Python Programming

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1 Overview

Python[1] is a high-level[2], structured[3], open-source[4] programming language that can be used for a wide variety of programming tasks. Python was created by Guido Van Rossum in the early 1990s, its following has grown steadily and interest is increased markedly in the last few years or so. It is named after Monty Python's Flying Circus comedy program.

Python[5] is used extensively for system administration (many vital components of Linux[6] Distributions are written in it), also its a great language to teach programming to novice. NASA has used Python for its software systems and has adopted it as the standard scripting language for its Integrated Planning System. Python is also extensively used by Google to implement many components of its Web Crawler and Search Engine & Yahoo! for managing its discussion groups.

Python within itself is an interpreted programming language that is automatically compiled into bytecode before execution (the bytecode is then normally saved to disk, just as automatically, so that compilation need not happen again until and unless the source gets changed). It is also a dynamically typed language that includes (but does not require one to use) object oriented features and constructs.

The most unusual aspect of Python is that whitespace is significant; instead of block delimiters (braces → "{}" in the C family of languages), indentation is used to indicate where blocks begin and end.

For example, the following Python code can be interactively typed at an interpreter prompt, display the famous "Hello World!" on the user screen:

```
 >>> print "Hello World!"
Hello World!
```

Another great Python feature is its availability for all Platforms. Python can run on Microsoft Windows, Macintosh & all Linux distributions with ease. This makes the programs very portable, as any program written for one Platform can easily be used at another.

Python provides a powerful assortment of built-in types (e.g., lists, dictionaries and strings), a number of built-in functions, and a few constructs, mostly statements. For example, loop constructs that can iterate over items in a collection instead of being limited to a simple range of integer values. Python also comes with a powerful standard library[7], which includes

1 http://en.wikibooks.org/wiki/Python
2 http://en.wikibooks.org/wiki/Computer%20programming%2FHighlevel
3 http://en.wikibooks.org/wiki/Computer%20programming%2FStructured%20programming
4 http://en.wikibooks.org/wiki/Open%20Source
5 http://en.wikibooks.org/wiki/Python
6 http://en.wikibooks.org/wiki/Linux
7 http://en.wikibooks.org/wiki/Python%20Programming%2FStandard%20Library

hundreds of modules to provide routines for a wide variety of services including regular expressions[8] and TCP/IP sessions.

Python is used and supported by a large Python Community[9] that exists on the Internet. The mailing lists and news groups[10] like the tutor list[11] actively support and help new python programmers. While they discourage doing homework for you, they are quite helpful and are populated by the authors of many of the Python textbooks currently available on the market.

Note:
Python 2 vs Python 3: Several years ago, the Python developers made the decision to come up with a major new version of Python. Initially called "Python 3000", this became the 3.*x* series of versions of Python. What was radical about this was that the new version is **backward-incompatible** with Python 2.*x* : certain old features (like the handling of Unicode strings) were deemed to be too unwieldy or broken to be worth carrying forward. Instead, new, cleaner ways of achieving the same things were added.

8 Chapter 22 on page 111
9 `http://www.python.org/community/index.html`
10 `http://www.python.org/community/lists.html`
11 `http://mail.python.org/mailman/listinfo/tutor`

2 Getting Python

In order to program in Python you need the Python interpreter. If it is not already installed or if the version you are using is obsolete, you will need to obtain and install Python using the methods below:

2.1 Python 2 vs Python 3

In 2008, a new version of Python (version 3) was published that was not entirely backward compatible. Developers were asked to switch to the new version as soon as possible but many of the common external modules are not yet (as of Aug 2010) available for Python 3. There is a program called *2to3* to convert the source code of a Python 2 program to the source code of a Python 3 program. Consider this fact before you start working with Python.

2.2 Installing Python in Windows

Go to the Python Homepage[1] or the ActiveState website[2] and get the proper version for your platform. Download it, read the instructions and get it installed.

In order to run Python from the command line, you will need to have the python directory in your PATH. Alternatively, you could use an Integrated Development Environment (IDE) for Python like DrPython`http://drpython.sourceforge.net/`, eric`http://www.die-offenbachs.de/eric/index.html`, PyScripter`http://mmm-experts.com/Products.aspx?ProductID=4`, or Python's own IDLE[3] (which ships with every version of Python since 2.3).

The PATH variable can be modified from the Window's System control panel. To add the PATH in Windows 7 :

1. Go to Start.
2. Right click on computer.
3. Click on properties.
4. Click on 'Advanced System Settings'
5. Click on 'Environmental Variables'.
6. In the system variables select Path and edit it, by appending a ';' (without quote) and adding 'C:\python27'(without quote).

1 `http://www.python.org/download/`
2 `http://activestate.com`
3 `http://en.wikipedia.org/wiki/IDLE_%28Python%29`

If you prefer having a temporary environment, you can create a new command prompt short-cut that automatically executes the following statement:

```
PATH %PATH%;c:\python27
```

If you downloaded a different version (such as Python 3.1), change the ”27” for the version of Python you have (27 is 2.7.x, the current version of Python 2.)

2.2.1 Cygwin

By default, the Cygwin installer for Windows does not include Python in the downloads. However, it can be selected from the list of packages.

2.3 Installing Python on Mac

Users on Apple Mac OS X will find that it already ships with Python 2.3 (OS X 10.4 Tiger) or Python 2.6.1 (OS X Snow Leopard), but if you want the more recent version head to Python Download Page[4] follow the instruction on the page and in the installers. As a bonus you will also install the Python IDE.

2.4 Installing Python on Unix environments

Python is available as a package for some Linux distributions. In some cases, the distribution CD will contain the python package for installation, while other distributions require downloading the source code and using the compilation scripts.

2.4.1 Gentoo GNU/Linux

Gentoo is an example of a distribution that installs Python by default - the package system *Portage* depends on Python.

2.4.2 Ubuntu GNU/Linux

Users of Ubuntu will notice that Python comes installed by default, only it sometimes is not the latest version. If you would like to update it, click here[5].

4 `http://www.python.org/download/mac`
5 `http://appnr.com/install/python`

2.4.3 Arch GNU/Linux

Arch does not install python by default, but is easily available for installation through the package manager to pacman. As root (or using sudo if you've installed and configured it), type:

```
$ pacman -Sy python
```

This will be update package databases and install python. Other versions can be built from source from the Arch User Repository.

2.4.4 Source code installations

Some platforms do not have a version of Python installed, and do not have pre-compiled binaries. In these cases, you will need to download the source code from the official site[6]. Once the download is complete, you will need to unpack the compressed archive into a folder.

To build Python, simply run the configure script (requires the Bash shell) and compile using make.

2.4.5 Other Distributions

Python, which is also referred to as CPython[7], is written in the C Programming[8] language. The C source code is generally portable, that means CPython can run on various platforms. More precisely, CPython can be made available on all platforms that provide a compiler to translate the C source code to binary code for that platform.

Apart from CPython there are also other implementations that run on top of a virtual machine. For example, on Java's JRE (Java Runtime Environment) or Microsoft's .NET CLR (Common Language Runtime). Both can access and use the libraries available on their platform. Specifically, they make use of reflection[9] that allows complete inspection and use of all classes and objects for their very technology.

Python Implementations (Platforms)

Environment	**Description**	**Get From**
Jython	Java Version of Python	Jython[10]
IronPython	C# Version of Python	IronPython[11]

6 http://www.python.org/download/
7 http://en.wikibooks.org/wiki/CPython
8 http://en.wikibooks.org/wiki/C%20Programming
9 http://en.wikipedia.org/wiki/Reflection_(computer_programming)
10 http://www.jython.org
11 http://www.ironpython.net

2.4.6 Integrated Development Environments (IDE)

CPython ships with IDLE; however, IDLE is not considered user-friendly.[12] For Linux, KDevelop and Spyder are popular. For Windows, PyScripter is free, quick to install, and comes included with PortablePython[13].

Some Integrated Development Environments (IDEs) for Python

Environment	**Description**	**Get From**
KDevelop	Cross Language IDE for KDE	KDevelop[14]
ActivePython	Highly Flexible, Pythonwin IDE	ActivePython[15]
Anjuta	IDE Linux/Unix	Anjuta[16]
Pythonwin	Windows Oriented Environment	Pythonwin[17]
PyScripter	Free Windows IDE (portable)	PyScripter[18]
VisualWx	Free GUI Builder	VisualWx[19]
Spyder	Free cross-platform IDE	Spyder[20]
Eclipse (PyDev plugin)	Open Source IDE	Eclipse[21]

The Python official wiki has a complete list of IDEs[22].

There are several commercial IDEs such as Komodo, BlackAdder, Code Crusader, Code Forge, and PyCharm. However, for beginners learning to program, purchasing a commercial IDE is unnecessary.

2.5 Keeping Up to Date

Python has a very active community and the language itself is evolving continuously. Make sure to check python.org[23] for recent releases and relevant tools. The website is an invaluable asset.

12 The Things I Hate About IDLE That I Wish Someone Would Fix ^{http://inventwithpython.com/blog/2011/11/29/the-things-i-hate-about-idle-that-i-wish-someone-would-fix/} .
13 http://www.portablepython.com/
14 http://www.kdevelop.org
15 http://www.activestate.com/
16 http://anjuta.sf.net/
17 http://www.python.org/windows/
18 http://code.google.com/p/pyscripter/
19 http://visualwx.altervista.org
20 http://code.google.com/p/spyderlib/
21 http://www.eclipse.org
22 http://wiki.python.org/moin/IntegratedDevelopmentEnvironments
23 http://www.python.org

Public Python-related mailing lists are hosted at mail.python.org[24]. Two examples of such mailing lists are the **Python-announce-list** to keep up with newly released third party-modules or software for Python and the general discussion list **Python-list** . These lists are mirrored to the Usenet newsgroups **comp.lang.python.announce** & **comp.lang.python** .

2.6 Notes

24 `http://mail.python.org`

3 Interactive mode

Python has two basic modes: normal and interactive. The normal mode is the mode where the scripted and finished `.py` files are run in the Python interpreter. Interactive mode is a command line shell which gives immediate feedback for each statement, while running previously fed statements in active memory. As new lines are fed into the interpreter, the fed program is evaluated both in part and in whole.

To start interactive mode, simply type "python" without any arguments. This is a good way to play around and try variations on syntax. Python should print something like this:

```
$ python
Python 3.0b3 (r30b3:66303, Sep  8 2008, 14:01:02) [MSC v.1500 32 bit (Intel)]
on win32
Type "help", "copyright", "credits" or "license" for more information.
>>>
```

(If Python doesn't run, make sure your path is set correctly. See Getting Python[1].)

The `>>>` is Python's way of telling you that you are in interactive mode. In interactive mode what you type is immediately run. Try typing `1+1` in. Python will respond with `2` . Interactive mode allows you to test out and see what Python will do. If you ever feel the need to play with new Python statements, go into interactive mode and try them out.

