Python Tutorial

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CHAPTER

TWO

USING THE PYTHON INTERPRETER

2.1 Invoking the Interpreter

The Python interpreter is usually installed as `/usr/local/bin/python3.7` on those machines where it is available; putting `/usr/local/bin` in your Unix shell's search path makes it possible to start it by typing the command:

```
python3.7
```

to the shell.[1] Since the choice of the directory where the interpreter lives is an installation option, other places are possible; check with your local Python guru or system administrator. (E.g., `/usr/local/python` is a popular alternative location.)

On Windows machines, the Python installation is usually placed in `C:\Program Files\Python37\`, though you can change this when you're running the installer. To add this directory to your path, you can type the following command into the command prompt in a DOS box:

```
set path=%path%;C:\Program Files\Python37\
```

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

The interpreter's line-editing features include interactive editing, history substitution and code completion on systems that support readline. Perhaps the quickest check to see whether command line editing is supported is typing `Control-P` to the first Python prompt you get. If it beeps, you have command line editing; see Appendix *Interactive Input Editing and History Substitution* for an introduction to the keys. If nothing appears to happen, or if `^P` is echoed, command line editing isn't available; you'll only be able to use backspace to remove characters from the current line.

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

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

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

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

[1] On Unix, the Python 3.x interpreter is by default not installed with the executable named `python`, so that it does not conflict with a simultaneously installed Python 2.x executable.

```
>>> word[-1]  # last character
'n'
>>> word[-2]  # second-last character
'o'
>>> word[-6]
'P'
```

Note that since -0 is the same as 0, negative indices start from -1.

In addition to indexing, *slicing* is also supported. While indexing is used to obtain individual characters, *slicing* allows you to obtain substring:

```
>>> word[0:2]  # characters from position 0 (included) to 2 (excluded)
'Py'
>>> word[2:5]  # characters from position 2 (included) to 5 (excluded)
'tho'
```

Note how the start is always included, and the end always excluded. This makes sure that `s[:i] + s[i:]` is always equal to `s`:

```
>>> word[:2] + word[2:]
'Python'
>>> word[:4] + word[4:]
'Python'
```

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

```
>>> word[:2]   # character from the beginning to position 2 (excluded)
'Py'
>>> word[4:]   # characters from position 4 (included) to the end
'on'
>>> word[-2:]  # characters from the second-last (included) to the end
'on'
```


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

```
 +---+---+---+---+---+---+
 | P | y | t | h | o | n |
 +---+---+---+---+---+---+
 0   1   2   3   4   5   6
-6  -5  -4  -3  -2  -1
```

The first row of numbers gives the position of the indices 0…6 in the string; the second row gives the corresponding negative indices. The slice from i to j consists of all characters between the edges labeled i and j, respectively.

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

Attempting to use an index that is too large will result in an error:

```
>>> word[42]  # the word only has 6 characters
Traceback (most recent call last):
  File "<stdin>", line 1, in <module>
IndexError: string index out of range
```

```
>>> print(range(10))
range(0, 10)
```

In many ways the object returned by `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` statement is such an *iterator*. The function `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` and `continue` Statements, and `else` Clauses on Loops

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

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


```
>>> for n in range(2, 10):
...     for x in range(2, n):
...         if n % x == 0:
...             print(n, 'equals', x, '*', n//x)
...             break
...     else:
...         # loop fell through without finding a factor
...         print(n, 'is a prime number')
...
2 is a prime number
3 is a prime number
4 equals 2 * 2
5 is a prime number
6 equals 2 * 3
7 is a prime number
8 equals 2 * 4
9 equals 3 * 3
```

(Yes, this is the correct code. Look closely: the `else` clause belongs to the `for` loop, **not** the `if` statement.)

When used with a loop, the `else` clause has more in common with the `else` clause of a `try` statement than it does that of `if` statements: a `try` statement's `else` clause runs when no exception occurs, and a loop's `else` clause runs when no `break` occurs. For more on the `try` statement and exceptions, see *Handling Exceptions*.

