print("Unexpected error:", sys.exc\_info()[0])

**raise**

The [try](https://docs.python.org/3/reference/compound_stmts.html#try) ... [except](https://docs.python.org/3/reference/compound_stmts.html#except) statement has an optional else clause, which, when present, must follow all except clauses. It is useful for code that must be executed if the try clause does not raise an exception. For example:

**for** arg **in** sys.argv[1:]:

**try**:

f = open(arg, 'r')

**except** IOError:

print('cannot open', arg)

**else**:

print(arg, 'has', len(f.readlines()), 'lines')

f.close()

The use of the [else](https://docs.python.org/3/reference/compound_stmts.html#else) clause is better than adding additional code to the [try](https://docs.python.org/3/reference/compound_stmts.html#try) clause because it avoids accidentally catching an exception that wasn’t raised by the code being protected by the [try](https://docs.python.org/3/reference/compound_stmts.html#try) ...[except](https://docs.python.org/3/reference/compound_stmts.html#except) statement.

When an exception occurs, it may have an associated value, also known as the exception’s argument. The presence and type of the argument depend on the exception type.

The except clause may specify a variable after the exception name. The variable is bound to an exception instance with the arguments stored in instance.args. For convenience, the exception instance defines [\_\_str\_\_()](https://docs.python.org/3/reference/datamodel.html#object.__str__) so the arguments can be printed directly without having to reference.args. One may also instantiate an exception first before raising it and add any attributes to it as desired.

>>>

**>>> try**:

**...**  **raise** Exception('spam', 'eggs')

**... except** Exception **as** inst:

**...**  print(type(inst)) *# the exception instance*

**...**  print(inst.args) *# arguments stored in .args*

**...**  print(inst) *# \_\_str\_\_ allows args to be printed directly,*

**...**  *# but may be overridden in exception subclasses*

**...**  x, y = inst.args *# unpack args*

**...**  print('x =', x)

**...**  print('y =', y)

**...**

<class 'Exception'>

('spam', 'eggs')

('spam', 'eggs')

x = spam

y = eggs

If an exception has arguments, they are printed as the last part (‘detail’) of the message for unhandled exceptions.

Exception handlers don’t just handle exceptions if they occur immediately in the try clause, but also if they occur inside functions that are called (even indirectly) in the try clause. For example:

>>>

**>>> def** this\_fails():

**...**  x = 1/0

**...**

**>>> try**:

**...**  this\_fails()

**... except** ZeroDivisionError **as** err:

**...**  print('Handling run-time error:', err)

**...**

Handling run-time error: int division or modulo by zero

## 8.4. Raising Exceptions

The [raise](https://docs.python.org/3/reference/simple_stmts.html#raise) statement allows the programmer to force a specified exception to occur. For example:

>>>

**>>> raise** NameError('HiThere')

Traceback (most recent call last):

File "<stdin>", line 1, in ?

NameError: HiThere

The sole argument to [raise](https://docs.python.org/3/reference/simple_stmts.html#raise) indicates the exception to be raised. This must be either an exception instance or an exception class (a class that derives from [Exception](https://docs.python.org/3/library/exceptions.html#Exception)).

If you need to determine whether an exception was raised but don’t intend to handle it, a simpler form of the [raise](https://docs.python.org/3/reference/simple_stmts.html#raise) statement allows you to re-raise the exception:

>>>

**>>> try**:

**...**  **raise** NameError('HiThere')

**... except** NameError:

**...**  print('An exception flew by!')

**...**  **raise**

**...**

An exception flew by!

Traceback (most recent call last):

File "<stdin>", line 2, in ?

NameError: HiThere

## 8.5. User-defined Exceptions

Programs may name their own exceptions by creating a new exception class (see [Classes](https://docs.python.org/3/tutorial/classes.html#tut-classes) for more about Python classes). Exceptions should typically be derived from the [Exception](https://docs.python.org/3/library/exceptions.html#Exception) class, either directly or indirectly. For example:

>>>

**>>> class** **MyError**(Exception):

**...**  **def** \_\_init\_\_(self, value):

**...**  self.value = value

**...**  **def** \_\_str\_\_(self):

**...**  **return** repr(self.value)

**...**

**>>> try**:

**...**  **raise** MyError(2\*2)

**... except** MyError **as** e:

**...**  print('My exception occurred, value:', e.value)

**...**

My exception occurred, value: 4

**>>> raise** MyError('oops!')

Traceback (most recent call last):

File "<stdin>", line 1, in ?

\_\_main\_\_.MyError: 'oops!'

In this example, the default [\_\_init\_\_()](https://docs.python.org/3/reference/datamodel.html#object.__init__) of [Exception](https://docs.python.org/3/library/exceptions.html#Exception) has been overridden. The new behavior simply creates the value attribute. This replaces the default behavior of creating the args attribute.

Exception classes can be defined which do anything any other class can do, but are usually kept simple, often only offering a number of attributes that allow information about the error to be extracted by handlers for the exception. When creating a module that can raise several distinct errors, a common practice is to create a base class for exceptions defined by that module, and subclass that to create specific exception classes for different error conditions:

**class** **Error**(Exception):

*"""Base class for exceptions in this module."""*

**pass**

**class** **InputError**(Error):

*"""Exception raised for errors in the input.*

*Attributes:*

*expression -- input expression in which the error occurred*

*message -- explanation of the error*

*"""*

**def** \_\_init\_\_(self, expression, message):

self.expression = expression

self.message = message

**class** **TransitionError**(Error):

*"""Raised when an operation attempts a state transition that's not*

*allowed.*

*Attributes:*

*previous -- state at beginning of transition*

*next -- attempted new state*

*message -- explanation of why the specific transition is not allowed*

*"""*

**def** \_\_init\_\_(self, previous, next, message):

self.previous = previous

self.next = next

self.message = message

Most exceptions are defined with names that end in “Error,” similar to the naming of the standard exceptions.

Many standard modules define their own exceptions to report errors that may occur in functions they define. More information on classes is presented in chapter [Classes](https://docs.python.org/3/tutorial/classes.html#tut-classes).

## 8.6. Defining Clean-up Actions

The [try](https://docs.python.org/3/reference/compound_stmts.html#try) statement has another optional clause which is intended to define clean-up actions that must be executed under all circumstances. For example:

>>>

**>>> try**:

**...**  **raise** KeyboardInterrupt

**... finally**:

**...**  print('Goodbye, world!')

**...**

Goodbye, world!

**KeyboardInterrupt**

Traceback (most recent call last):

File "<stdin>", line 2, in ?

A finally clause is always executed before leaving the [try](https://docs.python.org/3/reference/compound_stmts.html#try) statement, whether an exception has occurred or not. When an exception has occurred in the [try](https://docs.python.org/3/reference/compound_stmts.html#try) clause and has not been handled by an[except](https://docs.python.org/3/reference/compound_stmts.html#except) clause (or it has occurred in an [except](https://docs.python.org/3/reference/compound_stmts.html#except) or [else](https://docs.python.org/3/reference/compound_stmts.html#else) clause), it is re-raised after the [finally](https://docs.python.org/3/reference/compound_stmts.html#finally)clause has been executed. The [finally](https://docs.python.org/3/reference/compound_stmts.html#finally) clause is also executed “on the way out” when any other clause of the [try](https://docs.python.org/3/reference/compound_stmts.html#try) statement is left via a [break](https://docs.python.org/3/reference/simple_stmts.html#break), [continue](https://docs.python.org/3/reference/simple_stmts.html#continue) or [return](https://docs.python.org/3/reference/simple_stmts.html#return) statement. A more complicated example:

>>>

**>>> def** divide(x, y):

**...**  **try**:

**...**  result = x / y

**...**  **except** ZeroDivisionError:

**...**  print("division by zero!")

**...**  **else**:

**...**  print("result is", result)

**...**  **finally**:

**...**  print("executing finally clause")

**...**

**>>>** divide(2, 1)

result is 2.0

executing finally clause

**>>>** divide(2, 0)

division by zero!

executing finally clause

**>>>** divide("2", "1")

executing finally clause

Traceback (most recent call last):

File "<stdin>", line 1, in ?

File "<stdin>", line 3, in divide

TypeError: unsupported operand type(s) for /: 'str' and 'str'

As you can see, the [finally](https://docs.python.org/3/reference/compound_stmts.html#finally) clause is executed in any event. The [TypeError](https://docs.python.org/3/library/exceptions.html#TypeError) raised by dividing two strings is not handled by the [except](https://docs.python.org/3/reference/compound_stmts.html#except) clause and therefore re-raised after the [finally](https://docs.python.org/3/reference/compound_stmts.html#finally) clause has been executed.

In real world applications, the [finally](https://docs.python.org/3/reference/compound_stmts.html#finally) clause is useful for releasing external resources (such as files or network connections), regardless of whether the use of the resource was successful.

## 8.7. Predefined Clean-up Actions

Some objects define standard clean-up actions to be undertaken when the object is no longer needed, regardless of whether or not the operation using the object succeeded or failed. Look at the following example, which tries to open a file and print its contents to the screen.

**for** line **in** open("myfile.txt"):

print(line, end="")

The problem with this code is that it leaves the file open for an indeterminate amount of time after this part of the code has finished executing. This is not an issue in simple scripts, but can be a problem for larger applications. The [with](https://docs.python.org/3/reference/compound_stmts.html#with) statement allows objects like files to be used in a way that ensures they are always cleaned up promptly and correctly.

**with** open("myfile.txt") **as** f:

**for** line **in** f:

print(line, end="")

After the statement is executed, the file f is always closed, even if a problem was encountered while processing the lines. Objects which, like files, provide predefined clean-up actions will indicate this in their documentation.

# 8. Errors and Exceptions

Until now error messages haven’t been more than mentioned, but if you have tried out the examples you have probably seen some. There are (at least) two distinguishable kinds of errors: syntax errorsand exceptions.

## 8.1. Syntax Errors

Syntax errors, also known as parsing errors, are perhaps the most common kind of complaint you get while you are still learning Python:

>>>

**>>> while** **True** print('Hello world')

File "<stdin>", line 1, in ?

while True print('Hello world')

^

SyntaxError: invalid syntax

The parser repeats the offending line and displays a little ‘arrow’ pointing at the earliest point in the line where the error was detected. The error is caused by (or at least detected at) the token preceding the arrow: in the example, the error is detected at the function [print()](https://docs.python.org/3/library/functions.html#print), since a colon (':') is missing before it. File name and line number are printed so you know where to look in case the input came from a script.

## 8.2. Exceptions

Even if a statement or expression is syntactically correct, it may cause an error when an attempt is made to execute it. Errors detected during execution are called exceptions and are not unconditionally fatal: you will soon learn how to handle them in Python programs. Most exceptions are not handled by programs, however, and result in error messages as shown here:

>>>

**>>>** 10 \* (1/0)

Traceback (most recent call last):

File "<stdin>", line 1, in ?

ZeroDivisionError: division by zero

**>>>** 4 + spam\*3

Traceback (most recent call last):

File "<stdin>", line 1, in ?

NameError: name 'spam' is not defined

**>>>** '2' + 2

Traceback (most recent call last):

File "<stdin>", line 1, in ?

TypeError: Can't convert 'int' object to str implicitly

The last line of the error message indicates what happened. Exceptions come in different types, and the type is printed as part of the message: the types in the example are [ZeroDivisionError](https://docs.python.org/3/library/exceptions.html#ZeroDivisionError),[NameError](https://docs.python.org/3/library/exceptions.html#NameError) and [TypeError](https://docs.python.org/3/library/exceptions.html#TypeError). The string printed as the exception type is the name of the built-in exception that occurred. This is true for all built-in exceptions, but need not be true for user-defined exceptions (although it is a useful convention). Standard exception names are built-in identifiers (not reserved keywords).

The rest of the line provides detail based on the type of exception and what caused it.

The preceding part of the error message shows the context where the exception happened, in the form of a stack traceback. In general it contains a stack traceback listing source lines; however, it will not display lines read from standard input.

[Built-in Exceptions](https://docs.python.org/3/library/exceptions.html#bltin-exceptions) lists the built-in exceptions and their meanings.

## 8.3. Handling Exceptions

It is possible to write programs that handle selected exceptions. Look at the following example, which asks the user for input until a valid integer has been entered, but allows the user to interrupt the program (using Control-C or whatever the operating system supports); note that a user-generated interruption is signalled by raising the [KeyboardInterrupt](https://docs.python.org/3/library/exceptions.html#KeyboardInterrupt) exception.

>>>

**>>> while** **True**:

**...**  **try**:

**...**  x = int(input("Please enter a number: "))

**...**  **break**

**...**  **except** ValueError:

**...**  print("Oops! That was no valid number. Try again...")

**...**

The [try](https://docs.python.org/3/reference/compound_stmts.html#try) statement works as follows.

* First, the try clause (the statement(s) between the [try](https://docs.python.org/3/reference/compound_stmts.html#try) and [except](https://docs.python.org/3/reference/compound_stmts.html#except) keywords) is executed.
* If no exception occurs, the except clause is skipped and execution of the [try](https://docs.python.org/3/reference/compound_stmts.html#try) statement is finished.
* If an exception occurs during execution of the try clause, the rest of the clause is skipped. Then if its type matches the exception named after the [except](https://docs.python.org/3/reference/compound_stmts.html#except) keyword, the except clause is executed, and then execution continues after the [try](https://docs.python.org/3/reference/compound_stmts.html#try) statement.
* If an exception occurs which does not match the exception named in the except clause, it is passed on to outer [try](https://docs.python.org/3/reference/compound_stmts.html#try) statements; if no handler is found, it is an unhandled exception and execution stops with a message as shown above.

A [try](https://docs.python.org/3/reference/compound_stmts.html#try) statement may have more than one except clause, to specify handlers for different exceptions. At most one handler will be executed. Handlers only handle exceptions that occur in the corresponding try clause, not in other handlers of the same [try](https://docs.python.org/3/reference/compound_stmts.html#try) statement. An except clause may name multiple exceptions as a parenthesized tuple, for example:

... **except** (RuntimeError, TypeError, NameError):

... **pass**

The last except clause may omit the exception name(s), to serve as a wildcard. Use this with extreme caution, since it is easy to mask a real programming error in this way! It can also be used to print an error message and then re-raise the exception (allowing a caller to handle the exception as well):

**import** **sys**

**try**:

f = open('myfile.txt')

s = f.readline()

i = int(s.strip())

**except** OSError **as** err:

print("OS error: *{0}*".format(err))

**except** ValueError:

print("Could not convert data to an integer.")

**except**:

print("Unexpected error:", sys.exc\_info()[0])

**raise**

The [try](https://docs.python.org/3/reference/compound_stmts.html#try) ... [except](https://docs.python.org/3/reference/compound_stmts.html#except) statement has an optional else clause, which, when present, must follow all except clauses. It is useful for code that must be executed if the try clause does not raise an exception. For example:

**for** arg **in** sys.argv[1:]:

**try**:

f = open(arg, 'r')

**except** IOError:

print('cannot open', arg)

**else**:

print(arg, 'has', len(f.readlines()), 'lines')

f.close()

The use of the [else](https://docs.python.org/3/reference/compound_stmts.html#else) clause is better than adding additional code to the [try](https://docs.python.org/3/reference/compound_stmts.html#try) clause because it avoids accidentally catching an exception that wasn’t raised by the code being protected by the [try](https://docs.python.org/3/reference/compound_stmts.html#try) ...[except](https://docs.python.org/3/reference/compound_stmts.html#except) statement.

When an exception occurs, it may have an associated value, also known as the exception’s argument. The presence and type of the argument depend on the exception type.

The except clause may specify a variable after the exception name. The variable is bound to an exception instance with the arguments stored in instance.args. For convenience, the exception instance defines [\_\_str\_\_()](https://docs.python.org/3/reference/datamodel.html#object.__str__) so the arguments can be printed directly without having to reference.args. One may also instantiate an exception first before raising it and add any attributes to it as desired.

>>>

**>>> try**:

**...**  **raise** Exception('spam', 'eggs')

**... except** Exception **as** inst:

**...**  print(type(inst)) *# the exception instance*

**...**  print(inst.args) *# arguments stored in .args*

**...**  print(inst) *# \_\_str\_\_ allows args to be printed directly,*

**...**  *# but may be overridden in exception subclasses*

**...**  x, y = inst.args *# unpack args*

**...**  print('x =', x)

**...**  print('y =', y)

**...**

<class 'Exception'>

('spam', 'eggs')

('spam', 'eggs')

x = spam

y = eggs

If an exception has arguments, they are printed as the last part (‘detail’) of the message for unhandled exceptions.

Exception handlers don’t just handle exceptions if they occur immediately in the try clause, but also if they occur inside functions that are called (even indirectly) in the try clause. For example:

>>>

**>>> def** this\_fails():

**...**  x = 1/0

**...**

**>>> try**:

**...**  this\_fails()

**... except** ZeroDivisionError **as** err:

**...**  print('Handling run-time error:', err)

**...**

Handling run-time error: int division or modulo by zero

## 8.4. Raising Exceptions

The [raise](https://docs.python.org/3/reference/simple_stmts.html#raise) statement allows the programmer to force a specified exception to occur. For example:

>>>

**>>> raise** NameError('HiThere')

Traceback (most recent call last):

File "<stdin>", line 1, in ?

NameError: HiThere

The sole argument to [raise](https://docs.python.org/3/reference/simple_stmts.html#raise) indicates the exception to be raised. This must be either an exception instance or an exception class (a class that derives from [Exception](https://docs.python.org/3/library/exceptions.html#Exception)).

If you need to determine whether an exception was raised but don’t intend to handle it, a simpler form of the [raise](https://docs.python.org/3/reference/simple_stmts.html#raise) statement allows you to re-raise the exception:

>>>

**>>> try**:

**...**  **raise** NameError('HiThere')

**... except** NameError:

**...**  print('An exception flew by!')

**...**  **raise**

**...**

An exception flew by!

Traceback (most recent call last):

File "<stdin>", line 2, in ?

NameError: HiThere

## 8.5. User-defined Exceptions

Programs may name their own exceptions by creating a new exception class (see [Classes](https://docs.python.org/3/tutorial/classes.html#tut-classes) for more about Python classes). Exceptions should typically be derived from the [Exception](https://docs.python.org/3/library/exceptions.html#Exception) class, either directly or indirectly. For example:

>>>

**>>> class** **MyError**(Exception):

**...**  **def** \_\_init\_\_(self, value):

**...**  self.value = value

**...**  **def** \_\_str\_\_(self):

**...**  **return** repr(self.value)

**...**

**>>> try**:

**...**  **raise** MyError(2\*2)

**... except** MyError **as** e:

**...**  print('My exception occurred, value:', e.value)

**...**

My exception occurred, value: 4

**>>> raise** MyError('oops!')

Traceback (most recent call last):

File "<stdin>", line 1, in ?

\_\_main\_\_.MyError: 'oops!'

In this example, the default [\_\_init\_\_()](https://docs.python.org/3/reference/datamodel.html#object.__init__) of [Exception](https://docs.python.org/3/library/exceptions.html#Exception) has been overridden. The new behavior simply creates the value attribute. This replaces the default behavior of creating the args attribute.

Exception classes can be defined which do anything any other class can do, but are usually kept simple, often only offering a number of attributes that allow information about the error to be extracted by handlers for the exception. When creating a module that can raise several distinct errors, a common practice is to create a base class for exceptions defined by that module, and subclass that to create specific exception classes for different error conditions:

**class** **Error**(Exception):

*"""Base class for exceptions in this module."""*

**pass**

**class** **InputError**(Error):

*"""Exception raised for errors in the input.*

*Attributes:*

*expression -- input expression in which the error occurred*

*message -- explanation of the error*

*"""*

**def** \_\_init\_\_(self, expression, message):

self.expression = expression

self.message = message

**class** **TransitionError**(Error):

*"""Raised when an operation attempts a state transition that's not*

*allowed.*

*Attributes:*

*previous -- state at beginning of transition*

*next -- attempted new state*

*message -- explanation of why the specific transition is not allowed*

*"""*

**def** \_\_init\_\_(self, previous, next, message):

self.previous = previous

self.next = next

self.message = message

Most exceptions are defined with names that end in “Error,” similar to the naming of the standard exceptions.

Many standard modules define their own exceptions to report errors that may occur in functions they define. More information on classes is presented in chapter [Classes](https://docs.python.org/3/tutorial/classes.html#tut-classes).

## 8.6. Defining Clean-up Actions

The [try](https://docs.python.org/3/reference/compound_stmts.html#try) statement has another optional clause which is intended to define clean-up actions that must be executed under all circumstances. For example:

>>>

**>>> try**:

**...**  **raise** KeyboardInterrupt

**... finally**:

**...**  print('Goodbye, world!')

**...**

Goodbye, world!

**KeyboardInterrupt**

Traceback (most recent call last):

File "<stdin>", line 2, in ?

A finally clause is always executed before leaving the [try](https://docs.python.org/3/reference/compound_stmts.html#try) statement, whether an exception has occurred or not. When an exception has occurred in the [try](https://docs.python.org/3/reference/compound_stmts.html#try) clause and has not been handled by an[except](https://docs.python.org/3/reference/compound_stmts.html#except) clause (or it has occurred in an [except](https://docs.python.org/3/reference/compound_stmts.html#except) or [else](https://docs.python.org/3/reference/compound_stmts.html#else) clause), it is re-raised after the [finally](https://docs.python.org/3/reference/compound_stmts.html#finally)clause has been executed. The [finally](https://docs.python.org/3/reference/compound_stmts.html#finally) clause is also executed “on the way out” when any other clause of the [try](https://docs.python.org/3/reference/compound_stmts.html#try) statement is left via a [break](https://docs.python.org/3/reference/simple_stmts.html#break), [continue](https://docs.python.org/3/reference/simple_stmts.html#continue) or [return](https://docs.python.org/3/reference/simple_stmts.html#return) statement. A more complicated example:

>>>

**>>> def** divide(x, y):

**...**  **try**:

**...**  result = x / y

**...**  **except** ZeroDivisionError:

**...**  print("division by zero!")

**...**  **else**:

**...**  print("result is", result)

**...**  **finally**:

**...**  print("executing finally clause")

**...**

**>>>** divide(2, 1)

result is 2.0

executing finally clause

**>>>** divide(2, 0)

division by zero!

executing finally clause

**>>>** divide("2", "1")

executing finally clause

Traceback (most recent call last):

File "<stdin>", line 1, in ?

File "<stdin>", line 3, in divide

TypeError: unsupported operand type(s) for /: 'str' and 'str'

As you can see, the [finally](https://docs.python.org/3/reference/compound_stmts.html#finally) clause is executed in any event. The [TypeError](https://docs.python.org/3/library/exceptions.html#TypeError) raised by dividing two strings is not handled by the [except](https://docs.python.org/3/reference/compound_stmts.html#except) clause and therefore re-raised after the [finally](https://docs.python.org/3/reference/compound_stmts.html#finally) clause has been executed.

In real world applications, the [finally](https://docs.python.org/3/reference/compound_stmts.html#finally) clause is useful for releasing external resources (such as files or network connections), regardless of whether the use of the resource was successful.

## 8.7. Predefined Clean-up Actions

Some objects define standard clean-up actions to be undertaken when the object is no longer needed, regardless of whether or not the operation using the object succeeded or failed. Look at the following example, which tries to open a file and print its contents to the screen.

**for** line **in** open("myfile.txt"):

print(line, end="")

The problem with this code is that it leaves the file open for an indeterminate amount of time after this part of the code has finished executing. This is not an issue in simple scripts, but can be a problem for larger applications. The [with](https://docs.python.org/3/reference/compound_stmts.html#with) statement allows objects like files to be used in a way that ensures they are always cleaned up promptly and correctly.

**with** open("myfile.txt") **as** f:

**for** line **in** f:

print(line, end="")

After the statement is executed, the file f is always closed, even if a problem was encountered while processing the lines. Objects which, like files, provide predefined clean-up actions will indicate this in their documentation.

# 8. Errors and Exceptions

Until now error messages haven’t been more than mentioned, but if you have tried out the examples you have probably seen some. There are (at least) two distinguishable kinds of errors: syntax errorsand exceptions.

## 8.1. Syntax Errors

Syntax errors, also known as parsing errors, are perhaps the most common kind of complaint you get while you are still learning Python:

>>>

**>>> while** **True** print('Hello world')

File "<stdin>", line 1, in ?

while True print('Hello world')

^

SyntaxError: invalid syntax

The parser repeats the offending line and displays a little ‘arrow’ pointing at the earliest point in the line where the error was detected. The error is caused by (or at least detected at) the token preceding the arrow: in the example, the error is detected at the function [print()](https://docs.python.org/3/library/functions.html#print), since a colon (':') is missing before it. File name and line number are printed so you know where to look in case the input came from a script.

## 8.2. Exceptions

Even if a statement or expression is syntactically correct, it may cause an error when an attempt is made to execute it. Errors detected during execution are called exceptions and are not unconditionally fatal: you will soon learn how to handle them in Python programs. Most exceptions are not handled by programs, however, and result in error messages as shown here:

>>>

**>>>** 10 \* (1/0)

Traceback (most recent call last):

File "<stdin>", line 1, in ?

ZeroDivisionError: division by zero

**>>>** 4 + spam\*3

Traceback (most recent call last):

File "<stdin>", line 1, in ?

NameError: name 'spam' is not defined

**>>>** '2' + 2

Traceback (most recent call last):

File "<stdin>", line 1, in ?

TypeError: Can't convert 'int' object to str implicitly

The last line of the error message indicates what happened. Exceptions come in different types, and the type is printed as part of the message: the types in the example are [ZeroDivisionError](https://docs.python.org/3/library/exceptions.html#ZeroDivisionError),[NameError](https://docs.python.org/3/library/exceptions.html#NameError) and [TypeError](https://docs.python.org/3/library/exceptions.html#TypeError). The string printed as the exception type is the name of the built-in exception that occurred. This is true for all built-in exceptions, but need not be true for user-defined exceptions (although it is a useful convention). Standard exception names are built-in identifiers (not reserved keywords).

The rest of the line provides detail based on the type of exception and what caused it.

The preceding part of the error message shows the context where the exception happened, in the form of a stack traceback. In general it contains a stack traceback listing source lines; however, it will not display lines read from standard input.

[Built-in Exceptions](https://docs.python.org/3/library/exceptions.html#bltin-exceptions) lists the built-in exceptions and their meanings.

## 8.3. Handling Exceptions

It is possible to write programs that handle selected exceptions. Look at the following example, which asks the user for input until a valid integer has been entered, but allows the user to interrupt the program (using Control-C or whatever the operating system supports); note that a user-generated interruption is signalled by raising the [KeyboardInterrupt](https://docs.python.org/3/library/exceptions.html#KeyboardInterrupt) exception.

>>>

**>>> while** **True**:

**...**  **try**:

**...**  x = int(input("Please enter a number: "))

**...**  **break**

**...**  **except** ValueError:

**...**  print("Oops! That was no valid number. Try again...")

**...**

The [try](https://docs.python.org/3/reference/compound_stmts.html#try) statement works as follows.

* First, the try clause (the statement(s) between the [try](https://docs.python.org/3/reference/compound_stmts.html#try) and [except](https://docs.python.org/3/reference/compound_stmts.html#except) keywords) is executed.
* If no exception occurs, the except clause is skipped and execution of the [try](https://docs.python.org/3/reference/compound_stmts.html#try) statement is finished.
* If an exception occurs during execution of the try clause, the rest of the clause is skipped. Then if its type matches the exception named after the [except](https://docs.python.org/3/reference/compound_stmts.html#except) keyword, the except clause is executed, and then execution continues after the [try](https://docs.python.org/3/reference/compound_stmts.html#try) statement.
* If an exception occurs which does not match the exception named in the except clause, it is passed on to outer [try](https://docs.python.org/3/reference/compound_stmts.html#try) statements; if no handler is found, it is an unhandled exception and execution stops with a message as shown above.

A [try](https://docs.python.org/3/reference/compound_stmts.html#try) statement may have more than one except clause, to specify handlers for different exceptions. At most one handler will be executed. Handlers only handle exceptions that occur in the corresponding try clause, not in other handlers of the same [try](https://docs.python.org/3/reference/compound_stmts.html#try) statement. An except clause may name multiple exceptions as a parenthesized tuple, for example:

... **except** (RuntimeError, TypeError, NameError):

... **pass**

The last except clause may omit the exception name(s), to serve as a wildcard. Use this with extreme caution, since it is easy to mask a real programming error in this way! It can also be used to print an error message and then re-raise the exception (allowing a caller to handle the exception as well):

**import** **sys**

**try**:

f = open('myfile.txt')

s = f.readline()

i = int(s.strip())

**except** OSError **as** err:

print("OS error: *{0}*".format(err))

**except** ValueError:

print("Could not convert data to an integer.")

**except**:

print("Unexpected error:", sys.exc\_info()[0])

**raise**

The [try](https://docs.python.org/3/reference/compound_stmts.html#try) ... [except](https://docs.python.org/3/reference/compound_stmts.html#except) statement has an optional else clause, which, when present, must follow all except clauses. It is useful for code that must be executed if the try clause does not raise an exception. For example:

**for** arg **in** sys.argv[1:]:

**try**:

f = open(arg, 'r')

**except** IOError:

print('cannot open', arg)

**else**:

print(arg, 'has', len(f.readlines()), 'lines')

f.close()

The use of the [else](https://docs.python.org/3/reference/compound_stmts.html#else) clause is better than adding additional code to the [try](https://docs.python.org/3/reference/compound_stmts.html#try) clause because it avoids accidentally catching an exception that wasn’t raised by the code being protected by the [try](https://docs.python.org/3/reference/compound_stmts.html#try) ...[except](https://docs.python.org/3/reference/compound_stmts.html#except) statement.

When an exception occurs, it may have an associated value, also known as the exception’s argument. The presence and type of the argument depend on the exception type.

The except clause may specify a variable after the exception name. The variable is bound to an exception instance with the arguments stored in instance.args. For convenience, the exception instance defines [\_\_str\_\_()](https://docs.python.org/3/reference/datamodel.html#object.__str__) so the arguments can be printed directly without having to reference.args. One may also instantiate an exception first before raising it and add any attributes to it as desired.

>>>

**>>> try**:

**...**  **raise** Exception('spam', 'eggs')

**... except** Exception **as** inst:

**...**  print(type(inst)) *# the exception instance*

**...**  print(inst.args) *# arguments stored in .args*

**...**  print(inst) *# \_\_str\_\_ allows args to be printed directly,*

**...**  *# but may be overridden in exception subclasses*

**...**  x, y = inst.args *# unpack args*

**...**  print('x =', x)

**...**  print('y =', y)

**...**

<class 'Exception'>

('spam', 'eggs')

('spam', 'eggs')

x = spam

y = eggs

If an exception has arguments, they are printed as the last part (‘detail’) of the message for unhandled exceptions.

Exception handlers don’t just handle exceptions if they occur immediately in the try clause, but also if they occur inside functions that are called (even indirectly) in the try clause. For example:

>>>

**>>> def** this\_fails():

**...**  x = 1/0

**...**

**>>> try**:

**...**  this\_fails()

**... except** ZeroDivisionError **as** err:

**...**  print('Handling run-time error:', err)

**...**

Handling run-time error: int division or modulo by zero

## 8.4. Raising Exceptions

The [raise](https://docs.python.org/3/reference/simple_stmts.html#raise) statement allows the programmer to force a specified exception to occur. For example:

>>>

**>>> raise** NameError('HiThere')

Traceback (most recent call last):

File "<stdin>", line 1, in ?

NameError: HiThere

The sole argument to [raise](https://docs.python.org/3/reference/simple_stmts.html#raise) indicates the exception to be raised. This must be either an exception instance or an exception class (a class that derives from [Exception](https://docs.python.org/3/library/exceptions.html#Exception)).

If you need to determine whether an exception was raised but don’t intend to handle it, a simpler form of the [raise](https://docs.python.org/3/reference/simple_stmts.html#raise) statement allows you to re-raise the exception:

>>>

**>>> try**:

**...**  **raise** NameError('HiThere')

**... except** NameError:

**...**  print('An exception flew by!')

**...**  **raise**

**...**

An exception flew by!

Traceback (most recent call last):

File "<stdin>", line 2, in ?

NameError: HiThere

## 8.5. User-defined Exceptions

Programs may name their own exceptions by creating a new exception class (see [Classes](https://docs.python.org/3/tutorial/classes.html#tut-classes) for more about Python classes). Exceptions should typically be derived from the [Exception](https://docs.python.org/3/library/exceptions.html#Exception) class, either directly or indirectly. For example:

>>>

**>>> class** **MyError**(Exception):

**...**  **def** \_\_init\_\_(self, value):

**...**  self.value = value

**...**  **def** \_\_str\_\_(self):

**...**  **return** repr(self.value)

**...**

**>>> try**:

**...**  **raise** MyError(2\*2)

**... except** MyError **as** e:

**...**  print('My exception occurred, value:', e.value)

**...**

My exception occurred, value: 4

**>>> raise** MyError('oops!')

Traceback (most recent call last):

File "<stdin>", line 1, in ?

\_\_main\_\_.MyError: 'oops!'

In this example, the default [\_\_init\_\_()](https://docs.python.org/3/reference/datamodel.html#object.__init__) of [Exception](https://docs.python.org/3/library/exceptions.html#Exception) has been overridden. The new behavior simply creates the value attribute. This replaces the default behavior of creating the args attribute.

Exception classes can be defined which do anything any other class can do, but are usually kept simple, often only offering a number of attributes that allow information about the error to be extracted by handlers for the exception. When creating a module that can raise several distinct errors, a common practice is to create a base class for exceptions defined by that module, and subclass that to create specific exception classes for different error conditions:

**class** **Error**(Exception):

*"""Base class for exceptions in this module."""*

**pass**

**class** **InputError**(Error):

*"""Exception raised for errors in the input.*

*Attributes:*

*expression -- input expression in which the error occurred*

*message -- explanation of the error*

*"""*

**def** \_\_init\_\_(self, expression, message):

self.expression = expression

self.message = message

**class** **TransitionError**(Error):

*"""Raised when an operation attempts a state transition that's not*

*allowed.*

*Attributes:*

*previous -- state at beginning of transition*

*next -- attempted new state*

*message -- explanation of why the specific transition is not allowed*

*"""*

**def** \_\_init\_\_(self, previous, next, message):

self.previous = previous

self.next = next

self.message = message

Most exceptions are defined with names that end in “Error,” similar to the naming of the standard exceptions.

Many standard modules define their own exceptions to report errors that may occur in functions they define. More information on classes is presented in chapter [Classes](https://docs.python.org/3/tutorial/classes.html#tut-classes).

## 8.6. Defining Clean-up Actions

The [try](https://docs.python.org/3/reference/compound_stmts.html#try) statement has another optional clause which is intended to define clean-up actions that must be executed under all circumstances. For example:

>>>

**>>> try**:

**...**  **raise** KeyboardInterrupt

**... finally**:

**...**  print('Goodbye, world!')

**...**

Goodbye, world!

**KeyboardInterrupt**

Traceback (most recent call last):

File "<stdin>", line 2, in ?

A finally clause is always executed before leaving the [try](https://docs.python.org/3/reference/compound_stmts.html#try) statement, whether an exception has occurred or not. When an exception has occurred in the [try](https://docs.python.org/3/reference/compound_stmts.html#try) clause and has not been handled by an[except](https://docs.python.org/3/reference/compound_stmts.html#except) clause (or it has occurred in an [except](https://docs.python.org/3/reference/compound_stmts.html#except) or [else](https://docs.python.org/3/reference/compound_stmts.html#else) clause), it is re-raised after the [finally](https://docs.python.org/3/reference/compound_stmts.html#finally)clause has been executed. The [finally](https://docs.python.org/3/reference/compound_stmts.html#finally) clause is also executed “on the way out” when any other clause of the [try](https://docs.python.org/3/reference/compound_stmts.html#try) statement is left via a [break](https://docs.python.org/3/reference/simple_stmts.html#break), [continue](https://docs.python.org/3/reference/simple_stmts.html#continue) or [return](https://docs.python.org/3/reference/simple_stmts.html#return) statement. A more complicated example:

>>>

**>>> def** divide(x, y):

**...**  **try**:

**...**  result = x / y

**...**  **except** ZeroDivisionError:

**...**  print("division by zero!")

**...**  **else**:

**...**  print("result is", result)

**...**  **finally**:

**...**  print("executing finally clause")

**...**

**>>>** divide(2, 1)

result is 2.0

executing finally clause

**>>>** divide(2, 0)

division by zero!

executing finally clause

**>>>** divide("2", "1")

executing finally clause

Traceback (most recent call last):

File "<stdin>", line 1, in ?

File "<stdin>", line 3, in divide

TypeError: unsupported operand type(s) for /: 'str' and 'str'

As you can see, the [finally](https://docs.python.org/3/reference/compound_stmts.html#finally) clause is executed in any event. The [TypeError](https://docs.python.org/3/library/exceptions.html#TypeError) raised by dividing two strings is not handled by the [except](https://docs.python.org/3/reference/compound_stmts.html#except) clause and therefore re-raised after the [finally](https://docs.python.org/3/reference/compound_stmts.html#finally) clause has been executed.

In real world applications, the [finally](https://docs.python.org/3/reference/compound_stmts.html#finally) clause is useful for releasing external resources (such as files or network connections), regardless of whether the use of the resource was successful.

## 8.7. Predefined Clean-up Actions

Some objects define standard clean-up actions to be undertaken when the object is no longer needed, regardless of whether or not the operation using the object succeeded or failed. Look at the following example, which tries to open a file and print its contents to the screen.

**for** line **in** open("myfile.txt"):

print(line, end="")

The problem with this code is that it leaves the file open for an indeterminate amount of time after this part of the code has finished executing. This is not an issue in simple scripts, but can be a problem for larger applications. The [with](https://docs.python.org/3/reference/compound_stmts.html#with) statement allows objects like files to be used in a way that ensures they are always cleaned up promptly and correctly.

**with** open("myfile.txt") **as** f:

**for** line **in** f:

print(line, end="")

After the statement is executed, the file f is always closed, even if a problem was encountered while processing the lines. Objects which, like files, provide predefined clean-up actions will indicate this in their documentation.

# 8. Errors and Exceptions

Until now error messages haven’t been more than mentioned, but if you have tried out the examples you have probably seen some. There are (at least) two distinguishable kinds of errors: syntax errorsand exceptions.

## 8.1. Syntax Errors

Syntax errors, also known as parsing errors, are perhaps the most common kind of complaint you get while you are still learning Python:

>>>

**>>> while** **True** print('Hello world')

File "<stdin>", line 1, in ?

while True print('Hello world')

^

SyntaxError: invalid syntax

The parser repeats the offending line and displays a little ‘arrow’ pointing at the earliest point in the line where the error was detected. The error is caused by (or at least detected at) the token preceding the arrow: in the example, the error is detected at the function [print()](https://docs.python.org/3/library/functions.html#print), since a colon (':') is missing before it. File name and line number are printed so you know where to look in case the input came from a script.

## 8.2. Exceptions

Even if a statement or expression is syntactically correct, it may cause an error when an attempt is made to execute it. Errors detected during execution are called exceptions and are not unconditionally fatal: you will soon learn how to handle them in Python programs. Most exceptions are not handled by programs, however, and result in error messages as shown here:

>>>

**>>>** 10 \* (1/0)

Traceback (most recent call last):

File "<stdin>", line 1, in ?

ZeroDivisionError: division by zero

**>>>** 4 + spam\*3

Traceback (most recent call last):

File "<stdin>", line 1, in ?

NameError: name 'spam' is not defined

**>>>** '2' + 2

Traceback (most recent call last):

File "<stdin>", line 1, in ?

TypeError: Can't convert 'int' object to str implicitly

The last line of the error message indicates what happened. Exceptions come in different types, and the type is printed as part of the message: the types in the example are [ZeroDivisionError](https://docs.python.org/3/library/exceptions.html#ZeroDivisionError),[NameError](https://docs.python.org/3/library/exceptions.html#NameError) and [TypeError](https://docs.python.org/3/library/exceptions.html#TypeError). The string printed as the exception type is the name of the built-in exception that occurred. This is true for all built-in exceptions, but need not be true for user-defined exceptions (although it is a useful convention). Standard exception names are built-in identifiers (not reserved keywords).

The rest of the line provides detail based on the type of exception and what caused it.

The preceding part of the error message shows the context where the exception happened, in the form of a stack traceback. In general it contains a stack traceback listing source lines; however, it will not display lines read from standard input.

[Built-in Exceptions](https://docs.python.org/3/library/exceptions.html#bltin-exceptions) lists the built-in exceptions and their meanings.

## 8.3. Handling Exceptions

It is possible to write programs that handle selected exceptions. Look at the following example, which asks the user for input until a valid integer has been entered, but allows the user to interrupt the program (using Control-C or whatever the operating system supports); note that a user-generated interruption is signalled by raising the [KeyboardInterrupt](https://docs.python.org/3/library/exceptions.html#KeyboardInterrupt) exception.

>>>

**>>> while** **True**:

**...**  **try**:

**...**  x = int(input("Please enter a number: "))

**...**  **break**

**...**  **except** ValueError:

**...**  print("Oops! That was no valid number. Try again...")

**...**

The [try](https://docs.python.org/3/reference/compound_stmts.html#try) statement works as follows.

* First, the try clause (the statement(s) between the [try](https://docs.python.org/3/reference/compound_stmts.html#try) and [except](https://docs.python.org/3/reference/compound_stmts.html#except) keywords) is executed.
* If no exception occurs, the except clause is skipped and execution of the [try](https://docs.python.org/3/reference/compound_stmts.html#try) statement is finished.
* If an exception occurs during execution of the try clause, the rest of the clause is skipped. Then if its type matches the exception named after the [except](https://docs.python.org/3/reference/compound_stmts.html#except) keyword, the except clause is executed, and then execution continues after the [try](https://docs.python.org/3/reference/compound_stmts.html#try) statement.
* If an exception occurs which does not match the exception named in the except clause, it is passed on to outer [try](https://docs.python.org/3/reference/compound_stmts.html#try) statements; if no handler is found, it is an unhandled exception and execution stops with a message as shown above.

A [try](https://docs.python.org/3/reference/compound_stmts.html#try) statement may have more than one except clause, to specify handlers for different exceptions. At most one handler will be executed. Handlers only handle exceptions that occur in the corresponding try clause, not in other handlers of the same [try](https://docs.python.org/3/reference/compound_stmts.html#try) statement. An except clause may name multiple exceptions as a parenthesized tuple, for example:

... **except** (RuntimeError, TypeError, NameError):

... **pass**

The last except clause may omit the exception name(s), to serve as a wildcard. Use this with extreme caution, since it is easy to mask a real programming error in this way! It can also be used to print an error message and then re-raise the exception (allowing a caller to handle the exception as well):

**import** **sys**

**try**:

f = open('myfile.txt')

s = f.readline()

i = int(s.strip())

**except** OSError **as** err:

print("OS error: *{0}*".format(err))

**except** ValueError:

print("Could not convert data to an integer.")

**except**:

print("Unexpected error:", sys.exc\_info()[0])

**raise**

The [try](https://docs.python.org/3/reference/compound_stmts.html#try) ... [except](https://docs.python.org/3/reference/compound_stmts.html#except) statement has an optional else clause, which, when present, must follow all except clauses. It is useful for code that must be executed if the try clause does not raise an exception. For example:

**for** arg **in** sys.argv[1:]:

**try**:

f = open(arg, 'r')

**except** IOError:

print('cannot open', arg)

**else**:

print(arg, 'has', len(f.readlines()), 'lines')

f.close()

The use of the [else](https://docs.python.org/3/reference/compound_stmts.html#else) clause is better than adding additional code to the [try](https://docs.python.org/3/reference/compound_stmts.html#try) clause because it avoids accidentally catching an exception that wasn’t raised by the code being protected by the [try](https://docs.python.org/3/reference/compound_stmts.html#try) ...[except](https://docs.python.org/3/reference/compound_stmts.html#except) statement.

When an exception occurs, it may have an associated value, also known as the exception’s argument. The presence and type of the argument depend on the exception type.

The except clause may specify a variable after the exception name. The variable is bound to an exception instance with the arguments stored in instance.args. For convenience, the exception instance defines [\_\_str\_\_()](https://docs.python.org/3/reference/datamodel.html#object.__str__) so the arguments can be printed directly without having to reference.args. One may also instantiate an exception first before raising it and add any attributes to it as desired.

>>>

**>>> try**:

**...**  **raise** Exception('spam', 'eggs')

**... except** Exception **as** inst:

**...**  print(type(inst)) *# the exception instance*

**...**  print(inst.args) *# arguments stored in .args*

**...**  print(inst) *# \_\_str\_\_ allows args to be printed directly,*

**...**  *# but may be overridden in exception subclasses*

**...**  x, y = inst.args *# unpack args*

**...**  print('x =', x)

**...**  print('y =', y)

**...**

<class 'Exception'>

('spam', 'eggs')

('spam', 'eggs')

x = spam

y = eggs

If an exception has arguments, they are printed as the last part (‘detail’) of the message for unhandled exceptions.

Exception handlers don’t just handle exceptions if they occur immediately in the try clause, but also if they occur inside functions that are called (even indirectly) in the try clause. For example:

>>>

**>>> def** this\_fails():

**...**  x = 1/0

**...**

**>>> try**:

**...**  this\_fails()

**... except** ZeroDivisionError **as** err:

**...**  print('Handling run-time error:', err)

**...**

Handling run-time error: int division or modulo by zero

## 8.4. Raising Exceptions

The [raise](https://docs.python.org/3/reference/simple_stmts.html#raise) statement allows the programmer to force a specified exception to occur. For example:

>>>

**>>> raise** NameError('HiThere')

Traceback (most recent call last):

File "<stdin>", line 1, in ?

NameError: HiThere

The sole argument to [raise](https://docs.python.org/3/reference/simple_stmts.html#raise) indicates the exception to be raised. This must be either an exception instance or an exception class (a class that derives from [Exception](https://docs.python.org/3/library/exceptions.html#Exception)).

If you need to determine whether an exception was raised but don’t intend to handle it, a simpler form of the [raise](https://docs.python.org/3/reference/simple_stmts.html#raise) statement allows you to re-raise the exception:

>>>

**>>> try**:

**...**  **raise** NameError('HiThere')

**... except** NameError:

**...**  print('An exception flew by!')

**...**  **raise**

**...**

An exception flew by!

Traceback (most recent call last):

File "<stdin>", line 2, in ?

NameError: HiThere

## 8.5. User-defined Exceptions

Programs may name their own exceptions by creating a new exception class (see [Classes](https://docs.python.org/3/tutorial/classes.html#tut-classes) for more about Python classes). Exceptions should typically be derived from the [Exception](https://docs.python.org/3/library/exceptions.html#Exception) class, either directly or indirectly. For example:

>>>

**>>> class** **MyError**(Exception):

**...**  **def** \_\_init\_\_(self, value):

**...**  self.value = value

**...**  **def** \_\_str\_\_(self):

**...**  **return** repr(self.value)

**...**

**>>> try**:

**...**  **raise** MyError(2\*2)

**... except** MyError **as** e:

**...**  print('My exception occurred, value:', e.value)

**...**

My exception occurred, value: 4

**>>> raise** MyError('oops!')

Traceback (most recent call last):

File "<stdin>", line 1, in ?

\_\_main\_\_.MyError: 'oops!'

In this example, the default [\_\_init\_\_()](https://docs.python.org/3/reference/datamodel.html#object.__init__) of [Exception](https://docs.python.org/3/library/exceptions.html#Exception) has been overridden. The new behavior simply creates the value attribute. This replaces the default behavior of creating the args attribute.

Exception classes can be defined which do anything any other class can do, but are usually kept simple, often only offering a number of attributes that allow information about the error to be extracted by handlers for the exception. When creating a module that can raise several distinct errors, a common practice is to create a base class for exceptions defined by that module, and subclass that to create specific exception classes for different error conditions:

**class** **Error**(Exception):

*"""Base class for exceptions in this module."""*

**pass**

**class** **InputError**(Error):

*"""Exception raised for errors in the input.*

*Attributes:*

*expression -- input expression in which the error occurred*

*message -- explanation of the error*

*"""*

**def** \_\_init\_\_(self, expression, message):

self.expression = expression

self.message = message

**class** **TransitionError**(Error):

*"""Raised when an operation attempts a state transition that's not*

*allowed.*

*Attributes:*

*previous -- state at beginning of transition*

*next -- attempted new state*

*message -- explanation of why the specific transition is not allowed*

*"""*

**def** \_\_init\_\_(self, previous, next, message):

self.previous = previous

self.next = next

self.message = message

Most exceptions are defined with names that end in “Error,” similar to the naming of the standard exceptions.

Many standard modules define their own exceptions to report errors that may occur in functions they define. More information on classes is presented in chapter [Classes](https://docs.python.org/3/tutorial/classes.html#tut-classes).

## 8.6. Defining Clean-up Actions

The [try](https://docs.python.org/3/reference/compound_stmts.html#try) statement has another optional clause which is intended to define clean-up actions that must be executed under all circumstances. For example:

>>>

**>>> try**:

**...**  **raise** KeyboardInterrupt

**... finally**:

**...**  print('Goodbye, world!')

**...**

Goodbye, world!

**KeyboardInterrupt**

Traceback (most recent call last):

File "<stdin>", line 2, in ?

A finally clause is always executed before leaving the [try](https://docs.python.org/3/reference/compound_stmts.html#try) statement, whether an exception has occurred or not. When an exception has occurred in the [try](https://docs.python.org/3/reference/compound_stmts.html#try) clause and has not been handled by an[except](https://docs.python.org/3/reference/compound_stmts.html#except) clause (or it has occurred in an [except](https://docs.python.org/3/reference/compound_stmts.html#except) or [else](https://docs.python.org/3/reference/compound_stmts.html#else) clause), it is re-raised after the [finally](https://docs.python.org/3/reference/compound_stmts.html#finally)clause has been executed. The [finally](https://docs.python.org/3/reference/compound_stmts.html#finally) clause is also executed “on the way out” when any other clause of the [try](https://docs.python.org/3/reference/compound_stmts.html#try) statement is left via a [break](https://docs.python.org/3/reference/simple_stmts.html#break), [continue](https://docs.python.org/3/reference/simple_stmts.html#continue) or [return](https://docs.python.org/3/reference/simple_stmts.html#return) statement. A more complicated example:

>>>

**>>> def** divide(x, y):

**...**  **try**:

**...**  result = x / y

**...**  **except** ZeroDivisionError:

**...**  print("division by zero!")

**...**  **else**:

**...**  print("result is", result)

**...**  **finally**:

**...**  print("executing finally clause")

**...**

**>>>** divide(2, 1)

result is 2.0

executing finally clause

**>>>** divide(2, 0)

division by zero!

executing finally clause

**>>>** divide("2", "1")

executing finally clause

Traceback (most recent call last):

File "<stdin>", line 1, in ?

File "<stdin>", line 3, in divide

TypeError: unsupported operand type(s) for /: 'str' and 'str'

As you can see, the [finally](https://docs.python.org/3/reference/compound_stmts.html#finally) clause is executed in any event. The [TypeError](https://docs.python.org/3/library/exceptions.html#TypeError) raised by dividing two strings is not handled by the [except](https://docs.python.org/3/reference/compound_stmts.html#except) clause and therefore re-raised after the [finally](https://docs.python.org/3/reference/compound_stmts.html#finally) clause has been executed.

In real world applications, the [finally](https://docs.python.org/3/reference/compound_stmts.html#finally) clause is useful for releasing external resources (such as files or network connections), regardless of whether the use of the resource was successful.

## 8.7. Predefined Clean-up Actions

Some objects define standard clean-up actions to be undertaken when the object is no longer needed, regardless of whether or not the operation using the object succeeded or failed. Look at the following example, which tries to open a file and print its contents to the screen.

**for** line **in** open("myfile.txt"):

print(line, end="")

The problem with this code is that it leaves the file open for an indeterminate amount of time after this part of the code has finished executing. This is not an issue in simple scripts, but can be a problem for larger applications. The [with](https://docs.python.org/3/reference/compound_stmts.html#with) statement allows objects like files to be used in a way that ensures they are always cleaned up promptly and correctly.

**with** open("myfile.txt") **as** f:

**for** line **in** f:

print(line, end="")

After the statement is executed, the file f is always closed, even if a problem was encountered while processing the lines. Objects which, like files, provide predefined clean-up actions will indicate this in their documentation.

# 8. Errors and Exceptions

Until now error messages haven’t been more than mentioned, but if you have tried out the examples you have probably seen some. There are (at least) two distinguishable kinds of errors: syntax errorsand exceptions.

## 8.1. Syntax Errors

Syntax errors, also known as parsing errors, are perhaps the most common kind of complaint you get while you are still learning Python:

>>>

**>>> while** **True** print('Hello world')

File "<stdin>", line 1, in ?

while True print('Hello world')

^

SyntaxError: invalid syntax

The parser repeats the offending line and displays a little ‘arrow’ pointing at the earliest point in the line where the error was detected. The error is caused by (or at least detected at) the token preceding the arrow: in the example, the error is detected at the function [print()](https://docs.python.org/3/library/functions.html#print), since a colon (':') is missing before it. File name and line number are printed so you know where to look in case the input came from a script.

## 8.2. Exceptions

Even if a statement or expression is syntactically correct, it may cause an error when an attempt is made to execute it. Errors detected during execution are called exceptions and are not unconditionally fatal: you will soon learn how to handle them in Python programs. Most exceptions are not handled by programs, however, and result in error messages as shown here:

>>>

**>>>** 10 \* (1/0)

Traceback (most recent call last):

File "<stdin>", line 1, in ?

ZeroDivisionError: division by zero

**>>>** 4 + spam\*3

Traceback (most recent call last):

File "<stdin>", line 1, in ?

NameError: name 'spam' is not defined

**>>>** '2' + 2

Traceback (most recent call last):

File "<stdin>", line 1, in ?

TypeError: Can't convert 'int' object to str implicitly

The last line of the error message indicates what happened. Exceptions come in different types, and the type is printed as part of the message: the types in the example are [ZeroDivisionError](https://docs.python.org/3/library/exceptions.html#ZeroDivisionError),[NameError](https://docs.python.org/3/library/exceptions.html#NameError) and [TypeError](https://docs.python.org/3/library/exceptions.html#TypeError). The string printed as the exception type is the name of the built-in exception that occurred. This is true for all built-in exceptions, but need not be true for user-defined exceptions (although it is a useful convention). Standard exception names are built-in identifiers (not reserved keywords).

The rest of the line provides detail based on the type of exception and what caused it.

The preceding part of the error message shows the context where the exception happened, in the form of a stack traceback. In general it contains a stack traceback listing source lines; however, it will not display lines read from standard input.

[Built-in Exceptions](https://docs.python.org/3/library/exceptions.html#bltin-exceptions) lists the built-in exceptions and their meanings.

## 8.3. Handling Exceptions

It is possible to write programs that handle selected exceptions. Look at the following example, which asks the user for input until a valid integer has been entered, but allows the user to interrupt the program (using Control-C or whatever the operating system supports); note that a user-generated interruption is signalled by raising the [KeyboardInterrupt](https://docs.python.org/3/library/exceptions.html#KeyboardInterrupt) exception.

>>>

**>>> while** **True**:

**...**  **try**:

**...**  x = int(input("Please enter a number: "))

**...**  **break**

**...**  **except** ValueError:

**...**  print("Oops! That was no valid number. Try again...")

**...**

The [try](https://docs.python.org/3/reference/compound_stmts.html#try) statement works as follows.

* First, the try clause (the statement(s) between the [try](https://docs.python.org/3/reference/compound_stmts.html#try) and [except](https://docs.python.org/3/reference/compound_stmts.html#except) keywords) is executed.
* If no exception occurs, the except clause is skipped and execution of the [try](https://docs.python.org/3/reference/compound_stmts.html#try) statement is finished.
* If an exception occurs during execution of the try clause, the rest of the clause is skipped. Then if its type matches the exception named after the [except](https://docs.python.org/3/reference/compound_stmts.html#except) keyword, the except clause is executed, and then execution continues after the [try](https://docs.python.org/3/reference/compound_stmts.html#try) statement.
* If an exception occurs which does not match the exception named in the except clause, it is passed on to outer [try](https://docs.python.org/3/reference/compound_stmts.html#try) statements; if no handler is found, it is an unhandled exception and execution stops with a message as shown above.

A [try](https://docs.python.org/3/reference/compound_stmts.html#try) statement may have more than one except clause, to specify handlers for different exceptions. At most one handler will be executed. Handlers only handle exceptions that occur in the corresponding try clause, not in other handlers of the same [try](https://docs.python.org/3/reference/compound_stmts.html#try) statement. An except clause may name multiple exceptions as a parenthesized tuple, for example:

... **except** (RuntimeError, TypeError, NameError):

... **pass**

The last except clause may omit the exception name(s), to serve as a wildcard. Use this with extreme caution, since it is easy to mask a real programming error in this way! It can also be used to print an error message and then re-raise the exception (allowing a caller to handle the exception as well):

**import** **sys**

**try**:

f = open('myfile.txt')

s = f.readline()

i = int(s.strip())

**except** OSError **as** err:

print("OS error: *{0}*".format(err))

**except** ValueError:

print("Could not convert data to an integer.")

**except**:

print("Unexpected error:", sys.exc\_info()[0])

**raise**

The [try](https://docs.python.org/3/reference/compound_stmts.html#try) ... [except](https://docs.python.org/3/reference/compound_stmts.html#except) statement has an optional else clause, which, when present, must follow all except clauses. It is useful for code that must be executed if the try clause does not raise an exception. For example:

**for** arg **in** sys.argv[1:]:

**try**:

f = open(arg, 'r')

**except** IOError:

print('cannot open', arg)

**else**:

print(arg, 'has', len(f.readlines()), 'lines')

f.close()

The use of the [else](https://docs.python.org/3/reference/compound_stmts.html#else) clause is better than adding additional code to the [try](https://docs.python.org/3/reference/compound_stmts.html#try) clause because it avoids accidentally catching an exception that wasn’t raised by the code being protected by the [try](https://docs.python.org/3/reference/compound_stmts.html#try) ...[except](https://docs.python.org/3/reference/compound_stmts.html#except) statement.

When an exception occurs, it may have an associated value, also known as the exception’s argument. The presence and type of the argument depend on the exception type.

The except clause may specify a variable after the exception name. The variable is bound to an exception instance with the arguments stored in instance.args. For convenience, the exception instance defines [\_\_str\_\_()](https://docs.python.org/3/reference/datamodel.html#object.__str__) so the arguments can be printed directly without having to reference.args. One may also instantiate an exception first before raising it and add any attributes to it as desired.

>>>

**>>> try**:

**...**  **raise** Exception('spam', 'eggs')

**... except** Exception **as** inst:

**...**  print(type(inst)) *# the exception instance*

**...**  print(inst.args) *# arguments stored in .args*

**...**  print(inst) *# \_\_str\_\_ allows args to be printed directly,*

**...**  *# but may be overridden in exception subclasses*

**...**  x, y = inst.args *# unpack args*

**...**  print('x =', x)

**...**  print('y =', y)

**...**

<class 'Exception'>

('spam', 'eggs')

('spam', 'eggs')

x = spam

y = eggs

If an exception has arguments, they are printed as the last part (‘detail’) of the message for unhandled exceptions.

Exception handlers don’t just handle exceptions if they occur immediately in the try clause, but also if they occur inside functions that are called (even indirectly) in the try clause. For example:

>>>

**>>> def** this\_fails():

**...**  x = 1/0

**...**

**>>> try**:

**...**  this\_fails()

**... except** ZeroDivisionError **as** err:

**...**  print('Handling run-time error:', err)

**...**

Handling run-time error: int division or modulo by zero

## 8.4. Raising Exceptions

The [raise](https://docs.python.org/3/reference/simple_stmts.html#raise) statement allows the programmer to force a specified exception to occur. For example:

>>>

**>>> raise** NameError('HiThere')

Traceback (most recent call last):

File "<stdin>", line 1, in ?

NameError: HiThere

The sole argument to [raise](https://docs.python.org/3/reference/simple_stmts.html#raise) indicates the exception to be raised. This must be either an exception instance or an exception class (a class that derives from [Exception](https://docs.python.org/3/library/exceptions.html#Exception)).

If you need to determine whether an exception was raised but don’t intend to handle it, a simpler form of the [raise](https://docs.python.org/3/reference/simple_stmts.html#raise) statement allows you to re-raise the exception:

>>>

**>>> try**:

**...**  **raise** NameError('HiThere')

**... except** NameError:

**...**  print('An exception flew by!')

**...**  **raise**

**...**

An exception flew by!

Traceback (most recent call last):

File "<stdin>", line 2, in ?

NameError: HiThere

## 8.5. User-defined Exceptions

Programs may name their own exceptions by creating a new exception class (see [Classes](https://docs.python.org/3/tutorial/classes.html#tut-classes) for more about Python classes). Exceptions should typically be derived from the [Exception](https://docs.python.org/3/library/exceptions.html#Exception) class, either directly or indirectly. For example:

>>>

**>>> class** **MyError**(Exception):

**...**  **def** \_\_init\_\_(self, value):

**...**  self.value = value

**...**  **def** \_\_str\_\_(self):

**...**  **return** repr(self.value)

**...**

**>>> try**:

**...**  **raise** MyError(2\*2)

**... except** MyError **as** e:

**...**  print('My exception occurred, value:', e.value)

**...**

My exception occurred, value: 4

**>>> raise** MyError('oops!')

Traceback (most recent call last):

File "<stdin>", line 1, in ?

\_\_main\_\_.MyError: 'oops!'

In this example, the default [\_\_init\_\_()](https://docs.python.org/3/reference/datamodel.html#object.__init__) of [Exception](https://docs.python.org/3/library/exceptions.html#Exception) has been overridden. The new behavior simply creates the value attribute. This replaces the default behavior of creating the args attribute.

Exception classes can be defined which do anything any other class can do, but are usually kept simple, often only offering a number of attributes that allow information about the error to be extracted by handlers for the exception. When creating a module that can raise several distinct errors, a common practice is to create a base class for exceptions defined by that module, and subclass that to create specific exception classes for different error conditions:

**class** **Error**(Exception):

*"""Base class for exceptions in this module."""*

**pass**

**class** **InputError**(Error):

*"""Exception raised for errors in the input.*

*Attributes:*

*expression -- input expression in which the error occurred*

*message -- explanation of the error*

*"""*

**def** \_\_init\_\_(self, expression, message):

self.expression = expression

self.message = message

**class** **TransitionError**(Error):

*"""Raised when an operation attempts a state transition that's not*

*allowed.*

*Attributes:*

*previous -- state at beginning of transition*

*next -- attempted new state*

*message -- explanation of why the specific transition is not allowed*

*"""*

**def** \_\_init\_\_(self, previous, next, message):

self.previous = previous

self.next = next

self.message = message

Most exceptions are defined with names that end in “Error,” similar to the naming of the standard exceptions.

Many standard modules define their own exceptions to report errors that may occur in functions they define. More information on classes is presented in chapter [Classes](https://docs.python.org/3/tutorial/classes.html#tut-classes).

## 8.6. Defining Clean-up Actions

The [try](https://docs.python.org/3/reference/compound_stmts.html#try) statement has another optional clause which is intended to define clean-up actions that must be executed under all circumstances. For example:

>>>

**>>> try**:

**...**  **raise** KeyboardInterrupt

**... finally**:

**...**  print('Goodbye, world!')

**...**

Goodbye, world!

**KeyboardInterrupt**

Traceback (most recent call last):

File "<stdin>", line 2, in ?

A finally clause is always executed before leaving the [try](https://docs.python.org/3/reference/compound_stmts.html#try) statement, whether an exception has occurred or not. When an exception has occurred in the [try](https://docs.python.org/3/reference/compound_stmts.html#try) clause and has not been handled by an[except](https://docs.python.org/3/reference/compound_stmts.html#except) clause (or it has occurred in an [except](https://docs.python.org/3/reference/compound_stmts.html#except) or [else](https://docs.python.org/3/reference/compound_stmts.html#else) clause), it is re-raised after the [finally](https://docs.python.org/3/reference/compound_stmts.html#finally)clause has been executed. The [finally](https://docs.python.org/3/reference/compound_stmts.html#finally) clause is also executed “on the way out” when any other clause of the [try](https://docs.python.org/3/reference/compound_stmts.html#try) statement is left via a [break](https://docs.python.org/3/reference/simple_stmts.html#break), [continue](https://docs.python.org/3/reference/simple_stmts.html#continue) or [return](https://docs.python.org/3/reference/simple_stmts.html#return) statement. A more complicated example:

>>>

**>>> def** divide(x, y):

**...**  **try**:

**...**  result = x / y

**...**  **except** ZeroDivisionError:

**...**  print("division by zero!")

**...**  **else**:

**...**  print("result is", result)

**...**  **finally**:

**...**  print("executing finally clause")

**...**

**>>>** divide(2, 1)

result is 2.0

executing finally clause

**>>>** divide(2, 0)

division by zero!

executing finally clause

**>>>** divide("2", "1")

executing finally clause

Traceback (most recent call last):

File "<stdin>", line 1, in ?

File "<stdin>", line 3, in divide

TypeError: unsupported operand type(s) for /: 'str' and 'str'

As you can see, the [finally](https://docs.python.org/3/reference/compound_stmts.html#finally) clause is executed in any event. The [TypeError](https://docs.python.org/3/library/exceptions.html#TypeError) raised by dividing two strings is not handled by the [except](https://docs.python.org/3/reference/compound_stmts.html#except) clause and therefore re-raised after the [finally](https://docs.python.org/3/reference/compound_stmts.html#finally) clause has been executed.

In real world applications, the [finally](https://docs.python.org/3/reference/compound_stmts.html#finally) clause is useful for releasing external resources (such as files or network connections), regardless of whether the use of the resource was successful.

## 8.7. Predefined Clean-up Actions

Some objects define standard clean-up actions to be undertaken when the object is no longer needed, regardless of whether or not the operation using the object succeeded or failed. Look at the following example, which tries to open a file and print its contents to the screen.

**for** line **in** open("myfile.txt"):

print(line, end="")

The problem with this code is that it leaves the file open for an indeterminate amount of time after this part of the code has finished executing. This is not an issue in simple scripts, but can be a problem for larger applications. The [with](https://docs.python.org/3/reference/compound_stmts.html#with) statement allows objects like files to be used in a way that ensures they are always cleaned up promptly and correctly.

**with** open("myfile.txt") **as** f:

**for** line **in** f:

print(line, end="")

After the statement is executed, the file f is always closed, even if a problem was encountered while processing the lines. Objects which, like files, provide predefined clean-up actions will indicate this in their documentation.

# 8. Errors and Exceptions

Until now error messages haven’t been more than mentioned, but if you have tried out the examples you have probably seen some. There are (at least) two distinguishable kinds of errors: syntax errorsand exceptions.

## 8.1. Syntax Errors

Syntax errors, also known as parsing errors, are perhaps the most common kind of complaint you get while you are still learning Python:

>>>

**>>> while** **True** print('Hello world')

File "<stdin>", line 1, in ?

while True print('Hello world')

^

SyntaxError: invalid syntax

The parser repeats the offending line and displays a little ‘arrow’ pointing at the earliest point in the line where the error was detected. The error is caused by (or at least detected at) the token preceding the arrow: in the example, the error is detected at the function [print()](https://docs.python.org/3/library/functions.html#print), since a colon (':') is missing before it. File name and line number are printed so you know where to look in case the input came from a script.

## 8.2. Exceptions

Even if a statement or expression is syntactically correct, it may cause an error when an attempt is made to execute it. Errors detected during execution are called exceptions and are not unconditionally fatal: you will soon learn how to handle them in Python programs. Most exceptions are not handled by programs, however, and result in error messages as shown here:

>>>

**>>>** 10 \* (1/0)

Traceback (most recent call last):

File "<stdin>", line 1, in ?

ZeroDivisionError: division by zero

**>>>** 4 + spam\*3

Traceback (most recent call last):

File "<stdin>", line 1, in ?

NameError: name 'spam' is not defined

**>>>** '2' + 2

Traceback (most recent call last):

File "<stdin>", line 1, in ?

TypeError: Can't convert 'int' object to str implicitly

The last line of the error message indicates what happened. Exceptions come in different types, and the type is printed as part of the message: the types in the example are [ZeroDivisionError](https://docs.python.org/3/library/exceptions.html#ZeroDivisionError),[NameError](https://docs.python.org/3/library/exceptions.html#NameError) and [TypeError](https://docs.python.org/3/library/exceptions.html#TypeError). The string printed as the exception type is the name of the built-in exception that occurred. This is true for all built-in exceptions, but need not be true for user-defined exceptions (although it is a useful convention). Standard exception names are built-in identifiers (not reserved keywords).

The rest of the line provides detail based on the type of exception and what caused it.

The preceding part of the error message shows the context where the exception happened, in the form of a stack traceback. In general it contains a stack traceback listing source lines; however, it will not display lines read from standard input.

[Built-in Exceptions](https://docs.python.org/3/library/exceptions.html#bltin-exceptions) lists the built-in exceptions and their meanings.

## 8.3. Handling Exceptions

It is possible to write programs that handle selected exceptions. Look at the following example, which asks the user for input until a valid integer has been entered, but allows the user to interrupt the program (using Control-C or whatever the operating system supports); note that a user-generated interruption is signalled by raising the [KeyboardInterrupt](https://docs.python.org/3/library/exceptions.html#KeyboardInterrupt) exception.

>>>

**>>> while** **True**:

**...**  **try**:

**...**  x = int(input("Please enter a number: "))

**...**  **break**

**...**  **except** ValueError:

**...**  print("Oops! That was no valid number. Try again...")

**...**

The [try](https://docs.python.org/3/reference/compound_stmts.html#try) statement works as follows.

* First, the try clause (the statement(s) between the [try](https://docs.python.org/3/reference/compound_stmts.html#try) and [except](https://docs.python.org/3/reference/compound_stmts.html#except) keywords) is executed.
* If no exception occurs, the except clause is skipped and execution of the [try](https://docs.python.org/3/reference/compound_stmts.html#try) statement is finished.
* If an exception occurs during execution of the try clause, the rest of the clause is skipped. Then if its type matches the exception named after the [except](https://docs.python.org/3/reference/compound_stmts.html#except) keyword, the except clause is executed, and then execution continues after the [try](https://docs.python.org/3/reference/compound_stmts.html#try) statement.
* If an exception occurs which does not match the exception named in the except clause, it is passed on to outer [try](https://docs.python.org/3/reference/compound_stmts.html#try) statements; if no handler is found, it is an unhandled exception and execution stops with a message as shown above.

A [try](https://docs.python.org/3/reference/compound_stmts.html#try) statement may have more than one except clause, to specify handlers for different exceptions. At most one handler will be executed. Handlers only handle exceptions that occur in the corresponding try clause, not in other handlers of the same [try](https://docs.python.org/3/reference/compound_stmts.html#try) statement. An except clause may name multiple exceptions as a parenthesized tuple, for example:

... **except** (RuntimeError, TypeError, NameError):

... **pass**

The last except clause may omit the exception name(s), to serve as a wildcard. Use this with extreme caution, since it is easy to mask a real programming error in this way! It can also be used to print an error message and then re-raise the exception (allowing a caller to handle the exception as well):

**import** **sys**

**try**:

f = open('myfile.txt')

s = f.readline()

i = int(s.strip())

**except** OSError **as** err:

print("OS error: *{0}*".format(err))

**except** ValueError:

print("Could not convert data to an integer.")

**except**:

print("Unexpected error:", sys.exc\_info()[0])

**raise**

The [try](https://docs.python.org/3/reference/compound_stmts.html#try) ... [except](https://docs.python.org/3/reference/compound_stmts.html#except) statement has an optional else clause, which, when present, must follow all except clauses. It is useful for code that must be executed if the try clause does not raise an exception. For example:

**for** arg **in** sys.argv[1:]:

**try**:

f = open(arg, 'r')

**except** IOError:

print('cannot open', arg)

**else**:

print(arg, 'has', len(f.readlines()), 'lines')

f.close()

The use of the [else](https://docs.python.org/3/reference/compound_stmts.html#else) clause is better than adding additional code to the [try](https://docs.python.org/3/reference/compound_stmts.html#try) clause because it avoids accidentally catching an exception that wasn’t raised by the code being protected by the [try](https://docs.python.org/3/reference/compound_stmts.html#try) ...[except](https://docs.python.org/3/reference/compound_stmts.html#except) statement.

When an exception occurs, it may have an associated value, also known as the exception’s argument. The presence and type of the argument depend on the exception type.

The except clause may specify a variable after the exception name. The variable is bound to an exception instance with the arguments stored in instance.args. For convenience, the exception instance defines [\_\_str\_\_()](https://docs.python.org/3/reference/datamodel.html#object.__str__) so the arguments can be printed directly without having to reference.args. One may also instantiate an exception first before raising it and add any attributes to it as desired.

>>>

**>>> try**:

**...**  **raise** Exception('spam', 'eggs')

**... except** Exception **as** inst:

**...**  print(type(inst)) *# the exception instance*

**...**  print(inst.args) *# arguments stored in .args*

**...**  print(inst) *# \_\_str\_\_ allows args to be printed directly,*

**...**  *# but may be overridden in exception subclasses*

**...**  x, y = inst.args *# unpack args*

**...**  print('x =', x)

**...**  print('y =', y)

**...**

<class 'Exception'>

('spam', 'eggs')

('spam', 'eggs')

x = spam

y = eggs

If an exception has arguments, they are printed as the last part (‘detail’) of the message for unhandled exceptions.

Exception handlers don’t just handle exceptions if they occur immediately in the try clause, but also if they occur inside functions that are called (even indirectly) in the try clause. For example:

>>>

**>>> def** this\_fails():

**...**  x = 1/0

**...**

**>>> try**:

**...**  this\_fails()

**... except** ZeroDivisionError **as** err:

**...**  print('Handling run-time error:', err)

**...**

Handling run-time error: int division or modulo by zero

## 8.4. Raising Exceptions

The [raise](https://docs.python.org/3/reference/simple_stmts.html#raise) statement allows the programmer to force a specified exception to occur. For example:

>>>

**>>> raise** NameError('HiThere')

Traceback (most recent call last):

File "<stdin>", line 1, in ?

NameError: HiThere

The sole argument to [raise](https://docs.python.org/3/reference/simple_stmts.html#raise) indicates the exception to be raised. This must be either an exception instance or an exception class (a class that derives from [Exception](https://docs.python.org/3/library/exceptions.html#Exception)).

If you need to determine whether an exception was raised but don’t intend to handle it, a simpler form of the [raise](https://docs.python.org/3/reference/simple_stmts.html#raise) statement allows you to re-raise the exception:

>>>

**>>> try**:

**...**  **raise** NameError('HiThere')

**... except** NameError:

**...**  print('An exception flew by!')

**...**  **raise**

**...**

An exception flew by!

Traceback (most recent call last):

File "<stdin>", line 2, in ?

NameError: HiThere

## 8.5. User-defined Exceptions

Programs may name their own exceptions by creating a new exception class (see [Classes](https://docs.python.org/3/tutorial/classes.html#tut-classes) for more about Python classes). Exceptions should typically be derived from the [Exception](https://docs.python.org/3/library/exceptions.html#Exception) class, either directly or indirectly. For example:

>>>

**>>> class** **MyError**(Exception):

**...**  **def** \_\_init\_\_(self, value):

**...**  self.value = value

**...**  **def** \_\_str\_\_(self):

**...**  **return** repr(self.value)

**...**

**>>> try**:

**...**  **raise** MyError(2\*2)

**... except** MyError **as** e:

**...**  print('My exception occurred, value:', e.value)

**...**

My exception occurred, value: 4

**>>> raise** MyError('oops!')

Traceback (most recent call last):

File "<stdin>", line 1, in ?

\_\_main\_\_.MyError: 'oops!'

In this example, the default [\_\_init\_\_()](https://docs.python.org/3/reference/datamodel.html#object.__init__) of [Exception](https://docs.python.org/3/library/exceptions.html#Exception) has been overridden. The new behavior simply creates the value attribute. This replaces the default behavior of creating the args attribute.

Exception classes can be defined which do anything any other class can do, but are usually kept simple, often only offering a number of attributes that allow information about the error to be extracted by handlers for the exception. When creating a module that can raise several distinct errors, a common practice is to create a base class for exceptions defined by that module, and subclass that to create specific exception classes for different error conditions:

**class** **Error**(Exception):

*"""Base class for exceptions in this module."""*

**pass**

**class** **InputError**(Error):

*"""Exception raised for errors in the input.*

*Attributes:*

*expression -- input expression in which the error occurred*

*message -- explanation of the error*

*"""*

**def** \_\_init\_\_(self, expression, message):

self.expression = expression

self.message = message

**class** **TransitionError**(Error):

*"""Raised when an operation attempts a state transition that's not*

*allowed.*

*Attributes:*

*previous -- state at beginning of transition*

*next -- attempted new state*

*message -- explanation of why the specific transition is not allowed*

*"""*

**def** \_\_init\_\_(self, previous, next, message):

self.previous = previous

self.next = next

self.message = message

Most exceptions are defined with names that end in “Error,” similar to the naming of the standard exceptions.

Many standard modules define their own exceptions to report errors that may occur in functions they define. More information on classes is presented in chapter [Classes](https://docs.python.org/3/tutorial/classes.html#tut-classes).

## 8.6. Defining Clean-up Actions

The [try](https://docs.python.org/3/reference/compound_stmts.html#try) statement has another optional clause which is intended to define clean-up actions that must be executed under all circumstances. For example:

>>>

**>>> try**:

**...**  **raise** KeyboardInterrupt

**... finally**:

**...**  print('Goodbye, world!')

**...**

Goodbye, world!

**KeyboardInterrupt**

Traceback (most recent call last):

File "<stdin>", line 2, in ?

A finally clause is always executed before leaving the [try](https://docs.python.org/3/reference/compound_stmts.html#try) statement, whether an exception has occurred or not. When an exception has occurred in the [try](https://docs.python.org/3/reference/compound_stmts.html#try) clause and has not been handled by an[except](https://docs.python.org/3/reference/compound_stmts.html#except) clause (or it has occurred in an [except](https://docs.python.org/3/reference/compound_stmts.html#except) or [else](https://docs.python.org/3/reference/compound_stmts.html#else) clause), it is re-raised after the [finally](https://docs.python.org/3/reference/compound_stmts.html#finally)clause has been executed. The [finally](https://docs.python.org/3/reference/compound_stmts.html#finally) clause is also executed “on the way out” when any other clause of the [try](https://docs.python.org/3/reference/compound_stmts.html#try) statement is left via a [break](https://docs.python.org/3/reference/simple_stmts.html#break), [continue](https://docs.python.org/3/reference/simple_stmts.html#continue) or [return](https://docs.python.org/3/reference/simple_stmts.html#return) statement. A more complicated example:

>>>

**>>> def** divide(x, y):

**...**  **try**:

**...**  result = x / y

**...**  **except** ZeroDivisionError:

**...**  print("division by zero!")

**...**  **else**:

**...**  print("result is", result)

**...**  **finally**:

**...**  print("executing finally clause")

**...**

**>>>** divide(2, 1)

result is 2.0

executing finally clause

**>>>** divide(2, 0)

division by zero!

executing finally clause

**>>>** divide("2", "1")

executing finally clause

Traceback (most recent call last):

File "<stdin>", line 1, in ?

File "<stdin>", line 3, in divide

TypeError: unsupported operand type(s) for /: 'str' and 'str'

As you can see, the [finally](https://docs.python.org/3/reference/compound_stmts.html#finally) clause is executed in any event. The [TypeError](https://docs.python.org/3/library/exceptions.html#TypeError) raised by dividing two strings is not handled by the [except](https://docs.python.org/3/reference/compound_stmts.html#except) clause and therefore re-raised after the [finally](https://docs.python.org/3/reference/compound_stmts.html#finally) clause has been executed.

In real world applications, the [finally](https://docs.python.org/3/reference/compound_stmts.html#finally) clause is useful for releasing external resources (such as files or network connections), regardless of whether the use of the resource was successful.

## 8.7. Predefined Clean-up Actions

Some objects define standard clean-up actions to be undertaken when the object is no longer needed, regardless of whether or not the operation using the object succeeded or failed. Look at the following example, which tries to open a file and print its contents to the screen.

**for** line **in** open("myfile.txt"):

print(line, end="")

The problem with this code is that it leaves the file open for an indeterminate amount of time after this part of the code has finished executing. This is not an issue in simple scripts, but can be a problem for larger applications. The [with](https://docs.python.org/3/reference/compound_stmts.html#with) statement allows objects like files to be used in a way that ensures they are always cleaned up promptly and correctly.

**with** open("myfile.txt") **as** f:

**for** line **in** f:

print(line, end="")

After the statement is executed, the file f is always closed, even if a problem was encountered while processing the lines. Objects which, like files, provide predefined clean-up actions will indicate this in their documentation.

# 8. Errors and Exceptions

Until now error messages haven’t been more than mentioned, but if you have tried out the examples you have probably seen some. There are (at least) two distinguishable kinds of errors: syntax errorsand exceptions.

## 8.1. Syntax Errors

Syntax errors, also known as parsing errors, are perhaps the most common kind of complaint you get while you are still learning Python:

>>>

**>>> while** **True** print('Hello world')

File "<stdin>", line 1, in ?

while True print('Hello world')

^

SyntaxError: invalid syntax

The parser repeats the offending line and displays a little ‘arrow’ pointing at the earliest point in the line where the error was detected. The error is caused by (or at least detected at) the token preceding the arrow: in the example, the error is detected at the function [print()](https://docs.python.org/3/library/functions.html#print), since a colon (':') is missing before it. File name and line number are printed so you know where to look in case the input came from a script.

## 8.2. Exceptions

Even if a statement or expression is syntactically correct, it may cause an error when an attempt is made to execute it. Errors detected during execution are called exceptions and are not unconditionally fatal: you will soon learn how to handle them in Python programs. Most exceptions are not handled by programs, however, and result in error messages as shown here:

>>>

**>>>** 10 \* (1/0)

Traceback (most recent call last):

File "<stdin>", line 1, in ?

ZeroDivisionError: division by zero

**>>>** 4 + spam\*3

Traceback (most recent call last):

File "<stdin>", line 1, in ?

NameError: name 'spam' is not defined

**>>>** '2' + 2

Traceback (most recent call last):

File "<stdin>", line 1, in ?

TypeError: Can't convert 'int' object to str implicitly

The last line of the error message indicates what happened. Exceptions come in different types, and the type is printed as part of the message: the types in the example are [ZeroDivisionError](https://docs.python.org/3/library/exceptions.html#ZeroDivisionError),[NameError](https://docs.python.org/3/library/exceptions.html#NameError) and [TypeError](https://docs.python.org/3/library/exceptions.html#TypeError). The string printed as the exception type is the name of the built-in exception that occurred. This is true for all built-in exceptions, but need not be true for user-defined exceptions (although it is a useful convention). Standard exception names are built-in identifiers (not reserved keywords).

The rest of the line provides detail based on the type of exception and what caused it.

The preceding part of the error message shows the context where the exception happened, in the form of a stack traceback. In general it contains a stack traceback listing source lines; however, it will not display lines read from standard input.

[Built-in Exceptions](https://docs.python.org/3/library/exceptions.html#bltin-exceptions) lists the built-in exceptions and their meanings.

## 8.3. Handling Exceptions

It is possible to write programs that handle selected exceptions. Look at the following example, which asks the user for input until a valid integer has been entered, but allows the user to interrupt the program (using Control-C or whatever the operating system supports); note that a user-generated interruption is signalled by raising the [KeyboardInterrupt](https://docs.python.org/3/library/exceptions.html#KeyboardInterrupt) exception.

>>>

**>>> while** **True**:

**...**  **try**:

**...**  x = int(input("Please enter a number: "))

**...**  **break**

**...**  **except** ValueError:

**...**  print("Oops! That was no valid number. Try again...")

**...**

The [try](https://docs.python.org/3/reference/compound_stmts.html#try) statement works as follows.

* First, the try clause (the statement(s) between the [try](https://docs.python.org/3/reference/compound_stmts.html#try) and [except](https://docs.python.org/3/reference/compound_stmts.html#except) keywords) is executed.
* If no exception occurs, the except clause is skipped and execution of the [try](https://docs.python.org/3/reference/compound_stmts.html#try) statement is finished.
* If an exception occurs during execution of the try clause, the rest of the clause is skipped. Then if its type matches the exception named after the [except](https://docs.python.org/3/reference/compound_stmts.html#except) keyword, the except clause is executed, and then execution continues after the [try](https://docs.python.org/3/reference/compound_stmts.html#try) statement.
* If an exception occurs which does not match the exception named in the except clause, it is passed on to outer [try](https://docs.python.org/3/reference/compound_stmts.html#try) statements; if no handler is found, it is an unhandled exception and execution stops with a message as shown above.