A sample interactive session:

```
>>> 5
5
>>> print (5*7)
35
>>> "hello" * 4
'hellohellohellohello'
>>> "hello".__class__
<type 'str'>
```

However, you need to be careful in the interactive environment to avoid confusion. For example, the following is a valid Python script:

```
if 1:
  print("True")
print("Done")
```

If you try to enter this as written in the interactive environment, you might be surprised by the result:

1 Chapter 2 on page 5

```
>>> if 1:
...    print("True")
... print("Done")
  File "<stdin>", line 3
    print("Done")
        ^
SyntaxError: invalid syntax
```

What the interpreter is saying is that the indentation of the second print was unexpected. You should have entered a blank line to end the first (i.e., "if") statement, before you started writing the next print statement. For example, you should have entered the statements as though they were written:

```
if 1:
  print("True")

print("Done")
```

Which would have resulted in the following:

```
>>> if 1:
...    print("True")
...
True
>>> print("Done")
Done
>>>
```

3.0.1 Interactive mode

Instead of Python exiting when the program is finished, you can use the -i flag to start an interactive session. This can be **very** useful for debugging and prototyping.

```
python -i hello.py
```

4 Creating Python programs

1. REDIRECT Python Programming/Creating Python Programs[1]

1 Chapter 4 on page 13

5 Basic syntax

1. REDIRECT Python Programming/Basic Syntax[1]

1 Chapter 5 on page 15

6 Data types

1. REDIRECT Python Programming/Data Types[1]

1 Chapter 6 on page 17

7 Numbers

Python 2.x supports 4 numeric types - int, long, float and complex. Of these, the long type has been dropped in Python 3.x - the int type is now of unlimited length by default. You don't have to specify what type of variable you want; Python does that automatically.

- *Int:* The basic integer type in python, equivalent to the hardware 'c long' for the platform you are using in Python 2.x, unlimited in length in Python 3.x.
- *Long:* Integer type with unlimited length. In python 2.2 and later, Ints are automatically turned into long ints when they overflow. Dropped since Python 3.0, use int type instead.
- *Float:* This is a binary floating point number. Longs and Ints are automatically converted to floats when a float is used in an expression, and with the true-division `/` operator.
- *Complex:* This is a complex number consisting of two floats. Complex literals are written as a + bj where a and b are floating-point numbers denoting the real and imaginary parts respectively.

In general, the number types are automatically 'up cast' in this order:

Int → Long → Float → Complex. The farther to the right you go, the higher the precedence.

```
>>> x = 5
>>> type(x)
<type 'int'>
>>> x = 187687654564658970978909869576453
>>> type(x)
<type 'long'>
>>> x = 1.34763
>>> type(x)
<type 'float'>
>>> x = 5 + 2j
>>> type(x)
<type 'complex'>
```

The result of divisions is somewhat confusing. In Python 2.x, using the / operator on two integers will return another integer, using floor division. For example, `5/2` will give you 2. You have to specify one of the operands as a float to get true division, e.g. `5/2.` or `5./2` (the dot specifies you want to work with float) will yield 2.5. Starting with Python 2.2 this behavior can be changed to true division by the future division statement `from __future__ import division` . In Python 3.x, the result of using the / operator is always true division (you can ask for floor division explicitly by using the // operator since Python 2.2).

This illustrates the behavior of the / operator in Python 2.2+:

```
>>> 5/2
2
>>> 5/2.
2.5
>>> 5./2
2.5
>>> from __future__ import division
>>> 5/2
2.5
>>> 5//2
2
```

8 Strings

8.1 String operations

8.1.1 Equality

Two strings are equal if they have *exactly* the same contents, meaning that they are both the same length and each character has a one-to-one positional correspondence. Many other languages compare strings by identity instead; that is, two strings are considered equal only if they occupy the same space in memory. Python uses the `is` operator[1] to test the identity of strings and any two objects in general.

Examples:

```
>>> a = 'hello'; b = 'hello' # Assign 'hello' to a and b.
>>> a == b                   # check for equality
True
>>> a == 'hello'             #
True
>>> a == "hello"             # (choice of delimiter is unimportant)
True
>>> a == 'hello '            # (extra space)
False
>>> a == 'Hello'             # (wrong case)
False
```

8.1.2 Numerical

There are two quasi-numerical operations which can be done on strings -- addition and multiplication. String addition is just another name for concatenation. String multiplication is repetitive addition, or concatenation. So:

```
>>> c = 'a'
>>> c + 'b'
'ab'
>>> c * 5
'aaaaa'
```

8.1.3 Containment

There is a simple operator 'in' that returns True if the first operand is contained in the second. This also works on substrings

1 Chapter 12.7 on page 55

```
>>> x = 'hello'
>>> y = 'ell'
>>> x in y
False
>>> y in x
True
```

Note that 'print x in y' would have also returned the same value.

8.1.4 Indexing and Slicing

Much like arrays in other languages, the individual characters in a string can be accessed by an integer representing its position in the string. The first character in string s would be s[0] and the nth character would be at s[n-1].

```
>>> s = "Xanadu"
>>> s[1]
'a'
```

Unlike arrays in other languages, Python also indexes the arrays backwards, using negative numbers. The last character has index -1, the second to last character has index -2, and so on.

```
>>> s[-4]
'n'
```

We can also use "slices" to access a substring of s. s[a:b] will give us a string starting with s[a] and ending with s[b-1].

```
>>> s[1:4]
'ana'
```

None of these are assignable.

```
>>> print s
>>> s[0] = 'J'
Traceback (most recent call last):
File "<stdin>", line 1, in ?
TypeError: object does not support item assignment
>>> s[1:3] = "up"
Traceback (most recent call last):
File "<stdin>", line 1, in ?
TypeError: object does not support slice assignment
>>> print s
```

Outputs (assuming the errors were suppressed):

```
Xanadu
Xanadu
```

Another feature of slices is that if the beginning or end is left empty, it will default to the first or last index, depending on context:

```
>>> s[2:]
'nadu'
```

```
>>> s[:3]
'Xan'
>>> s[:]
'Xanadu'
```

You can also use negative numbers in slices:

```
>>> print s[-2:]
'du'
```

To understand slices, it's easiest not to count the elements themselves. It is a bit like counting not on your fingers, but in the spaces between them. The list is indexed like this:

```
Element:     1     2     3     4
Index:    0     1     2     3     4
         -4    -3    -2    -1
```

So, when we ask for the [1:3] slice, that means we start at index 1, and end at index 3, and take everything in between them. If you are used to indexes in C or Java, this can be a bit disconcerting until you get used to it.

8.2 String constants

String constants can be found in the standard string module such as; either single or double quotes may be used to delimit string constants.

8.3 String methods

There are a number of methods or built-in string functions:

- **capitalize**
- **center**
- **count**
- decode
- encode
- endswith
- **expandtabs**
- **find**
- **index**
- **isalnum**
- **isalpha**
- **isdigit**
- **islower**
- **isspace**
- **istitle**
- **isupper**
- **join**
- **ljust**

- **lower**
- **lstrip**
- **replace**
- **rfind**
- **rindex**
- **rjust**
- **rstrip**
- **split**
- **splitlines**
- startswith
- **strip**
- **swapcase**
- **title**
- translate
- **upper**
- zfill

Only emphasized items will be covered.

8.3.1 is*

isalnum(), isalpha(), isdigit(), islower(), isupper(), isspace(), and istitle() fit into this category.

The length of the string object being compared must be at least 1, or the is* methods will return False. In other words, a string object of len(string) == 0, is considered ”empty”, or False.

- **isalnum** returns True if the string is entirely composed of alphabetic and/or numeric characters (i.e. no punctuation).
- **isalpha** and **isdigit** work similarly for alphabetic characters or numeric characters only.
- **isspace** returns True if the string is composed entirely of whitespace.
- **islower** , **isupper** , and **istitle** return True if the string is in lowercase, uppercase, or titlecase respectively. Uncased characters are ”allowed”, such as digits, but there must be at least one cased character in the string object in order to return True. Titlecase means the first cased character of each word is uppercase, and any immediately following cased characters are lowercase. Curiously, 'Y2K'.istitle() returns True. That is because uppercase characters can only follow uncased characters. Likewise, lowercase characters can only follow uppercase or lowercase characters. Hint: whitespace is uncased.

Example:

```
>>> '2YK'.istitle()
False
>>> 'Y2K'.istitle()
True
>>> '2Y K'.istitle()
True
```

8.3.2 Title, Upper, Lower, Swapcase, Capitalize

Returns the string converted to title case, upper case, lower case, inverts case, or capitalizes, respectively.

The **title** method capitalizes the first letter of each word in the string (and makes the rest lower case). Words are identified as substrings of alphabetic characters that are separated by non-alphabetic characters, such as digits, or whitespace. This can lead to some unexpected behavior. For example, the string ”x1x” will be converted to ”X1X” instead of ”X1x”.

The **swapcase** method makes all uppercase letters lowercase and vice versa.

The **capitalize** method is like title except that it considers the entire string to be a word. (i.e. it makes the first character upper case and the rest lower case)

Example:

```
s = 'Hello, wOrLD'
print s              # 'Hello, wOrLD'
print s.title()      # 'Hello, World'
print s.swapcase()   # 'hELLO, WoRld'
print s.upper()      # 'HELLO, WORLD'
print s.lower()      # 'hello, world'
print s.capitalize() # 'Hello, world'
```

Keywords: to lower case, to upper case, lcase, ucase, downcase, upcase.

8.3.3 count

Returns the number of the specified substrings in the string. i.e.

```
>>> s = 'Hello, world'
>>> s.count('o') # print the number of 'o's in 'Hello, World' (2)
2
```

Hint: .count() is case-sensitive, so this example will only count the number of lowercase letter 'o's. For example, if you ran:

```
>>> s = 'HELLO, WORLD'
>>> s.count('o') # print the number of lowercase 'o's in 'HELLO, WORLD' (0)
0
```

8.3.4 strip, rstrip, lstrip

Returns a copy of the string with the leading (lstrip) and trailing (rstrip) whitespace removed. strip removes both.

```
>>> s = '\t Hello, world\n\t '
>>> print s
         Hello, world

>>> print s.strip()
Hello, world
>>> print s.lstrip()
Hello, world
```

```
        # ends here
>>> print s.rstrip()
         Hello, world
```

Note the leading and trailing tabs and newlines.

Strip methods can also be used to remove other types of characters.

```
import string
s = 'www.wikibooks.org'
print s
print s.strip('w')                 # Removes all w's from outside
print s.strip(string.lowercase)    # Removes all lowercase letters from outside
print s.strip(string.printable)    # Removes all printable characters
```

Outputs:

```
www.wikibooks.org
.wikibooks.org
.wikibooks.
```

Note that string.lowercase and string.printable require an import string statement

8.3.5 ljust, rjust, center

left, right or center justifies a string into a given field size (the rest is padded with spaces).

```
>>> s = 'foo'
>>> s
'foo'
>>> s.ljust(7)
'foo    '
>>> s.rjust(7)
'    foo'
>>> s.center(7)
'  foo  '
```

8.3.6 join

Joins together the given sequence with the string as separator:

```
>>> seq = ['1', '2', '3', '4', '5']
>>> ' '.join(seq)
'1 2 3 4 5'
>>> '+'.join(seq)
'1+2+3+4+5'
```

map may be helpful here: (it converts numbers in seq into strings)

```
>>> seq = [1,2,3,4,5]
>>> ' '.join(map(str, seq))
'1 2 3 4 5'
```

now arbitrary objects may be in seq instead of just strings.

8.3.7 find, index, rfind, rindex

The find and index methods return the index of the first found occurrence of the given subsequence. If it is not found, find returns -1 but index raises a ValueError. rfind and rindex are the same as find and index except that they search through the string from right to left (i.e. they find the last occurrence)

```
>>> s = 'Hello, world'
>>> s.find('l')
2
>>> s[s.index('l'):]
'llo, world'
>>> s.rfind('l')
10
>>> s[:s.rindex('l')]
'Hello, wor'
>>> s[s.index('l'):s.rindex('l')]
'llo, wor'
```

Because Python strings accept negative subscripts, index is probably better used in situations like the one shown because using find instead would yield an unintended value.