The `continue` statement, also borrowed from C, continues with the next iteration of the loop:

```
>>> for num in range(2, 10):
...     if num % 2 == 0:
...         print("Found an even number", num)
...         continue
...     print("Found a number", num)
Found an even number 2
```

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Strings.) There are tools which use docstrings to automatically produce online or printed documentation, or to let the user interactively browse through code; it's good practice to include docstrings in code that you write, so make a habit of it.

The *execution* of a function introduces a new symbol table used for the local variables of the function. More precisely, all variable assignments in a function store the value in the local symbol table; whereas variable references first look in the local symbol table, then in the local symbol tables of enclosing functions, then in the global symbol table, and finally in the table of built-in names. Thus, global variables cannot be directly assigned a value within a function (unless named in a `global` statement), although they may be referenced.

The actual parameters (arguments) to a function call are introduced in the local symbol table of the called function when it is called; thus, arguments are passed using *call by value* (where the *value* is always an object *reference*, not the value of the object).[1] When a function calls another function, a new local symbol table is created for that call.

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

```
>>> fib
<function fib at 10042ed0>
>>> f = fib
>>> f(100)
0 1 1 2 3 5 8 13 21 34 55 89
```

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

```
>>> fib(0)
>>> print(fib(0))
None
```


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

```
>>> def fib2(n):  # return Fibonacci series up to n
...     """Return a list containing the Fibonacci series up to n."""
...     result = []
...     a, b = 0, 1
...     while a < n:
...         result.append(a)    # see below
...         a, b = b, a+b
...     return result
...
>>> f100 = fib2(100)    # call it
>>> f100                # write the result
[0, 1, 1, 2, 3, 5, 8, 13, 21, 34, 55, 89]
```

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

- The `return` statement returns with a value from a function. `return` without an expression argument returns `None`. Falling off the end of a function also returns `None`.
- The statement `result.append(a)` calls a *method* of the list object `result`. A method is a function that 'belongs' to an object and is named `obj.methodname`, where `obj` is some object (this may be an

[1] 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).

CHAPTER

FIVE

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(`*iterable*`)`
Extend the list by appending all the items from the iterable. Equivalent to `a[len(a):] = iterable`.

`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 equal to *x*. It raises a `ValueError` 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*[, *start*[, *end*]]`)`
Return zero-based index in the list of the first item whose value is equal to *x*. Raises a `ValueError` if there is no such item.

The optional arguments *start* and *end* are interpreted as in the slice notation and are used to limit the search to a particular subsequence of the list. The returned index is computed relative to the beginning of the full sequence rather than the *start* argument.

`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()` for their explanation).

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```
...     [9, 10, 11, 12],
... ]
```

The following list comprehension will transpose rows and columns:

```
>>> [[row[i] for row in matrix] for i in range(4)]
[[1, 5, 9], [2, 6, 10], [3, 7, 11], [4, 8, 12]]
```

As we saw in the previous section, the nested listcomp is evaluated in the context of the `for` that follows it, so this example is equivalent to:

```
>>> transposed = []
>>> for i in range(4):
...     transposed.append([row[i] for row in matrix])
...
>>> transposed
[[1, 5, 9], [2, 6, 10], [3, 7, 11], [4, 8, 12]]
```

which, in turn, is the same as:

```
>>> transposed = []
>>> for i in range(4):
...     # the following 3 lines implement the nested listcomp
...     transposed_row = []
...     for row in matrix:
...         transposed_row.append(row[i])
...     transposed.append(transposed_row)
...
>>> transposed
[[1, 5, 9], [2, 6, 10], [3, 7, 11], [4, 8, 12]]
```


In the real world, you should prefer built-in functions to complex flow statements. The `zip()` function would do a great job for this use case:

```
>>> list(zip(*matrix))
[(1, 5, 9), (2, 6, 10), (3, 7, 11), (4, 8, 12)]
```

See *Unpacking Argument Lists* for details on the asterisk in this line.

5.2 The `del` statement

There is a way to remove an item from a list given its index instead of its value: the `del` statement. This differs from the `pop()` method which returns a value. The `del` statement can also be used to remove slices from a list or clear the entire list (which we did earlier by assignment of an empty list to the slice). For example:

```
>>> a = [-1, 1, 66.25, 333, 333, 1234.5]
>>> del a[0]
>>> a
[1, 66.25, 333, 333, 1234.5]
>>> del a[2:4]
>>> a
[1, 66.25, 1234.5]
>>> del a[:]
```

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5.5 Dictionaries

Another useful data type built into Python is the *dictionary* (see typesmapping). Dictionaries are sometimes found in other languages as "associative memories" or "associative arrays". Unlike sequences, which are indexed by a range of numbers, dictionaries are indexed by *keys*, which can be any immutable type; strings and numbers can always be keys. Tuples can be used as keys if they contain only strings, numbers, or tuples; if a tuple contains any mutable object either directly or indirectly, it cannot be used as a key. You can't use lists as keys, since lists can be modified in place using index assignments, slice assignments, or methods like `append()` and `extend()`.

It is best to think of a dictionary as a 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)` on a dictionary returns a list of all the keys used in the dictionary, in insertion order (if you want it sorted, just use `sorted(d)` instead). To check whether a single key is in the dictionary, use the `in` keyword.

Here is a small example using a dictionary:


```
>>> tel = {'jack': 4098, 'sape': 4139}
>>> tel['guido'] = 4127
>>> tel
{'jack': 4098, 'sape': 4139, 'guido': 4127}
>>> tel['jack']
4098
>>> del tel['sape']
>>> tel['irv'] = 4127
>>> tel
{'jack': 4098, 'guido': 4127, 'irv': 4127}
>>> list(tel)
['jack', 'guido', 'irv']
>>> sorted(tel)
['guido', 'irv', 'jack']
>>> 'guido' in tel
True
>>> 'jack' not in tel
False
```

The `dict()` constructor builds dictionaries directly from sequences of key-value pairs:

```
>>> dict([('sape', 4139), ('guido', 4127), ('jack', 4098)])
{'sape': 4139, 'guido': 4127, 'jack': 4098}
```

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, 'guido': 4127, 'jack': 4098}
```

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()` 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()` 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()` 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()` 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
```

```
>>> 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 Pillow 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
```

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```
>>> 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'))"
```

The `string` module contains a `Template` class that offers yet another way to substitute values into strings, using placeholders like `$x` and replacing them with values from a dictionary, but offers much less control of the formatting.

7.1.1 Formatted String Literals

Formatted string literals (also called f-strings for short) let you include the value of Python expressions inside a string by prefixing the string with `f` or `F` and writing expressions as `{expression}`.

An optional format specifier can follow the expression. This allows greater control over how the value is formatted. The following example rounds pi to three places after the decimal:

```
>>> import math
>>> print(f'The value of pi is approximately {math.pi:.3f}.')
```

Passing an integer after the `':'` will cause that field to be a minimum number of characters wide. This is useful for making columns line up.

```
>>> table = {'Sjoerd': 4127, 'Jack': 4098, 'Dcab': 7678}
>>> for name, phone in table.items():
...     print(f'{name:10} ==> {phone:10d}')
...
Sjoerd     ==>       4127
Jack       ==>       4098
Dcab       ==>       7678
```

Other modifiers can be used to convert the value before it is formatted. `'!a'` applies `ascii()`, `'!s'` applies `str()`, and `'!r'` applies `repr()`:

```
>>> animals = 'eels'
>>> print(f'My hovercraft is full of {animals}.')
My hovercraft is full of eels.
>>> print('My hovercraft is full of {animals !r}.')
My hovercraft is full of 'eels'.
```

For a reference on these format specifications, see the reference guide for the formatspec.