A [try](https://docs.python.org/3/reference/compound_stmts.html#try) statement may have more than one except clause, to specify handlers for different exceptions. At most one handler will be executed. Handlers only handle exceptions that occur in the corresponding try clause, not in other handlers of the same [try](https://docs.python.org/3/reference/compound_stmts.html#try) statement. An except clause may name multiple exceptions as a parenthesized tuple, for example:

... **except** (RuntimeError, TypeError, NameError):

... **pass**

The last except clause may omit the exception name(s), to serve as a wildcard. Use this with extreme caution, since it is easy to mask a real programming error in this way! It can also be used to print an error message and then re-raise the exception (allowing a caller to handle the exception as well):

**import** **sys**

**try**:

f = open('myfile.txt')

s = f.readline()

i = int(s.strip())

**except** OSError **as** err:

print("OS error: *{0}*".format(err))

**except** ValueError:

print("Could not convert data to an integer.")

**except**:

print("Unexpected error:", sys.exc\_info()[0])

**raise**

The [try](https://docs.python.org/3/reference/compound_stmts.html#try) ... [except](https://docs.python.org/3/reference/compound_stmts.html#except) statement has an optional else clause, which, when present, must follow all except clauses. It is useful for code that must be executed if the try clause does not raise an exception. For example:

**for** arg **in** sys.argv[1:]:

**try**:

f = open(arg, 'r')

**except** IOError:

print('cannot open', arg)

**else**:

print(arg, 'has', len(f.readlines()), 'lines')

f.close()

The use of the [else](https://docs.python.org/3/reference/compound_stmts.html#else) clause is better than adding additional code to the [try](https://docs.python.org/3/reference/compound_stmts.html#try) clause because it avoids accidentally catching an exception that wasn’t raised by the code being protected by the [try](https://docs.python.org/3/reference/compound_stmts.html#try) ...[except](https://docs.python.org/3/reference/compound_stmts.html#except) statement.

When an exception occurs, it may have an associated value, also known as the exception’s argument. The presence and type of the argument depend on the exception type.

The except clause may specify a variable after the exception name. The variable is bound to an exception instance with the arguments stored in instance.args. For convenience, the exception instance defines [\_\_str\_\_()](https://docs.python.org/3/reference/datamodel.html#object.__str__) so the arguments can be printed directly without having to reference.args. One may also instantiate an exception first before raising it and add any attributes to it as desired.

>>>

**>>> try**:

**...**  **raise** Exception('spam', 'eggs')

**... except** Exception **as** inst:

**...**  print(type(inst)) *# the exception instance*

**...**  print(inst.args) *# arguments stored in .args*

**...**  print(inst) *# \_\_str\_\_ allows args to be printed directly,*

**...**  *# but may be overridden in exception subclasses*

**...**  x, y = inst.args *# unpack args*

**...**  print('x =', x)

**...**  print('y =', y)

**...**

<class 'Exception'>

('spam', 'eggs')

('spam', 'eggs')

x = spam

y = eggs

If an exception has arguments, they are printed as the last part (‘detail’) of the message for unhandled exceptions.

Exception handlers don’t just handle exceptions if they occur immediately in the try clause, but also if they occur inside functions that are called (even indirectly) in the try clause. For example:

>>>

**>>> def** this\_fails():

**...**  x = 1/0

**...**

**>>> try**:

**...**  this\_fails()

**... except** ZeroDivisionError **as** err:

**...**  print('Handling run-time error:', err)

**...**

Handling run-time error: int division or modulo by zero

## 8.4. Raising Exceptions

The [raise](https://docs.python.org/3/reference/simple_stmts.html#raise) statement allows the programmer to force a specified exception to occur. For example:

>>>

**>>> raise** NameError('HiThere')

Traceback (most recent call last):

File "<stdin>", line 1, in ?

NameError: HiThere

The sole argument to [raise](https://docs.python.org/3/reference/simple_stmts.html#raise) indicates the exception to be raised. This must be either an exception instance or an exception class (a class that derives from [Exception](https://docs.python.org/3/library/exceptions.html#Exception)).

If you need to determine whether an exception was raised but don’t intend to handle it, a simpler form of the [raise](https://docs.python.org/3/reference/simple_stmts.html#raise) statement allows you to re-raise the exception:

>>>

**>>> try**:

**...**  **raise** NameError('HiThere')

**... except** NameError:

**...**  print('An exception flew by!')

**...**  **raise**

**...**

An exception flew by!

Traceback (most recent call last):

File "<stdin>", line 2, in ?

NameError: HiThere

## 8.5. User-defined Exceptions

Programs may name their own exceptions by creating a new exception class (see [Classes](https://docs.python.org/3/tutorial/classes.html#tut-classes) for more about Python classes). Exceptions should typically be derived from the [Exception](https://docs.python.org/3/library/exceptions.html#Exception) class, either directly or indirectly. For example:

>>>

**>>> class** **MyError**(Exception):

**...**  **def** \_\_init\_\_(self, value):

**...**  self.value = value

**...**  **def** \_\_str\_\_(self):

**...**  **return** repr(self.value)

**...**

**>>> try**:

**...**  **raise** MyError(2\*2)

**... except** MyError **as** e:

**...**  print('My exception occurred, value:', e.value)

**...**

My exception occurred, value: 4

**>>> raise** MyError('oops!')

Traceback (most recent call last):

File "<stdin>", line 1, in ?

\_\_main\_\_.MyError: 'oops!'

In this example, the default [\_\_init\_\_()](https://docs.python.org/3/reference/datamodel.html#object.__init__) of [Exception](https://docs.python.org/3/library/exceptions.html#Exception) has been overridden. The new behavior simply creates the value attribute. This replaces the default behavior of creating the args attribute.

Exception classes can be defined which do anything any other class can do, but are usually kept simple, often only offering a number of attributes that allow information about the error to be extracted by handlers for the exception. When creating a module that can raise several distinct errors, a common practice is to create a base class for exceptions defined by that module, and subclass that to create specific exception classes for different error conditions:

**class** **Error**(Exception):

*"""Base class for exceptions in this module."""*

**pass**

**class** **InputError**(Error):

*"""Exception raised for errors in the input.*

*Attributes:*

*expression -- input expression in which the error occurred*

*message -- explanation of the error*

*"""*

**def** \_\_init\_\_(self, expression, message):

self.expression = expression

self.message = message

**class** **TransitionError**(Error):

*"""Raised when an operation attempts a state transition that's not*

*allowed.*

*Attributes:*

*previous -- state at beginning of transition*

*next -- attempted new state*

*message -- explanation of why the specific transition is not allowed*

*"""*

**def** \_\_init\_\_(self, previous, next, message):

self.previous = previous

self.next = next

self.message = message

Most exceptions are defined with names that end in “Error,” similar to the naming of the standard exceptions.

Many standard modules define their own exceptions to report errors that may occur in functions they define. More information on classes is presented in chapter [Classes](https://docs.python.org/3/tutorial/classes.html#tut-classes).

## 8.6. Defining Clean-up Actions

The [try](https://docs.python.org/3/reference/compound_stmts.html#try) statement has another optional clause which is intended to define clean-up actions that must be executed under all circumstances. For example:

>>>

**>>> try**:

**...**  **raise** KeyboardInterrupt

**... finally**:

**...**  print('Goodbye, world!')

**...**

Goodbye, world!

**KeyboardInterrupt**

Traceback (most recent call last):

File "<stdin>", line 2, in ?

A finally clause is always executed before leaving the [try](https://docs.python.org/3/reference/compound_stmts.html#try) statement, whether an exception has occurred or not. When an exception has occurred in the [try](https://docs.python.org/3/reference/compound_stmts.html#try) clause and has not been handled by an[except](https://docs.python.org/3/reference/compound_stmts.html#except) clause (or it has occurred in an [except](https://docs.python.org/3/reference/compound_stmts.html#except) or [else](https://docs.python.org/3/reference/compound_stmts.html#else) clause), it is re-raised after the [finally](https://docs.python.org/3/reference/compound_stmts.html#finally)clause has been executed. The [finally](https://docs.python.org/3/reference/compound_stmts.html#finally) clause is also executed “on the way out” when any other clause of the [try](https://docs.python.org/3/reference/compound_stmts.html#try) statement is left via a [break](https://docs.python.org/3/reference/simple_stmts.html#break), [continue](https://docs.python.org/3/reference/simple_stmts.html#continue) or [return](https://docs.python.org/3/reference/simple_stmts.html#return) statement. A more complicated example:

>>>

**>>> def** divide(x, y):

**...**  **try**:

**...**  result = x / y

**...**  **except** ZeroDivisionError:

**...**  print("division by zero!")

**...**  **else**:

**...**  print("result is", result)

**...**  **finally**:

**...**  print("executing finally clause")

**...**

**>>>** divide(2, 1)

result is 2.0

executing finally clause

**>>>** divide(2, 0)

division by zero!

executing finally clause

**>>>** divide("2", "1")

executing finally clause

Traceback (most recent call last):

File "<stdin>", line 1, in ?

File "<stdin>", line 3, in divide

TypeError: unsupported operand type(s) for /: 'str' and 'str'

As you can see, the [finally](https://docs.python.org/3/reference/compound_stmts.html#finally) clause is executed in any event. The [TypeError](https://docs.python.org/3/library/exceptions.html#TypeError) raised by dividing two strings is not handled by the [except](https://docs.python.org/3/reference/compound_stmts.html#except) clause and therefore re-raised after the [finally](https://docs.python.org/3/reference/compound_stmts.html#finally) clause has been executed.

In real world applications, the [finally](https://docs.python.org/3/reference/compound_stmts.html#finally) clause is useful for releasing external resources (such as files or network connections), regardless of whether the use of the resource was successful.

## 8.7. Predefined Clean-up Actions

Some objects define standard clean-up actions to be undertaken when the object is no longer needed, regardless of whether or not the operation using the object succeeded or failed. Look at the following example, which tries to open a file and print its contents to the screen.

**for** line **in** open("myfile.txt"):

print(line, end="")

The problem with this code is that it leaves the file open for an indeterminate amount of time after this part of the code has finished executing. This is not an issue in simple scripts, but can be a problem for larger applications. The [with](https://docs.python.org/3/reference/compound_stmts.html#with) statement allows objects like files to be used in a way that ensures they are always cleaned up promptly and correctly.

**with** open("myfile.txt") **as** f:

**for** line **in** f:

print(line, end="")

After the statement is executed, the file f is always closed, even if a problem was encountered while processing the lines. Objects which, like files, provide predefined clean-up actions will indicate this in their documentation.

# 9. Classes

Compared with other programming languages, Python’s class mechanism adds classes with a minimum of new syntax and semantics. It is a mixture of the class mechanisms found in C++ and Modula-3. Python classes provide all the standard features of Object Oriented Programming: the class inheritance mechanism allows multiple base classes, a derived class can override any methods of its base class or classes, and a method can call the method of a base class with the same name. Objects can contain arbitrary amounts and kinds of data. As is true for modules, classes partake of the dynamic nature of Python: they are created at runtime, and can be modified further after creation.

In C++ terminology, normally class members (including the data members) are public (except see below [Private Variables](https://docs.python.org/3/tutorial/classes.html#tut-private)), and all member functions are virtual. As in Modula-3, there are no shorthands for referencing the object’s members from its methods: the method function is declared with an explicit first argument representing the object, which is provided implicitly by the call. As in Smalltalk, classes themselves are objects. This provides semantics for importing and renaming. Unlike C++ and Modula-3, built-in types can be used as base classes for extension by the user. Also, like in C++, most built-in operators with special syntax (arithmetic operators, subscripting etc.) can be redefined for class instances.

(Lacking universally accepted terminology to talk about classes, I will make occasional use of Smalltalk and C++ terms. I would use Modula-3 terms, since its object-oriented semantics are closer to those of Python than C++, but I expect that few readers have heard of it.)

## 9.1. A Word About Names and Objects

Objects have individuality, and multiple names (in multiple scopes) can be bound to the same object. This is known as aliasing in other languages. This is usually not appreciated on a first glance at Python, and can be safely ignored when dealing with immutable basic types (numbers, strings, tuples). However, aliasing has a possibly surprising effect on the semantics of Python code involving mutable objects such as lists, dictionaries, and most other types. This is usually used to the benefit of the program, since aliases behave like pointers in some respects. For example, passing an object is cheap since only a pointer is passed by the implementation; and if a function modifies an object passed as an argument, the caller will see the change — this eliminates the need for two different argument passing mechanisms as in Pascal.

## 9.2. Python Scopes and Namespaces

Before introducing classes, I first have to tell you something about Python’s scope rules. Class definitions play some neat tricks with namespaces, and you need to know how scopes and namespaces work to fully understand what’s going on. Incidentally, knowledge about this subject is useful for any advanced Python programmer.

Let’s begin with some definitions.

A namespace is a mapping from names to objects. Most namespaces are currently implemented as Python dictionaries, but that’s normally not noticeable in any way (except for performance), and it may change in the future. Examples of namespaces are: the set of built-in names (containing functions such as [abs()](https://docs.python.org/3/library/functions.html#abs), and built-in exception names); the global names in a module; and the local names in a function invocation. In a sense the set of attributes of an object also form a namespace. The important thing to know about namespaces is that there is absolutely no relation between names in different namespaces; for instance, two different modules may both define a function maximize without confusion — users of the modules must prefix it with the module name.

By the way, I use the word attribute for any name following a dot — for example, in the expressionz.real, real is an attribute of the object z. Strictly speaking, references to names in modules are attribute references: in the expression modname.funcname, modname is a module object and funcnameis an attribute of it. In this case there happens to be a straightforward mapping between the module’s attributes and the global names defined in the module: they share the same namespace! [[1]](https://docs.python.org/3/tutorial/classes.html#id2)

Attributes may be read-only or writable. In the latter case, assignment to attributes is possible. Module attributes are writable: you can write modname.the\_answer = 42. Writable attributes may also be deleted with the [del](https://docs.python.org/3/reference/simple_stmts.html#del) statement. For example, del modname.the\_answer will remove the attributethe\_answer from the object named by modname.

Namespaces are created at different moments and have different lifetimes. The namespace containing the built-in names is created when the Python interpreter starts up, and is never deleted. The global namespace for a module is created when the module definition is read in; normally, module namespaces also last until the interpreter quits. The statements executed by the top-level invocation of the interpreter, either read from a script file or interactively, are considered part of a module called[\_\_main\_\_](https://docs.python.org/3/library/__main__.html#module-__main__), so they have their own global namespace. (The built-in names actually also live in a module; this is called [builtins](https://docs.python.org/3/library/builtins.html#module-builtins).)

The local namespace for a function is created when the function is called, and deleted when the function returns or raises an exception that is not handled within the function. (Actually, forgetting would be a better way to describe what actually happens.) Of course, recursive invocations each have their own local namespace.

A scope is a textual region of a Python program where a namespace is directly accessible. “Directly accessible” here means that an unqualified reference to a name attempts to find the name in the namespace.

Although scopes are determined statically, they are used dynamically. At any time during execution, there are at least three nested scopes whose namespaces are directly accessible:

* the innermost scope, which is searched first, contains the local names
* the scopes of any enclosing functions, which are searched starting with the nearest enclosing scope, contains non-local, but also non-global names
* the next-to-last scope contains the current module’s global names
* the outermost scope (searched last) is the namespace containing built-in names

If a name is declared global, then all references and assignments go directly to the middle scope containing the module’s global names. To rebind variables found outside of the innermost scope, the[nonlocal](https://docs.python.org/3/reference/simple_stmts.html#nonlocal) statement can be used; if not declared nonlocal, those variables are read-only (an attempt to write to such a variable will simply create a new local variable in the innermost scope, leaving the identically named outer variable unchanged).

Usually, the local scope references the local names of the (textually) current function. Outside functions, the local scope references the same namespace as the global scope: the module’s namespace. Class definitions place yet another namespace in the local scope.

It is important to realize that scopes are determined textually: the global scope of a function defined in a module is that module’s namespace, no matter from where or by what alias the function is called. On the other hand, the actual search for names is done dynamically, at run time — however, the language definition is evolving towards static name resolution, at “compile” time, so don’t rely on dynamic name resolution! (In fact, local variables are already determined statically.)

A special quirk of Python is that – if no [global](https://docs.python.org/3/reference/simple_stmts.html#global) statement is in effect – assignments to names always go into the innermost scope. Assignments do not copy data — they just bind names to objects. The same is true for deletions: the statement del x removes the binding of x from the namespace referenced by the local scope. In fact, all operations that introduce new names use the local scope: in particular, [import](https://docs.python.org/3/reference/simple_stmts.html#import) statements and function definitions bind the module or function name in the local scope.

The [global](https://docs.python.org/3/reference/simple_stmts.html#global) statement can be used to indicate that particular variables live in the global scope and should be rebound there; the [nonlocal](https://docs.python.org/3/reference/simple_stmts.html#nonlocal) statement indicates that particular variables live in an enclosing scope and should be rebound there.

### 9.2.1. Scopes and Namespaces Example

This is an example demonstrating how to reference the different scopes and namespaces, and how[global](https://docs.python.org/3/reference/simple_stmts.html#global) and [nonlocal](https://docs.python.org/3/reference/simple_stmts.html#nonlocal) affect variable binding:

**def** scope\_test():

**def** do\_local():

spam = "local spam"

**def** do\_nonlocal():

**nonlocal** spam

spam = "nonlocal spam"

**def** do\_global():

**global** spam

spam = "global spam"

spam = "test spam"

do\_local()

print("After local assignment:", spam)

do\_nonlocal()

print("After nonlocal assignment:", spam)

do\_global()

print("After global assignment:", spam)

scope\_test()

print("In global scope:", spam)

The output of the example code is:

After local assignment: test spam

After nonlocal assignment: nonlocal spam

After global assignment: nonlocal spam

In global scope: global spam

Note how the local assignment (which is default) didn’t change scope\_test‘s binding of spam. The[nonlocal](https://docs.python.org/3/reference/simple_stmts.html#nonlocal) assignment changed scope\_test‘s binding of spam, and the [global](https://docs.python.org/3/reference/simple_stmts.html#global) assignment changed the module-level binding.

You can also see that there was no previous binding for spam before the [global](https://docs.python.org/3/reference/simple_stmts.html#global) assignment.

## 9.3. A First Look at Classes

Classes introduce a little bit of new syntax, three new object types, and some new semantics.

### 9.3.1. Class Definition Syntax

The simplest form of class definition looks like this:

**class** **ClassName**:

<statement-1>

.

.

.

<statement-N>

Class definitions, like function definitions ([def](https://docs.python.org/3/reference/compound_stmts.html#def) statements) must be executed before they have any effect. (You could conceivably place a class definition in a branch of an [if](https://docs.python.org/3/reference/compound_stmts.html#if) statement, or inside a function.)

In practice, the statements inside a class definition will usually be function definitions, but other statements are allowed, and sometimes useful — we’ll come back to this later. The function definitions inside a class normally have a peculiar form of argument list, dictated by the calling conventions for methods — again, this is explained later.

When a class definition is entered, a new namespace is created, and used as the local scope — thus, all assignments to local variables go into this new namespace. In particular, function definitions bind the name of the new function here.

When a class definition is left normally (via the end), a class object is created. This is basically a wrapper around the contents of the namespace created by the class definition; we’ll learn more about class objects in the next section. The original local scope (the one in effect just before the class definition was entered) is reinstated, and the class object is bound here to the class name given in the class definition header (ClassName in the example).

### 9.3.2. Class Objects

Class objects support two kinds of operations: attribute references and instantiation.

Attribute references use the standard syntax used for all attribute references in Python: obj.name. Valid attribute names are all the names that were in the class’s namespace when the class object was created. So, if the class definition looked like this:

**class** **MyClass**:

*"""A simple example class"""*

i = 12345

**def** f(self):

**return** 'hello world'

then MyClass.i and MyClass.f are valid attribute references, returning an integer and a function object, respectively. Class attributes can also be assigned to, so you can change the value ofMyClass.i by assignment. \_\_doc\_\_ is also a valid attribute, returning the docstring belonging to the class: "A simple example class".

Class instantiation uses function notation. Just pretend that the class object is a parameterless function that returns a new instance of the class. For example (assuming the above class):

x = MyClass()

creates a new instance of the class and assigns this object to the local variable x.

The instantiation operation (“calling” a class object) creates an empty object. Many classes like to create objects with instances customized to a specific initial state. Therefore a class may define a special method named [\_\_init\_\_()](https://docs.python.org/3/reference/datamodel.html#object.__init__), like this:

**def** \_\_init\_\_(self):

self.data = []

When a class defines an [\_\_init\_\_()](https://docs.python.org/3/reference/datamodel.html#object.__init__) method, class instantiation automatically invokes [\_\_init\_\_()](https://docs.python.org/3/reference/datamodel.html#object.__init__)for the newly-created class instance. So in this example, a new, initialized instance can be obtained by:

x = MyClass()

Of course, the [\_\_init\_\_()](https://docs.python.org/3/reference/datamodel.html#object.__init__) method may have arguments for greater flexibility. In that case, arguments given to the class instantiation operator are passed on to [\_\_init\_\_()](https://docs.python.org/3/reference/datamodel.html#object.__init__). For example,

>>>

**>>> class** **Complex**:

**...**  **def** \_\_init\_\_(self, realpart, imagpart):

**...**  self.r = realpart

**...**  self.i = imagpart

**...**

**>>>** x = Complex(3.0, -4.5)

**>>>** x.r, x.i

(3.0, -4.5)

### 9.3.3. Instance Objects

Now what can we do with instance objects? The only operations understood by instance objects are attribute references. There are two kinds of valid attribute names, data attributes and methods.

data attributes correspond to “instance variables” in Smalltalk, and to “data members” in C++. Data attributes need not be declared; like local variables, they spring into existence when they are first assigned to. For example, if x is the instance of MyClass created above, the following piece of code will print the value 16, without leaving a trace:

x.counter = 1

**while** x.counter < 10:

x.counter = x.counter \* 2

print(x.counter)

**del** x.counter

The other kind of instance attribute reference is a method. A method is a function that “belongs to” an object. (In Python, the term method is not unique to class instances: other object types can have methods as well. For example, list objects have methods called append, insert, remove, sort, and so on. However, in the following discussion, we’ll use the term method exclusively to mean methods of class instance objects, unless explicitly stated otherwise.)

Valid method names of an instance object depend on its class. By definition, all attributes of a class that are function objects define corresponding methods of its instances. So in our example, x.f is a valid method reference, since MyClass.f is a function, but x.i is not, since MyClass.i is not. But x.fis not the same thing as MyClass.f — it is a method object, not a function object.

### 9.3.4. Method Objects

Usually, a method is called right after it is bound:

x.f()

In the MyClass example, this will return the string 'hello world'. However, it is not necessary to call a method right away: x.f is a method object, and can be stored away and called at a later time. For example:

xf = x.f

**while** **True**:

print(xf())

will continue to print hello world until the end of time.

What exactly happens when a method is called? You may have noticed that x.f() was called without an argument above, even though the function definition for f() specified an argument. What happened to the argument? Surely Python raises an exception when a function that requires an argument is called without any — even if the argument isn’t actually used...

Actually, you may have guessed the answer: the special thing about methods is that the object is passed as the first argument of the function. In our example, the call x.f() is exactly equivalent toMyClass.f(x). In general, calling a method with a list of n arguments is equivalent to calling the corresponding function with an argument list that is created by inserting the method’s object before the first argument.

If you still don’t understand how methods work, a look at the implementation can perhaps clarify matters. When an instance attribute is referenced that isn’t a data attribute, its class is searched. If the name denotes a valid class attribute that is a function object, a method object is created by packing (pointers to) the instance object and the function object just found together in an abstract object: this is the method object. When the method object is called with an argument list, a new argument list is constructed from the instance object and the argument list, and the function object is called with this new argument list.

### 9.3.5. Class and Instance Variables

Generally speaking, instance variables are for data unique to each instance and class variables are for attributes and methods shared by all instances of the class:

**class** **Dog**:

kind = 'canine' *# class variable shared by all instances*

**def** \_\_init\_\_(self, name):

self.name = name *# instance variable unique to each instance*

>>> d = Dog('Fido')

>>> e = Dog('Buddy')

>>> d.kind *# shared by all dogs*

'canine'

>>> e.kind *# shared by all dogs*

'canine'

>>> d.name *# unique to d*

'Fido'

>>> e.name *# unique to e*

'Buddy'

As discussed in [A Word About Names and Objects](https://docs.python.org/3/tutorial/classes.html#tut-object), shared data can have possibly surprising effects with involving [mutable](https://docs.python.org/3/glossary.html#term-mutable) objects such as lists and dictionaries. For example, the tricks list in the following code should not be used as a class variable because just a single list would be shared by all Doginstances:

**class** **Dog**:

tricks = [] *# mistaken use of a class variable*

**def** \_\_init\_\_(self, name):

self.name = name

**def** add\_trick(self, trick):

self.tricks.append(trick)

>>> d = Dog('Fido')

>>> e = Dog('Buddy')

>>> d.add\_trick('roll over')

>>> e.add\_trick('play dead')

>>> d.tricks *# unexpectedly shared by all dogs*

['roll over', 'play dead']

Correct design of the class should use an instance variable instead:

**class** **Dog**:

**def** \_\_init\_\_(self, name):

self.name = name

self.tricks = [] *# creates a new empty list for each dog*

**def** add\_trick(self, trick):

self.tricks.append(trick)

>>> d = Dog('Fido')

>>> e = Dog('Buddy')

>>> d.add\_trick('roll over')

>>> e.add\_trick('play dead')

>>> d.tricks

['roll over']

>>> e.tricks

['play dead']

## 9.4. Random Remarks

Data attributes override method attributes with the same name; to avoid accidental name conflicts, which may cause hard-to-find bugs in large programs, it is wise to use some kind of convention that minimizes the chance of conflicts. Possible conventions include capitalizing method names, prefixing data attribute names with a small unique string (perhaps just an underscore), or using verbs for methods and nouns for data attributes.

Data attributes may be referenced by methods as well as by ordinary users (“clients”) of an object. In other words, classes are not usable to implement pure abstract data types. In fact, nothing in Python makes it possible to enforce data hiding — it is all based upon convention. (On the other hand, the Python implementation, written in C, can completely hide implementation details and control access to an object if necessary; this can be used by extensions to Python written in C.)

Clients should use data attributes with care — clients may mess up invariants maintained by the methods by stamping on their data attributes. Note that clients may add data attributes of their own to an instance object without affecting the validity of the methods, as long as name conflicts are avoided — again, a naming convention can save a lot of headaches here.

There is no shorthand for referencing data attributes (or other methods!) from within methods. I find that this actually increases the readability of methods: there is no chance of confusing local variables and instance variables when glancing through a method.

Often, the first argument of a method is called self. This is nothing more than a convention: the nameself has absolutely no special meaning to Python. Note, however, that by not following the convention your code may be less readable to other Python programmers, and it is also conceivable that a class browser program might be written that relies upon such a convention.

Any function object that is a class attribute defines a method for instances of that class. It is not necessary that the function definition is textually enclosed in the class definition: assigning a function object to a local variable in the class is also ok. For example:

*# Function defined outside the class*

**def** f1(self, x, y):

**return** min(x, x+y)

**class** **C**:

f = f1

**def** g(self):

**return** 'hello world'

h = g

Now f, g and h are all attributes of class C that refer to function objects, and consequently they are all methods of instances of C — h being exactly equivalent to g. Note that this practice usually only serves to confuse the reader of a program.

Methods may call other methods by using method attributes of the self argument:

**class** **Bag**:

**def** \_\_init\_\_(self):

self.data = []

**def** add(self, x):

self.data.append(x)

**def** addtwice(self, x):

self.add(x)

self.add(x)

Methods may reference global names in the same way as ordinary functions. The global scope associated with a method is the module containing its definition. (A class is never used as a global scope.) While one rarely encounters a good reason for using global data in a method, there are many legitimate uses of the global scope: for one thing, functions and modules imported into the global scope can be used by methods, as well as functions and classes defined in it. Usually, the class containing the method is itself defined in this global scope, and in the next section we’ll find some good reasons why a method would want to reference its own class.

Each value is an object, and therefore has a class (also called its type). It is stored asobject.\_\_class\_\_.

## 9.5. Inheritance

Of course, a language feature would not be worthy of the name “class” without supporting inheritance. The syntax for a derived class definition looks like this:

**class** **DerivedClassName**(BaseClassName):

<statement-1>

.

.

.

<statement-N>

The name BaseClassName must be defined in a scope containing the derived class definition. In place of a base class name, other arbitrary expressions are also allowed. This can be useful, for example, when the base class is defined in another module:

**class** **DerivedClassName**(modname.BaseClassName):

Execution of a derived class definition proceeds the same as for a base class. When the class object is constructed, the base class is remembered. This is used for resolving attribute references: if a requested attribute is not found in the class, the search proceeds to look in the base class. This rule is applied recursively if the base class itself is derived from some other class.

There’s nothing special about instantiation of derived classes: DerivedClassName() creates a new instance of the class. Method references are resolved as follows: the corresponding class attribute is searched, descending down the chain of base classes if necessary, and the method reference is valid if this yields a function object.

Derived classes may override methods of their base classes. Because methods have no special privileges when calling other methods of the same object, a method of a base class that calls another method defined in the same base class may end up calling a method of a derived class that overrides it. (For C++ programmers: all methods in Python are effectively virtual.)

An overriding method in a derived class may in fact want to extend rather than simply replace the base class method of the same name. There is a simple way to call the base class method directly: just callBaseClassName.methodname(self, arguments). This is occasionally useful to clients as well. (Note that this only works if the base class is accessible as BaseClassName in the global scope.)

Python has two built-in functions that work with inheritance:

* Use [isinstance()](https://docs.python.org/3/library/functions.html#isinstance) to check an instance’s type: isinstance(obj, int) will be True only ifobj.\_\_class\_\_ is [int](https://docs.python.org/3/library/functions.html#int) or some class derived from [int](https://docs.python.org/3/library/functions.html#int).
* Use [issubclass()](https://docs.python.org/3/library/functions.html#issubclass) to check class inheritance: issubclass(bool, int) is True since [bool](https://docs.python.org/3/library/functions.html#bool) is a subclass of [int](https://docs.python.org/3/library/functions.html#int). However, issubclass(float, int) is False since [float](https://docs.python.org/3/library/functions.html#float) is not a subclass of[int](https://docs.python.org/3/library/functions.html#int).

### 9.5.1. Multiple Inheritance

Python supports a form of multiple inheritance as well. A class definition with multiple base classes looks like this:

**class** **DerivedClassName**(Base1, Base2, Base3):

<statement-1>

.

.

.

<statement-N>

For most purposes, in the simplest cases, you can think of the search for attributes inherited from a parent class as depth-first, left-to-right, not searching twice in the same class where there is an overlap in the hierarchy. Thus, if an attribute is not found in DerivedClassName, it is searched for inBase1, then (recursively) in the base classes of Base1, and if it was not found there, it was searched for in Base2, and so on.

In fact, it is slightly more complex than that; the method resolution order changes dynamically to support cooperative calls to [super()](https://docs.python.org/3/library/functions.html#super). This approach is known in some other multiple-inheritance languages as call-next-method and is more powerful than the super call found in single-inheritance languages.

Dynamic ordering is necessary because all cases of multiple inheritance exhibit one or more diamond relationships (where at least one of the parent classes can be accessed through multiple paths from the bottommost class). For example, all classes inherit from [object](https://docs.python.org/3/library/functions.html#object), so any case of multiple inheritance provides more than one path to reach [object](https://docs.python.org/3/library/functions.html#object). To keep the base classes from being accessed more than once, the dynamic algorithm linearizes the search order in a way that preserves the left-to-right ordering specified in each class, that calls each parent only once, and that is monotonic (meaning that a class can be subclassed without affecting the precedence order of its parents). Taken together, these properties make it possible to design reliable and extensible classes with multiple inheritance. For more detail, see <https://www.python.org/download/releases/2.3/mro/>.

## 9.6. Private Variables

“Private” instance variables that cannot be accessed except from inside an object don’t exist in Python. However, there is a convention that is followed by most Python code: a name prefixed with an underscore (e.g. \_spam) should be treated as a non-public part of the API (whether it is a function, a method or a data member). It should be considered an implementation detail and subject to change without notice.

Since there is a valid use-case for class-private members (namely to avoid name clashes of names with names defined by subclasses), there is limited support for such a mechanism, called name mangling. Any identifier of the form \_\_spam (at least two leading underscores, at most one trailing underscore) is textually replaced with \_classname\_\_spam, where classname is the current class name with leading underscore(s) stripped. This mangling is done without regard to the syntactic position of the identifier, as long as it occurs within the definition of a class.

Name mangling is helpful for letting subclasses override methods without breaking intraclass method calls. For example:

**class** **Mapping**:

**def** \_\_init\_\_(self, iterable):

self.items\_list = []

self.\_\_update(iterable)

**def** update(self, iterable):

**for** item **in** iterable:

self.items\_list.append(item)

\_\_update = update *# private copy of original update() method*

**class** **MappingSubclass**(Mapping):

**def** update(self, keys, values):

*# provides new signature for update()*

*# but does not break \_\_init\_\_()*

**for** item **in** zip(keys, values):

self.items\_list.append(item)

Note that the mangling rules are designed mostly to avoid accidents; it still is possible to access or modify a variable that is considered private. This can even be useful in special circumstances, such as in the debugger.

Notice that code passed to exec() or eval() does not consider the classname of the invoking class to be the current class; this is similar to the effect of the global statement, the effect of which is likewise restricted to code that is byte-compiled together. The same restriction applies to getattr(),setattr() and delattr(), as well as when referencing \_\_dict\_\_ directly.

## 9.7. Odds and Ends

Sometimes it is useful to have a data type similar to the Pascal “record” or C “struct”, bundling together a few named data items. An empty class definition will do nicely:

**class** **Employee**:

**pass**

john = Employee() *# Create an empty employee record*

*# Fill the fields of the record*

john.name = 'John Doe'

john.dept = 'computer lab'

john.salary = 1000

A piece of Python code that expects a particular abstract data type can often be passed a class that emulates the methods of that data type instead. For instance, if you have a function that formats some data from a file object, you can define a class with methods read() and readline() that get the data from a string buffer instead, and pass it as an argument.

Instance method objects have attributes, too: m.\_\_self\_\_ is the instance object with the method m(), and m.\_\_func\_\_ is the function object corresponding to the method.

## 9.8. Exceptions Are Classes Too

User-defined exceptions are identified by classes as well. Using this mechanism it is possible to create extensible hierarchies of exceptions.

There are two new valid (semantic) forms for the [raise](https://docs.python.org/3/reference/simple_stmts.html#raise) statement:

**raise** Class

**raise** Instance

In the first form, Class must be an instance of [type](https://docs.python.org/3/library/functions.html#type) or of a class derived from it. The first form is a shorthand for:

**raise** Class()

A class in an [except](https://docs.python.org/3/reference/compound_stmts.html#except) clause is compatible with an exception if it is the same class or a base class thereof (but not the other way around — an except clause listing a derived class is not compatible with a base class). For example, the following code will print B, C, D in that order:

**class** **B**(Exception):

**pass**

**class** **C**(B):

**pass**

**class** **D**(C):

**pass**

**for** cls **in** [B, C, D]:

**try**:

**raise** cls()

**except** D:

print("D")

**except** C:

print("C")

**except** B:

print("B")

Note that if the except clauses were reversed (with except B first), it would have printed B, B, B — the first matching except clause is triggered.

When an error message is printed for an unhandled exception, the exception’s class name is printed, then a colon and a space, and finally the instance converted to a string using the built-in function[str()](https://docs.python.org/3/library/stdtypes.html#str).

## 9.9. Iterators

By now you have probably noticed that most container objects can be looped over using a [for](https://docs.python.org/3/reference/compound_stmts.html#for)statement:

**for** element **in** [1, 2, 3]:

print(element)

**for** element **in** (1, 2, 3):

print(element)

**for** key **in** {'one':1, 'two':2}:

print(key)

**for** char **in** "123":

print(char)

**for** line **in** open("myfile.txt"):

print(line, end='')

This style of access is clear, concise, and convenient. The use of iterators pervades and unifies Python. Behind the scenes, the [for](https://docs.python.org/3/reference/compound_stmts.html#for) statement calls [iter()](https://docs.python.org/3/library/functions.html#iter) on the container object. The function returns an iterator object that defines the method [\_\_next\_\_()](https://docs.python.org/3/library/stdtypes.html#iterator.__next__) which accesses elements in the container one at a time. When there are no more elements, [\_\_next\_\_()](https://docs.python.org/3/library/stdtypes.html#iterator.__next__) raises a [StopIteration](https://docs.python.org/3/library/exceptions.html#StopIteration)exception which tells the [for](https://docs.python.org/3/reference/compound_stmts.html#for) loop to terminate. You can call the [\_\_next\_\_()](https://docs.python.org/3/library/stdtypes.html#iterator.__next__) method using the[next()](https://docs.python.org/3/library/functions.html#next) built-in function; this example shows how it all works:

>>>

**>>>** s = 'abc'

**>>>** it = iter(s)

**>>>** it

<iterator object at 0x00A1DB50>

**>>>** next(it)

'a'

**>>>** next(it)

'b'

**>>>** next(it)

'c'

**>>>** next(it)

Traceback (most recent call last):

File "<stdin>", line 1, in ?

next(it)

StopIteration

Having seen the mechanics behind the iterator protocol, it is easy to add iterator behavior to your classes. Define an [\_\_iter\_\_()](https://docs.python.org/3/reference/datamodel.html#object.__iter__) method which returns an object with a [\_\_next\_\_()](https://docs.python.org/3/library/stdtypes.html#iterator.__next__) method. If the class defines \_\_next\_\_(), then [\_\_iter\_\_()](https://docs.python.org/3/reference/datamodel.html#object.__iter__) can just return self:

**class** **Reverse**:

*"""Iterator for looping over a sequence backwards."""*

**def** \_\_init\_\_(self, data):

self.data = data

self.index = len(data)

**def** \_\_iter\_\_(self):

**return** self

**def** \_\_next\_\_(self):

**if** self.index == 0:

**raise** StopIteration

self.index = self.index - 1

**return** self.data[self.index]

>>>

**>>>** rev = Reverse('spam')

**>>>** iter(rev)

<\_\_main\_\_.Reverse object at 0x00A1DB50>

**>>> for** char **in** rev:

**...**  print(char)

**...**

m

a

p

s

## 9.10. Generators

[Generator](https://docs.python.org/3/glossary.html#term-generator)s are a simple and powerful tool for creating iterators. They are written like regular functions but use the [yield](https://docs.python.org/3/reference/simple_stmts.html#yield) statement whenever they want to return data. Each time [next()](https://docs.python.org/3/library/functions.html#next) is called on it, the generator resumes where it left off (it remembers all the data values and which statement was last executed). An example shows that generators can be trivially easy to create:

**def** reverse(data):

**for** index **in** range(len(data)-1, -1, -1):

**yield** data[index]

>>>

**>>> for** char **in** reverse('golf'):

**...**  print(char)

**...**

f

l

o

g

Anything that can be done with generators can also be done with class-based iterators as described in the previous section. What makes generators so compact is that the [\_\_iter\_\_()](https://docs.python.org/3/reference/datamodel.html#object.__iter__) and [\_\_next\_\_()](https://docs.python.org/3/reference/expressions.html#generator.__next__)methods are created automatically.

Another key feature is that the local variables and execution state are automatically saved between calls. This made the function easier to write and much more clear than an approach using instance variables like self.index and self.data.

In addition to automatic method creation and saving program state, when generators terminate, they automatically raise [StopIteration](https://docs.python.org/3/library/exceptions.html#StopIteration). In combination, these features make it easy to create iterators with no more effort than writing a regular function.

## 9.11. Generator Expressions

Some simple generators can be coded succinctly as expressions using a syntax similar to list comprehensions but with parentheses instead of brackets. These expressions are designed for situations where the generator is used right away by an enclosing function. Generator expressions are more compact but less versatile than full generator definitions and tend to be more memory friendly than equivalent list comprehensions.

Examples:

>>>

**>>>** sum(i\*i **for** i **in** range(10)) *# sum of squares*

285

**>>>** xvec = [10, 20, 30]

**>>>** yvec = [7, 5, 3]

**>>>** sum(x\*y **for** x,y **in** zip(xvec, yvec)) *# dot product*

260

**>>> from** **math** **import** pi, sin

**>>>** sine\_table = {x: sin(x\*pi/180) **for** x **in** range(0, 91)}

**>>>** unique\_words = set(word **for** line **in** page **for** word **in** line.split())

**>>>** valedictorian = max((student.gpa, student.name) **for** student **in** graduates)

**>>>** data = 'golf'

**>>>** list(data[i] **for** i **in** range(len(data)-1, -1, -1))

['f', 'l', 'o', 'g']

**Footnotes**

|  |  |
| --- | --- |
| [[1]](https://docs.python.org/3/tutorial/classes.html#id1) | Except for one thing. Module objects have a secret read-only attribute called [\_\_dict\_\_](https://docs.python.org/3/library/stdtypes.html#object.__dict__) which returns the dictionary used to implement the module’s namespace; the name [\_\_dict\_\_](https://docs.python.org/3/library/stdtypes.html#object.__dict__) is an attribute but not a global name. Obviously, using this violates the abstraction of namespace implementation, and should be restricted to things like post-mortem debuggers. |

# 9. Classes

Compared with other programming languages, Python’s class mechanism adds classes with a minimum of new syntax and semantics. It is a mixture of the class mechanisms found in C++ and Modula-3. Python classes provide all the standard features of Object Oriented Programming: the class inheritance mechanism allows multiple base classes, a derived class can override any methods of its base class or classes, and a method can call the method of a base class with the same name. Objects can contain arbitrary amounts and kinds of data. As is true for modules, classes partake of the dynamic nature of Python: they are created at runtime, and can be modified further after creation.

In C++ terminology, normally class members (including the data members) are public (except see below [Private Variables](https://docs.python.org/3/tutorial/classes.html#tut-private)), and all member functions are virtual. As in Modula-3, there are no shorthands for referencing the object’s members from its methods: the method function is declared with an explicit first argument representing the object, which is provided implicitly by the call. As in Smalltalk, classes themselves are objects. This provides semantics for importing and renaming. Unlike C++ and Modula-3, built-in types can be used as base classes for extension by the user. Also, like in C++, most built-in operators with special syntax (arithmetic operators, subscripting etc.) can be redefined for class instances.

(Lacking universally accepted terminology to talk about classes, I will make occasional use of Smalltalk and C++ terms. I would use Modula-3 terms, since its object-oriented semantics are closer to those of Python than C++, but I expect that few readers have heard of it.)

## 9.1. A Word About Names and Objects

Objects have individuality, and multiple names (in multiple scopes) can be bound to the same object. This is known as aliasing in other languages. This is usually not appreciated on a first glance at Python, and can be safely ignored when dealing with immutable basic types (numbers, strings, tuples). However, aliasing has a possibly surprising effect on the semantics of Python code involving mutable objects such as lists, dictionaries, and most other types. This is usually used to the benefit of the program, since aliases behave like pointers in some respects. For example, passing an object is cheap since only a pointer is passed by the implementation; and if a function modifies an object passed as an argument, the caller will see the change — this eliminates the need for two different argument passing mechanisms as in Pascal.

## 9.2. Python Scopes and Namespaces

Before introducing classes, I first have to tell you something about Python’s scope rules. Class definitions play some neat tricks with namespaces, and you need to know how scopes and namespaces work to fully understand what’s going on. Incidentally, knowledge about this subject is useful for any advanced Python programmer.

Let’s begin with some definitions.

A namespace is a mapping from names to objects. Most namespaces are currently implemented as Python dictionaries, but that’s normally not noticeable in any way (except for performance), and it may change in the future. Examples of namespaces are: the set of built-in names (containing functions such as [abs()](https://docs.python.org/3/library/functions.html#abs), and built-in exception names); the global names in a module; and the local names in a function invocation. In a sense the set of attributes of an object also form a namespace. The important thing to know about namespaces is that there is absolutely no relation between names in different namespaces; for instance, two different modules may both define a function maximize without confusion — users of the modules must prefix it with the module name.

By the way, I use the word attribute for any name following a dot — for example, in the expressionz.real, real is an attribute of the object z. Strictly speaking, references to names in modules are attribute references: in the expression modname.funcname, modname is a module object and funcnameis an attribute of it. In this case there happens to be a straightforward mapping between the module’s attributes and the global names defined in the module: they share the same namespace! [[1]](https://docs.python.org/3/tutorial/classes.html#id2)

Attributes may be read-only or writable. In the latter case, assignment to attributes is possible. Module attributes are writable: you can write modname.the\_answer = 42. Writable attributes may also be deleted with the [del](https://docs.python.org/3/reference/simple_stmts.html#del) statement. For example, del modname.the\_answer will remove the attributethe\_answer from the object named by modname.

Namespaces are created at different moments and have different lifetimes. The namespace containing the built-in names is created when the Python interpreter starts up, and is never deleted. The global namespace for a module is created when the module definition is read in; normally, module namespaces also last until the interpreter quits. The statements executed by the top-level invocation of the interpreter, either read from a script file or interactively, are considered part of a module called[\_\_main\_\_](https://docs.python.org/3/library/__main__.html#module-__main__), so they have their own global namespace. (The built-in names actually also live in a module; this is called [builtins](https://docs.python.org/3/library/builtins.html#module-builtins).)

The local namespace for a function is created when the function is called, and deleted when the function returns or raises an exception that is not handled within the function. (Actually, forgetting would be a better way to describe what actually happens.) Of course, recursive invocations each have their own local namespace.

A scope is a textual region of a Python program where a namespace is directly accessible. “Directly accessible” here means that an unqualified reference to a name attempts to find the name in the namespace.

Although scopes are determined statically, they are used dynamically. At any time during execution, there are at least three nested scopes whose namespaces are directly accessible:

* the innermost scope, which is searched first, contains the local names
* the scopes of any enclosing functions, which are searched starting with the nearest enclosing scope, contains non-local, but also non-global names
* the next-to-last scope contains the current module’s global names
* the outermost scope (searched last) is the namespace containing built-in names

If a name is declared global, then all references and assignments go directly to the middle scope containing the module’s global names. To rebind variables found outside of the innermost scope, the[nonlocal](https://docs.python.org/3/reference/simple_stmts.html#nonlocal) statement can be used; if not declared nonlocal, those variables are read-only (an attempt to write to such a variable will simply create a new local variable in the innermost scope, leaving the identically named outer variable unchanged).

Usually, the local scope references the local names of the (textually) current function. Outside functions, the local scope references the same namespace as the global scope: the module’s namespace. Class definitions place yet another namespace in the local scope.

It is important to realize that scopes are determined textually: the global scope of a function defined in a module is that module’s namespace, no matter from where or by what alias the function is called. On the other hand, the actual search for names is done dynamically, at run time — however, the language definition is evolving towards static name resolution, at “compile” time, so don’t rely on dynamic name resolution! (In fact, local variables are already determined statically.)

A special quirk of Python is that – if no [global](https://docs.python.org/3/reference/simple_stmts.html#global) statement is in effect – assignments to names always go into the innermost scope. Assignments do not copy data — they just bind names to objects. The same is true for deletions: the statement del x removes the binding of x from the namespace referenced by the local scope. In fact, all operations that introduce new names use the local scope: in particular, [import](https://docs.python.org/3/reference/simple_stmts.html#import) statements and function definitions bind the module or function name in the local scope.

The [global](https://docs.python.org/3/reference/simple_stmts.html#global) statement can be used to indicate that particular variables live in the global scope and should be rebound there; the [nonlocal](https://docs.python.org/3/reference/simple_stmts.html#nonlocal) statement indicates that particular variables live in an enclosing scope and should be rebound there.

### 9.2.1. Scopes and Namespaces Example

This is an example demonstrating how to reference the different scopes and namespaces, and how[global](https://docs.python.org/3/reference/simple_stmts.html#global) and [nonlocal](https://docs.python.org/3/reference/simple_stmts.html#nonlocal) affect variable binding:

**def** scope\_test():

**def** do\_local():

spam = "local spam"

**def** do\_nonlocal():

**nonlocal** spam

spam = "nonlocal spam"

**def** do\_global():

**global** spam

spam = "global spam"

spam = "test spam"

do\_local()

print("After local assignment:", spam)

do\_nonlocal()

print("After nonlocal assignment:", spam)

do\_global()

print("After global assignment:", spam)

scope\_test()

print("In global scope:", spam)

The output of the example code is:

After local assignment: test spam

After nonlocal assignment: nonlocal spam

After global assignment: nonlocal spam

In global scope: global spam

Note how the local assignment (which is default) didn’t change scope\_test‘s binding of spam. The[nonlocal](https://docs.python.org/3/reference/simple_stmts.html#nonlocal) assignment changed scope\_test‘s binding of spam, and the [global](https://docs.python.org/3/reference/simple_stmts.html#global) assignment changed the module-level binding.

You can also see that there was no previous binding for spam before the [global](https://docs.python.org/3/reference/simple_stmts.html#global) assignment.

## 9.3. A First Look at Classes

Classes introduce a little bit of new syntax, three new object types, and some new semantics.

### 9.3.1. Class Definition Syntax

The simplest form of class definition looks like this:

**class** **ClassName**:

<statement-1>

.

.

.

<statement-N>

Class definitions, like function definitions ([def](https://docs.python.org/3/reference/compound_stmts.html#def) statements) must be executed before they have any effect. (You could conceivably place a class definition in a branch of an [if](https://docs.python.org/3/reference/compound_stmts.html#if) statement, or inside a function.)

In practice, the statements inside a class definition will usually be function definitions, but other statements are allowed, and sometimes useful — we’ll come back to this later. The function definitions inside a class normally have a peculiar form of argument list, dictated by the calling conventions for methods — again, this is explained later.

When a class definition is entered, a new namespace is created, and used as the local scope — thus, all assignments to local variables go into this new namespace. In particular, function definitions bind the name of the new function here.

When a class definition is left normally (via the end), a class object is created. This is basically a wrapper around the contents of the namespace created by the class definition; we’ll learn more about class objects in the next section. The original local scope (the one in effect just before the class definition was entered) is reinstated, and the class object is bound here to the class name given in the class definition header (ClassName in the example).

### 9.3.2. Class Objects

Class objects support two kinds of operations: attribute references and instantiation.

Attribute references use the standard syntax used for all attribute references in Python: obj.name. Valid attribute names are all the names that were in the class’s namespace when the class object was created. So, if the class definition looked like this:

**class** **MyClass**:

*"""A simple example class"""*

i = 12345

**def** f(self):

**return** 'hello world'

then MyClass.i and MyClass.f are valid attribute references, returning an integer and a function object, respectively. Class attributes can also be assigned to, so you can change the value ofMyClass.i by assignment. \_\_doc\_\_ is also a valid attribute, returning the docstring belonging to the class: "A simple example class".

Class instantiation uses function notation. Just pretend that the class object is a parameterless function that returns a new instance of the class. For example (assuming the above class):

x = MyClass()

creates a new instance of the class and assigns this object to the local variable x.

The instantiation operation (“calling” a class object) creates an empty object. Many classes like to create objects with instances customized to a specific initial state. Therefore a class may define a special method named [\_\_init\_\_()](https://docs.python.org/3/reference/datamodel.html#object.__init__), like this:

**def** \_\_init\_\_(self):

self.data = []

When a class defines an [\_\_init\_\_()](https://docs.python.org/3/reference/datamodel.html#object.__init__) method, class instantiation automatically invokes [\_\_init\_\_()](https://docs.python.org/3/reference/datamodel.html#object.__init__)for the newly-created class instance. So in this example, a new, initialized instance can be obtained by:

x = MyClass()

Of course, the [\_\_init\_\_()](https://docs.python.org/3/reference/datamodel.html#object.__init__) method may have arguments for greater flexibility. In that case, arguments given to the class instantiation operator are passed on to [\_\_init\_\_()](https://docs.python.org/3/reference/datamodel.html#object.__init__). For example,

>>>

**>>> class** **Complex**:

**...**  **def** \_\_init\_\_(self, realpart, imagpart):

**...**  self.r = realpart

**...**  self.i = imagpart

**...**

**>>>** x = Complex(3.0, -4.5)

**>>>** x.r, x.i

(3.0, -4.5)

### 9.3.3. Instance Objects

Now what can we do with instance objects? The only operations understood by instance objects are attribute references. There are two kinds of valid attribute names, data attributes and methods.

data attributes correspond to “instance variables” in Smalltalk, and to “data members” in C++. Data attributes need not be declared; like local variables, they spring into existence when they are first assigned to. For example, if x is the instance of MyClass created above, the following piece of code will print the value 16, without leaving a trace:

x.counter = 1

**while** x.counter < 10:

x.counter = x.counter \* 2

print(x.counter)

**del** x.counter

The other kind of instance attribute reference is a method. A method is a function that “belongs to” an object. (In Python, the term method is not unique to class instances: other object types can have methods as well. For example, list objects have methods called append, insert, remove, sort, and so on. However, in the following discussion, we’ll use the term method exclusively to mean methods of class instance objects, unless explicitly stated otherwise.)

Valid method names of an instance object depend on its class. By definition, all attributes of a class that are function objects define corresponding methods of its instances. So in our example, x.f is a valid method reference, since MyClass.f is a function, but x.i is not, since MyClass.i is not. But x.fis not the same thing as MyClass.f — it is a method object, not a function object.

### 9.3.4. Method Objects

Usually, a method is called right after it is bound:

x.f()

In the MyClass example, this will return the string 'hello world'. However, it is not necessary to call a method right away: x.f is a method object, and can be stored away and called at a later time. For example:

xf = x.f

**while** **True**:

print(xf())

will continue to print hello world until the end of time.

What exactly happens when a method is called? You may have noticed that x.f() was called without an argument above, even though the function definition for f() specified an argument. What happened to the argument? Surely Python raises an exception when a function that requires an argument is called without any — even if the argument isn’t actually used...

Actually, you may have guessed the answer: the special thing about methods is that the object is passed as the first argument of the function. In our example, the call x.f() is exactly equivalent toMyClass.f(x). In general, calling a method with a list of n arguments is equivalent to calling the corresponding function with an argument list that is created by inserting the method’s object before the first argument.

If you still don’t understand how methods work, a look at the implementation can perhaps clarify matters. When an instance attribute is referenced that isn’t a data attribute, its class is searched. If the name denotes a valid class attribute that is a function object, a method object is created by packing (pointers to) the instance object and the function object just found together in an abstract object: this is the method object. When the method object is called with an argument list, a new argument list is constructed from the instance object and the argument list, and the function object is called with this new argument list.

### 9.3.5. Class and Instance Variables

Generally speaking, instance variables are for data unique to each instance and class variables are for attributes and methods shared by all instances of the class:

**class** **Dog**:

kind = 'canine' *# class variable shared by all instances*

**def** \_\_init\_\_(self, name):

self.name = name *# instance variable unique to each instance*

>>> d = Dog('Fido')

>>> e = Dog('Buddy')

>>> d.kind *# shared by all dogs*

'canine'

>>> e.kind *# shared by all dogs*

'canine'

>>> d.name *# unique to d*

'Fido'

>>> e.name *# unique to e*

'Buddy'

As discussed in [A Word About Names and Objects](https://docs.python.org/3/tutorial/classes.html#tut-object), shared data can have possibly surprising effects with involving [mutable](https://docs.python.org/3/glossary.html#term-mutable) objects such as lists and dictionaries. For example, the tricks list in the following code should not be used as a class variable because just a single list would be shared by all Doginstances:

**class** **Dog**:

tricks = [] *# mistaken use of a class variable*

**def** \_\_init\_\_(self, name):

self.name = name

**def** add\_trick(self, trick):

self.tricks.append(trick)

>>> d = Dog('Fido')

>>> e = Dog('Buddy')

>>> d.add\_trick('roll over')

>>> e.add\_trick('play dead')

>>> d.tricks *# unexpectedly shared by all dogs*

['roll over', 'play dead']

Correct design of the class should use an instance variable instead:

**class** **Dog**:

**def** \_\_init\_\_(self, name):

self.name = name

self.tricks = [] *# creates a new empty list for each dog*

**def** add\_trick(self, trick):

self.tricks.append(trick)

>>> d = Dog('Fido')

>>> e = Dog('Buddy')

>>> d.add\_trick('roll over')

>>> e.add\_trick('play dead')

>>> d.tricks

['roll over']

>>> e.tricks

['play dead']

## 9.4. Random Remarks

Data attributes override method attributes with the same name; to avoid accidental name conflicts, which may cause hard-to-find bugs in large programs, it is wise to use some kind of convention that minimizes the chance of conflicts. Possible conventions include capitalizing method names, prefixing data attribute names with a small unique string (perhaps just an underscore), or using verbs for methods and nouns for data attributes.

Data attributes may be referenced by methods as well as by ordinary users (“clients”) of an object. In other words, classes are not usable to implement pure abstract data types. In fact, nothing in Python makes it possible to enforce data hiding — it is all based upon convention. (On the other hand, the Python implementation, written in C, can completely hide implementation details and control access to an object if necessary; this can be used by extensions to Python written in C.)

Clients should use data attributes with care — clients may mess up invariants maintained by the methods by stamping on their data attributes. Note that clients may add data attributes of their own to an instance object without affecting the validity of the methods, as long as name conflicts are avoided — again, a naming convention can save a lot of headaches here.

There is no shorthand for referencing data attributes (or other methods!) from within methods. I find that this actually increases the readability of methods: there is no chance of confusing local variables and instance variables when glancing through a method.

Often, the first argument of a method is called self. This is nothing more than a convention: the nameself has absolutely no special meaning to Python. Note, however, that by not following the convention your code may be less readable to other Python programmers, and it is also conceivable that a class browser program might be written that relies upon such a convention.

Any function object that is a class attribute defines a method for instances of that class. It is not necessary that the function definition is textually enclosed in the class definition: assigning a function object to a local variable in the class is also ok. For example:

*# Function defined outside the class*

**def** f1(self, x, y):

**return** min(x, x+y)

**class** **C**:

f = f1

**def** g(self):

**return** 'hello world'

h = g

Now f, g and h are all attributes of class C that refer to function objects, and consequently they are all methods of instances of C — h being exactly equivalent to g. Note that this practice usually only serves to confuse the reader of a program.

Methods may call other methods by using method attributes of the self argument:

**class** **Bag**:

**def** \_\_init\_\_(self):

self.data = []

**def** add(self, x):

self.data.append(x)

**def** addtwice(self, x):

self.add(x)

self.add(x)

Methods may reference global names in the same way as ordinary functions. The global scope associated with a method is the module containing its definition. (A class is never used as a global scope.) While one rarely encounters a good reason for using global data in a method, there are many legitimate uses of the global scope: for one thing, functions and modules imported into the global scope can be used by methods, as well as functions and classes defined in it. Usually, the class containing the method is itself defined in this global scope, and in the next section we’ll find some good reasons why a method would want to reference its own class.

Each value is an object, and therefore has a class (also called its type). It is stored asobject.\_\_class\_\_.

## 9.5. Inheritance

Of course, a language feature would not be worthy of the name “class” without supporting inheritance. The syntax for a derived class definition looks like this:

**class** **DerivedClassName**(BaseClassName):

<statement-1>

.

.

.

<statement-N>

The name BaseClassName must be defined in a scope containing the derived class definition. In place of a base class name, other arbitrary expressions are also allowed. This can be useful, for example, when the base class is defined in another module:

**class** **DerivedClassName**(modname.BaseClassName):

Execution of a derived class definition proceeds the same as for a base class. When the class object is constructed, the base class is remembered. This is used for resolving attribute references: if a requested attribute is not found in the class, the search proceeds to look in the base class. This rule is applied recursively if the base class itself is derived from some other class.

There’s nothing special about instantiation of derived classes: DerivedClassName() creates a new instance of the class. Method references are resolved as follows: the corresponding class attribute is searched, descending down the chain of base classes if necessary, and the method reference is valid if this yields a function object.

Derived classes may override methods of their base classes. Because methods have no special privileges when calling other methods of the same object, a method of a base class that calls another method defined in the same base class may end up calling a method of a derived class that overrides it. (For C++ programmers: all methods in Python are effectively virtual.)

An overriding method in a derived class may in fact want to extend rather than simply replace the base class method of the same name. There is a simple way to call the base class method directly: just callBaseClassName.methodname(self, arguments). This is occasionally useful to clients as well. (Note that this only works if the base class is accessible as BaseClassName in the global scope.)

Python has two built-in functions that work with inheritance:

* Use [isinstance()](https://docs.python.org/3/library/functions.html#isinstance) to check an instance’s type: isinstance(obj, int) will be True only ifobj.\_\_class\_\_ is [int](https://docs.python.org/3/library/functions.html#int) or some class derived from [int](https://docs.python.org/3/library/functions.html#int).
* Use [issubclass()](https://docs.python.org/3/library/functions.html#issubclass) to check class inheritance: issubclass(bool, int) is True since [bool](https://docs.python.org/3/library/functions.html#bool) is a subclass of [int](https://docs.python.org/3/library/functions.html#int). However, issubclass(float, int) is False since [float](https://docs.python.org/3/library/functions.html#float) is not a subclass of[int](https://docs.python.org/3/library/functions.html#int).

### 9.5.1. Multiple Inheritance

Python supports a form of multiple inheritance as well. A class definition with multiple base classes looks like this:

**class** **DerivedClassName**(Base1, Base2, Base3):

<statement-1>

.

.

.

<statement-N>

For most purposes, in the simplest cases, you can think of the search for attributes inherited from a parent class as depth-first, left-to-right, not searching twice in the same class where there is an overlap in the hierarchy. Thus, if an attribute is not found in DerivedClassName, it is searched for inBase1, then (recursively) in the base classes of Base1, and if it was not found there, it was searched for in Base2, and so on.

In fact, it is slightly more complex than that; the method resolution order changes dynamically to support cooperative calls to [super()](https://docs.python.org/3/library/functions.html#super). This approach is known in some other multiple-inheritance languages as call-next-method and is more powerful than the super call found in single-inheritance languages.

Dynamic ordering is necessary because all cases of multiple inheritance exhibit one or more diamond relationships (where at least one of the parent classes can be accessed through multiple paths from the bottommost class). For example, all classes inherit from [object](https://docs.python.org/3/library/functions.html#object), so any case of multiple inheritance provides more than one path to reach [object](https://docs.python.org/3/library/functions.html#object). To keep the base classes from being accessed more than once, the dynamic algorithm linearizes the search order in a way that preserves the left-to-right ordering specified in each class, that calls each parent only once, and that is monotonic (meaning that a class can be subclassed without affecting the precedence order of its parents). Taken together, these properties make it possible to design reliable and extensible classes with multiple inheritance. For more detail, see <https://www.python.org/download/releases/2.3/mro/>.

## 9.6. Private Variables

“Private” instance variables that cannot be accessed except from inside an object don’t exist in Python. However, there is a convention that is followed by most Python code: a name prefixed with an underscore (e.g. \_spam) should be treated as a non-public part of the API (whether it is a function, a method or a data member). It should be considered an implementation detail and subject to change without notice.

Since there is a valid use-case for class-private members (namely to avoid name clashes of names with names defined by subclasses), there is limited support for such a mechanism, called name mangling. Any identifier of the form \_\_spam (at least two leading underscores, at most one trailing underscore) is textually replaced with \_classname\_\_spam, where classname is the current class name with leading underscore(s) stripped. This mangling is done without regard to the syntactic position of the identifier, as long as it occurs within the definition of a class.

Name mangling is helpful for letting subclasses override methods without breaking intraclass method calls. For example:

**class** **Mapping**:

**def** \_\_init\_\_(self, iterable):

self.items\_list = []

self.\_\_update(iterable)

**def** update(self, iterable):

**for** item **in** iterable:

self.items\_list.append(item)

\_\_update = update *# private copy of original update() method*

**class** **MappingSubclass**(Mapping):

**def** update(self, keys, values):

*# provides new signature for update()*

*# but does not break \_\_init\_\_()*

**for** item **in** zip(keys, values):

self.items\_list.append(item)

Note that the mangling rules are designed mostly to avoid accidents; it still is possible to access or modify a variable that is considered private. This can even be useful in special circumstances, such as in the debugger.

Notice that code passed to exec() or eval() does not consider the classname of the invoking class to be the current class; this is similar to the effect of the global statement, the effect of which is likewise restricted to code that is byte-compiled together. The same restriction applies to getattr(),setattr() and delattr(), as well as when referencing \_\_dict\_\_ directly.

## 9.7. Odds and Ends

Sometimes it is useful to have a data type similar to the Pascal “record” or C “struct”, bundling together a few named data items. An empty class definition will do nicely:

**class** **Employee**:

**pass**

john = Employee() *# Create an empty employee record*

*# Fill the fields of the record*

john.name = 'John Doe'

john.dept = 'computer lab'

john.salary = 1000

A piece of Python code that expects a particular abstract data type can often be passed a class that emulates the methods of that data type instead. For instance, if you have a function that formats some data from a file object, you can define a class with methods read() and readline() that get the data from a string buffer instead, and pass it as an argument.

Instance method objects have attributes, too: m.\_\_self\_\_ is the instance object with the method m(), and m.\_\_func\_\_ is the function object corresponding to the method.

## 9.8. Exceptions Are Classes Too

User-defined exceptions are identified by classes as well. Using this mechanism it is possible to create extensible hierarchies of exceptions.

There are two new valid (semantic) forms for the [raise](https://docs.python.org/3/reference/simple_stmts.html#raise) statement:

**raise** Class

**raise** Instance

In the first form, Class must be an instance of [type](https://docs.python.org/3/library/functions.html#type) or of a class derived from it. The first form is a shorthand for:

**raise** Class()

A class in an [except](https://docs.python.org/3/reference/compound_stmts.html#except) clause is compatible with an exception if it is the same class or a base class thereof (but not the other way around — an except clause listing a derived class is not compatible with a base class). For example, the following code will print B, C, D in that order:

**class** **B**(Exception):

**pass**

**class** **C**(B):

**pass**

**class** **D**(C):

**pass**

**for** cls **in** [B, C, D]:

**try**:

**raise** cls()

**except** D:

print("D")

**except** C:

print("C")

**except** B:

print("B")

Note that if the except clauses were reversed (with except B first), it would have printed B, B, B — the first matching except clause is triggered.

When an error message is printed for an unhandled exception, the exception’s class name is printed, then a colon and a space, and finally the instance converted to a string using the built-in function[str()](https://docs.python.org/3/library/stdtypes.html#str).

## 9.9. Iterators

By now you have probably noticed that most container objects can be looped over using a [for](https://docs.python.org/3/reference/compound_stmts.html#for)statement:

**for** element **in** [1, 2, 3]:

print(element)

**for** element **in** (1, 2, 3):

print(element)

**for** key **in** {'one':1, 'two':2}:

print(key)

**for** char **in** "123":

print(char)

**for** line **in** open("myfile.txt"):

print(line, end='')

This style of access is clear, concise, and convenient. The use of iterators pervades and unifies Python. Behind the scenes, the [for](https://docs.python.org/3/reference/compound_stmts.html#for) statement calls [iter()](https://docs.python.org/3/library/functions.html#iter) on the container object. The function returns an iterator object that defines the method [\_\_next\_\_()](https://docs.python.org/3/library/stdtypes.html#iterator.__next__) which accesses elements in the container one at a time. When there are no more elements, [\_\_next\_\_()](https://docs.python.org/3/library/stdtypes.html#iterator.__next__) raises a [StopIteration](https://docs.python.org/3/library/exceptions.html#StopIteration)exception which tells the [for](https://docs.python.org/3/reference/compound_stmts.html#for) loop to terminate. You can call the [\_\_next\_\_()](https://docs.python.org/3/library/stdtypes.html#iterator.__next__) method using the[next()](https://docs.python.org/3/library/functions.html#next) built-in function; this example shows how it all works:

>>>

**>>>** s = 'abc'

**>>>** it = iter(s)

**>>>** it

<iterator object at 0x00A1DB50>

**>>>** next(it)

'a'

**>>>** next(it)

'b'

**>>>** next(it)

'c'

**>>>** next(it)

Traceback (most recent call last):

File "<stdin>", line 1, in ?

next(it)

StopIteration

Having seen the mechanics behind the iterator protocol, it is easy to add iterator behavior to your classes. Define an [\_\_iter\_\_()](https://docs.python.org/3/reference/datamodel.html#object.__iter__) method which returns an object with a [\_\_next\_\_()](https://docs.python.org/3/library/stdtypes.html#iterator.__next__) method. If the class defines \_\_next\_\_(), then [\_\_iter\_\_()](https://docs.python.org/3/reference/datamodel.html#object.__iter__) can just return self:

**class** **Reverse**:

*"""Iterator for looping over a sequence backwards."""*

**def** \_\_init\_\_(self, data):

self.data = data

self.index = len(data)

**def** \_\_iter\_\_(self):

**return** self

**def** \_\_next\_\_(self):

**if** self.index == 0:

**raise** StopIteration

self.index = self.index - 1

**return** self.data[self.index]

>>>

**>>>** rev = Reverse('spam')

**>>>** iter(rev)

<\_\_main\_\_.Reverse object at 0x00A1DB50>

**>>> for** char **in** rev:

**...**  print(char)

**...**

m

a

p

s

## 9.10. Generators

[Generator](https://docs.python.org/3/glossary.html#term-generator)s are a simple and powerful tool for creating iterators. They are written like regular functions but use the [yield](https://docs.python.org/3/reference/simple_stmts.html#yield) statement whenever they want to return data. Each time [next()](https://docs.python.org/3/library/functions.html#next) is called on it, the generator resumes where it left off (it remembers all the data values and which statement was last executed). An example shows that generators can be trivially easy to create:

**def** reverse(data):

**for** index **in** range(len(data)-1, -1, -1):

**yield** data[index]

>>>

**>>> for** char **in** reverse('golf'):

**...**  print(char)

**...**

f

l

o

g

Anything that can be done with generators can also be done with class-based iterators as described in the previous section. What makes generators so compact is that the [\_\_iter\_\_()](https://docs.python.org/3/reference/datamodel.html#object.__iter__) and [\_\_next\_\_()](https://docs.python.org/3/reference/expressions.html#generator.__next__)methods are created automatically.

Another key feature is that the local variables and execution state are automatically saved between calls. This made the function easier to write and much more clear than an approach using instance variables like self.index and self.data.

In addition to automatic method creation and saving program state, when generators terminate, they automatically raise [StopIteration](https://docs.python.org/3/library/exceptions.html#StopIteration). In combination, these features make it easy to create iterators with no more effort than writing a regular function.

## 9.11. Generator Expressions

Some simple generators can be coded succinctly as expressions using a syntax similar to list comprehensions but with parentheses instead of brackets. These expressions are designed for situations where the generator is used right away by an enclosing function. Generator expressions are more compact but less versatile than full generator definitions and tend to be more memory friendly than equivalent list comprehensions.

Examples:

>>>

**>>>** sum(i\*i **for** i **in** range(10)) *# sum of squares*

285

**>>>** xvec = [10, 20, 30]

**>>>** yvec = [7, 5, 3]

**>>>** sum(x\*y **for** x,y **in** zip(xvec, yvec)) *# dot product*

260

**>>> from** **math** **import** pi, sin

**>>>** sine\_table = {x: sin(x\*pi/180) **for** x **in** range(0, 91)}

**>>>** unique\_words = set(word **for** line **in** page **for** word **in** line.split())

**>>>** valedictorian = max((student.gpa, student.name) **for** student **in** graduates)

**>>>** data = 'golf'

**>>>** list(data[i] **for** i **in** range(len(data)-1, -1, -1))

['f', 'l', 'o', 'g']

**Footnotes**

|  |  |
| --- | --- |
| [[1]](https://docs.python.org/3/tutorial/classes.html#id1) | Except for one thing. Module objects have a secret read-only attribute called [\_\_dict\_\_](https://docs.python.org/3/library/stdtypes.html#object.__dict__) which returns the dictionary used to implement the module’s namespace; the name [\_\_dict\_\_](https://docs.python.org/3/library/stdtypes.html#object.__dict__) is an attribute but not a global name. Obviously, using this violates the abstraction of namespace implementation, and should be restricted to things like post-mortem debuggers. |

# 9. Classes

Compared with other programming languages, Python’s class mechanism adds classes with a minimum of new syntax and semantics. It is a mixture of the class mechanisms found in C++ and Modula-3. Python classes provide all the standard features of Object Oriented Programming: the class inheritance mechanism allows multiple base classes, a derived class can override any methods of its base class or classes, and a method can call the method of a base class with the same name. Objects can contain arbitrary amounts and kinds of data. As is true for modules, classes partake of the dynamic nature of Python: they are created at runtime, and can be modified further after creation.

In C++ terminology, normally class members (including the data members) are public (except see below [Private Variables](https://docs.python.org/3/tutorial/classes.html#tut-private)), and all member functions are virtual. As in Modula-3, there are no shorthands for referencing the object’s members from its methods: the method function is declared with an explicit first argument representing the object, which is provided implicitly by the call. As in Smalltalk, classes themselves are objects. This provides semantics for importing and renaming. Unlike C++ and Modula-3, built-in types can be used as base classes for extension by the user. Also, like in C++, most built-in operators with special syntax (arithmetic operators, subscripting etc.) can be redefined for class instances.

(Lacking universally accepted terminology to talk about classes, I will make occasional use of Smalltalk and C++ terms. I would use Modula-3 terms, since its object-oriented semantics are closer to those of Python than C++, but I expect that few readers have heard of it.)

## 9.1. A Word About Names and Objects

Objects have individuality, and multiple names (in multiple scopes) can be bound to the same object. This is known as aliasing in other languages. This is usually not appreciated on a first glance at Python, and can be safely ignored when dealing with immutable basic types (numbers, strings, tuples). However, aliasing has a possibly surprising effect on the semantics of Python code involving mutable objects such as lists, dictionaries, and most other types. This is usually used to the benefit of the program, since aliases behave like pointers in some respects. For example, passing an object is cheap since only a pointer is passed by the implementation; and if a function modifies an object passed as an argument, the caller will see the change — this eliminates the need for two different argument passing mechanisms as in Pascal.

## 9.2. Python Scopes and Namespaces

Before introducing classes, I first have to tell you something about Python’s scope rules. Class definitions play some neat tricks with namespaces, and you need to know how scopes and namespaces work to fully understand what’s going on. Incidentally, knowledge about this subject is useful for any advanced Python programmer.

Let’s begin with some definitions.

A namespace is a mapping from names to objects. Most namespaces are currently implemented as Python dictionaries, but that’s normally not noticeable in any way (except for performance), and it may change in the future. Examples of namespaces are: the set of built-in names (containing functions such as [abs()](https://docs.python.org/3/library/functions.html#abs), and built-in exception names); the global names in a module; and the local names in a function invocation. In a sense the set of attributes of an object also form a namespace. The important thing to know about namespaces is that there is absolutely no relation between names in different namespaces; for instance, two different modules may both define a function maximize without confusion — users of the modules must prefix it with the module name.

By the way, I use the word attribute for any name following a dot — for example, in the expressionz.real, real is an attribute of the object z. Strictly speaking, references to names in modules are attribute references: in the expression modname.funcname, modname is a module object and funcnameis an attribute of it. In this case there happens to be a straightforward mapping between the module’s attributes and the global names defined in the module: they share the same namespace! [[1]](https://docs.python.org/3/tutorial/classes.html#id2)

Attributes may be read-only or writable. In the latter case, assignment to attributes is possible. Module attributes are writable: you can write modname.the\_answer = 42. Writable attributes may also be deleted with the [del](https://docs.python.org/3/reference/simple_stmts.html#del) statement. For example, del modname.the\_answer will remove the attributethe\_answer from the object named by modname.

Namespaces are created at different moments and have different lifetimes. The namespace containing the built-in names is created when the Python interpreter starts up, and is never deleted. The global namespace for a module is created when the module definition is read in; normally, module namespaces also last until the interpreter quits. The statements executed by the top-level invocation of the interpreter, either read from a script file or interactively, are considered part of a module called[\_\_main\_\_](https://docs.python.org/3/library/__main__.html#module-__main__), so they have their own global namespace. (The built-in names actually also live in a module; this is called [builtins](https://docs.python.org/3/library/builtins.html#module-builtins).)

The local namespace for a function is created when the function is called, and deleted when the function returns or raises an exception that is not handled within the function. (Actually, forgetting would be a better way to describe what actually happens.) Of course, recursive invocations each have their own local namespace.

A scope is a textual region of a Python program where a namespace is directly accessible. “Directly accessible” here means that an unqualified reference to a name attempts to find the name in the namespace.

Although scopes are determined statically, they are used dynamically. At any time during execution, there are at least three nested scopes whose namespaces are directly accessible:

* the innermost scope, which is searched first, contains the local names
* the scopes of any enclosing functions, which are searched starting with the nearest enclosing scope, contains non-local, but also non-global names
* the next-to-last scope contains the current module’s global names
* the outermost scope (searched last) is the namespace containing built-in names

If a name is declared global, then all references and assignments go directly to the middle scope containing the module’s global names. To rebind variables found outside of the innermost scope, the[nonlocal](https://docs.python.org/3/reference/simple_stmts.html#nonlocal) statement can be used; if not declared nonlocal, those variables are read-only (an attempt to write to such a variable will simply create a new local variable in the innermost scope, leaving the identically named outer variable unchanged).

Usually, the local scope references the local names of the (textually) current function. Outside functions, the local scope references the same namespace as the global scope: the module’s namespace. Class definitions place yet another namespace in the local scope.

It is important to realize that scopes are determined textually: the global scope of a function defined in a module is that module’s namespace, no matter from where or by what alias the function is called. On the other hand, the actual search for names is done dynamically, at run time — however, the language definition is evolving towards static name resolution, at “compile” time, so don’t rely on dynamic name resolution! (In fact, local variables are already determined statically.)

A special quirk of Python is that – if no [global](https://docs.python.org/3/reference/simple_stmts.html#global) statement is in effect – assignments to names always go into the innermost scope. Assignments do not copy data — they just bind names to objects. The same is true for deletions: the statement del x removes the binding of x from the namespace referenced by the local scope. In fact, all operations that introduce new names use the local scope: in particular, [import](https://docs.python.org/3/reference/simple_stmts.html#import) statements and function definitions bind the module or function name in the local scope.

The [global](https://docs.python.org/3/reference/simple_stmts.html#global) statement can be used to indicate that particular variables live in the global scope and should be rebound there; the [nonlocal](https://docs.python.org/3/reference/simple_stmts.html#nonlocal) statement indicates that particular variables live in an enclosing scope and should be rebound there.

### 9.2.1. Scopes and Namespaces Example

This is an example demonstrating how to reference the different scopes and namespaces, and how[global](https://docs.python.org/3/reference/simple_stmts.html#global) and [nonlocal](https://docs.python.org/3/reference/simple_stmts.html#nonlocal) affect variable binding:

**def** scope\_test():

**def** do\_local():

spam = "local spam"

**def** do\_nonlocal():

**nonlocal** spam

spam = "nonlocal spam"

**def** do\_global():

**global** spam

spam = "global spam"

spam = "test spam"

do\_local()

print("After local assignment:", spam)

do\_nonlocal()

print("After nonlocal assignment:", spam)

do\_global()

print("After global assignment:", spam)

scope\_test()

print("In global scope:", spam)

The output of the example code is:

After local assignment: test spam

After nonlocal assignment: nonlocal spam

After global assignment: nonlocal spam

In global scope: global spam

Note how the local assignment (which is default) didn’t change scope\_test‘s binding of spam. The[nonlocal](https://docs.python.org/3/reference/simple_stmts.html#nonlocal) assignment changed scope\_test‘s binding of spam, and the [global](https://docs.python.org/3/reference/simple_stmts.html#global) assignment changed the module-level binding.

You can also see that there was no previous binding for spam before the [global](https://docs.python.org/3/reference/simple_stmts.html#global) assignment.

## 9.3. A First Look at Classes

Classes introduce a little bit of new syntax, three new object types, and some new semantics.

### 9.3.1. Class Definition Syntax

The simplest form of class definition looks like this:

**class** **ClassName**:

<statement-1>

.

.

.

<statement-N>

Class definitions, like function definitions ([def](https://docs.python.org/3/reference/compound_stmts.html#def) statements) must be executed before they have any effect. (You could conceivably place a class definition in a branch of an [if](https://docs.python.org/3/reference/compound_stmts.html#if) statement, or inside a function.)

In practice, the statements inside a class definition will usually be function definitions, but other statements are allowed, and sometimes useful — we’ll come back to this later. The function definitions inside a class normally have a peculiar form of argument list, dictated by the calling conventions for methods — again, this is explained later.

When a class definition is entered, a new namespace is created, and used as the local scope — thus, all assignments to local variables go into this new namespace. In particular, function definitions bind the name of the new function here.

When a class definition is left normally (via the end), a class object is created. This is basically a wrapper around the contents of the namespace created by the class definition; we’ll learn more about class objects in the next section. The original local scope (the one in effect just before the class definition was entered) is reinstated, and the class object is bound here to the class name given in the class definition header (ClassName in the example).

### 9.3.2. Class Objects

Class objects support two kinds of operations: attribute references and instantiation.

Attribute references use the standard syntax used for all attribute references in Python: obj.name. Valid attribute names are all the names that were in the class’s namespace when the class object was created. So, if the class definition looked like this:

**class** **MyClass**:

*"""A simple example class"""*

i = 12345

**def** f(self):

**return** 'hello world'

then MyClass.i and MyClass.f are valid attribute references, returning an integer and a function object, respectively. Class attributes can also be assigned to, so you can change the value ofMyClass.i by assignment. \_\_doc\_\_ is also a valid attribute, returning the docstring belonging to the class: "A simple example class".

Class instantiation uses function notation. Just pretend that the class object is a parameterless function that returns a new instance of the class. For example (assuming the above class):

x = MyClass()

creates a new instance of the class and assigns this object to the local variable x.

The instantiation operation (“calling” a class object) creates an empty object. Many classes like to create objects with instances customized to a specific initial state. Therefore a class may define a special method named [\_\_init\_\_()](https://docs.python.org/3/reference/datamodel.html#object.__init__), like this:

**def** \_\_init\_\_(self):

self.data = []

When a class defines an [\_\_init\_\_()](https://docs.python.org/3/reference/datamodel.html#object.__init__) method, class instantiation automatically invokes [\_\_init\_\_()](https://docs.python.org/3/reference/datamodel.html#object.__init__)for the newly-created class instance. So in this example, a new, initialized instance can be obtained by:

x = MyClass()

Of course, the [\_\_init\_\_()](https://docs.python.org/3/reference/datamodel.html#object.__init__) method may have arguments for greater flexibility. In that case, arguments given to the class instantiation operator are passed on to [\_\_init\_\_()](https://docs.python.org/3/reference/datamodel.html#object.__init__). For example,

>>>

**>>> class** **Complex**:

**...**  **def** \_\_init\_\_(self, realpart, imagpart):

**...**  self.r = realpart

**...**  self.i = imagpart

**...**

**>>>** x = Complex(3.0, -4.5)

**>>>** x.r, x.i

(3.0, -4.5)

### 9.3.3. Instance Objects

Now what can we do with instance objects? The only operations understood by instance objects are attribute references. There are two kinds of valid attribute names, data attributes and methods.

data attributes correspond to “instance variables” in Smalltalk, and to “data members” in C++. Data attributes need not be declared; like local variables, they spring into existence when they are first assigned to. For example, if x is the instance of MyClass created above, the following piece of code will print the value 16, without leaving a trace:

x.counter = 1

**while** x.counter < 10:

x.counter = x.counter \* 2

print(x.counter)

**del** x.counter

The other kind of instance attribute reference is a method. A method is a function that “belongs to” an object. (In Python, the term method is not unique to class instances: other object types can have methods as well. For example, list objects have methods called append, insert, remove, sort, and so on. However, in the following discussion, we’ll use the term method exclusively to mean methods of class instance objects, unless explicitly stated otherwise.)

Valid method names of an instance object depend on its class. By definition, all attributes of a class that are function objects define corresponding methods of its instances. So in our example, x.f is a valid method reference, since MyClass.f is a function, but x.i is not, since MyClass.i is not. But x.fis not the same thing as MyClass.f — it is a method object, not a function object.

### 9.3.4. Method Objects

Usually, a method is called right after it is bound:

x.f()

In the MyClass example, this will return the string 'hello world'. However, it is not necessary to call a method right away: x.f is a method object, and can be stored away and called at a later time. For example:

xf = x.f

**while** **True**:

print(xf())

will continue to print hello world until the end of time.

What exactly happens when a method is called? You may have noticed that x.f() was called without an argument above, even though the function definition for f() specified an argument. What happened to the argument? Surely Python raises an exception when a function that requires an argument is called without any — even if the argument isn’t actually used...

Actually, you may have guessed the answer: the special thing about methods is that the object is passed as the first argument of the function. In our example, the call x.f() is exactly equivalent toMyClass.f(x). In general, calling a method with a list of n arguments is equivalent to calling the corresponding function with an argument list that is created by inserting the method’s object before the first argument.

If you still don’t understand how methods work, a look at the implementation can perhaps clarify matters. When an instance attribute is referenced that isn’t a data attribute, its class is searched. If the name denotes a valid class attribute that is a function object, a method object is created by packing (pointers to) the instance object and the function object just found together in an abstract object: this is the method object. When the method object is called with an argument list, a new argument list is constructed from the instance object and the argument list, and the function object is called with this new argument list.