8.3.8 replace

Replace works just like it sounds. It returns a copy of the string with all occurrences of the first parameter replaced with the second parameter.

```
>>> 'Hello, world'.replace('o', 'X')
'HellX, wXrld'
```

Or, using variable assignment:

```
string = 'Hello, world'
newString = string.replace('o', 'X')
print string
print newString
```

Outputs:

```
Hello, world
HellX, wXrld
```

Notice, the original variable (`string`) remains unchanged after the call to `replace` .

8.3.9 expandtabs

Replaces tabs with the appropriate number of spaces (default number of spaces per tab = 8; this can be changed by passing the tab size as an argument).

```
s = 'abcdefg\tabc\ta'
print s
print len(s)
t = s.expandtabs()
```

```
print t
print len(t)
```

Outputs:

```
abcdefg abc     a
13
abcdefg abc     a
17
```

Notice how (although these both look the same) the second string (t) has a different length because each tab is represented by spaces not tab characters.

To use a tab size of 4 instead of 8:

```
v = s.expandtabs(4)
print v
print len(v)
```

Outputs:

```
abcdefg abc a
13
```

Please note each tab is not always counted as eight spaces. Rather a tab "pushes" the count to the next multiple of eight. For example:

```
s = '\t\t'
print s.expandtabs().replace(' ', '*')
print len(s.expandtabs())
```

Output:

```
****************
16
```

```
s = 'abc\tabc\tabc'
print s.expandtabs().replace(' ', '*')
print len(s.expandtabs())
```

Outputs:

```
abc*****abc*****abc
19
```

8.3.10 split, splitlines

The **split** method returns a list of the words in the string. It can take a separator argument to use instead of whitespace.

```
>>> s = 'Hello, world'
>>> s.split()
['Hello,', 'world']
>>> s.split('l')
['He', '', 'o, wor', 'd']
```

Note that in neither case is the separator included in the split strings, but empty strings are allowed.

The **splitlines** method breaks a multiline string into many single line strings. It is analogous to split('\n') (but accepts '\r' and '\r\n' as delimiters as well) except that if the string ends in a newline character, **splitlines** ignores that final character (see example).

```
>>> s = """
... One line
... Two lines
... Red lines
... Blue lines
... Green lines
... """
>>> s.split('\n')
['', 'One line', 'Two lines', 'Red lines', 'Blue lines', 'Green lines', '']
>>> s.splitlines()
['', 'One line', 'Two lines', 'Red lines', 'Blue lines', 'Green lines']
```

8.4 Exercises

1. Write a program that takes a string, (1) capitalizes the first letter, (2) creates a list containing each word, and (3) searches for the last occurrence of "a" in the first word.
2. Run the program on the string "Bananas are yellow."
3. Write a program that replaces all instances of "one" with "one (1)". For this exercise capitalization does not matter, so it should treat "one", "One", and "oNE" identically.
4. Run the program on the string "One banana was brown, but one was green."

8.5 External links

- "String Methods" chapter[2] -- python.org
- Python documentation of "string" module[3] -- python.org

2 http://docs.python.org/2/library/stdtypes.html?highlight=rstrip#string-methods
3 http://docs.python.org/2/library/string.html

9 Lists

A list in Python is an ordered group of items (or *elements*). It is a very general structure, and list elements don't have to be of the same type: you can put numbers, letters, strings and nested lists all on the same list.

9.1 Overview

Lists in Python at a glance:

```
list1 = []                      # A new empty list
list2 = [1, 2, 3, "cat"]        # A new non-empty list with mixed item types
list1.append("cat")             # Add a single member, at the end of the list
list1.extend(["dog", "mouse"])  # Add several members
if "cat" in list1:              # Membership test
  list1.remove("cat")           # Remove AKA delete
#list1.remove("elephant") - throws an error
for item in list1:              # Iteration AKA for each item
  print item
print "Item count:", len(list1) # Length AKA size AKA item count
list3 = [6, 7, 8, 9]
for i in range(0, len(list3)):  # Read-write iteration AKA for each item
  list3[i] += 1                 # Item access AKA element access by index
isempty = len(list3) == 0       # Test for emptiness
set1 = set(["cat", "dog"])      # Initialize set from a list
list4 = list(set1)              # Get a list from a set
list5 = list4[:]                # A shallow list copy
list4equal5 = list4==list5      # True: same by value
list4refEqual5 = list4 is list5 # False: not same by reference
list6 = list4[:]
del list6[:]                    # Clear AKA empty AKA erase
print list1, list2, list3, list4, list5, list6, list4equal5, list4refEqual5
print list3[1:3], list3[1:], list3[:2] # Slices
print max(list3 ), min(list3 ), sum(list3) # Aggregates
```

9.2 List creation

There are two different ways to make a list in Python. The first is through assignment ("statically"), the second is using list comprehensions ("actively").

9.2.1 Plain creation

To make a static list of items, write them between square brackets. For example:

```
[ 1,2,3,"This is a list",'c',Donkey("kong") ]
```

Observations:

1. The list contains items of different data types: integer, string, and Donkey class.
2. Objects can be created 'on the fly' and added to lists. The last item is a new instance of Donkey class.

Creation of a new list whose members are constructed from non-literal expressions:

```
a = 2
b = 3
myList = [a+b, b+a, len(["a","b"])]
```

9.2.2 List comprehensions

See also Tips and Tricks[1]

Using list comprehension, you describe the process using which the list should be created. To do that, the list is broken into two pieces. The first is a picture of what each element will look like, and the second is what you do to get it.

For instance, let's say we have a list of words:

```
listOfWords = ["this","is","a","list","of","words"]
```

To take the first letter of each word and make a list out of it using list comprehension, we can do this:

```
>>> listOfWords = ["this","is","a","list","of","words"]
>>> items = [ word[0] for word in listOfWords ]
>>> print items
['t', 'i', 'a', 'l', 'o', 'w']
```

List comprehension supports more than one for statement. It will evaluate the items in all of the objects sequentially and will loop over the shorter objects if one object is longer than the rest.

```
>>> item = [x+y for x in 'cat' for y in 'pot']
>>> print item
['cp', 'co', 'ct', 'ap', 'ao', 'at', 'tp', 'to', 'tt']
```

List comprehension supports an if statement, to only include members into the list that fulfill a certain condition:

```
>>> print [x+y for x in 'cat' for y in 'pot']
['cp', 'co', 'ct', 'ap', 'ao', 'at', 'tp', 'to', 'tt']
>>> print [x+y for x in 'cat' for y in 'pot' if x != 't' and y != 'o' ]
['cp', 'ct', 'ap', 'at']
>>> print [x+y for x in 'cat' for y in 'pot' if x != 't' or y != 'o' ]
['cp', 'co', 'ct', 'ap', 'ao', 'at', 'tp', 'tt']
```

1 http://en.wikibooks.org/wiki/Python%20Programming%2FTips_and_Tricks%23List_comprehension_and_generators

In version 2.x, Python's list comprehension does not define a scope. Any variables that are bound in an evaluation remain bound to whatever they were last bound to when the evaluation was completed. In version 3.x Python's list comprehension uses local variables:

```
>>> print x, y                      #Input to python version 2
r t                                 #Output using python 2

>>> print x, y                      #Input to python version 3
NameError: name 'x' is not defined  #Python 3 returns an error because x and
 y were not leaked
```

This is exactly the same as if the comprehension had been expanded into an explicitly-nested group of one or more 'for' statements and 0 or more 'if' statements.

9.2.3 List creation shortcuts

You can initialize a list to a size, with an initial value for each element:

```
>>> zeros=[0]*5
>>> print zeros
[0, 0, 0, 0, 0]
```

This works for any data type:

```
>>> foos=['foo']*3
>>> print foos
['foo', 'foo', 'foo']
```

But there is a caveat. When building a new list by multiplying, Python copies each item by reference. This poses a problem for mutable items, for instance in a multidimensional array where each element is itself a list. You'd guess that the easy way to generate a two dimensional array would be:

```
listoflists=[ [0]*4 ] *5
```

and this works, but probably doesn't do what you expect:

```
>>> listoflists=[ [0]*4 ] *5
>>> print listoflists
[[0, 0, 0, 0], [0, 0, 0, 0], [0, 0, 0, 0], [0, 0, 0, 0], [0, 0, 0, 0]]
>>> listoflists[0][2]=1
>>> print listoflists
[[0, 0, 1, 0], [0, 0, 1, 0], [0, 0, 1, 0], [0, 0, 1, 0], [0, 0, 1, 0]]
```

What's happening here is that Python is using the same reference to the inner list as the elements of the outer list. Another way of looking at this issue is to examine how Python sees the above definition:

```
>>> innerlist=[0]*4
>>> listoflists=[innerlist]*5
>>> print listoflists
[[0, 0, 0, 0], [0, 0, 0, 0], [0, 0, 0, 0], [0, 0, 0, 0], [0, 0, 0, 0]]
>>> innerlist[2]=1
>>> print listoflists
[[0, 0, 1, 0], [0, 0, 1, 0], [0, 0, 1, 0], [0, 0, 1, 0], [0, 0, 1, 0]]
```

Assuming the above effect is not what you intend, one way around this issue is to use list comprehensions:

```
>>> listoflists=[[0]*4 for i in range(5)]
>>> print listoflists
[[0, 0, 0, 0], [0, 0, 0, 0], [0, 0, 0, 0], [0, 0, 0, 0], [0, 0, 0, 0]]
>>> listoflists[0][2]=1
>>> print listoflists
[[0, 0, 1, 0], [0, 0, 0, 0], [0, 0, 0, 0], [0, 0, 0, 0], [0, 0, 0, 0]]
```

9.3 List Attributes

To find the length of a list use the built in len() method.

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

9.4 Combining lists

Lists can be combined in several ways. The easiest is just to 'add' them. For instance:

```
>>> [1,2] + [3,4]
[1, 2, 3, 4]
```

Another way to combine lists is with **extend** . If you need to combine lists inside of a lambda, **extend** is the way to go.

```
>>> a = [1,2,3]
>>> b = [4,5,6]
>>> a.extend(b)
>>> print a
[1, 2, 3, 4, 5, 6]
```

The other way to append a value to a list is to use **append** . For example:

```
>>> p=[1,2]
>>> p.append([3,4])
>>> p
[1, 2, [3, 4]]
>>> # or
>>> print p
[1, 2, [3, 4]]
```

However, [3,4] is an element of the list, and not part of the list. **append** always adds one element only to the end of a list. So if the intention was to concatenate two lists, always use **extend** .