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```
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 valid *offset* values are those returned from the `f.tell()`, or zero. Any other *offset* value produces undefined behaviour.

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`

Strings can easily be written to and read from a file. Numbers take a bit more effort, since the `read()` method only returns strings, which will have to be passed to a function like `int()`, which takes a string like `'123'` and returns its numeric value 123. 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). The standard module called `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:

```
>>> import json
>>> json.dumps([1, 'simple', 'list'])
'[1, "simple", "list"]'
```

Another variant of the `dumps()` function, called `dump()`, simply serializes the object to a *text file*. So if `f` is a *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* 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` module contains an explanation of this.

See also:

`pickle` - the pickle module

Contrary to *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.

```
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` 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.

CHAPTER

ELEVEN

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` module provides a version of `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` module offers more sophisticated control over printing both built-in and user defined objects in a way that is readable by the interpreter. When the result is longer than one line, the "pretty printer" adds line breaks and indentation to more clearly reveal data structure:

```
>>> import pprint
>>> t = [[['black', 'cyan'], 'white', ['green', 'red']], [['magenta',
...     'yellow'], 'blue']]
...
>>> pprint.pprint(t, width=30)
[[[['black', 'cyan'],
   'white',
   ['green', 'red']],
  [['magenta', 'yellow'],
   'blue']]]
```

The `textwrap` module formats paragraphs of text to fit a given screen width:

```
>>> import textwrap
>>> doc = """The wrap() method is just like fill() except that it returns
... a list of strings instead of one big string with newlines to separate
... the wrapped lines."""
...
>>> print(textwrap.fill(doc, width=40))
The wrap() method is just like fill()
except that it returns a list of strings
instead of one big string with newlines
to separate the wrapped lines.
```

The `locale` module accesses a database of culture specific data formats. The grouping attribute of locale's format function provides a direct way of formatting numbers with group separators:

CHAPTER

THIRTEEN

WHAT NOW?

Reading this tutorial has probably reinforced your interest in using Python — you should be eager to apply Python to solving your real-world problems. Where should you go to learn more?

This tutorial is part of Python's documentation set. Some other documents in the set are:

- library-index:

  You should browse through this manual, which gives complete (though terse) reference material about types, functions, and the modules in the standard library. The standard Python distribution includes a *lot* of additional code. There are modules to read Unix mailboxes, retrieve documents via HTTP, generate random numbers, parse command-line options, write CGI programs, compress data, and many other tasks. Skimming through the Library Reference will give you an idea of what's available.

- installing-index explains how to install additional modules written by other Python users.

- reference-index: A detailed explanation of Python's syntax and semantics. It's heavy reading, but is useful as a complete guide to the language itself.

More Python resources:

- https://www.python.org: The major Python Web site. It contains code, documentation, and pointers to Python-related pages around the Web. This Web site is mirrored in various places around the world, such as Europe, Japan, and Australia; a mirror may be faster than the main site, depending on your geographical location.

- https://docs.python.org: Fast access to Python's documentation.

- https://pypi.org: The Python Package Index, previously also nicknamed the Cheese Shop, is an index of user-created Python modules that are available for download. Once you begin releasing code, you can register it here so that others can find it.

- https://code.activestate.com/recipes/langs/python/: The Python Cookbook is a sizable collection of code examples, larger modules, and useful scripts. Particularly notable contributions are collected in a book also titled Python Cookbook (O'Reilly & Associates, ISBN 0-596-00797-3.)

- http://www.pyvideo.org collects links to Python-related videos from conferences and user-group meetings.

- https://scipy.org: The Scientific Python project includes modules for fast array computations and manipulations plus a host of packages for such things as linear algebra, Fourier transforms, non-linear solvers, random number distributions, statistical analysis and the like.

For Python-related questions and problem reports, you can post to the newsgroup *comp.lang.python*, or send them to the mailing list at python-list@python.org. The newsgroup and mailing list are gatewayed, so messages posted to one will automatically be forwarded to the other. There are hundreds of postings a day, asking (and answering) questions, suggesting new features, and announcing new modules. Mailing list archives are available at https://mail.python.org/pipermail/.