### 9.3.5. Class and Instance Variables

Generally speaking, instance variables are for data unique to each instance and class variables are for attributes and methods shared by all instances of the class:

**class** **Dog**:

kind = 'canine' *# class variable shared by all instances*

**def** \_\_init\_\_(self, name):

self.name = name *# instance variable unique to each instance*

>>> d = Dog('Fido')

>>> e = Dog('Buddy')

>>> d.kind *# shared by all dogs*

'canine'

>>> e.kind *# shared by all dogs*

'canine'

>>> d.name *# unique to d*

'Fido'

>>> e.name *# unique to e*

'Buddy'

As discussed in [A Word About Names and Objects](https://docs.python.org/3/tutorial/classes.html#tut-object), shared data can have possibly surprising effects with involving [mutable](https://docs.python.org/3/glossary.html#term-mutable) objects such as lists and dictionaries. For example, the tricks list in the following code should not be used as a class variable because just a single list would be shared by all Doginstances:

**class** **Dog**:

tricks = [] *# mistaken use of a class variable*

**def** \_\_init\_\_(self, name):

self.name = name

**def** add\_trick(self, trick):

self.tricks.append(trick)

>>> d = Dog('Fido')

>>> e = Dog('Buddy')

>>> d.add\_trick('roll over')

>>> e.add\_trick('play dead')

>>> d.tricks *# unexpectedly shared by all dogs*

['roll over', 'play dead']

Correct design of the class should use an instance variable instead:

**class** **Dog**:

**def** \_\_init\_\_(self, name):

self.name = name

self.tricks = [] *# creates a new empty list for each dog*

**def** add\_trick(self, trick):

self.tricks.append(trick)

>>> d = Dog('Fido')

>>> e = Dog('Buddy')

>>> d.add\_trick('roll over')

>>> e.add\_trick('play dead')

>>> d.tricks

['roll over']

>>> e.tricks

['play dead']

## 9.4. Random Remarks

Data attributes override method attributes with the same name; to avoid accidental name conflicts, which may cause hard-to-find bugs in large programs, it is wise to use some kind of convention that minimizes the chance of conflicts. Possible conventions include capitalizing method names, prefixing data attribute names with a small unique string (perhaps just an underscore), or using verbs for methods and nouns for data attributes.

Data attributes may be referenced by methods as well as by ordinary users (“clients”) of an object. In other words, classes are not usable to implement pure abstract data types. In fact, nothing in Python makes it possible to enforce data hiding — it is all based upon convention. (On the other hand, the Python implementation, written in C, can completely hide implementation details and control access to an object if necessary; this can be used by extensions to Python written in C.)

Clients should use data attributes with care — clients may mess up invariants maintained by the methods by stamping on their data attributes. Note that clients may add data attributes of their own to an instance object without affecting the validity of the methods, as long as name conflicts are avoided — again, a naming convention can save a lot of headaches here.

There is no shorthand for referencing data attributes (or other methods!) from within methods. I find that this actually increases the readability of methods: there is no chance of confusing local variables and instance variables when glancing through a method.

Often, the first argument of a method is called self. This is nothing more than a convention: the nameself has absolutely no special meaning to Python. Note, however, that by not following the convention your code may be less readable to other Python programmers, and it is also conceivable that a class browser program might be written that relies upon such a convention.

Any function object that is a class attribute defines a method for instances of that class. It is not necessary that the function definition is textually enclosed in the class definition: assigning a function object to a local variable in the class is also ok. For example:

*# Function defined outside the class*

**def** f1(self, x, y):

**return** min(x, x+y)

**class** **C**:

f = f1

**def** g(self):

**return** 'hello world'

h = g

Now f, g and h are all attributes of class C that refer to function objects, and consequently they are all methods of instances of C — h being exactly equivalent to g. Note that this practice usually only serves to confuse the reader of a program.

Methods may call other methods by using method attributes of the self argument:

**class** **Bag**:

**def** \_\_init\_\_(self):

self.data = []

**def** add(self, x):

self.data.append(x)

**def** addtwice(self, x):

self.add(x)

self.add(x)

Methods may reference global names in the same way as ordinary functions. The global scope associated with a method is the module containing its definition. (A class is never used as a global scope.) While one rarely encounters a good reason for using global data in a method, there are many legitimate uses of the global scope: for one thing, functions and modules imported into the global scope can be used by methods, as well as functions and classes defined in it. Usually, the class containing the method is itself defined in this global scope, and in the next section we’ll find some good reasons why a method would want to reference its own class.

Each value is an object, and therefore has a class (also called its type). It is stored asobject.\_\_class\_\_.

## 9.5. Inheritance

Of course, a language feature would not be worthy of the name “class” without supporting inheritance. The syntax for a derived class definition looks like this:

**class** **DerivedClassName**(BaseClassName):

<statement-1>

.

.

.

<statement-N>

The name BaseClassName must be defined in a scope containing the derived class definition. In place of a base class name, other arbitrary expressions are also allowed. This can be useful, for example, when the base class is defined in another module:

**class** **DerivedClassName**(modname.BaseClassName):

Execution of a derived class definition proceeds the same as for a base class. When the class object is constructed, the base class is remembered. This is used for resolving attribute references: if a requested attribute is not found in the class, the search proceeds to look in the base class. This rule is applied recursively if the base class itself is derived from some other class.

There’s nothing special about instantiation of derived classes: DerivedClassName() creates a new instance of the class. Method references are resolved as follows: the corresponding class attribute is searched, descending down the chain of base classes if necessary, and the method reference is valid if this yields a function object.

Derived classes may override methods of their base classes. Because methods have no special privileges when calling other methods of the same object, a method of a base class that calls another method defined in the same base class may end up calling a method of a derived class that overrides it. (For C++ programmers: all methods in Python are effectively virtual.)

An overriding method in a derived class may in fact want to extend rather than simply replace the base class method of the same name. There is a simple way to call the base class method directly: just callBaseClassName.methodname(self, arguments). This is occasionally useful to clients as well. (Note that this only works if the base class is accessible as BaseClassName in the global scope.)

Python has two built-in functions that work with inheritance:

* Use [isinstance()](https://docs.python.org/3/library/functions.html#isinstance) to check an instance’s type: isinstance(obj, int) will be True only ifobj.\_\_class\_\_ is [int](https://docs.python.org/3/library/functions.html#int) or some class derived from [int](https://docs.python.org/3/library/functions.html#int).
* Use [issubclass()](https://docs.python.org/3/library/functions.html#issubclass) to check class inheritance: issubclass(bool, int) is True since [bool](https://docs.python.org/3/library/functions.html#bool) is a subclass of [int](https://docs.python.org/3/library/functions.html#int). However, issubclass(float, int) is False since [float](https://docs.python.org/3/library/functions.html#float) is not a subclass of[int](https://docs.python.org/3/library/functions.html#int).

### 9.5.1. Multiple Inheritance

Python supports a form of multiple inheritance as well. A class definition with multiple base classes looks like this:

**class** **DerivedClassName**(Base1, Base2, Base3):

<statement-1>

.

.

.

<statement-N>

For most purposes, in the simplest cases, you can think of the search for attributes inherited from a parent class as depth-first, left-to-right, not searching twice in the same class where there is an overlap in the hierarchy. Thus, if an attribute is not found in DerivedClassName, it is searched for inBase1, then (recursively) in the base classes of Base1, and if it was not found there, it was searched for in Base2, and so on.

In fact, it is slightly more complex than that; the method resolution order changes dynamically to support cooperative calls to [super()](https://docs.python.org/3/library/functions.html#super). This approach is known in some other multiple-inheritance languages as call-next-method and is more powerful than the super call found in single-inheritance languages.

Dynamic ordering is necessary because all cases of multiple inheritance exhibit one or more diamond relationships (where at least one of the parent classes can be accessed through multiple paths from the bottommost class). For example, all classes inherit from [object](https://docs.python.org/3/library/functions.html#object), so any case of multiple inheritance provides more than one path to reach [object](https://docs.python.org/3/library/functions.html#object). To keep the base classes from being accessed more than once, the dynamic algorithm linearizes the search order in a way that preserves the left-to-right ordering specified in each class, that calls each parent only once, and that is monotonic (meaning that a class can be subclassed without affecting the precedence order of its parents). Taken together, these properties make it possible to design reliable and extensible classes with multiple inheritance. For more detail, see <https://www.python.org/download/releases/2.3/mro/>.

## 9.6. Private Variables

“Private” instance variables that cannot be accessed except from inside an object don’t exist in Python. However, there is a convention that is followed by most Python code: a name prefixed with an underscore (e.g. \_spam) should be treated as a non-public part of the API (whether it is a function, a method or a data member). It should be considered an implementation detail and subject to change without notice.

Since there is a valid use-case for class-private members (namely to avoid name clashes of names with names defined by subclasses), there is limited support for such a mechanism, called name mangling. Any identifier of the form \_\_spam (at least two leading underscores, at most one trailing underscore) is textually replaced with \_classname\_\_spam, where classname is the current class name with leading underscore(s) stripped. This mangling is done without regard to the syntactic position of the identifier, as long as it occurs within the definition of a class.

Name mangling is helpful for letting subclasses override methods without breaking intraclass method calls. For example:

**class** **Mapping**:

**def** \_\_init\_\_(self, iterable):

self.items\_list = []

self.\_\_update(iterable)

**def** update(self, iterable):

**for** item **in** iterable:

self.items\_list.append(item)

\_\_update = update *# private copy of original update() method*

**class** **MappingSubclass**(Mapping):

**def** update(self, keys, values):

*# provides new signature for update()*

*# but does not break \_\_init\_\_()*

**for** item **in** zip(keys, values):

self.items\_list.append(item)

Note that the mangling rules are designed mostly to avoid accidents; it still is possible to access or modify a variable that is considered private. This can even be useful in special circumstances, such as in the debugger.

Notice that code passed to exec() or eval() does not consider the classname of the invoking class to be the current class; this is similar to the effect of the global statement, the effect of which is likewise restricted to code that is byte-compiled together. The same restriction applies to getattr(),setattr() and delattr(), as well as when referencing \_\_dict\_\_ directly.

## 9.7. Odds and Ends

Sometimes it is useful to have a data type similar to the Pascal “record” or C “struct”, bundling together a few named data items. An empty class definition will do nicely:

**class** **Employee**:

**pass**

john = Employee() *# Create an empty employee record*

*# Fill the fields of the record*

john.name = 'John Doe'

john.dept = 'computer lab'

john.salary = 1000

A piece of Python code that expects a particular abstract data type can often be passed a class that emulates the methods of that data type instead. For instance, if you have a function that formats some data from a file object, you can define a class with methods read() and readline() that get the data from a string buffer instead, and pass it as an argument.

Instance method objects have attributes, too: m.\_\_self\_\_ is the instance object with the method m(), and m.\_\_func\_\_ is the function object corresponding to the method.

## 9.8. Exceptions Are Classes Too

User-defined exceptions are identified by classes as well. Using this mechanism it is possible to create extensible hierarchies of exceptions.

There are two new valid (semantic) forms for the [raise](https://docs.python.org/3/reference/simple_stmts.html#raise) statement:

**raise** Class

**raise** Instance

In the first form, Class must be an instance of [type](https://docs.python.org/3/library/functions.html#type) or of a class derived from it. The first form is a shorthand for:

**raise** Class()

A class in an [except](https://docs.python.org/3/reference/compound_stmts.html#except) clause is compatible with an exception if it is the same class or a base class thereof (but not the other way around — an except clause listing a derived class is not compatible with a base class). For example, the following code will print B, C, D in that order:

**class** **B**(Exception):

**pass**

**class** **C**(B):

**pass**

**class** **D**(C):

**pass**

**for** cls **in** [B, C, D]:

**try**:

**raise** cls()

**except** D:

print("D")

**except** C:

print("C")

**except** B:

print("B")

Note that if the except clauses were reversed (with except B first), it would have printed B, B, B — the first matching except clause is triggered.

When an error message is printed for an unhandled exception, the exception’s class name is printed, then a colon and a space, and finally the instance converted to a string using the built-in function[str()](https://docs.python.org/3/library/stdtypes.html#str).

## 9.9. Iterators

By now you have probably noticed that most container objects can be looped over using a [for](https://docs.python.org/3/reference/compound_stmts.html#for)statement:

**for** element **in** [1, 2, 3]:

print(element)

**for** element **in** (1, 2, 3):

print(element)

**for** key **in** {'one':1, 'two':2}:

print(key)

**for** char **in** "123":

print(char)

**for** line **in** open("myfile.txt"):

print(line, end='')

This style of access is clear, concise, and convenient. The use of iterators pervades and unifies Python. Behind the scenes, the [for](https://docs.python.org/3/reference/compound_stmts.html#for) statement calls [iter()](https://docs.python.org/3/library/functions.html#iter) on the container object. The function returns an iterator object that defines the method [\_\_next\_\_()](https://docs.python.org/3/library/stdtypes.html#iterator.__next__) which accesses elements in the container one at a time. When there are no more elements, [\_\_next\_\_()](https://docs.python.org/3/library/stdtypes.html#iterator.__next__) raises a [StopIteration](https://docs.python.org/3/library/exceptions.html#StopIteration)exception which tells the [for](https://docs.python.org/3/reference/compound_stmts.html#for) loop to terminate. You can call the [\_\_next\_\_()](https://docs.python.org/3/library/stdtypes.html#iterator.__next__) method using the[next()](https://docs.python.org/3/library/functions.html#next) built-in function; this example shows how it all works:

>>>

**>>>** s = 'abc'

**>>>** it = iter(s)

**>>>** it

<iterator object at 0x00A1DB50>

**>>>** next(it)

'a'

**>>>** next(it)

'b'

**>>>** next(it)

'c'

**>>>** next(it)

Traceback (most recent call last):

File "<stdin>", line 1, in ?

next(it)

StopIteration

Having seen the mechanics behind the iterator protocol, it is easy to add iterator behavior to your classes. Define an [\_\_iter\_\_()](https://docs.python.org/3/reference/datamodel.html#object.__iter__) method which returns an object with a [\_\_next\_\_()](https://docs.python.org/3/library/stdtypes.html#iterator.__next__) method. If the class defines \_\_next\_\_(), then [\_\_iter\_\_()](https://docs.python.org/3/reference/datamodel.html#object.__iter__) can just return self:

**class** **Reverse**:

*"""Iterator for looping over a sequence backwards."""*

**def** \_\_init\_\_(self, data):

self.data = data

self.index = len(data)

**def** \_\_iter\_\_(self):

**return** self

**def** \_\_next\_\_(self):

**if** self.index == 0:

**raise** StopIteration

self.index = self.index - 1

**return** self.data[self.index]

>>>

**>>>** rev = Reverse('spam')

**>>>** iter(rev)

<\_\_main\_\_.Reverse object at 0x00A1DB50>

**>>> for** char **in** rev:

**...**  print(char)

**...**

m

a

p

s

## 9.10. Generators

[Generator](https://docs.python.org/3/glossary.html#term-generator)s are a simple and powerful tool for creating iterators. They are written like regular functions but use the [yield](https://docs.python.org/3/reference/simple_stmts.html#yield) statement whenever they want to return data. Each time [next()](https://docs.python.org/3/library/functions.html#next) is called on it, the generator resumes where it left off (it remembers all the data values and which statement was last executed). An example shows that generators can be trivially easy to create:

**def** reverse(data):

**for** index **in** range(len(data)-1, -1, -1):

**yield** data[index]

>>>

**>>> for** char **in** reverse('golf'):

**...**  print(char)

**...**

f

l

o

g

Anything that can be done with generators can also be done with class-based iterators as described in the previous section. What makes generators so compact is that the [\_\_iter\_\_()](https://docs.python.org/3/reference/datamodel.html#object.__iter__) and [\_\_next\_\_()](https://docs.python.org/3/reference/expressions.html#generator.__next__)methods are created automatically.

Another key feature is that the local variables and execution state are automatically saved between calls. This made the function easier to write and much more clear than an approach using instance variables like self.index and self.data.

In addition to automatic method creation and saving program state, when generators terminate, they automatically raise [StopIteration](https://docs.python.org/3/library/exceptions.html#StopIteration). In combination, these features make it easy to create iterators with no more effort than writing a regular function.

## 9.11. Generator Expressions

Some simple generators can be coded succinctly as expressions using a syntax similar to list comprehensions but with parentheses instead of brackets. These expressions are designed for situations where the generator is used right away by an enclosing function. Generator expressions are more compact but less versatile than full generator definitions and tend to be more memory friendly than equivalent list comprehensions.

Examples:

>>>

**>>>** sum(i\*i **for** i **in** range(10)) *# sum of squares*

285

**>>>** xvec = [10, 20, 30]

**>>>** yvec = [7, 5, 3]

**>>>** sum(x\*y **for** x,y **in** zip(xvec, yvec)) *# dot product*

260

**>>> from** **math** **import** pi, sin

**>>>** sine\_table = {x: sin(x\*pi/180) **for** x **in** range(0, 91)}

**>>>** unique\_words = set(word **for** line **in** page **for** word **in** line.split())

**>>>** valedictorian = max((student.gpa, student.name) **for** student **in** graduates)

**>>>** data = 'golf'

**>>>** list(data[i] **for** i **in** range(len(data)-1, -1, -1))

['f', 'l', 'o', 'g']

**Footnotes**

|  |  |
| --- | --- |
| [[1]](https://docs.python.org/3/tutorial/classes.html#id1) | Except for one thing. Module objects have a secret read-only attribute called [\_\_dict\_\_](https://docs.python.org/3/library/stdtypes.html#object.__dict__) which returns the dictionary used to implement the module’s namespace; the name [\_\_dict\_\_](https://docs.python.org/3/library/stdtypes.html#object.__dict__) is an attribute but not a global name. Obviously, using this violates the abstraction of namespace implementation, and should be restricted to things like post-mortem debuggers. |

# 9. Classes

Compared with other programming languages, Python’s class mechanism adds classes with a minimum of new syntax and semantics. It is a mixture of the class mechanisms found in C++ and Modula-3. Python classes provide all the standard features of Object Oriented Programming: the class inheritance mechanism allows multiple base classes, a derived class can override any methods of its base class or classes, and a method can call the method of a base class with the same name. Objects can contain arbitrary amounts and kinds of data. As is true for modules, classes partake of the dynamic nature of Python: they are created at runtime, and can be modified further after creation.

In C++ terminology, normally class members (including the data members) are public (except see below [Private Variables](https://docs.python.org/3/tutorial/classes.html#tut-private)), and all member functions are virtual. As in Modula-3, there are no shorthands for referencing the object’s members from its methods: the method function is declared with an explicit first argument representing the object, which is provided implicitly by the call. As in Smalltalk, classes themselves are objects. This provides semantics for importing and renaming. Unlike C++ and Modula-3, built-in types can be used as base classes for extension by the user. Also, like in C++, most built-in operators with special syntax (arithmetic operators, subscripting etc.) can be redefined for class instances.

(Lacking universally accepted terminology to talk about classes, I will make occasional use of Smalltalk and C++ terms. I would use Modula-3 terms, since its object-oriented semantics are closer to those of Python than C++, but I expect that few readers have heard of it.)

## 9.1. A Word About Names and Objects

Objects have individuality, and multiple names (in multiple scopes) can be bound to the same object. This is known as aliasing in other languages. This is usually not appreciated on a first glance at Python, and can be safely ignored when dealing with immutable basic types (numbers, strings, tuples). However, aliasing has a possibly surprising effect on the semantics of Python code involving mutable objects such as lists, dictionaries, and most other types. This is usually used to the benefit of the program, since aliases behave like pointers in some respects. For example, passing an object is cheap since only a pointer is passed by the implementation; and if a function modifies an object passed as an argument, the caller will see the change — this eliminates the need for two different argument passing mechanisms as in Pascal.

## 9.2. Python Scopes and Namespaces

Before introducing classes, I first have to tell you something about Python’s scope rules. Class definitions play some neat tricks with namespaces, and you need to know how scopes and namespaces work to fully understand what’s going on. Incidentally, knowledge about this subject is useful for any advanced Python programmer.

Let’s begin with some definitions.

A namespace is a mapping from names to objects. Most namespaces are currently implemented as Python dictionaries, but that’s normally not noticeable in any way (except for performance), and it may change in the future. Examples of namespaces are: the set of built-in names (containing functions such as [abs()](https://docs.python.org/3/library/functions.html#abs), and built-in exception names); the global names in a module; and the local names in a function invocation. In a sense the set of attributes of an object also form a namespace. The important thing to know about namespaces is that there is absolutely no relation between names in different namespaces; for instance, two different modules may both define a function maximize without confusion — users of the modules must prefix it with the module name.

By the way, I use the word attribute for any name following a dot — for example, in the expressionz.real, real is an attribute of the object z. Strictly speaking, references to names in modules are attribute references: in the expression modname.funcname, modname is a module object and funcnameis an attribute of it. In this case there happens to be a straightforward mapping between the module’s attributes and the global names defined in the module: they share the same namespace! [[1]](https://docs.python.org/3/tutorial/classes.html#id2)

Attributes may be read-only or writable. In the latter case, assignment to attributes is possible. Module attributes are writable: you can write modname.the\_answer = 42. Writable attributes may also be deleted with the [del](https://docs.python.org/3/reference/simple_stmts.html#del) statement. For example, del modname.the\_answer will remove the attributethe\_answer from the object named by modname.

Namespaces are created at different moments and have different lifetimes. The namespace containing the built-in names is created when the Python interpreter starts up, and is never deleted. The global namespace for a module is created when the module definition is read in; normally, module namespaces also last until the interpreter quits. The statements executed by the top-level invocation of the interpreter, either read from a script file or interactively, are considered part of a module called[\_\_main\_\_](https://docs.python.org/3/library/__main__.html#module-__main__), so they have their own global namespace. (The built-in names actually also live in a module; this is called [builtins](https://docs.python.org/3/library/builtins.html#module-builtins).)

The local namespace for a function is created when the function is called, and deleted when the function returns or raises an exception that is not handled within the function. (Actually, forgetting would be a better way to describe what actually happens.) Of course, recursive invocations each have their own local namespace.

A scope is a textual region of a Python program where a namespace is directly accessible. “Directly accessible” here means that an unqualified reference to a name attempts to find the name in the namespace.

Although scopes are determined statically, they are used dynamically. At any time during execution, there are at least three nested scopes whose namespaces are directly accessible:

* the innermost scope, which is searched first, contains the local names
* the scopes of any enclosing functions, which are searched starting with the nearest enclosing scope, contains non-local, but also non-global names
* the next-to-last scope contains the current module’s global names
* the outermost scope (searched last) is the namespace containing built-in names

If a name is declared global, then all references and assignments go directly to the middle scope containing the module’s global names. To rebind variables found outside of the innermost scope, the[nonlocal](https://docs.python.org/3/reference/simple_stmts.html#nonlocal) statement can be used; if not declared nonlocal, those variables are read-only (an attempt to write to such a variable will simply create a new local variable in the innermost scope, leaving the identically named outer variable unchanged).

Usually, the local scope references the local names of the (textually) current function. Outside functions, the local scope references the same namespace as the global scope: the module’s namespace. Class definitions place yet another namespace in the local scope.

It is important to realize that scopes are determined textually: the global scope of a function defined in a module is that module’s namespace, no matter from where or by what alias the function is called. On the other hand, the actual search for names is done dynamically, at run time — however, the language definition is evolving towards static name resolution, at “compile” time, so don’t rely on dynamic name resolution! (In fact, local variables are already determined statically.)

A special quirk of Python is that – if no [global](https://docs.python.org/3/reference/simple_stmts.html#global) statement is in effect – assignments to names always go into the innermost scope. Assignments do not copy data — they just bind names to objects. The same is true for deletions: the statement del x removes the binding of x from the namespace referenced by the local scope. In fact, all operations that introduce new names use the local scope: in particular, [import](https://docs.python.org/3/reference/simple_stmts.html#import) statements and function definitions bind the module or function name in the local scope.

The [global](https://docs.python.org/3/reference/simple_stmts.html#global) statement can be used to indicate that particular variables live in the global scope and should be rebound there; the [nonlocal](https://docs.python.org/3/reference/simple_stmts.html#nonlocal) statement indicates that particular variables live in an enclosing scope and should be rebound there.

### 9.2.1. Scopes and Namespaces Example

This is an example demonstrating how to reference the different scopes and namespaces, and how[global](https://docs.python.org/3/reference/simple_stmts.html#global) and [nonlocal](https://docs.python.org/3/reference/simple_stmts.html#nonlocal) affect variable binding:

**def** scope\_test():

**def** do\_local():

spam = "local spam"

**def** do\_nonlocal():

**nonlocal** spam

spam = "nonlocal spam"

**def** do\_global():

**global** spam

spam = "global spam"

spam = "test spam"

do\_local()

print("After local assignment:", spam)

do\_nonlocal()

print("After nonlocal assignment:", spam)

do\_global()

print("After global assignment:", spam)

scope\_test()

print("In global scope:", spam)

The output of the example code is:

After local assignment: test spam

After nonlocal assignment: nonlocal spam

After global assignment: nonlocal spam

In global scope: global spam

Note how the local assignment (which is default) didn’t change scope\_test‘s binding of spam. The[nonlocal](https://docs.python.org/3/reference/simple_stmts.html#nonlocal) assignment changed scope\_test‘s binding of spam, and the [global](https://docs.python.org/3/reference/simple_stmts.html#global) assignment changed the module-level binding.

You can also see that there was no previous binding for spam before the [global](https://docs.python.org/3/reference/simple_stmts.html#global) assignment.

## 9.3. A First Look at Classes

Classes introduce a little bit of new syntax, three new object types, and some new semantics.

### 9.3.1. Class Definition Syntax

The simplest form of class definition looks like this:

**class** **ClassName**:

<statement-1>

.

.

.

<statement-N>

Class definitions, like function definitions ([def](https://docs.python.org/3/reference/compound_stmts.html#def) statements) must be executed before they have any effect. (You could conceivably place a class definition in a branch of an [if](https://docs.python.org/3/reference/compound_stmts.html#if) statement, or inside a function.)

In practice, the statements inside a class definition will usually be function definitions, but other statements are allowed, and sometimes useful — we’ll come back to this later. The function definitions inside a class normally have a peculiar form of argument list, dictated by the calling conventions for methods — again, this is explained later.

When a class definition is entered, a new namespace is created, and used as the local scope — thus, all assignments to local variables go into this new namespace. In particular, function definitions bind the name of the new function here.

When a class definition is left normally (via the end), a class object is created. This is basically a wrapper around the contents of the namespace created by the class definition; we’ll learn more about class objects in the next section. The original local scope (the one in effect just before the class definition was entered) is reinstated, and the class object is bound here to the class name given in the class definition header (ClassName in the example).

### 9.3.2. Class Objects

Class objects support two kinds of operations: attribute references and instantiation.

Attribute references use the standard syntax used for all attribute references in Python: obj.name. Valid attribute names are all the names that were in the class’s namespace when the class object was created. So, if the class definition looked like this:

**class** **MyClass**:

*"""A simple example class"""*

i = 12345

**def** f(self):

**return** 'hello world'

then MyClass.i and MyClass.f are valid attribute references, returning an integer and a function object, respectively. Class attributes can also be assigned to, so you can change the value ofMyClass.i by assignment. \_\_doc\_\_ is also a valid attribute, returning the docstring belonging to the class: "A simple example class".

Class instantiation uses function notation. Just pretend that the class object is a parameterless function that returns a new instance of the class. For example (assuming the above class):

x = MyClass()

creates a new instance of the class and assigns this object to the local variable x.

The instantiation operation (“calling” a class object) creates an empty object. Many classes like to create objects with instances customized to a specific initial state. Therefore a class may define a special method named [\_\_init\_\_()](https://docs.python.org/3/reference/datamodel.html#object.__init__), like this:

**def** \_\_init\_\_(self):

self.data = []

When a class defines an [\_\_init\_\_()](https://docs.python.org/3/reference/datamodel.html#object.__init__) method, class instantiation automatically invokes [\_\_init\_\_()](https://docs.python.org/3/reference/datamodel.html#object.__init__)for the newly-created class instance. So in this example, a new, initialized instance can be obtained by:

x = MyClass()

Of course, the [\_\_init\_\_()](https://docs.python.org/3/reference/datamodel.html#object.__init__) method may have arguments for greater flexibility. In that case, arguments given to the class instantiation operator are passed on to [\_\_init\_\_()](https://docs.python.org/3/reference/datamodel.html#object.__init__). For example,

>>>

**>>> class** **Complex**:

**...**  **def** \_\_init\_\_(self, realpart, imagpart):

**...**  self.r = realpart

**...**  self.i = imagpart

**...**

**>>>** x = Complex(3.0, -4.5)

**>>>** x.r, x.i

(3.0, -4.5)

### 9.3.3. Instance Objects

Now what can we do with instance objects? The only operations understood by instance objects are attribute references. There are two kinds of valid attribute names, data attributes and methods.

data attributes correspond to “instance variables” in Smalltalk, and to “data members” in C++. Data attributes need not be declared; like local variables, they spring into existence when they are first assigned to. For example, if x is the instance of MyClass created above, the following piece of code will print the value 16, without leaving a trace:

x.counter = 1

**while** x.counter < 10:

x.counter = x.counter \* 2

print(x.counter)

**del** x.counter

The other kind of instance attribute reference is a method. A method is a function that “belongs to” an object. (In Python, the term method is not unique to class instances: other object types can have methods as well. For example, list objects have methods called append, insert, remove, sort, and so on. However, in the following discussion, we’ll use the term method exclusively to mean methods of class instance objects, unless explicitly stated otherwise.)

Valid method names of an instance object depend on its class. By definition, all attributes of a class that are function objects define corresponding methods of its instances. So in our example, x.f is a valid method reference, since MyClass.f is a function, but x.i is not, since MyClass.i is not. But x.fis not the same thing as MyClass.f — it is a method object, not a function object.

### 9.3.4. Method Objects

Usually, a method is called right after it is bound:

x.f()

In the MyClass example, this will return the string 'hello world'. However, it is not necessary to call a method right away: x.f is a method object, and can be stored away and called at a later time. For example:

xf = x.f

**while** **True**:

print(xf())

will continue to print hello world until the end of time.

What exactly happens when a method is called? You may have noticed that x.f() was called without an argument above, even though the function definition for f() specified an argument. What happened to the argument? Surely Python raises an exception when a function that requires an argument is called without any — even if the argument isn’t actually used...

Actually, you may have guessed the answer: the special thing about methods is that the object is passed as the first argument of the function. In our example, the call x.f() is exactly equivalent toMyClass.f(x). In general, calling a method with a list of n arguments is equivalent to calling the corresponding function with an argument list that is created by inserting the method’s object before the first argument.

If you still don’t understand how methods work, a look at the implementation can perhaps clarify matters. When an instance attribute is referenced that isn’t a data attribute, its class is searched. If the name denotes a valid class attribute that is a function object, a method object is created by packing (pointers to) the instance object and the function object just found together in an abstract object: this is the method object. When the method object is called with an argument list, a new argument list is constructed from the instance object and the argument list, and the function object is called with this new argument list.

### 9.3.5. Class and Instance Variables

Generally speaking, instance variables are for data unique to each instance and class variables are for attributes and methods shared by all instances of the class:

**class** **Dog**:

kind = 'canine' *# class variable shared by all instances*

**def** \_\_init\_\_(self, name):

self.name = name *# instance variable unique to each instance*

>>> d = Dog('Fido')

>>> e = Dog('Buddy')

>>> d.kind *# shared by all dogs*

'canine'

>>> e.kind *# shared by all dogs*

'canine'

>>> d.name *# unique to d*

'Fido'

>>> e.name *# unique to e*

'Buddy'

As discussed in [A Word About Names and Objects](https://docs.python.org/3/tutorial/classes.html#tut-object), shared data can have possibly surprising effects with involving [mutable](https://docs.python.org/3/glossary.html#term-mutable) objects such as lists and dictionaries. For example, the tricks list in the following code should not be used as a class variable because just a single list would be shared by all Doginstances:

**class** **Dog**:

tricks = [] *# mistaken use of a class variable*

**def** \_\_init\_\_(self, name):

self.name = name

**def** add\_trick(self, trick):

self.tricks.append(trick)

>>> d = Dog('Fido')

>>> e = Dog('Buddy')

>>> d.add\_trick('roll over')

>>> e.add\_trick('play dead')

>>> d.tricks *# unexpectedly shared by all dogs*

['roll over', 'play dead']

Correct design of the class should use an instance variable instead:

**class** **Dog**:

**def** \_\_init\_\_(self, name):

self.name = name

self.tricks = [] *# creates a new empty list for each dog*

**def** add\_trick(self, trick):

self.tricks.append(trick)

>>> d = Dog('Fido')

>>> e = Dog('Buddy')

>>> d.add\_trick('roll over')

>>> e.add\_trick('play dead')

>>> d.tricks

['roll over']

>>> e.tricks

['play dead']

## 9.4. Random Remarks

Data attributes override method attributes with the same name; to avoid accidental name conflicts, which may cause hard-to-find bugs in large programs, it is wise to use some kind of convention that minimizes the chance of conflicts. Possible conventions include capitalizing method names, prefixing data attribute names with a small unique string (perhaps just an underscore), or using verbs for methods and nouns for data attributes.

Data attributes may be referenced by methods as well as by ordinary users (“clients”) of an object. In other words, classes are not usable to implement pure abstract data types. In fact, nothing in Python makes it possible to enforce data hiding — it is all based upon convention. (On the other hand, the Python implementation, written in C, can completely hide implementation details and control access to an object if necessary; this can be used by extensions to Python written in C.)

Clients should use data attributes with care — clients may mess up invariants maintained by the methods by stamping on their data attributes. Note that clients may add data attributes of their own to an instance object without affecting the validity of the methods, as long as name conflicts are avoided — again, a naming convention can save a lot of headaches here.

There is no shorthand for referencing data attributes (or other methods!) from within methods. I find that this actually increases the readability of methods: there is no chance of confusing local variables and instance variables when glancing through a method.

Often, the first argument of a method is called self. This is nothing more than a convention: the nameself has absolutely no special meaning to Python. Note, however, that by not following the convention your code may be less readable to other Python programmers, and it is also conceivable that a class browser program might be written that relies upon such a convention.

Any function object that is a class attribute defines a method for instances of that class. It is not necessary that the function definition is textually enclosed in the class definition: assigning a function object to a local variable in the class is also ok. For example:

*# Function defined outside the class*

**def** f1(self, x, y):

**return** min(x, x+y)

**class** **C**:

f = f1

**def** g(self):

**return** 'hello world'

h = g

Now f, g and h are all attributes of class C that refer to function objects, and consequently they are all methods of instances of C — h being exactly equivalent to g. Note that this practice usually only serves to confuse the reader of a program.

Methods may call other methods by using method attributes of the self argument:

**class** **Bag**:

**def** \_\_init\_\_(self):

self.data = []

**def** add(self, x):

self.data.append(x)

**def** addtwice(self, x):

self.add(x)

self.add(x)

Methods may reference global names in the same way as ordinary functions. The global scope associated with a method is the module containing its definition. (A class is never used as a global scope.) While one rarely encounters a good reason for using global data in a method, there are many legitimate uses of the global scope: for one thing, functions and modules imported into the global scope can be used by methods, as well as functions and classes defined in it. Usually, the class containing the method is itself defined in this global scope, and in the next section we’ll find some good reasons why a method would want to reference its own class.

Each value is an object, and therefore has a class (also called its type). It is stored asobject.\_\_class\_\_.

## 9.5. Inheritance

Of course, a language feature would not be worthy of the name “class” without supporting inheritance. The syntax for a derived class definition looks like this:

**class** **DerivedClassName**(BaseClassName):

<statement-1>

.

.

.

<statement-N>

The name BaseClassName must be defined in a scope containing the derived class definition. In place of a base class name, other arbitrary expressions are also allowed. This can be useful, for example, when the base class is defined in another module:

**class** **DerivedClassName**(modname.BaseClassName):

Execution of a derived class definition proceeds the same as for a base class. When the class object is constructed, the base class is remembered. This is used for resolving attribute references: if a requested attribute is not found in the class, the search proceeds to look in the base class. This rule is applied recursively if the base class itself is derived from some other class.

There’s nothing special about instantiation of derived classes: DerivedClassName() creates a new instance of the class. Method references are resolved as follows: the corresponding class attribute is searched, descending down the chain of base classes if necessary, and the method reference is valid if this yields a function object.

Derived classes may override methods of their base classes. Because methods have no special privileges when calling other methods of the same object, a method of a base class that calls another method defined in the same base class may end up calling a method of a derived class that overrides it. (For C++ programmers: all methods in Python are effectively virtual.)

An overriding method in a derived class may in fact want to extend rather than simply replace the base class method of the same name. There is a simple way to call the base class method directly: just callBaseClassName.methodname(self, arguments). This is occasionally useful to clients as well. (Note that this only works if the base class is accessible as BaseClassName in the global scope.)

Python has two built-in functions that work with inheritance:

* Use [isinstance()](https://docs.python.org/3/library/functions.html#isinstance) to check an instance’s type: isinstance(obj, int) will be True only ifobj.\_\_class\_\_ is [int](https://docs.python.org/3/library/functions.html#int) or some class derived from [int](https://docs.python.org/3/library/functions.html#int).
* Use [issubclass()](https://docs.python.org/3/library/functions.html#issubclass) to check class inheritance: issubclass(bool, int) is True since [bool](https://docs.python.org/3/library/functions.html#bool) is a subclass of [int](https://docs.python.org/3/library/functions.html#int). However, issubclass(float, int) is False since [float](https://docs.python.org/3/library/functions.html#float) is not a subclass of[int](https://docs.python.org/3/library/functions.html#int).

### 9.5.1. Multiple Inheritance

Python supports a form of multiple inheritance as well. A class definition with multiple base classes looks like this:

**class** **DerivedClassName**(Base1, Base2, Base3):

<statement-1>

.

.

.

<statement-N>

For most purposes, in the simplest cases, you can think of the search for attributes inherited from a parent class as depth-first, left-to-right, not searching twice in the same class where there is an overlap in the hierarchy. Thus, if an attribute is not found in DerivedClassName, it is searched for inBase1, then (recursively) in the base classes of Base1, and if it was not found there, it was searched for in Base2, and so on.

In fact, it is slightly more complex than that; the method resolution order changes dynamically to support cooperative calls to [super()](https://docs.python.org/3/library/functions.html#super). This approach is known in some other multiple-inheritance languages as call-next-method and is more powerful than the super call found in single-inheritance languages.

Dynamic ordering is necessary because all cases of multiple inheritance exhibit one or more diamond relationships (where at least one of the parent classes can be accessed through multiple paths from the bottommost class). For example, all classes inherit from [object](https://docs.python.org/3/library/functions.html#object), so any case of multiple inheritance provides more than one path to reach [object](https://docs.python.org/3/library/functions.html#object). To keep the base classes from being accessed more than once, the dynamic algorithm linearizes the search order in a way that preserves the left-to-right ordering specified in each class, that calls each parent only once, and that is monotonic (meaning that a class can be subclassed without affecting the precedence order of its parents). Taken together, these properties make it possible to design reliable and extensible classes with multiple inheritance. For more detail, see <https://www.python.org/download/releases/2.3/mro/>.

## 9.6. Private Variables

“Private” instance variables that cannot be accessed except from inside an object don’t exist in Python. However, there is a convention that is followed by most Python code: a name prefixed with an underscore (e.g. \_spam) should be treated as a non-public part of the API (whether it is a function, a method or a data member). It should be considered an implementation detail and subject to change without notice.

Since there is a valid use-case for class-private members (namely to avoid name clashes of names with names defined by subclasses), there is limited support for such a mechanism, called name mangling. Any identifier of the form \_\_spam (at least two leading underscores, at most one trailing underscore) is textually replaced with \_classname\_\_spam, where classname is the current class name with leading underscore(s) stripped. This mangling is done without regard to the syntactic position of the identifier, as long as it occurs within the definition of a class.

Name mangling is helpful for letting subclasses override methods without breaking intraclass method calls. For example:

**class** **Mapping**:

**def** \_\_init\_\_(self, iterable):

self.items\_list = []

self.\_\_update(iterable)

**def** update(self, iterable):

**for** item **in** iterable:

self.items\_list.append(item)

\_\_update = update *# private copy of original update() method*

**class** **MappingSubclass**(Mapping):

**def** update(self, keys, values):

*# provides new signature for update()*

*# but does not break \_\_init\_\_()*

**for** item **in** zip(keys, values):

self.items\_list.append(item)

Note that the mangling rules are designed mostly to avoid accidents; it still is possible to access or modify a variable that is considered private. This can even be useful in special circumstances, such as in the debugger.

Notice that code passed to exec() or eval() does not consider the classname of the invoking class to be the current class; this is similar to the effect of the global statement, the effect of which is likewise restricted to code that is byte-compiled together. The same restriction applies to getattr(),setattr() and delattr(), as well as when referencing \_\_dict\_\_ directly.

## 9.7. Odds and Ends

Sometimes it is useful to have a data type similar to the Pascal “record” or C “struct”, bundling together a few named data items. An empty class definition will do nicely:

**class** **Employee**:

**pass**

john = Employee() *# Create an empty employee record*

*# Fill the fields of the record*

john.name = 'John Doe'

john.dept = 'computer lab'

john.salary = 1000

A piece of Python code that expects a particular abstract data type can often be passed a class that emulates the methods of that data type instead. For instance, if you have a function that formats some data from a file object, you can define a class with methods read() and readline() that get the data from a string buffer instead, and pass it as an argument.

Instance method objects have attributes, too: m.\_\_self\_\_ is the instance object with the method m(), and m.\_\_func\_\_ is the function object corresponding to the method.

## 9.8. Exceptions Are Classes Too

User-defined exceptions are identified by classes as well. Using this mechanism it is possible to create extensible hierarchies of exceptions.

There are two new valid (semantic) forms for the [raise](https://docs.python.org/3/reference/simple_stmts.html#raise) statement:

**raise** Class

**raise** Instance

In the first form, Class must be an instance of [type](https://docs.python.org/3/library/functions.html#type) or of a class derived from it. The first form is a shorthand for:

**raise** Class()

A class in an [except](https://docs.python.org/3/reference/compound_stmts.html#except) clause is compatible with an exception if it is the same class or a base class thereof (but not the other way around — an except clause listing a derived class is not compatible with a base class). For example, the following code will print B, C, D in that order:

**class** **B**(Exception):

**pass**

**class** **C**(B):

**pass**

**class** **D**(C):

**pass**

**for** cls **in** [B, C, D]:

**try**:

**raise** cls()

**except** D:

print("D")

**except** C:

print("C")

**except** B:

print("B")

Note that if the except clauses were reversed (with except B first), it would have printed B, B, B — the first matching except clause is triggered.

When an error message is printed for an unhandled exception, the exception’s class name is printed, then a colon and a space, and finally the instance converted to a string using the built-in function[str()](https://docs.python.org/3/library/stdtypes.html#str).

## 9.9. Iterators

By now you have probably noticed that most container objects can be looped over using a [for](https://docs.python.org/3/reference/compound_stmts.html#for)statement:

**for** element **in** [1, 2, 3]:

print(element)

**for** element **in** (1, 2, 3):

print(element)

**for** key **in** {'one':1, 'two':2}:

print(key)

**for** char **in** "123":

print(char)

**for** line **in** open("myfile.txt"):

print(line, end='')

This style of access is clear, concise, and convenient. The use of iterators pervades and unifies Python. Behind the scenes, the [for](https://docs.python.org/3/reference/compound_stmts.html#for) statement calls [iter()](https://docs.python.org/3/library/functions.html#iter) on the container object. The function returns an iterator object that defines the method [\_\_next\_\_()](https://docs.python.org/3/library/stdtypes.html#iterator.__next__) which accesses elements in the container one at a time. When there are no more elements, [\_\_next\_\_()](https://docs.python.org/3/library/stdtypes.html#iterator.__next__) raises a [StopIteration](https://docs.python.org/3/library/exceptions.html#StopIteration)exception which tells the [for](https://docs.python.org/3/reference/compound_stmts.html#for) loop to terminate. You can call the [\_\_next\_\_()](https://docs.python.org/3/library/stdtypes.html#iterator.__next__) method using the[next()](https://docs.python.org/3/library/functions.html#next) built-in function; this example shows how it all works:

>>>

**>>>** s = 'abc'

**>>>** it = iter(s)

**>>>** it

<iterator object at 0x00A1DB50>

**>>>** next(it)

'a'

**>>>** next(it)

'b'

**>>>** next(it)

'c'

**>>>** next(it)

Traceback (most recent call last):

File "<stdin>", line 1, in ?

next(it)

StopIteration

Having seen the mechanics behind the iterator protocol, it is easy to add iterator behavior to your classes. Define an [\_\_iter\_\_()](https://docs.python.org/3/reference/datamodel.html#object.__iter__) method which returns an object with a [\_\_next\_\_()](https://docs.python.org/3/library/stdtypes.html#iterator.__next__) method. If the class defines \_\_next\_\_(), then [\_\_iter\_\_()](https://docs.python.org/3/reference/datamodel.html#object.__iter__) can just return self:

**class** **Reverse**:

*"""Iterator for looping over a sequence backwards."""*

**def** \_\_init\_\_(self, data):

self.data = data

self.index = len(data)

**def** \_\_iter\_\_(self):

**return** self

**def** \_\_next\_\_(self):

**if** self.index == 0:

**raise** StopIteration

self.index = self.index - 1

**return** self.data[self.index]

>>>

**>>>** rev = Reverse('spam')

**>>>** iter(rev)

<\_\_main\_\_.Reverse object at 0x00A1DB50>

**>>> for** char **in** rev:

**...**  print(char)

**...**

m

a

p

s

## 9.10. Generators

[Generator](https://docs.python.org/3/glossary.html#term-generator)s are a simple and powerful tool for creating iterators. They are written like regular functions but use the [yield](https://docs.python.org/3/reference/simple_stmts.html#yield) statement whenever they want to return data. Each time [next()](https://docs.python.org/3/library/functions.html#next) is called on it, the generator resumes where it left off (it remembers all the data values and which statement was last executed). An example shows that generators can be trivially easy to create:

**def** reverse(data):

**for** index **in** range(len(data)-1, -1, -1):

**yield** data[index]

>>>

**>>> for** char **in** reverse('golf'):

**...**  print(char)

**...**

f

l

o

g

Anything that can be done with generators can also be done with class-based iterators as described in the previous section. What makes generators so compact is that the [\_\_iter\_\_()](https://docs.python.org/3/reference/datamodel.html#object.__iter__) and [\_\_next\_\_()](https://docs.python.org/3/reference/expressions.html#generator.__next__)methods are created automatically.

Another key feature is that the local variables and execution state are automatically saved between calls. This made the function easier to write and much more clear than an approach using instance variables like self.index and self.data.

In addition to automatic method creation and saving program state, when generators terminate, they automatically raise [StopIteration](https://docs.python.org/3/library/exceptions.html#StopIteration). In combination, these features make it easy to create iterators with no more effort than writing a regular function.

## 9.11. Generator Expressions

Some simple generators can be coded succinctly as expressions using a syntax similar to list comprehensions but with parentheses instead of brackets. These expressions are designed for situations where the generator is used right away by an enclosing function. Generator expressions are more compact but less versatile than full generator definitions and tend to be more memory friendly than equivalent list comprehensions.

Examples:

>>>

**>>>** sum(i\*i **for** i **in** range(10)) *# sum of squares*

285

**>>>** xvec = [10, 20, 30]

**>>>** yvec = [7, 5, 3]

**>>>** sum(x\*y **for** x,y **in** zip(xvec, yvec)) *# dot product*

260

**>>> from** **math** **import** pi, sin

**>>>** sine\_table = {x: sin(x\*pi/180) **for** x **in** range(0, 91)}

**>>>** unique\_words = set(word **for** line **in** page **for** word **in** line.split())

**>>>** valedictorian = max((student.gpa, student.name) **for** student **in** graduates)

**>>>** data = 'golf'

**>>>** list(data[i] **for** i **in** range(len(data)-1, -1, -1))

['f', 'l', 'o', 'g']

**Footnotes**

|  |  |
| --- | --- |
| [[1]](https://docs.python.org/3/tutorial/classes.html#id1) | Except for one thing. Module objects have a secret read-only attribute called [\_\_dict\_\_](https://docs.python.org/3/library/stdtypes.html#object.__dict__) which returns the dictionary used to implement the module’s namespace; the name [\_\_dict\_\_](https://docs.python.org/3/library/stdtypes.html#object.__dict__) is an attribute but not a global name. Obviously, using this violates the abstraction of namespace implementation, and should be restricted to things like post-mortem debuggers. |

# 9. Classes

Compared with other programming languages, Python’s class mechanism adds classes with a minimum of new syntax and semantics. It is a mixture of the class mechanisms found in C++ and Modula-3. Python classes provide all the standard features of Object Oriented Programming: the class inheritance mechanism allows multiple base classes, a derived class can override any methods of its base class or classes, and a method can call the method of a base class with the same name. Objects can contain arbitrary amounts and kinds of data. As is true for modules, classes partake of the dynamic nature of Python: they are created at runtime, and can be modified further after creation.

In C++ terminology, normally class members (including the data members) are public (except see below [Private Variables](https://docs.python.org/3/tutorial/classes.html#tut-private)), and all member functions are virtual. As in Modula-3, there are no shorthands for referencing the object’s members from its methods: the method function is declared with an explicit first argument representing the object, which is provided implicitly by the call. As in Smalltalk, classes themselves are objects. This provides semantics for importing and renaming. Unlike C++ and Modula-3, built-in types can be used as base classes for extension by the user. Also, like in C++, most built-in operators with special syntax (arithmetic operators, subscripting etc.) can be redefined for class instances.

(Lacking universally accepted terminology to talk about classes, I will make occasional use of Smalltalk and C++ terms. I would use Modula-3 terms, since its object-oriented semantics are closer to those of Python than C++, but I expect that few readers have heard of it.)

## 9.1. A Word About Names and Objects

Objects have individuality, and multiple names (in multiple scopes) can be bound to the same object. This is known as aliasing in other languages. This is usually not appreciated on a first glance at Python, and can be safely ignored when dealing with immutable basic types (numbers, strings, tuples). However, aliasing has a possibly surprising effect on the semantics of Python code involving mutable objects such as lists, dictionaries, and most other types. This is usually used to the benefit of the program, since aliases behave like pointers in some respects. For example, passing an object is cheap since only a pointer is passed by the implementation; and if a function modifies an object passed as an argument, the caller will see the change — this eliminates the need for two different argument passing mechanisms as in Pascal.

## 9.2. Python Scopes and Namespaces

Before introducing classes, I first have to tell you something about Python’s scope rules. Class definitions play some neat tricks with namespaces, and you need to know how scopes and namespaces work to fully understand what’s going on. Incidentally, knowledge about this subject is useful for any advanced Python programmer.

Let’s begin with some definitions.

A namespace is a mapping from names to objects. Most namespaces are currently implemented as Python dictionaries, but that’s normally not noticeable in any way (except for performance), and it may change in the future. Examples of namespaces are: the set of built-in names (containing functions such as [abs()](https://docs.python.org/3/library/functions.html#abs), and built-in exception names); the global names in a module; and the local names in a function invocation. In a sense the set of attributes of an object also form a namespace. The important thing to know about namespaces is that there is absolutely no relation between names in different namespaces; for instance, two different modules may both define a function maximize without confusion — users of the modules must prefix it with the module name.

By the way, I use the word attribute for any name following a dot — for example, in the expressionz.real, real is an attribute of the object z. Strictly speaking, references to names in modules are attribute references: in the expression modname.funcname, modname is a module object and funcnameis an attribute of it. In this case there happens to be a straightforward mapping between the module’s attributes and the global names defined in the module: they share the same namespace! [[1]](https://docs.python.org/3/tutorial/classes.html#id2)

Attributes may be read-only or writable. In the latter case, assignment to attributes is possible. Module attributes are writable: you can write modname.the\_answer = 42. Writable attributes may also be deleted with the [del](https://docs.python.org/3/reference/simple_stmts.html#del) statement. For example, del modname.the\_answer will remove the attributethe\_answer from the object named by modname.

Namespaces are created at different moments and have different lifetimes. The namespace containing the built-in names is created when the Python interpreter starts up, and is never deleted. The global namespace for a module is created when the module definition is read in; normally, module namespaces also last until the interpreter quits. The statements executed by the top-level invocation of the interpreter, either read from a script file or interactively, are considered part of a module called[\_\_main\_\_](https://docs.python.org/3/library/__main__.html#module-__main__), so they have their own global namespace. (The built-in names actually also live in a module; this is called [builtins](https://docs.python.org/3/library/builtins.html#module-builtins).)

The local namespace for a function is created when the function is called, and deleted when the function returns or raises an exception that is not handled within the function. (Actually, forgetting would be a better way to describe what actually happens.) Of course, recursive invocations each have their own local namespace.

A scope is a textual region of a Python program where a namespace is directly accessible. “Directly accessible” here means that an unqualified reference to a name attempts to find the name in the namespace.

Although scopes are determined statically, they are used dynamically. At any time during execution, there are at least three nested scopes whose namespaces are directly accessible:

* the innermost scope, which is searched first, contains the local names
* the scopes of any enclosing functions, which are searched starting with the nearest enclosing scope, contains non-local, but also non-global names
* the next-to-last scope contains the current module’s global names
* the outermost scope (searched last) is the namespace containing built-in names

If a name is declared global, then all references and assignments go directly to the middle scope containing the module’s global names. To rebind variables found outside of the innermost scope, the[nonlocal](https://docs.python.org/3/reference/simple_stmts.html#nonlocal) statement can be used; if not declared nonlocal, those variables are read-only (an attempt to write to such a variable will simply create a new local variable in the innermost scope, leaving the identically named outer variable unchanged).

Usually, the local scope references the local names of the (textually) current function. Outside functions, the local scope references the same namespace as the global scope: the module’s namespace. Class definitions place yet another namespace in the local scope.

It is important to realize that scopes are determined textually: the global scope of a function defined in a module is that module’s namespace, no matter from where or by what alias the function is called. On the other hand, the actual search for names is done dynamically, at run time — however, the language definition is evolving towards static name resolution, at “compile” time, so don’t rely on dynamic name resolution! (In fact, local variables are already determined statically.)

A special quirk of Python is that – if no [global](https://docs.python.org/3/reference/simple_stmts.html#global) statement is in effect – assignments to names always go into the innermost scope. Assignments do not copy data — they just bind names to objects. The same is true for deletions: the statement del x removes the binding of x from the namespace referenced by the local scope. In fact, all operations that introduce new names use the local scope: in particular, [import](https://docs.python.org/3/reference/simple_stmts.html#import) statements and function definitions bind the module or function name in the local scope.

The [global](https://docs.python.org/3/reference/simple_stmts.html#global) statement can be used to indicate that particular variables live in the global scope and should be rebound there; the [nonlocal](https://docs.python.org/3/reference/simple_stmts.html#nonlocal) statement indicates that particular variables live in an enclosing scope and should be rebound there.

### 9.2.1. Scopes and Namespaces Example

This is an example demonstrating how to reference the different scopes and namespaces, and how[global](https://docs.python.org/3/reference/simple_stmts.html#global) and [nonlocal](https://docs.python.org/3/reference/simple_stmts.html#nonlocal) affect variable binding:

**def** scope\_test():

**def** do\_local():

spam = "local spam"

**def** do\_nonlocal():

**nonlocal** spam

spam = "nonlocal spam"

**def** do\_global():

**global** spam

spam = "global spam"

spam = "test spam"

do\_local()

print("After local assignment:", spam)

do\_nonlocal()

print("After nonlocal assignment:", spam)

do\_global()

print("After global assignment:", spam)

scope\_test()

print("In global scope:", spam)

The output of the example code is:

After local assignment: test spam

After nonlocal assignment: nonlocal spam

After global assignment: nonlocal spam

In global scope: global spam

Note how the local assignment (which is default) didn’t change scope\_test‘s binding of spam. The[nonlocal](https://docs.python.org/3/reference/simple_stmts.html#nonlocal) assignment changed scope\_test‘s binding of spam, and the [global](https://docs.python.org/3/reference/simple_stmts.html#global) assignment changed the module-level binding.

You can also see that there was no previous binding for spam before the [global](https://docs.python.org/3/reference/simple_stmts.html#global) assignment.

## 9.3. A First Look at Classes

Classes introduce a little bit of new syntax, three new object types, and some new semantics.

### 9.3.1. Class Definition Syntax

The simplest form of class definition looks like this:

**class** **ClassName**:

<statement-1>

.

.

.

<statement-N>

Class definitions, like function definitions ([def](https://docs.python.org/3/reference/compound_stmts.html#def) statements) must be executed before they have any effect. (You could conceivably place a class definition in a branch of an [if](https://docs.python.org/3/reference/compound_stmts.html#if) statement, or inside a function.)

In practice, the statements inside a class definition will usually be function definitions, but other statements are allowed, and sometimes useful — we’ll come back to this later. The function definitions inside a class normally have a peculiar form of argument list, dictated by the calling conventions for methods — again, this is explained later.

When a class definition is entered, a new namespace is created, and used as the local scope — thus, all assignments to local variables go into this new namespace. In particular, function definitions bind the name of the new function here.

When a class definition is left normally (via the end), a class object is created. This is basically a wrapper around the contents of the namespace created by the class definition; we’ll learn more about class objects in the next section. The original local scope (the one in effect just before the class definition was entered) is reinstated, and the class object is bound here to the class name given in the class definition header (ClassName in the example).

### 9.3.2. Class Objects

Class objects support two kinds of operations: attribute references and instantiation.

Attribute references use the standard syntax used for all attribute references in Python: obj.name. Valid attribute names are all the names that were in the class’s namespace when the class object was created. So, if the class definition looked like this:

**class** **MyClass**:

*"""A simple example class"""*

i = 12345

**def** f(self):

**return** 'hello world'

then MyClass.i and MyClass.f are valid attribute references, returning an integer and a function object, respectively. Class attributes can also be assigned to, so you can change the value ofMyClass.i by assignment. \_\_doc\_\_ is also a valid attribute, returning the docstring belonging to the class: "A simple example class".

Class instantiation uses function notation. Just pretend that the class object is a parameterless function that returns a new instance of the class. For example (assuming the above class):

x = MyClass()

creates a new instance of the class and assigns this object to the local variable x.

The instantiation operation (“calling” a class object) creates an empty object. Many classes like to create objects with instances customized to a specific initial state. Therefore a class may define a special method named [\_\_init\_\_()](https://docs.python.org/3/reference/datamodel.html#object.__init__), like this:

**def** \_\_init\_\_(self):

self.data = []

When a class defines an [\_\_init\_\_()](https://docs.python.org/3/reference/datamodel.html#object.__init__) method, class instantiation automatically invokes [\_\_init\_\_()](https://docs.python.org/3/reference/datamodel.html#object.__init__)for the newly-created class instance. So in this example, a new, initialized instance can be obtained by:

x = MyClass()

Of course, the [\_\_init\_\_()](https://docs.python.org/3/reference/datamodel.html#object.__init__) method may have arguments for greater flexibility. In that case, arguments given to the class instantiation operator are passed on to [\_\_init\_\_()](https://docs.python.org/3/reference/datamodel.html#object.__init__). For example,

>>>

**>>> class** **Complex**:

**...**  **def** \_\_init\_\_(self, realpart, imagpart):

**...**  self.r = realpart

**...**  self.i = imagpart

**...**

**>>>** x = Complex(3.0, -4.5)

**>>>** x.r, x.i

(3.0, -4.5)

### 9.3.3. Instance Objects

Now what can we do with instance objects? The only operations understood by instance objects are attribute references. There are two kinds of valid attribute names, data attributes and methods.

data attributes correspond to “instance variables” in Smalltalk, and to “data members” in C++. Data attributes need not be declared; like local variables, they spring into existence when they are first assigned to. For example, if x is the instance of MyClass created above, the following piece of code will print the value 16, without leaving a trace:

x.counter = 1

**while** x.counter < 10:

x.counter = x.counter \* 2

print(x.counter)

**del** x.counter

The other kind of instance attribute reference is a method. A method is a function that “belongs to” an object. (In Python, the term method is not unique to class instances: other object types can have methods as well. For example, list objects have methods called append, insert, remove, sort, and so on. However, in the following discussion, we’ll use the term method exclusively to mean methods of class instance objects, unless explicitly stated otherwise.)

Valid method names of an instance object depend on its class. By definition, all attributes of a class that are function objects define corresponding methods of its instances. So in our example, x.f is a valid method reference, since MyClass.f is a function, but x.i is not, since MyClass.i is not. But x.fis not the same thing as MyClass.f — it is a method object, not a function object.

### 9.3.4. Method Objects

Usually, a method is called right after it is bound:

x.f()

In the MyClass example, this will return the string 'hello world'. However, it is not necessary to call a method right away: x.f is a method object, and can be stored away and called at a later time. For example:

xf = x.f

**while** **True**:

print(xf())

will continue to print hello world until the end of time.

What exactly happens when a method is called? You may have noticed that x.f() was called without an argument above, even though the function definition for f() specified an argument. What happened to the argument? Surely Python raises an exception when a function that requires an argument is called without any — even if the argument isn’t actually used...

Actually, you may have guessed the answer: the special thing about methods is that the object is passed as the first argument of the function. In our example, the call x.f() is exactly equivalent toMyClass.f(x). In general, calling a method with a list of n arguments is equivalent to calling the corresponding function with an argument list that is created by inserting the method’s object before the first argument.

If you still don’t understand how methods work, a look at the implementation can perhaps clarify matters. When an instance attribute is referenced that isn’t a data attribute, its class is searched. If the name denotes a valid class attribute that is a function object, a method object is created by packing (pointers to) the instance object and the function object just found together in an abstract object: this is the method object. When the method object is called with an argument list, a new argument list is constructed from the instance object and the argument list, and the function object is called with this new argument list.

### 9.3.5. Class and Instance Variables

Generally speaking, instance variables are for data unique to each instance and class variables are for attributes and methods shared by all instances of the class:

**class** **Dog**:

kind = 'canine' *# class variable shared by all instances*

**def** \_\_init\_\_(self, name):

self.name = name *# instance variable unique to each instance*

>>> d = Dog('Fido')

>>> e = Dog('Buddy')

>>> d.kind *# shared by all dogs*

'canine'

>>> e.kind *# shared by all dogs*

'canine'

>>> d.name *# unique to d*

'Fido'

>>> e.name *# unique to e*

'Buddy'

As discussed in [A Word About Names and Objects](https://docs.python.org/3/tutorial/classes.html#tut-object), shared data can have possibly surprising effects with involving [mutable](https://docs.python.org/3/glossary.html#term-mutable) objects such as lists and dictionaries. For example, the tricks list in the following code should not be used as a class variable because just a single list would be shared by all Doginstances:

**class** **Dog**:

tricks = [] *# mistaken use of a class variable*

**def** \_\_init\_\_(self, name):

self.name = name

**def** add\_trick(self, trick):

self.tricks.append(trick)

>>> d = Dog('Fido')

>>> e = Dog('Buddy')

>>> d.add\_trick('roll over')

>>> e.add\_trick('play dead')

>>> d.tricks *# unexpectedly shared by all dogs*

['roll over', 'play dead']

Correct design of the class should use an instance variable instead:

**class** **Dog**:

**def** \_\_init\_\_(self, name):

self.name = name

self.tricks = [] *# creates a new empty list for each dog*

**def** add\_trick(self, trick):

self.tricks.append(trick)

>>> d = Dog('Fido')

>>> e = Dog('Buddy')

>>> d.add\_trick('roll over')

>>> e.add\_trick('play dead')

>>> d.tricks

['roll over']

>>> e.tricks

['play dead']

## 9.4. Random Remarks

Data attributes override method attributes with the same name; to avoid accidental name conflicts, which may cause hard-to-find bugs in large programs, it is wise to use some kind of convention that minimizes the chance of conflicts. Possible conventions include capitalizing method names, prefixing data attribute names with a small unique string (perhaps just an underscore), or using verbs for methods and nouns for data attributes.

Data attributes may be referenced by methods as well as by ordinary users (“clients”) of an object. In other words, classes are not usable to implement pure abstract data types. In fact, nothing in Python makes it possible to enforce data hiding — it is all based upon convention. (On the other hand, the Python implementation, written in C, can completely hide implementation details and control access to an object if necessary; this can be used by extensions to Python written in C.)

Clients should use data attributes with care — clients may mess up invariants maintained by the methods by stamping on their data attributes. Note that clients may add data attributes of their own to an instance object without affecting the validity of the methods, as long as name conflicts are avoided — again, a naming convention can save a lot of headaches here.

There is no shorthand for referencing data attributes (or other methods!) from within methods. I find that this actually increases the readability of methods: there is no chance of confusing local variables and instance variables when glancing through a method.

Often, the first argument of a method is called self. This is nothing more than a convention: the nameself has absolutely no special meaning to Python. Note, however, that by not following the convention your code may be less readable to other Python programmers, and it is also conceivable that a class browser program might be written that relies upon such a convention.

Any function object that is a class attribute defines a method for instances of that class. It is not necessary that the function definition is textually enclosed in the class definition: assigning a function object to a local variable in the class is also ok. For example:

*# Function defined outside the class*

**def** f1(self, x, y):

**return** min(x, x+y)

**class** **C**:

f = f1

**def** g(self):

**return** 'hello world'

h = g

Now f, g and h are all attributes of class C that refer to function objects, and consequently they are all methods of instances of C — h being exactly equivalent to g. Note that this practice usually only serves to confuse the reader of a program.

Methods may call other methods by using method attributes of the self argument:

**class** **Bag**:

**def** \_\_init\_\_(self):

self.data = []

**def** add(self, x):

self.data.append(x)

**def** addtwice(self, x):

self.add(x)

self.add(x)

Methods may reference global names in the same way as ordinary functions. The global scope associated with a method is the module containing its definition. (A class is never used as a global scope.) While one rarely encounters a good reason for using global data in a method, there are many legitimate uses of the global scope: for one thing, functions and modules imported into the global scope can be used by methods, as well as functions and classes defined in it. Usually, the class containing the method is itself defined in this global scope, and in the next section we’ll find some good reasons why a method would want to reference its own class.

Each value is an object, and therefore has a class (also called its type). It is stored asobject.\_\_class\_\_.

## 9.5. Inheritance

Of course, a language feature would not be worthy of the name “class” without supporting inheritance. The syntax for a derived class definition looks like this:

**class** **DerivedClassName**(BaseClassName):

<statement-1>

.

.

.

<statement-N>

The name BaseClassName must be defined in a scope containing the derived class definition. In place of a base class name, other arbitrary expressions are also allowed. This can be useful, for example, when the base class is defined in another module:

**class** **DerivedClassName**(modname.BaseClassName):

Execution of a derived class definition proceeds the same as for a base class. When the class object is constructed, the base class is remembered. This is used for resolving attribute references: if a requested attribute is not found in the class, the search proceeds to look in the base class. This rule is applied recursively if the base class itself is derived from some other class.

There’s nothing special about instantiation of derived classes: DerivedClassName() creates a new instance of the class. Method references are resolved as follows: the corresponding class attribute is searched, descending down the chain of base classes if necessary, and the method reference is valid if this yields a function object.

Derived classes may override methods of their base classes. Because methods have no special privileges when calling other methods of the same object, a method of a base class that calls another method defined in the same base class may end up calling a method of a derived class that overrides it. (For C++ programmers: all methods in Python are effectively virtual.)

An overriding method in a derived class may in fact want to extend rather than simply replace the base class method of the same name. There is a simple way to call the base class method directly: just callBaseClassName.methodname(self, arguments). This is occasionally useful to clients as well. (Note that this only works if the base class is accessible as BaseClassName in the global scope.)

Python has two built-in functions that work with inheritance:

* Use [isinstance()](https://docs.python.org/3/library/functions.html#isinstance) to check an instance’s type: isinstance(obj, int) will be True only ifobj.\_\_class\_\_ is [int](https://docs.python.org/3/library/functions.html#int) or some class derived from [int](https://docs.python.org/3/library/functions.html#int).
* Use [issubclass()](https://docs.python.org/3/library/functions.html#issubclass) to check class inheritance: issubclass(bool, int) is True since [bool](https://docs.python.org/3/library/functions.html#bool) is a subclass of [int](https://docs.python.org/3/library/functions.html#int). However, issubclass(float, int) is False since [float](https://docs.python.org/3/library/functions.html#float) is not a subclass of[int](https://docs.python.org/3/library/functions.html#int).

### 9.5.1. Multiple Inheritance

Python supports a form of multiple inheritance as well. A class definition with multiple base classes looks like this:

**class** **DerivedClassName**(Base1, Base2, Base3):

<statement-1>

.

.

.

<statement-N>

For most purposes, in the simplest cases, you can think of the search for attributes inherited from a parent class as depth-first, left-to-right, not searching twice in the same class where there is an overlap in the hierarchy. Thus, if an attribute is not found in DerivedClassName, it is searched for inBase1, then (recursively) in the base classes of Base1, and if it was not found there, it was searched for in Base2, and so on.

In fact, it is slightly more complex than that; the method resolution order changes dynamically to support cooperative calls to [super()](https://docs.python.org/3/library/functions.html#super). This approach is known in some other multiple-inheritance languages as call-next-method and is more powerful than the super call found in single-inheritance languages.

Dynamic ordering is necessary because all cases of multiple inheritance exhibit one or more diamond relationships (where at least one of the parent classes can be accessed through multiple paths from the bottommost class). For example, all classes inherit from [object](https://docs.python.org/3/library/functions.html#object), so any case of multiple inheritance provides more than one path to reach [object](https://docs.python.org/3/library/functions.html#object). To keep the base classes from being accessed more than once, the dynamic algorithm linearizes the search order in a way that preserves the left-to-right ordering specified in each class, that calls each parent only once, and that is monotonic (meaning that a class can be subclassed without affecting the precedence order of its parents). Taken together, these properties make it possible to design reliable and extensible classes with multiple inheritance. For more detail, see <https://www.python.org/download/releases/2.3/mro/>.

## 9.6. Private Variables

“Private” instance variables that cannot be accessed except from inside an object don’t exist in Python. However, there is a convention that is followed by most Python code: a name prefixed with an underscore (e.g. \_spam) should be treated as a non-public part of the API (whether it is a function, a method or a data member). It should be considered an implementation detail and subject to change without notice.

Since there is a valid use-case for class-private members (namely to avoid name clashes of names with names defined by subclasses), there is limited support for such a mechanism, called name mangling. Any identifier of the form \_\_spam (at least two leading underscores, at most one trailing underscore) is textually replaced with \_classname\_\_spam, where classname is the current class name with leading underscore(s) stripped. This mangling is done without regard to the syntactic position of the identifier, as long as it occurs within the definition of a class.

Name mangling is helpful for letting subclasses override methods without breaking intraclass method calls. For example:

**class** **Mapping**:

**def** \_\_init\_\_(self, iterable):

self.items\_list = []

self.\_\_update(iterable)

**def** update(self, iterable):

**for** item **in** iterable:

self.items\_list.append(item)

\_\_update = update *# private copy of original update() method*

**class** **MappingSubclass**(Mapping):

**def** update(self, keys, values):

*# provides new signature for update()*

*# but does not break \_\_init\_\_()*

**for** item **in** zip(keys, values):

self.items\_list.append(item)

Note that the mangling rules are designed mostly to avoid accidents; it still is possible to access or modify a variable that is considered private. This can even be useful in special circumstances, such as in the debugger.

Notice that code passed to exec() or eval() does not consider the classname of the invoking class to be the current class; this is similar to the effect of the global statement, the effect of which is likewise restricted to code that is byte-compiled together. The same restriction applies to getattr(),setattr() and delattr(), as well as when referencing \_\_dict\_\_ directly.

## 9.7. Odds and Ends

Sometimes it is useful to have a data type similar to the Pascal “record” or C “struct”, bundling together a few named data items. An empty class definition will do nicely:

**class** **Employee**:

**pass**

john = Employee() *# Create an empty employee record*

*# Fill the fields of the record*

john.name = 'John Doe'

john.dept = 'computer lab'

john.salary = 1000

A piece of Python code that expects a particular abstract data type can often be passed a class that emulates the methods of that data type instead. For instance, if you have a function that formats some data from a file object, you can define a class with methods read() and readline() that get the data from a string buffer instead, and pass it as an argument.

Instance method objects have attributes, too: m.\_\_self\_\_ is the instance object with the method m(), and m.\_\_func\_\_ is the function object corresponding to the method.

## 9.8. Exceptions Are Classes Too

User-defined exceptions are identified by classes as well. Using this mechanism it is possible to create extensible hierarchies of exceptions.

There are two new valid (semantic) forms for the [raise](https://docs.python.org/3/reference/simple_stmts.html#raise) statement:

**raise** Class

**raise** Instance

In the first form, Class must be an instance of [type](https://docs.python.org/3/library/functions.html#type) or of a class derived from it. The first form is a shorthand for:

**raise** Class()

A class in an [except](https://docs.python.org/3/reference/compound_stmts.html#except) clause is compatible with an exception if it is the same class or a base class thereof (but not the other way around — an except clause listing a derived class is not compatible with a base class). For example, the following code will print B, C, D in that order:

**class** **B**(Exception):

**pass**

**class** **C**(B):

**pass**

**class** **D**(C):

**pass**

**for** cls **in** [B, C, D]:

**try**:

**raise** cls()

**except** D:

print("D")

**except** C:

print("C")

**except** B:

print("B")

Note that if the except clauses were reversed (with except B first), it would have printed B, B, B — the first matching except clause is triggered.

When an error message is printed for an unhandled exception, the exception’s class name is printed, then a colon and a space, and finally the instance converted to a string using the built-in function[str()](https://docs.python.org/3/library/stdtypes.html#str).

## 9.9. Iterators

By now you have probably noticed that most container objects can be looped over using a [for](https://docs.python.org/3/reference/compound_stmts.html#for)statement:

**for** element **in** [1, 2, 3]:

print(element)

**for** element **in** (1, 2, 3):

print(element)

**for** key **in** {'one':1, 'two':2}:

print(key)

**for** char **in** "123":

print(char)

**for** line **in** open("myfile.txt"):

print(line, end='')

This style of access is clear, concise, and convenient. The use of iterators pervades and unifies Python. Behind the scenes, the [for](https://docs.python.org/3/reference/compound_stmts.html#for) statement calls [iter()](https://docs.python.org/3/library/functions.html#iter) on the container object. The function returns an iterator object that defines the method [\_\_next\_\_()](https://docs.python.org/3/library/stdtypes.html#iterator.__next__) which accesses elements in the container one at a time. When there are no more elements, [\_\_next\_\_()](https://docs.python.org/3/library/stdtypes.html#iterator.__next__) raises a [StopIteration](https://docs.python.org/3/library/exceptions.html#StopIteration)exception which tells the [for](https://docs.python.org/3/reference/compound_stmts.html#for) loop to terminate. You can call the [\_\_next\_\_()](https://docs.python.org/3/library/stdtypes.html#iterator.__next__) method using the[next()](https://docs.python.org/3/library/functions.html#next) built-in function; this example shows how it all works:

>>>

**>>>** s = 'abc'

**>>>** it = iter(s)

**>>>** it

<iterator object at 0x00A1DB50>

**>>>** next(it)

'a'

**>>>** next(it)

'b'

**>>>** next(it)

'c'

**>>>** next(it)

Traceback (most recent call last):

File "<stdin>", line 1, in ?

next(it)

StopIteration

Having seen the mechanics behind the iterator protocol, it is easy to add iterator behavior to your classes. Define an [\_\_iter\_\_()](https://docs.python.org/3/reference/datamodel.html#object.__iter__) method which returns an object with a [\_\_next\_\_()](https://docs.python.org/3/library/stdtypes.html#iterator.__next__) method. If the class defines \_\_next\_\_(), then [\_\_iter\_\_()](https://docs.python.org/3/reference/datamodel.html#object.__iter__) can just return self:

**class** **Reverse**:

*"""Iterator for looping over a sequence backwards."""*

**def** \_\_init\_\_(self, data):

self.data = data

self.index = len(data)

**def** \_\_iter\_\_(self):

**return** self

**def** \_\_next\_\_(self):

**if** self.index == 0:

**raise** StopIteration

self.index = self.index - 1

**return** self.data[self.index]

>>>

**>>>** rev = Reverse('spam')

**>>>** iter(rev)

<\_\_main\_\_.Reverse object at 0x00A1DB50>

**>>> for** char **in** rev:

**...**  print(char)

**...**

m

a

p

s

## 9.10. Generators

[Generator](https://docs.python.org/3/glossary.html#term-generator)s are a simple and powerful tool for creating iterators. They are written like regular functions but use the [yield](https://docs.python.org/3/reference/simple_stmts.html#yield) statement whenever they want to return data. Each time [next()](https://docs.python.org/3/library/functions.html#next) is called on it, the generator resumes where it left off (it remembers all the data values and which statement was last executed). An example shows that generators can be trivially easy to create:

**def** reverse(data):

**for** index **in** range(len(data)-1, -1, -1):

**yield** data[index]

>>>

**>>> for** char **in** reverse('golf'):

**...**  print(char)

**...**

f

l

o

g

Anything that can be done with generators can also be done with class-based iterators as described in the previous section. What makes generators so compact is that the [\_\_iter\_\_()](https://docs.python.org/3/reference/datamodel.html#object.__iter__) and [\_\_next\_\_()](https://docs.python.org/3/reference/expressions.html#generator.__next__)methods are created automatically.

Another key feature is that the local variables and execution state are automatically saved between calls. This made the function easier to write and much more clear than an approach using instance variables like self.index and self.data.

In addition to automatic method creation and saving program state, when generators terminate, they automatically raise [StopIteration](https://docs.python.org/3/library/exceptions.html#StopIteration). In combination, these features make it easy to create iterators with no more effort than writing a regular function.

## 9.11. Generator Expressions

Some simple generators can be coded succinctly as expressions using a syntax similar to list comprehensions but with parentheses instead of brackets. These expressions are designed for situations where the generator is used right away by an enclosing function. Generator expressions are more compact but less versatile than full generator definitions and tend to be more memory friendly than equivalent list comprehensions.

Examples:

>>>

**>>>** sum(i\*i **for** i **in** range(10)) *# sum of squares*

285

**>>>** xvec = [10, 20, 30]

**>>>** yvec = [7, 5, 3]

**>>>** sum(x\*y **for** x,y **in** zip(xvec, yvec)) *# dot product*

260

**>>> from** **math** **import** pi, sin

**>>>** sine\_table = {x: sin(x\*pi/180) **for** x **in** range(0, 91)}

**>>>** unique\_words = set(word **for** line **in** page **for** word **in** line.split())

**>>>** valedictorian = max((student.gpa, student.name) **for** student **in** graduates)

**>>>** data = 'golf'

**>>>** list(data[i] **for** i **in** range(len(data)-1, -1, -1))

['f', 'l', 'o', 'g']

**Footnotes**

|  |  |
| --- | --- |
| [[1]](https://docs.python.org/3/tutorial/classes.html#id1) | Except for one thing. Module objects have a secret read-only attribute called [\_\_dict\_\_](https://docs.python.org/3/library/stdtypes.html#object.__dict__) which returns the dictionary used to implement the module’s namespace; the name [\_\_dict\_\_](https://docs.python.org/3/library/stdtypes.html#object.__dict__) is an attribute but not a global name. Obviously, using this violates the abstraction of namespace implementation, and should be restricted to things like post-mortem debuggers. |

# 9. Classes

Compared with other programming languages, Python’s class mechanism adds classes with a minimum of new syntax and semantics. It is a mixture of the class mechanisms found in C++ and Modula-3. Python classes provide all the standard features of Object Oriented Programming: the class inheritance mechanism allows multiple base classes, a derived class can override any methods of its base class or classes, and a method can call the method of a base class with the same name. Objects can contain arbitrary amounts and kinds of data. As is true for modules, classes partake of the dynamic nature of Python: they are created at runtime, and can be modified further after creation.

In C++ terminology, normally class members (including the data members) are public (except see below [Private Variables](https://docs.python.org/3/tutorial/classes.html#tut-private)), and all member functions are virtual. As in Modula-3, there are no shorthands for referencing the object’s members from its methods: the method function is declared with an explicit first argument representing the object, which is provided implicitly by the call. As in Smalltalk, classes themselves are objects. This provides semantics for importing and renaming. Unlike C++ and Modula-3, built-in types can be used as base classes for extension by the user. Also, like in C++, most built-in operators with special syntax (arithmetic operators, subscripting etc.) can be redefined for class instances.

(Lacking universally accepted terminology to talk about classes, I will make occasional use of Smalltalk and C++ terms. I would use Modula-3 terms, since its object-oriented semantics are closer to those of Python than C++, but I expect that few readers have heard of it.)

## 9.1. A Word About Names and Objects

Objects have individuality, and multiple names (in multiple scopes) can be bound to the same object. This is known as aliasing in other languages. This is usually not appreciated on a first glance at Python, and can be safely ignored when dealing with immutable basic types (numbers, strings, tuples). However, aliasing has a possibly surprising effect on the semantics of Python code involving mutable objects such as lists, dictionaries, and most other types. This is usually used to the benefit of the program, since aliases behave like pointers in some respects. For example, passing an object is cheap since only a pointer is passed by the implementation; and if a function modifies an object passed as an argument, the caller will see the change — this eliminates the need for two different argument passing mechanisms as in Pascal.

## 9.2. Python Scopes and Namespaces

Before introducing classes, I first have to tell you something about Python’s scope rules. Class definitions play some neat tricks with namespaces, and you need to know how scopes and namespaces work to fully understand what’s going on. Incidentally, knowledge about this subject is useful for any advanced Python programmer.

Let’s begin with some definitions.

A namespace is a mapping from names to objects. Most namespaces are currently implemented as Python dictionaries, but that’s normally not noticeable in any way (except for performance), and it may change in the future. Examples of namespaces are: the set of built-in names (containing functions such as [abs()](https://docs.python.org/3/library/functions.html#abs), and built-in exception names); the global names in a module; and the local names in a function invocation. In a sense the set of attributes of an object also form a namespace. The important thing to know about namespaces is that there is absolutely no relation between names in different namespaces; for instance, two different modules may both define a function maximize without confusion — users of the modules must prefix it with the module name.

By the way, I use the word attribute for any name following a dot — for example, in the expressionz.real, real is an attribute of the object z. Strictly speaking, references to names in modules are attribute references: in the expression modname.funcname, modname is a module object and funcnameis an attribute of it. In this case there happens to be a straightforward mapping between the module’s attributes and the global names defined in the module: they share the same namespace! [[1]](https://docs.python.org/3/tutorial/classes.html#id2)

Attributes may be read-only or writable. In the latter case, assignment to attributes is possible. Module attributes are writable: you can write modname.the\_answer = 42. Writable attributes may also be deleted with the [del](https://docs.python.org/3/reference/simple_stmts.html#del) statement. For example, del modname.the\_answer will remove the attributethe\_answer from the object named by modname.

Namespaces are created at different moments and have different lifetimes. The namespace containing the built-in names is created when the Python interpreter starts up, and is never deleted. The global namespace for a module is created when the module definition is read in; normally, module namespaces also last until the interpreter quits. The statements executed by the top-level invocation of the interpreter, either read from a script file or interactively, are considered part of a module called[\_\_main\_\_](https://docs.python.org/3/library/__main__.html#module-__main__), so they have their own global namespace. (The built-in names actually also live in a module; this is called [builtins](https://docs.python.org/3/library/builtins.html#module-builtins).)

The local namespace for a function is created when the function is called, and deleted when the function returns or raises an exception that is not handled within the function. (Actually, forgetting would be a better way to describe what actually happens.) Of course, recursive invocations each have their own local namespace.

A scope is a textual region of a Python program where a namespace is directly accessible. “Directly accessible” here means that an unqualified reference to a name attempts to find the name in the namespace.

Although scopes are determined statically, they are used dynamically. At any time during execution, there are at least three nested scopes whose namespaces are directly accessible:

* the innermost scope, which is searched first, contains the local names
* the scopes of any enclosing functions, which are searched starting with the nearest enclosing scope, contains non-local, but also non-global names
* the next-to-last scope contains the current module’s global names
* the outermost scope (searched last) is the namespace containing built-in names

If a name is declared global, then all references and assignments go directly to the middle scope containing the module’s global names. To rebind variables found outside of the innermost scope, the[nonlocal](https://docs.python.org/3/reference/simple_stmts.html#nonlocal) statement can be used; if not declared nonlocal, those variables are read-only (an attempt to write to such a variable will simply create a new local variable in the innermost scope, leaving the identically named outer variable unchanged).

Usually, the local scope references the local names of the (textually) current function. Outside functions, the local scope references the same namespace as the global scope: the module’s namespace. Class definitions place yet another namespace in the local scope.

It is important to realize that scopes are determined textually: the global scope of a function defined in a module is that module’s namespace, no matter from where or by what alias the function is called. On the other hand, the actual search for names is done dynamically, at run time — however, the language definition is evolving towards static name resolution, at “compile” time, so don’t rely on dynamic name resolution! (In fact, local variables are already determined statically.)

A special quirk of Python is that – if no [global](https://docs.python.org/3/reference/simple_stmts.html#global) statement is in effect – assignments to names always go into the innermost scope. Assignments do not copy data — they just bind names to objects. The same is true for deletions: the statement del x removes the binding of x from the namespace referenced by the local scope. In fact, all operations that introduce new names use the local scope: in particular, [import](https://docs.python.org/3/reference/simple_stmts.html#import) statements and function definitions bind the module or function name in the local scope.