9.5 Getting pieces of lists (slices)

9.5.1 Continuous slices

Like strings[2], lists can be indexed and sliced.

```
>>> list = [2, 4, "usurp", 9.0,"n"]
>>> list[2]
'usurp'
>>> list[3:]
[9.0, 'n']
```

Much like the slice of a string is a substring, the slice of a list is a list. However, lists differ from strings in that we can assign new values to the items in a list.

```
>>> list[1] = 17
>>> list
[2, 17, 'usurp', 9.0,'n']
```

We can even assign new values to slices of the lists, which don't even have to be the same length

```
>>> list[1:4] = ["opportunistic", "elk"]
>>> list
[2, 'opportunistic', 'elk', 'n']
```

It's even possible to append things onto the end of lists by assigning to an empty slice:

```
>>> list[:0] = [3.14,2.71]
>>> list
[3.14, 2.71, 2, 'opportunistic', 'elk', 'n']
```

You can also completely change contents of a list:

```
>>> list[:] = ['new', 'list', 'contents']
>>> list
['new', 'list', 'contents']
```

On the right-hand side of assignment statement can be any iterable type:

```
>>> list[:2] = ('element',('t',),[])
>>> list
['element', ('t',), [], 'contents']
```

With slicing you can create copy of list because slice returns a new list:

```
>>> original = [1, 'element', []]
>>> list_copy = original[:]
>>> list_copy
[1, 'element', []]
>>> list_copy.append('new element')
>>> list_copy
[1, 'element', [], 'new element']
>>> original
[1, 'element', []]
```

2 Chapter 8 on page 21

but this is shallow copy and contains references to elements from original list, so be careful with mutable types:

```
>>> list_copy[2].append('something')
>>> original
[1, 'element', ['something']]
```

9.5.2 Non-Continuous slices

It is also possible to get non-continuous parts of an array. If one wanted to get every n-th occurrence of a list, one would use the :: operator. The syntax is a:b:n where a and b are the start and end of the slice to be operated upon.

```
>>> list = [i for i in range(10) ]
>>> list
[0, 1, 2, 3, 4, 5, 6, 7, 8, 9]
>>> list[::2]
[0, 2, 4, 6, 8]
>>> list[1:7:2]
[1, 3, 5]
```

9.6 Comparing lists

Lists can be compared for equality.

```
>>> [1,2] == [1,2]
True
>>> [1,2] == [3,4]
False
```

Lists can be compared using a less-than operator, which uses lexicographical order:

```
>>> [1,2] < [2,1]
True
>>> [2,2] < [2,1]
False
>>> ["a","b"] < ["b","a"]
True
```

9.7 Sorting lists

Sorting lists is easy with a sort method.

```
>>> list = [2, 3, 1, 'a', 'b']
>>> list.sort()
>>> list
[1, 2, 3, 'a', 'b']
```

Note that the list is sorted in place, and the sort() method returns **None** to emphasize this side effect.

If you use Python 2.4 or higher there are some more sort parameters:

sort(cmp,key,reverse)

cmp : method to be used for sorting key : function to be executed with key element. List is sorted by return-value of the function reverse : sort(reverse=True) or sort(reverse=False)

Python also includes a sorted() function.

```
>>> list = [5, 2, 3, 'q', 'p']
>>> sorted(list)
[2, 3, 5, 'p', 'q']
>>> list
[5, 2, 3, 'q', 'p']
```

Note that unlike the sort() method, sorted(list) does not sort the list in place, but instead returns the sorted list. The sorted() function, like the sort() method also accepts the reverse parameter.

9.8 Iteration

Iteration over lists:

Read-only iteration over a list, AKA for each element of the list:

```
list1 = [1, 2, 3, 4]
for item in list1:
  print item
```

Writable iteration over a list:

```
list1 = [1, 2, 3, 4]
for i in range(0, len(list1)):
  list1[i]+=1 # Modify the item at an index as you see fit
print list
```

From a number to a number with a step:

```
for i in range(1, 13+1, 3): # For i=1 to 13 step 3
  print i
for i in range(10, 5-1, -1): # For i=10 to 5 step -1
  print i
```

For each element of a list satisfying a condition (filtering):

```
for item in list:
  if not condition(item):
    continue
  print item
```

See also ../Loops#For_Loops[3].

3 http://en.wikibooks.org/wiki/..%2FLoops%23For_Loops

9.9 Removing

Removing aka deleting an item at an index (see also #pop(i)[4]):

```
list = [1, 2, 3, 4]
list.pop() # Remove the last item
list.pop(0) # Remove the first item , which is the item at index 0
print list

list = [1, 2, 3, 4]
del list[1] # Remove the 2nd element; an alternative to list.pop(1)
print list
```

Removing an element by value:

```
list = ["a", "a", "b"]
list.remove("a") # Removes only the 1st occurrence of "a"
print list
```

Keeping only items in a list satisfying a condition, and thus removing the items that do not satisfy it:

```
list = [1, 2, 3, 4]
newlist = [item for item in list if item >2]
print newlist
```

This uses a list comprehension[5].

9.10 Aggregates

There are some built-in functions for arithmetic aggregates over lists. These include minimum, maximum, and sum:

```
list = [1, 2, 3, 4]
print max(list), min(list), sum(list)
average = sum(list) / float(len(list)) # Provided the list is non-empty
# The float above ensures the division is a float one rather than integer one.
print average
```

The max and min functions also apply to lists of strings, returning maximum and minimum with respect to alphabetical order:

```
list = ["aa", "ab"]
print max(list), min(list) # Prints "ab aa"
```

9.11 Copying

Copying AKA cloning of lists:

Making a shallow copy:

4 Chapter 9.13.2 on page 40
5 Chapter 9.2.2 on page 32

```
list1= [1, 'element']
list2 = list1[:] # Copy using "[:]"
list2[0] = 2 # Only affects list2, not list1
print list1[0] # Displays 1

# By contrast
list1 = [1, 'element']
list2 = list1
list2[0] = 2 # Modifies the original list
print list1[0] # Displays 2
```

The above does not make a deep copy, which has the following consequence:

```
list1 = [1, [2, 3]] # Notice the second item being a nested list
list2 = list1[:] # A shallow copy
list2[1][0] = 4 # Modifies the 2nd item of list1 as well
print list1[1][0] # Displays 4 rather than 2
```

Making a deep copy:

```
import copy
list1 = [1, [2, 3]] # Notice the second item being a nested list
list2 = copy.deepcopy(list1) # A deep copy
list2[1][0] = 4 # Leaves the 2nd item of list1 unmodified
print list1[1][0] # Displays 2
```

See also #Continuous slices[6].

Links:

- 8.17. copy — Shallow and deep copy operations[7] at docs.python.org

9.12 Clearing

Clearing a list:

```
del list1[:] # Clear a list
list1 = []   # Not really clear but rather assign to a new empty list
```

Clearing using a proper approach makes a difference when the list is passed as an argument:

```
def workingClear(ilist):
  del ilist[:]
def brokenClear(ilist):
  ilist = [] # Lets ilist point to a new list, losing the reference to the
 argument list
list1=[1, 2]; workingClear(list1); print list1
list1=[1, 2]; brokenClear(list1); print list1
```

Keywords: emptying a list, erasing a list, clear a list, empty a list, erase a list.

6 Chapter 9.5.1 on page 35
7 http://docs.python.org/2/library/copy.html

9.13 List methods

9.13.1 append(x)

Add item *x* onto the end of the list.

```
>>> list = [1, 2, 3]
>>> list.append(4)
>>> list
[1, 2, 3, 4]
```

See pop(i)[8]

9.13.2 pop(i)

Remove the item in the list at the index *i* and return it. If *i* is not given, remove the the last item in the list and return it.

```
>>> list = [1, 2, 3, 4]
>>> a = list.pop(0)
>>> list
[2, 3, 4]
>>> a
1
>>> b = list.pop()
>>>list
[2, 3]
>>> b
4
```

9.14 operators

9.14.1 in

The operator 'in' is used for two purposes; either to iterate over every item in a list in a for loop, or to check if a value is in a list returning true or false.

```
>>> list = [1, 2, 3, 4]
>>> if 3 in list:
>>>    ....
>>> l = [0, 1, 2, 3, 4]
>>> 3 in l
True
>>> 18 in l
False
>>>for x in l:
>>>    print x
0
1
2
3
```

8 Chapter 9.13.2 on page 40

4

9.15 Subclassing

In a modern version of Python [which one?], there is a class called 'list'. You can make your own subclass of it, and determine list behaviour which is different from the default standard.

9.16 Exercises

1. Use a list comprehension to construct the list ['ab', 'ac', 'ad', 'bb', 'bc', 'bd'].
2. Use a slice on the above list to construct the list ['ab', 'ad', 'bc'].
3. Use a list comprehension to construct the list ['1a', '2a', '3a', '4a'].
4. Simultaneously remove the element '2a' from the above list and print it.
5. Copy the above list and add '2a' back into the list such that the original is still missing it.
6. Use a list comprehension to construct the list ['abe', 'abf', 'ace', 'acf', 'ade', 'adf', 'bbe', 'bbf', 'bce', 'bcf', 'bde', 'bdf']

9.17 External links

- Python documentation, chapter "Sequence Types"[9] -- python.org
- Python Tutorial, chapter "Lists"[10] -- python.org

}}

9 `http://docs.python.org/2/library/stdtypes.html?highlight=rstrip#sequence-types-str-unicode-list-tuple-bytearray-buffer-xrange`
10 `http://docs.python.org/2/tutorial/introduction.html#lists`

10 Dictionaries

A dictionary in Python is a collection of unordered values accessed by key rather than by index. The keys have to be hashable: integers, floating point numbers, strings, tuples, and frozensets are hashable, while lists, dictionaries, and sets other than frozensets are not. Dictionaries were available as early as in Python 1.4.

10.1 Overview

Dictionaries in Python at a glance:

```
dict1 = {}                      # Create an empty dictionary
dict2 = dict()                  # Create an empty dictionary 2
dict2 = {"r": 34, "i": 56}      # Initialize to non-empty value
dict3 = dict([("r", 34), ("i", 56)]) # Init from a list of tuples
dict4 = dict(r=34, i=56)        # Initialize to non-empty value 3
dict1["temperature"] = 32       # Assign value to a key
if "temperature" in dict1:      # Membership test of a key AKA key exists
  del dict1["temperature"]      # Delete AKA remove
equalbyvalue = dict2 == dict3
itemcount2 = len(dict2)         # Length AKA size AKA item count
isempty2 = len(dict2) == 0      # Emptiness test
for key in dict2:               # Iterate via keys
  print key, dict2[key]         # Print key and the associated value
  dict2[key] += 10              # Modify-access to the key-value pair
for value in dict2.values():    # Iterate via values
  print value
dict5 = {} # {x: dict2[x] + 1 for x in dict2 } # Dictionary comprehension in
 Python 2.7 or later
dict6 = dict2.copy()              # A shallow copy
dict6.update({"i": 60, "j": 30}) # Add or overwrite
dict7 = dict2.copy()
dict7.clear()                   # Clear AKA empty AKA erase
print dict1, dict2, dict3, dict4, dict5, dict6, dict7, equalbyvalue, itemcount2
```

10.2 Dictionary notation

Dictionaries may be created directly or converted from sequences. Dictionaries are enclosed in curly braces, `{}`

```
>>> d = {'city':'Paris', 'age':38, (102,1650,1601):'A matrix coordinate'}
>>> seq = [('city','Paris'), ('age', 38), ((102,1650,1601),'A matrix
 coordinate')]
>>> d
{'city': 'Paris', 'age': 38, (102, 1650, 1601): 'A matrix coordinate'}
>>> dict(seq)
{'city': 'Paris', 'age': 38, (102, 1650, 1601): 'A matrix coordinate'}
>>> d == dict(seq)
True
```

Also, dictionaries can be easily created by zipping two sequences.

```
>>> seq1 = ('a','b','c','d')
>>> seq2 = [1,2,3,4]
>>> d = dict(zip(seq1,seq2))
>>> d
{'a': 1, 'c': 3, 'b': 2, 'd': 4}
```

10.3 Operations on Dictionaries

The operations on dictionaries are somewhat unique. Slicing is not supported, since the items have no intrinsic order.

```
>>> d = {'a':1,'b':2, 'cat':'Fluffers'}
>>> d.keys()
['a', 'b', 'cat']
>>> d.values()
[1, 2, 'Fluffers']
>>> d['a']
1
>>> d['cat'] = 'Mr. Whiskers'
>>> d['cat']
'Mr. Whiskers'
>>> 'cat' in d
True
>>> 'dog' in d
False
```

10.4 Combining two Dictionaries

You can combine two dictionaries by using the update method of the primary dictionary. Note that the update method will merge existing elements if they conflict.

```
>>> d = {'apples': 1, 'oranges': 3, 'pears': 2}
>>> ud = {'pears': 4, 'grapes': 5, 'lemons': 6}
>>> d.update(ud)
>>> d
{'grapes': 5, 'pears': 4, 'lemons': 6, 'apples': 1, 'oranges': 3}
>>>
```

10.5 Deleting from dictionary

```
del dictionaryName[membername]
```

10.6 Exercises

Write a program that:

1. Asks the user for a string, then creates the following dictionary. The values are the letters in the string, with the corresponding key being the place in the string.
2. Replaces the entry whose key is the integer 3, with the value ”Pie”.
3. Asks the user for a string of digits, then prints out the values corresponding to those digits.