```
>>> 0.1
0.1000000000000000055511151231257827021181583404541015625
```

That is more digits than most people find useful, so Python keeps the number of digits manageable by displaying a rounded value instead

```
>>> 1 / 10
0.1
```

Just remember, even though the printed result looks like the exact value of 1/10, the actual stored value is the nearest representable binary fraction.

Interestingly, there are many different decimal numbers that share the same nearest approximate binary fraction. For example, the numbers `0.1` and `0.10000000000000001` and `0.1000000000000000055511151231257827021181583404541015625` are all approximated by `3602879701896397 / 2 ** 55`. Since all of these decimal values share the same approximation, any one of them could be displayed while still preserving the invariant `eval(repr(x)) == x`.

Historically, the Python prompt and built-in `repr()` function would choose the one with 17 significant digits, `0.10000000000000001`. Starting with Python 3.1, Python (on most systems) is now able to choose the shortest of these and simply display `0.1`.

Note that this is in the very nature of binary floating-point: this is not a bug in Python, and it is not a bug in your code either. You'll see the same kind of thing in all languages that support your hardware's floating-point arithmetic (although some languages may not *display* the difference by default, or in all output modes).

For more pleasant output, you may wish to use string formatting to produce a limited number of significant digits:

```
>>> format(math.pi, '.12g')  # give 12 significant digits
'3.14159265359'

>>> format(math.pi, '.2f')  # give 2 digits after the point
'3.14'

>>> repr(math.pi)
'3.141592653589793'
```


It's important to realize that this is, in a real sense, an illusion: you're simply rounding the *display* of the true machine value.

One illusion may beget another. For example, since 0.1 is not exactly 1/10, summing three values of 0.1 may not yield exactly 0.3, either:

```
>>> .1 + .1 + .1 == .3
False
```

Also, since the 0.1 cannot get any closer to the exact value of 1/10 and 0.3 cannot get any closer to the exact value of 3/10, then pre-rounding with `round()` function cannot help:

```
>>> round(.1, 1) + round(.1, 1) + round(.1, 1) == round(.3, 1)
False
```

Though the numbers cannot be made closer to their intended exact values, the `round()` function can be useful for post-rounding so that results with inexact values become comparable to one another:

```
>>> round(.1 + .1 + .1, 10) == round(.3, 10)
True
```

have a shorter development/debug cycle than compiled ones, though their programs generally also run more slowly. See also *interactive*.

interpreter shutdown When asked to shut down, the Python interpreter enters a special phase where it gradually releases all allocated resources, such as modules and various critical internal structures. It also makes several calls to the *garbage collector*. This can trigger the execution of code in user-defined destructors or weakref callbacks. Code executed during the shutdown phase can encounter various exceptions as the resources it relies on may not function anymore (common examples are library modules or the warnings machinery).

The main reason for interpreter shutdown is that the `__main__` module or the script being run has finished executing.

iterable An object capable of returning its members one at a time. Examples of iterables include all sequence types (such as `list`, `str`, and `tuple`) and some non-sequence types like `dict`, *file objects*, and objects of any classes you define with an `__iter__()` method or with a `__getitem__()` method that implements *Sequence* semantics.

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

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

More information can be found in typeiter.

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

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

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

keyword argument See *argument*.

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

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

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C.3.14 libffi

The `_ctypes` extension is built using an included copy of the libffi sources unless the build is configured `--with-system-libffi`:

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C.3.15 zlib

The `zlib` extension is built using an included copy of the zlib sources if the zlib version found on the system is too old to be used for the build:

```
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```

C.3.16 cfuhash

The implementation of the hash table used by the `tracemalloc` is based on the cfuhash project:

```
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