The [global](https://docs.python.org/3/reference/simple_stmts.html#global) statement can be used to indicate that particular variables live in the global scope and should be rebound there; the [nonlocal](https://docs.python.org/3/reference/simple_stmts.html#nonlocal) statement indicates that particular variables live in an enclosing scope and should be rebound there.

### 9.2.1. Scopes and Namespaces Example

This is an example demonstrating how to reference the different scopes and namespaces, and how[global](https://docs.python.org/3/reference/simple_stmts.html#global) and [nonlocal](https://docs.python.org/3/reference/simple_stmts.html#nonlocal) affect variable binding:

**def** scope\_test():

**def** do\_local():

spam = "local spam"

**def** do\_nonlocal():

**nonlocal** spam

spam = "nonlocal spam"

**def** do\_global():

**global** spam

spam = "global spam"

spam = "test spam"

do\_local()

print("After local assignment:", spam)

do\_nonlocal()

print("After nonlocal assignment:", spam)

do\_global()

print("After global assignment:", spam)

scope\_test()

print("In global scope:", spam)

The output of the example code is:

After local assignment: test spam

After nonlocal assignment: nonlocal spam

After global assignment: nonlocal spam

In global scope: global spam

Note how the local assignment (which is default) didn’t change scope\_test‘s binding of spam. The[nonlocal](https://docs.python.org/3/reference/simple_stmts.html#nonlocal) assignment changed scope\_test‘s binding of spam, and the [global](https://docs.python.org/3/reference/simple_stmts.html#global) assignment changed the module-level binding.

You can also see that there was no previous binding for spam before the [global](https://docs.python.org/3/reference/simple_stmts.html#global) assignment.

## 9.3. A First Look at Classes

Classes introduce a little bit of new syntax, three new object types, and some new semantics.

### 9.3.1. Class Definition Syntax

The simplest form of class definition looks like this:

**class** **ClassName**:

<statement-1>

.

.

.

<statement-N>

Class definitions, like function definitions ([def](https://docs.python.org/3/reference/compound_stmts.html#def) statements) must be executed before they have any effect. (You could conceivably place a class definition in a branch of an [if](https://docs.python.org/3/reference/compound_stmts.html#if) statement, or inside a function.)

In practice, the statements inside a class definition will usually be function definitions, but other statements are allowed, and sometimes useful — we’ll come back to this later. The function definitions inside a class normally have a peculiar form of argument list, dictated by the calling conventions for methods — again, this is explained later.

When a class definition is entered, a new namespace is created, and used as the local scope — thus, all assignments to local variables go into this new namespace. In particular, function definitions bind the name of the new function here.

When a class definition is left normally (via the end), a class object is created. This is basically a wrapper around the contents of the namespace created by the class definition; we’ll learn more about class objects in the next section. The original local scope (the one in effect just before the class definition was entered) is reinstated, and the class object is bound here to the class name given in the class definition header (ClassName in the example).

### 9.3.2. Class Objects

Class objects support two kinds of operations: attribute references and instantiation.

Attribute references use the standard syntax used for all attribute references in Python: obj.name. Valid attribute names are all the names that were in the class’s namespace when the class object was created. So, if the class definition looked like this:

**class** **MyClass**:

*"""A simple example class"""*

i = 12345

**def** f(self):

**return** 'hello world'

then MyClass.i and MyClass.f are valid attribute references, returning an integer and a function object, respectively. Class attributes can also be assigned to, so you can change the value ofMyClass.i by assignment. \_\_doc\_\_ is also a valid attribute, returning the docstring belonging to the class: "A simple example class".

Class instantiation uses function notation. Just pretend that the class object is a parameterless function that returns a new instance of the class. For example (assuming the above class):

x = MyClass()

creates a new instance of the class and assigns this object to the local variable x.

The instantiation operation (“calling” a class object) creates an empty object. Many classes like to create objects with instances customized to a specific initial state. Therefore a class may define a special method named [\_\_init\_\_()](https://docs.python.org/3/reference/datamodel.html#object.__init__), like this:

**def** \_\_init\_\_(self):

self.data = []

When a class defines an [\_\_init\_\_()](https://docs.python.org/3/reference/datamodel.html#object.__init__) method, class instantiation automatically invokes [\_\_init\_\_()](https://docs.python.org/3/reference/datamodel.html#object.__init__)for the newly-created class instance. So in this example, a new, initialized instance can be obtained by:

x = MyClass()

Of course, the [\_\_init\_\_()](https://docs.python.org/3/reference/datamodel.html#object.__init__) method may have arguments for greater flexibility. In that case, arguments given to the class instantiation operator are passed on to [\_\_init\_\_()](https://docs.python.org/3/reference/datamodel.html#object.__init__). For example,

>>>

**>>> class** **Complex**:

**...**  **def** \_\_init\_\_(self, realpart, imagpart):

**...**  self.r = realpart

**...**  self.i = imagpart

**...**

**>>>** x = Complex(3.0, -4.5)

**>>>** x.r, x.i

(3.0, -4.5)

### 9.3.3. Instance Objects

Now what can we do with instance objects? The only operations understood by instance objects are attribute references. There are two kinds of valid attribute names, data attributes and methods.

data attributes correspond to “instance variables” in Smalltalk, and to “data members” in C++. Data attributes need not be declared; like local variables, they spring into existence when they are first assigned to. For example, if x is the instance of MyClass created above, the following piece of code will print the value 16, without leaving a trace:

x.counter = 1

**while** x.counter < 10:

x.counter = x.counter \* 2

print(x.counter)

**del** x.counter

The other kind of instance attribute reference is a method. A method is a function that “belongs to” an object. (In Python, the term method is not unique to class instances: other object types can have methods as well. For example, list objects have methods called append, insert, remove, sort, and so on. However, in the following discussion, we’ll use the term method exclusively to mean methods of class instance objects, unless explicitly stated otherwise.)

Valid method names of an instance object depend on its class. By definition, all attributes of a class that are function objects define corresponding methods of its instances. So in our example, x.f is a valid method reference, since MyClass.f is a function, but x.i is not, since MyClass.i is not. But x.fis not the same thing as MyClass.f — it is a method object, not a function object.

### 9.3.4. Method Objects

Usually, a method is called right after it is bound:

x.f()

In the MyClass example, this will return the string 'hello world'. However, it is not necessary to call a method right away: x.f is a method object, and can be stored away and called at a later time. For example:

xf = x.f

**while** **True**:

print(xf())

will continue to print hello world until the end of time.

What exactly happens when a method is called? You may have noticed that x.f() was called without an argument above, even though the function definition for f() specified an argument. What happened to the argument? Surely Python raises an exception when a function that requires an argument is called without any — even if the argument isn’t actually used...

Actually, you may have guessed the answer: the special thing about methods is that the object is passed as the first argument of the function. In our example, the call x.f() is exactly equivalent toMyClass.f(x). In general, calling a method with a list of n arguments is equivalent to calling the corresponding function with an argument list that is created by inserting the method’s object before the first argument.

If you still don’t understand how methods work, a look at the implementation can perhaps clarify matters. When an instance attribute is referenced that isn’t a data attribute, its class is searched. If the name denotes a valid class attribute that is a function object, a method object is created by packing (pointers to) the instance object and the function object just found together in an abstract object: this is the method object. When the method object is called with an argument list, a new argument list is constructed from the instance object and the argument list, and the function object is called with this new argument list.

### 9.3.5. Class and Instance Variables

Generally speaking, instance variables are for data unique to each instance and class variables are for attributes and methods shared by all instances of the class:

**class** **Dog**:

kind = 'canine' *# class variable shared by all instances*

**def** \_\_init\_\_(self, name):

self.name = name *# instance variable unique to each instance*

>>> d = Dog('Fido')

>>> e = Dog('Buddy')

>>> d.kind *# shared by all dogs*

'canine'

>>> e.kind *# shared by all dogs*

'canine'

>>> d.name *# unique to d*

'Fido'

>>> e.name *# unique to e*

'Buddy'

As discussed in [A Word About Names and Objects](https://docs.python.org/3/tutorial/classes.html#tut-object), shared data can have possibly surprising effects with involving [mutable](https://docs.python.org/3/glossary.html#term-mutable) objects such as lists and dictionaries. For example, the tricks list in the following code should not be used as a class variable because just a single list would be shared by all Doginstances:

**class** **Dog**:

tricks = [] *# mistaken use of a class variable*

**def** \_\_init\_\_(self, name):

self.name = name

**def** add\_trick(self, trick):

self.tricks.append(trick)

>>> d = Dog('Fido')

>>> e = Dog('Buddy')

>>> d.add\_trick('roll over')

>>> e.add\_trick('play dead')

>>> d.tricks *# unexpectedly shared by all dogs*

['roll over', 'play dead']

Correct design of the class should use an instance variable instead:

**class** **Dog**:

**def** \_\_init\_\_(self, name):

self.name = name

self.tricks = [] *# creates a new empty list for each dog*

**def** add\_trick(self, trick):

self.tricks.append(trick)

>>> d = Dog('Fido')

>>> e = Dog('Buddy')

>>> d.add\_trick('roll over')

>>> e.add\_trick('play dead')

>>> d.tricks

['roll over']

>>> e.tricks

['play dead']

## 9.4. Random Remarks

Data attributes override method attributes with the same name; to avoid accidental name conflicts, which may cause hard-to-find bugs in large programs, it is wise to use some kind of convention that minimizes the chance of conflicts. Possible conventions include capitalizing method names, prefixing data attribute names with a small unique string (perhaps just an underscore), or using verbs for methods and nouns for data attributes.

Data attributes may be referenced by methods as well as by ordinary users (“clients”) of an object. In other words, classes are not usable to implement pure abstract data types. In fact, nothing in Python makes it possible to enforce data hiding — it is all based upon convention. (On the other hand, the Python implementation, written in C, can completely hide implementation details and control access to an object if necessary; this can be used by extensions to Python written in C.)

Clients should use data attributes with care — clients may mess up invariants maintained by the methods by stamping on their data attributes. Note that clients may add data attributes of their own to an instance object without affecting the validity of the methods, as long as name conflicts are avoided — again, a naming convention can save a lot of headaches here.

There is no shorthand for referencing data attributes (or other methods!) from within methods. I find that this actually increases the readability of methods: there is no chance of confusing local variables and instance variables when glancing through a method.

Often, the first argument of a method is called self. This is nothing more than a convention: the nameself has absolutely no special meaning to Python. Note, however, that by not following the convention your code may be less readable to other Python programmers, and it is also conceivable that a class browser program might be written that relies upon such a convention.

Any function object that is a class attribute defines a method for instances of that class. It is not necessary that the function definition is textually enclosed in the class definition: assigning a function object to a local variable in the class is also ok. For example:

*# Function defined outside the class*

**def** f1(self, x, y):

**return** min(x, x+y)

**class** **C**:

f = f1

**def** g(self):

**return** 'hello world'

h = g

Now f, g and h are all attributes of class C that refer to function objects, and consequently they are all methods of instances of C — h being exactly equivalent to g. Note that this practice usually only serves to confuse the reader of a program.

Methods may call other methods by using method attributes of the self argument:

**class** **Bag**:

**def** \_\_init\_\_(self):

self.data = []

**def** add(self, x):

self.data.append(x)

**def** addtwice(self, x):

self.add(x)

self.add(x)

Methods may reference global names in the same way as ordinary functions. The global scope associated with a method is the module containing its definition. (A class is never used as a global scope.) While one rarely encounters a good reason for using global data in a method, there are many legitimate uses of the global scope: for one thing, functions and modules imported into the global scope can be used by methods, as well as functions and classes defined in it. Usually, the class containing the method is itself defined in this global scope, and in the next section we’ll find some good reasons why a method would want to reference its own class.

Each value is an object, and therefore has a class (also called its type). It is stored asobject.\_\_class\_\_.

## 9.5. Inheritance

Of course, a language feature would not be worthy of the name “class” without supporting inheritance. The syntax for a derived class definition looks like this:

**class** **DerivedClassName**(BaseClassName):

<statement-1>

.

.

.

<statement-N>

The name BaseClassName must be defined in a scope containing the derived class definition. In place of a base class name, other arbitrary expressions are also allowed. This can be useful, for example, when the base class is defined in another module:

**class** **DerivedClassName**(modname.BaseClassName):

Execution of a derived class definition proceeds the same as for a base class. When the class object is constructed, the base class is remembered. This is used for resolving attribute references: if a requested attribute is not found in the class, the search proceeds to look in the base class. This rule is applied recursively if the base class itself is derived from some other class.

There’s nothing special about instantiation of derived classes: DerivedClassName() creates a new instance of the class. Method references are resolved as follows: the corresponding class attribute is searched, descending down the chain of base classes if necessary, and the method reference is valid if this yields a function object.

Derived classes may override methods of their base classes. Because methods have no special privileges when calling other methods of the same object, a method of a base class that calls another method defined in the same base class may end up calling a method of a derived class that overrides it. (For C++ programmers: all methods in Python are effectively virtual.)

An overriding method in a derived class may in fact want to extend rather than simply replace the base class method of the same name. There is a simple way to call the base class method directly: just callBaseClassName.methodname(self, arguments). This is occasionally useful to clients as well. (Note that this only works if the base class is accessible as BaseClassName in the global scope.)

Python has two built-in functions that work with inheritance:

* Use [isinstance()](https://docs.python.org/3/library/functions.html#isinstance) to check an instance’s type: isinstance(obj, int) will be True only ifobj.\_\_class\_\_ is [int](https://docs.python.org/3/library/functions.html#int) or some class derived from [int](https://docs.python.org/3/library/functions.html#int).
* Use [issubclass()](https://docs.python.org/3/library/functions.html#issubclass) to check class inheritance: issubclass(bool, int) is True since [bool](https://docs.python.org/3/library/functions.html#bool) is a subclass of [int](https://docs.python.org/3/library/functions.html#int). However, issubclass(float, int) is False since [float](https://docs.python.org/3/library/functions.html#float) is not a subclass of[int](https://docs.python.org/3/library/functions.html#int).

### 9.5.1. Multiple Inheritance

Python supports a form of multiple inheritance as well. A class definition with multiple base classes looks like this:

**class** **DerivedClassName**(Base1, Base2, Base3):

<statement-1>

.

.

.

<statement-N>

For most purposes, in the simplest cases, you can think of the search for attributes inherited from a parent class as depth-first, left-to-right, not searching twice in the same class where there is an overlap in the hierarchy. Thus, if an attribute is not found in DerivedClassName, it is searched for inBase1, then (recursively) in the base classes of Base1, and if it was not found there, it was searched for in Base2, and so on.

In fact, it is slightly more complex than that; the method resolution order changes dynamically to support cooperative calls to [super()](https://docs.python.org/3/library/functions.html#super). This approach is known in some other multiple-inheritance languages as call-next-method and is more powerful than the super call found in single-inheritance languages.

Dynamic ordering is necessary because all cases of multiple inheritance exhibit one or more diamond relationships (where at least one of the parent classes can be accessed through multiple paths from the bottommost class). For example, all classes inherit from [object](https://docs.python.org/3/library/functions.html#object), so any case of multiple inheritance provides more than one path to reach [object](https://docs.python.org/3/library/functions.html#object). To keep the base classes from being accessed more than once, the dynamic algorithm linearizes the search order in a way that preserves the left-to-right ordering specified in each class, that calls each parent only once, and that is monotonic (meaning that a class can be subclassed without affecting the precedence order of its parents). Taken together, these properties make it possible to design reliable and extensible classes with multiple inheritance. For more detail, see <https://www.python.org/download/releases/2.3/mro/>.

## 9.6. Private Variables

“Private” instance variables that cannot be accessed except from inside an object don’t exist in Python. However, there is a convention that is followed by most Python code: a name prefixed with an underscore (e.g. \_spam) should be treated as a non-public part of the API (whether it is a function, a method or a data member). It should be considered an implementation detail and subject to change without notice.

Since there is a valid use-case for class-private members (namely to avoid name clashes of names with names defined by subclasses), there is limited support for such a mechanism, called name mangling. Any identifier of the form \_\_spam (at least two leading underscores, at most one trailing underscore) is textually replaced with \_classname\_\_spam, where classname is the current class name with leading underscore(s) stripped. This mangling is done without regard to the syntactic position of the identifier, as long as it occurs within the definition of a class.

Name mangling is helpful for letting subclasses override methods without breaking intraclass method calls. For example:

**class** **Mapping**:

**def** \_\_init\_\_(self, iterable):

self.items\_list = []

self.\_\_update(iterable)

**def** update(self, iterable):

**for** item **in** iterable:

self.items\_list.append(item)

\_\_update = update *# private copy of original update() method*

**class** **MappingSubclass**(Mapping):

**def** update(self, keys, values):

*# provides new signature for update()*

*# but does not break \_\_init\_\_()*

**for** item **in** zip(keys, values):

self.items\_list.append(item)

Note that the mangling rules are designed mostly to avoid accidents; it still is possible to access or modify a variable that is considered private. This can even be useful in special circumstances, such as in the debugger.

Notice that code passed to exec() or eval() does not consider the classname of the invoking class to be the current class; this is similar to the effect of the global statement, the effect of which is likewise restricted to code that is byte-compiled together. The same restriction applies to getattr(),setattr() and delattr(), as well as when referencing \_\_dict\_\_ directly.

## 9.7. Odds and Ends

Sometimes it is useful to have a data type similar to the Pascal “record” or C “struct”, bundling together a few named data items. An empty class definition will do nicely:

**class** **Employee**:

**pass**

john = Employee() *# Create an empty employee record*

*# Fill the fields of the record*

john.name = 'John Doe'

john.dept = 'computer lab'

john.salary = 1000

A piece of Python code that expects a particular abstract data type can often be passed a class that emulates the methods of that data type instead. For instance, if you have a function that formats some data from a file object, you can define a class with methods read() and readline() that get the data from a string buffer instead, and pass it as an argument.

Instance method objects have attributes, too: m.\_\_self\_\_ is the instance object with the method m(), and m.\_\_func\_\_ is the function object corresponding to the method.

## 9.8. Exceptions Are Classes Too

User-defined exceptions are identified by classes as well. Using this mechanism it is possible to create extensible hierarchies of exceptions.

There are two new valid (semantic) forms for the [raise](https://docs.python.org/3/reference/simple_stmts.html#raise) statement:

**raise** Class

**raise** Instance

In the first form, Class must be an instance of [type](https://docs.python.org/3/library/functions.html#type) or of a class derived from it. The first form is a shorthand for:

**raise** Class()

A class in an [except](https://docs.python.org/3/reference/compound_stmts.html#except) clause is compatible with an exception if it is the same class or a base class thereof (but not the other way around — an except clause listing a derived class is not compatible with a base class). For example, the following code will print B, C, D in that order:

**class** **B**(Exception):

**pass**

**class** **C**(B):

**pass**

**class** **D**(C):

**pass**

**for** cls **in** [B, C, D]:

**try**:

**raise** cls()

**except** D:

print("D")

**except** C:

print("C")

**except** B:

print("B")

Note that if the except clauses were reversed (with except B first), it would have printed B, B, B — the first matching except clause is triggered.

When an error message is printed for an unhandled exception, the exception’s class name is printed, then a colon and a space, and finally the instance converted to a string using the built-in function[str()](https://docs.python.org/3/library/stdtypes.html#str).

## 9.9. Iterators

By now you have probably noticed that most container objects can be looped over using a [for](https://docs.python.org/3/reference/compound_stmts.html#for)statement:

**for** element **in** [1, 2, 3]:

print(element)

**for** element **in** (1, 2, 3):

print(element)

**for** key **in** {'one':1, 'two':2}:

print(key)

**for** char **in** "123":

print(char)

**for** line **in** open("myfile.txt"):

print(line, end='')

This style of access is clear, concise, and convenient. The use of iterators pervades and unifies Python. Behind the scenes, the [for](https://docs.python.org/3/reference/compound_stmts.html#for) statement calls [iter()](https://docs.python.org/3/library/functions.html#iter) on the container object. The function returns an iterator object that defines the method [\_\_next\_\_()](https://docs.python.org/3/library/stdtypes.html#iterator.__next__) which accesses elements in the container one at a time. When there are no more elements, [\_\_next\_\_()](https://docs.python.org/3/library/stdtypes.html#iterator.__next__) raises a [StopIteration](https://docs.python.org/3/library/exceptions.html#StopIteration)exception which tells the [for](https://docs.python.org/3/reference/compound_stmts.html#for) loop to terminate. You can call the [\_\_next\_\_()](https://docs.python.org/3/library/stdtypes.html#iterator.__next__) method using the[next()](https://docs.python.org/3/library/functions.html#next) built-in function; this example shows how it all works:

>>>

**>>>** s = 'abc'

**>>>** it = iter(s)

**>>>** it

<iterator object at 0x00A1DB50>

**>>>** next(it)

'a'

**>>>** next(it)

'b'

**>>>** next(it)

'c'

**>>>** next(it)

Traceback (most recent call last):

File "<stdin>", line 1, in ?

next(it)

StopIteration

Having seen the mechanics behind the iterator protocol, it is easy to add iterator behavior to your classes. Define an [\_\_iter\_\_()](https://docs.python.org/3/reference/datamodel.html#object.__iter__) method which returns an object with a [\_\_next\_\_()](https://docs.python.org/3/library/stdtypes.html#iterator.__next__) method. If the class defines \_\_next\_\_(), then [\_\_iter\_\_()](https://docs.python.org/3/reference/datamodel.html#object.__iter__) can just return self:

**class** **Reverse**:

*"""Iterator for looping over a sequence backwards."""*

**def** \_\_init\_\_(self, data):

self.data = data

self.index = len(data)

**def** \_\_iter\_\_(self):

**return** self

**def** \_\_next\_\_(self):

**if** self.index == 0:

**raise** StopIteration

self.index = self.index - 1

**return** self.data[self.index]

>>>

**>>>** rev = Reverse('spam')

**>>>** iter(rev)

<\_\_main\_\_.Reverse object at 0x00A1DB50>

**>>> for** char **in** rev:

**...**  print(char)

**...**

m

a

p

s

## 9.10. Generators

[Generator](https://docs.python.org/3/glossary.html#term-generator)s are a simple and powerful tool for creating iterators. They are written like regular functions but use the [yield](https://docs.python.org/3/reference/simple_stmts.html#yield) statement whenever they want to return data. Each time [next()](https://docs.python.org/3/library/functions.html#next) is called on it, the generator resumes where it left off (it remembers all the data values and which statement was last executed). An example shows that generators can be trivially easy to create:

**def** reverse(data):

**for** index **in** range(len(data)-1, -1, -1):

**yield** data[index]

>>>

**>>> for** char **in** reverse('golf'):

**...**  print(char)

**...**

f

l

o

g

Anything that can be done with generators can also be done with class-based iterators as described in the previous section. What makes generators so compact is that the [\_\_iter\_\_()](https://docs.python.org/3/reference/datamodel.html#object.__iter__) and [\_\_next\_\_()](https://docs.python.org/3/reference/expressions.html#generator.__next__)methods are created automatically.

Another key feature is that the local variables and execution state are automatically saved between calls. This made the function easier to write and much more clear than an approach using instance variables like self.index and self.data.

In addition to automatic method creation and saving program state, when generators terminate, they automatically raise [StopIteration](https://docs.python.org/3/library/exceptions.html#StopIteration). In combination, these features make it easy to create iterators with no more effort than writing a regular function.

## 9.11. Generator Expressions

Some simple generators can be coded succinctly as expressions using a syntax similar to list comprehensions but with parentheses instead of brackets. These expressions are designed for situations where the generator is used right away by an enclosing function. Generator expressions are more compact but less versatile than full generator definitions and tend to be more memory friendly than equivalent list comprehensions.

Examples:

>>>

**>>>** sum(i\*i **for** i **in** range(10)) *# sum of squares*

285

**>>>** xvec = [10, 20, 30]

**>>>** yvec = [7, 5, 3]

**>>>** sum(x\*y **for** x,y **in** zip(xvec, yvec)) *# dot product*

260

**>>> from** **math** **import** pi, sin

**>>>** sine\_table = {x: sin(x\*pi/180) **for** x **in** range(0, 91)}

**>>>** unique\_words = set(word **for** line **in** page **for** word **in** line.split())

**>>>** valedictorian = max((student.gpa, student.name) **for** student **in** graduates)

**>>>** data = 'golf'

**>>>** list(data[i] **for** i **in** range(len(data)-1, -1, -1))

['f', 'l', 'o', 'g']

**Footnotes**

|  |  |
| --- | --- |
| [[1]](https://docs.python.org/3/tutorial/classes.html#id1) | Except for one thing. Module objects have a secret read-only attribute called [\_\_dict\_\_](https://docs.python.org/3/library/stdtypes.html#object.__dict__) which returns the dictionary used to implement the module’s namespace; the name [\_\_dict\_\_](https://docs.python.org/3/library/stdtypes.html#object.__dict__) is an attribute but not a global name. Obviously, using this violates the abstraction of namespace implementation, and should be restricted to things like post-mortem debuggers. |

# 9. Classes

Compared with other programming languages, Python’s class mechanism adds classes with a minimum of new syntax and semantics. It is a mixture of the class mechanisms found in C++ and Modula-3. Python classes provide all the standard features of Object Oriented Programming: the class inheritance mechanism allows multiple base classes, a derived class can override any methods of its base class or classes, and a method can call the method of a base class with the same name. Objects can contain arbitrary amounts and kinds of data. As is true for modules, classes partake of the dynamic nature of Python: they are created at runtime, and can be modified further after creation.

In C++ terminology, normally class members (including the data members) are public (except see below [Private Variables](https://docs.python.org/3/tutorial/classes.html#tut-private)), and all member functions are virtual. As in Modula-3, there are no shorthands for referencing the object’s members from its methods: the method function is declared with an explicit first argument representing the object, which is provided implicitly by the call. As in Smalltalk, classes themselves are objects. This provides semantics for importing and renaming. Unlike C++ and Modula-3, built-in types can be used as base classes for extension by the user. Also, like in C++, most built-in operators with special syntax (arithmetic operators, subscripting etc.) can be redefined for class instances.

(Lacking universally accepted terminology to talk about classes, I will make occasional use of Smalltalk and C++ terms. I would use Modula-3 terms, since its object-oriented semantics are closer to those of Python than C++, but I expect that few readers have heard of it.)

## 9.1. A Word About Names and Objects

Objects have individuality, and multiple names (in multiple scopes) can be bound to the same object. This is known as aliasing in other languages. This is usually not appreciated on a first glance at Python, and can be safely ignored when dealing with immutable basic types (numbers, strings, tuples). However, aliasing has a possibly surprising effect on the semantics of Python code involving mutable objects such as lists, dictionaries, and most other types. This is usually used to the benefit of the program, since aliases behave like pointers in some respects. For example, passing an object is cheap since only a pointer is passed by the implementation; and if a function modifies an object passed as an argument, the caller will see the change — this eliminates the need for two different argument passing mechanisms as in Pascal.

## 9.2. Python Scopes and Namespaces

Before introducing classes, I first have to tell you something about Python’s scope rules. Class definitions play some neat tricks with namespaces, and you need to know how scopes and namespaces work to fully understand what’s going on. Incidentally, knowledge about this subject is useful for any advanced Python programmer.

Let’s begin with some definitions.

A namespace is a mapping from names to objects. Most namespaces are currently implemented as Python dictionaries, but that’s normally not noticeable in any way (except for performance), and it may change in the future. Examples of namespaces are: the set of built-in names (containing functions such as [abs()](https://docs.python.org/3/library/functions.html#abs), and built-in exception names); the global names in a module; and the local names in a function invocation. In a sense the set of attributes of an object also form a namespace. The important thing to know about namespaces is that there is absolutely no relation between names in different namespaces; for instance, two different modules may both define a function maximize without confusion — users of the modules must prefix it with the module name.

By the way, I use the word attribute for any name following a dot — for example, in the expressionz.real, real is an attribute of the object z. Strictly speaking, references to names in modules are attribute references: in the expression modname.funcname, modname is a module object and funcnameis an attribute of it. In this case there happens to be a straightforward mapping between the module’s attributes and the global names defined in the module: they share the same namespace! [[1]](https://docs.python.org/3/tutorial/classes.html#id2)

Attributes may be read-only or writable. In the latter case, assignment to attributes is possible. Module attributes are writable: you can write modname.the\_answer = 42. Writable attributes may also be deleted with the [del](https://docs.python.org/3/reference/simple_stmts.html#del) statement. For example, del modname.the\_answer will remove the attributethe\_answer from the object named by modname.

Namespaces are created at different moments and have different lifetimes. The namespace containing the built-in names is created when the Python interpreter starts up, and is never deleted. The global namespace for a module is created when the module definition is read in; normally, module namespaces also last until the interpreter quits. The statements executed by the top-level invocation of the interpreter, either read from a script file or interactively, are considered part of a module called[\_\_main\_\_](https://docs.python.org/3/library/__main__.html#module-__main__), so they have their own global namespace. (The built-in names actually also live in a module; this is called [builtins](https://docs.python.org/3/library/builtins.html#module-builtins).)

The local namespace for a function is created when the function is called, and deleted when the function returns or raises an exception that is not handled within the function. (Actually, forgetting would be a better way to describe what actually happens.) Of course, recursive invocations each have their own local namespace.

A scope is a textual region of a Python program where a namespace is directly accessible. “Directly accessible” here means that an unqualified reference to a name attempts to find the name in the namespace.

Although scopes are determined statically, they are used dynamically. At any time during execution, there are at least three nested scopes whose namespaces are directly accessible:

* the innermost scope, which is searched first, contains the local names
* the scopes of any enclosing functions, which are searched starting with the nearest enclosing scope, contains non-local, but also non-global names
* the next-to-last scope contains the current module’s global names
* the outermost scope (searched last) is the namespace containing built-in names

If a name is declared global, then all references and assignments go directly to the middle scope containing the module’s global names. To rebind variables found outside of the innermost scope, the[nonlocal](https://docs.python.org/3/reference/simple_stmts.html#nonlocal) statement can be used; if not declared nonlocal, those variables are read-only (an attempt to write to such a variable will simply create a new local variable in the innermost scope, leaving the identically named outer variable unchanged).

Usually, the local scope references the local names of the (textually) current function. Outside functions, the local scope references the same namespace as the global scope: the module’s namespace. Class definitions place yet another namespace in the local scope.

It is important to realize that scopes are determined textually: the global scope of a function defined in a module is that module’s namespace, no matter from where or by what alias the function is called. On the other hand, the actual search for names is done dynamically, at run time — however, the language definition is evolving towards static name resolution, at “compile” time, so don’t rely on dynamic name resolution! (In fact, local variables are already determined statically.)

A special quirk of Python is that – if no [global](https://docs.python.org/3/reference/simple_stmts.html#global) statement is in effect – assignments to names always go into the innermost scope. Assignments do not copy data — they just bind names to objects. The same is true for deletions: the statement del x removes the binding of x from the namespace referenced by the local scope. In fact, all operations that introduce new names use the local scope: in particular, [import](https://docs.python.org/3/reference/simple_stmts.html#import) statements and function definitions bind the module or function name in the local scope.

The [global](https://docs.python.org/3/reference/simple_stmts.html#global) statement can be used to indicate that particular variables live in the global scope and should be rebound there; the [nonlocal](https://docs.python.org/3/reference/simple_stmts.html#nonlocal) statement indicates that particular variables live in an enclosing scope and should be rebound there.

### 9.2.1. Scopes and Namespaces Example

This is an example demonstrating how to reference the different scopes and namespaces, and how[global](https://docs.python.org/3/reference/simple_stmts.html#global) and [nonlocal](https://docs.python.org/3/reference/simple_stmts.html#nonlocal) affect variable binding:

**def** scope\_test():

**def** do\_local():

spam = "local spam"

**def** do\_nonlocal():

**nonlocal** spam

spam = "nonlocal spam"

**def** do\_global():

**global** spam

spam = "global spam"

spam = "test spam"

do\_local()

print("After local assignment:", spam)

do\_nonlocal()

print("After nonlocal assignment:", spam)

do\_global()

print("After global assignment:", spam)

scope\_test()

print("In global scope:", spam)

The output of the example code is:

After local assignment: test spam

After nonlocal assignment: nonlocal spam

After global assignment: nonlocal spam

In global scope: global spam

Note how the local assignment (which is default) didn’t change scope\_test‘s binding of spam. The[nonlocal](https://docs.python.org/3/reference/simple_stmts.html#nonlocal) assignment changed scope\_test‘s binding of spam, and the [global](https://docs.python.org/3/reference/simple_stmts.html#global) assignment changed the module-level binding.

You can also see that there was no previous binding for spam before the [global](https://docs.python.org/3/reference/simple_stmts.html#global) assignment.

## 9.3. A First Look at Classes

Classes introduce a little bit of new syntax, three new object types, and some new semantics.

### 9.3.1. Class Definition Syntax

The simplest form of class definition looks like this:

**class** **ClassName**:

<statement-1>

.

.

.

<statement-N>

Class definitions, like function definitions ([def](https://docs.python.org/3/reference/compound_stmts.html#def) statements) must be executed before they have any effect. (You could conceivably place a class definition in a branch of an [if](https://docs.python.org/3/reference/compound_stmts.html#if) statement, or inside a function.)

In practice, the statements inside a class definition will usually be function definitions, but other statements are allowed, and sometimes useful — we’ll come back to this later. The function definitions inside a class normally have a peculiar form of argument list, dictated by the calling conventions for methods — again, this is explained later.

When a class definition is entered, a new namespace is created, and used as the local scope — thus, all assignments to local variables go into this new namespace. In particular, function definitions bind the name of the new function here.

When a class definition is left normally (via the end), a class object is created. This is basically a wrapper around the contents of the namespace created by the class definition; we’ll learn more about class objects in the next section. The original local scope (the one in effect just before the class definition was entered) is reinstated, and the class object is bound here to the class name given in the class definition header (ClassName in the example).

### 9.3.2. Class Objects

Class objects support two kinds of operations: attribute references and instantiation.

Attribute references use the standard syntax used for all attribute references in Python: obj.name. Valid attribute names are all the names that were in the class’s namespace when the class object was created. So, if the class definition looked like this:

**class** **MyClass**:

*"""A simple example class"""*

i = 12345

**def** f(self):

**return** 'hello world'

then MyClass.i and MyClass.f are valid attribute references, returning an integer and a function object, respectively. Class attributes can also be assigned to, so you can change the value ofMyClass.i by assignment. \_\_doc\_\_ is also a valid attribute, returning the docstring belonging to the class: "A simple example class".

Class instantiation uses function notation. Just pretend that the class object is a parameterless function that returns a new instance of the class. For example (assuming the above class):

x = MyClass()

creates a new instance of the class and assigns this object to the local variable x.

The instantiation operation (“calling” a class object) creates an empty object. Many classes like to create objects with instances customized to a specific initial state. Therefore a class may define a special method named [\_\_init\_\_()](https://docs.python.org/3/reference/datamodel.html#object.__init__), like this:

**def** \_\_init\_\_(self):

self.data = []

When a class defines an [\_\_init\_\_()](https://docs.python.org/3/reference/datamodel.html#object.__init__) method, class instantiation automatically invokes [\_\_init\_\_()](https://docs.python.org/3/reference/datamodel.html#object.__init__)for the newly-created class instance. So in this example, a new, initialized instance can be obtained by:

x = MyClass()

Of course, the [\_\_init\_\_()](https://docs.python.org/3/reference/datamodel.html#object.__init__) method may have arguments for greater flexibility. In that case, arguments given to the class instantiation operator are passed on to [\_\_init\_\_()](https://docs.python.org/3/reference/datamodel.html#object.__init__). For example,

>>>

**>>> class** **Complex**:

**...**  **def** \_\_init\_\_(self, realpart, imagpart):

**...**  self.r = realpart

**...**  self.i = imagpart

**...**

**>>>** x = Complex(3.0, -4.5)

**>>>** x.r, x.i

(3.0, -4.5)

### 9.3.3. Instance Objects

Now what can we do with instance objects? The only operations understood by instance objects are attribute references. There are two kinds of valid attribute names, data attributes and methods.

data attributes correspond to “instance variables” in Smalltalk, and to “data members” in C++. Data attributes need not be declared; like local variables, they spring into existence when they are first assigned to. For example, if x is the instance of MyClass created above, the following piece of code will print the value 16, without leaving a trace:

x.counter = 1

**while** x.counter < 10:

x.counter = x.counter \* 2

print(x.counter)

**del** x.counter

The other kind of instance attribute reference is a method. A method is a function that “belongs to” an object. (In Python, the term method is not unique to class instances: other object types can have methods as well. For example, list objects have methods called append, insert, remove, sort, and so on. However, in the following discussion, we’ll use the term method exclusively to mean methods of class instance objects, unless explicitly stated otherwise.)

Valid method names of an instance object depend on its class. By definition, all attributes of a class that are function objects define corresponding methods of its instances. So in our example, x.f is a valid method reference, since MyClass.f is a function, but x.i is not, since MyClass.i is not. But x.fis not the same thing as MyClass.f — it is a method object, not a function object.

### 9.3.4. Method Objects

Usually, a method is called right after it is bound:

x.f()

In the MyClass example, this will return the string 'hello world'. However, it is not necessary to call a method right away: x.f is a method object, and can be stored away and called at a later time. For example:

xf = x.f

**while** **True**:

print(xf())

will continue to print hello world until the end of time.

What exactly happens when a method is called? You may have noticed that x.f() was called without an argument above, even though the function definition for f() specified an argument. What happened to the argument? Surely Python raises an exception when a function that requires an argument is called without any — even if the argument isn’t actually used...

Actually, you may have guessed the answer: the special thing about methods is that the object is passed as the first argument of the function. In our example, the call x.f() is exactly equivalent toMyClass.f(x). In general, calling a method with a list of n arguments is equivalent to calling the corresponding function with an argument list that is created by inserting the method’s object before the first argument.

If you still don’t understand how methods work, a look at the implementation can perhaps clarify matters. When an instance attribute is referenced that isn’t a data attribute, its class is searched. If the name denotes a valid class attribute that is a function object, a method object is created by packing (pointers to) the instance object and the function object just found together in an abstract object: this is the method object. When the method object is called with an argument list, a new argument list is constructed from the instance object and the argument list, and the function object is called with this new argument list.

### 9.3.5. Class and Instance Variables

Generally speaking, instance variables are for data unique to each instance and class variables are for attributes and methods shared by all instances of the class:

**class** **Dog**:

kind = 'canine' *# class variable shared by all instances*

**def** \_\_init\_\_(self, name):

self.name = name *# instance variable unique to each instance*

>>> d = Dog('Fido')

>>> e = Dog('Buddy')

>>> d.kind *# shared by all dogs*

'canine'

>>> e.kind *# shared by all dogs*

'canine'

>>> d.name *# unique to d*

'Fido'

>>> e.name *# unique to e*

'Buddy'

As discussed in [A Word About Names and Objects](https://docs.python.org/3/tutorial/classes.html#tut-object), shared data can have possibly surprising effects with involving [mutable](https://docs.python.org/3/glossary.html#term-mutable) objects such as lists and dictionaries. For example, the tricks list in the following code should not be used as a class variable because just a single list would be shared by all Doginstances:

**class** **Dog**:

tricks = [] *# mistaken use of a class variable*

**def** \_\_init\_\_(self, name):

self.name = name

**def** add\_trick(self, trick):

self.tricks.append(trick)

>>> d = Dog('Fido')

>>> e = Dog('Buddy')

>>> d.add\_trick('roll over')

>>> e.add\_trick('play dead')

>>> d.tricks *# unexpectedly shared by all dogs*

['roll over', 'play dead']

Correct design of the class should use an instance variable instead:

**class** **Dog**:

**def** \_\_init\_\_(self, name):

self.name = name

self.tricks = [] *# creates a new empty list for each dog*

**def** add\_trick(self, trick):

self.tricks.append(trick)

>>> d = Dog('Fido')

>>> e = Dog('Buddy')

>>> d.add\_trick('roll over')

>>> e.add\_trick('play dead')

>>> d.tricks

['roll over']

>>> e.tricks

['play dead']

## 9.4. Random Remarks

Data attributes override method attributes with the same name; to avoid accidental name conflicts, which may cause hard-to-find bugs in large programs, it is wise to use some kind of convention that minimizes the chance of conflicts. Possible conventions include capitalizing method names, prefixing data attribute names with a small unique string (perhaps just an underscore), or using verbs for methods and nouns for data attributes.

Data attributes may be referenced by methods as well as by ordinary users (“clients”) of an object. In other words, classes are not usable to implement pure abstract data types. In fact, nothing in Python makes it possible to enforce data hiding — it is all based upon convention. (On the other hand, the Python implementation, written in C, can completely hide implementation details and control access to an object if necessary; this can be used by extensions to Python written in C.)

Clients should use data attributes with care — clients may mess up invariants maintained by the methods by stamping on their data attributes. Note that clients may add data attributes of their own to an instance object without affecting the validity of the methods, as long as name conflicts are avoided — again, a naming convention can save a lot of headaches here.

There is no shorthand for referencing data attributes (or other methods!) from within methods. I find that this actually increases the readability of methods: there is no chance of confusing local variables and instance variables when glancing through a method.

Often, the first argument of a method is called self. This is nothing more than a convention: the nameself has absolutely no special meaning to Python. Note, however, that by not following the convention your code may be less readable to other Python programmers, and it is also conceivable that a class browser program might be written that relies upon such a convention.

Any function object that is a class attribute defines a method for instances of that class. It is not necessary that the function definition is textually enclosed in the class definition: assigning a function object to a local variable in the class is also ok. For example:

*# Function defined outside the class*

**def** f1(self, x, y):

**return** min(x, x+y)

**class** **C**:

f = f1

**def** g(self):

**return** 'hello world'

h = g

Now f, g and h are all attributes of class C that refer to function objects, and consequently they are all methods of instances of C — h being exactly equivalent to g. Note that this practice usually only serves to confuse the reader of a program.

Methods may call other methods by using method attributes of the self argument:

**class** **Bag**:

**def** \_\_init\_\_(self):

self.data = []

**def** add(self, x):

self.data.append(x)

**def** addtwice(self, x):

self.add(x)

self.add(x)

Methods may reference global names in the same way as ordinary functions. The global scope associated with a method is the module containing its definition. (A class is never used as a global scope.) While one rarely encounters a good reason for using global data in a method, there are many legitimate uses of the global scope: for one thing, functions and modules imported into the global scope can be used by methods, as well as functions and classes defined in it. Usually, the class containing the method is itself defined in this global scope, and in the next section we’ll find some good reasons why a method would want to reference its own class.

Each value is an object, and therefore has a class (also called its type). It is stored asobject.\_\_class\_\_.

## 9.5. Inheritance

Of course, a language feature would not be worthy of the name “class” without supporting inheritance. The syntax for a derived class definition looks like this:

**class** **DerivedClassName**(BaseClassName):

<statement-1>

.

.

.

<statement-N>

The name BaseClassName must be defined in a scope containing the derived class definition. In place of a base class name, other arbitrary expressions are also allowed. This can be useful, for example, when the base class is defined in another module:

**class** **DerivedClassName**(modname.BaseClassName):

Execution of a derived class definition proceeds the same as for a base class. When the class object is constructed, the base class is remembered. This is used for resolving attribute references: if a requested attribute is not found in the class, the search proceeds to look in the base class. This rule is applied recursively if the base class itself is derived from some other class.

There’s nothing special about instantiation of derived classes: DerivedClassName() creates a new instance of the class. Method references are resolved as follows: the corresponding class attribute is searched, descending down the chain of base classes if necessary, and the method reference is valid if this yields a function object.

Derived classes may override methods of their base classes. Because methods have no special privileges when calling other methods of the same object, a method of a base class that calls another method defined in the same base class may end up calling a method of a derived class that overrides it. (For C++ programmers: all methods in Python are effectively virtual.)

An overriding method in a derived class may in fact want to extend rather than simply replace the base class method of the same name. There is a simple way to call the base class method directly: just callBaseClassName.methodname(self, arguments). This is occasionally useful to clients as well. (Note that this only works if the base class is accessible as BaseClassName in the global scope.)

Python has two built-in functions that work with inheritance:

* Use [isinstance()](https://docs.python.org/3/library/functions.html#isinstance) to check an instance’s type: isinstance(obj, int) will be True only ifobj.\_\_class\_\_ is [int](https://docs.python.org/3/library/functions.html#int) or some class derived from [int](https://docs.python.org/3/library/functions.html#int).
* Use [issubclass()](https://docs.python.org/3/library/functions.html#issubclass) to check class inheritance: issubclass(bool, int) is True since [bool](https://docs.python.org/3/library/functions.html#bool) is a subclass of [int](https://docs.python.org/3/library/functions.html#int). However, issubclass(float, int) is False since [float](https://docs.python.org/3/library/functions.html#float) is not a subclass of[int](https://docs.python.org/3/library/functions.html#int).

### 9.5.1. Multiple Inheritance

Python supports a form of multiple inheritance as well. A class definition with multiple base classes looks like this:

**class** **DerivedClassName**(Base1, Base2, Base3):

<statement-1>

.

.

.

<statement-N>

For most purposes, in the simplest cases, you can think of the search for attributes inherited from a parent class as depth-first, left-to-right, not searching twice in the same class where there is an overlap in the hierarchy. Thus, if an attribute is not found in DerivedClassName, it is searched for inBase1, then (recursively) in the base classes of Base1, and if it was not found there, it was searched for in Base2, and so on.

In fact, it is slightly more complex than that; the method resolution order changes dynamically to support cooperative calls to [super()](https://docs.python.org/3/library/functions.html#super). This approach is known in some other multiple-inheritance languages as call-next-method and is more powerful than the super call found in single-inheritance languages.

Dynamic ordering is necessary because all cases of multiple inheritance exhibit one or more diamond relationships (where at least one of the parent classes can be accessed through multiple paths from the bottommost class). For example, all classes inherit from [object](https://docs.python.org/3/library/functions.html#object), so any case of multiple inheritance provides more than one path to reach [object](https://docs.python.org/3/library/functions.html#object). To keep the base classes from being accessed more than once, the dynamic algorithm linearizes the search order in a way that preserves the left-to-right ordering specified in each class, that calls each parent only once, and that is monotonic (meaning that a class can be subclassed without affecting the precedence order of its parents). Taken together, these properties make it possible to design reliable and extensible classes with multiple inheritance. For more detail, see <https://www.python.org/download/releases/2.3/mro/>.

## 9.6. Private Variables

“Private” instance variables that cannot be accessed except from inside an object don’t exist in Python. However, there is a convention that is followed by most Python code: a name prefixed with an underscore (e.g. \_spam) should be treated as a non-public part of the API (whether it is a function, a method or a data member). It should be considered an implementation detail and subject to change without notice.

Since there is a valid use-case for class-private members (namely to avoid name clashes of names with names defined by subclasses), there is limited support for such a mechanism, called name mangling. Any identifier of the form \_\_spam (at least two leading underscores, at most one trailing underscore) is textually replaced with \_classname\_\_spam, where classname is the current class name with leading underscore(s) stripped. This mangling is done without regard to the syntactic position of the identifier, as long as it occurs within the definition of a class.

Name mangling is helpful for letting subclasses override methods without breaking intraclass method calls. For example:

**class** **Mapping**:

**def** \_\_init\_\_(self, iterable):

self.items\_list = []

self.\_\_update(iterable)

**def** update(self, iterable):

**for** item **in** iterable:

self.items\_list.append(item)

\_\_update = update *# private copy of original update() method*

**class** **MappingSubclass**(Mapping):

**def** update(self, keys, values):

*# provides new signature for update()*

*# but does not break \_\_init\_\_()*

**for** item **in** zip(keys, values):

self.items\_list.append(item)

Note that the mangling rules are designed mostly to avoid accidents; it still is possible to access or modify a variable that is considered private. This can even be useful in special circumstances, such as in the debugger.

Notice that code passed to exec() or eval() does not consider the classname of the invoking class to be the current class; this is similar to the effect of the global statement, the effect of which is likewise restricted to code that is byte-compiled together. The same restriction applies to getattr(),setattr() and delattr(), as well as when referencing \_\_dict\_\_ directly.

## 9.7. Odds and Ends

Sometimes it is useful to have a data type similar to the Pascal “record” or C “struct”, bundling together a few named data items. An empty class definition will do nicely:

**class** **Employee**:

**pass**

john = Employee() *# Create an empty employee record*

*# Fill the fields of the record*

john.name = 'John Doe'

john.dept = 'computer lab'

john.salary = 1000

A piece of Python code that expects a particular abstract data type can often be passed a class that emulates the methods of that data type instead. For instance, if you have a function that formats some data from a file object, you can define a class with methods read() and readline() that get the data from a string buffer instead, and pass it as an argument.

Instance method objects have attributes, too: m.\_\_self\_\_ is the instance object with the method m(), and m.\_\_func\_\_ is the function object corresponding to the method.

## 9.8. Exceptions Are Classes Too

User-defined exceptions are identified by classes as well. Using this mechanism it is possible to create extensible hierarchies of exceptions.

There are two new valid (semantic) forms for the [raise](https://docs.python.org/3/reference/simple_stmts.html#raise) statement:

**raise** Class

**raise** Instance

In the first form, Class must be an instance of [type](https://docs.python.org/3/library/functions.html#type) or of a class derived from it. The first form is a shorthand for:

**raise** Class()

A class in an [except](https://docs.python.org/3/reference/compound_stmts.html#except) clause is compatible with an exception if it is the same class or a base class thereof (but not the other way around — an except clause listing a derived class is not compatible with a base class). For example, the following code will print B, C, D in that order:

**class** **B**(Exception):

**pass**

**class** **C**(B):

**pass**

**class** **D**(C):

**pass**

**for** cls **in** [B, C, D]:

**try**:

**raise** cls()

**except** D:

print("D")

**except** C:

print("C")

**except** B:

print("B")

Note that if the except clauses were reversed (with except B first), it would have printed B, B, B — the first matching except clause is triggered.

When an error message is printed for an unhandled exception, the exception’s class name is printed, then a colon and a space, and finally the instance converted to a string using the built-in function[str()](https://docs.python.org/3/library/stdtypes.html#str).

## 9.9. Iterators

By now you have probably noticed that most container objects can be looped over using a [for](https://docs.python.org/3/reference/compound_stmts.html#for)statement:

**for** element **in** [1, 2, 3]:

print(element)

**for** element **in** (1, 2, 3):

print(element)

**for** key **in** {'one':1, 'two':2}:

print(key)

**for** char **in** "123":

print(char)

**for** line **in** open("myfile.txt"):

print(line, end='')

This style of access is clear, concise, and convenient. The use of iterators pervades and unifies Python. Behind the scenes, the [for](https://docs.python.org/3/reference/compound_stmts.html#for) statement calls [iter()](https://docs.python.org/3/library/functions.html#iter) on the container object. The function returns an iterator object that defines the method [\_\_next\_\_()](https://docs.python.org/3/library/stdtypes.html#iterator.__next__) which accesses elements in the container one at a time. When there are no more elements, [\_\_next\_\_()](https://docs.python.org/3/library/stdtypes.html#iterator.__next__) raises a [StopIteration](https://docs.python.org/3/library/exceptions.html#StopIteration)exception which tells the [for](https://docs.python.org/3/reference/compound_stmts.html#for) loop to terminate. You can call the [\_\_next\_\_()](https://docs.python.org/3/library/stdtypes.html#iterator.__next__) method using the[next()](https://docs.python.org/3/library/functions.html#next) built-in function; this example shows how it all works:

>>>

**>>>** s = 'abc'

**>>>** it = iter(s)

**>>>** it

<iterator object at 0x00A1DB50>

**>>>** next(it)

'a'

**>>>** next(it)

'b'

**>>>** next(it)

'c'

**>>>** next(it)

Traceback (most recent call last):

File "<stdin>", line 1, in ?

next(it)

StopIteration

Having seen the mechanics behind the iterator protocol, it is easy to add iterator behavior to your classes. Define an [\_\_iter\_\_()](https://docs.python.org/3/reference/datamodel.html#object.__iter__) method which returns an object with a [\_\_next\_\_()](https://docs.python.org/3/library/stdtypes.html#iterator.__next__) method. If the class defines \_\_next\_\_(), then [\_\_iter\_\_()](https://docs.python.org/3/reference/datamodel.html#object.__iter__) can just return self:

**class** **Reverse**:

*"""Iterator for looping over a sequence backwards."""*

**def** \_\_init\_\_(self, data):

self.data = data

self.index = len(data)

**def** \_\_iter\_\_(self):

**return** self

**def** \_\_next\_\_(self):

**if** self.index == 0:

**raise** StopIteration

self.index = self.index - 1

**return** self.data[self.index]

>>>

**>>>** rev = Reverse('spam')

**>>>** iter(rev)

<\_\_main\_\_.Reverse object at 0x00A1DB50>

**>>> for** char **in** rev:

**...**  print(char)

**...**

m

a

p

s

## 9.10. Generators

[Generator](https://docs.python.org/3/glossary.html#term-generator)s are a simple and powerful tool for creating iterators. They are written like regular functions but use the [yield](https://docs.python.org/3/reference/simple_stmts.html#yield) statement whenever they want to return data. Each time [next()](https://docs.python.org/3/library/functions.html#next) is called on it, the generator resumes where it left off (it remembers all the data values and which statement was last executed). An example shows that generators can be trivially easy to create:

**def** reverse(data):

**for** index **in** range(len(data)-1, -1, -1):

**yield** data[index]

>>>

**>>> for** char **in** reverse('golf'):

**...**  print(char)

**...**

f

l

o

g

Anything that can be done with generators can also be done with class-based iterators as described in the previous section. What makes generators so compact is that the [\_\_iter\_\_()](https://docs.python.org/3/reference/datamodel.html#object.__iter__) and [\_\_next\_\_()](https://docs.python.org/3/reference/expressions.html#generator.__next__)methods are created automatically.

Another key feature is that the local variables and execution state are automatically saved between calls. This made the function easier to write and much more clear than an approach using instance variables like self.index and self.data.

In addition to automatic method creation and saving program state, when generators terminate, they automatically raise [StopIteration](https://docs.python.org/3/library/exceptions.html#StopIteration). In combination, these features make it easy to create iterators with no more effort than writing a regular function.

## 9.11. Generator Expressions

Some simple generators can be coded succinctly as expressions using a syntax similar to list comprehensions but with parentheses instead of brackets. These expressions are designed for situations where the generator is used right away by an enclosing function. Generator expressions are more compact but less versatile than full generator definitions and tend to be more memory friendly than equivalent list comprehensions.

Examples:

>>>

**>>>** sum(i\*i **for** i **in** range(10)) *# sum of squares*

285

**>>>** xvec = [10, 20, 30]

**>>>** yvec = [7, 5, 3]

**>>>** sum(x\*y **for** x,y **in** zip(xvec, yvec)) *# dot product*

260

**>>> from** **math** **import** pi, sin

**>>>** sine\_table = {x: sin(x\*pi/180) **for** x **in** range(0, 91)}

**>>>** unique\_words = set(word **for** line **in** page **for** word **in** line.split())

**>>>** valedictorian = max((student.gpa, student.name) **for** student **in** graduates)

**>>>** data = 'golf'

**>>>** list(data[i] **for** i **in** range(len(data)-1, -1, -1))

['f', 'l', 'o', 'g']

**Footnotes**

|  |  |
| --- | --- |
| [[1]](https://docs.python.org/3/tutorial/classes.html#id1) | Except for one thing. Module objects have a secret read-only attribute called [\_\_dict\_\_](https://docs.python.org/3/library/stdtypes.html#object.__dict__) which returns the dictionary used to implement the module’s namespace; the name [\_\_dict\_\_](https://docs.python.org/3/library/stdtypes.html#object.__dict__) is an attribute but not a global name. Obviously, using this violates the abstraction of namespace implementation, and should be restricted to things like post-mortem debuggers. |

# 9. Classes

Compared with other programming languages, Python’s class mechanism adds classes with a minimum of new syntax and semantics. It is a mixture of the class mechanisms found in C++ and Modula-3. Python classes provide all the standard features of Object Oriented Programming: the class inheritance mechanism allows multiple base classes, a derived class can override any methods of its base class or classes, and a method can call the method of a base class with the same name. Objects can contain arbitrary amounts and kinds of data. As is true for modules, classes partake of the dynamic nature of Python: they are created at runtime, and can be modified further after creation.

In C++ terminology, normally class members (including the data members) are public (except see below [Private Variables](https://docs.python.org/3/tutorial/classes.html#tut-private)), and all member functions are virtual. As in Modula-3, there are no shorthands for referencing the object’s members from its methods: the method function is declared with an explicit first argument representing the object, which is provided implicitly by the call. As in Smalltalk, classes themselves are objects. This provides semantics for importing and renaming. Unlike C++ and Modula-3, built-in types can be used as base classes for extension by the user. Also, like in C++, most built-in operators with special syntax (arithmetic operators, subscripting etc.) can be redefined for class instances.

(Lacking universally accepted terminology to talk about classes, I will make occasional use of Smalltalk and C++ terms. I would use Modula-3 terms, since its object-oriented semantics are closer to those of Python than C++, but I expect that few readers have heard of it.)

## 9.1. A Word About Names and Objects

Objects have individuality, and multiple names (in multiple scopes) can be bound to the same object. This is known as aliasing in other languages. This is usually not appreciated on a first glance at Python, and can be safely ignored when dealing with immutable basic types (numbers, strings, tuples). However, aliasing has a possibly surprising effect on the semantics of Python code involving mutable objects such as lists, dictionaries, and most other types. This is usually used to the benefit of the program, since aliases behave like pointers in some respects. For example, passing an object is cheap since only a pointer is passed by the implementation; and if a function modifies an object passed as an argument, the caller will see the change — this eliminates the need for two different argument passing mechanisms as in Pascal.

## 9.2. Python Scopes and Namespaces

Before introducing classes, I first have to tell you something about Python’s scope rules. Class definitions play some neat tricks with namespaces, and you need to know how scopes and namespaces work to fully understand what’s going on. Incidentally, knowledge about this subject is useful for any advanced Python programmer.

Let’s begin with some definitions.

A namespace is a mapping from names to objects. Most namespaces are currently implemented as Python dictionaries, but that’s normally not noticeable in any way (except for performance), and it may change in the future. Examples of namespaces are: the set of built-in names (containing functions such as [abs()](https://docs.python.org/3/library/functions.html#abs), and built-in exception names); the global names in a module; and the local names in a function invocation. In a sense the set of attributes of an object also form a namespace. The important thing to know about namespaces is that there is absolutely no relation between names in different namespaces; for instance, two different modules may both define a function maximize without confusion — users of the modules must prefix it with the module name.

By the way, I use the word attribute for any name following a dot — for example, in the expressionz.real, real is an attribute of the object z. Strictly speaking, references to names in modules are attribute references: in the expression modname.funcname, modname is a module object and funcnameis an attribute of it. In this case there happens to be a straightforward mapping between the module’s attributes and the global names defined in the module: they share the same namespace! [[1]](https://docs.python.org/3/tutorial/classes.html#id2)

Attributes may be read-only or writable. In the latter case, assignment to attributes is possible. Module attributes are writable: you can write modname.the\_answer = 42. Writable attributes may also be deleted with the [del](https://docs.python.org/3/reference/simple_stmts.html#del) statement. For example, del modname.the\_answer will remove the attributethe\_answer from the object named by modname.

Namespaces are created at different moments and have different lifetimes. The namespace containing the built-in names is created when the Python interpreter starts up, and is never deleted. The global namespace for a module is created when the module definition is read in; normally, module namespaces also last until the interpreter quits. The statements executed by the top-level invocation of the interpreter, either read from a script file or interactively, are considered part of a module called[\_\_main\_\_](https://docs.python.org/3/library/__main__.html#module-__main__), so they have their own global namespace. (The built-in names actually also live in a module; this is called [builtins](https://docs.python.org/3/library/builtins.html#module-builtins).)

The local namespace for a function is created when the function is called, and deleted when the function returns or raises an exception that is not handled within the function. (Actually, forgetting would be a better way to describe what actually happens.) Of course, recursive invocations each have their own local namespace.

A scope is a textual region of a Python program where a namespace is directly accessible. “Directly accessible” here means that an unqualified reference to a name attempts to find the name in the namespace.

Although scopes are determined statically, they are used dynamically. At any time during execution, there are at least three nested scopes whose namespaces are directly accessible:

* the innermost scope, which is searched first, contains the local names
* the scopes of any enclosing functions, which are searched starting with the nearest enclosing scope, contains non-local, but also non-global names
* the next-to-last scope contains the current module’s global names
* the outermost scope (searched last) is the namespace containing built-in names

If a name is declared global, then all references and assignments go directly to the middle scope containing the module’s global names. To rebind variables found outside of the innermost scope, the[nonlocal](https://docs.python.org/3/reference/simple_stmts.html#nonlocal) statement can be used; if not declared nonlocal, those variables are read-only (an attempt to write to such a variable will simply create a new local variable in the innermost scope, leaving the identically named outer variable unchanged).

Usually, the local scope references the local names of the (textually) current function. Outside functions, the local scope references the same namespace as the global scope: the module’s namespace. Class definitions place yet another namespace in the local scope.

It is important to realize that scopes are determined textually: the global scope of a function defined in a module is that module’s namespace, no matter from where or by what alias the function is called. On the other hand, the actual search for names is done dynamically, at run time — however, the language definition is evolving towards static name resolution, at “compile” time, so don’t rely on dynamic name resolution! (In fact, local variables are already determined statically.)

A special quirk of Python is that – if no [global](https://docs.python.org/3/reference/simple_stmts.html#global) statement is in effect – assignments to names always go into the innermost scope. Assignments do not copy data — they just bind names to objects. The same is true for deletions: the statement del x removes the binding of x from the namespace referenced by the local scope. In fact, all operations that introduce new names use the local scope: in particular, [import](https://docs.python.org/3/reference/simple_stmts.html#import) statements and function definitions bind the module or function name in the local scope.

The [global](https://docs.python.org/3/reference/simple_stmts.html#global) statement can be used to indicate that particular variables live in the global scope and should be rebound there; the [nonlocal](https://docs.python.org/3/reference/simple_stmts.html#nonlocal) statement indicates that particular variables live in an enclosing scope and should be rebound there.

### 9.2.1. Scopes and Namespaces Example

This is an example demonstrating how to reference the different scopes and namespaces, and how[global](https://docs.python.org/3/reference/simple_stmts.html#global) and [nonlocal](https://docs.python.org/3/reference/simple_stmts.html#nonlocal) affect variable binding:

**def** scope\_test():

**def** do\_local():

spam = "local spam"

**def** do\_nonlocal():

**nonlocal** spam

spam = "nonlocal spam"

**def** do\_global():

**global** spam

spam = "global spam"

spam = "test spam"

do\_local()

print("After local assignment:", spam)

do\_nonlocal()

print("After nonlocal assignment:", spam)

do\_global()

print("After global assignment:", spam)

scope\_test()

print("In global scope:", spam)

The output of the example code is:

After local assignment: test spam

After nonlocal assignment: nonlocal spam

After global assignment: nonlocal spam

In global scope: global spam

Note how the local assignment (which is default) didn’t change scope\_test‘s binding of spam. The[nonlocal](https://docs.python.org/3/reference/simple_stmts.html#nonlocal) assignment changed scope\_test‘s binding of spam, and the [global](https://docs.python.org/3/reference/simple_stmts.html#global) assignment changed the module-level binding.

You can also see that there was no previous binding for spam before the [global](https://docs.python.org/3/reference/simple_stmts.html#global) assignment.

## 9.3. A First Look at Classes

Classes introduce a little bit of new syntax, three new object types, and some new semantics.

### 9.3.1. Class Definition Syntax

The simplest form of class definition looks like this:

**class** **ClassName**:

<statement-1>

.

.

.

<statement-N>

Class definitions, like function definitions ([def](https://docs.python.org/3/reference/compound_stmts.html#def) statements) must be executed before they have any effect. (You could conceivably place a class definition in a branch of an [if](https://docs.python.org/3/reference/compound_stmts.html#if) statement, or inside a function.)

In practice, the statements inside a class definition will usually be function definitions, but other statements are allowed, and sometimes useful — we’ll come back to this later. The function definitions inside a class normally have a peculiar form of argument list, dictated by the calling conventions for methods — again, this is explained later.

When a class definition is entered, a new namespace is created, and used as the local scope — thus, all assignments to local variables go into this new namespace. In particular, function definitions bind the name of the new function here.

When a class definition is left normally (via the end), a class object is created. This is basically a wrapper around the contents of the namespace created by the class definition; we’ll learn more about class objects in the next section. The original local scope (the one in effect just before the class definition was entered) is reinstated, and the class object is bound here to the class name given in the class definition header (ClassName in the example).

### 9.3.2. Class Objects

Class objects support two kinds of operations: attribute references and instantiation.

Attribute references use the standard syntax used for all attribute references in Python: obj.name. Valid attribute names are all the names that were in the class’s namespace when the class object was created. So, if the class definition looked like this:

**class** **MyClass**:

*"""A simple example class"""*

i = 12345

**def** f(self):

**return** 'hello world'

then MyClass.i and MyClass.f are valid attribute references, returning an integer and a function object, respectively. Class attributes can also be assigned to, so you can change the value ofMyClass.i by assignment. \_\_doc\_\_ is also a valid attribute, returning the docstring belonging to the class: "A simple example class".

Class instantiation uses function notation. Just pretend that the class object is a parameterless function that returns a new instance of the class. For example (assuming the above class):

x = MyClass()

creates a new instance of the class and assigns this object to the local variable x.

The instantiation operation (“calling” a class object) creates an empty object. Many classes like to create objects with instances customized to a specific initial state. Therefore a class may define a special method named [\_\_init\_\_()](https://docs.python.org/3/reference/datamodel.html#object.__init__), like this:

**def** \_\_init\_\_(self):

self.data = []

When a class defines an [\_\_init\_\_()](https://docs.python.org/3/reference/datamodel.html#object.__init__) method, class instantiation automatically invokes [\_\_init\_\_()](https://docs.python.org/3/reference/datamodel.html#object.__init__)for the newly-created class instance. So in this example, a new, initialized instance can be obtained by:

x = MyClass()

Of course, the [\_\_init\_\_()](https://docs.python.org/3/reference/datamodel.html#object.__init__) method may have arguments for greater flexibility. In that case, arguments given to the class instantiation operator are passed on to [\_\_init\_\_()](https://docs.python.org/3/reference/datamodel.html#object.__init__). For example,

>>>

**>>> class** **Complex**:

**...**  **def** \_\_init\_\_(self, realpart, imagpart):

**...**  self.r = realpart

**...**  self.i = imagpart

**...**

**>>>** x = Complex(3.0, -4.5)

**>>>** x.r, x.i

(3.0, -4.5)

### 9.3.3. Instance Objects

Now what can we do with instance objects? The only operations understood by instance objects are attribute references. There are two kinds of valid attribute names, data attributes and methods.

data attributes correspond to “instance variables” in Smalltalk, and to “data members” in C++. Data attributes need not be declared; like local variables, they spring into existence when they are first assigned to. For example, if x is the instance of MyClass created above, the following piece of code will print the value 16, without leaving a trace:

x.counter = 1

**while** x.counter < 10:

x.counter = x.counter \* 2

print(x.counter)

**del** x.counter

The other kind of instance attribute reference is a method. A method is a function that “belongs to” an object. (In Python, the term method is not unique to class instances: other object types can have methods as well. For example, list objects have methods called append, insert, remove, sort, and so on. However, in the following discussion, we’ll use the term method exclusively to mean methods of class instance objects, unless explicitly stated otherwise.)

Valid method names of an instance object depend on its class. By definition, all attributes of a class that are function objects define corresponding methods of its instances. So in our example, x.f is a valid method reference, since MyClass.f is a function, but x.i is not, since MyClass.i is not. But x.fis not the same thing as MyClass.f — it is a method object, not a function object.

### 9.3.4. Method Objects

Usually, a method is called right after it is bound:

x.f()

In the MyClass example, this will return the string 'hello world'. However, it is not necessary to call a method right away: x.f is a method object, and can be stored away and called at a later time. For example:

xf = x.f

**while** **True**:

print(xf())

will continue to print hello world until the end of time.

What exactly happens when a method is called? You may have noticed that x.f() was called without an argument above, even though the function definition for f() specified an argument. What happened to the argument? Surely Python raises an exception when a function that requires an argument is called without any — even if the argument isn’t actually used...

Actually, you may have guessed the answer: the special thing about methods is that the object is passed as the first argument of the function. In our example, the call x.f() is exactly equivalent toMyClass.f(x). In general, calling a method with a list of n arguments is equivalent to calling the corresponding function with an argument list that is created by inserting the method’s object before the first argument.

If you still don’t understand how methods work, a look at the implementation can perhaps clarify matters. When an instance attribute is referenced that isn’t a data attribute, its class is searched. If the name denotes a valid class attribute that is a function object, a method object is created by packing (pointers to) the instance object and the function object just found together in an abstract object: this is the method object. When the method object is called with an argument list, a new argument list is constructed from the instance object and the argument list, and the function object is called with this new argument list.

### 9.3.5. Class and Instance Variables

Generally speaking, instance variables are for data unique to each instance and class variables are for attributes and methods shared by all instances of the class:

**class** **Dog**:

kind = 'canine' *# class variable shared by all instances*

**def** \_\_init\_\_(self, name):

self.name = name *# instance variable unique to each instance*

>>> d = Dog('Fido')

>>> e = Dog('Buddy')

>>> d.kind *# shared by all dogs*

'canine'

>>> e.kind *# shared by all dogs*

'canine'

>>> d.name *# unique to d*

'Fido'

>>> e.name *# unique to e*

'Buddy'

As discussed in [A Word About Names and Objects](https://docs.python.org/3/tutorial/classes.html#tut-object), shared data can have possibly surprising effects with involving [mutable](https://docs.python.org/3/glossary.html#term-mutable) objects such as lists and dictionaries. For example, the tricks list in the following code should not be used as a class variable because just a single list would be shared by all Doginstances:

**class** **Dog**:

tricks = [] *# mistaken use of a class variable*

**def** \_\_init\_\_(self, name):

self.name = name

**def** add\_trick(self, trick):

self.tricks.append(trick)

>>> d = Dog('Fido')

>>> e = Dog('Buddy')

>>> d.add\_trick('roll over')

>>> e.add\_trick('play dead')

>>> d.tricks *# unexpectedly shared by all dogs*

['roll over', 'play dead']

Correct design of the class should use an instance variable instead:

**class** **Dog**:

**def** \_\_init\_\_(self, name):

self.name = name

self.tricks = [] *# creates a new empty list for each dog*

**def** add\_trick(self, trick):

self.tricks.append(trick)

>>> d = Dog('Fido')

>>> e = Dog('Buddy')

>>> d.add\_trick('roll over')

>>> e.add\_trick('play dead')

>>> d.tricks

['roll over']

>>> e.tricks

['play dead']

## 9.4. Random Remarks

Data attributes override method attributes with the same name; to avoid accidental name conflicts, which may cause hard-to-find bugs in large programs, it is wise to use some kind of convention that minimizes the chance of conflicts. Possible conventions include capitalizing method names, prefixing data attribute names with a small unique string (perhaps just an underscore), or using verbs for methods and nouns for data attributes.

Data attributes may be referenced by methods as well as by ordinary users (“clients”) of an object. In other words, classes are not usable to implement pure abstract data types. In fact, nothing in Python makes it possible to enforce data hiding — it is all based upon convention. (On the other hand, the Python implementation, written in C, can completely hide implementation details and control access to an object if necessary; this can be used by extensions to Python written in C.)

Clients should use data attributes with care — clients may mess up invariants maintained by the methods by stamping on their data attributes. Note that clients may add data attributes of their own to an instance object without affecting the validity of the methods, as long as name conflicts are avoided — again, a naming convention can save a lot of headaches here.

There is no shorthand for referencing data attributes (or other methods!) from within methods. I find that this actually increases the readability of methods: there is no chance of confusing local variables and instance variables when glancing through a method.

Often, the first argument of a method is called self. This is nothing more than a convention: the nameself has absolutely no special meaning to Python. Note, however, that by not following the convention your code may be less readable to other Python programmers, and it is also conceivable that a class browser program might be written that relies upon such a convention.

Any function object that is a class attribute defines a method for instances of that class. It is not necessary that the function definition is textually enclosed in the class definition: assigning a function object to a local variable in the class is also ok. For example:

*# Function defined outside the class*

**def** f1(self, x, y):

**return** min(x, x+y)

**class** **C**:

f = f1

**def** g(self):

**return** 'hello world'

h = g

Now f, g and h are all attributes of class C that refer to function objects, and consequently they are all methods of instances of C — h being exactly equivalent to g. Note that this practice usually only serves to confuse the reader of a program.

Methods may call other methods by using method attributes of the self argument:

**class** **Bag**:

**def** \_\_init\_\_(self):

self.data = []

**def** add(self, x):

self.data.append(x)

**def** addtwice(self, x):

self.add(x)

self.add(x)

Methods may reference global names in the same way as ordinary functions. The global scope associated with a method is the module containing its definition. (A class is never used as a global scope.) While one rarely encounters a good reason for using global data in a method, there are many legitimate uses of the global scope: for one thing, functions and modules imported into the global scope can be used by methods, as well as functions and classes defined in it. Usually, the class containing the method is itself defined in this global scope, and in the next section we’ll find some good reasons why a method would want to reference its own class.

Each value is an object, and therefore has a class (also called its type). It is stored asobject.\_\_class\_\_.

## 9.5. Inheritance

Of course, a language feature would not be worthy of the name “class” without supporting inheritance. The syntax for a derived class definition looks like this:

**class** **DerivedClassName**(BaseClassName):

<statement-1>

.

.

.

<statement-N>

The name BaseClassName must be defined in a scope containing the derived class definition. In place of a base class name, other arbitrary expressions are also allowed. This can be useful, for example, when the base class is defined in another module:

**class** **DerivedClassName**(modname.BaseClassName):

Execution of a derived class definition proceeds the same as for a base class. When the class object is constructed, the base class is remembered. This is used for resolving attribute references: if a requested attribute is not found in the class, the search proceeds to look in the base class. This rule is applied recursively if the base class itself is derived from some other class.

There’s nothing special about instantiation of derived classes: DerivedClassName() creates a new instance of the class. Method references are resolved as follows: the corresponding class attribute is searched, descending down the chain of base classes if necessary, and the method reference is valid if this yields a function object.

Derived classes may override methods of their base classes. Because methods have no special privileges when calling other methods of the same object, a method of a base class that calls another method defined in the same base class may end up calling a method of a derived class that overrides it. (For C++ programmers: all methods in Python are effectively virtual.)

An overriding method in a derived class may in fact want to extend rather than simply replace the base class method of the same name. There is a simple way to call the base class method directly: just callBaseClassName.methodname(self, arguments). This is occasionally useful to clients as well. (Note that this only works if the base class is accessible as BaseClassName in the global scope.)

Python has two built-in functions that work with inheritance:

* Use [isinstance()](https://docs.python.org/3/library/functions.html#isinstance) to check an instance’s type: isinstance(obj, int) will be True only ifobj.\_\_class\_\_ is [int](https://docs.python.org/3/library/functions.html#int) or some class derived from [int](https://docs.python.org/3/library/functions.html#int).
* Use [issubclass()](https://docs.python.org/3/library/functions.html#issubclass) to check class inheritance: issubclass(bool, int) is True since [bool](https://docs.python.org/3/library/functions.html#bool) is a subclass of [int](https://docs.python.org/3/library/functions.html#int). However, issubclass(float, int) is False since [float](https://docs.python.org/3/library/functions.html#float) is not a subclass of[int](https://docs.python.org/3/library/functions.html#int).

### 9.5.1. Multiple Inheritance

Python supports a form of multiple inheritance as well. A class definition with multiple base classes looks like this:

**class** **DerivedClassName**(Base1, Base2, Base3):

<statement-1>

.

.

.

<statement-N>

For most purposes, in the simplest cases, you can think of the search for attributes inherited from a parent class as depth-first, left-to-right, not searching twice in the same class where there is an overlap in the hierarchy. Thus, if an attribute is not found in DerivedClassName, it is searched for inBase1, then (recursively) in the base classes of Base1, and if it was not found there, it was searched for in Base2, and so on.

In fact, it is slightly more complex than that; the method resolution order changes dynamically to support cooperative calls to [super()](https://docs.python.org/3/library/functions.html#super). This approach is known in some other multiple-inheritance languages as call-next-method and is more powerful than the super call found in single-inheritance languages.

Dynamic ordering is necessary because all cases of multiple inheritance exhibit one or more diamond relationships (where at least one of the parent classes can be accessed through multiple paths from the bottommost class). For example, all classes inherit from [object](https://docs.python.org/3/library/functions.html#object), so any case of multiple inheritance provides more than one path to reach [object](https://docs.python.org/3/library/functions.html#object). To keep the base classes from being accessed more than once, the dynamic algorithm linearizes the search order in a way that preserves the left-to-right ordering specified in each class, that calls each parent only once, and that is monotonic (meaning that a class can be subclassed without affecting the precedence order of its parents). Taken together, these properties make it possible to design reliable and extensible classes with multiple inheritance. For more detail, see <https://www.python.org/download/releases/2.3/mro/>.

## 9.6. Private Variables

“Private” instance variables that cannot be accessed except from inside an object don’t exist in Python. However, there is a convention that is followed by most Python code: a name prefixed with an underscore (e.g. \_spam) should be treated as a non-public part of the API (whether it is a function, a method or a data member). It should be considered an implementation detail and subject to change without notice.

Since there is a valid use-case for class-private members (namely to avoid name clashes of names with names defined by subclasses), there is limited support for such a mechanism, called name mangling. Any identifier of the form \_\_spam (at least two leading underscores, at most one trailing underscore) is textually replaced with \_classname\_\_spam, where classname is the current class name with leading underscore(s) stripped. This mangling is done without regard to the syntactic position of the identifier, as long as it occurs within the definition of a class.

Name mangling is helpful for letting subclasses override methods without breaking intraclass method calls. For example:

**class** **Mapping**:

**def** \_\_init\_\_(self, iterable):

self.items\_list = []

self.\_\_update(iterable)

**def** update(self, iterable):

**for** item **in** iterable:

self.items\_list.append(item)

\_\_update = update *# private copy of original update() method*

**class** **MappingSubclass**(Mapping):

**def** update(self, keys, values):

*# provides new signature for update()*

*# but does not break \_\_init\_\_()*

**for** item **in** zip(keys, values):

self.items\_list.append(item)

Note that the mangling rules are designed mostly to avoid accidents; it still is possible to access or modify a variable that is considered private. This can even be useful in special circumstances, such as in the debugger.

Notice that code passed to exec() or eval() does not consider the classname of the invoking class to be the current class; this is similar to the effect of the global statement, the effect of which is likewise restricted to code that is byte-compiled together. The same restriction applies to getattr(),setattr() and delattr(), as well as when referencing \_\_dict\_\_ directly.

## 9.7. Odds and Ends

Sometimes it is useful to have a data type similar to the Pascal “record” or C “struct”, bundling together a few named data items. An empty class definition will do nicely:

**class** **Employee**:

**pass**

john = Employee() *# Create an empty employee record*

*# Fill the fields of the record*

john.name = 'John Doe'

john.dept = 'computer lab'

john.salary = 1000

A piece of Python code that expects a particular abstract data type can often be passed a class that emulates the methods of that data type instead. For instance, if you have a function that formats some data from a file object, you can define a class with methods read() and readline() that get the data from a string buffer instead, and pass it as an argument.

Instance method objects have attributes, too: m.\_\_self\_\_ is the instance object with the method m(), and m.\_\_func\_\_ is the function object corresponding to the method.

## 9.8. Exceptions Are Classes Too

User-defined exceptions are identified by classes as well. Using this mechanism it is possible to create extensible hierarchies of exceptions.

There are two new valid (semantic) forms for the [raise](https://docs.python.org/3/reference/simple_stmts.html#raise) statement:

**raise** Class

**raise** Instance

In the first form, Class must be an instance of [type](https://docs.python.org/3/library/functions.html#type) or of a class derived from it. The first form is a shorthand for:

**raise** Class()

A class in an [except](https://docs.python.org/3/reference/compound_stmts.html#except) clause is compatible with an exception if it is the same class or a base class thereof (but not the other way around — an except clause listing a derived class is not compatible with a base class). For example, the following code will print B, C, D in that order:

**class** **B**(Exception):

**pass**

**class** **C**(B):

**pass**

**class** **D**(C):

**pass**

**for** cls **in** [B, C, D]:

**try**:

**raise** cls()

**except** D:

print("D")

**except** C:

print("C")

**except** B:

print("B")

Note that if the except clauses were reversed (with except B first), it would have printed B, B, B — the first matching except clause is triggered.

When an error message is printed for an unhandled exception, the exception’s class name is printed, then a colon and a space, and finally the instance converted to a string using the built-in function[str()](https://docs.python.org/3/library/stdtypes.html#str).

## 9.9. Iterators

By now you have probably noticed that most container objects can be looped over using a [for](https://docs.python.org/3/reference/compound_stmts.html#for)statement:

**for** element **in** [1, 2, 3]:

print(element)

**for** element **in** (1, 2, 3):

print(element)

**for** key **in** {'one':1, 'two':2}:

print(key)

**for** char **in** "123":

print(char)

**for** line **in** open("myfile.txt"):

print(line, end='')

This style of access is clear, concise, and convenient. The use of iterators pervades and unifies Python. Behind the scenes, the [for](https://docs.python.org/3/reference/compound_stmts.html#for) statement calls [iter()](https://docs.python.org/3/library/functions.html#iter) on the container object. The function returns an iterator object that defines the method [\_\_next\_\_()](https://docs.python.org/3/library/stdtypes.html#iterator.__next__) which accesses elements in the container one at a time. When there are no more elements, [\_\_next\_\_()](https://docs.python.org/3/library/stdtypes.html#iterator.__next__) raises a [StopIteration](https://docs.python.org/3/library/exceptions.html#StopIteration)exception which tells the [for](https://docs.python.org/3/reference/compound_stmts.html#for) loop to terminate. You can call the [\_\_next\_\_()](https://docs.python.org/3/library/stdtypes.html#iterator.__next__) method using the[next()](https://docs.python.org/3/library/functions.html#next) built-in function; this example shows how it all works:

>>>

**>>>** s = 'abc'

**>>>** it = iter(s)

**>>>** it

<iterator object at 0x00A1DB50>

**>>>** next(it)

'a'

**>>>** next(it)

'b'

**>>>** next(it)

'c'

**>>>** next(it)

Traceback (most recent call last):

File "<stdin>", line 1, in ?

next(it)

StopIteration

Having seen the mechanics behind the iterator protocol, it is easy to add iterator behavior to your classes. Define an [\_\_iter\_\_()](https://docs.python.org/3/reference/datamodel.html#object.__iter__) method which returns an object with a [\_\_next\_\_()](https://docs.python.org/3/library/stdtypes.html#iterator.__next__) method. If the class defines \_\_next\_\_(), then [\_\_iter\_\_()](https://docs.python.org/3/reference/datamodel.html#object.__iter__) can just return self:

**class** **Reverse**:

*"""Iterator for looping over a sequence backwards."""*

**def** \_\_init\_\_(self, data):

self.data = data

self.index = len(data)

**def** \_\_iter\_\_(self):

**return** self

**def** \_\_next\_\_(self):

**if** self.index == 0:

**raise** StopIteration

self.index = self.index - 1

**return** self.data[self.index]

>>>

**>>>** rev = Reverse('spam')

**>>>** iter(rev)

<\_\_main\_\_.Reverse object at 0x00A1DB50>

**>>> for** char **in** rev:

**...**  print(char)

**...**

m

a

p

s

## 9.10. Generators

[Generator](https://docs.python.org/3/glossary.html#term-generator)s are a simple and powerful tool for creating iterators. They are written like regular functions but use the [yield](https://docs.python.org/3/reference/simple_stmts.html#yield) statement whenever they want to return data. Each time [next()](https://docs.python.org/3/library/functions.html#next) is called on it, the generator resumes where it left off (it remembers all the data values and which statement was last executed). An example shows that generators can be trivially easy to create:

**def** reverse(data):

**for** index **in** range(len(data)-1, -1, -1):

**yield** data[index]

>>>

**>>> for** char **in** reverse('golf'):

**...**  print(char)

**...**

f

l

o

g

Anything that can be done with generators can also be done with class-based iterators as described in the previous section. What makes generators so compact is that the [\_\_iter\_\_()](https://docs.python.org/3/reference/datamodel.html#object.__iter__) and [\_\_next\_\_()](https://docs.python.org/3/reference/expressions.html#generator.__next__)methods are created automatically.

Another key feature is that the local variables and execution state are automatically saved between calls. This made the function easier to write and much more clear than an approach using instance variables like self.index and self.data.

In addition to automatic method creation and saving program state, when generators terminate, they automatically raise [StopIteration](https://docs.python.org/3/library/exceptions.html#StopIteration). In combination, these features make it easy to create iterators with no more effort than writing a regular function.

## 9.11. Generator Expressions

Some simple generators can be coded succinctly as expressions using a syntax similar to list comprehensions but with parentheses instead of brackets. These expressions are designed for situations where the generator is used right away by an enclosing function. Generator expressions are more compact but less versatile than full generator definitions and tend to be more memory friendly than equivalent list comprehensions.