10.7 External links

- Python documentation, chapter ”Dictionaries”[1] -- python.org
- Python documentation, The Python Standard Library, 5.8. Mapping Types[2] -- python.org

1 `http://docs.python.org/2/tutorial/datastructures.html#dictionaries`
2 `http://docs.python.org/2/library/stdtypes.html#typesmapping`

11 Sets

Starting with version 2.3, Python comes with an implementation of the mathematical set. Initially this implementation had to be imported from the standard module `set` , but with Python 2.6 the types set and frozenset[1] became built-in types. A set is an unordered collection of objects, unlike sequence objects such as lists and tuples, in which each element is indexed. Sets cannot have duplicate members - a given object appears in a set 0 or 1 times. All members of a set have to be hashable, just like dictionary keys. Integers, floating point numbers, tuples, and strings are hashable; dictionaries, lists, and other sets (except frozensets) are not.

11.0.1 Overview

Sets in Python at a glance:

```
set1 = set()                   # A new empty set
set1.add("cat")                # Add a single member
set1.update(["dog", "mouse"])  # Add several members
if "cat" in set1:              # Membership test
  set1.remove("cat")
#set1.remove("elephant") - throws an error
print set1
for item in set1:              # Iteration AKA for each element
  print item
print "Item count:", len(set1) # Length AKA size AKA item count
isempty = len(set1) == 0       # Test for emptiness
set1 = set(["cat", "dog"])     # Initialize set from a list
set2 = set(["dog", "mouse"])
set3 = set1 & set2             # Intersection
set4 = set1 | set2             # Union
set5 = set1 - set3             # Set difference
set6 = set1 ^ set2             # Symmetric difference
issubset = set1 <= set2        # Subset test
issuperset = set1 >= set2      # Superset test
set7 = set1.copy()             # A shallow copy
set7.remove("cat")
set8 = set1.copy()
set8.clear()                   # Clear AKA empty AKA erase
print set1, set2, set3, set4, set5, set6, set7, set8, issubset, issuperset
```

11.0.2 Constructing Sets

One way to construct sets is by passing any sequential object to the ”set” constructor.

```
>>> set([0, 1, 2, 3])
set([0, 1, 2, 3])
```

1 Chapter 11.0.8 on page 51

```
>>> set("obtuse")
set(['b', 'e', 'o', 's', 'u', 't'])
```

We can also add elements to sets one by one, using the "add" function.

```
>>> s = set([12, 26, 54])
>>> s.add(32)
>>> s
set([32, 26, 12, 54])
```

Note that since a set does not contain duplicate elements, if we add one of the members of s to s again, the add function will have no effect. This same behavior occurs in the "update" function, which adds a group of elements to a set.

```
>>> s.update([26, 12, 9, 14])
>>> s
set([32, 9, 12, 14, 54, 26])
```

Note that you can give any type of sequential structure, or even another set, to the update function, regardless of what structure was used to initialize the set.

The set function also provides a copy constructor. However, remember that the copy constructor will copy the set, but not the individual elements.

```
>>> s2 = s.copy()
>>> s2
set([32, 9, 12, 14, 54, 26])
```

11.0.3 Membership Testing

We can check if an object is in the set using the same "in" operator as with sequential data types.

```
>>> 32 in s
True
>>> 6 in s
False
>>> 6 not in s
True
```

We can also test the membership of entire sets. Given two sets S_1 and S_2, we check if S_1 is a subset[2] or a superset of S_2.

```
>>> s.issubset(set([32, 8, 9, 12, 14, -4, 54, 26, 19]))
True
>>> s.issuperset(set([9, 12]))
True
```

Note that "issubset" and "issuperset" can also accept sequential data types as arguments

```
>>> s.issuperset([32, 9])
True
```

2 http://en.wikipedia.org/wiki/Subset

Note that the <= and >= operators also express the issubset and issuperset functions respectively.

```
>>> set([4, 5, 7]) <= set([4, 5, 7, 9])
True
>>> set([9, 12, 15]) >= set([9, 12])
True
```

Like lists, tuples, and string, we can use the ”len” function to find the number of items in a set.

11.0.4 Removing Items

There are three functions which remove individual items from a set, called pop, remove, and discard. The first, pop, simply removes an item from the set. Note that there is no defined behavior as to which element it chooses to remove.

```
>>> s = set([1,2,3,4,5,6])
>>> s.pop()
1
>>> s
set([2,3,4,5,6])
```

We also have the ”remove” function to remove a specified element.

```
>>> s.remove(3)
>>> s
set([2,4,5,6])
```

However, removing a item which isn't in the set causes an error.

```
>>> s.remove(9)
Traceback (most recent call last):
  File "<stdin>", line 1, in ?
KeyError: 9
```

If you wish to avoid this error, use ”discard.” It has the same functionality as remove, but will simply do nothing if the element isn't in the set

We also have another operation for removing elements from a set, clear, which simply removes all elements from the set.

```
>>> s.clear()
>>> s
set([])
```

11.0.5 Iteration Over Sets

We can also have a loop move over each of the items in a set. However, since sets are unordered, it is undefined which order the iteration will follow.

```
>>> s = set("blerg")
>>> for n in s:
...     print n,
...
r b e l g
```

11.0.6 Set Operations

Python allows us to perform all the standard mathematical set operations, using members of set. Note that each of these set operations has several forms. One of these forms, s1.function(s2) will return another set which is created by "function" applied to S_1 and S_2. The other form, s1.function_update(s2), will change S_1 to be the set created by "function" of S_1 and S_2. Finally, some functions have equivalent special operators. For example, s1 & s2 is equivalent to s1.intersection(s2)

Intersection

Any element which is in both S_1 and S_2 will appear in their intersection[3].

```
>>> s1 = set([4, 6, 9])
>>> s2 = set([1, 6, 8])
>>> s1.intersection(s2)
set([6])
>>> s1 & s2
set([6])
>>> s1.intersection_update(s2)
>>> s1
set([6])
```

Union

The union[4] is the merger of two sets. Any element in S_1 or S_2 will appear in their union.

```
>>> s1 = set([4, 6, 9])
>>> s2 = set([1, 6, 8])
>>> s1.union(s2)
set([1, 4, 6, 8, 9])
>>> s1 | s2
set([1, 4, 6, 8, 9])
```

Note that union's update function is simply "update" above[5].

Symmetric Difference

The symmetric difference[6] of two sets is the set of elements which are in one of either set, but not in both.

3 http://en.wikipedia.org/wiki/intersection_%28set_theory%29
4 http://en.wikipedia.org/wiki/union_%28set_theory%29
5 Chapter 11.0.2 on page 47
6 http://en.wikipedia.org/wiki/symmetric_difference

```
>>> s1 = set([4, 6, 9])
>>> s2 = set([1, 6, 8])
>>> s1.symmetric_difference(s2)
set([8, 1, 4, 9])
>>> s1 ^ s2
set([8, 1, 4, 9])
>>> s1.symmetric_difference_update(s2)
>>> s1
set([8, 1, 4, 9])
```

Set Difference

Python can also find the set difference[7] of S_1 and S_2, which is the elements that are in S_1 but not in S_2.

```
>>> s1 = set([4, 6, 9])
>>> s2 = set([1, 6, 8])
>>> s1.difference(s2)
set([9, 4])
>>> s1 - s2
set([9, 4])
>>> s1.difference_update(s2)
>>> s1
set([9, 4])
```

11.0.7 Multiple sets

Starting with Python 2.6, "union", "intersection", and "difference" can work with multiple input by using the set constructor. For example, using "set.intersection()":

```
>>> s1 = set([3, 6, 7, 9])
>>> s2 = set([6, 7, 9, 10])
>>> s3 = set([7, 9, 10, 11])
>>> set.intersection(s1, s2, s3)
set([9, 7])
```

11.0.8 frozenset

A frozenset is basically the same as a set, except that it is immutable - once it is created, its members cannot be changed. Since they are immutable, they are also hashable, which means that frozensets can be used as members in other sets and as dictionary keys. frozensets have the same functions as normal sets, except none of the functions that change the contents (update, remove, pop, etc.) are available.

```
>>> fs = frozenset([2, 3, 4])
>>> s1 = set([fs, 4, 5, 6])
>>> s1
set([4, frozenset([2, 3, 4]), 6, 5])
>>> fs.intersection(s1)
frozenset([4])
>>> fs.add(6)
```

7 http://en.wikipedia.org/wiki/Complement_%28set_theory%29%23Relative_Complement

```
Traceback (most recent call last):
  File "<stdin>", line 1, in <module>
AttributeError: 'frozenset' object has no attribute 'add'
```

11.0.9 Exercises

1. Create the set {'cat', 1, 2, 3}, call it s.
2. Create the set {'c', 'a', 't', '1', '2', '3'}.
3. Create the frozen set {'cat', 1, 2, 3}, call it fs.
4. Create a set containing the frozenset fs, it should look like {frozenset({'cat', 2, 3, 1})}.

11.0.10 Reference

- Python Tutorial, section "Data Structures", subsection "Sets"[8] -- python.org
- Python Library Reference on Set Types[9] -- python.org

8 http://docs.python.org/2/tutorial/datastructures.html#sets
9 http://docs.python.org/library/stdtypes.html#set-types-set-frozenset

12 Operators

12.1 Basics

Python math works like you would expect.

```
>>> x = 2
>>> y = 3
>>> z = 5
>>> x * y
6
>>> x + y
5
>>> x * y + z
11
>>> (x + y) * z
25
```

Note that Python adheres to the PEMDAS order of operations[1].

12.2 Powers

There is a built in exponentiation operator **, which can take either integers, floating point or complex numbers. This occupies its proper place in the order of operations.

```
>>> 2**8
256
```

12.3 Division and Type Conversion

For Python 2.x, dividing two integers or longs uses integer division, also known as "floor division" (applying the floor function[2] after division. So, for example, 5 / 2 is 2. Using "/" to do division this way is deprecated; if you want floor division, use "//" (available in Python 2.2 and later).

"/" does "true division" for floats and complex numbers; for example, 5.0/2.0 is 2.5.

For Python 3.x, "/" does "true division" for all types.[3][4]

1 http://en.wikipedia.org/wiki/Order%20of%20operations%20
2 http://en.wikipedia.org/wiki/Floor%20function
3 [http://www.python.org/doc/2.2.3/whatsnew/node7.html What's New in Python 2.2
4 PEP 238 -- Changing the Division Operator ^{http://www.python.org/dev/peps/pep-0238/}

Dividing by or into a floating point number (there are no fractional types in Python) will cause Python to use true division. To coerce an integer to become a float, 'float()' with the integer as a parameter

```
>>> x = 5
>>> float(x)
5.0
```

This can be generalized for other numeric types: int(), complex(), long().