Examples:

>>>

**>>>** sum(i\*i **for** i **in** range(10)) *# sum of squares*

285

**>>>** xvec = [10, 20, 30]

**>>>** yvec = [7, 5, 3]

**>>>** sum(x\*y **for** x,y **in** zip(xvec, yvec)) *# dot product*

260

**>>> from** **math** **import** pi, sin

**>>>** sine\_table = {x: sin(x\*pi/180) **for** x **in** range(0, 91)}

**>>>** unique\_words = set(word **for** line **in** page **for** word **in** line.split())

**>>>** valedictorian = max((student.gpa, student.name) **for** student **in** graduates)

**>>>** data = 'golf'

**>>>** list(data[i] **for** i **in** range(len(data)-1, -1, -1))

['f', 'l', 'o', 'g']

**Footnotes**

|  |  |
| --- | --- |
| [[1]](https://docs.python.org/3/tutorial/classes.html#id1) | Except for one thing. Module objects have a secret read-only attribute called [\_\_dict\_\_](https://docs.python.org/3/library/stdtypes.html#object.__dict__) which returns the dictionary used to implement the module’s namespace; the name [\_\_dict\_\_](https://docs.python.org/3/library/stdtypes.html#object.__dict__) is an attribute but not a global name. Obviously, using this violates the abstraction of namespace implementation, and should be restricted to things like post-mortem debuggers. |

# 9. Classes

Compared with other programming languages, Python’s class mechanism adds classes with a minimum of new syntax and semantics. It is a mixture of the class mechanisms found in C++ and Modula-3. Python classes provide all the standard features of Object Oriented Programming: the class inheritance mechanism allows multiple base classes, a derived class can override any methods of its base class or classes, and a method can call the method of a base class with the same name. Objects can contain arbitrary amounts and kinds of data. As is true for modules, classes partake of the dynamic nature of Python: they are created at runtime, and can be modified further after creation.

In C++ terminology, normally class members (including the data members) are public (except see below [Private Variables](https://docs.python.org/3/tutorial/classes.html#tut-private)), and all member functions are virtual. As in Modula-3, there are no shorthands for referencing the object’s members from its methods: the method function is declared with an explicit first argument representing the object, which is provided implicitly by the call. As in Smalltalk, classes themselves are objects. This provides semantics for importing and renaming. Unlike C++ and Modula-3, built-in types can be used as base classes for extension by the user. Also, like in C++, most built-in operators with special syntax (arithmetic operators, subscripting etc.) can be redefined for class instances.

(Lacking universally accepted terminology to talk about classes, I will make occasional use of Smalltalk and C++ terms. I would use Modula-3 terms, since its object-oriented semantics are closer to those of Python than C++, but I expect that few readers have heard of it.)

## 9.1. A Word About Names and Objects

Objects have individuality, and multiple names (in multiple scopes) can be bound to the same object. This is known as aliasing in other languages. This is usually not appreciated on a first glance at Python, and can be safely ignored when dealing with immutable basic types (numbers, strings, tuples). However, aliasing has a possibly surprising effect on the semantics of Python code involving mutable objects such as lists, dictionaries, and most other types. This is usually used to the benefit of the program, since aliases behave like pointers in some respects. For example, passing an object is cheap since only a pointer is passed by the implementation; and if a function modifies an object passed as an argument, the caller will see the change — this eliminates the need for two different argument passing mechanisms as in Pascal.

## 9.2. Python Scopes and Namespaces

Before introducing classes, I first have to tell you something about Python’s scope rules. Class definitions play some neat tricks with namespaces, and you need to know how scopes and namespaces work to fully understand what’s going on. Incidentally, knowledge about this subject is useful for any advanced Python programmer.

Let’s begin with some definitions.

A namespace is a mapping from names to objects. Most namespaces are currently implemented as Python dictionaries, but that’s normally not noticeable in any way (except for performance), and it may change in the future. Examples of namespaces are: the set of built-in names (containing functions such as [abs()](https://docs.python.org/3/library/functions.html#abs), and built-in exception names); the global names in a module; and the local names in a function invocation. In a sense the set of attributes of an object also form a namespace. The important thing to know about namespaces is that there is absolutely no relation between names in different namespaces; for instance, two different modules may both define a function maximize without confusion — users of the modules must prefix it with the module name.

By the way, I use the word attribute for any name following a dot — for example, in the expressionz.real, real is an attribute of the object z. Strictly speaking, references to names in modules are attribute references: in the expression modname.funcname, modname is a module object and funcnameis an attribute of it. In this case there happens to be a straightforward mapping between the module’s attributes and the global names defined in the module: they share the same namespace! [[1]](https://docs.python.org/3/tutorial/classes.html#id2)

Attributes may be read-only or writable. In the latter case, assignment to attributes is possible. Module attributes are writable: you can write modname.the\_answer = 42. Writable attributes may also be deleted with the [del](https://docs.python.org/3/reference/simple_stmts.html#del) statement. For example, del modname.the\_answer will remove the attributethe\_answer from the object named by modname.

Namespaces are created at different moments and have different lifetimes. The namespace containing the built-in names is created when the Python interpreter starts up, and is never deleted. The global namespace for a module is created when the module definition is read in; normally, module namespaces also last until the interpreter quits. The statements executed by the top-level invocation of the interpreter, either read from a script file or interactively, are considered part of a module called[\_\_main\_\_](https://docs.python.org/3/library/__main__.html#module-__main__), so they have their own global namespace. (The built-in names actually also live in a module; this is called [builtins](https://docs.python.org/3/library/builtins.html#module-builtins).)

The local namespace for a function is created when the function is called, and deleted when the function returns or raises an exception that is not handled within the function. (Actually, forgetting would be a better way to describe what actually happens.) Of course, recursive invocations each have their own local namespace.

A scope is a textual region of a Python program where a namespace is directly accessible. “Directly accessible” here means that an unqualified reference to a name attempts to find the name in the namespace.

Although scopes are determined statically, they are used dynamically. At any time during execution, there are at least three nested scopes whose namespaces are directly accessible:

* the innermost scope, which is searched first, contains the local names
* the scopes of any enclosing functions, which are searched starting with the nearest enclosing scope, contains non-local, but also non-global names
* the next-to-last scope contains the current module’s global names
* the outermost scope (searched last) is the namespace containing built-in names

If a name is declared global, then all references and assignments go directly to the middle scope containing the module’s global names. To rebind variables found outside of the innermost scope, the[nonlocal](https://docs.python.org/3/reference/simple_stmts.html#nonlocal) statement can be used; if not declared nonlocal, those variables are read-only (an attempt to write to such a variable will simply create a new local variable in the innermost scope, leaving the identically named outer variable unchanged).

Usually, the local scope references the local names of the (textually) current function. Outside functions, the local scope references the same namespace as the global scope: the module’s namespace. Class definitions place yet another namespace in the local scope.

It is important to realize that scopes are determined textually: the global scope of a function defined in a module is that module’s namespace, no matter from where or by what alias the function is called. On the other hand, the actual search for names is done dynamically, at run time — however, the language definition is evolving towards static name resolution, at “compile” time, so don’t rely on dynamic name resolution! (In fact, local variables are already determined statically.)

A special quirk of Python is that – if no [global](https://docs.python.org/3/reference/simple_stmts.html#global) statement is in effect – assignments to names always go into the innermost scope. Assignments do not copy data — they just bind names to objects. The same is true for deletions: the statement del x removes the binding of x from the namespace referenced by the local scope. In fact, all operations that introduce new names use the local scope: in particular, [import](https://docs.python.org/3/reference/simple_stmts.html#import) statements and function definitions bind the module or function name in the local scope.

The [global](https://docs.python.org/3/reference/simple_stmts.html#global) statement can be used to indicate that particular variables live in the global scope and should be rebound there; the [nonlocal](https://docs.python.org/3/reference/simple_stmts.html#nonlocal) statement indicates that particular variables live in an enclosing scope and should be rebound there.

### 9.2.1. Scopes and Namespaces Example

This is an example demonstrating how to reference the different scopes and namespaces, and how[global](https://docs.python.org/3/reference/simple_stmts.html#global) and [nonlocal](https://docs.python.org/3/reference/simple_stmts.html#nonlocal) affect variable binding:

**def** scope\_test():

**def** do\_local():

spam = "local spam"

**def** do\_nonlocal():

**nonlocal** spam

spam = "nonlocal spam"

**def** do\_global():

**global** spam

spam = "global spam"

spam = "test spam"

do\_local()

print("After local assignment:", spam)

do\_nonlocal()

print("After nonlocal assignment:", spam)

do\_global()

print("After global assignment:", spam)

scope\_test()

print("In global scope:", spam)

The output of the example code is:

After local assignment: test spam

After nonlocal assignment: nonlocal spam

After global assignment: nonlocal spam

In global scope: global spam

Note how the local assignment (which is default) didn’t change scope\_test‘s binding of spam. The[nonlocal](https://docs.python.org/3/reference/simple_stmts.html#nonlocal) assignment changed scope\_test‘s binding of spam, and the [global](https://docs.python.org/3/reference/simple_stmts.html#global) assignment changed the module-level binding.

You can also see that there was no previous binding for spam before the [global](https://docs.python.org/3/reference/simple_stmts.html#global) assignment.

## 9.3. A First Look at Classes

Classes introduce a little bit of new syntax, three new object types, and some new semantics.

### 9.3.1. Class Definition Syntax

The simplest form of class definition looks like this:

**class** **ClassName**:

<statement-1>

.

.

.

<statement-N>

Class definitions, like function definitions ([def](https://docs.python.org/3/reference/compound_stmts.html#def) statements) must be executed before they have any effect. (You could conceivably place a class definition in a branch of an [if](https://docs.python.org/3/reference/compound_stmts.html#if) statement, or inside a function.)

In practice, the statements inside a class definition will usually be function definitions, but other statements are allowed, and sometimes useful — we’ll come back to this later. The function definitions inside a class normally have a peculiar form of argument list, dictated by the calling conventions for methods — again, this is explained later.

When a class definition is entered, a new namespace is created, and used as the local scope — thus, all assignments to local variables go into this new namespace. In particular, function definitions bind the name of the new function here.

When a class definition is left normally (via the end), a class object is created. This is basically a wrapper around the contents of the namespace created by the class definition; we’ll learn more about class objects in the next section. The original local scope (the one in effect just before the class definition was entered) is reinstated, and the class object is bound here to the class name given in the class definition header (ClassName in the example).

### 9.3.2. Class Objects

Class objects support two kinds of operations: attribute references and instantiation.

Attribute references use the standard syntax used for all attribute references in Python: obj.name. Valid attribute names are all the names that were in the class’s namespace when the class object was created. So, if the class definition looked like this:

**class** **MyClass**:

*"""A simple example class"""*

i = 12345

**def** f(self):

**return** 'hello world'

then MyClass.i and MyClass.f are valid attribute references, returning an integer and a function object, respectively. Class attributes can also be assigned to, so you can change the value ofMyClass.i by assignment. \_\_doc\_\_ is also a valid attribute, returning the docstring belonging to the class: "A simple example class".

Class instantiation uses function notation. Just pretend that the class object is a parameterless function that returns a new instance of the class. For example (assuming the above class):

x = MyClass()

creates a new instance of the class and assigns this object to the local variable x.

The instantiation operation (“calling” a class object) creates an empty object. Many classes like to create objects with instances customized to a specific initial state. Therefore a class may define a special method named [\_\_init\_\_()](https://docs.python.org/3/reference/datamodel.html#object.__init__), like this:

**def** \_\_init\_\_(self):

self.data = []

When a class defines an [\_\_init\_\_()](https://docs.python.org/3/reference/datamodel.html#object.__init__) method, class instantiation automatically invokes [\_\_init\_\_()](https://docs.python.org/3/reference/datamodel.html#object.__init__)for the newly-created class instance. So in this example, a new, initialized instance can be obtained by:

x = MyClass()

Of course, the [\_\_init\_\_()](https://docs.python.org/3/reference/datamodel.html#object.__init__) method may have arguments for greater flexibility. In that case, arguments given to the class instantiation operator are passed on to [\_\_init\_\_()](https://docs.python.org/3/reference/datamodel.html#object.__init__). For example,

>>>

**>>> class** **Complex**:

**...**  **def** \_\_init\_\_(self, realpart, imagpart):

**...**  self.r = realpart

**...**  self.i = imagpart

**...**

**>>>** x = Complex(3.0, -4.5)

**>>>** x.r, x.i

(3.0, -4.5)

### 9.3.3. Instance Objects

Now what can we do with instance objects? The only operations understood by instance objects are attribute references. There are two kinds of valid attribute names, data attributes and methods.

data attributes correspond to “instance variables” in Smalltalk, and to “data members” in C++. Data attributes need not be declared; like local variables, they spring into existence when they are first assigned to. For example, if x is the instance of MyClass created above, the following piece of code will print the value 16, without leaving a trace:

x.counter = 1

**while** x.counter < 10:

x.counter = x.counter \* 2

print(x.counter)

**del** x.counter

The other kind of instance attribute reference is a method. A method is a function that “belongs to” an object. (In Python, the term method is not unique to class instances: other object types can have methods as well. For example, list objects have methods called append, insert, remove, sort, and so on. However, in the following discussion, we’ll use the term method exclusively to mean methods of class instance objects, unless explicitly stated otherwise.)

Valid method names of an instance object depend on its class. By definition, all attributes of a class that are function objects define corresponding methods of its instances. So in our example, x.f is a valid method reference, since MyClass.f is a function, but x.i is not, since MyClass.i is not. But x.fis not the same thing as MyClass.f — it is a method object, not a function object.

### 9.3.4. Method Objects

Usually, a method is called right after it is bound:

x.f()

In the MyClass example, this will return the string 'hello world'. However, it is not necessary to call a method right away: x.f is a method object, and can be stored away and called at a later time. For example:

xf = x.f

**while** **True**:

print(xf())

will continue to print hello world until the end of time.

What exactly happens when a method is called? You may have noticed that x.f() was called without an argument above, even though the function definition for f() specified an argument. What happened to the argument? Surely Python raises an exception when a function that requires an argument is called without any — even if the argument isn’t actually used...

Actually, you may have guessed the answer: the special thing about methods is that the object is passed as the first argument of the function. In our example, the call x.f() is exactly equivalent toMyClass.f(x). In general, calling a method with a list of n arguments is equivalent to calling the corresponding function with an argument list that is created by inserting the method’s object before the first argument.

If you still don’t understand how methods work, a look at the implementation can perhaps clarify matters. When an instance attribute is referenced that isn’t a data attribute, its class is searched. If the name denotes a valid class attribute that is a function object, a method object is created by packing (pointers to) the instance object and the function object just found together in an abstract object: this is the method object. When the method object is called with an argument list, a new argument list is constructed from the instance object and the argument list, and the function object is called with this new argument list.

### 9.3.5. Class and Instance Variables

Generally speaking, instance variables are for data unique to each instance and class variables are for attributes and methods shared by all instances of the class:

**class** **Dog**:

kind = 'canine' *# class variable shared by all instances*

**def** \_\_init\_\_(self, name):

self.name = name *# instance variable unique to each instance*

>>> d = Dog('Fido')

>>> e = Dog('Buddy')

>>> d.kind *# shared by all dogs*

'canine'

>>> e.kind *# shared by all dogs*

'canine'

>>> d.name *# unique to d*

'Fido'

>>> e.name *# unique to e*

'Buddy'

As discussed in [A Word About Names and Objects](https://docs.python.org/3/tutorial/classes.html#tut-object), shared data can have possibly surprising effects with involving [mutable](https://docs.python.org/3/glossary.html#term-mutable) objects such as lists and dictionaries. For example, the tricks list in the following code should not be used as a class variable because just a single list would be shared by all Doginstances:

**class** **Dog**:

tricks = [] *# mistaken use of a class variable*

**def** \_\_init\_\_(self, name):

self.name = name

**def** add\_trick(self, trick):

self.tricks.append(trick)

>>> d = Dog('Fido')

>>> e = Dog('Buddy')

>>> d.add\_trick('roll over')

>>> e.add\_trick('play dead')

>>> d.tricks *# unexpectedly shared by all dogs*

['roll over', 'play dead']

Correct design of the class should use an instance variable instead:

**class** **Dog**:

**def** \_\_init\_\_(self, name):

self.name = name

self.tricks = [] *# creates a new empty list for each dog*

**def** add\_trick(self, trick):

self.tricks.append(trick)

>>> d = Dog('Fido')

>>> e = Dog('Buddy')

>>> d.add\_trick('roll over')

>>> e.add\_trick('play dead')

>>> d.tricks

['roll over']

>>> e.tricks

['play dead']

## 9.4. Random Remarks

Data attributes override method attributes with the same name; to avoid accidental name conflicts, which may cause hard-to-find bugs in large programs, it is wise to use some kind of convention that minimizes the chance of conflicts. Possible conventions include capitalizing method names, prefixing data attribute names with a small unique string (perhaps just an underscore), or using verbs for methods and nouns for data attributes.

Data attributes may be referenced by methods as well as by ordinary users (“clients”) of an object. In other words, classes are not usable to implement pure abstract data types. In fact, nothing in Python makes it possible to enforce data hiding — it is all based upon convention. (On the other hand, the Python implementation, written in C, can completely hide implementation details and control access to an object if necessary; this can be used by extensions to Python written in C.)

Clients should use data attributes with care — clients may mess up invariants maintained by the methods by stamping on their data attributes. Note that clients may add data attributes of their own to an instance object without affecting the validity of the methods, as long as name conflicts are avoided — again, a naming convention can save a lot of headaches here.

There is no shorthand for referencing data attributes (or other methods!) from within methods. I find that this actually increases the readability of methods: there is no chance of confusing local variables and instance variables when glancing through a method.

Often, the first argument of a method is called self. This is nothing more than a convention: the nameself has absolutely no special meaning to Python. Note, however, that by not following the convention your code may be less readable to other Python programmers, and it is also conceivable that a class browser program might be written that relies upon such a convention.

Any function object that is a class attribute defines a method for instances of that class. It is not necessary that the function definition is textually enclosed in the class definition: assigning a function object to a local variable in the class is also ok. For example:

*# Function defined outside the class*

**def** f1(self, x, y):

**return** min(x, x+y)

**class** **C**:

f = f1

**def** g(self):

**return** 'hello world'

h = g

Now f, g and h are all attributes of class C that refer to function objects, and consequently they are all methods of instances of C — h being exactly equivalent to g. Note that this practice usually only serves to confuse the reader of a program.

Methods may call other methods by using method attributes of the self argument:

**class** **Bag**:

**def** \_\_init\_\_(self):

self.data = []

**def** add(self, x):

self.data.append(x)

**def** addtwice(self, x):

self.add(x)

self.add(x)

Methods may reference global names in the same way as ordinary functions. The global scope associated with a method is the module containing its definition. (A class is never used as a global scope.) While one rarely encounters a good reason for using global data in a method, there are many legitimate uses of the global scope: for one thing, functions and modules imported into the global scope can be used by methods, as well as functions and classes defined in it. Usually, the class containing the method is itself defined in this global scope, and in the next section we’ll find some good reasons why a method would want to reference its own class.

Each value is an object, and therefore has a class (also called its type). It is stored asobject.\_\_class\_\_.

## 9.5. Inheritance

Of course, a language feature would not be worthy of the name “class” without supporting inheritance. The syntax for a derived class definition looks like this:

**class** **DerivedClassName**(BaseClassName):

<statement-1>

.

.

.

<statement-N>

The name BaseClassName must be defined in a scope containing the derived class definition. In place of a base class name, other arbitrary expressions are also allowed. This can be useful, for example, when the base class is defined in another module:

**class** **DerivedClassName**(modname.BaseClassName):

Execution of a derived class definition proceeds the same as for a base class. When the class object is constructed, the base class is remembered. This is used for resolving attribute references: if a requested attribute is not found in the class, the search proceeds to look in the base class. This rule is applied recursively if the base class itself is derived from some other class.

There’s nothing special about instantiation of derived classes: DerivedClassName() creates a new instance of the class. Method references are resolved as follows: the corresponding class attribute is searched, descending down the chain of base classes if necessary, and the method reference is valid if this yields a function object.

Derived classes may override methods of their base classes. Because methods have no special privileges when calling other methods of the same object, a method of a base class that calls another method defined in the same base class may end up calling a method of a derived class that overrides it. (For C++ programmers: all methods in Python are effectively virtual.)

An overriding method in a derived class may in fact want to extend rather than simply replace the base class method of the same name. There is a simple way to call the base class method directly: just callBaseClassName.methodname(self, arguments). This is occasionally useful to clients as well. (Note that this only works if the base class is accessible as BaseClassName in the global scope.)

Python has two built-in functions that work with inheritance:

* Use [isinstance()](https://docs.python.org/3/library/functions.html#isinstance) to check an instance’s type: isinstance(obj, int) will be True only ifobj.\_\_class\_\_ is [int](https://docs.python.org/3/library/functions.html#int) or some class derived from [int](https://docs.python.org/3/library/functions.html#int).
* Use [issubclass()](https://docs.python.org/3/library/functions.html#issubclass) to check class inheritance: issubclass(bool, int) is True since [bool](https://docs.python.org/3/library/functions.html#bool) is a subclass of [int](https://docs.python.org/3/library/functions.html#int). However, issubclass(float, int) is False since [float](https://docs.python.org/3/library/functions.html#float) is not a subclass of[int](https://docs.python.org/3/library/functions.html#int).

### 9.5.1. Multiple Inheritance

Python supports a form of multiple inheritance as well. A class definition with multiple base classes looks like this:

**class** **DerivedClassName**(Base1, Base2, Base3):

<statement-1>

.

.

.

<statement-N>

For most purposes, in the simplest cases, you can think of the search for attributes inherited from a parent class as depth-first, left-to-right, not searching twice in the same class where there is an overlap in the hierarchy. Thus, if an attribute is not found in DerivedClassName, it is searched for inBase1, then (recursively) in the base classes of Base1, and if it was not found there, it was searched for in Base2, and so on.

In fact, it is slightly more complex than that; the method resolution order changes dynamically to support cooperative calls to [super()](https://docs.python.org/3/library/functions.html#super). This approach is known in some other multiple-inheritance languages as call-next-method and is more powerful than the super call found in single-inheritance languages.

Dynamic ordering is necessary because all cases of multiple inheritance exhibit one or more diamond relationships (where at least one of the parent classes can be accessed through multiple paths from the bottommost class). For example, all classes inherit from [object](https://docs.python.org/3/library/functions.html#object), so any case of multiple inheritance provides more than one path to reach [object](https://docs.python.org/3/library/functions.html#object). To keep the base classes from being accessed more than once, the dynamic algorithm linearizes the search order in a way that preserves the left-to-right ordering specified in each class, that calls each parent only once, and that is monotonic (meaning that a class can be subclassed without affecting the precedence order of its parents). Taken together, these properties make it possible to design reliable and extensible classes with multiple inheritance. For more detail, see <https://www.python.org/download/releases/2.3/mro/>.

## 9.6. Private Variables

“Private” instance variables that cannot be accessed except from inside an object don’t exist in Python. However, there is a convention that is followed by most Python code: a name prefixed with an underscore (e.g. \_spam) should be treated as a non-public part of the API (whether it is a function, a method or a data member). It should be considered an implementation detail and subject to change without notice.

Since there is a valid use-case for class-private members (namely to avoid name clashes of names with names defined by subclasses), there is limited support for such a mechanism, called name mangling. Any identifier of the form \_\_spam (at least two leading underscores, at most one trailing underscore) is textually replaced with \_classname\_\_spam, where classname is the current class name with leading underscore(s) stripped. This mangling is done without regard to the syntactic position of the identifier, as long as it occurs within the definition of a class.

Name mangling is helpful for letting subclasses override methods without breaking intraclass method calls. For example:

**class** **Mapping**:

**def** \_\_init\_\_(self, iterable):

self.items\_list = []

self.\_\_update(iterable)

**def** update(self, iterable):

**for** item **in** iterable:

self.items\_list.append(item)

\_\_update = update *# private copy of original update() method*

**class** **MappingSubclass**(Mapping):

**def** update(self, keys, values):

*# provides new signature for update()*

*# but does not break \_\_init\_\_()*

**for** item **in** zip(keys, values):

self.items\_list.append(item)

Note that the mangling rules are designed mostly to avoid accidents; it still is possible to access or modify a variable that is considered private. This can even be useful in special circumstances, such as in the debugger.

Notice that code passed to exec() or eval() does not consider the classname of the invoking class to be the current class; this is similar to the effect of the global statement, the effect of which is likewise restricted to code that is byte-compiled together. The same restriction applies to getattr(),setattr() and delattr(), as well as when referencing \_\_dict\_\_ directly.

## 9.7. Odds and Ends

Sometimes it is useful to have a data type similar to the Pascal “record” or C “struct”, bundling together a few named data items. An empty class definition will do nicely:

**class** **Employee**:

**pass**

john = Employee() *# Create an empty employee record*

*# Fill the fields of the record*

john.name = 'John Doe'

john.dept = 'computer lab'

john.salary = 1000

A piece of Python code that expects a particular abstract data type can often be passed a class that emulates the methods of that data type instead. For instance, if you have a function that formats some data from a file object, you can define a class with methods read() and readline() that get the data from a string buffer instead, and pass it as an argument.

Instance method objects have attributes, too: m.\_\_self\_\_ is the instance object with the method m(), and m.\_\_func\_\_ is the function object corresponding to the method.

## 9.8. Exceptions Are Classes Too

User-defined exceptions are identified by classes as well. Using this mechanism it is possible to create extensible hierarchies of exceptions.

There are two new valid (semantic) forms for the [raise](https://docs.python.org/3/reference/simple_stmts.html#raise) statement:

**raise** Class

**raise** Instance

In the first form, Class must be an instance of [type](https://docs.python.org/3/library/functions.html#type) or of a class derived from it. The first form is a shorthand for:

**raise** Class()

A class in an [except](https://docs.python.org/3/reference/compound_stmts.html#except) clause is compatible with an exception if it is the same class or a base class thereof (but not the other way around — an except clause listing a derived class is not compatible with a base class). For example, the following code will print B, C, D in that order:

**class** **B**(Exception):

**pass**

**class** **C**(B):

**pass**

**class** **D**(C):

**pass**

**for** cls **in** [B, C, D]:

**try**:

**raise** cls()

**except** D:

print("D")

**except** C:

print("C")

**except** B:

print("B")

Note that if the except clauses were reversed (with except B first), it would have printed B, B, B — the first matching except clause is triggered.

When an error message is printed for an unhandled exception, the exception’s class name is printed, then a colon and a space, and finally the instance converted to a string using the built-in function[str()](https://docs.python.org/3/library/stdtypes.html#str).

## 9.9. Iterators

By now you have probably noticed that most container objects can be looped over using a [for](https://docs.python.org/3/reference/compound_stmts.html#for)statement:

**for** element **in** [1, 2, 3]:

print(element)

**for** element **in** (1, 2, 3):

print(element)

**for** key **in** {'one':1, 'two':2}:

print(key)

**for** char **in** "123":

print(char)

**for** line **in** open("myfile.txt"):

print(line, end='')

This style of access is clear, concise, and convenient. The use of iterators pervades and unifies Python. Behind the scenes, the [for](https://docs.python.org/3/reference/compound_stmts.html#for) statement calls [iter()](https://docs.python.org/3/library/functions.html#iter) on the container object. The function returns an iterator object that defines the method [\_\_next\_\_()](https://docs.python.org/3/library/stdtypes.html#iterator.__next__) which accesses elements in the container one at a time. When there are no more elements, [\_\_next\_\_()](https://docs.python.org/3/library/stdtypes.html#iterator.__next__) raises a [StopIteration](https://docs.python.org/3/library/exceptions.html#StopIteration)exception which tells the [for](https://docs.python.org/3/reference/compound_stmts.html#for) loop to terminate. You can call the [\_\_next\_\_()](https://docs.python.org/3/library/stdtypes.html#iterator.__next__) method using the[next()](https://docs.python.org/3/library/functions.html#next) built-in function; this example shows how it all works:

>>>

**>>>** s = 'abc'

**>>>** it = iter(s)

**>>>** it

<iterator object at 0x00A1DB50>

**>>>** next(it)

'a'

**>>>** next(it)

'b'

**>>>** next(it)

'c'

**>>>** next(it)

Traceback (most recent call last):

File "<stdin>", line 1, in ?

next(it)

StopIteration

Having seen the mechanics behind the iterator protocol, it is easy to add iterator behavior to your classes. Define an [\_\_iter\_\_()](https://docs.python.org/3/reference/datamodel.html#object.__iter__) method which returns an object with a [\_\_next\_\_()](https://docs.python.org/3/library/stdtypes.html#iterator.__next__) method. If the class defines \_\_next\_\_(), then [\_\_iter\_\_()](https://docs.python.org/3/reference/datamodel.html#object.__iter__) can just return self:

**class** **Reverse**:

*"""Iterator for looping over a sequence backwards."""*

**def** \_\_init\_\_(self, data):

self.data = data

self.index = len(data)

**def** \_\_iter\_\_(self):

**return** self

**def** \_\_next\_\_(self):

**if** self.index == 0:

**raise** StopIteration

self.index = self.index - 1

**return** self.data[self.index]

>>>

**>>>** rev = Reverse('spam')

**>>>** iter(rev)

<\_\_main\_\_.Reverse object at 0x00A1DB50>

**>>> for** char **in** rev:

**...**  print(char)

**...**

m

a

p

s

## 9.10. Generators

[Generator](https://docs.python.org/3/glossary.html#term-generator)s are a simple and powerful tool for creating iterators. They are written like regular functions but use the [yield](https://docs.python.org/3/reference/simple_stmts.html#yield) statement whenever they want to return data. Each time [next()](https://docs.python.org/3/library/functions.html#next) is called on it, the generator resumes where it left off (it remembers all the data values and which statement was last executed). An example shows that generators can be trivially easy to create:

**def** reverse(data):

**for** index **in** range(len(data)-1, -1, -1):

**yield** data[index]

>>>

**>>> for** char **in** reverse('golf'):

**...**  print(char)

**...**

f

l

o

g

Anything that can be done with generators can also be done with class-based iterators as described in the previous section. What makes generators so compact is that the [\_\_iter\_\_()](https://docs.python.org/3/reference/datamodel.html#object.__iter__) and [\_\_next\_\_()](https://docs.python.org/3/reference/expressions.html#generator.__next__)methods are created automatically.

Another key feature is that the local variables and execution state are automatically saved between calls. This made the function easier to write and much more clear than an approach using instance variables like self.index and self.data.

In addition to automatic method creation and saving program state, when generators terminate, they automatically raise [StopIteration](https://docs.python.org/3/library/exceptions.html#StopIteration). In combination, these features make it easy to create iterators with no more effort than writing a regular function.

## 9.11. Generator Expressions

Some simple generators can be coded succinctly as expressions using a syntax similar to list comprehensions but with parentheses instead of brackets. These expressions are designed for situations where the generator is used right away by an enclosing function. Generator expressions are more compact but less versatile than full generator definitions and tend to be more memory friendly than equivalent list comprehensions.

Examples:

>>>

**>>>** sum(i\*i **for** i **in** range(10)) *# sum of squares*

285

**>>>** xvec = [10, 20, 30]

**>>>** yvec = [7, 5, 3]

**>>>** sum(x\*y **for** x,y **in** zip(xvec, yvec)) *# dot product*

260

**>>> from** **math** **import** pi, sin

**>>>** sine\_table = {x: sin(x\*pi/180) **for** x **in** range(0, 91)}

**>>>** unique\_words = set(word **for** line **in** page **for** word **in** line.split())

**>>>** valedictorian = max((student.gpa, student.name) **for** student **in** graduates)

**>>>** data = 'golf'

**>>>** list(data[i] **for** i **in** range(len(data)-1, -1, -1))

['f', 'l', 'o', 'g']

**Footnotes**

|  |  |
| --- | --- |
| [[1]](https://docs.python.org/3/tutorial/classes.html#id1) | Except for one thing. Module objects have a secret read-only attribute called [\_\_dict\_\_](https://docs.python.org/3/library/stdtypes.html#object.__dict__) which returns the dictionary used to implement the module’s namespace; the name [\_\_dict\_\_](https://docs.python.org/3/library/stdtypes.html#object.__dict__) is an attribute but not a global name. Obviously, using this violates the abstraction of namespace implementation, and should be restricted to things like post-mortem debuggers. |

# 9. Classes

Compared with other programming languages, Python’s class mechanism adds classes with a minimum of new syntax and semantics. It is a mixture of the class mechanisms found in C++ and Modula-3. Python classes provide all the standard features of Object Oriented Programming: the class inheritance mechanism allows multiple base classes, a derived class can override any methods of its base class or classes, and a method can call the method of a base class with the same name. Objects can contain arbitrary amounts and kinds of data. As is true for modules, classes partake of the dynamic nature of Python: they are created at runtime, and can be modified further after creation.

In C++ terminology, normally class members (including the data members) are public (except see below [Private Variables](https://docs.python.org/3/tutorial/classes.html#tut-private)), and all member functions are virtual. As in Modula-3, there are no shorthands for referencing the object’s members from its methods: the method function is declared with an explicit first argument representing the object, which is provided implicitly by the call. As in Smalltalk, classes themselves are objects. This provides semantics for importing and renaming. Unlike C++ and Modula-3, built-in types can be used as base classes for extension by the user. Also, like in C++, most built-in operators with special syntax (arithmetic operators, subscripting etc.) can be redefined for class instances.

(Lacking universally accepted terminology to talk about classes, I will make occasional use of Smalltalk and C++ terms. I would use Modula-3 terms, since its object-oriented semantics are closer to those of Python than C++, but I expect that few readers have heard of it.)

## 9.1. A Word About Names and Objects

Objects have individuality, and multiple names (in multiple scopes) can be bound to the same object. This is known as aliasing in other languages. This is usually not appreciated on a first glance at Python, and can be safely ignored when dealing with immutable basic types (numbers, strings, tuples). However, aliasing has a possibly surprising effect on the semantics of Python code involving mutable objects such as lists, dictionaries, and most other types. This is usually used to the benefit of the program, since aliases behave like pointers in some respects. For example, passing an object is cheap since only a pointer is passed by the implementation; and if a function modifies an object passed as an argument, the caller will see the change — this eliminates the need for two different argument passing mechanisms as in Pascal.

## 9.2. Python Scopes and Namespaces

Before introducing classes, I first have to tell you something about Python’s scope rules. Class definitions play some neat tricks with namespaces, and you need to know how scopes and namespaces work to fully understand what’s going on. Incidentally, knowledge about this subject is useful for any advanced Python programmer.

Let’s begin with some definitions.

A namespace is a mapping from names to objects. Most namespaces are currently implemented as Python dictionaries, but that’s normally not noticeable in any way (except for performance), and it may change in the future. Examples of namespaces are: the set of built-in names (containing functions such as [abs()](https://docs.python.org/3/library/functions.html#abs), and built-in exception names); the global names in a module; and the local names in a function invocation. In a sense the set of attributes of an object also form a namespace. The important thing to know about namespaces is that there is absolutely no relation between names in different namespaces; for instance, two different modules may both define a function maximize without confusion — users of the modules must prefix it with the module name.

By the way, I use the word attribute for any name following a dot — for example, in the expressionz.real, real is an attribute of the object z. Strictly speaking, references to names in modules are attribute references: in the expression modname.funcname, modname is a module object and funcnameis an attribute of it. In this case there happens to be a straightforward mapping between the module’s attributes and the global names defined in the module: they share the same namespace! [[1]](https://docs.python.org/3/tutorial/classes.html#id2)

Attributes may be read-only or writable. In the latter case, assignment to attributes is possible. Module attributes are writable: you can write modname.the\_answer = 42. Writable attributes may also be deleted with the [del](https://docs.python.org/3/reference/simple_stmts.html#del) statement. For example, del modname.the\_answer will remove the attributethe\_answer from the object named by modname.

Namespaces are created at different moments and have different lifetimes. The namespace containing the built-in names is created when the Python interpreter starts up, and is never deleted. The global namespace for a module is created when the module definition is read in; normally, module namespaces also last until the interpreter quits. The statements executed by the top-level invocation of the interpreter, either read from a script file or interactively, are considered part of a module called[\_\_main\_\_](https://docs.python.org/3/library/__main__.html#module-__main__), so they have their own global namespace. (The built-in names actually also live in a module; this is called [builtins](https://docs.python.org/3/library/builtins.html#module-builtins).)

The local namespace for a function is created when the function is called, and deleted when the function returns or raises an exception that is not handled within the function. (Actually, forgetting would be a better way to describe what actually happens.) Of course, recursive invocations each have their own local namespace.

A scope is a textual region of a Python program where a namespace is directly accessible. “Directly accessible” here means that an unqualified reference to a name attempts to find the name in the namespace.

Although scopes are determined statically, they are used dynamically. At any time during execution, there are at least three nested scopes whose namespaces are directly accessible:

* the innermost scope, which is searched first, contains the local names
* the scopes of any enclosing functions, which are searched starting with the nearest enclosing scope, contains non-local, but also non-global names
* the next-to-last scope contains the current module’s global names
* the outermost scope (searched last) is the namespace containing built-in names

If a name is declared global, then all references and assignments go directly to the middle scope containing the module’s global names. To rebind variables found outside of the innermost scope, the[nonlocal](https://docs.python.org/3/reference/simple_stmts.html#nonlocal) statement can be used; if not declared nonlocal, those variables are read-only (an attempt to write to such a variable will simply create a new local variable in the innermost scope, leaving the identically named outer variable unchanged).

Usually, the local scope references the local names of the (textually) current function. Outside functions, the local scope references the same namespace as the global scope: the module’s namespace. Class definitions place yet another namespace in the local scope.

It is important to realize that scopes are determined textually: the global scope of a function defined in a module is that module’s namespace, no matter from where or by what alias the function is called. On the other hand, the actual search for names is done dynamically, at run time — however, the language definition is evolving towards static name resolution, at “compile” time, so don’t rely on dynamic name resolution! (In fact, local variables are already determined statically.)

A special quirk of Python is that – if no [global](https://docs.python.org/3/reference/simple_stmts.html#global) statement is in effect – assignments to names always go into the innermost scope. Assignments do not copy data — they just bind names to objects. The same is true for deletions: the statement del x removes the binding of x from the namespace referenced by the local scope. In fact, all operations that introduce new names use the local scope: in particular, [import](https://docs.python.org/3/reference/simple_stmts.html#import) statements and function definitions bind the module or function name in the local scope.

The [global](https://docs.python.org/3/reference/simple_stmts.html#global) statement can be used to indicate that particular variables live in the global scope and should be rebound there; the [nonlocal](https://docs.python.org/3/reference/simple_stmts.html#nonlocal) statement indicates that particular variables live in an enclosing scope and should be rebound there.

### 9.2.1. Scopes and Namespaces Example

This is an example demonstrating how to reference the different scopes and namespaces, and how[global](https://docs.python.org/3/reference/simple_stmts.html#global) and [nonlocal](https://docs.python.org/3/reference/simple_stmts.html#nonlocal) affect variable binding:

**def** scope\_test():

**def** do\_local():

spam = "local spam"

**def** do\_nonlocal():

**nonlocal** spam

spam = "nonlocal spam"

**def** do\_global():

**global** spam

spam = "global spam"

spam = "test spam"

do\_local()

print("After local assignment:", spam)

do\_nonlocal()

print("After nonlocal assignment:", spam)

do\_global()

print("After global assignment:", spam)

scope\_test()

print("In global scope:", spam)

The output of the example code is:

After local assignment: test spam

After nonlocal assignment: nonlocal spam

After global assignment: nonlocal spam

In global scope: global spam

Note how the local assignment (which is default) didn’t change scope\_test‘s binding of spam. The[nonlocal](https://docs.python.org/3/reference/simple_stmts.html#nonlocal) assignment changed scope\_test‘s binding of spam, and the [global](https://docs.python.org/3/reference/simple_stmts.html#global) assignment changed the module-level binding.

You can also see that there was no previous binding for spam before the [global](https://docs.python.org/3/reference/simple_stmts.html#global) assignment.

## 9.3. A First Look at Classes

Classes introduce a little bit of new syntax, three new object types, and some new semantics.

### 9.3.1. Class Definition Syntax

The simplest form of class definition looks like this:

**class** **ClassName**:

<statement-1>

.

.

.

<statement-N>

Class definitions, like function definitions ([def](https://docs.python.org/3/reference/compound_stmts.html#def) statements) must be executed before they have any effect. (You could conceivably place a class definition in a branch of an [if](https://docs.python.org/3/reference/compound_stmts.html#if) statement, or inside a function.)

In practice, the statements inside a class definition will usually be function definitions, but other statements are allowed, and sometimes useful — we’ll come back to this later. The function definitions inside a class normally have a peculiar form of argument list, dictated by the calling conventions for methods — again, this is explained later.

When a class definition is entered, a new namespace is created, and used as the local scope — thus, all assignments to local variables go into this new namespace. In particular, function definitions bind the name of the new function here.

When a class definition is left normally (via the end), a class object is created. This is basically a wrapper around the contents of the namespace created by the class definition; we’ll learn more about class objects in the next section. The original local scope (the one in effect just before the class definition was entered) is reinstated, and the class object is bound here to the class name given in the class definition header (ClassName in the example).

### 9.3.2. Class Objects

Class objects support two kinds of operations: attribute references and instantiation.

Attribute references use the standard syntax used for all attribute references in Python: obj.name. Valid attribute names are all the names that were in the class’s namespace when the class object was created. So, if the class definition looked like this:

**class** **MyClass**:

*"""A simple example class"""*

i = 12345

**def** f(self):

**return** 'hello world'

then MyClass.i and MyClass.f are valid attribute references, returning an integer and a function object, respectively. Class attributes can also be assigned to, so you can change the value ofMyClass.i by assignment. \_\_doc\_\_ is also a valid attribute, returning the docstring belonging to the class: "A simple example class".

Class instantiation uses function notation. Just pretend that the class object is a parameterless function that returns a new instance of the class. For example (assuming the above class):

x = MyClass()

creates a new instance of the class and assigns this object to the local variable x.

The instantiation operation (“calling” a class object) creates an empty object. Many classes like to create objects with instances customized to a specific initial state. Therefore a class may define a special method named [\_\_init\_\_()](https://docs.python.org/3/reference/datamodel.html#object.__init__), like this:

**def** \_\_init\_\_(self):

self.data = []

When a class defines an [\_\_init\_\_()](https://docs.python.org/3/reference/datamodel.html#object.__init__) method, class instantiation automatically invokes [\_\_init\_\_()](https://docs.python.org/3/reference/datamodel.html#object.__init__)for the newly-created class instance. So in this example, a new, initialized instance can be obtained by:

x = MyClass()

Of course, the [\_\_init\_\_()](https://docs.python.org/3/reference/datamodel.html#object.__init__) method may have arguments for greater flexibility. In that case, arguments given to the class instantiation operator are passed on to [\_\_init\_\_()](https://docs.python.org/3/reference/datamodel.html#object.__init__). For example,

>>>

**>>> class** **Complex**:

**...**  **def** \_\_init\_\_(self, realpart, imagpart):

**...**  self.r = realpart

**...**  self.i = imagpart

**...**

**>>>** x = Complex(3.0, -4.5)

**>>>** x.r, x.i

(3.0, -4.5)

### 9.3.3. Instance Objects

Now what can we do with instance objects? The only operations understood by instance objects are attribute references. There are two kinds of valid attribute names, data attributes and methods.

data attributes correspond to “instance variables” in Smalltalk, and to “data members” in C++. Data attributes need not be declared; like local variables, they spring into existence when they are first assigned to. For example, if x is the instance of MyClass created above, the following piece of code will print the value 16, without leaving a trace:

x.counter = 1

**while** x.counter < 10:

x.counter = x.counter \* 2

print(x.counter)

**del** x.counter

The other kind of instance attribute reference is a method. A method is a function that “belongs to” an object. (In Python, the term method is not unique to class instances: other object types can have methods as well. For example, list objects have methods called append, insert, remove, sort, and so on. However, in the following discussion, we’ll use the term method exclusively to mean methods of class instance objects, unless explicitly stated otherwise.)

Valid method names of an instance object depend on its class. By definition, all attributes of a class that are function objects define corresponding methods of its instances. So in our example, x.f is a valid method reference, since MyClass.f is a function, but x.i is not, since MyClass.i is not. But x.fis not the same thing as MyClass.f — it is a method object, not a function object.

### 9.3.4. Method Objects

Usually, a method is called right after it is bound:

x.f()

In the MyClass example, this will return the string 'hello world'. However, it is not necessary to call a method right away: x.f is a method object, and can be stored away and called at a later time. For example:

xf = x.f

**while** **True**:

print(xf())

will continue to print hello world until the end of time.

What exactly happens when a method is called? You may have noticed that x.f() was called without an argument above, even though the function definition for f() specified an argument. What happened to the argument? Surely Python raises an exception when a function that requires an argument is called without any — even if the argument isn’t actually used...

Actually, you may have guessed the answer: the special thing about methods is that the object is passed as the first argument of the function. In our example, the call x.f() is exactly equivalent toMyClass.f(x). In general, calling a method with a list of n arguments is equivalent to calling the corresponding function with an argument list that is created by inserting the method’s object before the first argument.

If you still don’t understand how methods work, a look at the implementation can perhaps clarify matters. When an instance attribute is referenced that isn’t a data attribute, its class is searched. If the name denotes a valid class attribute that is a function object, a method object is created by packing (pointers to) the instance object and the function object just found together in an abstract object: this is the method object. When the method object is called with an argument list, a new argument list is constructed from the instance object and the argument list, and the function object is called with this new argument list.

### 9.3.5. Class and Instance Variables

Generally speaking, instance variables are for data unique to each instance and class variables are for attributes and methods shared by all instances of the class:

**class** **Dog**:

kind = 'canine' *# class variable shared by all instances*

**def** \_\_init\_\_(self, name):

self.name = name *# instance variable unique to each instance*

>>> d = Dog('Fido')

>>> e = Dog('Buddy')

>>> d.kind *# shared by all dogs*

'canine'

>>> e.kind *# shared by all dogs*

'canine'

>>> d.name *# unique to d*

'Fido'

>>> e.name *# unique to e*

'Buddy'

As discussed in [A Word About Names and Objects](https://docs.python.org/3/tutorial/classes.html#tut-object), shared data can have possibly surprising effects with involving [mutable](https://docs.python.org/3/glossary.html#term-mutable) objects such as lists and dictionaries. For example, the tricks list in the following code should not be used as a class variable because just a single list would be shared by all Doginstances:

**class** **Dog**:

tricks = [] *# mistaken use of a class variable*

**def** \_\_init\_\_(self, name):

self.name = name

**def** add\_trick(self, trick):

self.tricks.append(trick)

>>> d = Dog('Fido')

>>> e = Dog('Buddy')

>>> d.add\_trick('roll over')

>>> e.add\_trick('play dead')

>>> d.tricks *# unexpectedly shared by all dogs*

['roll over', 'play dead']

Correct design of the class should use an instance variable instead:

**class** **Dog**:

**def** \_\_init\_\_(self, name):

self.name = name

self.tricks = [] *# creates a new empty list for each dog*

**def** add\_trick(self, trick):

self.tricks.append(trick)

>>> d = Dog('Fido')

>>> e = Dog('Buddy')

>>> d.add\_trick('roll over')

>>> e.add\_trick('play dead')

>>> d.tricks

['roll over']

>>> e.tricks

['play dead']

## 9.4. Random Remarks

Data attributes override method attributes with the same name; to avoid accidental name conflicts, which may cause hard-to-find bugs in large programs, it is wise to use some kind of convention that minimizes the chance of conflicts. Possible conventions include capitalizing method names, prefixing data attribute names with a small unique string (perhaps just an underscore), or using verbs for methods and nouns for data attributes.

Data attributes may be referenced by methods as well as by ordinary users (“clients”) of an object. In other words, classes are not usable to implement pure abstract data types. In fact, nothing in Python makes it possible to enforce data hiding — it is all based upon convention. (On the other hand, the Python implementation, written in C, can completely hide implementation details and control access to an object if necessary; this can be used by extensions to Python written in C.)

Clients should use data attributes with care — clients may mess up invariants maintained by the methods by stamping on their data attributes. Note that clients may add data attributes of their own to an instance object without affecting the validity of the methods, as long as name conflicts are avoided — again, a naming convention can save a lot of headaches here.

There is no shorthand for referencing data attributes (or other methods!) from within methods. I find that this actually increases the readability of methods: there is no chance of confusing local variables and instance variables when glancing through a method.

Often, the first argument of a method is called self. This is nothing more than a convention: the nameself has absolutely no special meaning to Python. Note, however, that by not following the convention your code may be less readable to other Python programmers, and it is also conceivable that a class browser program might be written that relies upon such a convention.

Any function object that is a class attribute defines a method for instances of that class. It is not necessary that the function definition is textually enclosed in the class definition: assigning a function object to a local variable in the class is also ok. For example:

*# Function defined outside the class*

**def** f1(self, x, y):

**return** min(x, x+y)

**class** **C**:

f = f1

**def** g(self):

**return** 'hello world'

h = g

Now f, g and h are all attributes of class C that refer to function objects, and consequently they are all methods of instances of C — h being exactly equivalent to g. Note that this practice usually only serves to confuse the reader of a program.

Methods may call other methods by using method attributes of the self argument:

**class** **Bag**:

**def** \_\_init\_\_(self):

self.data = []

**def** add(self, x):

self.data.append(x)

**def** addtwice(self, x):

self.add(x)

self.add(x)

Methods may reference global names in the same way as ordinary functions. The global scope associated with a method is the module containing its definition. (A class is never used as a global scope.) While one rarely encounters a good reason for using global data in a method, there are many legitimate uses of the global scope: for one thing, functions and modules imported into the global scope can be used by methods, as well as functions and classes defined in it. Usually, the class containing the method is itself defined in this global scope, and in the next section we’ll find some good reasons why a method would want to reference its own class.

Each value is an object, and therefore has a class (also called its type). It is stored asobject.\_\_class\_\_.

## 9.5. Inheritance

Of course, a language feature would not be worthy of the name “class” without supporting inheritance. The syntax for a derived class definition looks like this:

**class** **DerivedClassName**(BaseClassName):

<statement-1>

.

.

.

<statement-N>

The name BaseClassName must be defined in a scope containing the derived class definition. In place of a base class name, other arbitrary expressions are also allowed. This can be useful, for example, when the base class is defined in another module:

**class** **DerivedClassName**(modname.BaseClassName):

Execution of a derived class definition proceeds the same as for a base class. When the class object is constructed, the base class is remembered. This is used for resolving attribute references: if a requested attribute is not found in the class, the search proceeds to look in the base class. This rule is applied recursively if the base class itself is derived from some other class.

There’s nothing special about instantiation of derived classes: DerivedClassName() creates a new instance of the class. Method references are resolved as follows: the corresponding class attribute is searched, descending down the chain of base classes if necessary, and the method reference is valid if this yields a function object.

Derived classes may override methods of their base classes. Because methods have no special privileges when calling other methods of the same object, a method of a base class that calls another method defined in the same base class may end up calling a method of a derived class that overrides it. (For C++ programmers: all methods in Python are effectively virtual.)

An overriding method in a derived class may in fact want to extend rather than simply replace the base class method of the same name. There is a simple way to call the base class method directly: just callBaseClassName.methodname(self, arguments). This is occasionally useful to clients as well. (Note that this only works if the base class is accessible as BaseClassName in the global scope.)

Python has two built-in functions that work with inheritance:

* Use [isinstance()](https://docs.python.org/3/library/functions.html#isinstance) to check an instance’s type: isinstance(obj, int) will be True only ifobj.\_\_class\_\_ is [int](https://docs.python.org/3/library/functions.html#int) or some class derived from [int](https://docs.python.org/3/library/functions.html#int).
* Use [issubclass()](https://docs.python.org/3/library/functions.html#issubclass) to check class inheritance: issubclass(bool, int) is True since [bool](https://docs.python.org/3/library/functions.html#bool) is a subclass of [int](https://docs.python.org/3/library/functions.html#int). However, issubclass(float, int) is False since [float](https://docs.python.org/3/library/functions.html#float) is not a subclass of[int](https://docs.python.org/3/library/functions.html#int).

### 9.5.1. Multiple Inheritance

Python supports a form of multiple inheritance as well. A class definition with multiple base classes looks like this:

**class** **DerivedClassName**(Base1, Base2, Base3):

<statement-1>

.

.

.

<statement-N>

For most purposes, in the simplest cases, you can think of the search for attributes inherited from a parent class as depth-first, left-to-right, not searching twice in the same class where there is an overlap in the hierarchy. Thus, if an attribute is not found in DerivedClassName, it is searched for inBase1, then (recursively) in the base classes of Base1, and if it was not found there, it was searched for in Base2, and so on.

In fact, it is slightly more complex than that; the method resolution order changes dynamically to support cooperative calls to [super()](https://docs.python.org/3/library/functions.html#super). This approach is known in some other multiple-inheritance languages as call-next-method and is more powerful than the super call found in single-inheritance languages.

Dynamic ordering is necessary because all cases of multiple inheritance exhibit one or more diamond relationships (where at least one of the parent classes can be accessed through multiple paths from the bottommost class). For example, all classes inherit from [object](https://docs.python.org/3/library/functions.html#object), so any case of multiple inheritance provides more than one path to reach [object](https://docs.python.org/3/library/functions.html#object). To keep the base classes from being accessed more than once, the dynamic algorithm linearizes the search order in a way that preserves the left-to-right ordering specified in each class, that calls each parent only once, and that is monotonic (meaning that a class can be subclassed without affecting the precedence order of its parents). Taken together, these properties make it possible to design reliable and extensible classes with multiple inheritance. For more detail, see <https://www.python.org/download/releases/2.3/mro/>.

## 9.6. Private Variables

“Private” instance variables that cannot be accessed except from inside an object don’t exist in Python. However, there is a convention that is followed by most Python code: a name prefixed with an underscore (e.g. \_spam) should be treated as a non-public part of the API (whether it is a function, a method or a data member). It should be considered an implementation detail and subject to change without notice.

Since there is a valid use-case for class-private members (namely to avoid name clashes of names with names defined by subclasses), there is limited support for such a mechanism, called name mangling. Any identifier of the form \_\_spam (at least two leading underscores, at most one trailing underscore) is textually replaced with \_classname\_\_spam, where classname is the current class name with leading underscore(s) stripped. This mangling is done without regard to the syntactic position of the identifier, as long as it occurs within the definition of a class.

Name mangling is helpful for letting subclasses override methods without breaking intraclass method calls. For example:

**class** **Mapping**:

**def** \_\_init\_\_(self, iterable):

self.items\_list = []

self.\_\_update(iterable)

**def** update(self, iterable):

**for** item **in** iterable:

self.items\_list.append(item)

\_\_update = update *# private copy of original update() method*

**class** **MappingSubclass**(Mapping):

**def** update(self, keys, values):

*# provides new signature for update()*

*# but does not break \_\_init\_\_()*

**for** item **in** zip(keys, values):

self.items\_list.append(item)

Note that the mangling rules are designed mostly to avoid accidents; it still is possible to access or modify a variable that is considered private. This can even be useful in special circumstances, such as in the debugger.

Notice that code passed to exec() or eval() does not consider the classname of the invoking class to be the current class; this is similar to the effect of the global statement, the effect of which is likewise restricted to code that is byte-compiled together. The same restriction applies to getattr(),setattr() and delattr(), as well as when referencing \_\_dict\_\_ directly.

## 9.7. Odds and Ends

Sometimes it is useful to have a data type similar to the Pascal “record” or C “struct”, bundling together a few named data items. An empty class definition will do nicely:

**class** **Employee**:

**pass**

john = Employee() *# Create an empty employee record*

*# Fill the fields of the record*

john.name = 'John Doe'

john.dept = 'computer lab'

john.salary = 1000

A piece of Python code that expects a particular abstract data type can often be passed a class that emulates the methods of that data type instead. For instance, if you have a function that formats some data from a file object, you can define a class with methods read() and readline() that get the data from a string buffer instead, and pass it as an argument.

Instance method objects have attributes, too: m.\_\_self\_\_ is the instance object with the method m(), and m.\_\_func\_\_ is the function object corresponding to the method.

## 9.8. Exceptions Are Classes Too

User-defined exceptions are identified by classes as well. Using this mechanism it is possible to create extensible hierarchies of exceptions.

There are two new valid (semantic) forms for the [raise](https://docs.python.org/3/reference/simple_stmts.html#raise) statement:

**raise** Class

**raise** Instance

In the first form, Class must be an instance of [type](https://docs.python.org/3/library/functions.html#type) or of a class derived from it. The first form is a shorthand for:

**raise** Class()

A class in an [except](https://docs.python.org/3/reference/compound_stmts.html#except) clause is compatible with an exception if it is the same class or a base class thereof (but not the other way around — an except clause listing a derived class is not compatible with a base class). For example, the following code will print B, C, D in that order:

**class** **B**(Exception):

**pass**

**class** **C**(B):

**pass**

**class** **D**(C):

**pass**

**for** cls **in** [B, C, D]:

**try**:

**raise** cls()

**except** D:

print("D")

**except** C:

print("C")

**except** B:

print("B")

Note that if the except clauses were reversed (with except B first), it would have printed B, B, B — the first matching except clause is triggered.

When an error message is printed for an unhandled exception, the exception’s class name is printed, then a colon and a space, and finally the instance converted to a string using the built-in function[str()](https://docs.python.org/3/library/stdtypes.html#str).

## 9.9. Iterators

By now you have probably noticed that most container objects can be looped over using a [for](https://docs.python.org/3/reference/compound_stmts.html#for)statement:

**for** element **in** [1, 2, 3]:

print(element)

**for** element **in** (1, 2, 3):

print(element)

**for** key **in** {'one':1, 'two':2}:

print(key)

**for** char **in** "123":

print(char)

**for** line **in** open("myfile.txt"):

print(line, end='')

This style of access is clear, concise, and convenient. The use of iterators pervades and unifies Python. Behind the scenes, the [for](https://docs.python.org/3/reference/compound_stmts.html#for) statement calls [iter()](https://docs.python.org/3/library/functions.html#iter) on the container object. The function returns an iterator object that defines the method [\_\_next\_\_()](https://docs.python.org/3/library/stdtypes.html#iterator.__next__) which accesses elements in the container one at a time. When there are no more elements, [\_\_next\_\_()](https://docs.python.org/3/library/stdtypes.html#iterator.__next__) raises a [StopIteration](https://docs.python.org/3/library/exceptions.html#StopIteration)exception which tells the [for](https://docs.python.org/3/reference/compound_stmts.html#for) loop to terminate. You can call the [\_\_next\_\_()](https://docs.python.org/3/library/stdtypes.html#iterator.__next__) method using the[next()](https://docs.python.org/3/library/functions.html#next) built-in function; this example shows how it all works:

>>>

**>>>** s = 'abc'

**>>>** it = iter(s)

**>>>** it

<iterator object at 0x00A1DB50>

**>>>** next(it)

'a'

**>>>** next(it)

'b'

**>>>** next(it)

'c'

**>>>** next(it)

Traceback (most recent call last):

File "<stdin>", line 1, in ?

next(it)

StopIteration

Having seen the mechanics behind the iterator protocol, it is easy to add iterator behavior to your classes. Define an [\_\_iter\_\_()](https://docs.python.org/3/reference/datamodel.html#object.__iter__) method which returns an object with a [\_\_next\_\_()](https://docs.python.org/3/library/stdtypes.html#iterator.__next__) method. If the class defines \_\_next\_\_(), then [\_\_iter\_\_()](https://docs.python.org/3/reference/datamodel.html#object.__iter__) can just return self:

**class** **Reverse**:

*"""Iterator for looping over a sequence backwards."""*

**def** \_\_init\_\_(self, data):

self.data = data

self.index = len(data)

**def** \_\_iter\_\_(self):

**return** self

**def** \_\_next\_\_(self):

**if** self.index == 0:

**raise** StopIteration

self.index = self.index - 1

**return** self.data[self.index]

>>>

**>>>** rev = Reverse('spam')

**>>>** iter(rev)

<\_\_main\_\_.Reverse object at 0x00A1DB50>

**>>> for** char **in** rev:

**...**  print(char)

**...**

m

a

p

s

## 9.10. Generators

[Generator](https://docs.python.org/3/glossary.html#term-generator)s are a simple and powerful tool for creating iterators. They are written like regular functions but use the [yield](https://docs.python.org/3/reference/simple_stmts.html#yield) statement whenever they want to return data. Each time [next()](https://docs.python.org/3/library/functions.html#next) is called on it, the generator resumes where it left off (it remembers all the data values and which statement was last executed). An example shows that generators can be trivially easy to create:

**def** reverse(data):

**for** index **in** range(len(data)-1, -1, -1):

**yield** data[index]

>>>

**>>> for** char **in** reverse('golf'):

**...**  print(char)

**...**

f

l

o

g

Anything that can be done with generators can also be done with class-based iterators as described in the previous section. What makes generators so compact is that the [\_\_iter\_\_()](https://docs.python.org/3/reference/datamodel.html#object.__iter__) and [\_\_next\_\_()](https://docs.python.org/3/reference/expressions.html#generator.__next__)methods are created automatically.

Another key feature is that the local variables and execution state are automatically saved between calls. This made the function easier to write and much more clear than an approach using instance variables like self.index and self.data.

In addition to automatic method creation and saving program state, when generators terminate, they automatically raise [StopIteration](https://docs.python.org/3/library/exceptions.html#StopIteration). In combination, these features make it easy to create iterators with no more effort than writing a regular function.

## 9.11. Generator Expressions

Some simple generators can be coded succinctly as expressions using a syntax similar to list comprehensions but with parentheses instead of brackets. These expressions are designed for situations where the generator is used right away by an enclosing function. Generator expressions are more compact but less versatile than full generator definitions and tend to be more memory friendly than equivalent list comprehensions.

Examples:

>>>

**>>>** sum(i\*i **for** i **in** range(10)) *# sum of squares*

285

**>>>** xvec = [10, 20, 30]

**>>>** yvec = [7, 5, 3]

**>>>** sum(x\*y **for** x,y **in** zip(xvec, yvec)) *# dot product*

260

**>>> from** **math** **import** pi, sin

**>>>** sine\_table = {x: sin(x\*pi/180) **for** x **in** range(0, 91)}

**>>>** unique\_words = set(word **for** line **in** page **for** word **in** line.split())

**>>>** valedictorian = max((student.gpa, student.name) **for** student **in** graduates)

**>>>** data = 'golf'

**>>>** list(data[i] **for** i **in** range(len(data)-1, -1, -1))

['f', 'l', 'o', 'g']

**Footnotes**

|  |  |
| --- | --- |
| [[1]](https://docs.python.org/3/tutorial/classes.html#id1) | Except for one thing. Module objects have a secret read-only attribute called [\_\_dict\_\_](https://docs.python.org/3/library/stdtypes.html#object.__dict__) which returns the dictionary used to implement the module’s namespace; the name [\_\_dict\_\_](https://docs.python.org/3/library/stdtypes.html#object.__dict__) is an attribute but not a global name. Obviously, using this violates the abstraction of namespace implementation, and should be restricted to things like post-mortem debuggers. |

# 9. Classes

Compared with other programming languages, Python’s class mechanism adds classes with a minimum of new syntax and semantics. It is a mixture of the class mechanisms found in C++ and Modula-3. Python classes provide all the standard features of Object Oriented Programming: the class inheritance mechanism allows multiple base classes, a derived class can override any methods of its base class or classes, and a method can call the method of a base class with the same name. Objects can contain arbitrary amounts and kinds of data. As is true for modules, classes partake of the dynamic nature of Python: they are created at runtime, and can be modified further after creation.

In C++ terminology, normally class members (including the data members) are public (except see below [Private Variables](https://docs.python.org/3/tutorial/classes.html#tut-private)), and all member functions are virtual. As in Modula-3, there are no shorthands for referencing the object’s members from its methods: the method function is declared with an explicit first argument representing the object, which is provided implicitly by the call. As in Smalltalk, classes themselves are objects. This provides semantics for importing and renaming. Unlike C++ and Modula-3, built-in types can be used as base classes for extension by the user. Also, like in C++, most built-in operators with special syntax (arithmetic operators, subscripting etc.) can be redefined for class instances.

(Lacking universally accepted terminology to talk about classes, I will make occasional use of Smalltalk and C++ terms. I would use Modula-3 terms, since its object-oriented semantics are closer to those of Python than C++, but I expect that few readers have heard of it.)

## 9.1. A Word About Names and Objects

Objects have individuality, and multiple names (in multiple scopes) can be bound to the same object. This is known as aliasing in other languages. This is usually not appreciated on a first glance at Python, and can be safely ignored when dealing with immutable basic types (numbers, strings, tuples). However, aliasing has a possibly surprising effect on the semantics of Python code involving mutable objects such as lists, dictionaries, and most other types. This is usually used to the benefit of the program, since aliases behave like pointers in some respects. For example, passing an object is cheap since only a pointer is passed by the implementation; and if a function modifies an object passed as an argument, the caller will see the change — this eliminates the need for two different argument passing mechanisms as in Pascal.

## 9.2. Python Scopes and Namespaces

Before introducing classes, I first have to tell you something about Python’s scope rules. Class definitions play some neat tricks with namespaces, and you need to know how scopes and namespaces work to fully understand what’s going on. Incidentally, knowledge about this subject is useful for any advanced Python programmer.

Let’s begin with some definitions.

A namespace is a mapping from names to objects. Most namespaces are currently implemented as Python dictionaries, but that’s normally not noticeable in any way (except for performance), and it may change in the future. Examples of namespaces are: the set of built-in names (containing functions such as [abs()](https://docs.python.org/3/library/functions.html#abs), and built-in exception names); the global names in a module; and the local names in a function invocation. In a sense the set of attributes of an object also form a namespace. The important thing to know about namespaces is that there is absolutely no relation between names in different namespaces; for instance, two different modules may both define a function maximize without confusion — users of the modules must prefix it with the module name.

By the way, I use the word attribute for any name following a dot — for example, in the expressionz.real, real is an attribute of the object z. Strictly speaking, references to names in modules are attribute references: in the expression modname.funcname, modname is a module object and funcnameis an attribute of it. In this case there happens to be a straightforward mapping between the module’s attributes and the global names defined in the module: they share the same namespace! [[1]](https://docs.python.org/3/tutorial/classes.html#id2)

Attributes may be read-only or writable. In the latter case, assignment to attributes is possible. Module attributes are writable: you can write modname.the\_answer = 42. Writable attributes may also be deleted with the [del](https://docs.python.org/3/reference/simple_stmts.html#del) statement. For example, del modname.the\_answer will remove the attributethe\_answer from the object named by modname.

Namespaces are created at different moments and have different lifetimes. The namespace containing the built-in names is created when the Python interpreter starts up, and is never deleted. The global namespace for a module is created when the module definition is read in; normally, module namespaces also last until the interpreter quits. The statements executed by the top-level invocation of the interpreter, either read from a script file or interactively, are considered part of a module called[\_\_main\_\_](https://docs.python.org/3/library/__main__.html#module-__main__), so they have their own global namespace. (The built-in names actually also live in a module; this is called [builtins](https://docs.python.org/3/library/builtins.html#module-builtins).)

The local namespace for a function is created when the function is called, and deleted when the function returns or raises an exception that is not handled within the function. (Actually, forgetting would be a better way to describe what actually happens.) Of course, recursive invocations each have their own local namespace.

A scope is a textual region of a Python program where a namespace is directly accessible. “Directly accessible” here means that an unqualified reference to a name attempts to find the name in the namespace.

Although scopes are determined statically, they are used dynamically. At any time during execution, there are at least three nested scopes whose namespaces are directly accessible:

* the innermost scope, which is searched first, contains the local names
* the scopes of any enclosing functions, which are searched starting with the nearest enclosing scope, contains non-local, but also non-global names
* the next-to-last scope contains the current module’s global names
* the outermost scope (searched last) is the namespace containing built-in names

If a name is declared global, then all references and assignments go directly to the middle scope containing the module’s global names. To rebind variables found outside of the innermost scope, the[nonlocal](https://docs.python.org/3/reference/simple_stmts.html#nonlocal) statement can be used; if not declared nonlocal, those variables are read-only (an attempt to write to such a variable will simply create a new local variable in the innermost scope, leaving the identically named outer variable unchanged).

Usually, the local scope references the local names of the (textually) current function. Outside functions, the local scope references the same namespace as the global scope: the module’s namespace. Class definitions place yet another namespace in the local scope.

It is important to realize that scopes are determined textually: the global scope of a function defined in a module is that module’s namespace, no matter from where or by what alias the function is called. On the other hand, the actual search for names is done dynamically, at run time — however, the language definition is evolving towards static name resolution, at “compile” time, so don’t rely on dynamic name resolution! (In fact, local variables are already determined statically.)

A special quirk of Python is that – if no [global](https://docs.python.org/3/reference/simple_stmts.html#global) statement is in effect – assignments to names always go into the innermost scope. Assignments do not copy data — they just bind names to objects. The same is true for deletions: the statement del x removes the binding of x from the namespace referenced by the local scope. In fact, all operations that introduce new names use the local scope: in particular, [import](https://docs.python.org/3/reference/simple_stmts.html#import) statements and function definitions bind the module or function name in the local scope.

The [global](https://docs.python.org/3/reference/simple_stmts.html#global) statement can be used to indicate that particular variables live in the global scope and should be rebound there; the [nonlocal](https://docs.python.org/3/reference/simple_stmts.html#nonlocal) statement indicates that particular variables live in an enclosing scope and should be rebound there.

### 9.2.1. Scopes and Namespaces Example

This is an example demonstrating how to reference the different scopes and namespaces, and how[global](https://docs.python.org/3/reference/simple_stmts.html#global) and [nonlocal](https://docs.python.org/3/reference/simple_stmts.html#nonlocal) affect variable binding:

**def** scope\_test():

**def** do\_local():

spam = "local spam"

**def** do\_nonlocal():

**nonlocal** spam

spam = "nonlocal spam"

**def** do\_global():

**global** spam

spam = "global spam"

spam = "test spam"

do\_local()

print("After local assignment:", spam)

do\_nonlocal()

print("After nonlocal assignment:", spam)

do\_global()

print("After global assignment:", spam)

scope\_test()

print("In global scope:", spam)

The output of the example code is:

After local assignment: test spam

After nonlocal assignment: nonlocal spam

After global assignment: nonlocal spam

In global scope: global spam

Note how the local assignment (which is default) didn’t change scope\_test‘s binding of spam. The[nonlocal](https://docs.python.org/3/reference/simple_stmts.html#nonlocal) assignment changed scope\_test‘s binding of spam, and the [global](https://docs.python.org/3/reference/simple_stmts.html#global) assignment changed the module-level binding.

You can also see that there was no previous binding for spam before the [global](https://docs.python.org/3/reference/simple_stmts.html#global) assignment.

## 9.3. A First Look at Classes

Classes introduce a little bit of new syntax, three new object types, and some new semantics.

### 9.3.1. Class Definition Syntax

The simplest form of class definition looks like this:

**class** **ClassName**:

<statement-1>

.

.

.

<statement-N>

Class definitions, like function definitions ([def](https://docs.python.org/3/reference/compound_stmts.html#def) statements) must be executed before they have any effect. (You could conceivably place a class definition in a branch of an [if](https://docs.python.org/3/reference/compound_stmts.html#if) statement, or inside a function.)

In practice, the statements inside a class definition will usually be function definitions, but other statements are allowed, and sometimes useful — we’ll come back to this later. The function definitions inside a class normally have a peculiar form of argument list, dictated by the calling conventions for methods — again, this is explained later.

When a class definition is entered, a new namespace is created, and used as the local scope — thus, all assignments to local variables go into this new namespace. In particular, function definitions bind the name of the new function here.

When a class definition is left normally (via the end), a class object is created. This is basically a wrapper around the contents of the namespace created by the class definition; we’ll learn more about class objects in the next section. The original local scope (the one in effect just before the class definition was entered) is reinstated, and the class object is bound here to the class name given in the class definition header (ClassName in the example).

### 9.3.2. Class Objects

Class objects support two kinds of operations: attribute references and instantiation.

Attribute references use the standard syntax used for all attribute references in Python: obj.name. Valid attribute names are all the names that were in the class’s namespace when the class object was created. So, if the class definition looked like this:

**class** **MyClass**:

*"""A simple example class"""*

i = 12345

**def** f(self):

**return** 'hello world'

then MyClass.i and MyClass.f are valid attribute references, returning an integer and a function object, respectively. Class attributes can also be assigned to, so you can change the value ofMyClass.i by assignment. \_\_doc\_\_ is also a valid attribute, returning the docstring belonging to the class: "A simple example class".

Class instantiation uses function notation. Just pretend that the class object is a parameterless function that returns a new instance of the class. For example (assuming the above class):

x = MyClass()

creates a new instance of the class and assigns this object to the local variable x.

The instantiation operation (“calling” a class object) creates an empty object. Many classes like to create objects with instances customized to a specific initial state. Therefore a class may define a special method named [\_\_init\_\_()](https://docs.python.org/3/reference/datamodel.html#object.__init__), like this:

**def** \_\_init\_\_(self):

self.data = []

When a class defines an [\_\_init\_\_()](https://docs.python.org/3/reference/datamodel.html#object.__init__) method, class instantiation automatically invokes [\_\_init\_\_()](https://docs.python.org/3/reference/datamodel.html#object.__init__)for the newly-created class instance. So in this example, a new, initialized instance can be obtained by:

x = MyClass()

Of course, the [\_\_init\_\_()](https://docs.python.org/3/reference/datamodel.html#object.__init__) method may have arguments for greater flexibility. In that case, arguments given to the class instantiation operator are passed on to [\_\_init\_\_()](https://docs.python.org/3/reference/datamodel.html#object.__init__). For example,

>>>

**>>> class** **Complex**:

**...**  **def** \_\_init\_\_(self, realpart, imagpart):

**...**  self.r = realpart

**...**  self.i = imagpart

**...**

**>>>** x = Complex(3.0, -4.5)

**>>>** x.r, x.i

(3.0, -4.5)

### 9.3.3. Instance Objects

Now what can we do with instance objects? The only operations understood by instance objects are attribute references. There are two kinds of valid attribute names, data attributes and methods.

data attributes correspond to “instance variables” in Smalltalk, and to “data members” in C++. Data attributes need not be declared; like local variables, they spring into existence when they are first assigned to. For example, if x is the instance of MyClass created above, the following piece of code will print the value 16, without leaving a trace:

x.counter = 1

**while** x.counter < 10:

x.counter = x.counter \* 2

print(x.counter)

**del** x.counter

The other kind of instance attribute reference is a method. A method is a function that “belongs to” an object. (In Python, the term method is not unique to class instances: other object types can have methods as well. For example, list objects have methods called append, insert, remove, sort, and so on. However, in the following discussion, we’ll use the term method exclusively to mean methods of class instance objects, unless explicitly stated otherwise.)

Valid method names of an instance object depend on its class. By definition, all attributes of a class that are function objects define corresponding methods of its instances. So in our example, x.f is a valid method reference, since MyClass.f is a function, but x.i is not, since MyClass.i is not. But x.fis not the same thing as MyClass.f — it is a method object, not a function object.

### 9.3.4. Method Objects

Usually, a method is called right after it is bound:

x.f()

In the MyClass example, this will return the string 'hello world'. However, it is not necessary to call a method right away: x.f is a method object, and can be stored away and called at a later time. For example:

xf = x.f

**while** **True**:

print(xf())

will continue to print hello world until the end of time.

What exactly happens when a method is called? You may have noticed that x.f() was called without an argument above, even though the function definition for f() specified an argument. What happened to the argument? Surely Python raises an exception when a function that requires an argument is called without any — even if the argument isn’t actually used...

Actually, you may have guessed the answer: the special thing about methods is that the object is passed as the first argument of the function. In our example, the call x.f() is exactly equivalent toMyClass.f(x). In general, calling a method with a list of n arguments is equivalent to calling the corresponding function with an argument list that is created by inserting the method’s object before the first argument.

If you still don’t understand how methods work, a look at the implementation can perhaps clarify matters. When an instance attribute is referenced that isn’t a data attribute, its class is searched. If the name denotes a valid class attribute that is a function object, a method object is created by packing (pointers to) the instance object and the function object just found together in an abstract object: this is the method object. When the method object is called with an argument list, a new argument list is constructed from the instance object and the argument list, and the function object is called with this new argument list.

### 9.3.5. Class and Instance Variables

Generally speaking, instance variables are for data unique to each instance and class variables are for attributes and methods shared by all instances of the class:

**class** **Dog**:

kind = 'canine' *# class variable shared by all instances*

**def** \_\_init\_\_(self, name):

self.name = name *# instance variable unique to each instance*

>>> d = Dog('Fido')

>>> e = Dog('Buddy')

>>> d.kind *# shared by all dogs*

'canine'

>>> e.kind *# shared by all dogs*

'canine'

>>> d.name *# unique to d*

'Fido'

>>> e.name *# unique to e*

'Buddy'

As discussed in [A Word About Names and Objects](https://docs.python.org/3/tutorial/classes.html#tut-object), shared data can have possibly surprising effects with involving [mutable](https://docs.python.org/3/glossary.html#term-mutable) objects such as lists and dictionaries. For example, the tricks list in the following code should not be used as a class variable because just a single list would be shared by all Doginstances:

**class** **Dog**:

tricks = [] *# mistaken use of a class variable*

**def** \_\_init\_\_(self, name):

self.name = name

**def** add\_trick(self, trick):

self.tricks.append(trick)

>>> d = Dog('Fido')

>>> e = Dog('Buddy')

>>> d.add\_trick('roll over')

>>> e.add\_trick('play dead')

>>> d.tricks *# unexpectedly shared by all dogs*

['roll over', 'play dead']

Correct design of the class should use an instance variable instead:

**class** **Dog**:

**def** \_\_init\_\_(self, name):

self.name = name

self.tricks = [] *# creates a new empty list for each dog*

**def** add\_trick(self, trick):

self.tricks.append(trick)

>>> d = Dog('Fido')

>>> e = Dog('Buddy')

>>> d.add\_trick('roll over')

>>> e.add\_trick('play dead')

>>> d.tricks

['roll over']

>>> e.tricks

['play dead']

## 9.4. Random Remarks

Data attributes override method attributes with the same name; to avoid accidental name conflicts, which may cause hard-to-find bugs in large programs, it is wise to use some kind of convention that minimizes the chance of conflicts. Possible conventions include capitalizing method names, prefixing data attribute names with a small unique string (perhaps just an underscore), or using verbs for methods and nouns for data attributes.

Data attributes may be referenced by methods as well as by ordinary users (“clients”) of an object. In other words, classes are not usable to implement pure abstract data types. In fact, nothing in Python makes it possible to enforce data hiding — it is all based upon convention. (On the other hand, the Python implementation, written in C, can completely hide implementation details and control access to an object if necessary; this can be used by extensions to Python written in C.)

Clients should use data attributes with care — clients may mess up invariants maintained by the methods by stamping on their data attributes. Note that clients may add data attributes of their own to an instance object without affecting the validity of the methods, as long as name conflicts are avoided — again, a naming convention can save a lot of headaches here.

There is no shorthand for referencing data attributes (or other methods!) from within methods. I find that this actually increases the readability of methods: there is no chance of confusing local variables and instance variables when glancing through a method.

Often, the first argument of a method is called self. This is nothing more than a convention: the nameself has absolutely no special meaning to Python. Note, however, that by not following the convention your code may be less readable to other Python programmers, and it is also conceivable that a class browser program might be written that relies upon such a convention.

Any function object that is a class attribute defines a method for instances of that class. It is not necessary that the function definition is textually enclosed in the class definition: assigning a function object to a local variable in the class is also ok. For example:

*# Function defined outside the class*

**def** f1(self, x, y):

**return** min(x, x+y)

**class** **C**:

f = f1

**def** g(self):

**return** 'hello world'

h = g

Now f, g and h are all attributes of class C that refer to function objects, and consequently they are all methods of instances of C — h being exactly equivalent to g. Note that this practice usually only serves to confuse the reader of a program.

Methods may call other methods by using method attributes of the self argument:

**class** **Bag**:

**def** \_\_init\_\_(self):

self.data = []

**def** add(self, x):

self.data.append(x)

**def** addtwice(self, x):

self.add(x)

self.add(x)

Methods may reference global names in the same way as ordinary functions. The global scope associated with a method is the module containing its definition. (A class is never used as a global scope.) While one rarely encounters a good reason for using global data in a method, there are many legitimate uses of the global scope: for one thing, functions and modules imported into the global scope can be used by methods, as well as functions and classes defined in it. Usually, the class containing the method is itself defined in this global scope, and in the next section we’ll find some good reasons why a method would want to reference its own class.

Each value is an object, and therefore has a class (also called its type). It is stored asobject.\_\_class\_\_.

## 9.5. Inheritance

Of course, a language feature would not be worthy of the name “class” without supporting inheritance. The syntax for a derived class definition looks like this:

**class** **DerivedClassName**(BaseClassName):

<statement-1>

.

.

.

<statement-N>

The name BaseClassName must be defined in a scope containing the derived class definition. In place of a base class name, other arbitrary expressions are also allowed. This can be useful, for example, when the base class is defined in another module:

**class** **DerivedClassName**(modname.BaseClassName):

Execution of a derived class definition proceeds the same as for a base class. When the class object is constructed, the base class is remembered. This is used for resolving attribute references: if a requested attribute is not found in the class, the search proceeds to look in the base class. This rule is applied recursively if the base class itself is derived from some other class.

There’s nothing special about instantiation of derived classes: DerivedClassName() creates a new instance of the class. Method references are resolved as follows: the corresponding class attribute is searched, descending down the chain of base classes if necessary, and the method reference is valid if this yields a function object.

Derived classes may override methods of their base classes. Because methods have no special privileges when calling other methods of the same object, a method of a base class that calls another method defined in the same base class may end up calling a method of a derived class that overrides it. (For C++ programmers: all methods in Python are effectively virtual.)

An overriding method in a derived class may in fact want to extend rather than simply replace the base class method of the same name. There is a simple way to call the base class method directly: just callBaseClassName.methodname(self, arguments). This is occasionally useful to clients as well. (Note that this only works if the base class is accessible as BaseClassName in the global scope.)

Python has two built-in functions that work with inheritance:

* Use [isinstance()](https://docs.python.org/3/library/functions.html#isinstance) to check an instance’s type: isinstance(obj, int) will be True only ifobj.\_\_class\_\_ is [int](https://docs.python.org/3/library/functions.html#int) or some class derived from [int](https://docs.python.org/3/library/functions.html#int).
* Use [issubclass()](https://docs.python.org/3/library/functions.html#issubclass) to check class inheritance: issubclass(bool, int) is True since [bool](https://docs.python.org/3/library/functions.html#bool) is a subclass of [int](https://docs.python.org/3/library/functions.html#int). However, issubclass(float, int) is False since [float](https://docs.python.org/3/library/functions.html#float) is not a subclass of[int](https://docs.python.org/3/library/functions.html#int).

### 9.5.1. Multiple Inheritance

Python supports a form of multiple inheritance as well. A class definition with multiple base classes looks like this:

**class** **DerivedClassName**(Base1, Base2, Base3):

<statement-1>

.

.

.

<statement-N>

For most purposes, in the simplest cases, you can think of the search for attributes inherited from a parent class as depth-first, left-to-right, not searching twice in the same class where there is an overlap in the hierarchy. Thus, if an attribute is not found in DerivedClassName, it is searched for inBase1, then (recursively) in the base classes of Base1, and if it was not found there, it was searched for in Base2, and so on.

In fact, it is slightly more complex than that; the method resolution order changes dynamically to support cooperative calls to [super()](https://docs.python.org/3/library/functions.html#super). This approach is known in some other multiple-inheritance languages as call-next-method and is more powerful than the super call found in single-inheritance languages.

Dynamic ordering is necessary because all cases of multiple inheritance exhibit one or more diamond relationships (where at least one of the parent classes can be accessed through multiple paths from the bottommost class). For example, all classes inherit from [object](https://docs.python.org/3/library/functions.html#object), so any case of multiple inheritance provides more than one path to reach [object](https://docs.python.org/3/library/functions.html#object). To keep the base classes from being accessed more than once, the dynamic algorithm linearizes the search order in a way that preserves the left-to-right ordering specified in each class, that calls each parent only once, and that is monotonic (meaning that a class can be subclassed without affecting the precedence order of its parents). Taken together, these properties make it possible to design reliable and extensible classes with multiple inheritance. For more detail, see <https://www.python.org/download/releases/2.3/mro/>.

## 9.6. Private Variables

“Private” instance variables that cannot be accessed except from inside an object don’t exist in Python. However, there is a convention that is followed by most Python code: a name prefixed with an underscore (e.g. \_spam) should be treated as a non-public part of the API (whether it is a function, a method or a data member). It should be considered an implementation detail and subject to change without notice.

Since there is a valid use-case for class-private members (namely to avoid name clashes of names with names defined by subclasses), there is limited support for such a mechanism, called name mangling. Any identifier of the form \_\_spam (at least two leading underscores, at most one trailing underscore) is textually replaced with \_classname\_\_spam, where classname is the current class name with leading underscore(s) stripped. This mangling is done without regard to the syntactic position of the identifier, as long as it occurs within the definition of a class.

Name mangling is helpful for letting subclasses override methods without breaking intraclass method calls. For example:

**class** **Mapping**:

**def** \_\_init\_\_(self, iterable):

self.items\_list = []

self.\_\_update(iterable)

**def** update(self, iterable):

**for** item **in** iterable:

self.items\_list.append(item)

\_\_update = update *# private copy of original update() method*

**class** **MappingSubclass**(Mapping):

**def** update(self, keys, values):

*# provides new signature for update()*

*# but does not break \_\_init\_\_()*

**for** item **in** zip(keys, values):

self.items\_list.append(item)

Note that the mangling rules are designed mostly to avoid accidents; it still is possible to access or modify a variable that is considered private. This can even be useful in special circumstances, such as in the debugger.

Notice that code passed to exec() or eval() does not consider the classname of the invoking class to be the current class; this is similar to the effect of the global statement, the effect of which is likewise restricted to code that is byte-compiled together. The same restriction applies to getattr(),setattr() and delattr(), as well as when referencing \_\_dict\_\_ directly.

## 9.7. Odds and Ends

Sometimes it is useful to have a data type similar to the Pascal “record” or C “struct”, bundling together a few named data items. An empty class definition will do nicely:

**class** **Employee**:

**pass**

john = Employee() *# Create an empty employee record*

*# Fill the fields of the record*

john.name = 'John Doe'

john.dept = 'computer lab'

john.salary = 1000

A piece of Python code that expects a particular abstract data type can often be passed a class that emulates the methods of that data type instead. For instance, if you have a function that formats some data from a file object, you can define a class with methods read() and readline() that get the data from a string buffer instead, and pass it as an argument.

Instance method objects have attributes, too: m.\_\_self\_\_ is the instance object with the method m(), and m.\_\_func\_\_ is the function object corresponding to the method.

## 9.8. Exceptions Are Classes Too

User-defined exceptions are identified by classes as well. Using this mechanism it is possible to create extensible hierarchies of exceptions.

There are two new valid (semantic) forms for the [raise](https://docs.python.org/3/reference/simple_stmts.html#raise) statement:

**raise** Class

**raise** Instance

In the first form, Class must be an instance of [type](https://docs.python.org/3/library/functions.html#type) or of a class derived from it. The first form is a shorthand for:

**raise** Class()

A class in an [except](https://docs.python.org/3/reference/compound_stmts.html#except) clause is compatible with an exception if it is the same class or a base class thereof (but not the other way around — an except clause listing a derived class is not compatible with a base class). For example, the following code will print B, C, D in that order:

**class** **B**(Exception):

**pass**

**class** **C**(B):

**pass**

**class** **D**(C):

**pass**

**for** cls **in** [B, C, D]:

**try**:

**raise** cls()

**except** D:

print("D")

**except** C:

print("C")

**except** B:

print("B")

Note that if the except clauses were reversed (with except B first), it would have printed B, B, B — the first matching except clause is triggered.

When an error message is printed for an unhandled exception, the exception’s class name is printed, then a colon and a space, and finally the instance converted to a string using the built-in function[str()](https://docs.python.org/3/library/stdtypes.html#str).

## 9.9. Iterators

By now you have probably noticed that most container objects can be looped over using a [for](https://docs.python.org/3/reference/compound_stmts.html#for)statement:

**for** element **in** [1, 2, 3]:

print(element)

**for** element **in** (1, 2, 3):

print(element)

**for** key **in** {'one':1, 'two':2}:

print(key)

**for** char **in** "123":

print(char)

**for** line **in** open("myfile.txt"):

print(line, end='')

This style of access is clear, concise, and convenient. The use of iterators pervades and unifies Python. Behind the scenes, the [for](https://docs.python.org/3/reference/compound_stmts.html#for) statement calls [iter()](https://docs.python.org/3/library/functions.html#iter) on the container object. The function returns an iterator object that defines the method [\_\_next\_\_()](https://docs.python.org/3/library/stdtypes.html#iterator.__next__) which accesses elements in the container one at a time. When there are no more elements, [\_\_next\_\_()](https://docs.python.org/3/library/stdtypes.html#iterator.__next__) raises a [StopIteration](https://docs.python.org/3/library/exceptions.html#StopIteration)exception which tells the [for](https://docs.python.org/3/reference/compound_stmts.html#for) loop to terminate. You can call the [\_\_next\_\_()](https://docs.python.org/3/library/stdtypes.html#iterator.__next__) method using the[next()](https://docs.python.org/3/library/functions.html#next) built-in function; this example shows how it all works:

>>>

**>>>** s = 'abc'

**>>>** it = iter(s)

**>>>** it

<iterator object at 0x00A1DB50>

**>>>** next(it)

'a'

**>>>** next(it)

'b'

**>>>** next(it)

'c'

**>>>** next(it)

Traceback (most recent call last):

File "<stdin>", line 1, in ?

next(it)

StopIteration

Having seen the mechanics behind the iterator protocol, it is easy to add iterator behavior to your classes. Define an [\_\_iter\_\_()](https://docs.python.org/3/reference/datamodel.html#object.__iter__) method which returns an object with a [\_\_next\_\_()](https://docs.python.org/3/library/stdtypes.html#iterator.__next__) method. If the class defines \_\_next\_\_(), then [\_\_iter\_\_()](https://docs.python.org/3/reference/datamodel.html#object.__iter__) can just return self:

**class** **Reverse**:

*"""Iterator for looping over a sequence backwards."""*

**def** \_\_init\_\_(self, data):

self.data = data

self.index = len(data)

**def** \_\_iter\_\_(self):

**return** self

**def** \_\_next\_\_(self):

**if** self.index == 0:

**raise** StopIteration

self.index = self.index - 1

**return** self.data[self.index]

>>>

**>>>** rev = Reverse('spam')

**>>>** iter(rev)

<\_\_main\_\_.Reverse object at 0x00A1DB50>

**>>> for** char **in** rev:

**...**  print(char)

**...**

m

a

p

s

## 9.10. Generators

[Generator](https://docs.python.org/3/glossary.html#term-generator)s are a simple and powerful tool for creating iterators. They are written like regular functions but use the [yield](https://docs.python.org/3/reference/simple_stmts.html#yield) statement whenever they want to return data. Each time [next()](https://docs.python.org/3/library/functions.html#next) is called on it, the generator resumes where it left off (it remembers all the data values and which statement was last executed). An example shows that generators can be trivially easy to create:

**def** reverse(data):

**for** index **in** range(len(data)-1, -1, -1):

**yield** data[index]

>>>

**>>> for** char **in** reverse('golf'):

**...**  print(char)

**...**

f

l

o

g

Anything that can be done with generators can also be done with class-based iterators as described in the previous section. What makes generators so compact is that the [\_\_iter\_\_()](https://docs.python.org/3/reference/datamodel.html#object.__iter__) and [\_\_next\_\_()](https://docs.python.org/3/reference/expressions.html#generator.__next__)methods are created automatically.

Another key feature is that the local variables and execution state are automatically saved between calls. This made the function easier to write and much more clear than an approach using instance variables like self.index and self.data.

In addition to automatic method creation and saving program state, when generators terminate, they automatically raise [StopIteration](https://docs.python.org/3/library/exceptions.html#StopIteration). In combination, these features make it easy to create iterators with no more effort than writing a regular function.

## 9.11. Generator Expressions

Some simple generators can be coded succinctly as expressions using a syntax similar to list comprehensions but with parentheses instead of brackets. These expressions are designed for situations where the generator is used right away by an enclosing function. Generator expressions are more compact but less versatile than full generator definitions and tend to be more memory friendly than equivalent list comprehensions.

Examples:

>>>

**>>>** sum(i\*i **for** i **in** range(10)) *# sum of squares*

285

**>>>** xvec = [10, 20, 30]

**>>>** yvec = [7, 5, 3]

**>>>** sum(x\*y **for** x,y **in** zip(xvec, yvec)) *# dot product*

260

**>>> from** **math** **import** pi, sin

**>>>** sine\_table = {x: sin(x\*pi/180) **for** x **in** range(0, 91)}

**>>>** unique\_words = set(word **for** line **in** page **for** word **in** line.split())

**>>>** valedictorian = max((student.gpa, student.name) **for** student **in** graduates)

**>>>** data = 'golf'

**>>>** list(data[i] **for** i **in** range(len(data)-1, -1, -1))

['f', 'l', 'o', 'g']

**Footnotes**

|  |  |
| --- | --- |
| [[1]](https://docs.python.org/3/tutorial/classes.html#id1) | Except for one thing. Module objects have a secret read-only attribute called [\_\_dict\_\_](https://docs.python.org/3/library/stdtypes.html#object.__dict__) which returns the dictionary used to implement the module’s namespace; the name [\_\_dict\_\_](https://docs.python.org/3/library/stdtypes.html#object.__dict__) is an attribute but not a global name. Obviously, using this violates the abstraction of namespace implementation, and should be restricted to things like post-mortem debuggers. |

# 9. Classes

Compared with other programming languages, Python’s class mechanism adds classes with a minimum of new syntax and semantics. It is a mixture of the class mechanisms found in C++ and Modula-3. Python classes provide all the standard features of Object Oriented Programming: the class inheritance mechanism allows multiple base classes, a derived class can override any methods of its base class or classes, and a method can call the method of a base class with the same name. Objects can contain arbitrary amounts and kinds of data. As is true for modules, classes partake of the dynamic nature of Python: they are created at runtime, and can be modified further after creation.

In C++ terminology, normally class members (including the data members) are public (except see below [Private Variables](https://docs.python.org/3/tutorial/classes.html#tut-private)), and all member functions are virtual. As in Modula-3, there are no shorthands for referencing the object’s members from its methods: the method function is declared with an explicit first argument representing the object, which is provided implicitly by the call. As in Smalltalk, classes themselves are objects. This provides semantics for importing and renaming. Unlike C++ and Modula-3, built-in types can be used as base classes for extension by the user. Also, like in C++, most built-in operators with special syntax (arithmetic operators, subscripting etc.) can be redefined for class instances.

(Lacking universally accepted terminology to talk about classes, I will make occasional use of Smalltalk and C++ terms. I would use Modula-3 terms, since its object-oriented semantics are closer to those of Python than C++, but I expect that few readers have heard of it.)

## 9.1. A Word About Names and Objects

Objects have individuality, and multiple names (in multiple scopes) can be bound to the same object. This is known as aliasing in other languages. This is usually not appreciated on a first glance at Python, and can be safely ignored when dealing with immutable basic types (numbers, strings, tuples). However, aliasing has a possibly surprising effect on the semantics of Python code involving mutable objects such as lists, dictionaries, and most other types. This is usually used to the benefit of the program, since aliases behave like pointers in some respects. For example, passing an object is cheap since only a pointer is passed by the implementation; and if a function modifies an object passed as an argument, the caller will see the change — this eliminates the need for two different argument passing mechanisms as in Pascal.

## 9.2. Python Scopes and Namespaces

Before introducing classes, I first have to tell you something about Python’s scope rules. Class definitions play some neat tricks with namespaces, and you need to know how scopes and namespaces work to fully understand what’s going on. Incidentally, knowledge about this subject is useful for any advanced Python programmer.

Let’s begin with some definitions.

A namespace is a mapping from names to objects. Most namespaces are currently implemented as Python dictionaries, but that’s normally not noticeable in any way (except for performance), and it may change in the future. Examples of namespaces are: the set of built-in names (containing functions such as [abs()](https://docs.python.org/3/library/functions.html#abs), and built-in exception names); the global names in a module; and the local names in a function invocation. In a sense the set of attributes of an object also form a namespace. The important thing to know about namespaces is that there is absolutely no relation between names in different namespaces; for instance, two different modules may both define a function maximize without confusion — users of the modules must prefix it with the module name.

By the way, I use the word attribute for any name following a dot — for example, in the expressionz.real, real is an attribute of the object z. Strictly speaking, references to names in modules are attribute references: in the expression modname.funcname, modname is a module object and funcnameis an attribute of it. In this case there happens to be a straightforward mapping between the module’s attributes and the global names defined in the module: they share the same namespace! [[1]](https://docs.python.org/3/tutorial/classes.html#id2)

Attributes may be read-only or writable. In the latter case, assignment to attributes is possible. Module attributes are writable: you can write modname.the\_answer = 42. Writable attributes may also be deleted with the [del](https://docs.python.org/3/reference/simple_stmts.html#del) statement. For example, del modname.the\_answer will remove the attributethe\_answer from the object named by modname.

Namespaces are created at different moments and have different lifetimes. The namespace containing the built-in names is created when the Python interpreter starts up, and is never deleted. The global namespace for a module is created when the module definition is read in; normally, module namespaces also last until the interpreter quits. The statements executed by the top-level invocation of the interpreter, either read from a script file or interactively, are considered part of a module called[\_\_main\_\_](https://docs.python.org/3/library/__main__.html#module-__main__), so they have their own global namespace. (The built-in names actually also live in a module; this is called [builtins](https://docs.python.org/3/library/builtins.html#module-builtins).)

The local namespace for a function is created when the function is called, and deleted when the function returns or raises an exception that is not handled within the function. (Actually, forgetting would be a better way to describe what actually happens.) Of course, recursive invocations each have their own local namespace.

A scope is a textual region of a Python program where a namespace is directly accessible. “Directly accessible” here means that an unqualified reference to a name attempts to find the name in the namespace.

Although scopes are determined statically, they are used dynamically. At any time during execution, there are at least three nested scopes whose namespaces are directly accessible:

* the innermost scope, which is searched first, contains the local names
* the scopes of any enclosing functions, which are searched starting with the nearest enclosing scope, contains non-local, but also non-global names
* the next-to-last scope contains the current module’s global names
* the outermost scope (searched last) is the namespace containing built-in names

If a name is declared global, then all references and assignments go directly to the middle scope containing the module’s global names. To rebind variables found outside of the innermost scope, the[nonlocal](https://docs.python.org/3/reference/simple_stmts.html#nonlocal) statement can be used; if not declared nonlocal, those variables are read-only (an attempt to write to such a variable will simply create a new local variable in the innermost scope, leaving the identically named outer variable unchanged).

Usually, the local scope references the local names of the (textually) current function. Outside functions, the local scope references the same namespace as the global scope: the module’s namespace. Class definitions place yet another namespace in the local scope.

It is important to realize that scopes are determined textually: the global scope of a function defined in a module is that module’s namespace, no matter from where or by what alias the function is called. On the other hand, the actual search for names is done dynamically, at run time — however, the language definition is evolving towards static name resolution, at “compile” time, so don’t rely on dynamic name resolution! (In fact, local variables are already determined statically.)

A special quirk of Python is that – if no [global](https://docs.python.org/3/reference/simple_stmts.html#global) statement is in effect – assignments to names always go into the innermost scope. Assignments do not copy data — they just bind names to objects. The same is true for deletions: the statement del x removes the binding of x from the namespace referenced by the local scope. In fact, all operations that introduce new names use the local scope: in particular, [import](https://docs.python.org/3/reference/simple_stmts.html#import) statements and function definitions bind the module or function name in the local scope.

The [global](https://docs.python.org/3/reference/simple_stmts.html#global) statement can be used to indicate that particular variables live in the global scope and should be rebound there; the [nonlocal](https://docs.python.org/3/reference/simple_stmts.html#nonlocal) statement indicates that particular variables live in an enclosing scope and should be rebound there.

### 9.2.1. Scopes and Namespaces Example

This is an example demonstrating how to reference the different scopes and namespaces, and how[global](https://docs.python.org/3/reference/simple_stmts.html#global) and [nonlocal](https://docs.python.org/3/reference/simple_stmts.html#nonlocal) affect variable binding:

**def** scope\_test():

**def** do\_local():

spam = "local spam"

**def** do\_nonlocal():

**nonlocal** spam

spam = "nonlocal spam"

**def** do\_global():

**global** spam

spam = "global spam"

spam = "test spam"

do\_local()

print("After local assignment:", spam)

do\_nonlocal()

print("After nonlocal assignment:", spam)

do\_global()

print("After global assignment:", spam)

scope\_test()

print("In global scope:", spam)

The output of the example code is:

After local assignment: test spam

After nonlocal assignment: nonlocal spam

After global assignment: nonlocal spam

In global scope: global spam

Note how the local assignment (which is default) didn’t change scope\_test‘s binding of spam. The[nonlocal](https://docs.python.org/3/reference/simple_stmts.html#nonlocal) assignment changed scope\_test‘s binding of spam, and the [global](https://docs.python.org/3/reference/simple_stmts.html#global) assignment changed the module-level binding.

You can also see that there was no previous binding for spam before the [global](https://docs.python.org/3/reference/simple_stmts.html#global) assignment.

## 9.3. A First Look at Classes

Classes introduce a little bit of new syntax, three new object types, and some new semantics.

### 9.3.1. Class Definition Syntax

The simplest form of class definition looks like this:

**class** **ClassName**:

<statement-1>

.

.

.

<statement-N>

Class definitions, like function definitions ([def](https://docs.python.org/3/reference/compound_stmts.html#def) statements) must be executed before they have any effect. (You could conceivably place a class definition in a branch of an [if](https://docs.python.org/3/reference/compound_stmts.html#if) statement, or inside a function.)

In practice, the statements inside a class definition will usually be function definitions, but other statements are allowed, and sometimes useful — we’ll come back to this later. The function definitions inside a class normally have a peculiar form of argument list, dictated by the calling conventions for methods — again, this is explained later.

When a class definition is entered, a new namespace is created, and used as the local scope — thus, all assignments to local variables go into this new namespace. In particular, function definitions bind the name of the new function here.

When a class definition is left normally (via the end), a class object is created. This is basically a wrapper around the contents of the namespace created by the class definition; we’ll learn more about class objects in the next section. The original local scope (the one in effect just before the class definition was entered) is reinstated, and the class object is bound here to the class name given in the class definition header (ClassName in the example).

### 9.3.2. Class Objects

Class objects support two kinds of operations: attribute references and instantiation.

Attribute references use the standard syntax used for all attribute references in Python: obj.name. Valid attribute names are all the names that were in the class’s namespace when the class object was created. So, if the class definition looked like this:

**class** **MyClass**:

*"""A simple example class"""*

i = 12345

**def** f(self):

**return** 'hello world'

then MyClass.i and MyClass.f are valid attribute references, returning an integer and a function object, respectively. Class attributes can also be assigned to, so you can change the value ofMyClass.i by assignment. \_\_doc\_\_ is also a valid attribute, returning the docstring belonging to the class: "A simple example class".

Class instantiation uses function notation. Just pretend that the class object is a parameterless function that returns a new instance of the class. For example (assuming the above class):

x = MyClass()

creates a new instance of the class and assigns this object to the local variable x.

The instantiation operation (“calling” a class object) creates an empty object. Many classes like to create objects with instances customized to a specific initial state. Therefore a class may define a special method named [\_\_init\_\_()](https://docs.python.org/3/reference/datamodel.html#object.__init__), like this:

**def** \_\_init\_\_(self):

self.data = []

When a class defines an [\_\_init\_\_()](https://docs.python.org/3/reference/datamodel.html#object.__init__) method, class instantiation automatically invokes [\_\_init\_\_()](https://docs.python.org/3/reference/datamodel.html#object.__init__)for the newly-created class instance. So in this example, a new, initialized instance can be obtained by:

x = MyClass()

Of course, the [\_\_init\_\_()](https://docs.python.org/3/reference/datamodel.html#object.__init__) method may have arguments for greater flexibility. In that case, arguments given to the class instantiation operator are passed on to [\_\_init\_\_()](https://docs.python.org/3/reference/datamodel.html#object.__init__). For example,

>>>

**>>> class** **Complex**:

**...**  **def** \_\_init\_\_(self, realpart, imagpart):

**...**  self.r = realpart

**...**  self.i = imagpart

**...**

**>>>** x = Complex(3.0, -4.5)

**>>>** x.r, x.i

(3.0, -4.5)

### 9.3.3. Instance Objects

Now what can we do with instance objects? The only operations understood by instance objects are attribute references. There are two kinds of valid attribute names, data attributes and methods.

data attributes correspond to “instance variables” in Smalltalk, and to “data members” in C++. Data attributes need not be declared; like local variables, they spring into existence when they are first assigned to. For example, if x is the instance of MyClass created above, the following piece of code will print the value 16, without leaving a trace:

x.counter = 1

**while** x.counter < 10:

x.counter = x.counter \* 2

print(x.counter)

**del** x.counter

The other kind of instance attribute reference is a method. A method is a function that “belongs to” an object. (In Python, the term method is not unique to class instances: other object types can have methods as well. For example, list objects have methods called append, insert, remove, sort, and so on. However, in the following discussion, we’ll use the term method exclusively to mean methods of class instance objects, unless explicitly stated otherwise.)

Valid method names of an instance object depend on its class. By definition, all attributes of a class that are function objects define corresponding methods of its instances. So in our example, x.f is a valid method reference, since MyClass.f is a function, but x.i is not, since MyClass.i is not. But x.fis not the same thing as MyClass.f — it is a method object, not a function object.

### 9.3.4. Method Objects

Usually, a method is called right after it is bound:

x.f()

In the MyClass example, this will return the string 'hello world'. However, it is not necessary to call a method right away: x.f is a method object, and can be stored away and called at a later time. For example:

xf = x.f

**while** **True**:

print(xf())

will continue to print hello world until the end of time.

What exactly happens when a method is called? You may have noticed that x.f() was called without an argument above, even though the function definition for f() specified an argument. What happened to the argument? Surely Python raises an exception when a function that requires an argument is called without any — even if the argument isn’t actually used...

Actually, you may have guessed the answer: the special thing about methods is that the object is passed as the first argument of the function. In our example, the call x.f() is exactly equivalent toMyClass.f(x). In general, calling a method with a list of n arguments is equivalent to calling the corresponding function with an argument list that is created by inserting the method’s object before the first argument.

If you still don’t understand how methods work, a look at the implementation can perhaps clarify matters. When an instance attribute is referenced that isn’t a data attribute, its class is searched. If the name denotes a valid class attribute that is a function object, a method object is created by packing (pointers to) the instance object and the function object just found together in an abstract object: this is the method object. When the method object is called with an argument list, a new argument list is constructed from the instance object and the argument list, and the function object is called with this new argument list.

### 9.3.5. Class and Instance Variables

Generally speaking, instance variables are for data unique to each instance and class variables are for attributes and methods shared by all instances of the class:

**class** **Dog**:

kind = 'canine' *# class variable shared by all instances*

**def** \_\_init\_\_(self, name):

self.name = name *# instance variable unique to each instance*

>>> d = Dog('Fido')

>>> e = Dog('Buddy')

>>> d.kind *# shared by all dogs*

'canine'

>>> e.kind *# shared by all dogs*

'canine'

>>> d.name *# unique to d*

'Fido'

>>> e.name *# unique to e*

'Buddy'

As discussed in [A Word About Names and Objects](https://docs.python.org/3/tutorial/classes.html#tut-object), shared data can have possibly surprising effects with involving [mutable](https://docs.python.org/3/glossary.html#term-mutable) objects such as lists and dictionaries. For example, the tricks list in the following code should not be used as a class variable because just a single list would be shared by all Doginstances:

**class** **Dog**:

tricks = [] *# mistaken use of a class variable*

**def** \_\_init\_\_(self, name):

self.name = name

**def** add\_trick(self, trick):

self.tricks.append(trick)

>>> d = Dog('Fido')

>>> e = Dog('Buddy')

>>> d.add\_trick('roll over')

>>> e.add\_trick('play dead')

>>> d.tricks *# unexpectedly shared by all dogs*

['roll over', 'play dead']

Correct design of the class should use an instance variable instead:

**class** **Dog**:

**def** \_\_init\_\_(self, name):

self.name = name

self.tricks = [] *# creates a new empty list for each dog*

**def** add\_trick(self, trick):

self.tricks.append(trick)

>>> d = Dog('Fido')

>>> e = Dog('Buddy')

>>> d.add\_trick('roll over')

>>> e.add\_trick('play dead')

>>> d.tricks

['roll over']

>>> e.tricks

['play dead']

## 9.4. Random Remarks

Data attributes override method attributes with the same name; to avoid accidental name conflicts, which may cause hard-to-find bugs in large programs, it is wise to use some kind of convention that minimizes the chance of conflicts. Possible conventions include capitalizing method names, prefixing data attribute names with a small unique string (perhaps just an underscore), or using verbs for methods and nouns for data attributes.

Data attributes may be referenced by methods as well as by ordinary users (“clients”) of an object. In other words, classes are not usable to implement pure abstract data types. In fact, nothing in Python makes it possible to enforce data hiding — it is all based upon convention. (On the other hand, the Python implementation, written in C, can completely hide implementation details and control access to an object if necessary; this can be used by extensions to Python written in C.)

Clients should use data attributes with care — clients may mess up invariants maintained by the methods by stamping on their data attributes. Note that clients may add data attributes of their own to an instance object without affecting the validity of the methods, as long as name conflicts are avoided — again, a naming convention can save a lot of headaches here.

There is no shorthand for referencing data attributes (or other methods!) from within methods. I find that this actually increases the readability of methods: there is no chance of confusing local variables and instance variables when glancing through a method.

Often, the first argument of a method is called self. This is nothing more than a convention: the nameself has absolutely no special meaning to Python. Note, however, that by not following the convention your code may be less readable to other Python programmers, and it is also conceivable that a class browser program might be written that relies upon such a convention.

Any function object that is a class attribute defines a method for instances of that class. It is not necessary that the function definition is textually enclosed in the class definition: assigning a function object to a local variable in the class is also ok. For example:

*# Function defined outside the class*

**def** f1(self, x, y):

**return** min(x, x+y)

**class** **C**:

f = f1

**def** g(self):

**return** 'hello world'

h = g

Now f, g and h are all attributes of class C that refer to function objects, and consequently they are all methods of instances of C — h being exactly equivalent to g. Note that this practice usually only serves to confuse the reader of a program.

Methods may call other methods by using method attributes of the self argument:

**class** **Bag**:

**def** \_\_init\_\_(self):

self.data = []

**def** add(self, x):

self.data.append(x)

**def** addtwice(self, x):

self.add(x)

self.add(x)

Methods may reference global names in the same way as ordinary functions. The global scope associated with a method is the module containing its definition. (A class is never used as a global scope.) While one rarely encounters a good reason for using global data in a method, there are many legitimate uses of the global scope: for one thing, functions and modules imported into the global scope can be used by methods, as well as functions and classes defined in it. Usually, the class containing the method is itself defined in this global scope, and in the next section we’ll find some good reasons why a method would want to reference its own class.

Each value is an object, and therefore has a class (also called its type). It is stored asobject.\_\_class\_\_.

## 9.5. Inheritance

Of course, a language feature would not be worthy of the name “class” without supporting inheritance. The syntax for a derived class definition looks like this:

**class** **DerivedClassName**(BaseClassName):

<statement-1>

.

.

.

<statement-N>

The name BaseClassName must be defined in a scope containing the derived class definition. In place of a base class name, other arbitrary expressions are also allowed. This can be useful, for example, when the base class is defined in another module:

**class** **DerivedClassName**(modname.BaseClassName):

Execution of a derived class definition proceeds the same as for a base class. When the class object is constructed, the base class is remembered. This is used for resolving attribute references: if a requested attribute is not found in the class, the search proceeds to look in the base class. This rule is applied recursively if the base class itself is derived from some other class.

There’s nothing special about instantiation of derived classes: DerivedClassName() creates a new instance of the class. Method references are resolved as follows: the corresponding class attribute is searched, descending down the chain of base classes if necessary, and the method reference is valid if this yields a function object.

Derived classes may override methods of their base classes. Because methods have no special privileges when calling other methods of the same object, a method of a base class that calls another method defined in the same base class may end up calling a method of a derived class that overrides it. (For C++ programmers: all methods in Python are effectively virtual.)

An overriding method in a derived class may in fact want to extend rather than simply replace the base class method of the same name. There is a simple way to call the base class method directly: just callBaseClassName.methodname(self, arguments). This is occasionally useful to clients as well. (Note that this only works if the base class is accessible as BaseClassName in the global scope.)

Python has two built-in functions that work with inheritance:

* Use [isinstance()](https://docs.python.org/3/library/functions.html#isinstance) to check an instance’s type: isinstance(obj, int) will be True only ifobj.\_\_class\_\_ is [int](https://docs.python.org/3/library/functions.html#int) or some class derived from [int](https://docs.python.org/3/library/functions.html#int).
* Use [issubclass()](https://docs.python.org/3/library/functions.html#issubclass) to check class inheritance: issubclass(bool, int) is True since [bool](https://docs.python.org/3/library/functions.html#bool) is a subclass of [int](https://docs.python.org/3/library/functions.html#int). However, issubclass(float, int) is False since [float](https://docs.python.org/3/library/functions.html#float) is not a subclass of[int](https://docs.python.org/3/library/functions.html#int).

### 9.5.1. Multiple Inheritance

Python supports a form of multiple inheritance as well. A class definition with multiple base classes looks like this:

**class** **DerivedClassName**(Base1, Base2, Base3):

<statement-1>

.

.

.

<statement-N>

For most purposes, in the simplest cases, you can think of the search for attributes inherited from a parent class as depth-first, left-to-right, not searching twice in the same class where there is an overlap in the hierarchy. Thus, if an attribute is not found in DerivedClassName, it is searched for inBase1, then (recursively) in the base classes of Base1, and if it was not found there, it was searched for in Base2, and so on.

In fact, it is slightly more complex than that; the method resolution order changes dynamically to support cooperative calls to [super()](https://docs.python.org/3/library/functions.html#super). This approach is known in some other multiple-inheritance languages as call-next-method and is more powerful than the super call found in single-inheritance languages.

Dynamic ordering is necessary because all cases of multiple inheritance exhibit one or more diamond relationships (where at least one of the parent classes can be accessed through multiple paths from the bottommost class). For example, all classes inherit from [object](https://docs.python.org/3/library/functions.html#object), so any case of multiple inheritance provides more than one path to reach [object](https://docs.python.org/3/library/functions.html#object). To keep the base classes from being accessed more than once, the dynamic algorithm linearizes the search order in a way that preserves the left-to-right ordering specified in each class, that calls each parent only once, and that is monotonic (meaning that a class can be subclassed without affecting the precedence order of its parents). Taken together, these properties make it possible to design reliable and extensible classes with multiple inheritance. For more detail, see <https://www.python.org/download/releases/2.3/mro/>.

## 9.6. Private Variables

“Private” instance variables that cannot be accessed except from inside an object don’t exist in Python. However, there is a convention that is followed by most Python code: a name prefixed with an underscore (e.g. \_spam) should be treated as a non-public part of the API (whether it is a function, a method or a data member). It should be considered an implementation detail and subject to change without notice.

Since there is a valid use-case for class-private members (namely to avoid name clashes of names with names defined by subclasses), there is limited support for such a mechanism, called name mangling. Any identifier of the form \_\_spam (at least two leading underscores, at most one trailing underscore) is textually replaced with \_classname\_\_spam, where classname is the current class name with leading underscore(s) stripped. This mangling is done without regard to the syntactic position of the identifier, as long as it occurs within the definition of a class.

Name mangling is helpful for letting subclasses override methods without breaking intraclass method calls. For example:

**class** **Mapping**:

**def** \_\_init\_\_(self, iterable):

self.items\_list = []

self.\_\_update(iterable)

**def** update(self, iterable):

**for** item **in** iterable:

self.items\_list.append(item)

\_\_update = update *# private copy of original update() method*

**class** **MappingSubclass**(Mapping):

**def** update(self, keys, values):

*# provides new signature for update()*

*# but does not break \_\_init\_\_()*

**for** item **in** zip(keys, values):

self.items\_list.append(item)

Note that the mangling rules are designed mostly to avoid accidents; it still is possible to access or modify a variable that is considered private. This can even be useful in special circumstances, such as in the debugger.

Notice that code passed to exec() or eval() does not consider the classname of the invoking class to be the current class; this is similar to the effect of the global statement, the effect of which is likewise restricted to code that is byte-compiled together. The same restriction applies to getattr(),setattr() and delattr(), as well as when referencing \_\_dict\_\_ directly.

## 9.7. Odds and Ends

Sometimes it is useful to have a data type similar to the Pascal “record” or C “struct”, bundling together a few named data items. An empty class definition will do nicely:

**class** **Employee**:

**pass**

john = Employee() *# Create an empty employee record*

*# Fill the fields of the record*

john.name = 'John Doe'

john.dept = 'computer lab'

john.salary = 1000

A piece of Python code that expects a particular abstract data type can often be passed a class that emulates the methods of that data type instead. For instance, if you have a function that formats some data from a file object, you can define a class with methods read() and readline() that get the data from a string buffer instead, and pass it as an argument.

Instance method objects have attributes, too: m.\_\_self\_\_ is the instance object with the method m(), and m.\_\_func\_\_ is the function object corresponding to the method.

## 9.8. Exceptions Are Classes Too

User-defined exceptions are identified by classes as well. Using this mechanism it is possible to create extensible hierarchies of exceptions.

There are two new valid (semantic) forms for the [raise](https://docs.python.org/3/reference/simple_stmts.html#raise) statement:

**raise** Class

**raise** Instance

In the first form, Class must be an instance of [type](https://docs.python.org/3/library/functions.html#type) or of a class derived from it. The first form is a shorthand for:

**raise** Class()

A class in an [except](https://docs.python.org/3/reference/compound_stmts.html#except) clause is compatible with an exception if it is the same class or a base class thereof (but not the other way around — an except clause listing a derived class is not compatible with a base class). For example, the following code will print B, C, D in that order:

**class** **B**(Exception):

**pass**

**class** **C**(B):

**pass**

**class** **D**(C):

**pass**

**for** cls **in** [B, C, D]:

**try**:

**raise** cls()

**except** D:

print("D")

**except** C:

print("C")

**except** B:

print("B")

Note that if the except clauses were reversed (with except B first), it would have printed B, B, B — the first matching except clause is triggered.

When an error message is printed for an unhandled exception, the exception’s class name is printed, then a colon and a space, and finally the instance converted to a string using the built-in function[str()](https://docs.python.org/3/library/stdtypes.html#str).

## 9.9. Iterators

By now you have probably noticed that most container objects can be looped over using a [for](https://docs.python.org/3/reference/compound_stmts.html#for)statement:

**for** element **in** [1, 2, 3]:

print(element)

**for** element **in** (1, 2, 3):

print(element)

**for** key **in** {'one':1, 'two':2}:

print(key)

**for** char **in** "123":

print(char)

**for** line **in** open("myfile.txt"):

print(line, end='')

This style of access is clear, concise, and convenient. The use of iterators pervades and unifies Python. Behind the scenes, the [for](https://docs.python.org/3/reference/compound_stmts.html#for) statement calls [iter()](https://docs.python.org/3/library/functions.html#iter) on the container object. The function returns an iterator object that defines the method [\_\_next\_\_()](https://docs.python.org/3/library/stdtypes.html#iterator.__next__) which accesses elements in the container one at a time. When there are no more elements, [\_\_next\_\_()](https://docs.python.org/3/library/stdtypes.html#iterator.__next__) raises a [StopIteration](https://docs.python.org/3/library/exceptions.html#StopIteration)exception which tells the [for](https://docs.python.org/3/reference/compound_stmts.html#for) loop to terminate. You can call the [\_\_next\_\_()](https://docs.python.org/3/library/stdtypes.html#iterator.__next__) method using the[next()](https://docs.python.org/3/library/functions.html#next) built-in function; this example shows how it all works:

>>>

**>>>** s = 'abc'

**>>>** it = iter(s)

**>>>** it

<iterator object at 0x00A1DB50>

**>>>** next(it)

'a'

**>>>** next(it)

'b'

**>>>** next(it)

'c'

**>>>** next(it)

Traceback (most recent call last):

File "<stdin>", line 1, in ?

next(it)

StopIteration

Having seen the mechanics behind the iterator protocol, it is easy to add iterator behavior to your classes. Define an [\_\_iter\_\_()](https://docs.python.org/3/reference/datamodel.html#object.__iter__) method which returns an object with a [\_\_next\_\_()](https://docs.python.org/3/library/stdtypes.html#iterator.__next__) method. If the class defines \_\_next\_\_(), then [\_\_iter\_\_()](https://docs.python.org/3/reference/datamodel.html#object.__iter__) can just return self:

**class** **Reverse**:

*"""Iterator for looping over a sequence backwards."""*

**def** \_\_init\_\_(self, data):

self.data = data

self.index = len(data)

**def** \_\_iter\_\_(self):

**return** self

**def** \_\_next\_\_(self):

**if** self.index == 0:

**raise** StopIteration

self.index = self.index - 1

**return** self.data[self.index]

>>>

**>>>** rev = Reverse('spam')

**>>>** iter(rev)

<\_\_main\_\_.Reverse object at 0x00A1DB50>

**>>> for** char **in** rev:

**...**  print(char)

**...**

m

a

p

s

## 9.10. Generators

[Generator](https://docs.python.org/3/glossary.html#term-generator)s are a simple and powerful tool for creating iterators. They are written like regular functions but use the [yield](https://docs.python.org/3/reference/simple_stmts.html#yield) statement whenever they want to return data. Each time [next()](https://docs.python.org/3/library/functions.html#next) is called on it, the generator resumes where it left off (it remembers all the data values and which statement was last executed). An example shows that generators can be trivially easy to create:

**def** reverse(data):

**for** index **in** range(len(data)-1, -1, -1):

**yield** data[index]

>>>

**>>> for** char **in** reverse('golf'):

**...**  print(char)

**...**

f

l

o

g

Anything that can be done with generators can also be done with class-based iterators as described in the previous section. What makes generators so compact is that the [\_\_iter\_\_()](https://docs.python.org/3/reference/datamodel.html#object.__iter__) and [\_\_next\_\_()](https://docs.python.org/3/reference/expressions.html#generator.__next__)methods are created automatically.

Another key feature is that the local variables and execution state are automatically saved between calls. This made the function easier to write and much more clear than an approach using instance variables like self.index and self.data.

In addition to automatic method creation and saving program state, when generators terminate, they automatically raise [StopIteration](https://docs.python.org/3/library/exceptions.html#StopIteration). In combination, these features make it easy to create iterators with no more effort than writing a regular function.

## 9.11. Generator Expressions

Some simple generators can be coded succinctly as expressions using a syntax similar to list comprehensions but with parentheses instead of brackets. These expressions are designed for situations where the generator is used right away by an enclosing function. Generator expressions are more compact but less versatile than full generator definitions and tend to be more memory friendly than equivalent list comprehensions.

Examples:

>>>

**>>>** sum(i\*i **for** i **in** range(10)) *# sum of squares*

285

**>>>** xvec = [10, 20, 30]

**>>>** yvec = [7, 5, 3]

**>>>** sum(x\*y **for** x,y **in** zip(xvec, yvec)) *# dot product*

260

**>>> from** **math** **import** pi, sin

**>>>** sine\_table = {x: sin(x\*pi/180) **for** x **in** range(0, 91)}

**>>>** unique\_words = set(word **for** line **in** page **for** word **in** line.split())

**>>>** valedictorian = max((student.gpa, student.name) **for** student **in** graduates)

**>>>** data = 'golf'

**>>>** list(data[i] **for** i **in** range(len(data)-1, -1, -1))

['f', 'l', 'o', 'g']

**Footnotes**

|  |  |
| --- | --- |
| [[1]](https://docs.python.org/3/tutorial/classes.html#id1) | Except for one thing. Module objects have a secret read-only attribute called [\_\_dict\_\_](https://docs.python.org/3/library/stdtypes.html#object.__dict__) which returns the dictionary used to implement the module’s namespace; the name [\_\_dict\_\_](https://docs.python.org/3/library/stdtypes.html#object.__dict__) is an attribute but not a global name. Obviously, using this violates the abstraction of namespace implementation, and should be restricted to things like post-mortem debuggers. |

# 9. Classes

Compared with other programming languages, Python’s class mechanism adds classes with a minimum of new syntax and semantics. It is a mixture of the class mechanisms found in C++ and Modula-3. Python classes provide all the standard features of Object Oriented Programming: the class inheritance mechanism allows multiple base classes, a derived class can override any methods of its base class or classes, and a method can call the method of a base class with the same name. Objects can contain arbitrary amounts and kinds of data. As is true for modules, classes partake of the dynamic nature of Python: they are created at runtime, and can be modified further after creation.

In C++ terminology, normally class members (including the data members) are public (except see below [Private Variables](https://docs.python.org/3/tutorial/classes.html#tut-private)), and all member functions are virtual. As in Modula-3, there are no shorthands for referencing the object’s members from its methods: the method function is declared with an explicit first argument representing the object, which is provided implicitly by the call. As in Smalltalk, classes themselves are objects. This provides semantics for importing and renaming. Unlike C++ and Modula-3, built-in types can be used as base classes for extension by the user. Also, like in C++, most built-in operators with special syntax (arithmetic operators, subscripting etc.) can be redefined for class instances.

(Lacking universally accepted terminology to talk about classes, I will make occasional use of Smalltalk and C++ terms. I would use Modula-3 terms, since its object-oriented semantics are closer to those of Python than C++, but I expect that few readers have heard of it.)

## 9.1. A Word About Names and Objects

Objects have individuality, and multiple names (in multiple scopes) can be bound to the same object. This is known as aliasing in other languages. This is usually not appreciated on a first glance at Python, and can be safely ignored when dealing with immutable basic types (numbers, strings, tuples). However, aliasing has a possibly surprising effect on the semantics of Python code involving mutable objects such as lists, dictionaries, and most other types. This is usually used to the benefit of the program, since aliases behave like pointers in some respects. For example, passing an object is cheap since only a pointer is passed by the implementation; and if a function modifies an object passed as an argument, the caller will see the change — this eliminates the need for two different argument passing mechanisms as in Pascal.

## 9.2. Python Scopes and Namespaces

Before introducing classes, I first have to tell you something about Python’s scope rules. Class definitions play some neat tricks with namespaces, and you need to know how scopes and namespaces work to fully understand what’s going on. Incidentally, knowledge about this subject is useful for any advanced Python programmer.

Let’s begin with some definitions.

A namespace is a mapping from names to objects. Most namespaces are currently implemented as Python dictionaries, but that’s normally not noticeable in any way (except for performance), and it may change in the future. Examples of namespaces are: the set of built-in names (containing functions such as [abs()](https://docs.python.org/3/library/functions.html#abs), and built-in exception names); the global names in a module; and the local names in a function invocation. In a sense the set of attributes of an object also form a namespace. The important thing to know about namespaces is that there is absolutely no relation between names in different namespaces; for instance, two different modules may both define a function maximize without confusion — users of the modules must prefix it with the module name.

By the way, I use the word attribute for any name following a dot — for example, in the expressionz.real, real is an attribute of the object z. Strictly speaking, references to names in modules are attribute references: in the expression modname.funcname, modname is a module object and funcnameis an attribute of it. In this case there happens to be a straightforward mapping between the module’s attributes and the global names defined in the module: they share the same namespace! [[1]](https://docs.python.org/3/tutorial/classes.html#id2)

Attributes may be read-only or writable. In the latter case, assignment to attributes is possible. Module attributes are writable: you can write modname.the\_answer = 42. Writable attributes may also be deleted with the [del](https://docs.python.org/3/reference/simple_stmts.html#del) statement. For example, del modname.the\_answer will remove the attributethe\_answer from the object named by modname.

Namespaces are created at different moments and have different lifetimes. The namespace containing the built-in names is created when the Python interpreter starts up, and is never deleted. The global namespace for a module is created when the module definition is read in; normally, module namespaces also last until the interpreter quits. The statements executed by the top-level invocation of the interpreter, either read from a script file or interactively, are considered part of a module called[\_\_main\_\_](https://docs.python.org/3/library/__main__.html#module-__main__), so they have their own global namespace. (The built-in names actually also live in a module; this is called [builtins](https://docs.python.org/3/library/builtins.html#module-builtins).)

The local namespace for a function is created when the function is called, and deleted when the function returns or raises an exception that is not handled within the function. (Actually, forgetting would be a better way to describe what actually happens.) Of course, recursive invocations each have their own local namespace.

A scope is a textual region of a Python program where a namespace is directly accessible. “Directly accessible” here means that an unqualified reference to a name attempts to find the name in the namespace.

Although scopes are determined statically, they are used dynamically. At any time during execution, there are at least three nested scopes whose namespaces are directly accessible:

* the innermost scope, which is searched first, contains the local names
* the scopes of any enclosing functions, which are searched starting with the nearest enclosing scope, contains non-local, but also non-global names
* the next-to-last scope contains the current module’s global names
* the outermost scope (searched last) is the namespace containing built-in names

If a name is declared global, then all references and assignments go directly to the middle scope containing the module’s global names. To rebind variables found outside of the innermost scope, the[nonlocal](https://docs.python.org/3/reference/simple_stmts.html#nonlocal) statement can be used; if not declared nonlocal, those variables are read-only (an attempt to write to such a variable will simply create a new local variable in the innermost scope, leaving the identically named outer variable unchanged).

Usually, the local scope references the local names of the (textually) current function. Outside functions, the local scope references the same namespace as the global scope: the module’s namespace. Class definitions place yet another namespace in the local scope.

It is important to realize that scopes are determined textually: the global scope of a function defined in a module is that module’s namespace, no matter from where or by what alias the function is called. On the other hand, the actual search for names is done dynamically, at run time — however, the language definition is evolving towards static name resolution, at “compile” time, so don’t rely on dynamic name resolution! (In fact, local variables are already determined statically.)

A special quirk of Python is that – if no [global](https://docs.python.org/3/reference/simple_stmts.html#global) statement is in effect – assignments to names always go into the innermost scope. Assignments do not copy data — they just bind names to objects. The same is true for deletions: the statement del x removes the binding of x from the namespace referenced by the local scope. In fact, all operations that introduce new names use the local scope: in particular, [import](https://docs.python.org/3/reference/simple_stmts.html#import) statements and function definitions bind the module or function name in the local scope.

The [global](https://docs.python.org/3/reference/simple_stmts.html#global) statement can be used to indicate that particular variables live in the global scope and should be rebound there; the [nonlocal](https://docs.python.org/3/reference/simple_stmts.html#nonlocal) statement indicates that particular variables live in an enclosing scope and should be rebound there.

### 9.2.1. Scopes and Namespaces Example

This is an example demonstrating how to reference the different scopes and namespaces, and how[global](https://docs.python.org/3/reference/simple_stmts.html#global) and [nonlocal](https://docs.python.org/3/reference/simple_stmts.html#nonlocal) affect variable binding:

**def** scope\_test():

**def** do\_local():

spam = "local spam"

**def** do\_nonlocal():

**nonlocal** spam

spam = "nonlocal spam"

**def** do\_global():

**global** spam

spam = "global spam"

spam = "test spam"

do\_local()

print("After local assignment:", spam)

do\_nonlocal()

print("After nonlocal assignment:", spam)

do\_global()

print("After global assignment:", spam)

scope\_test()

print("In global scope:", spam)

The output of the example code is:

After local assignment: test spam

After nonlocal assignment: nonlocal spam

After global assignment: nonlocal spam

In global scope: global spam

Note how the local assignment (which is default) didn’t change scope\_test‘s binding of spam. The[nonlocal](https://docs.python.org/3/reference/simple_stmts.html#nonlocal) assignment changed scope\_test‘s binding of spam, and the [global](https://docs.python.org/3/reference/simple_stmts.html#global) assignment changed the module-level binding.

You can also see that there was no previous binding for spam before the [global](https://docs.python.org/3/reference/simple_stmts.html#global) assignment.

## 9.3. A First Look at Classes

Classes introduce a little bit of new syntax, three new object types, and some new semantics.

### 9.3.1. Class Definition Syntax

The simplest form of class definition looks like this:

**class** **ClassName**:

<statement-1>

.

.

.

<statement-N>

Class definitions, like function definitions ([def](https://docs.python.org/3/reference/compound_stmts.html#def) statements) must be executed before they have any effect. (You could conceivably place a class definition in a branch of an [if](https://docs.python.org/3/reference/compound_stmts.html#if) statement, or inside a function.)

In practice, the statements inside a class definition will usually be function definitions, but other statements are allowed, and sometimes useful — we’ll come back to this later. The function definitions inside a class normally have a peculiar form of argument list, dictated by the calling conventions for methods — again, this is explained later.

When a class definition is entered, a new namespace is created, and used as the local scope — thus, all assignments to local variables go into this new namespace. In particular, function definitions bind the name of the new function here.

When a class definition is left normally (via the end), a class object is created. This is basically a wrapper around the contents of the namespace created by the class definition; we’ll learn more about class objects in the next section. The original local scope (the one in effect just before the class definition was entered) is reinstated, and the class object is bound here to the class name given in the class definition header (ClassName in the example).

### 9.3.2. Class Objects

Class objects support two kinds of operations: attribute references and instantiation.

Attribute references use the standard syntax used for all attribute references in Python: obj.name. Valid attribute names are all the names that were in the class’s namespace when the class object was created. So, if the class definition looked like this:

**class** **MyClass**:

*"""A simple example class"""*

i = 12345

**def** f(self):

**return** 'hello world'

then MyClass.i and MyClass.f are valid attribute references, returning an integer and a function object, respectively. Class attributes can also be assigned to, so you can change the value ofMyClass.i by assignment. \_\_doc\_\_ is also a valid attribute, returning the docstring belonging to the class: "A simple example class".

Class instantiation uses function notation. Just pretend that the class object is a parameterless function that returns a new instance of the class. For example (assuming the above class):

x = MyClass()

creates a new instance of the class and assigns this object to the local variable x.

The instantiation operation (“calling” a class object) creates an empty object. Many classes like to create objects with instances customized to a specific initial state. Therefore a class may define a special method named [\_\_init\_\_()](https://docs.python.org/3/reference/datamodel.html#object.__init__), like this:

**def** \_\_init\_\_(self):

self.data = []

When a class defines an [\_\_init\_\_()](https://docs.python.org/3/reference/datamodel.html#object.__init__) method, class instantiation automatically invokes [\_\_init\_\_()](https://docs.python.org/3/reference/datamodel.html#object.__init__)for the newly-created class instance. So in this example, a new, initialized instance can be obtained by:

x = MyClass()

Of course, the [\_\_init\_\_()](https://docs.python.org/3/reference/datamodel.html#object.__init__) method may have arguments for greater flexibility. In that case, arguments given to the class instantiation operator are passed on to [\_\_init\_\_()](https://docs.python.org/3/reference/datamodel.html#object.__init__). For example,

>>>

**>>> class** **Complex**:

**...**  **def** \_\_init\_\_(self, realpart, imagpart):

**...**  self.r = realpart

**...**  self.i = imagpart

**...**

**>>>** x = Complex(3.0, -4.5)

**>>>** x.r, x.i

(3.0, -4.5)

### 9.3.3. Instance Objects

Now what can we do with instance objects? The only operations understood by instance objects are attribute references. There are two kinds of valid attribute names, data attributes and methods.

data attributes correspond to “instance variables” in Smalltalk, and to “data members” in C++. Data attributes need not be declared; like local variables, they spring into existence when they are first assigned to. For example, if x is the instance of MyClass created above, the following piece of code will print the value 16, without leaving a trace:

x.counter = 1

**while** x.counter < 10:

x.counter = x.counter \* 2

print(x.counter)

**del** x.counter

The other kind of instance attribute reference is a method. A method is a function that “belongs to” an object. (In Python, the term method is not unique to class instances: other object types can have methods as well. For example, list objects have methods called append, insert, remove, sort, and so on. However, in the following discussion, we’ll use the term method exclusively to mean methods of class instance objects, unless explicitly stated otherwise.)

Valid method names of an instance object depend on its class. By definition, all attributes of a class that are function objects define corresponding methods of its instances. So in our example, x.f is a valid method reference, since MyClass.f is a function, but x.i is not, since MyClass.i is not. But x.fis not the same thing as MyClass.f — it is a method object, not a function object.

### 9.3.4. Method Objects

Usually, a method is called right after it is bound:

x.f()

In the MyClass example, this will return the string 'hello world'. However, it is not necessary to call a method right away: x.f is a method object, and can be stored away and called at a later time. For example:

xf = x.f

**while** **True**:

print(xf())

will continue to print hello world until the end of time.

What exactly happens when a method is called? You may have noticed that x.f() was called without an argument above, even though the function definition for f() specified an argument. What happened to the argument? Surely Python raises an exception when a function that requires an argument is called without any — even if the argument isn’t actually used...

Actually, you may have guessed the answer: the special thing about methods is that the object is passed as the first argument of the function. In our example, the call x.f() is exactly equivalent toMyClass.f(x). In general, calling a method with a list of n arguments is equivalent to calling the corresponding function with an argument list that is created by inserting the method’s object before the first argument.

If you still don’t understand how methods work, a look at the implementation can perhaps clarify matters. When an instance attribute is referenced that isn’t a data attribute, its class is searched. If the name denotes a valid class attribute that is a function object, a method object is created by packing (pointers to) the instance object and the function object just found together in an abstract object: this is the method object. When the method object is called with an argument list, a new argument list is constructed from the instance object and the argument list, and the function object is called with this new argument list.

### 9.3.5. Class and Instance Variables

Generally speaking, instance variables are for data unique to each instance and class variables are for attributes and methods shared by all instances of the class:

**class** **Dog**:

kind = 'canine' *# class variable shared by all instances*

**def** \_\_init\_\_(self, name):

self.name = name *# instance variable unique to each instance*

>>> d = Dog('Fido')

>>> e = Dog('Buddy')

>>> d.kind *# shared by all dogs*

'canine'

>>> e.kind *# shared by all dogs*

'canine'

>>> d.name *# unique to d*

'Fido'

>>> e.name *# unique to e*

'Buddy'

As discussed in [A Word About Names and Objects](https://docs.python.org/3/tutorial/classes.html#tut-object), shared data can have possibly surprising effects with involving [mutable](https://docs.python.org/3/glossary.html#term-mutable) objects such as lists and dictionaries. For example, the tricks list in the following code should not be used as a class variable because just a single list would be shared by all Doginstances:

**class** **Dog**:

tricks = [] *# mistaken use of a class variable*

**def** \_\_init\_\_(self, name):

self.name = name

**def** add\_trick(self, trick):

self.tricks.append(trick)

>>> d = Dog('Fido')

>>> e = Dog('Buddy')

>>> d.add\_trick('roll over')

>>> e.add\_trick('play dead')

>>> d.tricks *# unexpectedly shared by all dogs*

['roll over', 'play dead']

Correct design of the class should use an instance variable instead:

**class** **Dog**:

**def** \_\_init\_\_(self, name):

self.name = name

self.tricks = [] *# creates a new empty list for each dog*

**def** add\_trick(self, trick):

self.tricks.append(trick)

>>> d = Dog('Fido')

>>> e = Dog('Buddy')

>>> d.add\_trick('roll over')

>>> e.add\_trick('play dead')

>>> d.tricks

['roll over']

>>> e.tricks

['play dead']

## 9.4. Random Remarks

Data attributes override method attributes with the same name; to avoid accidental name conflicts, which may cause hard-to-find bugs in large programs, it is wise to use some kind of convention that minimizes the chance of conflicts. Possible conventions include capitalizing method names, prefixing data attribute names with a small unique string (perhaps just an underscore), or using verbs for methods and nouns for data attributes.

Data attributes may be referenced by methods as well as by ordinary users (“clients”) of an object. In other words, classes are not usable to implement pure abstract data types. In fact, nothing in Python makes it possible to enforce data hiding — it is all based upon convention. (On the other hand, the Python implementation, written in C, can completely hide implementation details and control access to an object if necessary; this can be used by extensions to Python written in C.)

Clients should use data attributes with care — clients may mess up invariants maintained by the methods by stamping on their data attributes. Note that clients may add data attributes of their own to an instance object without affecting the validity of the methods, as long as name conflicts are avoided — again, a naming convention can save a lot of headaches here.

There is no shorthand for referencing data attributes (or other methods!) from within methods. I find that this actually increases the readability of methods: there is no chance of confusing local variables and instance variables when glancing through a method.

Often, the first argument of a method is called self. This is nothing more than a convention: the nameself has absolutely no special meaning to Python. Note, however, that by not following the convention your code may be less readable to other Python programmers, and it is also conceivable that a class browser program might be written that relies upon such a convention.

Any function object that is a class attribute defines a method for instances of that class. It is not necessary that the function definition is textually enclosed in the class definition: assigning a function object to a local variable in the class is also ok. For example:

*# Function defined outside the class*

**def** f1(self, x, y):

**return** min(x, x+y)

**class** **C**:

f = f1

**def** g(self):

**return** 'hello world'

h = g

Now f, g and h are all attributes of class C that refer to function objects, and consequently they are all methods of instances of C — h being exactly equivalent to g. Note that this practice usually only serves to confuse the reader of a program.

Methods may call other methods by using method attributes of the self argument:

**class** **Bag**:

**def** \_\_init\_\_(self):

self.data = []

**def** add(self, x):

self.data.append(x)

**def** addtwice(self, x):

self.add(x)

self.add(x)

Methods may reference global names in the same way as ordinary functions. The global scope associated with a method is the module containing its definition. (A class is never used as a global scope.) While one rarely encounters a good reason for using global data in a method, there are many legitimate uses of the global scope: for one thing, functions and modules imported into the global scope can be used by methods, as well as functions and classes defined in it. Usually, the class containing the method is itself defined in this global scope, and in the next section we’ll find some good reasons why a method would want to reference its own class.

Each value is an object, and therefore has a class (also called its type). It is stored asobject.\_\_class\_\_.

## 9.5. Inheritance

Of course, a language feature would not be worthy of the name “class” without supporting inheritance. The syntax for a derived class definition looks like this:

**class** **DerivedClassName**(BaseClassName):

<statement-1>

.

.

.

<statement-N>

The name BaseClassName must be defined in a scope containing the derived class definition. In place of a base class name, other arbitrary expressions are also allowed. This can be useful, for example, when the base class is defined in another module:

**class** **DerivedClassName**(modname.BaseClassName):

Execution of a derived class definition proceeds the same as for a base class. When the class object is constructed, the base class is remembered. This is used for resolving attribute references: if a requested attribute is not found in the class, the search proceeds to look in the base class. This rule is applied recursively if the base class itself is derived from some other class.

There’s nothing special about instantiation of derived classes: DerivedClassName() creates a new instance of the class. Method references are resolved as follows: the corresponding class attribute is searched, descending down the chain of base classes if necessary, and the method reference is valid if this yields a function object.

Derived classes may override methods of their base classes. Because methods have no special privileges when calling other methods of the same object, a method of a base class that calls another method defined in the same base class may end up calling a method of a derived class that overrides it. (For C++ programmers: all methods in Python are effectively virtual.)

An overriding method in a derived class may in fact want to extend rather than simply replace the base class method of the same name. There is a simple way to call the base class method directly: just callBaseClassName.methodname(self, arguments). This is occasionally useful to clients as well. (Note that this only works if the base class is accessible as BaseClassName in the global scope.)

Python has two built-in functions that work with inheritance:

* Use [isinstance()](https://docs.python.org/3/library/functions.html#isinstance) to check an instance’s type: isinstance(obj, int) will be True only ifobj.\_\_class\_\_ is [int](https://docs.python.org/3/library/functions.html#int) or some class derived from [int](https://docs.python.org/3/library/functions.html#int).
* Use [issubclass()](https://docs.python.org/3/library/functions.html#issubclass) to check class inheritance: issubclass(bool, int) is True since [bool](https://docs.python.org/3/library/functions.html#bool) is a subclass of [int](https://docs.python.org/3/library/functions.html#int). However, issubclass(float, int) is False since [float](https://docs.python.org/3/library/functions.html#float) is not a subclass of[int](https://docs.python.org/3/library/functions.html#int).

### 9.5.1. Multiple Inheritance

Python supports a form of multiple inheritance as well. A class definition with multiple base classes looks like this:

**class** **DerivedClassName**(Base1, Base2, Base3):

<statement-1>

.

.

.

<statement-N>

For most purposes, in the simplest cases, you can think of the search for attributes inherited from a parent class as depth-first, left-to-right, not searching twice in the same class where there is an overlap in the hierarchy. Thus, if an attribute is not found in DerivedClassName, it is searched for inBase1, then (recursively) in the base classes of Base1, and if it was not found there, it was searched for in Base2, and so on.

In fact, it is slightly more complex than that; the method resolution order changes dynamically to support cooperative calls to [super()](https://docs.python.org/3/library/functions.html#super). This approach is known in some other multiple-inheritance languages as call-next-method and is more powerful than the super call found in single-inheritance languages.

Dynamic ordering is necessary because all cases of multiple inheritance exhibit one or more diamond relationships (where at least one of the parent classes can be accessed through multiple paths from the bottommost class). For example, all classes inherit from [object](https://docs.python.org/3/library/functions.html#object), so any case of multiple inheritance provides more than one path to reach [object](https://docs.python.org/3/library/functions.html#object). To keep the base classes from being accessed more than once, the dynamic algorithm linearizes the search order in a way that preserves the left-to-right ordering specified in each class, that calls each parent only once, and that is monotonic (meaning that a class can be subclassed without affecting the precedence order of its parents). Taken together, these properties make it possible to design reliable and extensible classes with multiple inheritance. For more detail, see <https://www.python.org/download/releases/2.3/mro/>.

## 9.6. Private Variables

“Private” instance variables that cannot be accessed except from inside an object don’t exist in Python. However, there is a convention that is followed by most Python code: a name prefixed with an underscore (e.g. \_spam) should be treated as a non-public part of the API (whether it is a function, a method or a data member). It should be considered an implementation detail and subject to change without notice.

Since there is a valid use-case for class-private members (namely to avoid name clashes of names with names defined by subclasses), there is limited support for such a mechanism, called name mangling. Any identifier of the form \_\_spam (at least two leading underscores, at most one trailing underscore) is textually replaced with \_classname\_\_spam, where classname is the current class name with leading underscore(s) stripped. This mangling is done without regard to the syntactic position of the identifier, as long as it occurs within the definition of a class.

Name mangling is helpful for letting subclasses override methods without breaking intraclass method calls. For example:

**class** **Mapping**:

**def** \_\_init\_\_(self, iterable):

self.items\_list = []

self.\_\_update(iterable)

**def** update(self, iterable):

**for** item **in** iterable:

self.items\_list.append(item)

\_\_update = update *# private copy of original update() method*

**class** **MappingSubclass**(Mapping):

**def** update(self, keys, values):

*# provides new signature for update()*

*# but does not break \_\_init\_\_()*

**for** item **in** zip(keys, values):

self.items\_list.append(item)

Note that the mangling rules are designed mostly to avoid accidents; it still is possible to access or modify a variable that is considered private. This can even be useful in special circumstances, such as in the debugger.

Notice that code passed to exec() or eval() does not consider the classname of the invoking class to be the current class; this is similar to the effect of the global statement, the effect of which is likewise restricted to code that is byte-compiled together. The same restriction applies to getattr(),setattr() and delattr(), as well as when referencing \_\_dict\_\_ directly.

## 9.7. Odds and Ends

Sometimes it is useful to have a data type similar to the Pascal “record” or C “struct”, bundling together a few named data items. An empty class definition will do nicely:

**class** **Employee**:

**pass**

john = Employee() *# Create an empty employee record*

*# Fill the fields of the record*

john.name = 'John Doe'

john.dept = 'computer lab'

john.salary = 1000

A piece of Python code that expects a particular abstract data type can often be passed a class that emulates the methods of that data type instead. For instance, if you have a function that formats some data from a file object, you can define a class with methods read() and readline() that get the data from a string buffer instead, and pass it as an argument.

Instance method objects have attributes, too: m.\_\_self\_\_ is the instance object with the method m(), and m.\_\_func\_\_ is the function object corresponding to the method.

## 9.8. Exceptions Are Classes Too

User-defined exceptions are identified by classes as well. Using this mechanism it is possible to create extensible hierarchies of exceptions.

There are two new valid (semantic) forms for the [raise](https://docs.python.org/3/reference/simple_stmts.html#raise) statement:

**raise** Class

**raise** Instance

In the first form, Class must be an instance of [type](https://docs.python.org/3/library/functions.html#type) or of a class derived from it. The first form is a shorthand for:

**raise** Class()

A class in an [except](https://docs.python.org/3/reference/compound_stmts.html#except) clause is compatible with an exception if it is the same class or a base class thereof (but not the other way around — an except clause listing a derived class is not compatible with a base class). For example, the following code will print B, C, D in that order:

**class** **B**(Exception):

**pass**

**class** **C**(B):

**pass**

**class** **D**(C):

**pass**

**for** cls **in** [B, C, D]:

**try**:

**raise** cls()

**except** D:

print("D")

**except** C:

print("C")

**except** B:

print("B")

Note that if the except clauses were reversed (with except B first), it would have printed B, B, B — the first matching except clause is triggered.

When an error message is printed for an unhandled exception, the exception’s class name is printed, then a colon and a space, and finally the instance converted to a string using the built-in function[str()](https://docs.python.org/3/library/stdtypes.html#str).

## 9.9. Iterators

By now you have probably noticed that most container objects can be looped over using a [for](https://docs.python.org/3/reference/compound_stmts.html#for)statement:

**for** element **in** [1, 2, 3]:

print(element)

**for** element **in** (1, 2, 3):

print(element)

**for** key **in** {'one':1, 'two':2}:

print(key)

**for** char **in** "123":

print(char)

**for** line **in** open("myfile.txt"):

print(line, end='')

This style of access is clear, concise, and convenient. The use of iterators pervades and unifies Python. Behind the scenes, the [for](https://docs.python.org/3/reference/compound_stmts.html#for) statement calls [iter()](https://docs.python.org/3/library/functions.html#iter) on the container object. The function returns an iterator object that defines the method [\_\_next\_\_()](https://docs.python.org/3/library/stdtypes.html#iterator.__next__) which accesses elements in the container one at a time. When there are no more elements, [\_\_next\_\_()](https://docs.python.org/3/library/stdtypes.html#iterator.__next__) raises a [StopIteration](https://docs.python.org/3/library/exceptions.html#StopIteration)exception which tells the [for](https://docs.python.org/3/reference/compound_stmts.html#for) loop to terminate. You can call the [\_\_next\_\_()](https://docs.python.org/3/library/stdtypes.html#iterator.__next__) method using the[next()](https://docs.python.org/3/library/functions.html#next) built-in function; this example shows how it all works:

>>>

**>>>** s = 'abc'

**>>>** it = iter(s)

**>>>** it

<iterator object at 0x00A1DB50>

**>>>** next(it)

'a'

**>>>** next(it)

'b'

**>>>** next(it)

'c'

**>>>** next(it)

Traceback (most recent call last):

File "<stdin>", line 1, in ?

next(it)

StopIteration

Having seen the mechanics behind the iterator protocol, it is easy to add iterator behavior to your classes. Define an [\_\_iter\_\_()](https://docs.python.org/3/reference/datamodel.html#object.__iter__) method which returns an object with a [\_\_next\_\_()](https://docs.python.org/3/library/stdtypes.html#iterator.__next__) method. If the class defines \_\_next\_\_(), then [\_\_iter\_\_()](https://docs.python.org/3/reference/datamodel.html#object.__iter__) can just return self:

**class** **Reverse**:

*"""Iterator for looping over a sequence backwards."""*

**def** \_\_init\_\_(self, data):

self.data = data

self.index = len(data)

**def** \_\_iter\_\_(self):

**return** self

**def** \_\_next\_\_(self):

**if** self.index == 0:

**raise** StopIteration

self.index = self.index - 1

**return** self.data[self.index]

>>>

**>>>** rev = Reverse('spam')

**>>>** iter(rev)

<\_\_main\_\_.Reverse object at 0x00A1DB50>

**>>> for** char **in** rev:

**...**  print(char)

**...**

m

a

p

s

## 9.10. Generators

[Generator](https://docs.python.org/3/glossary.html#term-generator)s are a simple and powerful tool for creating iterators. They are written like regular functions but use the [yield](https://docs.python.org/3/reference/simple_stmts.html#yield) statement whenever they want to return data. Each time [next()](https://docs.python.org/3/library/functions.html#next) is called on it, the generator resumes where it left off (it remembers all the data values and which statement was last executed). An example shows that generators can be trivially easy to create:

**def** reverse(data):

**for** index **in** range(len(data)-1, -1, -1):

**yield** data[index]

>>>

**>>> for** char **in** reverse('golf'):

**...**  print(char)

**...**

f

l

o

g

Anything that can be done with generators can also be done with class-based iterators as described in the previous section. What makes generators so compact is that the [\_\_iter\_\_()](https://docs.python.org/3/reference/datamodel.html#object.__iter__) and [\_\_next\_\_()](https://docs.python.org/3/reference/expressions.html#generator.__next__)methods are created automatically.

Another key feature is that the local variables and execution state are automatically saved between calls. This made the function easier to write and much more clear than an approach using instance variables like self.index and self.data.

In addition to automatic method creation and saving program state, when generators terminate, they automatically raise [StopIteration](https://docs.python.org/3/library/exceptions.html#StopIteration). In combination, these features make it easy to create iterators with no more effort than writing a regular function.

## 9.11. Generator Expressions

Some simple generators can be coded succinctly as expressions using a syntax similar to list comprehensions but with parentheses instead of brackets. These expressions are designed for situations where the generator is used right away by an enclosing function. Generator expressions are more compact but less versatile than full generator definitions and tend to be more memory friendly than equivalent list comprehensions.

Examples:

>>>

**>>>** sum(i\*i **for** i **in** range(10)) *# sum of squares*

285

**>>>** xvec = [10, 20, 30]

**>>>** yvec = [7, 5, 3]

**>>>** sum(x\*y **for** x,y **in** zip(xvec, yvec)) *# dot product*

260

**>>> from** **math** **import** pi, sin

**>>>** sine\_table = {x: sin(x\*pi/180) **for** x **in** range(0, 91)}

**>>>** unique\_words = set(word **for** line **in** page **for** word **in** line.split())

**>>>** valedictorian = max((student.gpa, student.name) **for** student **in** graduates)

**>>>** data = 'golf'

**>>>** list(data[i] **for** i **in** range(len(data)-1, -1, -1))

['f', 'l', 'o', 'g']

**Footnotes**

|  |  |
| --- | --- |
| [[1]](https://docs.python.org/3/tutorial/classes.html#id1) | Except for one thing. Module objects have a secret read-only attribute called [\_\_dict\_\_](https://docs.python.org/3/library/stdtypes.html#object.__dict__) which returns the dictionary used to implement the module’s namespace; the name [\_\_dict\_\_](https://docs.python.org/3/library/stdtypes.html#object.__dict__) is an attribute but not a global name. Obviously, using this violates the abstraction of namespace implementation, and should be restricted to things like post-mortem debuggers. |

# 9. Classes

Compared with other programming languages, Python’s class mechanism adds classes with a minimum of new syntax and semantics. It is a mixture of the class mechanisms found in C++ and Modula-3. Python classes provide all the standard features of Object Oriented Programming: the class inheritance mechanism allows multiple base classes, a derived class can override any methods of its base class or classes, and a method can call the method of a base class with the same name. Objects can contain arbitrary amounts and kinds of data. As is true for modules, classes partake of the dynamic nature of Python: they are created at runtime, and can be modified further after creation.

In C++ terminology, normally class members (including the data members) are public (except see below [Private Variables](https://docs.python.org/3/tutorial/classes.html#tut-private)), and all member functions are virtual. As in Modula-3, there are no shorthands for referencing the object’s members from its methods: the method function is declared with an explicit first argument representing the object, which is provided implicitly by the call. As in Smalltalk, classes themselves are objects. This provides semantics for importing and renaming. Unlike C++ and Modula-3, built-in types can be used as base classes for extension by the user. Also, like in C++, most built-in operators with special syntax (arithmetic operators, subscripting etc.) can be redefined for class instances.

(Lacking universally accepted terminology to talk about classes, I will make occasional use of Smalltalk and C++ terms. I would use Modula-3 terms, since its object-oriented semantics are closer to those of Python than C++, but I expect that few readers have heard of it.)

## 9.1. A Word About Names and Objects

Objects have individuality, and multiple names (in multiple scopes) can be bound to the same object. This is known as aliasing in other languages. This is usually not appreciated on a first glance at Python, and can be safely ignored when dealing with immutable basic types (numbers, strings, tuples). However, aliasing has a possibly surprising effect on the semantics of Python code involving mutable objects such as lists, dictionaries, and most other types. This is usually used to the benefit of the program, since aliases behave like pointers in some respects. For example, passing an object is cheap since only a pointer is passed by the implementation; and if a function modifies an object passed as an argument, the caller will see the change — this eliminates the need for two different argument passing mechanisms as in Pascal.

## 9.2. Python Scopes and Namespaces

Before introducing classes, I first have to tell you something about Python’s scope rules. Class definitions play some neat tricks with namespaces, and you need to know how scopes and namespaces work to fully understand what’s going on. Incidentally, knowledge about this subject is useful for any advanced Python programmer.

Let’s begin with some definitions.

A namespace is a mapping from names to objects. Most namespaces are currently implemented as Python dictionaries, but that’s normally not noticeable in any way (except for performance), and it may change in the future. Examples of namespaces are: the set of built-in names (containing functions such as [abs()](https://docs.python.org/3/library/functions.html#abs), and built-in exception names); the global names in a module; and the local names in a function invocation. In a sense the set of attributes of an object also form a namespace. The important thing to know about namespaces is that there is absolutely no relation between names in different namespaces; for instance, two different modules may both define a function maximize without confusion — users of the modules must prefix it with the module name.

By the way, I use the word attribute for any name following a dot — for example, in the expressionz.real, real is an attribute of the object z. Strictly speaking, references to names in modules are attribute references: in the expression modname.funcname, modname is a module object and funcnameis an attribute of it. In this case there happens to be a straightforward mapping between the module’s attributes and the global names defined in the module: they share the same namespace! [[1]](https://docs.python.org/3/tutorial/classes.html#id2)

Attributes may be read-only or writable. In the latter case, assignment to attributes is possible. Module attributes are writable: you can write modname.the\_answer = 42. Writable attributes may also be deleted with the [del](https://docs.python.org/3/reference/simple_stmts.html#del) statement. For example, del modname.the\_answer will remove the attributethe\_answer from the object named by modname.

Namespaces are created at different moments and have different lifetimes. The namespace containing the built-in names is created when the Python interpreter starts up, and is never deleted. The global namespace for a module is created when the module definition is read in; normally, module namespaces also last until the interpreter quits. The statements executed by the top-level invocation of the interpreter, either read from a script file or interactively, are considered part of a module called[\_\_main\_\_](https://docs.python.org/3/library/__main__.html#module-__main__), so they have their own global namespace. (The built-in names actually also live in a module; this is called [builtins](https://docs.python.org/3/library/builtins.html#module-builtins).)

The local namespace for a function is created when the function is called, and deleted when the function returns or raises an exception that is not handled within the function. (Actually, forgetting would be a better way to describe what actually happens.) Of course, recursive invocations each have their own local namespace.

A scope is a textual region of a Python program where a namespace is directly accessible. “Directly accessible” here means that an unqualified reference to a name attempts to find the name in the namespace.

Although scopes are determined statically, they are used dynamically. At any time during execution, there are at least three nested scopes whose namespaces are directly accessible:

* the innermost scope, which is searched first, contains the local names
* the scopes of any enclosing functions, which are searched starting with the nearest enclosing scope, contains non-local, but also non-global names
* the next-to-last scope contains the current module’s global names
* the outermost scope (searched last) is the namespace containing built-in names

If a name is declared global, then all references and assignments go directly to the middle scope containing the module’s global names. To rebind variables found outside of the innermost scope, the[nonlocal](https://docs.python.org/3/reference/simple_stmts.html#nonlocal) statement can be used; if not declared nonlocal, those variables are read-only (an attempt to write to such a variable will simply create a new local variable in the innermost scope, leaving the identically named outer variable unchanged).

Usually, the local scope references the local names of the (textually) current function. Outside functions, the local scope references the same namespace as the global scope: the module’s namespace. Class definitions place yet another namespace in the local scope.

It is important to realize that scopes are determined textually: the global scope of a function defined in a module is that module’s namespace, no matter from where or by what alias the function is called. On the other hand, the actual search for names is done dynamically, at run time — however, the language definition is evolving towards static name resolution, at “compile” time, so don’t rely on dynamic name resolution! (In fact, local variables are already determined statically.)

A special quirk of Python is that – if no [global](https://docs.python.org/3/reference/simple_stmts.html#global) statement is in effect – assignments to names always go into the innermost scope. Assignments do not copy data — they just bind names to objects. The same is true for deletions: the statement del x removes the binding of x from the namespace referenced by the local scope. In fact, all operations that introduce new names use the local scope: in particular, [import](https://docs.python.org/3/reference/simple_stmts.html#import) statements and function definitions bind the module or function name in the local scope.

The [global](https://docs.python.org/3/reference/simple_stmts.html#global) statement can be used to indicate that particular variables live in the global scope and should be rebound there; the [nonlocal](https://docs.python.org/3/reference/simple_stmts.html#nonlocal) statement indicates that particular variables live in an enclosing scope and should be rebound there.

### 9.2.1. Scopes and Namespaces Example

This is an example demonstrating how to reference the different scopes and namespaces, and how[global](https://docs.python.org/3/reference/simple_stmts.html#global) and [nonlocal](https://docs.python.org/3/reference/simple_stmts.html#nonlocal) affect variable binding:

**def** scope\_test():

**def** do\_local():

spam = "local spam"

**def** do\_nonlocal():

**nonlocal** spam

spam = "nonlocal spam"

**def** do\_global():

**global** spam

spam = "global spam"

spam = "test spam"

do\_local()

print("After local assignment:", spam)

do\_nonlocal()

print("After nonlocal assignment:", spam)

do\_global()

print("After global assignment:", spam)

scope\_test()

print("In global scope:", spam)

The output of the example code is:

After local assignment: test spam

After nonlocal assignment: nonlocal spam

After global assignment: nonlocal spam

In global scope: global spam

Note how the local assignment (which is default) didn’t change scope\_test‘s binding of spam. The[nonlocal](https://docs.python.org/3/reference/simple_stmts.html#nonlocal) assignment changed scope\_test‘s binding of spam, and the [global](https://docs.python.org/3/reference/simple_stmts.html#global) assignment changed the module-level binding.

You can also see that there was no previous binding for spam before the [global](https://docs.python.org/3/reference/simple_stmts.html#global) assignment.

## 9.3. A First Look at Classes

Classes introduce a little bit of new syntax, three new object types, and some new semantics.

### 9.3.1. Class Definition Syntax

The simplest form of class definition looks like this:

**class** **ClassName**:

<statement-1>

.

.

.

<statement-N>

Class definitions, like function definitions ([def](https://docs.python.org/3/reference/compound_stmts.html#def) statements) must be executed before they have any effect. (You could conceivably place a class definition in a branch of an [if](https://docs.python.org/3/reference/compound_stmts.html#if) statement, or inside a function.)

In practice, the statements inside a class definition will usually be function definitions, but other statements are allowed, and sometimes useful — we’ll come back to this later. The function definitions inside a class normally have a peculiar form of argument list, dictated by the calling conventions for methods — again, this is explained later.

When a class definition is entered, a new namespace is created, and used as the local scope — thus, all assignments to local variables go into this new namespace. In particular, function definitions bind the name of the new function here.

When a class definition is left normally (via the end), a class object is created. This is basically a wrapper around the contents of the namespace created by the class definition; we’ll learn more about class objects in the next section. The original local scope (the one in effect just before the class definition was entered) is reinstated, and the class object is bound here to the class name given in the class definition header (ClassName in the example).

### 9.3.2. Class Objects

Class objects support two kinds of operations: attribute references and instantiation.

Attribute references use the standard syntax used for all attribute references in Python: obj.name. Valid attribute names are all the names that were in the class’s namespace when the class object was created. So, if the class definition looked like this:

**class** **MyClass**:

*"""A simple example class"""*

i = 12345

**def** f(self):

**return** 'hello world'

then MyClass.i and MyClass.f are valid attribute references, returning an integer and a function object, respectively. Class attributes can also be assigned to, so you can change the value ofMyClass.i by assignment. \_\_doc\_\_ is also a valid attribute, returning the docstring belonging to the class: "A simple example class".

Class instantiation uses function notation. Just pretend that the class object is a parameterless function that returns a new instance of the class. For example (assuming the above class):

x = MyClass()

creates a new instance of the class and assigns this object to the local variable x.

The instantiation operation (“calling” a class object) creates an empty object. Many classes like to create objects with instances customized to a specific initial state. Therefore a class may define a special method named [\_\_init\_\_()](https://docs.python.org/3/reference/datamodel.html#object.__init__), like this:

**def** \_\_init\_\_(self):

self.data = []

When a class defines an [\_\_init\_\_()](https://docs.python.org/3/reference/datamodel.html#object.__init__) method, class instantiation automatically invokes [\_\_init\_\_()](https://docs.python.org/3/reference/datamodel.html#object.__init__)for the newly-created class instance. So in this example, a new, initialized instance can be obtained by:

x = MyClass()

Of course, the [\_\_init\_\_()](https://docs.python.org/3/reference/datamodel.html#object.__init__) method may have arguments for greater flexibility. In that case, arguments given to the class instantiation operator are passed on to [\_\_init\_\_()](https://docs.python.org/3/reference/datamodel.html#object.__init__). For example,

>>>

**>>> class** **Complex**:

**...**  **def** \_\_init\_\_(self, realpart, imagpart):

**...**  self.r = realpart

**...**  self.i = imagpart

**...**

**>>>** x = Complex(3.0, -4.5)

**>>>** x.r, x.i

(3.0, -4.5)

### 9.3.3. Instance Objects

Now what can we do with instance objects? The only operations understood by instance objects are attribute references. There are two kinds of valid attribute names, data attributes and methods.

data attributes correspond to “instance variables” in Smalltalk, and to “data members” in C++. Data attributes need not be declared; like local variables, they spring into existence when they are first assigned to. For example, if x is the instance of MyClass created above, the following piece of code will print the value 16, without leaving a trace:

x.counter = 1

**while** x.counter < 10:

x.counter = x.counter \* 2

print(x.counter)

**del** x.counter

The other kind of instance attribute reference is a method. A method is a function that “belongs to” an object. (In Python, the term method is not unique to class instances: other object types can have methods as well. For example, list objects have methods called append, insert, remove, sort, and so on. However, in the following discussion, we’ll use the term method exclusively to mean methods of class instance objects, unless explicitly stated otherwise.)

Valid method names of an instance object depend on its class. By definition, all attributes of a class that are function objects define corresponding methods of its instances. So in our example, x.f is a valid method reference, since MyClass.f is a function, but x.i is not, since MyClass.i is not. But x.fis not the same thing as MyClass.f — it is a method object, not a function object.

### 9.3.4. Method Objects

Usually, a method is called right after it is bound:

x.f()

In the MyClass example, this will return the string 'hello world'. However, it is not necessary to call a method right away: x.f is a method object, and can be stored away and called at a later time. For example:

xf = x.f

**while** **True**:

print(xf())

will continue to print hello world until the end of time.

What exactly happens when a method is called? You may have noticed that x.f() was called without an argument above, even though the function definition for f() specified an argument. What happened to the argument? Surely Python raises an exception when a function that requires an argument is called without any — even if the argument isn’t actually used...

Actually, you may have guessed the answer: the special thing about methods is that the object is passed as the first argument of the function. In our example, the call x.f() is exactly equivalent toMyClass.f(x). In general, calling a method with a list of n arguments is equivalent to calling the corresponding function with an argument list that is created by inserting the method’s object before the first argument.

If you still don’t understand how methods work, a look at the implementation can perhaps clarify matters. When an instance attribute is referenced that isn’t a data attribute, its class is searched. If the name denotes a valid class attribute that is a function object, a method object is created by packing (pointers to) the instance object and the function object just found together in an abstract object: this is the method object. When the method object is called with an argument list, a new argument list is constructed from the instance object and the argument list, and the function object is called with this new argument list.

### 9.3.5. Class and Instance Variables

Generally speaking, instance variables are for data unique to each instance and class variables are for attributes and methods shared by all instances of the class:

**class** **Dog**:

kind = 'canine' *# class variable shared by all instances*

**def** \_\_init\_\_(self, name):

self.name = name *# instance variable unique to each instance*

>>> d = Dog('Fido')

>>> e = Dog('Buddy')

>>> d.kind *# shared by all dogs*

'canine'

>>> e.kind *# shared by all dogs*

'canine'

>>> d.name *# unique to d*

'Fido'

>>> e.name *# unique to e*

'Buddy'

As discussed in [A Word About Names and Objects](https://docs.python.org/3/tutorial/classes.html#tut-object), shared data can have possibly surprising effects with involving [mutable](https://docs.python.org/3/glossary.html#term-mutable) objects such as lists and dictionaries. For example, the tricks list in the following code should not be used as a class variable because just a single list would be shared by all Doginstances:

**class** **Dog**:

tricks = [] *# mistaken use of a class variable*

**def** \_\_init\_\_(self, name):

self.name = name

**def** add\_trick(self, trick):

self.tricks.append(trick)

>>> d = Dog('Fido')

>>> e = Dog('Buddy')

>>> d.add\_trick('roll over')

>>> e.add\_trick('play dead')

>>> d.tricks *# unexpectedly shared by all dogs*

['roll over', 'play dead']

Correct design of the class should use an instance variable instead:

**class** **Dog**:

**def** \_\_init\_\_(self, name):

self.name = name

self.tricks = [] *# creates a new empty list for each dog*

**def** add\_trick(self, trick):

self.tricks.append(trick)

>>> d = Dog('Fido')

>>> e = Dog('Buddy')

>>> d.add\_trick('roll over')

>>> e.add\_trick('play dead')

>>> d.tricks

['roll over']

>>> e.tricks

['play dead']

## 9.4. Random Remarks

Data attributes override method attributes with the same name; to avoid accidental name conflicts, which may cause hard-to-find bugs in large programs, it is wise to use some kind of convention that minimizes the chance of conflicts. Possible conventions include capitalizing method names, prefixing data attribute names with a small unique string (perhaps just an underscore), or using verbs for methods and nouns for data attributes.