Beware that due to the limitations of floating point arithmetic[5], rounding errors can cause unexpected results. For example:

```
>>> print 0.6/0.2
3.0
>>> print 0.6//0.2
2.0
```

12.4 Modulo

The modulus (remainder of the division of the two operands, rather than the quotient) can be found using the % operator, or by the divmod builtin function. The divmod function returns a tuple containing the quotient and remainder.

```
>>> 10%7
3
```

12.5 Negation

Unlike some other languages, variables can be negated directly:

```
>>> x = 5
>>> -x
-5
```

12.6 Comparison

Numbers, strings and other types can be compared for equality/inequality and ordering:

```
>>> 2 == 3
False
>>> 3 == 3
True
>>> 2 < 3
True
```

5 http://en.wikipedia.org/wiki/floating%20point

```
>>> "a" < "aa"
True
```

12.7 Identity

The operators `is` and `is not` test for object identity: `x is y` is true if and only if x and y are references to the same object in memory. `x is not y` yields the inverse truth value. Note that an identity test is more stringent than an equality test since two distinct objects may have the same value.

```
>>> [1,2,3] == [1,2,3]
True
>>> [1,2,3] is [1,2,3]
False
```

For the built-in immutable data types[6] (like int, str and tuple) Python uses caching mechanisms to improve performance, i.e., the interpreter may decide to reuse an existing immutable object instead of generating a new one with the same value. The details of object caching are subject to changes between different Python versions and are not guaranteed to be system-independent, so identity checks on immutable objects like `'hello' is 'hello'` , `(1,2,3) is (1,2,3)` , `4 is 2**2` may give different results on different machines.

12.8 Augmented Assignment

There is shorthand for assigning the output of an operation to one of the inputs:

```
>>> x = 2
>>> x # 2
2
>>> x *= 3
>>> x # 2 * 3
6
>>> x += 4
>>> x # 2 * 3 + 4
10
>>> x /= 5
>>> x # (2 * 3 + 4) / 5
2
>>> x **= 2
>>> x # ((2 * 3 + 4) / 5) ** 2
4
>>> x %= 3
>>> x # ((2 * 3 + 4) / 5) ** 2 % 3
1

>>> x = 'repeat this  '
>>> x  # repeat this
repeat this
>>> x *= 3  # fill with x repeated three times
>>> x
repeat this  repeat this  repeat this
```

6 Chapter 7 on page 19

12.9 Boolean

or:

```
if a or b:
    do_this
else:
    do_this
```

and:

```
if a and b:
    do_this
else:
    do_this
```

not:

```
if not a:
    do_this
else:
    do_this
```

The order of operations here is: "not" first, "and" second, "or" third. In particular, "True or True and False or False" becomes "True or False or False" which is True.

Caution, Boolean operators are valid on things other than Booleans; for instance "1 and 6" will return 6. Specifically, "and" returns either the first value considered to be false, or the last value if all are considered true. "or" returns the first true value, or the last value if all are considered false.

12.10 Exercises

1. Use Python to calculate $2^{2^{2^2}} = 65536$.
2. Use Python to calculate $\frac{(3+2)^4}{7} \approx 89.285$.
3. Use Python to calculate 11111111111111111111+22222222222222222222, but in one line of code with at most 15 characters. (Hint: each of those numbers is 20 digits long, so you have to find some other way to input those numbers)
4. Exactly one of the following expressions evaluates to "cat"; the other evaluates to "dog". Trace the logic to determine which one is which, then check your answer using Python.

```
1 and "cat" or "dog"
0 and "cat" or "dog"
```

12.11 References

13 Flow control

14 Functions

14.1 Function Calls

A *callable object* is an object that can accept some arguments (also called parameters) and possibly return an object (often a tuple containing multiple objects).

A function is the simplest callable object in Python, but there are others, such as classes[1] or certain class instances.

Defining Functions

A function is defined in Python by the following format:

```
def functionname(arg1, arg2, ...):
    statement1
    statement2
    ...
```

```
>>> def functionname(arg1,arg2):
...     return arg1+arg2
...
>>> t = functionname(24,24) # Result: 48
```

If a function takes no arguments, it must still include the parentheses, but without anything in them:

```
def functionname():
    statement1
    statement2
    ...
```

The arguments in the function definition bind the arguments passed at function invocation (i.e. when the function is called), which are called actual parameters, to the names given when the function is defined, which are called formal parameters. The interior of the function has no knowledge of the names given to the actual parameters; the names of the actual parameters may not even be accessible (they could be inside another function).

A function can 'return' a value, for example:

```
def square(x):
    return x*x
```

1 Chapter 19 on page 79

A function can define variables within the function body, which are considered 'local' to the function. The locals together with the arguments comprise all the variables within the scope of the function. Any names within the function are unbound when the function returns or reaches the end of the function body.

You can **return multiple values** as follows:

```
def first2items(list1):
  return list1[0], list1[1]
a, b = first2items(["Hello", "world", "hi", "universe"])
print a + " " + b
```

Keywords: returning multiple values, multiple return values.

14.1.1 Declaring Arguments

When calling a function that takes some values for further processing, we need to send some values as Function **Arguments** . For example:

```
>>> def find_max(a,b):
   if(a>b):
      print "a is greater than b"
   else:
      print "b is greater than a"
>>> find_max(30,45)  #Here (30,45) are the arguments passing for finding max
 between this two numbers
```

Default Argument Values

If any of the formal parameters in the function definition are declared with the format "arg = value," then you will have the option of not specifying a value for those arguments when calling the function. If you do not specify a value, then that parameter will have the default value given when the function executes.

```
>>> def display_message(message, truncate_after=4):
...     print message[:truncate_after]
...
>>> display_message("message")
mess
>>> display_message("message", 6)
messag
```

Links:

- 4.7.1. Default Argument Values[2], The Python Tutorial, docs.python.org

2 http://docs.python.org/2/tutorial/controlflow.html#default-argument-values

Variable-Length Argument Lists

Python allows you to declare two special arguments which allow you to create arbitrary-length argument lists. This means that each time you call the function, you can specify any number of arguments above a certain number.

```
def function(first,second,*remaining):
    statement1
    statement2
    ...
```

When calling the above function, you must provide value for each of the first two arguments. However, since the third parameter is marked with an asterisk, any actual parameters after the first two will be packed into a tuple and bound to "remaining."

```
>>> def print_tail(first,*tail):
...     print tail
...
>>> print_tail(1, 5, 2, "omega")
(5, 2, 'omega')
```

If we declare a formal parameter prefixed with *two* asterisks, then it will be bound to a dictionary containing any keyword arguments in the actual parameters which do not correspond to any formal parameters. For example, consider the function:

```
def make_dictionary(max_length=10, **entries):
    return dict([(key, entries[key]) for i, key in enumerate(entries.keys()) if
 i < max_length])
```

If we call this function with any keyword arguments other than max_length, they will be placed in the dictionary "entries." If we include the keyword argument of max_length, it will be bound to the formal parameter max_length, as usual.

```
>>> make_dictionary(max_length=2, key1=5, key2=7, key3=9)
{'key3': 9, 'key2': 7}
```

Links:

- 4.7.3. Arbitrary Argument Lists[3], The Python Tutorial, docs.python.org

By Value and by Reference

Objects passed as arguments to functions are passed *by reference* ; they are not being copied around. Thus, passing a large list as an argument does not involve copying all its members to a new location in memory. Note that even integers are objects. However, the distinction of *by value* and *by reference* present in some other programming languages often serves to distinguish whether the passed arguments can be *actually changed* by the called function and whether the *calling function can see the changes* .

Passed objects of *mutable* types such as lists and dictionaries can be changed by the called function and the changes are visible to the calling function. Passed objects of *immutable*

3 http://docs.python.org/2/tutorial/controlflow.html#arbitrary-argument-lists

types such as integers and strings cannot be changed by the called function; the calling function can be certain that the called function will not change them. For mutability, see also Data Types[4] chapter.

An example:

```
def appendItem(ilist, item):
  ilist.append(item) # Modifies ilist in a way visible to the caller

def replaceItems(ilist, newcontentlist):
  del ilist[:]                 # Modification visible to the caller
  ilist.extend(newcontentlist) # Modification visible to the caller
  ilist = [5, 6] # No outside effect; lets the local ilist point to a new list
 object,
                # losing the reference to the list object passed as an argument
def clearSet(iset):
  iset.clear()

def tryToTouchAnInteger(iint):
  iint += 1 # No outside effect; lets the local iint to point to a new int
 object,
           # losing the reference to the int object passed as an argument
  print "iint inside:",iint # 4 if iint was 3 on function entry

list1 = [1, 2]
appendItem(list1, 3)
print list1 # [1, 2, 3]
replaceItems(list1, [3, 4])
print list1 # [3, 4]
set1 = set([1, 2])
clearSet(set1 )
print set1 # set([])
int1 = 3
tryToTouchAnInteger(int1)
print int1 # 3
```

14.1.2 Preventing Argument Change

An argument cannot be declared to be constant, not to be changed by the called function. If an argument is of an immutable type, it cannot be changed anyway, but if it is of a mutable type such as list, the calling function is at the mercy of the called function. Thus, if the calling function wants to make sure a passed list does not get changed, it has to pass a copy of the list.

An example:

```
def evilGetLength(ilist):
  length = len(ilist)
  del ilist[:] # Muhaha: clear the list
  return length

list1 = [1, 2]
print evilGetLength(list1) # list1 gets cleared
print list1
list1 = [1, 2]
print evilGetLength(list1[:]) # Pass a copy of list1
print list1
```

4 Chapter 7 on page 19

14.1.3 Calling Functions

A function can be called by appending the arguments in parentheses to the function name, or an empty matched set of parentheses if the function takes no arguments.

```
foo()
square(3)
bar(5, x)
```

A function's return value can be used by assigning it to a variable, like so:

```
x = foo()
y = bar(5,x)
```

As shown above, when calling a function you can specify the parameters by name and you can do so in any order

```
def display_message(message, start=0, end=4):
   print message[start:end]

display_message("message", end=3)
```

This above is valid and start will have the default value of 0. A restriction placed on this is after the first named argument then all arguments after it must also be named. The following is not valid

```
display_message(end=5, start=1, "my message")
```

because the third argument (”my message”) is an unnamed argument.

14.2 Closures

A *closure* is a nested function with an after-return access to the data of the outer function, where the nested function is returned by the outer function as a function object. Thus, even when the outer function has finished its execution after being called, the closure function returned by it can refer to the values of the variables that the outer function had when it defined the closure function.

An example:

```
def adder(outer_argument): # outer function
  def adder_inner(inner_argument): # inner function, nested function
    return outer_argument + inner_argument # Notice outer_argument
  return adder_inner
add5 = adder(5) # a function that adds 5 to its argument
add7 = adder(7) # a function that adds 7 to its argument
print add5(3) # prints 8
print add7(3) # prints 10
```

Closures are possible in Python because functions are *first-class objects* . A function is merely an object of type function. Being an object means it is possible to pass a function object (an uncalled function) around as argument or as return value or to assign another name to the function object. A unique feature that makes closure useful is that the enclosed function may use the names defined in the parent function's scope.

14.3 Lambda Expressions

A lambda is an anonymous (unnamed) function. It is used primarily to write very short functions that are a hassle to define in the normal way. A function like this:

```
>>> def add(a, b):
...    return a + b
...
>>> add(4, 3)
7
```

may also be defined using lambda

```
>>> print (lambda a, b: a + b)(4, 3)
7
```

Lambda is often used as an argument to other functions that expects a function object, such as sorted()'s 'key' argument.

```
>>> sorted([[3, 4], [3, 5], [1, 2], [7, 3]], key=lambda x: x[1])
[[1, 2], [7, 3], [3, 4], [3, 5]]
```

The lambda form is often useful as a closure, such as illustrated in the following example:

```
>>> def attribution(name):
...    return lambda x: x + ' -- ' + name
...
>>> pp = attribution('John')
>>> pp('Dinner is in the fridge')
'Dinner is in the fridge -- John'
```

Note that the lambda function can use the values of variables from the scope[5] in which it was created (like pre and post). This is the essence of closure.

Links:

- 4.7.5. Lambda Expressions[6], The Python Tutorial, docs.python.org

14.3.1 Generator Functions

When discussing loops, you can across the concept of an *iterator* . This yields in turn each element of some sequence, rather than the entire sequence at once, allowing you to deal with sequences much larger than might be able to fit in memory at once.

You can create your own iterators, by defining what is known as a *generator function* . To illustrate the usefulness of this, let us start by considering a simple function to return the *concatenation* of two lists:

```
def concat(a, b) :
    return a + b
#end concat
```

5 Chapter 15 on page 67
6 `http://docs.python.org/2/tutorial/controlflow.html#lambda-expressions`

```
print concat([5, 4, 3], ["a", "b", "c"])
# prints [5, 4, 3, 'a', 'b', 'c']
```

Imagine wanting to do something like `concat(range(0, 1000000), range(1000000, 2000000))`

That would work, but it would consume a lot of memory.

Consider an alternative definition, which takes two iterators as arguments:

```
def concat(a, b) :
    for i in a :
        yield i
    #end for
    for i in b :
        yield i
    #end b
#end concat
```

Notice the use of the **yield** statement, instead of **return** . We can now use this something like

```
for i in concat(xrange(0, 1000000), xrange(1000000, 2000000))
    print i
#end for
```

and print out an awful lot of numbers, without using a lot of memory at all.

Note:
You can still pass a list or other sequence type wherever Python expects an iterator (like to an argument of your `concat` function); this will still work, and makes it easy not to have to worry about the difference where you don't need to.

14.3.2 External Links

- 4.6. Defining Functions[7], The Python Tutorial, docs.python.org

de:Python unter Linux: Funktionen[8] es:Inmersión en Python/Su primer programa en Python/Declaración de funciones[9] fr:Programmation_Python/Fonction[10] pt:Python/Conceitos básicos/Funções[11]

7 http://docs.python.org/2/tutorial/controlflow.html#defining-functions
8 http://de.wikibooks.org/wiki/Python%20unter%20Linux%3A%20Funktionen
9 http://es.wikibooks.org/wiki/Inmersi%C3%B3n%20en%20Python%2FSu%20primer%20programa%20en%20Python%2FDeclaraci%C3%B3n%20de%20funciones
10 http://fr.wikibooks.org/wiki/Programmation_Python%2FFonction
11 http://pt.wikibooks.org/wiki/Python%2FConceitos%20b%C3%A1sicos%2FFun%C3%A7%C3%B5es

15 Scoping

15.0.3 Variables

Variables in Python are automatically declared by assignment. Variables are always references to objects, and are never typed. Variables exist only in the current scope or global scope. When they go out of scope, the variables are destroyed, but the objects to which they refer are not (unless the number of references to the object drops to zero).

Scope is delineated by function and class blocks. Both functions and their scopes can be nested. So therefore

```
def foo():
    def bar():
        x = 5 # x is now in scope
        return x + y # y is defined in the enclosing scope later
    y = 10
    return bar() # now that y is defined, bar's scope includes y
```

Now when this code is tested,

```
>>> foo()
15
>>> bar()
Traceback (most recent call last):
  File "<pyshell#26>", line 1, in -toplevel-
    bar()
NameError: name 'bar' is not defined
```

The name 'bar' is not found because a higher scope does not have access to the names lower in the hierarchy.

It is a common pitfall to fail to lookup an attribute (such as a method) of an object (such as a container) referenced by a variable before the variable is assigned the object. In its most common form:

```
>>> for x in range(10):
         y.append(x) # append is an attribute of lists

Traceback (most recent call last):
  File "<pyshell#46>", line 2, in -toplevel-
    y.append(x)
NameError: name 'y' is not defined
```

Here, to correct this problem, one must add y = [] before the for loop.

16 Exceptions

Python handles all errors with exceptions.

An *exception* is a signal that an error or other unusual condition has occurred. There are a number of built-in exceptions, which indicate conditions like reading past the end of a file, or dividing by zero. You can also define your own exceptions.

16.0.4 Raising exceptions

Whenever your program attempts to do something erroneous or meaningless, Python raises exception to such conduct:

```
>>> 1 / 0
Traceback (most recent call last):
    File "<stdin>", line 1, in ?
ZeroDivisionError: integer division or modulo by zero
```

This *traceback* indicates that the ZeroDivisionError exception is being raised. This is a built-in exception -- see below for a list of all the other ones.

16.0.5 Catching exceptions

In order to handle errors, you can set up *exception handling blocks* in your code. The keywords try and except are used to catch exceptions. When an error occurs within the try block, Python looks for a matching except block to handle it. If there is one, execution jumps there.

If you execute this code:

```
try:
    print 1/0
except ZeroDivisionError:
    print "You can't divide by zero, you're silly."
```

Then Python will print this:

You can’t divide by zero, you’re silly.

If you don’t specify an exception type on the except line, it will cheerfully catch all exceptions. This is generally a bad idea in production code, since it means your program will blissfully ignore *unexpected* errors as well as ones which the except block is actually prepared to handle.

Exceptions can propagate up the call stack:

```
def f(x):
    return g(x) + 1

def g(x):
    if x < 0: raise ValueError, "I can't cope with a negative number here."
    else: return 5

try:
    print f(-6)
except ValueError:
    print "That value was invalid."
```

In this code, the print statement calls the function f. That function calls the function g, which will raise an exception of type ValueError. Neither f nor g has a try/except block to handle ValueError. So the exception raised propagates out to the main code, where there *is* an exception-handling block waiting for it. This code prints:

That value was invalid.

Sometimes it is useful to find out exactly what went wrong, or to print the python error text yourself. For example:

```
try:
    the_file = open("the_parrot")
except IOError, (ErrorNumber, ErrorMessage):
    if ErrorNumber == 2: # file not found
        print "Sorry, 'the_parrot' has apparently joined the choir invisible."
    else:
        print "Congratulation! you have managed to trip a #%d error" %
 ErrorNumber
        print ErrorMessage
```

Which of course will print:

Sorry, 'the_parrot' has apparently joined the choir invisible.

Custom Exceptions

Code similar to that seen above can be used to create custom exceptions and pass information along with them. This can be extremely useful when trying to debug complicated projects. Here is how that code would look; first creating the custom exception class:

```
class CustomException(Exception):
    def __init__(self, value):
        self.parameter = value
    def __str__(self):
        return repr(self.parameter)
```

And then using that exception:

```
try:
    raise CustomException("My Useful Error Message")
except CustomException, (instance):
    print "Caught: " + instance.parameter
```

Trying over and over again

16.0.6 Recovering and continuing with finally

Exceptions could lead to a situation where, after raising an exception, the code block where the exception occurred might not be revisited. In some cases this might leave external resources used by the program in an unknown state.

`finally` clause allows programmers to close such resources in case of an exception. Between 2.4 and 2.5 version of python there is change of syntax for `finally` clause.

- Python 2.4

```
try:
    result = None
    try:
        result = x/y
    except ZeroDivisionError:
        print "division by zero!"
    print "result is ", result
finally:
    print "executing finally clause"
```

- Python 2.5

```
try:
    result = x / y
except ZeroDivisionError:
    print "division by zero!"
else:
    print "result is", result
finally:
    print "executing finally clause"
```

16.0.7 Built-in exception classes

All built-in Python exceptions[1]

16.0.8 Exotic uses of exceptions

Exceptions are good for more than just error handling. If you have a complicated piece of code to choose which of several courses of action to take, it can be useful to use exceptions to jump out of the code as soon as the decision can be made. The Python-based mailing list software Mailman does this in deciding how a message should be handled. Using exceptions like this may seem like it's a sort of GOTO -- and indeed it is, but a limited one called an *escape continuation* . Continuations are a powerful functional-programming tool and it can be useful to learn them.

Just as a simple example of how exceptions make programming easier, say you want to add items to a list but you don't want to use "if" statements to initialize the list we could replace this:

1 `http://docs.python.org/library/exceptions.html`

```
if hasattr(self, 'items'):
    self.items.extend(new_items)
else:
    self.items = list(new_items)
```

Using exceptions, we can emphasize the normal program flow—that usually we just extend the list—rather than emphasizing the unusual case:

```
try:
    self.items.extend(new_items)
except AttributeError:
    self.items = list(new_items)
```

17 Input and output

1. REDIRECT Python Programming/Input and Output[1]

1 Chapter 17 on page 73

18 Modules

Modules are a simple way to structure a program. Mostly, there are modules in the standard library and there are other Python files, or directories containing Python files, in the current directory (each of which constitute a module). You can also instruct Python to search other directories for modules by placing their paths in the PYTHONPATH environment variable.

18.1 Importing a Module

Modules in Python are used by importing them. For example,

```
import math
```

This imports the math standard module. All of the functions in that module are namespaced by the module name, i.e.

```
import math
print math.sqrt(10)
```

This is often a nuisance, so other syntaxes are available to simplify this,

```
from string import whitespace
from math import *
from math import sin as SIN
from math import cos as COS
from ftplib import FTP as ftp_connection
print sqrt(10)
```

The first statement means whitespace is added to the current scope (but nothing else is). The second statement means that all the elements in the math namespace is added to the current scope.

Modules can be three different kinds of things:

- Python files
- Shared Objects (under Unix and Linux) with the .so suffix
- DLL's (under Windows) with the .pyd suffix
- directories

Modules are loaded in the order they're found, which is controlled by sys.path. The current directory is always on the path.

Directories should include a file in them called __init__.py, which should probably include the other files in the directory.

Creating a DLL that interfaces with Python is covered in another section.

18.2 Creating a Module

18.2.1 From a File

The easiest way to create a module by having a file called mymod.py either in a directory recognized by the PYTHONPATH variable or (even easier) in the same directory where you are working. If you have the following file mymod.py

```
class Object1:
        def __init__(self):
                self.name = 'object 1'
```

you can already import this ”module” and create instances of the object *Object1* .

```
import mymod
myobject = mymod.Object1()
from mymod import *
myobject = Object1()
```

18.2.2 From a Directory

It is not feasible for larger projects to keep all classes in a single file. It is often easier to store all files in directories and load all files with one command. Each directory needs to have a `__init__.py` file which contains python commands that are executed upon loading the directory.