Data attributes may be referenced by methods as well as by ordinary users (“clients”) of an object. In other words, classes are not usable to implement pure abstract data types. In fact, nothing in Python makes it possible to enforce data hiding — it is all based upon convention. (On the other hand, the Python implementation, written in C, can completely hide implementation details and control access to an object if necessary; this can be used by extensions to Python written in C.)

Clients should use data attributes with care — clients may mess up invariants maintained by the methods by stamping on their data attributes. Note that clients may add data attributes of their own to an instance object without affecting the validity of the methods, as long as name conflicts are avoided — again, a naming convention can save a lot of headaches here.

There is no shorthand for referencing data attributes (or other methods!) from within methods. I find that this actually increases the readability of methods: there is no chance of confusing local variables and instance variables when glancing through a method.

Often, the first argument of a method is called self. This is nothing more than a convention: the nameself has absolutely no special meaning to Python. Note, however, that by not following the convention your code may be less readable to other Python programmers, and it is also conceivable that a class browser program might be written that relies upon such a convention.

Any function object that is a class attribute defines a method for instances of that class. It is not necessary that the function definition is textually enclosed in the class definition: assigning a function object to a local variable in the class is also ok. For example:

*# Function defined outside the class*

**def** f1(self, x, y):

**return** min(x, x+y)

**class** **C**:

f = f1

**def** g(self):

**return** 'hello world'

h = g

Now f, g and h are all attributes of class C that refer to function objects, and consequently they are all methods of instances of C — h being exactly equivalent to g. Note that this practice usually only serves to confuse the reader of a program.

Methods may call other methods by using method attributes of the self argument:

**class** **Bag**:

**def** \_\_init\_\_(self):

self.data = []

**def** add(self, x):

self.data.append(x)

**def** addtwice(self, x):

self.add(x)

self.add(x)

Methods may reference global names in the same way as ordinary functions. The global scope associated with a method is the module containing its definition. (A class is never used as a global scope.) While one rarely encounters a good reason for using global data in a method, there are many legitimate uses of the global scope: for one thing, functions and modules imported into the global scope can be used by methods, as well as functions and classes defined in it. Usually, the class containing the method is itself defined in this global scope, and in the next section we’ll find some good reasons why a method would want to reference its own class.

Each value is an object, and therefore has a class (also called its type). It is stored asobject.\_\_class\_\_.

## 9.5. Inheritance

Of course, a language feature would not be worthy of the name “class” without supporting inheritance. The syntax for a derived class definition looks like this:

**class** **DerivedClassName**(BaseClassName):

<statement-1>

.

.

.

<statement-N>

The name BaseClassName must be defined in a scope containing the derived class definition. In place of a base class name, other arbitrary expressions are also allowed. This can be useful, for example, when the base class is defined in another module:

**class** **DerivedClassName**(modname.BaseClassName):

Execution of a derived class definition proceeds the same as for a base class. When the class object is constructed, the base class is remembered. This is used for resolving attribute references: if a requested attribute is not found in the class, the search proceeds to look in the base class. This rule is applied recursively if the base class itself is derived from some other class.

There’s nothing special about instantiation of derived classes: DerivedClassName() creates a new instance of the class. Method references are resolved as follows: the corresponding class attribute is searched, descending down the chain of base classes if necessary, and the method reference is valid if this yields a function object.

Derived classes may override methods of their base classes. Because methods have no special privileges when calling other methods of the same object, a method of a base class that calls another method defined in the same base class may end up calling a method of a derived class that overrides it. (For C++ programmers: all methods in Python are effectively virtual.)

An overriding method in a derived class may in fact want to extend rather than simply replace the base class method of the same name. There is a simple way to call the base class method directly: just callBaseClassName.methodname(self, arguments). This is occasionally useful to clients as well. (Note that this only works if the base class is accessible as BaseClassName in the global scope.)

Python has two built-in functions that work with inheritance:

* Use [isinstance()](https://docs.python.org/3/library/functions.html#isinstance) to check an instance’s type: isinstance(obj, int) will be True only ifobj.\_\_class\_\_ is [int](https://docs.python.org/3/library/functions.html#int) or some class derived from [int](https://docs.python.org/3/library/functions.html#int).
* Use [issubclass()](https://docs.python.org/3/library/functions.html#issubclass) to check class inheritance: issubclass(bool, int) is True since [bool](https://docs.python.org/3/library/functions.html#bool) is a subclass of [int](https://docs.python.org/3/library/functions.html#int). However, issubclass(float, int) is False since [float](https://docs.python.org/3/library/functions.html#float) is not a subclass of[int](https://docs.python.org/3/library/functions.html#int).

### 9.5.1. Multiple Inheritance

Python supports a form of multiple inheritance as well. A class definition with multiple base classes looks like this:

**class** **DerivedClassName**(Base1, Base2, Base3):

<statement-1>

.

.

.

<statement-N>

For most purposes, in the simplest cases, you can think of the search for attributes inherited from a parent class as depth-first, left-to-right, not searching twice in the same class where there is an overlap in the hierarchy. Thus, if an attribute is not found in DerivedClassName, it is searched for inBase1, then (recursively) in the base classes of Base1, and if it was not found there, it was searched for in Base2, and so on.

In fact, it is slightly more complex than that; the method resolution order changes dynamically to support cooperative calls to [super()](https://docs.python.org/3/library/functions.html#super). This approach is known in some other multiple-inheritance languages as call-next-method and is more powerful than the super call found in single-inheritance languages.

Dynamic ordering is necessary because all cases of multiple inheritance exhibit one or more diamond relationships (where at least one of the parent classes can be accessed through multiple paths from the bottommost class). For example, all classes inherit from [object](https://docs.python.org/3/library/functions.html#object), so any case of multiple inheritance provides more than one path to reach [object](https://docs.python.org/3/library/functions.html#object). To keep the base classes from being accessed more than once, the dynamic algorithm linearizes the search order in a way that preserves the left-to-right ordering specified in each class, that calls each parent only once, and that is monotonic (meaning that a class can be subclassed without affecting the precedence order of its parents). Taken together, these properties make it possible to design reliable and extensible classes with multiple inheritance. For more detail, see <https://www.python.org/download/releases/2.3/mro/>.

## 9.6. Private Variables

“Private” instance variables that cannot be accessed except from inside an object don’t exist in Python. However, there is a convention that is followed by most Python code: a name prefixed with an underscore (e.g. \_spam) should be treated as a non-public part of the API (whether it is a function, a method or a data member). It should be considered an implementation detail and subject to change without notice.

Since there is a valid use-case for class-private members (namely to avoid name clashes of names with names defined by subclasses), there is limited support for such a mechanism, called name mangling. Any identifier of the form \_\_spam (at least two leading underscores, at most one trailing underscore) is textually replaced with \_classname\_\_spam, where classname is the current class name with leading underscore(s) stripped. This mangling is done without regard to the syntactic position of the identifier, as long as it occurs within the definition of a class.

Name mangling is helpful for letting subclasses override methods without breaking intraclass method calls. For example:

**class** **Mapping**:

**def** \_\_init\_\_(self, iterable):

self.items\_list = []

self.\_\_update(iterable)

**def** update(self, iterable):

**for** item **in** iterable:

self.items\_list.append(item)

\_\_update = update *# private copy of original update() method*

**class** **MappingSubclass**(Mapping):

**def** update(self, keys, values):

*# provides new signature for update()*

*# but does not break \_\_init\_\_()*

**for** item **in** zip(keys, values):

self.items\_list.append(item)

Note that the mangling rules are designed mostly to avoid accidents; it still is possible to access or modify a variable that is considered private. This can even be useful in special circumstances, such as in the debugger.

Notice that code passed to exec() or eval() does not consider the classname of the invoking class to be the current class; this is similar to the effect of the global statement, the effect of which is likewise restricted to code that is byte-compiled together. The same restriction applies to getattr(),setattr() and delattr(), as well as when referencing \_\_dict\_\_ directly.

## 9.7. Odds and Ends

Sometimes it is useful to have a data type similar to the Pascal “record” or C “struct”, bundling together a few named data items. An empty class definition will do nicely:

**class** **Employee**:

**pass**

john = Employee() *# Create an empty employee record*

*# Fill the fields of the record*

john.name = 'John Doe'

john.dept = 'computer lab'

john.salary = 1000

A piece of Python code that expects a particular abstract data type can often be passed a class that emulates the methods of that data type instead. For instance, if you have a function that formats some data from a file object, you can define a class with methods read() and readline() that get the data from a string buffer instead, and pass it as an argument.

Instance method objects have attributes, too: m.\_\_self\_\_ is the instance object with the method m(), and m.\_\_func\_\_ is the function object corresponding to the method.

## 9.8. Exceptions Are Classes Too

User-defined exceptions are identified by classes as well. Using this mechanism it is possible to create extensible hierarchies of exceptions.

There are two new valid (semantic) forms for the [raise](https://docs.python.org/3/reference/simple_stmts.html#raise) statement:

**raise** Class

**raise** Instance

In the first form, Class must be an instance of [type](https://docs.python.org/3/library/functions.html#type) or of a class derived from it. The first form is a shorthand for:

**raise** Class()

A class in an [except](https://docs.python.org/3/reference/compound_stmts.html#except) clause is compatible with an exception if it is the same class or a base class thereof (but not the other way around — an except clause listing a derived class is not compatible with a base class). For example, the following code will print B, C, D in that order:

**class** **B**(Exception):

**pass**

**class** **C**(B):

**pass**

**class** **D**(C):

**pass**

**for** cls **in** [B, C, D]:

**try**:

**raise** cls()

**except** D:

print("D")

**except** C:

print("C")

**except** B:

print("B")

Note that if the except clauses were reversed (with except B first), it would have printed B, B, B — the first matching except clause is triggered.

When an error message is printed for an unhandled exception, the exception’s class name is printed, then a colon and a space, and finally the instance converted to a string using the built-in function[str()](https://docs.python.org/3/library/stdtypes.html#str).

## 9.9. Iterators

By now you have probably noticed that most container objects can be looped over using a [for](https://docs.python.org/3/reference/compound_stmts.html#for)statement:

**for** element **in** [1, 2, 3]:

print(element)

**for** element **in** (1, 2, 3):

print(element)

**for** key **in** {'one':1, 'two':2}:

print(key)

**for** char **in** "123":

print(char)

**for** line **in** open("myfile.txt"):

print(line, end='')

This style of access is clear, concise, and convenient. The use of iterators pervades and unifies Python. Behind the scenes, the [for](https://docs.python.org/3/reference/compound_stmts.html#for) statement calls [iter()](https://docs.python.org/3/library/functions.html#iter) on the container object. The function returns an iterator object that defines the method [\_\_next\_\_()](https://docs.python.org/3/library/stdtypes.html#iterator.__next__) which accesses elements in the container one at a time. When there are no more elements, [\_\_next\_\_()](https://docs.python.org/3/library/stdtypes.html#iterator.__next__) raises a [StopIteration](https://docs.python.org/3/library/exceptions.html#StopIteration)exception which tells the [for](https://docs.python.org/3/reference/compound_stmts.html#for) loop to terminate. You can call the [\_\_next\_\_()](https://docs.python.org/3/library/stdtypes.html#iterator.__next__) method using the[next()](https://docs.python.org/3/library/functions.html#next) built-in function; this example shows how it all works:

>>>

**>>>** s = 'abc'

**>>>** it = iter(s)

**>>>** it

<iterator object at 0x00A1DB50>

**>>>** next(it)

'a'

**>>>** next(it)

'b'

**>>>** next(it)

'c'

**>>>** next(it)

Traceback (most recent call last):

File "<stdin>", line 1, in ?

next(it)

StopIteration

Having seen the mechanics behind the iterator protocol, it is easy to add iterator behavior to your classes. Define an [\_\_iter\_\_()](https://docs.python.org/3/reference/datamodel.html#object.__iter__) method which returns an object with a [\_\_next\_\_()](https://docs.python.org/3/library/stdtypes.html#iterator.__next__) method. If the class defines \_\_next\_\_(), then [\_\_iter\_\_()](https://docs.python.org/3/reference/datamodel.html#object.__iter__) can just return self:

**class** **Reverse**:

*"""Iterator for looping over a sequence backwards."""*

**def** \_\_init\_\_(self, data):

self.data = data

self.index = len(data)

**def** \_\_iter\_\_(self):

**return** self

**def** \_\_next\_\_(self):

**if** self.index == 0:

**raise** StopIteration

self.index = self.index - 1

**return** self.data[self.index]

>>>

**>>>** rev = Reverse('spam')

**>>>** iter(rev)

<\_\_main\_\_.Reverse object at 0x00A1DB50>

**>>> for** char **in** rev:

**...**  print(char)

**...**

m

a

p

s

## 9.10. Generators

[Generator](https://docs.python.org/3/glossary.html#term-generator)s are a simple and powerful tool for creating iterators. They are written like regular functions but use the [yield](https://docs.python.org/3/reference/simple_stmts.html#yield) statement whenever they want to return data. Each time [next()](https://docs.python.org/3/library/functions.html#next) is called on it, the generator resumes where it left off (it remembers all the data values and which statement was last executed). An example shows that generators can be trivially easy to create:

**def** reverse(data):

**for** index **in** range(len(data)-1, -1, -1):

**yield** data[index]

>>>

**>>> for** char **in** reverse('golf'):

**...**  print(char)

**...**

f

l

o

g

Anything that can be done with generators can also be done with class-based iterators as described in the previous section. What makes generators so compact is that the [\_\_iter\_\_()](https://docs.python.org/3/reference/datamodel.html#object.__iter__) and [\_\_next\_\_()](https://docs.python.org/3/reference/expressions.html#generator.__next__)methods are created automatically.

Another key feature is that the local variables and execution state are automatically saved between calls. This made the function easier to write and much more clear than an approach using instance variables like self.index and self.data.

In addition to automatic method creation and saving program state, when generators terminate, they automatically raise [StopIteration](https://docs.python.org/3/library/exceptions.html#StopIteration). In combination, these features make it easy to create iterators with no more effort than writing a regular function.

## 9.11. Generator Expressions

Some simple generators can be coded succinctly as expressions using a syntax similar to list comprehensions but with parentheses instead of brackets. These expressions are designed for situations where the generator is used right away by an enclosing function. Generator expressions are more compact but less versatile than full generator definitions and tend to be more memory friendly than equivalent list comprehensions.

Examples:

>>>

**>>>** sum(i\*i **for** i **in** range(10)) *# sum of squares*

285

**>>>** xvec = [10, 20, 30]

**>>>** yvec = [7, 5, 3]

**>>>** sum(x\*y **for** x,y **in** zip(xvec, yvec)) *# dot product*

260

**>>> from** **math** **import** pi, sin

**>>>** sine\_table = {x: sin(x\*pi/180) **for** x **in** range(0, 91)}

**>>>** unique\_words = set(word **for** line **in** page **for** word **in** line.split())

**>>>** valedictorian = max((student.gpa, student.name) **for** student **in** graduates)

**>>>** data = 'golf'

**>>>** list(data[i] **for** i **in** range(len(data)-1, -1, -1))

['f', 'l', 'o', 'g']

**Footnotes**

|  |  |
| --- | --- |
| [[1]](https://docs.python.org/3/tutorial/classes.html#id1) | Except for one thing. Module objects have a secret read-only attribute called [\_\_dict\_\_](https://docs.python.org/3/library/stdtypes.html#object.__dict__) which returns the dictionary used to implement the module’s namespace; the name [\_\_dict\_\_](https://docs.python.org/3/library/stdtypes.html#object.__dict__) is an attribute but not a global name. Obviously, using this violates the abstraction of namespace implementation, and should be restricted to things like post-mortem debuggers. |

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>>>

**>>> import** **os**

**>>>** os.getcwd() *# Return the current working directory*

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**>>>** os.chdir('/server/accesslogs') *# Change current working directory*

**>>>** os.system('mkdir today') *# Run the command mkdir in the system shell*

0

Be sure to use the import os style instead of from os import \*. This will keep [os.open()](https://docs.python.org/3/library/os.html#os.open) from shadowing the built-in [open()](https://docs.python.org/3/library/functions.html#open) function which operates much differently.

The built-in [dir()](https://docs.python.org/3/library/functions.html#dir) and [help()](https://docs.python.org/3/library/functions.html#help) functions are useful as interactive aids for working with large modules like [os](https://docs.python.org/3/library/os.html#module-os):

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<returns a list of all module functions>

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**>>> import** **shutil**

**>>>** shutil.copyfile('data.db', 'archive.db')

'archive.db'

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'installdir'

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The [glob](https://docs.python.org/3/library/glob.html#module-glob) module provides a function for making file lists from directory wildcard searches:

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**>>> import** **glob**

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Common utility scripts often need to process command line arguments. These arguments are stored in the [sys](https://docs.python.org/3/library/sys.html#module-sys) module’s argv attribute as a list. For instance the following output results from running pythondemo.py one two three at the command line:

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**>>>** print(sys.argv)

['demo.py', 'one', 'two', 'three']

The [getopt](https://docs.python.org/3/library/getopt.html#module-getopt) module processes sys.argv using the conventions of the Unix [getopt()](https://docs.python.org/3/library/getopt.html#module-getopt) function. More powerful and flexible command line processing is provided by the [argparse](https://docs.python.org/3/library/argparse.html#module-argparse) module.

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The [sys](https://docs.python.org/3/library/sys.html#module-sys) module also has attributes for stdin, stdout, and stderr. The latter is useful for emitting warnings and error messages to make them visible even when stdout has been redirected:

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**>>>** sys.stderr.write('Warning, log file not found starting a new one**\n**')

Warning, log file not found starting a new one

The most direct way to terminate a script is to use sys.exit().

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**>>> import** **re**

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['foot', 'fell', 'fastest']

**>>>** re.sub(r'(\b[a-z]+) \1', r'\1', 'cat in the the hat')

'cat in the hat'

When only simple capabilities are needed, string methods are preferred because they are easier to read and debug:

>>>

**>>>** 'tea for too'.replace('too', 'two')

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The [math](https://docs.python.org/3/library/math.html#module-math) module gives access to the underlying C library functions for floating point math:

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**>>> import** **math**

**>>>** math.cos(math.pi / 4)

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**>>>** math.log(1024, 2)

10.0

The [random](https://docs.python.org/3/library/random.html#module-random) module provides tools for making random selections:

>>>

**>>> import** **random**

**>>>** random.choice(['apple', 'pear', 'banana'])

'apple'

**>>>** random.sample(range(100), 10) *# sampling without replacement*

[30, 83, 16, 4, 8, 81, 41, 50, 18, 33]

**>>>** random.random() *# random float*

0.17970987693706186

**>>>** random.randrange(6) *# random integer chosen from range(6)*

4

The [statistics](https://docs.python.org/3/library/statistics.html#module-statistics) module calculates basic statistical properties (the mean, median, variance, etc.) of numeric data:

>>>

**>>> import** **statistics**

**>>>** data = [2.75, 1.75, 1.25, 0.25, 0.5, 1.25, 3.5]

**>>>** statistics.mean(data)

1.6071428571428572

**>>>** statistics.median(data)

1.25

**>>>** statistics.variance(data)

1.3720238095238095

The SciPy project <[https://scipy.org](https://scipy.org/)> has many other modules for numerical computations.

## 10.7. Internet Access

There are a number of modules for accessing the internet and processing internet protocols. Two of the simplest are [urllib.request](https://docs.python.org/3/library/urllib.request.html#module-urllib.request) for retrieving data from URLs and [smtplib](https://docs.python.org/3/library/smtplib.html#module-smtplib) for sending mail:

>>>

**>>> from** **urllib.request** **import** urlopen

**>>> with** urlopen('http://tycho.usno.navy.mil/cgi-bin/timer.pl') **as** response:

**...**  **for** line **in** response:

**...**  line = line.decode('utf-8') *# Decoding the binary data to text.*

**...**  **if** 'EST' **in** line **or** 'EDT' **in** line: *# look for Eastern Time*

**...**  print(line)

<BR>Nov. 25, 09:43:32 PM EST

**>>> import** **smtplib**

**>>>** server = smtplib.SMTP('localhost')

**>>>** server.sendmail('soothsayer@example.org', 'jcaesar@example.org',

**...** *"""To: jcaesar@example.org*

**...** *From: soothsayer@example.org*

**...**

**...** *Beware the Ides of March.*

**...** *"""*)

**>>>** server.quit()

(Note that the second example needs a mailserver running on localhost.)

## 10.8. Dates and Times

The [datetime](https://docs.python.org/3/library/datetime.html#module-datetime) module supplies classes for manipulating dates and times in both simple and complex ways. While date and time arithmetic is supported, the focus of the implementation is on efficient member extraction for output formatting and manipulation. The module also supports objects that are timezone aware.

>>>

**>>>** *# dates are easily constructed and formatted*

**>>> from** **datetime** **import** date

**>>>** now = date.today()

**>>>** now

datetime.date(2003, 12, 2)

**>>>** now.strftime("%m-*%d*-%y. *%d* %b %Y is a %A on the *%d* day of %B.")

'12-02-03. 02 Dec 2003 is a Tuesday on the 02 day of December.'

**>>>** *# dates support calendar arithmetic*

**>>>** birthday = date(1964, 7, 31)

**>>>** age = now - birthday

**>>>** age.days

14368

## 10.9. Data Compression

Common data archiving and compression formats are directly supported by modules including: [zlib](https://docs.python.org/3/library/zlib.html#module-zlib),[gzip](https://docs.python.org/3/library/gzip.html#module-gzip), [bz2](https://docs.python.org/3/library/bz2.html#module-bz2), [lzma](https://docs.python.org/3/library/lzma.html#module-lzma), [zipfile](https://docs.python.org/3/library/zipfile.html#module-zipfile) and [tarfile](https://docs.python.org/3/library/tarfile.html#module-tarfile).

>>>

**>>> import** **zlib**

**>>>** s = b'witch which has which witches wrist watch'

**>>>** len(s)

41

**>>>** t = zlib.compress(s)

**>>>** len(t)

37

**>>>** zlib.decompress(t)

b'witch which has which witches wrist watch'

**>>>** zlib.crc32(s)

226805979

## 10.10. Performance Measurement

Some Python users develop a deep interest in knowing the relative performance of different approaches to the same problem. Python provides a measurement tool that answers those questions immediately.

For example, it may be tempting to use the tuple packing and unpacking feature instead of the traditional approach to swapping arguments. The [timeit](https://docs.python.org/3/library/timeit.html#module-timeit) module quickly demonstrates a modest performance advantage:

>>>

**>>> from** **timeit** **import** Timer

**>>>** Timer('t=a; a=b; b=t', 'a=1; b=2').timeit()

0.57535828626024577

**>>>** Timer('a,b = b,a', 'a=1; b=2').timeit()

0.54962537085770791

In contrast to [timeit](https://docs.python.org/3/library/timeit.html#module-timeit)‘s fine level of granularity, the [profile](https://docs.python.org/3/library/profile.html#module-profile) and [pstats](https://docs.python.org/3/library/profile.html#module-pstats) modules provide tools for identifying time critical sections in larger blocks of code.

## 10.11. Quality Control

One approach for developing high quality software is to write tests for each function as it is developed and to run those tests frequently during the development process.

The [doctest](https://docs.python.org/3/library/doctest.html#module-doctest) module provides a tool for scanning a module and validating tests embedded in a program’s docstrings. Test construction is as simple as cutting-and-pasting a typical call along with its results into the docstring. This improves the documentation by providing the user with an example and it allows the doctest module to make sure the code remains true to the documentation:

**def** average(values):

*"""Computes the arithmetic mean of a list of numbers.*

*>>> print(average([20, 30, 70]))*

*40.0*

*"""*

**return** sum(values) / len(values)

**import** **doctest**

doctest.testmod() *# automatically validate the embedded tests*

The [unittest](https://docs.python.org/3/library/unittest.html#module-unittest) module is not as effortless as the [doctest](https://docs.python.org/3/library/doctest.html#module-doctest) module, but it allows a more comprehensive set of tests to be maintained in a separate file:

**import** **unittest**

**class** **TestStatisticalFunctions**(unittest.TestCase):

**def** test\_average(self):

self.assertEqual(average([20, 30, 70]), 40.0)

self.assertEqual(round(average([1, 5, 7]), 1), 4.3)

**with** self.assertRaises(ZeroDivisionError):

average([])

**with** self.assertRaises(TypeError):

average(20, 30, 70)

unittest.main() *# Calling from the command line invokes all tests*

## 10.12. Batteries Included

Python has a “batteries included” philosophy. This is best seen through the sophisticated and robust capabilities of its larger packages. For example:

* The [xmlrpc.client](https://docs.python.org/3/library/xmlrpc.client.html#module-xmlrpc.client) and [xmlrpc.server](https://docs.python.org/3/library/xmlrpc.server.html#module-xmlrpc.server) modules make implementing remote procedure calls into an almost trivial task. Despite the modules names, no direct knowledge or handling of XML is needed.
* The [email](https://docs.python.org/3/library/email.html#module-email) package is a library for managing email messages, including MIME and other RFC 2822-based message documents. Unlike [smtplib](https://docs.python.org/3/library/smtplib.html#module-smtplib) and [poplib](https://docs.python.org/3/library/poplib.html#module-poplib) which actually send and receive messages, the email package has a complete toolset for building or decoding complex message structures (including attachments) and for implementing internet encoding and header protocols.
* The [json](https://docs.python.org/3/library/json.html#module-json) package provides robust support for parsing this popular data interchange format. The[csv](https://docs.python.org/3/library/csv.html#module-csv) module supports direct reading and writing of files in Comma-Separated Value format, commonly supported by databases and spreadsheets. XML processing is supported by the[xml.etree.ElementTree](https://docs.python.org/3/library/xml.etree.elementtree.html#module-xml.etree.ElementTree), [xml.dom](https://docs.python.org/3/library/xml.dom.html#module-xml.dom) and [xml.sax](https://docs.python.org/3/library/xml.sax.html#module-xml.sax) packages. Together, these modules and packages greatly simplify data interchange between Python applications and other tools.
* The [sqlite3](https://docs.python.org/3/library/sqlite3.html#module-sqlite3) module is a wrapper for the SQLite database library, providing a persistent database that can be updated and accessed using slightly nonstandard SQL syntax.
* Internationalization is supported by a number of modules including [gettext](https://docs.python.org/3/library/gettext.html#module-gettext), [locale](https://docs.python.org/3/library/locale.html#module-locale), and the[codecs](https://docs.python.org/3/library/codecs.html#module-codecs) package.

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**...**

**...** *Beware the Ides of March.*

**...** *"""*)

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(Note that the second example needs a mailserver running on localhost.)

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'12-02-03. 02 Dec 2003 is a Tuesday on the 02 day of December.'

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Common data archiving and compression formats are directly supported by modules including: [zlib](https://docs.python.org/3/library/zlib.html#module-zlib),[gzip](https://docs.python.org/3/library/gzip.html#module-gzip), [bz2](https://docs.python.org/3/library/bz2.html#module-bz2), [lzma](https://docs.python.org/3/library/lzma.html#module-lzma), [zipfile](https://docs.python.org/3/library/zipfile.html#module-zipfile) and [tarfile](https://docs.python.org/3/library/tarfile.html#module-tarfile).

>>>

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226805979

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226805979

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* The [email](https://docs.python.org/3/library/email.html#module-email) package is a library for managing email messages, including MIME and other RFC 2822-based message documents. Unlike [smtplib](https://docs.python.org/3/library/smtplib.html#module-smtplib) and [poplib](https://docs.python.org/3/library/poplib.html#module-poplib) which actually send and receive messages, the email package has a complete toolset for building or decoding complex message structures (including attachments) and for implementing internet encoding and header protocols.
* The [json](https://docs.python.org/3/library/json.html#module-json) package provides robust support for parsing this popular data interchange format. The[csv](https://docs.python.org/3/library/csv.html#module-csv) module supports direct reading and writing of files in Comma-Separated Value format, commonly supported by databases and spreadsheets. XML processing is supported by the[xml.etree.ElementTree](https://docs.python.org/3/library/xml.etree.elementtree.html#module-xml.etree.ElementTree), [xml.dom](https://docs.python.org/3/library/xml.dom.html#module-xml.dom) and [xml.sax](https://docs.python.org/3/library/xml.sax.html#module-xml.sax) packages. Together, these modules and packages greatly simplify data interchange between Python applications and other tools.
* The [sqlite3](https://docs.python.org/3/library/sqlite3.html#module-sqlite3) module is a wrapper for the SQLite database library, providing a persistent database that can be updated and accessed using slightly nonstandard SQL syntax.
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**>>> import** **random**

**>>>** random.choice(['apple', 'pear', 'banana'])

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**>>>** random.sample(range(100), 10) *# sampling without replacement*

[30, 83, 16, 4, 8, 81, 41, 50, 18, 33]

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4

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**>>> import** **statistics**

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The SciPy project <[https://scipy.org](https://scipy.org/)> has many other modules for numerical computations.

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**>>> from** **urllib.request** **import** urlopen

**>>> with** urlopen('http://tycho.usno.navy.mil/cgi-bin/timer.pl') **as** response:

**...**  **for** line **in** response:

**...**  line = line.decode('utf-8') *# Decoding the binary data to text.*

**...**  **if** 'EST' **in** line **or** 'EDT' **in** line: *# look for Eastern Time*

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**>>> import** **smtplib**

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226805979

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4

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**>>>** age.days

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226805979

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* The [xmlrpc.client](https://docs.python.org/3/library/xmlrpc.client.html#module-xmlrpc.client) and [xmlrpc.server](https://docs.python.org/3/library/xmlrpc.server.html#module-xmlrpc.server) modules make implementing remote procedure calls into an almost trivial task. Despite the modules names, no direct knowledge or handling of XML is needed.
* The [email](https://docs.python.org/3/library/email.html#module-email) package is a library for managing email messages, including MIME and other RFC 2822-based message documents. Unlike [smtplib](https://docs.python.org/3/library/smtplib.html#module-smtplib) and [poplib](https://docs.python.org/3/library/poplib.html#module-poplib) which actually send and receive messages, the email package has a complete toolset for building or decoding complex message structures (including attachments) and for implementing internet encoding and header protocols.
* The [json](https://docs.python.org/3/library/json.html#module-json) package provides robust support for parsing this popular data interchange format. The[csv](https://docs.python.org/3/library/csv.html#module-csv) module supports direct reading and writing of files in Comma-Separated Value format, commonly supported by databases and spreadsheets. XML processing is supported by the[xml.etree.ElementTree](https://docs.python.org/3/library/xml.etree.elementtree.html#module-xml.etree.ElementTree), [xml.dom](https://docs.python.org/3/library/xml.dom.html#module-xml.dom) and [xml.sax](https://docs.python.org/3/library/xml.sax.html#module-xml.sax) packages. Together, these modules and packages greatly simplify data interchange between Python applications and other tools.
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**>>> import** **random**

**>>>** random.choice(['apple', 'pear', 'banana'])

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**>>>** random.sample(range(100), 10) *# sampling without replacement*

[30, 83, 16, 4, 8, 81, 41, 50, 18, 33]

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**>>> import** **statistics**

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**>>> from** **urllib.request** **import** urlopen

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**>>>** *# dates are easily constructed and formatted*

**>>> from** **datetime** **import** date

**>>>** now = date.today()

**>>>** now

datetime.date(2003, 12, 2)

**>>>** now.strftime("%m-*%d*-%y. *%d* %b %Y is a %A on the *%d* day of %B.")

'12-02-03. 02 Dec 2003 is a Tuesday on the 02 day of December.'

**>>>** *# dates support calendar arithmetic*

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datetime.date(2003, 12, 2)

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'12-02-03. 02 Dec 2003 is a Tuesday on the 02 day of December.'

**>>>** *# dates support calendar arithmetic*

**>>>** birthday = date(1964, 7, 31)

**>>>** age = now - birthday

**>>>** age.days

14368

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226805979

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* The [xmlrpc.client](https://docs.python.org/3/library/xmlrpc.client.html#module-xmlrpc.client) and [xmlrpc.server](https://docs.python.org/3/library/xmlrpc.server.html#module-xmlrpc.server) modules make implementing remote procedure calls into an almost trivial task. Despite the modules names, no direct knowledge or handling of XML is needed.
* The [email](https://docs.python.org/3/library/email.html#module-email) package is a library for managing email messages, including MIME and other RFC 2822-based message documents. Unlike [smtplib](https://docs.python.org/3/library/smtplib.html#module-smtplib) and [poplib](https://docs.python.org/3/library/poplib.html#module-poplib) which actually send and receive messages, the email package has a complete toolset for building or decoding complex message structures (including attachments) and for implementing internet encoding and header protocols.
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**>>>** random.sample(range(100), 10) *# sampling without replacement*

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The SciPy project <[https://scipy.org](https://scipy.org/)> has many other modules for numerical computations.

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**>>> from** **urllib.request** **import** urlopen

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**>>>** *# dates are easily constructed and formatted*

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>>>

**>>>** *# dates are easily constructed and formatted*

**>>> from** **datetime** **import** date

**>>>** now = date.today()

**>>>** now

datetime.date(2003, 12, 2)

**>>>** now.strftime("%m-*%d*-%y. *%d* %b %Y is a %A on the *%d* day of %B.")

'12-02-03. 02 Dec 2003 is a Tuesday on the 02 day of December.'

**>>>** *# dates support calendar arithmetic*

**>>>** birthday = date(1964, 7, 31)

**>>>** age = now - birthday

**>>>** age.days

14368

## 10.9. Data Compression

Common data archiving and compression formats are directly supported by modules including: [zlib](https://docs.python.org/3/library/zlib.html#module-zlib),[gzip](https://docs.python.org/3/library/gzip.html#module-gzip), [bz2](https://docs.python.org/3/library/bz2.html#module-bz2), [lzma](https://docs.python.org/3/library/lzma.html#module-lzma), [zipfile](https://docs.python.org/3/library/zipfile.html#module-zipfile) and [tarfile](https://docs.python.org/3/library/tarfile.html#module-tarfile).

>>>

**>>> import** **zlib**

**>>>** s = b'witch which has which witches wrist watch'

**>>>** len(s)

41

**>>>** t = zlib.compress(s)

**>>>** len(t)

37

**>>>** zlib.decompress(t)

b'witch which has which witches wrist watch'

**>>>** zlib.crc32(s)

226805979

## 10.10. Performance Measurement

Some Python users develop a deep interest in knowing the relative performance of different approaches to the same problem. Python provides a measurement tool that answers those questions immediately.

For example, it may be tempting to use the tuple packing and unpacking feature instead of the traditional approach to swapping arguments. The [timeit](https://docs.python.org/3/library/timeit.html#module-timeit) module quickly demonstrates a modest performance advantage:

>>>

**>>> from** **timeit** **import** Timer

**>>>** Timer('t=a; a=b; b=t', 'a=1; b=2').timeit()

0.57535828626024577

**>>>** Timer('a,b = b,a', 'a=1; b=2').timeit()

0.54962537085770791

In contrast to [timeit](https://docs.python.org/3/library/timeit.html#module-timeit)‘s fine level of granularity, the [profile](https://docs.python.org/3/library/profile.html#module-profile) and [pstats](https://docs.python.org/3/library/profile.html#module-pstats) modules provide tools for identifying time critical sections in larger blocks of code.

## 10.11. Quality Control

One approach for developing high quality software is to write tests for each function as it is developed and to run those tests frequently during the development process.

The [doctest](https://docs.python.org/3/library/doctest.html#module-doctest) module provides a tool for scanning a module and validating tests embedded in a program’s docstrings. Test construction is as simple as cutting-and-pasting a typical call along with its results into the docstring. This improves the documentation by providing the user with an example and it allows the doctest module to make sure the code remains true to the documentation:

**def** average(values):

*"""Computes the arithmetic mean of a list of numbers.*

*>>> print(average([20, 30, 70]))*

*40.0*

*"""*

**return** sum(values) / len(values)

**import** **doctest**

doctest.testmod() *# automatically validate the embedded tests*

The [unittest](https://docs.python.org/3/library/unittest.html#module-unittest) module is not as effortless as the [doctest](https://docs.python.org/3/library/doctest.html#module-doctest) module, but it allows a more comprehensive set of tests to be maintained in a separate file:

**import** **unittest**

**class** **TestStatisticalFunctions**(unittest.TestCase):

**def** test\_average(self):

self.assertEqual(average([20, 30, 70]), 40.0)

self.assertEqual(round(average([1, 5, 7]), 1), 4.3)

**with** self.assertRaises(ZeroDivisionError):

average([])

**with** self.assertRaises(TypeError):

average(20, 30, 70)

unittest.main() *# Calling from the command line invokes all tests*

## 10.12. Batteries Included

Python has a “batteries included” philosophy. This is best seen through the sophisticated and robust capabilities of its larger packages. For example:

* The [xmlrpc.client](https://docs.python.org/3/library/xmlrpc.client.html#module-xmlrpc.client) and [xmlrpc.server](https://docs.python.org/3/library/xmlrpc.server.html#module-xmlrpc.server) modules make implementing remote procedure calls into an almost trivial task. Despite the modules names, no direct knowledge or handling of XML is needed.
* The [email](https://docs.python.org/3/library/email.html#module-email) package is a library for managing email messages, including MIME and other RFC 2822-based message documents. Unlike [smtplib](https://docs.python.org/3/library/smtplib.html#module-smtplib) and [poplib](https://docs.python.org/3/library/poplib.html#module-poplib) which actually send and receive messages, the email package has a complete toolset for building or decoding complex message structures (including attachments) and for implementing internet encoding and header protocols.
* The [json](https://docs.python.org/3/library/json.html#module-json) package provides robust support for parsing this popular data interchange format. The[csv](https://docs.python.org/3/library/csv.html#module-csv) module supports direct reading and writing of files in Comma-Separated Value format, commonly supported by databases and spreadsheets. XML processing is supported by the[xml.etree.ElementTree](https://docs.python.org/3/library/xml.etree.elementtree.html#module-xml.etree.ElementTree), [xml.dom](https://docs.python.org/3/library/xml.dom.html#module-xml.dom) and [xml.sax](https://docs.python.org/3/library/xml.sax.html#module-xml.sax) packages. Together, these modules and packages greatly simplify data interchange between Python applications and other tools.
* The [sqlite3](https://docs.python.org/3/library/sqlite3.html#module-sqlite3) module is a wrapper for the SQLite database library, providing a persistent database that can be updated and accessed using slightly nonstandard SQL syntax.
* Internationalization is supported by a number of modules including [gettext](https://docs.python.org/3/library/gettext.html#module-gettext), [locale](https://docs.python.org/3/library/locale.html#module-locale), and the[codecs](https://docs.python.org/3/library/codecs.html#module-codecs) package.

# 11. Brief Tour of the Standard Library – Part II

This second tour covers more advanced modules that support professional programming needs. These modules rarely occur in small scripts.

## 11.1. Output Formatting

The [reprlib](https://docs.python.org/3/library/reprlib.html#module-reprlib) module provides a version of [repr()](https://docs.python.org/3/library/functions.html#repr) customized for abbreviated displays of large or deeply nested containers:

>>>

**>>> import** **reprlib**

**>>>** reprlib.repr(set('supercalifragilisticexpialidocious'))

"{'a', 'c', 'd', 'e', 'f', 'g', ...}"

The [pprint](https://docs.python.org/3/library/pprint.html#module-pprint) module offers more sophisticated control over printing both built-in and user defined objects in a way that is readable by the interpreter. When the result is longer than one line, the “pretty printer” adds line breaks and indentation to more clearly reveal data structure:

>>>

**>>> import** **pprint**

**>>>** t = [[[['black', 'cyan'], 'white', ['green', 'red']], [['magenta',

**...**  'yellow'], 'blue']]]

**...**

**>>>** pprint.pprint(t, width=30)

[[[['black', 'cyan'],

'white',

['green', 'red']],

[['magenta', 'yellow'],

'blue']]]

The [textwrap](https://docs.python.org/3/library/textwrap.html#module-textwrap) module formats paragraphs of text to fit a given screen width:

>>>

**>>> import** **textwrap**

**>>>** doc = """The wrap() method is just like fill() except that it returns

**...** a list of strings instead of one big string with newlines to separate

**...** the wrapped lines."""

**...**

**>>>** print(textwrap.fill(doc, width=40))

The wrap() method is just like fill()

except that it returns a list of strings

instead of one big string with newlines

to separate the wrapped lines.

The [locale](https://docs.python.org/3/library/locale.html#module-locale) module accesses a database of culture specific data formats. The grouping attribute of locale’s format function provides a direct way of formatting numbers with group separators:

>>>

**>>> import** **locale**

**>>>** locale.setlocale(locale.LC\_ALL, 'English\_United States.1252')

'English\_United States.1252'

**>>>** conv = locale.localeconv() *# get a mapping of conventions*

**>>>** x = 1234567.8

**>>>** locale.format("*%d*", x, grouping=**True**)

'1,234,567'

**>>>** locale.format\_string("*%s%.\*f*", (conv['currency\_symbol'],

**...**  conv['frac\_digits'], x), grouping=**True**)

'$1,234,567.80'

## 11.2. Templating

The [string](https://docs.python.org/3/library/string.html#module-string) module includes a versatile [Template](https://docs.python.org/3/library/string.html#string.Template) class with a simplified syntax suitable for editing by end-users. This allows users to customize their applications without having to alter the application.

The format uses placeholder names formed by $ with valid Python identifiers (alphanumeric characters and underscores). Surrounding the placeholder with braces allows it to be followed by more alphanumeric letters with no intervening spaces. Writing $$ creates a single escaped $:

>>>

**>>> from** **string** **import** Template

**>>>** t = Template('$*{village}*folk send $$10 to $cause.')

**>>>** t.substitute(village='Nottingham', cause='the ditch fund')

'Nottinghamfolk send $10 to the ditch fund.'

The [substitute()](https://docs.python.org/3/library/string.html#string.Template.substitute) method raises a [KeyError](https://docs.python.org/3/library/exceptions.html#KeyError) when a placeholder is not supplied in a dictionary or a keyword argument. For mail-merge style applications, user supplied data may be incomplete and the[safe\_substitute()](https://docs.python.org/3/library/string.html#string.Template.safe_substitute) method may be more appropriate — it will leave placeholders unchanged if data is missing:

>>>

**>>>** t = Template('Return the $item to $owner.')

**>>>** d = dict(item='unladen swallow')

**>>>** t.substitute(d)

Traceback (most recent call last):

*...*

KeyError: 'owner'

**>>>** t.safe\_substitute(d)

'Return the unladen swallow to $owner.'

Template subclasses can specify a custom delimiter. For example, a batch renaming utility for a photo browser may elect to use percent signs for placeholders such as the current date, image sequence number, or file format:

>>>

**>>> import** **time**, **os.path**

**>>>** photofiles = ['img\_1074.jpg', 'img\_1076.jpg', 'img\_1077.jpg']

**>>> class** **BatchRename**(Template):

**...**  delimiter = '%'

**>>>** fmt = input('Enter rename style (*%d*-date %n-seqnum *%f*-format): ')

Enter rename style (%d-date %n-seqnum %f-format): Ashley\_%n%f

**>>>** t = BatchRename(fmt)

**>>>** date = time.strftime('*%d*%b%y')

**>>> for** i, filename **in** enumerate(photofiles):

**...**  base, ext = os.path.splitext(filename)

**...**  newname = t.substitute(d=date, n=i, f=ext)

**...**  print('*{0}* --> *{1}*'.format(filename, newname))

img\_1074.jpg --> Ashley\_0.jpg

img\_1076.jpg --> Ashley\_1.jpg

img\_1077.jpg --> Ashley\_2.jpg

Another application for templating is separating program logic from the details of multiple output formats. This makes it possible to substitute custom templates for XML files, plain text reports, and HTML web reports.

## 11.3. Working with Binary Data Record Layouts

The [struct](https://docs.python.org/3/library/struct.html#module-struct) module provides [pack()](https://docs.python.org/3/library/struct.html#struct.pack) and [unpack()](https://docs.python.org/3/library/struct.html#struct.unpack) functions for working with variable length binary record formats. The following example shows how to loop through header information in a ZIP file without using the [zipfile](https://docs.python.org/3/library/zipfile.html#module-zipfile) module. Pack codes "H" and "I" represent two and four byte unsigned numbers respectively. The "<" indicates that they are standard size and in little-endian byte order:

**import** **struct**

**with** open('myfile.zip', 'rb') **as** f:

data = f.read()

start = 0

**for** i **in** range(3): *# show the first 3 file headers*

start += 14

fields = struct.unpack('<IIIHH', data[start:start+16])

crc32, comp\_size, uncomp\_size, filenamesize, extra\_size = fields

start += 16

filename = data[start:start+filenamesize]

start += filenamesize

extra = data[start:start+extra\_size]

print(filename, hex(crc32), comp\_size, uncomp\_size)

start += extra\_size + comp\_size *# skip to the next header*

## 11.4. Multi-threading

Threading is a technique for decoupling tasks which are not sequentially dependent. Threads can be used to improve the responsiveness of applications that accept user input while other tasks run in the background. A related use case is running I/O in parallel with computations in another thread.

The following code shows how the high level [threading](https://docs.python.org/3/library/threading.html#module-threading) module can run tasks in background while the main program continues to run:

**import** **threading**, **zipfile**

**class** **AsyncZip**(threading.Thread):

**def** \_\_init\_\_(self, infile, outfile):

threading.Thread.\_\_init\_\_(self)

self.infile = infile

self.outfile = outfile

**def** run(self):

f = zipfile.ZipFile(self.outfile, 'w', zipfile.ZIP\_DEFLATED)

f.write(self.infile)

f.close()

print('Finished background zip of:', self.infile)

background = AsyncZip('mydata.txt', 'myarchive.zip')

background.start()

print('The main program continues to run in foreground.')

background.join() *# Wait for the background task to finish*

print('Main program waited until background was done.')

The principal challenge of multi-threaded applications is coordinating threads that share data or other resources. To that end, the threading module provides a number of synchronization primitives including locks, events, condition variables, and semaphores.

While those tools are powerful, minor design errors can result in problems that are difficult to reproduce. So, the preferred approach to task coordination is to concentrate all access to a resource in a single thread and then use the [queue](https://docs.python.org/3/library/queue.html#module-queue) module to feed that thread with requests from other threads. Applications using [Queue](https://docs.python.org/3/library/queue.html#queue.Queue) objects for inter-thread communication and coordination are easier to design, more readable, and more reliable.

## 11.5. Logging

The [logging](https://docs.python.org/3/library/logging.html#module-logging) module offers a full featured and flexible logging system. At its simplest, log messages are sent to a file or to sys.stderr:

**import** **logging**

logging.debug('Debugging information')

logging.info('Informational message')

logging.warning('Warning:config file *%s* not found', 'server.conf')

logging.error('Error occurred')

logging.critical('Critical error -- shutting down')

This produces the following output:

WARNING:root:Warning:config file server.conf not found

ERROR:root:Error occurred

CRITICAL:root:Critical error -- shutting down

By default, informational and debugging messages are suppressed and the output is sent to standard error. Other output options include routing messages through email, datagrams, sockets, or to an HTTP Server. New filters can select different routing based on message priority: DEBUG, INFO,WARNING, ERROR, and CRITICAL.

The logging system can be configured directly from Python or can be loaded from a user editable configuration file for customized logging without altering the application.

## 11.6. Weak References

Python does automatic memory management (reference counting for most objects and [garbage collection](https://docs.python.org/3/glossary.html#term-garbage-collection) to eliminate cycles). The memory is freed shortly after the last reference to it has been eliminated.

This approach works fine for most applications but occasionally there is a need to track objects only as long as they are being used by something else. Unfortunately, just tracking them creates a reference that makes them permanent. The [weakref](https://docs.python.org/3/library/weakref.html#module-weakref) module provides tools for tracking objects without creating a reference. When the object is no longer needed, it is automatically removed from a weakref table and a callback is triggered for weakref objects. Typical applications include caching objects that are expensive to create:

>>>

**>>> import** **weakref**, **gc**

**>>> class** **A**:

**...**  **def** \_\_init\_\_(self, value):

**...**  self.value = value

**...**  **def** \_\_repr\_\_(self):

**...**  **return** str(self.value)

**...**

**>>>** a = A(10) *# create a reference*

**>>>** d = weakref.WeakValueDictionary()

**>>>** d['primary'] = a *# does not create a reference*

**>>>** d['primary'] *# fetch the object if it is still alive*

10

**>>> del** a *# remove the one reference*

**>>>** gc.collect() *# run garbage collection right away*

0

**>>>** d['primary'] *# entry was automatically removed*

Traceback (most recent call last):

File "<stdin>", line 1, in <module>

d['primary'] *# entry was automatically removed*

File "C:/python35/lib/weakref.py", line 46, in \_\_getitem\_\_

o = self.data[key]()

KeyError: 'primary'

## 11.7. Tools for Working with Lists

Many data structure needs can be met with the built-in list type. However, sometimes there is a need for alternative implementations with different performance trade-offs.

The [array](https://docs.python.org/3/library/array.html#module-array) module provides an [array()](https://docs.python.org/3/library/array.html#array.array) object that is like a list that stores only homogeneous data and stores it more compactly. The following example shows an array of numbers stored as two byte unsigned binary numbers (typecode "H") rather than the usual 16 bytes per entry for regular lists of Python int objects:

>>>

**>>> from** **array** **import** array

**>>>** a = array('H', [4000, 10, 700, 22222])

**>>>** sum(a)

26932

**>>>** a[1:3]

array('H', [10, 700])

The [collections](https://docs.python.org/3/library/collections.html#module-collections) module provides a [deque()](https://docs.python.org/3/library/collections.html#collections.deque) object that is like a list with faster appends and pops from the left side but slower lookups in the middle. These objects are well suited for implementing queues and breadth first tree searches:

>>>

**>>> from** **collections** **import** deque

**>>>** d = deque(["task1", "task2", "task3"])

**>>>** d.append("task4")

**>>>** print("Handling", d.popleft())

Handling task1

unsearched = deque([starting\_node])

**def** breadth\_first\_search(unsearched):

node = unsearched.popleft()

**for** m **in** gen\_moves(node):

**if** is\_goal(m):

**return** m

unsearched.append(m)

In addition to alternative list implementations, the library also offers other tools such as the [bisect](https://docs.python.org/3/library/bisect.html#module-bisect)module with functions for manipulating sorted lists:

>>>

**>>> import** **bisect**

**>>>** scores = [(100, 'perl'), (200, 'tcl'), (400, 'lua'), (500, 'python')]

**>>>** bisect.insort(scores, (300, 'ruby'))

**>>>** scores

[(100, 'perl'), (200, 'tcl'), (300, 'ruby'), (400, 'lua'), (500, 'python')]

The [heapq](https://docs.python.org/3/library/heapq.html#module-heapq) module provides functions for implementing heaps based on regular lists. The lowest valued entry is always kept at position zero. This is useful for applications which repeatedly access the smallest element but do not want to run a full list sort:

>>>

**>>> from** **heapq** **import** heapify, heappop, heappush

**>>>** data = [1, 3, 5, 7, 9, 2, 4, 6, 8, 0]

**>>>** heapify(data) *# rearrange the list into heap order*

**>>>** heappush(data, -5) *# add a new entry*

**>>>** [heappop(data) **for** i **in** range(3)] *# fetch the three smallest entries*

[-5, 0, 1]

## 11.8. Decimal Floating Point Arithmetic

The [decimal](https://docs.python.org/3/library/decimal.html#module-decimal) module offers a [Decimal](https://docs.python.org/3/library/decimal.html#decimal.Decimal) datatype for decimal floating point arithmetic. Compared to the built-in [float](https://docs.python.org/3/library/functions.html#float) implementation of binary floating point, the class is especially helpful for

* financial applications and other uses which require exact decimal representation,
* control over precision,
* control over rounding to meet legal or regulatory requirements,
* tracking of significant decimal places, or
* applications where the user expects the results to match calculations done by hand.

For example, calculating a 5% tax on a 70 cent phone charge gives different results in decimal floating point and binary floating point. The difference becomes significant if the results are rounded to the nearest cent:

>>>

**>>> from** **decimal** **import** \*

**>>>** round(Decimal('0.70') \* Decimal('1.05'), 2)

Decimal('0.74')

**>>>** round(.70 \* 1.05, 2)

0.73

The [Decimal](https://docs.python.org/3/library/decimal.html#decimal.Decimal) result keeps a trailing zero, automatically inferring four place significance from multiplicands with two place significance. Decimal reproduces mathematics as done by hand and avoids issues that can arise when binary floating point cannot exactly represent decimal quantities.

Exact representation enables the [Decimal](https://docs.python.org/3/library/decimal.html#decimal.Decimal) class to perform modulo calculations and equality tests that are unsuitable for binary floating point:

>>>

**>>>** Decimal('1.00') % Decimal('.10')

Decimal('0.00')

**>>>** 1.00 % 0.10

0.09999999999999995

**>>>** sum([Decimal('0.1')]\*10) == Decimal('1.0')

True

**>>>** sum([0.1]\*10) == 1.0

False

The [decimal](https://docs.python.org/3/library/decimal.html#module-decimal) module provides arithmetic with as much precision as needed:

>>>

**>>>** getcontext().prec = 36

**>>>** Decimal(1) / Decimal(7)

Decimal('0.142857142857142857142857142857142857')

# 11. Brief Tour of the Standard Library – Part II

This second tour covers more advanced modules that support professional programming needs. These modules rarely occur in small scripts.

## 11.1. Output Formatting

The [reprlib](https://docs.python.org/3/library/reprlib.html#module-reprlib) module provides a version of [repr()](https://docs.python.org/3/library/functions.html#repr) customized for abbreviated displays of large or deeply nested containers:

>>>

**>>> import** **reprlib**

**>>>** reprlib.repr(set('supercalifragilisticexpialidocious'))

"{'a', 'c', 'd', 'e', 'f', 'g', ...}"

The [pprint](https://docs.python.org/3/library/pprint.html#module-pprint) module offers more sophisticated control over printing both built-in and user defined objects in a way that is readable by the interpreter. When the result is longer than one line, the “pretty printer” adds line breaks and indentation to more clearly reveal data structure:

>>>

**>>> import** **pprint**

**>>>** t = [[[['black', 'cyan'], 'white', ['green', 'red']], [['magenta',

**...**  'yellow'], 'blue']]]

**...**

**>>>** pprint.pprint(t, width=30)

[[[['black', 'cyan'],

'white',

['green', 'red']],

[['magenta', 'yellow'],

'blue']]]

The [textwrap](https://docs.python.org/3/library/textwrap.html#module-textwrap) module formats paragraphs of text to fit a given screen width:

>>>

**>>> import** **textwrap**

**>>>** doc = """The wrap() method is just like fill() except that it returns

**...** a list of strings instead of one big string with newlines to separate

**...** the wrapped lines."""

**...**

**>>>** print(textwrap.fill(doc, width=40))

The wrap() method is just like fill()

except that it returns a list of strings

instead of one big string with newlines

to separate the wrapped lines.

The [locale](https://docs.python.org/3/library/locale.html#module-locale) module accesses a database of culture specific data formats. The grouping attribute of locale’s format function provides a direct way of formatting numbers with group separators:

>>>

**>>> import** **locale**

**>>>** locale.setlocale(locale.LC\_ALL, 'English\_United States.1252')

'English\_United States.1252'

**>>>** conv = locale.localeconv() *# get a mapping of conventions*

**>>>** x = 1234567.8

**>>>** locale.format("*%d*", x, grouping=**True**)

'1,234,567'

**>>>** locale.format\_string("*%s%.\*f*", (conv['currency\_symbol'],

**...**  conv['frac\_digits'], x), grouping=**True**)

'$1,234,567.80'

## 11.2. Templating

The [string](https://docs.python.org/3/library/string.html#module-string) module includes a versatile [Template](https://docs.python.org/3/library/string.html#string.Template) class with a simplified syntax suitable for editing by end-users. This allows users to customize their applications without having to alter the application.

The format uses placeholder names formed by $ with valid Python identifiers (alphanumeric characters and underscores). Surrounding the placeholder with braces allows it to be followed by more alphanumeric letters with no intervening spaces. Writing $$ creates a single escaped $:

>>>

**>>> from** **string** **import** Template

**>>>** t = Template('$*{village}*folk send $$10 to $cause.')

**>>>** t.substitute(village='Nottingham', cause='the ditch fund')

'Nottinghamfolk send $10 to the ditch fund.'

The [substitute()](https://docs.python.org/3/library/string.html#string.Template.substitute) method raises a [KeyError](https://docs.python.org/3/library/exceptions.html#KeyError) when a placeholder is not supplied in a dictionary or a keyword argument. For mail-merge style applications, user supplied data may be incomplete and the[safe\_substitute()](https://docs.python.org/3/library/string.html#string.Template.safe_substitute) method may be more appropriate — it will leave placeholders unchanged if data is missing:

>>>

**>>>** t = Template('Return the $item to $owner.')

**>>>** d = dict(item='unladen swallow')

**>>>** t.substitute(d)

Traceback (most recent call last):

*...*

KeyError: 'owner'

**>>>** t.safe\_substitute(d)

'Return the unladen swallow to $owner.'

Template subclasses can specify a custom delimiter. For example, a batch renaming utility for a photo browser may elect to use percent signs for placeholders such as the current date, image sequence number, or file format:

>>>

**>>> import** **time**, **os.path**

**>>>** photofiles = ['img\_1074.jpg', 'img\_1076.jpg', 'img\_1077.jpg']

**>>> class** **BatchRename**(Template):

**...**  delimiter = '%'

**>>>** fmt = input('Enter rename style (*%d*-date %n-seqnum *%f*-format): ')

Enter rename style (%d-date %n-seqnum %f-format): Ashley\_%n%f

**>>>** t = BatchRename(fmt)

**>>>** date = time.strftime('*%d*%b%y')

**>>> for** i, filename **in** enumerate(photofiles):

**...**  base, ext = os.path.splitext(filename)

**...**  newname = t.substitute(d=date, n=i, f=ext)

**...**  print('*{0}* --> *{1}*'.format(filename, newname))

img\_1074.jpg --> Ashley\_0.jpg

img\_1076.jpg --> Ashley\_1.jpg

img\_1077.jpg --> Ashley\_2.jpg

Another application for templating is separating program logic from the details of multiple output formats. This makes it possible to substitute custom templates for XML files, plain text reports, and HTML web reports.

## 11.3. Working with Binary Data Record Layouts

The [struct](https://docs.python.org/3/library/struct.html#module-struct) module provides [pack()](https://docs.python.org/3/library/struct.html#struct.pack) and [unpack()](https://docs.python.org/3/library/struct.html#struct.unpack) functions for working with variable length binary record formats. The following example shows how to loop through header information in a ZIP file without using the [zipfile](https://docs.python.org/3/library/zipfile.html#module-zipfile) module. Pack codes "H" and "I" represent two and four byte unsigned numbers respectively. The "<" indicates that they are standard size and in little-endian byte order:

**import** **struct**

**with** open('myfile.zip', 'rb') **as** f:

data = f.read()

start = 0

**for** i **in** range(3): *# show the first 3 file headers*

start += 14

fields = struct.unpack('<IIIHH', data[start:start+16])

crc32, comp\_size, uncomp\_size, filenamesize, extra\_size = fields

start += 16

filename = data[start:start+filenamesize]

start += filenamesize

extra = data[start:start+extra\_size]

print(filename, hex(crc32), comp\_size, uncomp\_size)

start += extra\_size + comp\_size *# skip to the next header*

## 11.4. Multi-threading

Threading is a technique for decoupling tasks which are not sequentially dependent. Threads can be used to improve the responsiveness of applications that accept user input while other tasks run in the background. A related use case is running I/O in parallel with computations in another thread.

The following code shows how the high level [threading](https://docs.python.org/3/library/threading.html#module-threading) module can run tasks in background while the main program continues to run:

**import** **threading**, **zipfile**

**class** **AsyncZip**(threading.Thread):

**def** \_\_init\_\_(self, infile, outfile):

threading.Thread.\_\_init\_\_(self)

self.infile = infile

self.outfile = outfile

**def** run(self):

f = zipfile.ZipFile(self.outfile, 'w', zipfile.ZIP\_DEFLATED)

f.write(self.infile)

f.close()

print('Finished background zip of:', self.infile)

background = AsyncZip('mydata.txt', 'myarchive.zip')

background.start()

print('The main program continues to run in foreground.')

background.join() *# Wait for the background task to finish*

print('Main program waited until background was done.')

The principal challenge of multi-threaded applications is coordinating threads that share data or other resources. To that end, the threading module provides a number of synchronization primitives including locks, events, condition variables, and semaphores.

While those tools are powerful, minor design errors can result in problems that are difficult to reproduce. So, the preferred approach to task coordination is to concentrate all access to a resource in a single thread and then use the [queue](https://docs.python.org/3/library/queue.html#module-queue) module to feed that thread with requests from other threads. Applications using [Queue](https://docs.python.org/3/library/queue.html#queue.Queue) objects for inter-thread communication and coordination are easier to design, more readable, and more reliable.

## 11.5. Logging

The [logging](https://docs.python.org/3/library/logging.html#module-logging) module offers a full featured and flexible logging system. At its simplest, log messages are sent to a file or to sys.stderr:

**import** **logging**

logging.debug('Debugging information')

logging.info('Informational message')

logging.warning('Warning:config file *%s* not found', 'server.conf')

logging.error('Error occurred')

logging.critical('Critical error -- shutting down')

This produces the following output:

WARNING:root:Warning:config file server.conf not found

ERROR:root:Error occurred

CRITICAL:root:Critical error -- shutting down

By default, informational and debugging messages are suppressed and the output is sent to standard error. Other output options include routing messages through email, datagrams, sockets, or to an HTTP Server. New filters can select different routing based on message priority: DEBUG, INFO,WARNING, ERROR, and CRITICAL.

The logging system can be configured directly from Python or can be loaded from a user editable configuration file for customized logging without altering the application.

## 11.6. Weak References

Python does automatic memory management (reference counting for most objects and [garbage collection](https://docs.python.org/3/glossary.html#term-garbage-collection) to eliminate cycles). The memory is freed shortly after the last reference to it has been eliminated.

This approach works fine for most applications but occasionally there is a need to track objects only as long as they are being used by something else. Unfortunately, just tracking them creates a reference that makes them permanent. The [weakref](https://docs.python.org/3/library/weakref.html#module-weakref) module provides tools for tracking objects without creating a reference. When the object is no longer needed, it is automatically removed from a weakref table and a callback is triggered for weakref objects. Typical applications include caching objects that are expensive to create:

>>>

**>>> import** **weakref**, **gc**

**>>> class** **A**:

**...**  **def** \_\_init\_\_(self, value):

**...**  self.value = value

**...**  **def** \_\_repr\_\_(self):

**...**  **return** str(self.value)

**...**

**>>>** a = A(10) *# create a reference*

**>>>** d = weakref.WeakValueDictionary()

**>>>** d['primary'] = a *# does not create a reference*

**>>>** d['primary'] *# fetch the object if it is still alive*

10

**>>> del** a *# remove the one reference*

**>>>** gc.collect() *# run garbage collection right away*

0

**>>>** d['primary'] *# entry was automatically removed*

Traceback (most recent call last):

File "<stdin>", line 1, in <module>

d['primary'] *# entry was automatically removed*

File "C:/python35/lib/weakref.py", line 46, in \_\_getitem\_\_

o = self.data[key]()

KeyError: 'primary'

## 11.7. Tools for Working with Lists

Many data structure needs can be met with the built-in list type. However, sometimes there is a need for alternative implementations with different performance trade-offs.

The [array](https://docs.python.org/3/library/array.html#module-array) module provides an [array()](https://docs.python.org/3/library/array.html#array.array) object that is like a list that stores only homogeneous data and stores it more compactly. The following example shows an array of numbers stored as two byte unsigned binary numbers (typecode "H") rather than the usual 16 bytes per entry for regular lists of Python int objects:

>>>

**>>> from** **array** **import** array

**>>>** a = array('H', [4000, 10, 700, 22222])

**>>>** sum(a)

26932

**>>>** a[1:3]

array('H', [10, 700])

The [collections](https://docs.python.org/3/library/collections.html#module-collections) module provides a [deque()](https://docs.python.org/3/library/collections.html#collections.deque) object that is like a list with faster appends and pops from the left side but slower lookups in the middle. These objects are well suited for implementing queues and breadth first tree searches:

>>>

**>>> from** **collections** **import** deque

**>>>** d = deque(["task1", "task2", "task3"])

**>>>** d.append("task4")

**>>>** print("Handling", d.popleft())

Handling task1

unsearched = deque([starting\_node])

**def** breadth\_first\_search(unsearched):

node = unsearched.popleft()

**for** m **in** gen\_moves(node):

**if** is\_goal(m):

**return** m

unsearched.append(m)

In addition to alternative list implementations, the library also offers other tools such as the [bisect](https://docs.python.org/3/library/bisect.html#module-bisect)module with functions for manipulating sorted lists:

>>>

**>>> import** **bisect**

**>>>** scores = [(100, 'perl'), (200, 'tcl'), (400, 'lua'), (500, 'python')]

**>>>** bisect.insort(scores, (300, 'ruby'))

**>>>** scores

[(100, 'perl'), (200, 'tcl'), (300, 'ruby'), (400, 'lua'), (500, 'python')]

The [heapq](https://docs.python.org/3/library/heapq.html#module-heapq) module provides functions for implementing heaps based on regular lists. The lowest valued entry is always kept at position zero. This is useful for applications which repeatedly access the smallest element but do not want to run a full list sort:

>>>

**>>> from** **heapq** **import** heapify, heappop, heappush

**>>>** data = [1, 3, 5, 7, 9, 2, 4, 6, 8, 0]

**>>>** heapify(data) *# rearrange the list into heap order*

**>>>** heappush(data, -5) *# add a new entry*

**>>>** [heappop(data) **for** i **in** range(3)] *# fetch the three smallest entries*

[-5, 0, 1]

## 11.8. Decimal Floating Point Arithmetic

The [decimal](https://docs.python.org/3/library/decimal.html#module-decimal) module offers a [Decimal](https://docs.python.org/3/library/decimal.html#decimal.Decimal) datatype for decimal floating point arithmetic. Compared to the built-in [float](https://docs.python.org/3/library/functions.html#float) implementation of binary floating point, the class is especially helpful for

* financial applications and other uses which require exact decimal representation,
* control over precision,
* control over rounding to meet legal or regulatory requirements,
* tracking of significant decimal places, or
* applications where the user expects the results to match calculations done by hand.

For example, calculating a 5% tax on a 70 cent phone charge gives different results in decimal floating point and binary floating point. The difference becomes significant if the results are rounded to the nearest cent:

>>>

**>>> from** **decimal** **import** \*

**>>>** round(Decimal('0.70') \* Decimal('1.05'), 2)

Decimal('0.74')

**>>>** round(.70 \* 1.05, 2)

0.73

The [Decimal](https://docs.python.org/3/library/decimal.html#decimal.Decimal) result keeps a trailing zero, automatically inferring four place significance from multiplicands with two place significance. Decimal reproduces mathematics as done by hand and avoids issues that can arise when binary floating point cannot exactly represent decimal quantities.

Exact representation enables the [Decimal](https://docs.python.org/3/library/decimal.html#decimal.Decimal) class to perform modulo calculations and equality tests that are unsuitable for binary floating point:

>>>

**>>>** Decimal('1.00') % Decimal('.10')

Decimal('0.00')

**>>>** 1.00 % 0.10

0.09999999999999995

**>>>** sum([Decimal('0.1')]\*10) == Decimal('1.0')

True

**>>>** sum([0.1]\*10) == 1.0

False

The [decimal](https://docs.python.org/3/library/decimal.html#module-decimal) module provides arithmetic with as much precision as needed:

>>>

**>>>** getcontext().prec = 36

**>>>** Decimal(1) / Decimal(7)

Decimal('0.142857142857142857142857142857142857')

# 11. Brief Tour of the Standard Library – Part II

This second tour covers more advanced modules that support professional programming needs. These modules rarely occur in small scripts.

## 11.1. Output Formatting

The [reprlib](https://docs.python.org/3/library/reprlib.html#module-reprlib) module provides a version of [repr()](https://docs.python.org/3/library/functions.html#repr) customized for abbreviated displays of large or deeply nested containers:

>>>

**>>> import** **reprlib**

**>>>** reprlib.repr(set('supercalifragilisticexpialidocious'))

"{'a', 'c', 'd', 'e', 'f', 'g', ...}"

The [pprint](https://docs.python.org/3/library/pprint.html#module-pprint) module offers more sophisticated control over printing both built-in and user defined objects in a way that is readable by the interpreter. When the result is longer than one line, the “pretty printer” adds line breaks and indentation to more clearly reveal data structure:

>>>

**>>> import** **pprint**

**>>>** t = [[[['black', 'cyan'], 'white', ['green', 'red']], [['magenta',

**...**  'yellow'], 'blue']]]

**...**

**>>>** pprint.pprint(t, width=30)

[[[['black', 'cyan'],

'white',

['green', 'red']],

[['magenta', 'yellow'],

'blue']]]

The [textwrap](https://docs.python.org/3/library/textwrap.html#module-textwrap) module formats paragraphs of text to fit a given screen width:

>>>

**>>> import** **textwrap**

**>>>** doc = """The wrap() method is just like fill() except that it returns

**...** a list of strings instead of one big string with newlines to separate

**...** the wrapped lines."""

**...**

**>>>** print(textwrap.fill(doc, width=40))

The wrap() method is just like fill()

except that it returns a list of strings

instead of one big string with newlines

to separate the wrapped lines.

The [locale](https://docs.python.org/3/library/locale.html#module-locale) module accesses a database of culture specific data formats. The grouping attribute of locale’s format function provides a direct way of formatting numbers with group separators:

>>>

**>>> import** **locale**

**>>>** locale.setlocale(locale.LC\_ALL, 'English\_United States.1252')

'English\_United States.1252'

**>>>** conv = locale.localeconv() *# get a mapping of conventions*

**>>>** x = 1234567.8

**>>>** locale.format("*%d*", x, grouping=**True**)

'1,234,567'

**>>>** locale.format\_string("*%s%.\*f*", (conv['currency\_symbol'],

**...**  conv['frac\_digits'], x), grouping=**True**)

'$1,234,567.80'

## 11.2. Templating

The [string](https://docs.python.org/3/library/string.html#module-string) module includes a versatile [Template](https://docs.python.org/3/library/string.html#string.Template) class with a simplified syntax suitable for editing by end-users. This allows users to customize their applications without having to alter the application.

The format uses placeholder names formed by $ with valid Python identifiers (alphanumeric characters and underscores). Surrounding the placeholder with braces allows it to be followed by more alphanumeric letters with no intervening spaces. Writing $$ creates a single escaped $:

>>>

**>>> from** **string** **import** Template

**>>>** t = Template('$*{village}*folk send $$10 to $cause.')

**>>>** t.substitute(village='Nottingham', cause='the ditch fund')

'Nottinghamfolk send $10 to the ditch fund.'

The [substitute()](https://docs.python.org/3/library/string.html#string.Template.substitute) method raises a [KeyError](https://docs.python.org/3/library/exceptions.html#KeyError) when a placeholder is not supplied in a dictionary or a keyword argument. For mail-merge style applications, user supplied data may be incomplete and the[safe\_substitute()](https://docs.python.org/3/library/string.html#string.Template.safe_substitute) method may be more appropriate — it will leave placeholders unchanged if data is missing:

>>>

**>>>** t = Template('Return the $item to $owner.')

**>>>** d = dict(item='unladen swallow')

**>>>** t.substitute(d)

Traceback (most recent call last):

*...*

KeyError: 'owner'

**>>>** t.safe\_substitute(d)

'Return the unladen swallow to $owner.'

Template subclasses can specify a custom delimiter. For example, a batch renaming utility for a photo browser may elect to use percent signs for placeholders such as the current date, image sequence number, or file format:

>>>

**>>> import** **time**, **os.path**

**>>>** photofiles = ['img\_1074.jpg', 'img\_1076.jpg', 'img\_1077.jpg']

**>>> class** **BatchRename**(Template):

**...**  delimiter = '%'

**>>>** fmt = input('Enter rename style (*%d*-date %n-seqnum *%f*-format): ')

Enter rename style (%d-date %n-seqnum %f-format): Ashley\_%n%f

**>>>** t = BatchRename(fmt)

**>>>** date = time.strftime('*%d*%b%y')

**>>> for** i, filename **in** enumerate(photofiles):

**...**  base, ext = os.path.splitext(filename)

**...**  newname = t.substitute(d=date, n=i, f=ext)

**...**  print('*{0}* --> *{1}*'.format(filename, newname))

img\_1074.jpg --> Ashley\_0.jpg

img\_1076.jpg --> Ashley\_1.jpg

img\_1077.jpg --> Ashley\_2.jpg

Another application for templating is separating program logic from the details of multiple output formats. This makes it possible to substitute custom templates for XML files, plain text reports, and HTML web reports.

## 11.3. Working with Binary Data Record Layouts

The [struct](https://docs.python.org/3/library/struct.html#module-struct) module provides [pack()](https://docs.python.org/3/library/struct.html#struct.pack) and [unpack()](https://docs.python.org/3/library/struct.html#struct.unpack) functions for working with variable length binary record formats. The following example shows how to loop through header information in a ZIP file without using the [zipfile](https://docs.python.org/3/library/zipfile.html#module-zipfile) module. Pack codes "H" and "I" represent two and four byte unsigned numbers respectively. The "<" indicates that they are standard size and in little-endian byte order:

**import** **struct**

**with** open('myfile.zip', 'rb') **as** f:

data = f.read()

start = 0

**for** i **in** range(3): *# show the first 3 file headers*

start += 14

fields = struct.unpack('<IIIHH', data[start:start+16])

crc32, comp\_size, uncomp\_size, filenamesize, extra\_size = fields

start += 16

filename = data[start:start+filenamesize]

start += filenamesize

extra = data[start:start+extra\_size]

print(filename, hex(crc32), comp\_size, uncomp\_size)

start += extra\_size + comp\_size *# skip to the next header*

## 11.4. Multi-threading

Threading is a technique for decoupling tasks which are not sequentially dependent. Threads can be used to improve the responsiveness of applications that accept user input while other tasks run in the background. A related use case is running I/O in parallel with computations in another thread.

The following code shows how the high level [threading](https://docs.python.org/3/library/threading.html#module-threading) module can run tasks in background while the main program continues to run:

**import** **threading**, **zipfile**

**class** **AsyncZip**(threading.Thread):

**def** \_\_init\_\_(self, infile, outfile):

threading.Thread.\_\_init\_\_(self)

self.infile = infile

self.outfile = outfile

**def** run(self):

f = zipfile.ZipFile(self.outfile, 'w', zipfile.ZIP\_DEFLATED)

f.write(self.infile)

f.close()

print('Finished background zip of:', self.infile)

background = AsyncZip('mydata.txt', 'myarchive.zip')

background.start()

print('The main program continues to run in foreground.')

background.join() *# Wait for the background task to finish*

print('Main program waited until background was done.')

The principal challenge of multi-threaded applications is coordinating threads that share data or other resources. To that end, the threading module provides a number of synchronization primitives including locks, events, condition variables, and semaphores.

While those tools are powerful, minor design errors can result in problems that are difficult to reproduce. So, the preferred approach to task coordination is to concentrate all access to a resource in a single thread and then use the [queue](https://docs.python.org/3/library/queue.html#module-queue) module to feed that thread with requests from other threads. Applications using [Queue](https://docs.python.org/3/library/queue.html#queue.Queue) objects for inter-thread communication and coordination are easier to design, more readable, and more reliable.

## 11.5. Logging

The [logging](https://docs.python.org/3/library/logging.html#module-logging) module offers a full featured and flexible logging system. At its simplest, log messages are sent to a file or to sys.stderr:

**import** **logging**

logging.debug('Debugging information')

logging.info('Informational message')

logging.warning('Warning:config file *%s* not found', 'server.conf')

logging.error('Error occurred')

logging.critical('Critical error -- shutting down')

This produces the following output:

WARNING:root:Warning:config file server.conf not found

ERROR:root:Error occurred

CRITICAL:root:Critical error -- shutting down

By default, informational and debugging messages are suppressed and the output is sent to standard error. Other output options include routing messages through email, datagrams, sockets, or to an HTTP Server. New filters can select different routing based on message priority: DEBUG, INFO,WARNING, ERROR, and CRITICAL.

The logging system can be configured directly from Python or can be loaded from a user editable configuration file for customized logging without altering the application.

## 11.6. Weak References

Python does automatic memory management (reference counting for most objects and [garbage collection](https://docs.python.org/3/glossary.html#term-garbage-collection) to eliminate cycles). The memory is freed shortly after the last reference to it has been eliminated.

This approach works fine for most applications but occasionally there is a need to track objects only as long as they are being used by something else. Unfortunately, just tracking them creates a reference that makes them permanent. The [weakref](https://docs.python.org/3/library/weakref.html#module-weakref) module provides tools for tracking objects without creating a reference. When the object is no longer needed, it is automatically removed from a weakref table and a callback is triggered for weakref objects. Typical applications include caching objects that are expensive to create:

>>>

**>>> import** **weakref**, **gc**

**>>> class** **A**:

**...**  **def** \_\_init\_\_(self, value):

**...**  self.value = value

**...**  **def** \_\_repr\_\_(self):

**...**  **return** str(self.value)

**...**

**>>>** a = A(10) *# create a reference*

**>>>** d = weakref.WeakValueDictionary()

**>>>** d['primary'] = a *# does not create a reference*

**>>>** d['primary'] *# fetch the object if it is still alive*

10

**>>> del** a *# remove the one reference*

**>>>** gc.collect() *# run garbage collection right away*

0

**>>>** d['primary'] *# entry was automatically removed*

Traceback (most recent call last):

File "<stdin>", line 1, in <module>

d['primary'] *# entry was automatically removed*

File "C:/python35/lib/weakref.py", line 46, in \_\_getitem\_\_

o = self.data[key]()

KeyError: 'primary'

## 11.7. Tools for Working with Lists

Many data structure needs can be met with the built-in list type. However, sometimes there is a need for alternative implementations with different performance trade-offs.

The [array](https://docs.python.org/3/library/array.html#module-array) module provides an [array()](https://docs.python.org/3/library/array.html#array.array) object that is like a list that stores only homogeneous data and stores it more compactly. The following example shows an array of numbers stored as two byte unsigned binary numbers (typecode "H") rather than the usual 16 bytes per entry for regular lists of Python int objects:

>>>

**>>> from** **array** **import** array

**>>>** a = array('H', [4000, 10, 700, 22222])

**>>>** sum(a)

26932

**>>>** a[1:3]

array('H', [10, 700])

The [collections](https://docs.python.org/3/library/collections.html#module-collections) module provides a [deque()](https://docs.python.org/3/library/collections.html#collections.deque) object that is like a list with faster appends and pops from the left side but slower lookups in the middle. These objects are well suited for implementing queues and breadth first tree searches:

>>>

**>>> from** **collections** **import** deque

**>>>** d = deque(["task1", "task2", "task3"])

**>>>** d.append("task4")

**>>>** print("Handling", d.popleft())

Handling task1

unsearched = deque([starting\_node])

**def** breadth\_first\_search(unsearched):

node = unsearched.popleft()

**for** m **in** gen\_moves(node):

**if** is\_goal(m):

**return** m

unsearched.append(m)

In addition to alternative list implementations, the library also offers other tools such as the [bisect](https://docs.python.org/3/library/bisect.html#module-bisect)module with functions for manipulating sorted lists:

>>>

**>>> import** **bisect**

**>>>** scores = [(100, 'perl'), (200, 'tcl'), (400, 'lua'), (500, 'python')]

**>>>** bisect.insort(scores, (300, 'ruby'))

**>>>** scores

[(100, 'perl'), (200, 'tcl'), (300, 'ruby'), (400, 'lua'), (500, 'python')]

The [heapq](https://docs.python.org/3/library/heapq.html#module-heapq) module provides functions for implementing heaps based on regular lists. The lowest valued entry is always kept at position zero. This is useful for applications which repeatedly access the smallest element but do not want to run a full list sort:

>>>

**>>> from** **heapq** **import** heapify, heappop, heappush

**>>>** data = [1, 3, 5, 7, 9, 2, 4, 6, 8, 0]

**>>>** heapify(data) *# rearrange the list into heap order*

**>>>** heappush(data, -5) *# add a new entry*

**>>>** [heappop(data) **for** i **in** range(3)] *# fetch the three smallest entries*

[-5, 0, 1]

## 11.8. Decimal Floating Point Arithmetic

The [decimal](https://docs.python.org/3/library/decimal.html#module-decimal) module offers a [Decimal](https://docs.python.org/3/library/decimal.html#decimal.Decimal) datatype for decimal floating point arithmetic. Compared to the built-in [float](https://docs.python.org/3/library/functions.html#float) implementation of binary floating point, the class is especially helpful for

* financial applications and other uses which require exact decimal representation,
* control over precision,
* control over rounding to meet legal or regulatory requirements,
* tracking of significant decimal places, or
* applications where the user expects the results to match calculations done by hand.

For example, calculating a 5% tax on a 70 cent phone charge gives different results in decimal floating point and binary floating point. The difference becomes significant if the results are rounded to the nearest cent:

>>>

**>>> from** **decimal** **import** \*

**>>>** round(Decimal('0.70') \* Decimal('1.05'), 2)

Decimal('0.74')

**>>>** round(.70 \* 1.05, 2)

0.73

The [Decimal](https://docs.python.org/3/library/decimal.html#decimal.Decimal) result keeps a trailing zero, automatically inferring four place significance from multiplicands with two place significance. Decimal reproduces mathematics as done by hand and avoids issues that can arise when binary floating point cannot exactly represent decimal quantities.

Exact representation enables the [Decimal](https://docs.python.org/3/library/decimal.html#decimal.Decimal) class to perform modulo calculations and equality tests that are unsuitable for binary floating point:

>>>

**>>>** Decimal('1.00') % Decimal('.10')

Decimal('0.00')

**>>>** 1.00 % 0.10

0.09999999999999995

**>>>** sum([Decimal('0.1')]\*10) == Decimal('1.0')

True

**>>>** sum([0.1]\*10) == 1.0

False

The [decimal](https://docs.python.org/3/library/decimal.html#module-decimal) module provides arithmetic with as much precision as needed:

>>>

**>>>** getcontext().prec = 36

**>>>** Decimal(1) / Decimal(7)

Decimal('0.142857142857142857142857142857142857')

# 11. Brief Tour of the Standard Library – Part II

This second tour covers more advanced modules that support professional programming needs. These modules rarely occur in small scripts.

## 11.1. Output Formatting

The [reprlib](https://docs.python.org/3/library/reprlib.html#module-reprlib) module provides a version of [repr()](https://docs.python.org/3/library/functions.html#repr) customized for abbreviated displays of large or deeply nested containers:

>>>

**>>> import** **reprlib**

**>>>** reprlib.repr(set('supercalifragilisticexpialidocious'))

"{'a', 'c', 'd', 'e', 'f', 'g', ...}"

The [pprint](https://docs.python.org/3/library/pprint.html#module-pprint) module offers more sophisticated control over printing both built-in and user defined objects in a way that is readable by the interpreter. When the result is longer than one line, the “pretty printer” adds line breaks and indentation to more clearly reveal data structure:

>>>

**>>> import** **pprint**

**>>>** t = [[[['black', 'cyan'], 'white', ['green', 'red']], [['magenta',

**...**  'yellow'], 'blue']]]

**...**

**>>>** pprint.pprint(t, width=30)

[[[['black', 'cyan'],

'white',

['green', 'red']],

[['magenta', 'yellow'],

'blue']]]

The [textwrap](https://docs.python.org/3/library/textwrap.html#module-textwrap) module formats paragraphs of text to fit a given screen width:

>>>

**>>> import** **textwrap**

**>>>** doc = """The wrap() method is just like fill() except that it returns

**...** a list of strings instead of one big string with newlines to separate

**...** the wrapped lines."""

**...**

**>>>** print(textwrap.fill(doc, width=40))

The wrap() method is just like fill()

except that it returns a list of strings

instead of one big string with newlines

to separate the wrapped lines.

The [locale](https://docs.python.org/3/library/locale.html#module-locale) module accesses a database of culture specific data formats. The grouping attribute of locale’s format function provides a direct way of formatting numbers with group separators:

>>>

**>>> import** **locale**

**>>>** locale.setlocale(locale.LC\_ALL, 'English\_United States.1252')

'English\_United States.1252'

**>>>** conv = locale.localeconv() *# get a mapping of conventions*

**>>>** x = 1234567.8

**>>>** locale.format("*%d*", x, grouping=**True**)

'1,234,567'

**>>>** locale.format\_string("*%s%.\*f*", (conv['currency\_symbol'],

**...**  conv['frac\_digits'], x), grouping=**True**)

'$1,234,567.80'

## 11.2. Templating

The [string](https://docs.python.org/3/library/string.html#module-string) module includes a versatile [Template](https://docs.python.org/3/library/string.html#string.Template) class with a simplified syntax suitable for editing by end-users. This allows users to customize their applications without having to alter the application.

The format uses placeholder names formed by $ with valid Python identifiers (alphanumeric characters and underscores). Surrounding the placeholder with braces allows it to be followed by more alphanumeric letters with no intervening spaces. Writing $$ creates a single escaped $:

>>>

**>>> from** **string** **import** Template

**>>>** t = Template('$*{village}*folk send $$10 to $cause.')

**>>>** t.substitute(village='Nottingham', cause='the ditch fund')

'Nottinghamfolk send $10 to the ditch fund.'

The [substitute()](https://docs.python.org/3/library/string.html#string.Template.substitute) method raises a [KeyError](https://docs.python.org/3/library/exceptions.html#KeyError) when a placeholder is not supplied in a dictionary or a keyword argument. For mail-merge style applications, user supplied data may be incomplete and the[safe\_substitute()](https://docs.python.org/3/library/string.html#string.Template.safe_substitute) method may be more appropriate — it will leave placeholders unchanged if data is missing:

>>>

**>>>** t = Template('Return the $item to $owner.')

**>>>** d = dict(item='unladen swallow')

**>>>** t.substitute(d)

Traceback (most recent call last):

*...*

KeyError: 'owner'

**>>>** t.safe\_substitute(d)

'Return the unladen swallow to $owner.'

Template subclasses can specify a custom delimiter. For example, a batch renaming utility for a photo browser may elect to use percent signs for placeholders such as the current date, image sequence number, or file format:

>>>

**>>> import** **time**, **os.path**

**>>>** photofiles = ['img\_1074.jpg', 'img\_1076.jpg', 'img\_1077.jpg']

**>>> class** **BatchRename**(Template):

**...**  delimiter = '%'

**>>>** fmt = input('Enter rename style (*%d*-date %n-seqnum *%f*-format): ')

Enter rename style (%d-date %n-seqnum %f-format): Ashley\_%n%f

**>>>** t = BatchRename(fmt)

**>>>** date = time.strftime('*%d*%b%y')

**>>> for** i, filename **in** enumerate(photofiles):

**...**  base, ext = os.path.splitext(filename)

**...**  newname = t.substitute(d=date, n=i, f=ext)

**...**  print('*{0}* --> *{1}*'.format(filename, newname))

img\_1074.jpg --> Ashley\_0.jpg

img\_1076.jpg --> Ashley\_1.jpg

img\_1077.jpg --> Ashley\_2.jpg

Another application for templating is separating program logic from the details of multiple output formats. This makes it possible to substitute custom templates for XML files, plain text reports, and HTML web reports.

## 11.3. Working with Binary Data Record Layouts

The [struct](https://docs.python.org/3/library/struct.html#module-struct) module provides [pack()](https://docs.python.org/3/library/struct.html#struct.pack) and [unpack()](https://docs.python.org/3/library/struct.html#struct.unpack) functions for working with variable length binary record formats. The following example shows how to loop through header information in a ZIP file without using the [zipfile](https://docs.python.org/3/library/zipfile.html#module-zipfile) module. Pack codes "H" and "I" represent two and four byte unsigned numbers respectively. The "<" indicates that they are standard size and in little-endian byte order:

**import** **struct**

**with** open('myfile.zip', 'rb') **as** f:

data = f.read()

start = 0

**for** i **in** range(3): *# show the first 3 file headers*

start += 14

fields = struct.unpack('<IIIHH', data[start:start+16])

crc32, comp\_size, uncomp\_size, filenamesize, extra\_size = fields

start += 16

filename = data[start:start+filenamesize]

start += filenamesize

extra = data[start:start+extra\_size]

print(filename, hex(crc32), comp\_size, uncomp\_size)

start += extra\_size + comp\_size *# skip to the next header*

## 11.4. Multi-threading

Threading is a technique for decoupling tasks which are not sequentially dependent. Threads can be used to improve the responsiveness of applications that accept user input while other tasks run in the background. A related use case is running I/O in parallel with computations in another thread.

The following code shows how the high level [threading](https://docs.python.org/3/library/threading.html#module-threading) module can run tasks in background while the main program continues to run:

**import** **threading**, **zipfile**

**class** **AsyncZip**(threading.Thread):

**def** \_\_init\_\_(self, infile, outfile):

threading.Thread.\_\_init\_\_(self)

self.infile = infile

self.outfile = outfile

**def** run(self):

f = zipfile.ZipFile(self.outfile, 'w', zipfile.ZIP\_DEFLATED)

f.write(self.infile)

f.close()

print('Finished background zip of:', self.infile)

background = AsyncZip('mydata.txt', 'myarchive.zip')

background.start()

print('The main program continues to run in foreground.')

background.join() *# Wait for the background task to finish*

print('Main program waited until background was done.')

The principal challenge of multi-threaded applications is coordinating threads that share data or other resources. To that end, the threading module provides a number of synchronization primitives including locks, events, condition variables, and semaphores.

While those tools are powerful, minor design errors can result in problems that are difficult to reproduce. So, the preferred approach to task coordination is to concentrate all access to a resource in a single thread and then use the [queue](https://docs.python.org/3/library/queue.html#module-queue) module to feed that thread with requests from other threads. Applications using [Queue](https://docs.python.org/3/library/queue.html#queue.Queue) objects for inter-thread communication and coordination are easier to design, more readable, and more reliable.

## 11.5. Logging

The [logging](https://docs.python.org/3/library/logging.html#module-logging) module offers a full featured and flexible logging system. At its simplest, log messages are sent to a file or to sys.stderr:

**import** **logging**

logging.debug('Debugging information')

logging.info('Informational message')

logging.warning('Warning:config file *%s* not found', 'server.conf')

logging.error('Error occurred')

logging.critical('Critical error -- shutting down')

This produces the following output:

WARNING:root:Warning:config file server.conf not found

ERROR:root:Error occurred

CRITICAL:root:Critical error -- shutting down

By default, informational and debugging messages are suppressed and the output is sent to standard error. Other output options include routing messages through email, datagrams, sockets, or to an HTTP Server. New filters can select different routing based on message priority: DEBUG, INFO,WARNING, ERROR, and CRITICAL.

The logging system can be configured directly from Python or can be loaded from a user editable configuration file for customized logging without altering the application.

## 11.6. Weak References

Python does automatic memory management (reference counting for most objects and [garbage collection](https://docs.python.org/3/glossary.html#term-garbage-collection) to eliminate cycles). The memory is freed shortly after the last reference to it has been eliminated.

This approach works fine for most applications but occasionally there is a need to track objects only as long as they are being used by something else. Unfortunately, just tracking them creates a reference that makes them permanent. The [weakref](https://docs.python.org/3/library/weakref.html#module-weakref) module provides tools for tracking objects without creating a reference. When the object is no longer needed, it is automatically removed from a weakref table and a callback is triggered for weakref objects. Typical applications include caching objects that are expensive to create:

>>>

**>>> import** **weakref**, **gc**

**>>> class** **A**:

**...**  **def** \_\_init\_\_(self, value):

**...**  self.value = value

**...**  **def** \_\_repr\_\_(self):

**...**  **return** str(self.value)

**...**

**>>>** a = A(10) *# create a reference*

**>>>** d = weakref.WeakValueDictionary()

**>>>** d['primary'] = a *# does not create a reference*

**>>>** d['primary'] *# fetch the object if it is still alive*

10

**>>> del** a *# remove the one reference*

**>>>** gc.collect() *# run garbage collection right away*

0

**>>>** d['primary'] *# entry was automatically removed*

Traceback (most recent call last):

File "<stdin>", line 1, in <module>

d['primary'] *# entry was automatically removed*

File "C:/python35/lib/weakref.py", line 46, in \_\_getitem\_\_

o = self.data[key]()

KeyError: 'primary'

## 11.7. Tools for Working with Lists

Many data structure needs can be met with the built-in list type. However, sometimes there is a need for alternative implementations with different performance trade-offs.

The [array](https://docs.python.org/3/library/array.html#module-array) module provides an [array()](https://docs.python.org/3/library/array.html#array.array) object that is like a list that stores only homogeneous data and stores it more compactly. The following example shows an array of numbers stored as two byte unsigned binary numbers (typecode "H") rather than the usual 16 bytes per entry for regular lists of Python int objects:

>>>

**>>> from** **array** **import** array

**>>>** a = array('H', [4000, 10, 700, 22222])

**>>>** sum(a)

26932

**>>>** a[1:3]

array('H', [10, 700])

The [collections](https://docs.python.org/3/library/collections.html#module-collections) module provides a [deque()](https://docs.python.org/3/library/collections.html#collections.deque) object that is like a list with faster appends and pops from the left side but slower lookups in the middle. These objects are well suited for implementing queues and breadth first tree searches:

>>>

**>>> from** **collections** **import** deque

**>>>** d = deque(["task1", "task2", "task3"])

**>>>** d.append("task4")

**>>>** print("Handling", d.popleft())

Handling task1

unsearched = deque([starting\_node])

**def** breadth\_first\_search(unsearched):

node = unsearched.popleft()

**for** m **in** gen\_moves(node):

**if** is\_goal(m):

**return** m

unsearched.append(m)

In addition to alternative list implementations, the library also offers other tools such as the [bisect](https://docs.python.org/3/library/bisect.html#module-bisect)module with functions for manipulating sorted lists:

>>>

**>>> import** **bisect**

**>>>** scores = [(100, 'perl'), (200, 'tcl'), (400, 'lua'), (500, 'python')]

**>>>** bisect.insort(scores, (300, 'ruby'))

**>>>** scores

[(100, 'perl'), (200, 'tcl'), (300, 'ruby'), (400, 'lua'), (500, 'python')]

The [heapq](https://docs.python.org/3/library/heapq.html#module-heapq) module provides functions for implementing heaps based on regular lists. The lowest valued entry is always kept at position zero. This is useful for applications which repeatedly access the smallest element but do not want to run a full list sort:

>>>

**>>> from** **heapq** **import** heapify, heappop, heappush

**>>>** data = [1, 3, 5, 7, 9, 2, 4, 6, 8, 0]

**>>>** heapify(data) *# rearrange the list into heap order*

**>>>** heappush(data, -5) *# add a new entry*

**>>>** [heappop(data) **for** i **in** range(3)] *# fetch the three smallest entries*

[-5, 0, 1]

## 11.8. Decimal Floating Point Arithmetic

The [decimal](https://docs.python.org/3/library/decimal.html#module-decimal) module offers a [Decimal](https://docs.python.org/3/library/decimal.html#decimal.Decimal) datatype for decimal floating point arithmetic. Compared to the built-in [float](https://docs.python.org/3/library/functions.html#float) implementation of binary floating point, the class is especially helpful for

* financial applications and other uses which require exact decimal representation,
* control over precision,
* control over rounding to meet legal or regulatory requirements,
* tracking of significant decimal places, or
* applications where the user expects the results to match calculations done by hand.

For example, calculating a 5% tax on a 70 cent phone charge gives different results in decimal floating point and binary floating point. The difference becomes significant if the results are rounded to the nearest cent:

>>>

**>>> from** **decimal** **import** \*

**>>>** round(Decimal('0.70') \* Decimal('1.05'), 2)

Decimal('0.74')

**>>>** round(.70 \* 1.05, 2)

0.73

The [Decimal](https://docs.python.org/3/library/decimal.html#decimal.Decimal) result keeps a trailing zero, automatically inferring four place significance from multiplicands with two place significance. Decimal reproduces mathematics as done by hand and avoids issues that can arise when binary floating point cannot exactly represent decimal quantities.

Exact representation enables the [Decimal](https://docs.python.org/3/library/decimal.html#decimal.Decimal) class to perform modulo calculations and equality tests that are unsuitable for binary floating point:

>>>

**>>>** Decimal('1.00') % Decimal('.10')

Decimal('0.00')

**>>>** 1.00 % 0.10

0.09999999999999995

**>>>** sum([Decimal('0.1')]\*10) == Decimal('1.0')

True

**>>>** sum([0.1]\*10) == 1.0

False

The [decimal](https://docs.python.org/3/library/decimal.html#module-decimal) module provides arithmetic with as much precision as needed:

>>>

**>>>** getcontext().prec = 36

**>>>** Decimal(1) / Decimal(7)

Decimal('0.142857142857142857142857142857142857')

# 11. Brief Tour of the Standard Library – Part II

This second tour covers more advanced modules that support professional programming needs. These modules rarely occur in small scripts.

## 11.1. Output Formatting

The [reprlib](https://docs.python.org/3/library/reprlib.html#module-reprlib) module provides a version of [repr()](https://docs.python.org/3/library/functions.html#repr) customized for abbreviated displays of large or deeply nested containers:

>>>

**>>> import** **reprlib**

**>>>** reprlib.repr(set('supercalifragilisticexpialidocious'))

"{'a', 'c', 'd', 'e', 'f', 'g', ...}"

The [pprint](https://docs.python.org/3/library/pprint.html#module-pprint) module offers more sophisticated control over printing both built-in and user defined objects in a way that is readable by the interpreter. When the result is longer than one line, the “pretty printer” adds line breaks and indentation to more clearly reveal data structure:

>>>

**>>> import** **pprint**

**>>>** t = [[[['black', 'cyan'], 'white', ['green', 'red']], [['magenta',

**...**  'yellow'], 'blue']]]

**...**

**>>>** pprint.pprint(t, width=30)

[[[['black', 'cyan'],

'white',

['green', 'red']],

[['magenta', 'yellow'],

'blue']]]

The [textwrap](https://docs.python.org/3/library/textwrap.html#module-textwrap) module formats paragraphs of text to fit a given screen width:

>>>

**>>> import** **textwrap**

**>>>** doc = """The wrap() method is just like fill() except that it returns

**...** a list of strings instead of one big string with newlines to separate

**...** the wrapped lines."""

**...**

**>>>** print(textwrap.fill(doc, width=40))

The wrap() method is just like fill()

except that it returns a list of strings

instead of one big string with newlines

to separate the wrapped lines.

The [locale](https://docs.python.org/3/library/locale.html#module-locale) module accesses a database of culture specific data formats. The grouping attribute of locale’s format function provides a direct way of formatting numbers with group separators:

>>>

**>>> import** **locale**

**>>>** locale.setlocale(locale.LC\_ALL, 'English\_United States.1252')

'English\_United States.1252'

**>>>** conv = locale.localeconv() *# get a mapping of conventions*

**>>>** x = 1234567.8

**>>>** locale.format("*%d*", x, grouping=**True**)

'1,234,567'

**>>>** locale.format\_string("*%s%.\*f*", (conv['currency\_symbol'],

**...**  conv['frac\_digits'], x), grouping=**True**)

'$1,234,567.80'

## 11.2. Templating

The [string](https://docs.python.org/3/library/string.html#module-string) module includes a versatile [Template](https://docs.python.org/3/library/string.html#string.Template) class with a simplified syntax suitable for editing by end-users. This allows users to customize their applications without having to alter the application.

The format uses placeholder names formed by $ with valid Python identifiers (alphanumeric characters and underscores). Surrounding the placeholder with braces allows it to be followed by more alphanumeric letters with no intervening spaces. Writing $$ creates a single escaped $:

>>>

**>>> from** **string** **import** Template

**>>>** t = Template('$*{village}*folk send $$10 to $cause.')

**>>>** t.substitute(village='Nottingham', cause='the ditch fund')

'Nottinghamfolk send $10 to the ditch fund.'

The [substitute()](https://docs.python.org/3/library/string.html#string.Template.substitute) method raises a [KeyError](https://docs.python.org/3/library/exceptions.html#KeyError) when a placeholder is not supplied in a dictionary or a keyword argument. For mail-merge style applications, user supplied data may be incomplete and the[safe\_substitute()](https://docs.python.org/3/library/string.html#string.Template.safe_substitute) method may be more appropriate — it will leave placeholders unchanged if data is missing:

>>>

**>>>** t = Template('Return the $item to $owner.')

**>>>** d = dict(item='unladen swallow')

**>>>** t.substitute(d)

Traceback (most recent call last):

*...*

KeyError: 'owner'

**>>>** t.safe\_substitute(d)

'Return the unladen swallow to $owner.'

Template subclasses can specify a custom delimiter. For example, a batch renaming utility for a photo browser may elect to use percent signs for placeholders such as the current date, image sequence number, or file format:

>>>

**>>> import** **time**, **os.path**

**>>>** photofiles = ['img\_1074.jpg', 'img\_1076.jpg', 'img\_1077.jpg']

**>>> class** **BatchRename**(Template):

**...**  delimiter = '%'

**>>>** fmt = input('Enter rename style (*%d*-date %n-seqnum *%f*-format): ')

Enter rename style (%d-date %n-seqnum %f-format): Ashley\_%n%f

**>>>** t = BatchRename(fmt)

**>>>** date = time.strftime('*%d*%b%y')

**>>> for** i, filename **in** enumerate(photofiles):

**...**  base, ext = os.path.splitext(filename)

**...**  newname = t.substitute(d=date, n=i, f=ext)

**...**  print('*{0}* --> *{1}*'.format(filename, newname))

img\_1074.jpg --> Ashley\_0.jpg

img\_1076.jpg --> Ashley\_1.jpg

img\_1077.jpg --> Ashley\_2.jpg

Another application for templating is separating program logic from the details of multiple output formats. This makes it possible to substitute custom templates for XML files, plain text reports, and HTML web reports.

## 11.3. Working with Binary Data Record Layouts

The [struct](https://docs.python.org/3/library/struct.html#module-struct) module provides [pack()](https://docs.python.org/3/library/struct.html#struct.pack) and [unpack()](https://docs.python.org/3/library/struct.html#struct.unpack) functions for working with variable length binary record formats. The following example shows how to loop through header information in a ZIP file without using the [zipfile](https://docs.python.org/3/library/zipfile.html#module-zipfile) module. Pack codes "H" and "I" represent two and four byte unsigned numbers respectively. The "<" indicates that they are standard size and in little-endian byte order:

**import** **struct**

**with** open('myfile.zip', 'rb') **as** f:

data = f.read()

start = 0

**for** i **in** range(3): *# show the first 3 file headers*

start += 14

fields = struct.unpack('<IIIHH', data[start:start+16])

crc32, comp\_size, uncomp\_size, filenamesize, extra\_size = fields

start += 16

filename = data[start:start+filenamesize]

start += filenamesize

extra = data[start:start+extra\_size]

print(filename, hex(crc32), comp\_size, uncomp\_size)

start += extra\_size + comp\_size *# skip to the next header*

## 11.4. Multi-threading

Threading is a technique for decoupling tasks which are not sequentially dependent. Threads can be used to improve the responsiveness of applications that accept user input while other tasks run in the background. A related use case is running I/O in parallel with computations in another thread.

The following code shows how the high level [threading](https://docs.python.org/3/library/threading.html#module-threading) module can run tasks in background while the main program continues to run:

**import** **threading**, **zipfile**

**class** **AsyncZip**(threading.Thread):

**def** \_\_init\_\_(self, infile, outfile):

threading.Thread.\_\_init\_\_(self)

self.infile = infile

self.outfile = outfile

**def** run(self):

f = zipfile.ZipFile(self.outfile, 'w', zipfile.ZIP\_DEFLATED)

f.write(self.infile)

f.close()

print('Finished background zip of:', self.infile)

background = AsyncZip('mydata.txt', 'myarchive.zip')

background.start()

print('The main program continues to run in foreground.')

background.join() *# Wait for the background task to finish*

print('Main program waited until background was done.')

The principal challenge of multi-threaded applications is coordinating threads that share data or other resources. To that end, the threading module provides a number of synchronization primitives including locks, events, condition variables, and semaphores.

While those tools are powerful, minor design errors can result in problems that are difficult to reproduce. So, the preferred approach to task coordination is to concentrate all access to a resource in a single thread and then use the [queue](https://docs.python.org/3/library/queue.html#module-queue) module to feed that thread with requests from other threads. Applications using [Queue](https://docs.python.org/3/library/queue.html#queue.Queue) objects for inter-thread communication and coordination are easier to design, more readable, and more reliable.

## 11.5. Logging

The [logging](https://docs.python.org/3/library/logging.html#module-logging) module offers a full featured and flexible logging system. At its simplest, log messages are sent to a file or to sys.stderr:

**import** **logging**

logging.debug('Debugging information')

logging.info('Informational message')

logging.warning('Warning:config file *%s* not found', 'server.conf')

logging.error('Error occurred')

logging.critical('Critical error -- shutting down')

This produces the following output:

WARNING:root:Warning:config file server.conf not found

ERROR:root:Error occurred

CRITICAL:root:Critical error -- shutting down

By default, informational and debugging messages are suppressed and the output is sent to standard error. Other output options include routing messages through email, datagrams, sockets, or to an HTTP Server. New filters can select different routing based on message priority: DEBUG, INFO,WARNING, ERROR, and CRITICAL.

The logging system can be configured directly from Python or can be loaded from a user editable configuration file for customized logging without altering the application.

## 11.6. Weak References

Python does automatic memory management (reference counting for most objects and [garbage collection](https://docs.python.org/3/glossary.html#term-garbage-collection) to eliminate cycles). The memory is freed shortly after the last reference to it has been eliminated.

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>>>

**>>> import** **weakref**, **gc**

**>>> class** **A**:

**...**  **def** \_\_init\_\_(self, value):

**...**  self.value = value

**...**  **def** \_\_repr\_\_(self):

**...**  **return** str(self.value)

**...**

**>>>** a = A(10) *# create a reference*

**>>>** d = weakref.WeakValueDictionary()

**>>>** d['primary'] = a *# does not create a reference*

**>>>** d['primary'] *# fetch the object if it is still alive*

10

**>>> del** a *# remove the one reference*

**>>>** gc.collect() *# run garbage collection right away*

0

**>>>** d['primary'] *# entry was automatically removed*

Traceback (most recent call last):

File "<stdin>", line 1, in <module>

d['primary'] *# entry was automatically removed*

File "C:/python35/lib/weakref.py", line 46, in \_\_getitem\_\_

o = self.data[key]()

KeyError: 'primary'

## 11.7. Tools for Working with Lists

Many data structure needs can be met with the built-in list type. However, sometimes there is a need for alternative implementations with different performance trade-offs.

The [array](https://docs.python.org/3/library/array.html#module-array) module provides an [array()](https://docs.python.org/3/library/array.html#array.array) object that is like a list that stores only homogeneous data and stores it more compactly. The following example shows an array of numbers stored as two byte unsigned binary numbers (typecode "H") rather than the usual 16 bytes per entry for regular lists of Python int objects:

>>>

**>>> from** **array** **import** array

**>>>** a = array('H', [4000, 10, 700, 22222])

**>>>** sum(a)

26932

**>>>** a[1:3]

array('H', [10, 700])

The [collections](https://docs.python.org/3/library/collections.html#module-collections) module provides a [deque()](https://docs.python.org/3/library/collections.html#collections.deque) object that is like a list with faster appends and pops from the left side but slower lookups in the middle. These objects are well suited for implementing queues and breadth first tree searches:

>>>

**>>> from** **collections** **import** deque

**>>>** d = deque(["task1", "task2", "task3"])

**>>>** d.append("task4")

**>>>** print("Handling", d.popleft())

Handling task1

unsearched = deque([starting\_node])

**def** breadth\_first\_search(unsearched):

node = unsearched.popleft()

**for** m **in** gen\_moves(node):

**if** is\_goal(m):

**return** m

unsearched.append(m)

In addition to alternative list implementations, the library also offers other tools such as the [bisect](https://docs.python.org/3/library/bisect.html#module-bisect)module with functions for manipulating sorted lists:

>>>

**>>> import** **bisect**

**>>>** scores = [(100, 'perl'), (200, 'tcl'), (400, 'lua'), (500, 'python')]

**>>>** bisect.insort(scores, (300, 'ruby'))

**>>>** scores

[(100, 'perl'), (200, 'tcl'), (300, 'ruby'), (400, 'lua'), (500, 'python')]

The [heapq](https://docs.python.org/3/library/heapq.html#module-heapq) module provides functions for implementing heaps based on regular lists. The lowest valued entry is always kept at position zero. This is useful for applications which repeatedly access the smallest element but do not want to run a full list sort:

>>>

**>>> from** **heapq** **import** heapify, heappop, heappush

**>>>** data = [1, 3, 5, 7, 9, 2, 4, 6, 8, 0]

**>>>** heapify(data) *# rearrange the list into heap order*

**>>>** heappush(data, -5) *# add a new entry*

**>>>** [heappop(data) **for** i **in** range(3)] *# fetch the three smallest entries*

[-5, 0, 1]

## 11.8. Decimal Floating Point Arithmetic

The [decimal](https://docs.python.org/3/library/decimal.html#module-decimal) module offers a [Decimal](https://docs.python.org/3/library/decimal.html#decimal.Decimal) datatype for decimal floating point arithmetic. Compared to the built-in [float](https://docs.python.org/3/library/functions.html#float) implementation of binary floating point, the class is especially helpful for

* financial applications and other uses which require exact decimal representation,
* control over precision,
* control over rounding to meet legal or regulatory requirements,
* tracking of significant decimal places, or
* applications where the user expects the results to match calculations done by hand.

For example, calculating a 5% tax on a 70 cent phone charge gives different results in decimal floating point and binary floating point. The difference becomes significant if the results are rounded to the nearest cent:

>>>

**>>> from** **decimal** **import** \*

**>>>** round(Decimal('0.70') \* Decimal('1.05'), 2)

Decimal('0.74')

**>>>** round(.70 \* 1.05, 2)

0.73

The [Decimal](https://docs.python.org/3/library/decimal.html#decimal.Decimal) result keeps a trailing zero, automatically inferring four place significance from multiplicands with two place significance. Decimal reproduces mathematics as done by hand and avoids issues that can arise when binary floating point cannot exactly represent decimal quantities.

Exact representation enables the [Decimal](https://docs.python.org/3/library/decimal.html#decimal.Decimal) class to perform modulo calculations and equality tests that are unsuitable for binary floating point:

>>>

**>>>** Decimal('1.00') % Decimal('.10')

Decimal('0.00')

**>>>** 1.00 % 0.10

0.09999999999999995

**>>>** sum([Decimal('0.1')]\*10) == Decimal('1.0')

True

**>>>** sum([0.1]\*10) == 1.0

False

The [decimal](https://docs.python.org/3/library/decimal.html#module-decimal) module provides arithmetic with as much precision as needed:

>>>

**>>>** getcontext().prec = 36

**>>>** Decimal(1) / Decimal(7)

Decimal('0.142857142857142857142857142857142857')

# 11. Brief Tour of the Standard Library – Part II

This second tour covers more advanced modules that support professional programming needs. These modules rarely occur in small scripts.

## 11.1. Output Formatting

The [reprlib](https://docs.python.org/3/library/reprlib.html#module-reprlib) module provides a version of [repr()](https://docs.python.org/3/library/functions.html#repr) customized for abbreviated displays of large or deeply nested containers:

>>>

**>>> import** **reprlib**

**>>>** reprlib.repr(set('supercalifragilisticexpialidocious'))

"{'a', 'c', 'd', 'e', 'f', 'g', ...}"

The [pprint](https://docs.python.org/3/library/pprint.html#module-pprint) module offers more sophisticated control over printing both built-in and user defined objects in a way that is readable by the interpreter. When the result is longer than one line, the “pretty printer” adds line breaks and indentation to more clearly reveal data structure:

>>>

**>>> import** **pprint**

**>>>** t = [[[['black', 'cyan'], 'white', ['green', 'red']], [['magenta',

**...**  'yellow'], 'blue']]]

**...**

**>>>** pprint.pprint(t, width=30)

[[[['black', 'cyan'],

'white',

['green', 'red']],

[['magenta', 'yellow'],

'blue']]]

The [textwrap](https://docs.python.org/3/library/textwrap.html#module-textwrap) module formats paragraphs of text to fit a given screen width:

>>>

**>>> import** **textwrap**

**>>>** doc = """The wrap() method is just like fill() except that it returns

**...** a list of strings instead of one big string with newlines to separate

**...** the wrapped lines."""

**...**

**>>>** print(textwrap.fill(doc, width=40))

The wrap() method is just like fill()

except that it returns a list of strings

instead of one big string with newlines

to separate the wrapped lines.

The [locale](https://docs.python.org/3/library/locale.html#module-locale) module accesses a database of culture specific data formats. The grouping attribute of locale’s format function provides a direct way of formatting numbers with group separators:

>>>

**>>> import** **locale**

**>>>** locale.setlocale(locale.LC\_ALL, 'English\_United States.1252')

'English\_United States.1252'

**>>>** conv = locale.localeconv() *# get a mapping of conventions*

**>>>** x = 1234567.8

**>>>** locale.format("*%d*", x, grouping=**True**)

'1,234,567'

**>>>** locale.format\_string("*%s%.\*f*", (conv['currency\_symbol'],

**...**  conv['frac\_digits'], x), grouping=**True**)

'$1,234,567.80'

## 11.2. Templating

The [string](https://docs.python.org/3/library/string.html#module-string) module includes a versatile [Template](https://docs.python.org/3/library/string.html#string.Template) class with a simplified syntax suitable for editing by end-users. This allows users to customize their applications without having to alter the application.

The format uses placeholder names formed by $ with valid Python identifiers (alphanumeric characters and underscores). Surrounding the placeholder with braces allows it to be followed by more alphanumeric letters with no intervening spaces. Writing $$ creates a single escaped $:

>>>

**>>> from** **string** **import** Template

**>>>** t = Template('$*{village}*folk send $$10 to $cause.')

**>>>** t.substitute(village='Nottingham', cause='the ditch fund')

'Nottinghamfolk send $10 to the ditch fund.'

The [substitute()](https://docs.python.org/3/library/string.html#string.Template.substitute) method raises a [KeyError](https://docs.python.org/3/library/exceptions.html#KeyError) when a placeholder is not supplied in a dictionary or a keyword argument. For mail-merge style applications, user supplied data may be incomplete and the[safe\_substitute()](https://docs.python.org/3/library/string.html#string.Template.safe_substitute) method may be more appropriate — it will leave placeholders unchanged if data is missing:

>>>

**>>>** t = Template('Return the $item to $owner.')

**>>>** d = dict(item='unladen swallow')

**>>>** t.substitute(d)

Traceback (most recent call last):

*...*

KeyError: 'owner'

**>>>** t.safe\_substitute(d)

'Return the unladen swallow to $owner.'

Template subclasses can specify a custom delimiter. For example, a batch renaming utility for a photo browser may elect to use percent signs for placeholders such as the current date, image sequence number, or file format:

>>>

**>>> import** **time**, **os.path**

**>>>** photofiles = ['img\_1074.jpg', 'img\_1076.jpg', 'img\_1077.jpg']

**>>> class** **BatchRename**(Template):

**...**  delimiter = '%'

**>>>** fmt = input('Enter rename style (*%d*-date %n-seqnum *%f*-format): ')

Enter rename style (%d-date %n-seqnum %f-format): Ashley\_%n%f

**>>>** t = BatchRename(fmt)

**>>>** date = time.strftime('*%d*%b%y')

**>>> for** i, filename **in** enumerate(photofiles):

**...**  base, ext = os.path.splitext(filename)

**...**  newname = t.substitute(d=date, n=i, f=ext)

**...**  print('*{0}* --> *{1}*'.format(filename, newname))

img\_1074.jpg --> Ashley\_0.jpg

img\_1076.jpg --> Ashley\_1.jpg

img\_1077.jpg --> Ashley\_2.jpg

Another application for templating is separating program logic from the details of multiple output formats. This makes it possible to substitute custom templates for XML files, plain text reports, and HTML web reports.

## 11.3. Working with Binary Data Record Layouts

The [struct](https://docs.python.org/3/library/struct.html#module-struct) module provides [pack()](https://docs.python.org/3/library/struct.html#struct.pack) and [unpack()](https://docs.python.org/3/library/struct.html#struct.unpack) functions for working with variable length binary record formats. The following example shows how to loop through header information in a ZIP file without using the [zipfile](https://docs.python.org/3/library/zipfile.html#module-zipfile) module. Pack codes "H" and "I" represent two and four byte unsigned numbers respectively. The "<" indicates that they are standard size and in little-endian byte order:

**import** **struct**

**with** open('myfile.zip', 'rb') **as** f:

data = f.read()

start = 0

**for** i **in** range(3): *# show the first 3 file headers*

start += 14

fields = struct.unpack('<IIIHH', data[start:start+16])

crc32, comp\_size, uncomp\_size, filenamesize, extra\_size = fields

start += 16

filename = data[start:start+filenamesize]

start += filenamesize

extra = data[start:start+extra\_size]

print(filename, hex(crc32), comp\_size, uncomp\_size)

start += extra\_size + comp\_size *# skip to the next header*

## 11.4. Multi-threading

Threading is a technique for decoupling tasks which are not sequentially dependent. Threads can be used to improve the responsiveness of applications that accept user input while other tasks run in the background. A related use case is running I/O in parallel with computations in another thread.

The following code shows how the high level [threading](https://docs.python.org/3/library/threading.html#module-threading) module can run tasks in background while the main program continues to run:

**import** **threading**, **zipfile**

**class** **AsyncZip**(threading.Thread):

**def** \_\_init\_\_(self, infile, outfile):

threading.Thread.\_\_init\_\_(self)

self.infile = infile

self.outfile = outfile

**def** run(self):

f = zipfile.ZipFile(self.outfile, 'w', zipfile.ZIP\_DEFLATED)

f.write(self.infile)

f.close()

print('Finished background zip of:', self.infile)

background = AsyncZip('mydata.txt', 'myarchive.zip')

background.start()

print('The main program continues to run in foreground.')

background.join() *# Wait for the background task to finish*

print('Main program waited until background was done.')

The principal challenge of multi-threaded applications is coordinating threads that share data or other resources. To that end, the threading module provides a number of synchronization primitives including locks, events, condition variables, and semaphores.

While those tools are powerful, minor design errors can result in problems that are difficult to reproduce. So, the preferred approach to task coordination is to concentrate all access to a resource in a single thread and then use the [queue](https://docs.python.org/3/library/queue.html#module-queue) module to feed that thread with requests from other threads. Applications using [Queue](https://docs.python.org/3/library/queue.html#queue.Queue) objects for inter-thread communication and coordination are easier to design, more readable, and more reliable.

## 11.5. Logging

The [logging](https://docs.python.org/3/library/logging.html#module-logging) module offers a full featured and flexible logging system. At its simplest, log messages are sent to a file or to sys.stderr:

**import** **logging**

logging.debug('Debugging information')

logging.info('Informational message')

logging.warning('Warning:config file *%s* not found', 'server.conf')

logging.error('Error occurred')

logging.critical('Critical error -- shutting down')

This produces the following output:

WARNING:root:Warning:config file server.conf not found

ERROR:root:Error occurred

CRITICAL:root:Critical error -- shutting down

By default, informational and debugging messages are suppressed and the output is sent to standard error. Other output options include routing messages through email, datagrams, sockets, or to an HTTP Server. New filters can select different routing based on message priority: DEBUG, INFO,WARNING, ERROR, and CRITICAL.

The logging system can be configured directly from Python or can be loaded from a user editable configuration file for customized logging without altering the application.

## 11.6. Weak References

Python does automatic memory management (reference counting for most objects and [garbage collection](https://docs.python.org/3/glossary.html#term-garbage-collection) to eliminate cycles). The memory is freed shortly after the last reference to it has been eliminated.

This approach works fine for most applications but occasionally there is a need to track objects only as long as they are being used by something else. Unfortunately, just tracking them creates a reference that makes them permanent. The [weakref](https://docs.python.org/3/library/weakref.html#module-weakref) module provides tools for tracking objects without creating a reference. When the object is no longer needed, it is automatically removed from a weakref table and a callback is triggered for weakref objects. Typical applications include caching objects that are expensive to create:

>>>

**>>> import** **weakref**, **gc**

**>>> class** **A**:

**...**  **def** \_\_init\_\_(self, value):

**...**  self.value = value

**...**  **def** \_\_repr\_\_(self):

**...**  **return** str(self.value)

**...**

**>>>** a = A(10) *# create a reference*

**>>>** d = weakref.WeakValueDictionary()

**>>>** d['primary'] = a *# does not create a reference*

**>>>** d['primary'] *# fetch the object if it is still alive*

10

**>>> del** a *# remove the one reference*

**>>>** gc.collect() *# run garbage collection right away*

0

**>>>** d['primary'] *# entry was automatically removed*

Traceback (most recent call last):

File "<stdin>", line 1, in <module>

d['primary'] *# entry was automatically removed*

File "C:/python35/lib/weakref.py", line 46, in \_\_getitem\_\_

o = self.data[key]()

KeyError: 'primary'

## 11.7. Tools for Working with Lists

Many data structure needs can be met with the built-in list type. However, sometimes there is a need for alternative implementations with different performance trade-offs.

The [array](https://docs.python.org/3/library/array.html#module-array) module provides an [array()](https://docs.python.org/3/library/array.html#array.array) object that is like a list that stores only homogeneous data and stores it more compactly. The following example shows an array of numbers stored as two byte unsigned binary numbers (typecode "H") rather than the usual 16 bytes per entry for regular lists of Python int objects:

>>>

**>>> from** **array** **import** array

**>>>** a = array('H', [4000, 10, 700, 22222])

**>>>** sum(a)

26932

**>>>** a[1:3]

array('H', [10, 700])

The [collections](https://docs.python.org/3/library/collections.html#module-collections) module provides a [deque()](https://docs.python.org/3/library/collections.html#collections.deque) object that is like a list with faster appends and pops from the left side but slower lookups in the middle. These objects are well suited for implementing queues and breadth first tree searches:

>>>

**>>> from** **collections** **import** deque

**>>>** d = deque(["task1", "task2", "task3"])

**>>>** d.append("task4")

**>>>** print("Handling", d.popleft())

Handling task1

unsearched = deque([starting\_node])

**def** breadth\_first\_search(unsearched):

node = unsearched.popleft()

**for** m **in** gen\_moves(node):

**if** is\_goal(m):

**return** m

unsearched.append(m)

In addition to alternative list implementations, the library also offers other tools such as the [bisect](https://docs.python.org/3/library/bisect.html#module-bisect)module with functions for manipulating sorted lists:

>>>

**>>> import** **bisect**

**>>>** scores = [(100, 'perl'), (200, 'tcl'), (400, 'lua'), (500, 'python')]

**>>>** bisect.insort(scores, (300, 'ruby'))

**>>>** scores

[(100, 'perl'), (200, 'tcl'), (300, 'ruby'), (400, 'lua'), (500, 'python')]

The [heapq](https://docs.python.org/3/library/heapq.html#module-heapq) module provides functions for implementing heaps based on regular lists. The lowest valued entry is always kept at position zero. This is useful for applications which repeatedly access the smallest element but do not want to run a full list sort:

>>>

**>>> from** **heapq** **import** heapify, heappop, heappush

**>>>** data = [1, 3, 5, 7, 9, 2, 4, 6, 8, 0]

**>>>** heapify(data) *# rearrange the list into heap order*

**>>>** heappush(data, -5) *# add a new entry*

**>>>** [heappop(data) **for** i **in** range(3)] *# fetch the three smallest entries*

[-5, 0, 1]

## 11.8. Decimal Floating Point Arithmetic

The [decimal](https://docs.python.org/3/library/decimal.html#module-decimal) module offers a [Decimal](https://docs.python.org/3/library/decimal.html#decimal.Decimal) datatype for decimal floating point arithmetic. Compared to the built-in [float](https://docs.python.org/3/library/functions.html#float) implementation of binary floating point, the class is especially helpful for

* financial applications and other uses which require exact decimal representation,
* control over precision,
* control over rounding to meet legal or regulatory requirements,
* tracking of significant decimal places, or
* applications where the user expects the results to match calculations done by hand.

For example, calculating a 5% tax on a 70 cent phone charge gives different results in decimal floating point and binary floating point. The difference becomes significant if the results are rounded to the nearest cent:

>>>

**>>> from** **decimal** **import** \*

**>>>** round(Decimal('0.70') \* Decimal('1.05'), 2)

Decimal('0.74')

**>>>** round(.70 \* 1.05, 2)

0.73

The [Decimal](https://docs.python.org/3/library/decimal.html#decimal.Decimal) result keeps a trailing zero, automatically inferring four place significance from multiplicands with two place significance. Decimal reproduces mathematics as done by hand and avoids issues that can arise when binary floating point cannot exactly represent decimal quantities.

Exact representation enables the [Decimal](https://docs.python.org/3/library/decimal.html#decimal.Decimal) class to perform modulo calculations and equality tests that are unsuitable for binary floating point:

>>>

**>>>** Decimal('1.00') % Decimal('.10')

Decimal('0.00')

**>>>** 1.00 % 0.10

0.09999999999999995

**>>>** sum([Decimal('0.1')]\*10) == Decimal('1.0')

True

**>>>** sum([0.1]\*10) == 1.0

False

The [decimal](https://docs.python.org/3/library/decimal.html#module-decimal) module provides arithmetic with as much precision as needed:

>>>

**>>>** getcontext().prec = 36

**>>>** Decimal(1) / Decimal(7)

Decimal('0.142857142857142857142857142857142857')

# 11. Brief Tour of the Standard Library – Part II

This second tour covers more advanced modules that support professional programming needs. These modules rarely occur in small scripts.

## 11.1. Output Formatting

The [reprlib](https://docs.python.org/3/library/reprlib.html#module-reprlib) module provides a version of [repr()](https://docs.python.org/3/library/functions.html#repr) customized for abbreviated displays of large or deeply nested containers:

>>>

**>>> import** **reprlib**

**>>>** reprlib.repr(set('supercalifragilisticexpialidocious'))

"{'a', 'c', 'd', 'e', 'f', 'g', ...}"

The [pprint](https://docs.python.org/3/library/pprint.html#module-pprint) module offers more sophisticated control over printing both built-in and user defined objects in a way that is readable by the interpreter. When the result is longer than one line, the “pretty printer” adds line breaks and indentation to more clearly reveal data structure:

>>>

**>>> import** **pprint**

**>>>** t = [[[['black', 'cyan'], 'white', ['green', 'red']], [['magenta',

**...**  'yellow'], 'blue']]]

**...**

**>>>** pprint.pprint(t, width=30)

[[[['black', 'cyan'],

'white',

['green', 'red']],

[['magenta', 'yellow'],

'blue']]]

The [textwrap](https://docs.python.org/3/library/textwrap.html#module-textwrap) module formats paragraphs of text to fit a given screen width:

>>>

**>>> import** **textwrap**

**>>>** doc = """The wrap() method is just like fill() except that it returns

**...** a list of strings instead of one big string with newlines to separate

**...** the wrapped lines."""

**...**

**>>>** print(textwrap.fill(doc, width=40))

The wrap() method is just like fill()

except that it returns a list of strings

instead of one big string with newlines

to separate the wrapped lines.

The [locale](https://docs.python.org/3/library/locale.html#module-locale) module accesses a database of culture specific data formats. The grouping attribute of locale’s format function provides a direct way of formatting numbers with group separators:

>>>

**>>> import** **locale**

**>>>** locale.setlocale(locale.LC\_ALL, 'English\_United States.1252')

'English\_United States.1252'

**>>>** conv = locale.localeconv() *# get a mapping of conventions*

**>>>** x = 1234567.8

**>>>** locale.format("*%d*", x, grouping=**True**)

'1,234,567'

**>>>** locale.format\_string("*%s%.\*f*", (conv['currency\_symbol'],

**...**  conv['frac\_digits'], x), grouping=**True**)

'$1,234,567.80'

## 11.2. Templating

The [string](https://docs.python.org/3/library/string.html#module-string) module includes a versatile [Template](https://docs.python.org/3/library/string.html#string.Template) class with a simplified syntax suitable for editing by end-users. This allows users to customize their applications without having to alter the application.

The format uses placeholder names formed by $ with valid Python identifiers (alphanumeric characters and underscores). Surrounding the placeholder with braces allows it to be followed by more alphanumeric letters with no intervening spaces. Writing $$ creates a single escaped $:

>>>

**>>> from** **string** **import** Template

**>>>** t = Template('$*{village}*folk send $$10 to $cause.')

**>>>** t.substitute(village='Nottingham', cause='the ditch fund')

'Nottinghamfolk send $10 to the ditch fund.'

The [substitute()](https://docs.python.org/3/library/string.html#string.Template.substitute) method raises a [KeyError](https://docs.python.org/3/library/exceptions.html#KeyError) when a placeholder is not supplied in a dictionary or a keyword argument. For mail-merge style applications, user supplied data may be incomplete and the[safe\_substitute()](https://docs.python.org/3/library/string.html#string.Template.safe_substitute) method may be more appropriate — it will leave placeholders unchanged if data is missing:

>>>

**>>>** t = Template('Return the $item to $owner.')

**>>>** d = dict(item='unladen swallow')

**>>>** t.substitute(d)

Traceback (most recent call last):

*...*

KeyError: 'owner'

**>>>** t.safe\_substitute(d)

'Return the unladen swallow to $owner.'

Template subclasses can specify a custom delimiter. For example, a batch renaming utility for a photo browser may elect to use percent signs for placeholders such as the current date, image sequence number, or file format:

>>>

**>>> import** **time**, **os.path**

**>>>** photofiles = ['img\_1074.jpg', 'img\_1076.jpg', 'img\_1077.jpg']

**>>> class** **BatchRename**(Template):

**...**  delimiter = '%'

**>>>** fmt = input('Enter rename style (*%d*-date %n-seqnum *%f*-format): ')

Enter rename style (%d-date %n-seqnum %f-format): Ashley\_%n%f

**>>>** t = BatchRename(fmt)

**>>>** date = time.strftime('*%d*%b%y')

**>>> for** i, filename **in** enumerate(photofiles):

**...**  base, ext = os.path.splitext(filename)

**...**  newname = t.substitute(d=date, n=i, f=ext)

**...**  print('*{0}* --> *{1}*'.format(filename, newname))

img\_1074.jpg --> Ashley\_0.jpg

img\_1076.jpg --> Ashley\_1.jpg

img\_1077.jpg --> Ashley\_2.jpg

Another application for templating is separating program logic from the details of multiple output formats. This makes it possible to substitute custom templates for XML files, plain text reports, and HTML web reports.

## 11.3. Working with Binary Data Record Layouts

The [struct](https://docs.python.org/3/library/struct.html#module-struct) module provides [pack()](https://docs.python.org/3/library/struct.html#struct.pack) and [unpack()](https://docs.python.org/3/library/struct.html#struct.unpack) functions for working with variable length binary record formats. The following example shows how to loop through header information in a ZIP file without using the [zipfile](https://docs.python.org/3/library/zipfile.html#module-zipfile) module. Pack codes "H" and "I" represent two and four byte unsigned numbers respectively. The "<" indicates that they are standard size and in little-endian byte order:

**import** **struct**

**with** open('myfile.zip', 'rb') **as** f:

data = f.read()

start = 0

**for** i **in** range(3): *# show the first 3 file headers*

start += 14

fields = struct.unpack('<IIIHH', data[start:start+16])

crc32, comp\_size, uncomp\_size, filenamesize, extra\_size = fields

start += 16

filename = data[start:start+filenamesize]

start += filenamesize

extra = data[start:start+extra\_size]

print(filename, hex(crc32), comp\_size, uncomp\_size)

start += extra\_size + comp\_size *# skip to the next header*

## 11.4. Multi-threading

Threading is a technique for decoupling tasks which are not sequentially dependent. Threads can be used to improve the responsiveness of applications that accept user input while other tasks run in the background. A related use case is running I/O in parallel with computations in another thread.

The following code shows how the high level [threading](https://docs.python.org/3/library/threading.html#module-threading) module can run tasks in background while the main program continues to run:

**import** **threading**, **zipfile**

**class** **AsyncZip**(threading.Thread):

**def** \_\_init\_\_(self, infile, outfile):

threading.Thread.\_\_init\_\_(self)

self.infile = infile

self.outfile = outfile

**def** run(self):

f = zipfile.ZipFile(self.outfile, 'w', zipfile.ZIP\_DEFLATED)

f.write(self.infile)

f.close()

print('Finished background zip of:', self.infile)

background = AsyncZip('mydata.txt', 'myarchive.zip')

background.start()

print('The main program continues to run in foreground.')

background.join() *# Wait for the background task to finish*

print('Main program waited until background was done.')

The principal challenge of multi-threaded applications is coordinating threads that share data or other resources. To that end, the threading module provides a number of synchronization primitives including locks, events, condition variables, and semaphores.

While those tools are powerful, minor design errors can result in problems that are difficult to reproduce. So, the preferred approach to task coordination is to concentrate all access to a resource in a single thread and then use the [queue](https://docs.python.org/3/library/queue.html#module-queue) module to feed that thread with requests from other threads. Applications using [Queue](https://docs.python.org/3/library/queue.html#queue.Queue) objects for inter-thread communication and coordination are easier to design, more readable, and more reliable.

## 11.5. Logging

The [logging](https://docs.python.org/3/library/logging.html#module-logging) module offers a full featured and flexible logging system. At its simplest, log messages are sent to a file or to sys.stderr:

**import** **logging**

logging.debug('Debugging information')

logging.info('Informational message')

logging.warning('Warning:config file *%s* not found', 'server.conf')

logging.error('Error occurred')

logging.critical('Critical error -- shutting down')

This produces the following output:

WARNING:root:Warning:config file server.conf not found

ERROR:root:Error occurred

CRITICAL:root:Critical error -- shutting down

By default, informational and debugging messages are suppressed and the output is sent to standard error. Other output options include routing messages through email, datagrams, sockets, or to an HTTP Server. New filters can select different routing based on message priority: DEBUG, INFO,WARNING, ERROR, and CRITICAL.

The logging system can be configured directly from Python or can be loaded from a user editable configuration file for customized logging without altering the application.

## 11.6. Weak References

Python does automatic memory management (reference counting for most objects and [garbage collection](https://docs.python.org/3/glossary.html#term-garbage-collection) to eliminate cycles). The memory is freed shortly after the last reference to it has been eliminated.

This approach works fine for most applications but occasionally there is a need to track objects only as long as they are being used by something else. Unfortunately, just tracking them creates a reference that makes them permanent. The [weakref](https://docs.python.org/3/library/weakref.html#module-weakref) module provides tools for tracking objects without creating a reference. When the object is no longer needed, it is automatically removed from a weakref table and a callback is triggered for weakref objects. Typical applications include caching objects that are expensive to create:

>>>

**>>> import** **weakref**, **gc**

**>>> class** **A**:

**...**  **def** \_\_init\_\_(self, value):

**...**  self.value = value

**...**  **def** \_\_repr\_\_(self):

**...**  **return** str(self.value)

**...**

**>>>** a = A(10) *# create a reference*

**>>>** d = weakref.WeakValueDictionary()

**>>>** d['primary'] = a *# does not create a reference*

**>>>** d['primary'] *# fetch the object if it is still alive*

10

**>>> del** a *# remove the one reference*

**>>>** gc.collect() *# run garbage collection right away*

0

**>>>** d['primary'] *# entry was automatically removed*

Traceback (most recent call last):

File "<stdin>", line 1, in <module>

d['primary'] *# entry was automatically removed*

File "C:/python35/lib/weakref.py", line 46, in \_\_getitem\_\_

o = self.data[key]()

KeyError: 'primary'

## 11.7. Tools for Working with Lists

Many data structure needs can be met with the built-in list type. However, sometimes there is a need for alternative implementations with different performance trade-offs.

The [array](https://docs.python.org/3/library/array.html#module-array) module provides an [array()](https://docs.python.org/3/library/array.html#array.array) object that is like a list that stores only homogeneous data and stores it more compactly. The following example shows an array of numbers stored as two byte unsigned binary numbers (typecode "H") rather than the usual 16 bytes per entry for regular lists of Python int objects:

>>>

**>>> from** **array** **import** array

**>>>** a = array('H', [4000, 10, 700, 22222])

**>>>** sum(a)

26932

**>>>** a[1:3]

array('H', [10, 700])

The [collections](https://docs.python.org/3/library/collections.html#module-collections) module provides a [deque()](https://docs.python.org/3/library/collections.html#collections.deque) object that is like a list with faster appends and pops from the left side but slower lookups in the middle. These objects are well suited for implementing queues and breadth first tree searches:

>>>

**>>> from** **collections** **import** deque

**>>>** d = deque(["task1", "task2", "task3"])

**>>>** d.append("task4")

**>>>** print("Handling", d.popleft())

Handling task1

unsearched = deque([starting\_node])

**def** breadth\_first\_search(unsearched):

node = unsearched.popleft()

**for** m **in** gen\_moves(node):

**if** is\_goal(m):

**return** m

unsearched.append(m)

In addition to alternative list implementations, the library also offers other tools such as the [bisect](https://docs.python.org/3/library/bisect.html#module-bisect)module with functions for manipulating sorted lists:

>>>

**>>> import** **bisect**

**>>>** scores = [(100, 'perl'), (200, 'tcl'), (400, 'lua'), (500, 'python')]

**>>>** bisect.insort(scores, (300, 'ruby'))

**>>>** scores

[(100, 'perl'), (200, 'tcl'), (300, 'ruby'), (400, 'lua'), (500, 'python')]

The [heapq](https://docs.python.org/3/library/heapq.html#module-heapq) module provides functions for implementing heaps based on regular lists. The lowest valued entry is always kept at position zero. This is useful for applications which repeatedly access the smallest element but do not want to run a full list sort:

>>>

**>>> from** **heapq** **import** heapify, heappop, heappush

**>>>** data = [1, 3, 5, 7, 9, 2, 4, 6, 8, 0]

**>>>** heapify(data) *# rearrange the list into heap order*

**>>>** heappush(data, -5) *# add a new entry*

**>>>** [heappop(data) **for** i **in** range(3)] *# fetch the three smallest entries*

[-5, 0, 1]

## 11.8. Decimal Floating Point Arithmetic

The [decimal](https://docs.python.org/3/library/decimal.html#module-decimal) module offers a [Decimal](https://docs.python.org/3/library/decimal.html#decimal.Decimal) datatype for decimal floating point arithmetic. Compared to the built-in [float](https://docs.python.org/3/library/functions.html#float) implementation of binary floating point, the class is especially helpful for

* financial applications and other uses which require exact decimal representation,
* control over precision,
* control over rounding to meet legal or regulatory requirements,
* tracking of significant decimal places, or
* applications where the user expects the results to match calculations done by hand.

For example, calculating a 5% tax on a 70 cent phone charge gives different results in decimal floating point and binary floating point. The difference becomes significant if the results are rounded to the nearest cent:

>>>

**>>> from** **decimal** **import** \*

**>>>** round(Decimal('0.70') \* Decimal('1.05'), 2)

Decimal('0.74')

**>>>** round(.70 \* 1.05, 2)

0.73

The [Decimal](https://docs.python.org/3/library/decimal.html#decimal.Decimal) result keeps a trailing zero, automatically inferring four place significance from multiplicands with two place significance. Decimal reproduces mathematics as done by hand and avoids issues that can arise when binary floating point cannot exactly represent decimal quantities.

Exact representation enables the [Decimal](https://docs.python.org/3/library/decimal.html#decimal.Decimal) class to perform modulo calculations and equality tests that are unsuitable for binary floating point:

>>>

**>>>** Decimal('1.00') % Decimal('.10')

Decimal('0.00')

**>>>** 1.00 % 0.10

0.09999999999999995

**>>>** sum([Decimal('0.1')]\*10) == Decimal('1.0')

True

**>>>** sum([0.1]\*10) == 1.0

False

The [decimal](https://docs.python.org/3/library/decimal.html#module-decimal) module provides arithmetic with as much precision as needed:

>>>

**>>>** getcontext().prec = 36

**>>>** Decimal(1) / Decimal(7)

Decimal('0.142857142857142857142857142857142857')

# 11. Brief Tour of the Standard Library – Part II

This second tour covers more advanced modules that support professional programming needs. These modules rarely occur in small scripts.

## 11.1. Output Formatting

The [reprlib](https://docs.python.org/3/library/reprlib.html#module-reprlib) module provides a version of [repr()](https://docs.python.org/3/library/functions.html#repr) customized for abbreviated displays of large or deeply nested containers:

>>>

**>>> import** **reprlib**

**>>>** reprlib.repr(set('supercalifragilisticexpialidocious'))

"{'a', 'c', 'd', 'e', 'f', 'g', ...}"

The [pprint](https://docs.python.org/3/library/pprint.html#module-pprint) module offers more sophisticated control over printing both built-in and user defined objects in a way that is readable by the interpreter. When the result is longer than one line, the “pretty printer” adds line breaks and indentation to more clearly reveal data structure:

>>>

**>>> import** **pprint**

**>>>** t = [[[['black', 'cyan'], 'white', ['green', 'red']], [['magenta',

**...**  'yellow'], 'blue']]]

**...**

**>>>** pprint.pprint(t, width=30)

[[[['black', 'cyan'],

'white',

['green', 'red']],

[['magenta', 'yellow'],

'blue']]]

The [textwrap](https://docs.python.org/3/library/textwrap.html#module-textwrap) module formats paragraphs of text to fit a given screen width:

>>>

**>>> import** **textwrap**

**>>>** doc = """The wrap() method is just like fill() except that it returns

**...** a list of strings instead of one big string with newlines to separate

**...** the wrapped lines."""

**...**

**>>>** print(textwrap.fill(doc, width=40))

The wrap() method is just like fill()

except that it returns a list of strings

instead of one big string with newlines

to separate the wrapped lines.

The [locale](https://docs.python.org/3/library/locale.html#module-locale) module accesses a database of culture specific data formats. The grouping attribute of locale’s format function provides a direct way of formatting numbers with group separators:

>>>

**>>> import** **locale**

**>>>** locale.setlocale(locale.LC\_ALL, 'English\_United States.1252')

'English\_United States.1252'

**>>>** conv = locale.localeconv() *# get a mapping of conventions*

**>>>** x = 1234567.8

**>>>** locale.format("*%d*", x, grouping=**True**)

'1,234,567'

**>>>** locale.format\_string("*%s%.\*f*", (conv['currency\_symbol'],

**...**  conv['frac\_digits'], x), grouping=**True**)

'$1,234,567.80'

## 11.2. Templating

The [string](https://docs.python.org/3/library/string.html#module-string) module includes a versatile [Template](https://docs.python.org/3/library/string.html#string.Template) class with a simplified syntax suitable for editing by end-users. This allows users to customize their applications without having to alter the application.

The format uses placeholder names formed by $ with valid Python identifiers (alphanumeric characters and underscores). Surrounding the placeholder with braces allows it to be followed by more alphanumeric letters with no intervening spaces. Writing $$ creates a single escaped $:

>>>

**>>> from** **string** **import** Template

**>>>** t = Template('$*{village}*folk send $$10 to $cause.')

**>>>** t.substitute(village='Nottingham', cause='the ditch fund')

'Nottinghamfolk send $10 to the ditch fund.'

The [substitute()](https://docs.python.org/3/library/string.html#string.Template.substitute) method raises a [KeyError](https://docs.python.org/3/library/exceptions.html#KeyError) when a placeholder is not supplied in a dictionary or a keyword argument. For mail-merge style applications, user supplied data may be incomplete and the[safe\_substitute()](https://docs.python.org/3/library/string.html#string.Template.safe_substitute) method may be more appropriate — it will leave placeholders unchanged if data is missing:

>>>

**>>>** t = Template('Return the $item to $owner.')

**>>>** d = dict(item='unladen swallow')

**>>>** t.substitute(d)

Traceback (most recent call last):

*...*

KeyError: 'owner'

**>>>** t.safe\_substitute(d)

'Return the unladen swallow to $owner.'

Template subclasses can specify a custom delimiter. For example, a batch renaming utility for a photo browser may elect to use percent signs for placeholders such as the current date, image sequence number, or file format:

>>>

**>>> import** **time**, **os.path**

**>>>** photofiles = ['img\_1074.jpg', 'img\_1076.jpg', 'img\_1077.jpg']

**>>> class** **BatchRename**(Template):

**...**  delimiter = '%'

**>>>** fmt = input('Enter rename style (*%d*-date %n-seqnum *%f*-format): ')

Enter rename style (%d-date %n-seqnum %f-format): Ashley\_%n%f

**>>>** t = BatchRename(fmt)

**>>>** date = time.strftime('*%d*%b%y')

**>>> for** i, filename **in** enumerate(photofiles):

**...**  base, ext = os.path.splitext(filename)

**...**  newname = t.substitute(d=date, n=i, f=ext)

**...**  print('*{0}* --> *{1}*'.format(filename, newname))

img\_1074.jpg --> Ashley\_0.jpg

img\_1076.jpg --> Ashley\_1.jpg

img\_1077.jpg --> Ashley\_2.jpg

Another application for templating is separating program logic from the details of multiple output formats. This makes it possible to substitute custom templates for XML files, plain text reports, and HTML web reports.

## 11.3. Working with Binary Data Record Layouts

The [struct](https://docs.python.org/3/library/struct.html#module-struct) module provides [pack()](https://docs.python.org/3/library/struct.html#struct.pack) and [unpack()](https://docs.python.org/3/library/struct.html#struct.unpack) functions for working with variable length binary record formats. The following example shows how to loop through header information in a ZIP file without using the [zipfile](https://docs.python.org/3/library/zipfile.html#module-zipfile) module. Pack codes "H" and "I" represent two and four byte unsigned numbers respectively. The "<" indicates that they are standard size and in little-endian byte order:

**import** **struct**

**with** open('myfile.zip', 'rb') **as** f:

data = f.read()

start = 0

**for** i **in** range(3): *# show the first 3 file headers*

start += 14

fields = struct.unpack('<IIIHH', data[start:start+16])

crc32, comp\_size, uncomp\_size, filenamesize, extra\_size = fields

start += 16

filename = data[start:start+filenamesize]

start += filenamesize

extra = data[start:start+extra\_size]

print(filename, hex(crc32), comp\_size, uncomp\_size)

start += extra\_size + comp\_size *# skip to the next header*

## 11.4. Multi-threading

Threading is a technique for decoupling tasks which are not sequentially dependent. Threads can be used to improve the responsiveness of applications that accept user input while other tasks run in the background. A related use case is running I/O in parallel with computations in another thread.

The following code shows how the high level [threading](https://docs.python.org/3/library/threading.html#module-threading) module can run tasks in background while the main program continues to run:

**import** **threading**, **zipfile**

**class** **AsyncZip**(threading.Thread):

**def** \_\_init\_\_(self, infile, outfile):

threading.Thread.\_\_init\_\_(self)

self.infile = infile

self.outfile = outfile

**def** run(self):

f = zipfile.ZipFile(self.outfile, 'w', zipfile.ZIP\_DEFLATED)

f.write(self.infile)

f.close()

print('Finished background zip of:', self.infile)

background = AsyncZip('mydata.txt', 'myarchive.zip')

background.start()

print('The main program continues to run in foreground.')

background.join() *# Wait for the background task to finish*

print('Main program waited until background was done.')

The principal challenge of multi-threaded applications is coordinating threads that share data or other resources. To that end, the threading module provides a number of synchronization primitives including locks, events, condition variables, and semaphores.

While those tools are powerful, minor design errors can result in problems that are difficult to reproduce. So, the preferred approach to task coordination is to concentrate all access to a resource in a single thread and then use the [queue](https://docs.python.org/3/library/queue.html#module-queue) module to feed that thread with requests from other threads. Applications using [Queue](https://docs.python.org/3/library/queue.html#queue.Queue) objects for inter-thread communication and coordination are easier to design, more readable, and more reliable.

## 11.5. Logging

The [logging](https://docs.python.org/3/library/logging.html#module-logging) module offers a full featured and flexible logging system. At its simplest, log messages are sent to a file or to sys.stderr:

**import** **logging**

logging.debug('Debugging information')

logging.info('Informational message')

logging.warning('Warning:config file *%s* not found', 'server.conf')

logging.error('Error occurred')

logging.critical('Critical error -- shutting down')

This produces the following output:

WARNING:root:Warning:config file server.conf not found

ERROR:root:Error occurred

CRITICAL:root:Critical error -- shutting down

By default, informational and debugging messages are suppressed and the output is sent to standard error. Other output options include routing messages through email, datagrams, sockets, or to an HTTP Server. New filters can select different routing based on message priority: DEBUG, INFO,WARNING, ERROR, and CRITICAL.

The logging system can be configured directly from Python or can be loaded from a user editable configuration file for customized logging without altering the application.

## 11.6. Weak References

Python does automatic memory management (reference counting for most objects and [garbage collection](https://docs.python.org/3/glossary.html#term-garbage-collection) to eliminate cycles). The memory is freed shortly after the last reference to it has been eliminated.

This approach works fine for most applications but occasionally there is a need to track objects only as long as they are being used by something else. Unfortunately, just tracking them creates a reference that makes them permanent. The [weakref](https://docs.python.org/3/library/weakref.html#module-weakref) module provides tools for tracking objects without creating a reference. When the object is no longer needed, it is automatically removed from a weakref table and a callback is triggered for weakref objects. Typical applications include caching objects that are expensive to create:

>>>

**>>> import** **weakref**, **gc**

**>>> class** **A**:

**...**  **def** \_\_init\_\_(self, value):

**...**  self.value = value

**...**  **def** \_\_repr\_\_(self):

**...**  **return** str(self.value)

**...**

**>>>** a = A(10) *# create a reference*

**>>>** d = weakref.WeakValueDictionary()

**>>>** d['primary'] = a *# does not create a reference*

**>>>** d['primary'] *# fetch the object if it is still alive*

10

**>>> del** a *# remove the one reference*

**>>>** gc.collect() *# run garbage collection right away*

0

**>>>** d['primary'] *# entry was automatically removed*

Traceback (most recent call last):

File "<stdin>", line 1, in <module>

d['primary'] *# entry was automatically removed*

File "C:/python35/lib/weakref.py", line 46, in \_\_getitem\_\_

o = self.data[key]()

KeyError: 'primary'

## 11.7. Tools for Working with Lists

Many data structure needs can be met with the built-in list type. However, sometimes there is a need for alternative implementations with different performance trade-offs.

The [array](https://docs.python.org/3/library/array.html#module-array) module provides an [array()](https://docs.python.org/3/library/array.html#array.array) object that is like a list that stores only homogeneous data and stores it more compactly. The following example shows an array of numbers stored as two byte unsigned binary numbers (typecode "H") rather than the usual 16 bytes per entry for regular lists of Python int objects:

>>>

**>>> from** **array** **import** array

**>>>** a = array('H', [4000, 10, 700, 22222])

**>>>** sum(a)

26932

**>>>** a[1:3]

array('H', [10, 700])

The [collections](https://docs.python.org/3/library/collections.html#module-collections) module provides a [deque()](https://docs.python.org/3/library/collections.html#collections.deque) object that is like a list with faster appends and pops from the left side but slower lookups in the middle. These objects are well suited for implementing queues and breadth first tree searches:

>>>

**>>> from** **collections** **import** deque

**>>>** d = deque(["task1", "task2", "task3"])

**>>>** d.append("task4")

**>>>** print("Handling", d.popleft())

Handling task1

unsearched = deque([starting\_node])

**def** breadth\_first\_search(unsearched):

node = unsearched.popleft()

**for** m **in** gen\_moves(node):

**if** is\_goal(m):

**return** m

unsearched.append(m)

In addition to alternative list implementations, the library also offers other tools such as the [bisect](https://docs.python.org/3/library/bisect.html#module-bisect)module with functions for manipulating sorted lists:

>>>

**>>> import** **bisect**

**>>>** scores = [(100, 'perl'), (200, 'tcl'), (400, 'lua'), (500, 'python')]

**>>>** bisect.insort(scores, (300, 'ruby'))

**>>>** scores

[(100, 'perl'), (200, 'tcl'), (300, 'ruby'), (400, 'lua'), (500, 'python')]

The [heapq](https://docs.python.org/3/library/heapq.html#module-heapq) module provides functions for implementing heaps based on regular lists. The lowest valued entry is always kept at position zero. This is useful for applications which repeatedly access the smallest element but do not want to run a full list sort:

>>>

**>>> from** **heapq** **import** heapify, heappop, heappush

**>>>** data = [1, 3, 5, 7, 9, 2, 4, 6, 8, 0]

**>>>** heapify(data) *# rearrange the list into heap order*

**>>>** heappush(data, -5) *# add a new entry*

**>>>** [heappop(data) **for** i **in** range(3)] *# fetch the three smallest entries*

[-5, 0, 1]

## 11.8. Decimal Floating Point Arithmetic

The [decimal](https://docs.python.org/3/library/decimal.html#module-decimal) module offers a [Decimal](https://docs.python.org/3/library/decimal.html#decimal.Decimal) datatype for decimal floating point arithmetic. Compared to the built-in [float](https://docs.python.org/3/library/functions.html#float) implementation of binary floating point, the class is especially helpful for

* financial applications and other uses which require exact decimal representation,
* control over precision,
* control over rounding to meet legal or regulatory requirements,
* tracking of significant decimal places, or
* applications where the user expects the results to match calculations done by hand.

For example, calculating a 5% tax on a 70 cent phone charge gives different results in decimal floating point and binary floating point. The difference becomes significant if the results are rounded to the nearest cent:

>>>

**>>> from** **decimal** **import** \*

**>>>** round(Decimal('0.70') \* Decimal('1.05'), 2)

Decimal('0.74')

**>>>** round(.70 \* 1.05, 2)

0.73

The [Decimal](https://docs.python.org/3/library/decimal.html#decimal.Decimal) result keeps a trailing zero, automatically inferring four place significance from multiplicands with two place significance. Decimal reproduces mathematics as done by hand and avoids issues that can arise when binary floating point cannot exactly represent decimal quantities.

Exact representation enables the [Decimal](https://docs.python.org/3/library/decimal.html#decimal.Decimal) class to perform modulo calculations and equality tests that are unsuitable for binary floating point:

>>>

**>>>** Decimal('1.00') % Decimal('.10')

Decimal('0.00')

**>>>** 1.00 % 0.10

0.09999999999999995

**>>>** sum([Decimal('0.1')]\*10) == Decimal('1.0')

True

**>>>** sum([0.1]\*10) == 1.0

False

The [decimal](https://docs.python.org/3/library/decimal.html#module-decimal) module provides arithmetic with as much precision as needed:

>>>

**>>>** getcontext().prec = 36

**>>>** Decimal(1) / Decimal(7)

Decimal('0.142857142857142857142857142857142857')

# 11. Brief Tour of the Standard Library – Part II

This second tour covers more advanced modules that support professional programming needs. These modules rarely occur in small scripts.

## 11.1. Output Formatting

The [reprlib](https://docs.python.org/3/library/reprlib.html#module-reprlib) module provides a version of [repr()](https://docs.python.org/3/library/functions.html#repr) customized for abbreviated displays of large or deeply nested containers:

>>>

**>>> import** **reprlib**

**>>>** reprlib.repr(set('supercalifragilisticexpialidocious'))

"{'a', 'c', 'd', 'e', 'f', 'g', ...}"

The [pprint](https://docs.python.org/3/library/pprint.html#module-pprint) module offers more sophisticated control over printing both built-in and user defined objects in a way that is readable by the interpreter. When the result is longer than one line, the “pretty printer” adds line breaks and indentation to more clearly reveal data structure:

>>>

**>>> import** **pprint**

**>>>** t = [[[['black', 'cyan'], 'white', ['green', 'red']], [['magenta',

**...**  'yellow'], 'blue']]]

**...**

**>>>** pprint.pprint(t, width=30)

[[[['black', 'cyan'],

'white',

['green', 'red']],

[['magenta', 'yellow'],

'blue']]]

The [textwrap](https://docs.python.org/3/library/textwrap.html#module-textwrap) module formats paragraphs of text to fit a given screen width:

>>>

**>>> import** **textwrap**

**>>>** doc = """The wrap() method is just like fill() except that it returns

**...** a list of strings instead of one big string with newlines to separate

**...** the wrapped lines."""

**...**

**>>>** print(textwrap.fill(doc, width=40))

The wrap() method is just like fill()

except that it returns a list of strings

instead of one big string with newlines

to separate the wrapped lines.

The [locale](https://docs.python.org/3/library/locale.html#module-locale) module accesses a database of culture specific data formats. The grouping attribute of locale’s format function provides a direct way of formatting numbers with group separators:

>>>

**>>> import** **locale**

**>>>** locale.setlocale(locale.LC\_ALL, 'English\_United States.1252')

'English\_United States.1252'

**>>>** conv = locale.localeconv() *# get a mapping of conventions*

**>>>** x = 1234567.8

**>>>** locale.format("*%d*", x, grouping=**True**)

'1,234,567'

**>>>** locale.format\_string("*%s%.\*f*", (conv['currency\_symbol'],

**...**  conv['frac\_digits'], x), grouping=**True**)

'$1,234,567.80'

## 11.2. Templating

The [string](https://docs.python.org/3/library/string.html#module-string) module includes a versatile [Template](https://docs.python.org/3/library/string.html#string.Template) class with a simplified syntax suitable for editing by end-users. This allows users to customize their applications without having to alter the application.

The format uses placeholder names formed by $ with valid Python identifiers (alphanumeric characters and underscores). Surrounding the placeholder with braces allows it to be followed by more alphanumeric letters with no intervening spaces. Writing $$ creates a single escaped $:

>>>

**>>> from** **string** **import** Template

**>>>** t = Template('$*{village}*folk send $$10 to $cause.')

**>>>** t.substitute(village='Nottingham', cause='the ditch fund')

'Nottinghamfolk send $10 to the ditch fund.'

The [substitute()](https://docs.python.org/3/library/string.html#string.Template.substitute) method raises a [KeyError](https://docs.python.org/3/library/exceptions.html#KeyError) when a placeholder is not supplied in a dictionary or a keyword argument. For mail-merge style applications, user supplied data may be incomplete and the[safe\_substitute()](https://docs.python.org/3/library/string.html#string.Template.safe_substitute) method may be more appropriate — it will leave placeholders unchanged if data is missing:

>>>

**>>>** t = Template('Return the $item to $owner.')

**>>>** d = dict(item='unladen swallow')

**>>>** t.substitute(d)

Traceback (most recent call last):

*...*

KeyError: 'owner'

**>>>** t.safe\_substitute(d)

'Return the unladen swallow to $owner.'

Template subclasses can specify a custom delimiter. For example, a batch renaming utility for a photo browser may elect to use percent signs for placeholders such as the current date, image sequence number, or file format:

>>>

**>>> import** **time**, **os.path**

**>>>** photofiles = ['img\_1074.jpg', 'img\_1076.jpg', 'img\_1077.jpg']

**>>> class** **BatchRename**(Template):

**...**  delimiter = '%'

**>>>** fmt = input('Enter rename style (*%d*-date %n-seqnum *%f*-format): ')

Enter rename style (%d-date %n-seqnum %f-format): Ashley\_%n%f

**>>>** t = BatchRename(fmt)

**>>>** date = time.strftime('*%d*%b%y')

**>>> for** i, filename **in** enumerate(photofiles):

**...**  base, ext = os.path.splitext(filename)

**...**  newname = t.substitute(d=date, n=i, f=ext)

**...**  print('*{0}* --> *{1}*'.format(filename, newname))

img\_1074.jpg --> Ashley\_0.jpg

img\_1076.jpg --> Ashley\_1.jpg

img\_1077.jpg --> Ashley\_2.jpg

Another application for templating is separating program logic from the details of multiple output formats. This makes it possible to substitute custom templates for XML files, plain text reports, and HTML web reports.

## 11.3. Working with Binary Data Record Layouts

The [struct](https://docs.python.org/3/library/struct.html#module-struct) module provides [pack()](https://docs.python.org/3/library/struct.html#struct.pack) and [unpack()](https://docs.python.org/3/library/struct.html#struct.unpack) functions for working with variable length binary record formats. The following example shows how to loop through header information in a ZIP file without using the [zipfile](https://docs.python.org/3/library/zipfile.html#module-zipfile) module. Pack codes "H" and "I" represent two and four byte unsigned numbers respectively. The "<" indicates that they are standard size and in little-endian byte order:

**import** **struct**

**with** open('myfile.zip', 'rb') **as** f:

data = f.read()

start = 0

**for** i **in** range(3): *# show the first 3 file headers*

start += 14

fields = struct.unpack('<IIIHH', data[start:start+16])

crc32, comp\_size, uncomp\_size, filenamesize, extra\_size = fields

start += 16

filename = data[start:start+filenamesize]

start += filenamesize

extra = data[start:start+extra\_size]

print(filename, hex(crc32), comp\_size, uncomp\_size)

start += extra\_size + comp\_size *# skip to the next header*

## 11.4. Multi-threading

Threading is a technique for decoupling tasks which are not sequentially dependent. Threads can be used to improve the responsiveness of applications that accept user input while other tasks run in the background. A related use case is running I/O in parallel with computations in another thread.

The following code shows how the high level [threading](https://docs.python.org/3/library/threading.html#module-threading) module can run tasks in background while the main program continues to run:

**import** **threading**, **zipfile**

**class** **AsyncZip**(threading.Thread):

**def** \_\_init\_\_(self, infile, outfile):

threading.Thread.\_\_init\_\_(self)

self.infile = infile

self.outfile = outfile

**def** run(self):

f = zipfile.ZipFile(self.outfile, 'w', zipfile.ZIP\_DEFLATED)

f.write(self.infile)

f.close()

print('Finished background zip of:', self.infile)

background = AsyncZip('mydata.txt', 'myarchive.zip')

background.start()

print('The main program continues to run in foreground.')

background.join() *# Wait for the background task to finish*

print('Main program waited until background was done.')

The principal challenge of multi-threaded applications is coordinating threads that share data or other resources. To that end, the threading module provides a number of synchronization primitives including locks, events, condition variables, and semaphores.

While those tools are powerful, minor design errors can result in problems that are difficult to reproduce. So, the preferred approach to task coordination is to concentrate all access to a resource in a single thread and then use the [queue](https://docs.python.org/3/library/queue.html#module-queue) module to feed that thread with requests from other threads. Applications using [Queue](https://docs.python.org/3/library/queue.html#queue.Queue) objects for inter-thread communication and coordination are easier to design, more readable, and more reliable.

## 11.5. Logging

The [logging](https://docs.python.org/3/library/logging.html#module-logging) module offers a full featured and flexible logging system. At its simplest, log messages are sent to a file or to sys.stderr:

**import** **logging**

logging.debug('Debugging information')

logging.info('Informational message')

logging.warning('Warning:config file *%s* not found', 'server.conf')

logging.error('Error occurred')

logging.critical('Critical error -- shutting down')

This produces the following output:

WARNING:root:Warning:config file server.conf not found

ERROR:root:Error occurred

CRITICAL:root:Critical error -- shutting down

By default, informational and debugging messages are suppressed and the output is sent to standard error. Other output options include routing messages through email, datagrams, sockets, or to an HTTP Server. New filters can select different routing based on message priority: DEBUG, INFO,WARNING, ERROR, and CRITICAL.

The logging system can be configured directly from Python or can be loaded from a user editable configuration file for customized logging without altering the application.

## 11.6. Weak References

Python does automatic memory management (reference counting for most objects and [garbage collection](https://docs.python.org/3/glossary.html#term-garbage-collection) to eliminate cycles). The memory is freed shortly after the last reference to it has been eliminated.

This approach works fine for most applications but occasionally there is a need to track objects only as long as they are being used by something else. Unfortunately, just tracking them creates a reference that makes them permanent. The [weakref](https://docs.python.org/3/library/weakref.html#module-weakref) module provides tools for tracking objects without creating a reference. When the object is no longer needed, it is automatically removed from a weakref table and a callback is triggered for weakref objects. Typical applications include caching objects that are expensive to create:

>>>

**>>> import** **weakref**, **gc**

**>>> class** **A**:

**...**  **def** \_\_init\_\_(self, value):

**...**  self.value = value

**...**  **def** \_\_repr\_\_(self):

**...**  **return** str(self.value)

**...**

**>>>** a = A(10) *# create a reference*

**>>>** d = weakref.WeakValueDictionary()

**>>>** d['primary'] = a *# does not create a reference*

**>>>** d['primary'] *# fetch the object if it is still alive*

10

**>>> del** a *# remove the one reference*

**>>>** gc.collect() *# run garbage collection right away*

0

**>>>** d['primary'] *# entry was automatically removed*

Traceback (most recent call last):

File "<stdin>", line 1, in <module>

d['primary'] *# entry was automatically removed*

File "C:/python35/lib/weakref.py", line 46, in \_\_getitem\_\_

o = self.data[key]()

KeyError: 'primary'

## 11.7. Tools for Working with Lists

Many data structure needs can be met with the built-in list type. However, sometimes there is a need for alternative implementations with different performance trade-offs.

The [array](https://docs.python.org/3/library/array.html#module-array) module provides an [array()](https://docs.python.org/3/library/array.html#array.array) object that is like a list that stores only homogeneous data and stores it more compactly. The following example shows an array of numbers stored as two byte unsigned binary numbers (typecode "H") rather than the usual 16 bytes per entry for regular lists of Python int objects:

>>>

**>>> from** **array** **import** array

**>>>** a = array('H', [4000, 10, 700, 22222])

**>>>** sum(a)

26932

**>>>** a[1:3]

array('H', [10, 700])

The [collections](https://docs.python.org/3/library/collections.html#module-collections) module provides a [deque()](https://docs.python.org/3/library/collections.html#collections.deque) object that is like a list with faster appends and pops from the left side but slower lookups in the middle. These objects are well suited for implementing queues and breadth first tree searches:

>>>

**>>> from** **collections** **import** deque

**>>>** d = deque(["task1", "task2", "task3"])

**>>>** d.append("task4")

**>>>** print("Handling", d.popleft())

Handling task1

unsearched = deque([starting\_node])

**def** breadth\_first\_search(unsearched):

node = unsearched.popleft()

**for** m **in** gen\_moves(node):

**if** is\_goal(m):

**return** m

unsearched.append(m)

In addition to alternative list implementations, the library also offers other tools such as the [bisect](https://docs.python.org/3/library/bisect.html#module-bisect)module with functions for manipulating sorted lists:

>>>

**>>> import** **bisect**

**>>>** scores = [(100, 'perl'), (200, 'tcl'), (400, 'lua'), (500, 'python')]

**>>>** bisect.insort(scores, (300, 'ruby'))

**>>>** scores

[(100, 'perl'), (200, 'tcl'), (300, 'ruby'), (400, 'lua'), (500, 'python')]

The [heapq](https://docs.python.org/3/library/heapq.html#module-heapq) module provides functions for implementing heaps based on regular lists. The lowest valued entry is always kept at position zero. This is useful for applications which repeatedly access the smallest element but do not want to run a full list sort:

>>>

**>>> from** **heapq** **import** heapify, heappop, heappush

**>>>** data = [1, 3, 5, 7, 9, 2, 4, 6, 8, 0]

**>>>** heapify(data) *# rearrange the list into heap order*

**>>>** heappush(data, -5) *# add a new entry*

**>>>** [heappop(data) **for** i **in** range(3)] *# fetch the three smallest entries*

[-5, 0, 1]

## 11.8. Decimal Floating Point Arithmetic

The [decimal](https://docs.python.org/3/library/decimal.html#module-decimal) module offers a [Decimal](https://docs.python.org/3/library/decimal.html#decimal.Decimal) datatype for decimal floating point arithmetic. Compared to the built-in [float](https://docs.python.org/3/library/functions.html#float) implementation of binary floating point, the class is especially helpful for

* financial applications and other uses which require exact decimal representation,
* control over precision,
* control over rounding to meet legal or regulatory requirements,
* tracking of significant decimal places, or
* applications where the user expects the results to match calculations done by hand.

For example, calculating a 5% tax on a 70 cent phone charge gives different results in decimal floating point and binary floating point. The difference becomes significant if the results are rounded to the nearest cent:

>>>

**>>> from** **decimal** **import** \*

**>>>** round(Decimal('0.70') \* Decimal('1.05'), 2)

Decimal('0.74')

**>>>** round(.70 \* 1.05, 2)

0.73

The [Decimal](https://docs.python.org/3/library/decimal.html#decimal.Decimal) result keeps a trailing zero, automatically inferring four place significance from multiplicands with two place significance. Decimal reproduces mathematics as done by hand and avoids issues that can arise when binary floating point cannot exactly represent decimal quantities.

Exact representation enables the [Decimal](https://docs.python.org/3/library/decimal.html#decimal.Decimal) class to perform modulo calculations and equality tests that are unsuitable for binary floating point:

>>>

**>>>** Decimal('1.00') % Decimal('.10')

Decimal('0.00')

**>>>** 1.00 % 0.10

0.09999999999999995

**>>>** sum([Decimal('0.1')]\*10) == Decimal('1.0')

True

**>>>** sum([0.1]\*10) == 1.0

False

The [decimal](https://docs.python.org/3/library/decimal.html#module-decimal) module provides arithmetic with as much precision as needed:

>>>

**>>>** getcontext().prec = 36

**>>>** Decimal(1) / Decimal(7)

Decimal('0.142857142857142857142857142857142857')