Suppose we have two more objects called `Object2` and `Object3` and we want to load all three objects with one command. We then create a directory called *mymod* and we store three files called `Object1.py` , `Object2.py` and `Object3.py` in it. These files would then contain one object per file but this not required (although it adds clarity). We would then write the following `__init__.py` file:

```
from Object1 import *
from Object2 import *
from Object3 import *

__all__ = ["Object1", "Object2", "Object3"]
```

The first three commands tell python what to do when somebody loads the module. The last statement defining __all__ tells python what to do when somebody executes *from mymod import ** . Usually we want to use parts of a module in other parts of a module, e.g. we want to use Object1 in Object2. We can do this easily with an *from . import ** command as the following file *Object2.py* shows:

```
from . import *

class Object2:
        def __init__(self):
                self.name = 'object 2'
                self.otherObject = Object1()
```

We can now start python and import *mymod* as we have in the previous section.

18.3 External links

- Python Documentation[1]

1 `http://docs.python.org/tutorial/modules.html`

19 Classes

Classes are a way of aggregating similar data and functions. A class is basically a scope inside which various code (especially function definitions) is executed, and the locals to this scope become *attributes* of the class, and of any objects constructed by this class. An object constructed by a class is called an *instance* of that class.

19.0.1 Defining a Class

To define a class, use the following format:

```
class ClassName:
    "Here is an explanation about your class"
    pass
```

The capitalization in this class definition is the convention, but is not required by the language. It's usually good to add at least a short explanation of what your class is supposed to do. The pass statement in the code above is just to say to the python interpreter just go on and do nothing. You can remove it as soon as you are adding your first statement.

19.0.2 Instance Construction

The class is a callable object that constructs an instance of the class when called. Let's say we create a class Foo.

```
class Foo:
    "Foo is our new toy."
    pass
```

To construct an instance of the class, Foo, "call" the class object:

```
f = Foo()
```

This constructs an instance of class Foo and creates a reference to it in f.

19.0.3 Class Members

In order to access the member of an instance of a class, use the syntax <class instance>.<member>. It is also possible to access the members of the class definition with <class name>.<member>.

Methods

A method is a function within a class. The first argument (methods must always take at least one argument) is always the instance of the class on which the function is invoked. For example

```
>>> class Foo:
...     def setx(self, x):
...         self.x = x
...     def bar(self):
...         print self.x
```

If this code were executed, nothing would happen, at least until an instance of Foo were constructed, and then bar were called on that instance.

Invoking Methods

Calling a method is much like calling a function, but instead of passing the instance as the first parameter like the list of formal parameters suggests, use the function as an attribute of the instance.

```
>>> f = Foo()
>>> f.setx(5)
>>> f.bar()
```

This will output

```
5
```

It is possible to call the method on an arbitrary object, by using it as an attribute of the defining class instead of an instance of that class, like so:

```
>>> Foo.setx(f,5)
>>> Foo.bar(f)
```

This will have the same output.

Dynamic Class Structure

As shown by the method setx above, the members of a Python class can change during runtime, not just their values, unlike classes in languages like C or Java. We can even delete f.x after running the code above.

```
>>> del f.x
>>> f.bar()
```

```
Traceback (most recent call last):
  File "<stdin>", line 1, in ?
  File "<stdin>", line 5, in bar
AttributeError: Foo instance has no attribute 'x'
```

Another effect of this is that we can change the definition of the Foo class during program execution. In the code below, we create a member of the Foo class definition named y. If we then create a new instance of Foo, it will now have this new member.

```
>>> Foo.y = 10
>>> g = Foo()
>>> g.y
10
```

Viewing Class Dictionaries

At the heart of all this is a dictionary[1] that can be accessed by "vars(ClassName)"

```
>>> vars(g)
{}
```

At first, this output makes no sense. We just saw that g had the member y, so why isn't it in the member dictionary? If you remember, though, we put y in the class definition, Foo, not g.

```
>>> vars(Foo)
{'y': 10, 'bar': <function bar at 0x4d6a3c>, '__module__': '__main__',
 'setx': <function setx at 0x4d6a04>, '__doc__': None}
```

And there we have all the members of the Foo class definition. When Python checks for g.member, it first checks g's vars dictionary for "member," then Foo. If we create a new member of g, it will be added to g's dictionary, but not Foo's.

```
>>> g.setx(5)
>>> vars(g)
{'x': 5}
```

Note that if we now assign a value to g.y, we are not assigning that value to Foo.y. Foo.y will still be 10, but g.y will now override Foo.y

```
>>> g.y = 9
>>> vars(g)
{'y': 9, 'x': 5}
>>> vars(Foo)
{'y': 10, 'bar': <function bar at 0x4d6a3c>, '__module__': '__main__',
 'setx': <function setx at 0x4d6a04>, '__doc__': None}
```

Sure enough, if we check the values:

```
>>> g.y
9
>>> Foo.y
10
```

Note that f.y will also be 10, as Python won't find 'y' in vars(f), so it will get the value of 'y' from vars(Foo).

1 Chapter 10 on page 43

Some may have also noticed that the methods in Foo appear in the class dictionary along with the x and y. If you remember from the section on lambda functions[2], we can treat functions just like variables. This means that we can assign methods to a class during runtime in the same way we assigned variables. If you do this, though, remember that if we call a method of a class instance, the first parameter passed to the method will always be the class instance itself.

Changing Class Dictionaries

We can also access the members dictionary of a class using the __dict__ member of the class.

```
>>> g.__dict__
{'y': 9, 'x': 5}
```

If we add, remove, or change key-value pairs from g.__dict__, this has the same effect as if we had made those changes to the members of g.

```
>>> g.__dict__['z'] = -4
>>> g.z
-4
```

19.0.4 New Style Classes

New style classes were introduced in python 2.2. A new-style class is a class that has a built-in as its base, most commonly object. At a low level, a major difference between old and new classes is their type. Old class instances were all of type `instance` . New style class instances will return the same thing as x.__class__ for their type. This puts user defined classes on a level playing field with built-ins. Old/Classic classes are slated to disappear in Python 3. With this in mind all development should use new style classes. New Style classes also add constructs like properties and static methods familiar to Java programmers.

Old/Classic Class

```
>>> class ClassicFoo:
...     def __init__(self):
...         pass
```

New Style Class

```
>>> class NewStyleFoo(object):
...     def __init__(self):
...         pass
```

Properties

Properties are attributes with getter and setter methods.

2 Chapter 14.3 on page 64

```
>>> class SpamWithProperties(object):
...     def __init__(self):
...         self.__egg = "MyEgg"
...     def get_egg(self):
...         return self.__egg
...     def set_egg(self, egg):
...         self.__egg = egg
...     egg = property(get_egg, set_egg)

>>> sp = SpamWithProperties()
>>> sp.egg
'MyEgg'
>>> sp.egg = "Eggs With Spam"
>>> sp.egg
'Eggs With Spam'
>>>
```

and since Python 2.6, with @property decorator

```
>>> class SpamWithProperties(object):
...     def __init__(self):
...         self.__egg = "MyEgg"
...     @property
...     def egg(self):
...         return self.__egg
...     @egg.setter
...     def egg(self, egg):
...         self.__egg = egg
```

Static Methods

Static methods in Python are just like their counterparts in C++ or Java. Static methods have no "self" argument and don't require you to instantiate the class before using them. They can be defined using staticmethod()

```
>>> class StaticSpam(object):
...     def StaticNoSpam():
...         print "You can't have have the spam, spam, eggs and spam without any
 spam... that's disgusting"
...     NoSpam = staticmethod(StaticNoSpam)

>>> StaticSpam.NoSpam()
'You can\'t have have the spam, spam, eggs and spam without any spam... that\'s
 disgusting'
```

They can also be defined using the function decorator @staticmethod.

```
>>> class StaticSpam(object):
...     @staticmethod
...     def StaticNoSpam():
...         print "You can't have have the spam, spam, eggs and spam without any
 spam... that's disgusting"
```

19.0.5 Inheritance

Like all object oriented languages, Python provides for inheritance. Inheritance is a simple concept by which a class can extend the facilities of another class, or in Python's case, multiple other classes. Use the following format for this:

```
class ClassName(superclass1,superclass2,superclass3,...):
    ...
```

The subclass will then have all the members of its superclasses. If a method is defined in the subclass and in the superclass, the member in the subclass will override the one in the superclass. In order to use the method defined in the superclass, it is necessary to call the method as an attribute on the defining class, as in Foo.setx(f,5) above:

```
>>> class Foo:
...     def bar(self):
...         print "I'm doing Foo.bar()"
...     x = 10
...
>>> class Bar(Foo):
...     def bar(self):
...         print "I'm doing Bar.bar()"
...         Foo.bar(self)
...     y = 9
...
>>> g = Bar()
>>> Bar.bar(g)
I'm doing Bar.bar()
I'm doing Foo.bar()
>>> g.y
9
>>> g.x
10
```

Once again, we can see what's going on under the hood by looking at the class dictionaries.

```
>>> vars(g)
{}
>>> vars(Bar)
{'y': 9, '__module__': '__main__', 'bar': <function bar at 0x4d6a04>,
 '__doc__': None}
>>> vars(Foo)
{'x': 10, '__module__': '__main__', 'bar': <function bar at 0x4d6994>,
 '__doc__': None}
```

When we call g.x, it first looks in the vars(g) dictionary, as usual. Also as above, it checks vars(Bar) next, since g is an instance of Bar. However, thanks to inheritance, Python will check vars(Foo) if it doesn't find x in vars(Bar).

19.0.6 Special Methods

There are a number of methods which have reserved names which are used for special purposes like mimicking numerical or container operations, among other things. All of these names begin and end with two underscores. It is convention that methods beginning with a single underscore are 'private' to the scope they are introduced within.

Initialization and Deletion

__init__

One of these purposes is constructing an instance, and the special name for this is '__init__'. __init__() is called before an instance is returned (it is not necessary to return the instance manually). As an example,

```
class A:
    def __init__(self):
        print 'A.__init__()'
a = A()
```

outputs

```
A.__init__()
```

__init__() can take arguments, in which case it is necessary to pass arguments to the class in order to create an instance. For example,

```
class Foo:
    def __init__ (self, printme):
        print printme
foo = Foo('Hi!')
```

outputs

```
Hi!
```

Here is an example showing the difference between using __init__() and not using __init__():

```
class Foo:
    def __init__ (self, x):
         print x
foo = Foo('Hi!')
class Foo2:
    def setx(self, x):
        print x
f = Foo2()
Foo2.setx(f,'Hi!')
```

outputs

```
Hi!
Hi!
```

__del__

Similarly, '__del__' is called when an instance is destroyed; e.g. when it is no longer referenced.

Representation

String Representation Override Functions	
Function	**Operator**
__str__	str(A)
__repr__	repr(A)
__unicode__	unicode(x) (2.x only)

__str__

Converting an object to a string, as with the print statement or with the str() conversion function, can be overridden by overriding __str__. Usually, __str__ returns a formatted version of the objects content. This will NOT usually be something that can be executed.For example:

```
class Bar:
    def __init__ (self, iamthis):
        self.iamthis = iamthis
    def __str__ (self):
        return self.iamthis
bar = Bar('apple')
print bar
```

outputs apple

__repr__

This function is much like __str__(). If __str__ is not present but this one is, this function's output is used instead for printing.__repr__ is used to return a representation of the object in string form. In general, it can be executed to get back the original object.For example:

```
class Bar:
    def __init__ (self, iamthis):
        self.iamthis = iamthis
    def __repr__(self):
        return "Bar('%s')" % self.iamthis
bar = Bar('apple')
bar
```

outputs (note the difference: now is not necessary to put it inside a print) Bar('apple')

Attributes

Attribute Override Functions		
Function	**Indirect form**	**Direct Form**
__getattr__	getattr(A, B)	A.B
__setattr__	setattr(A, B, C)	A.B = C
__delattr__	delattr(A, B)	del A.B

__setattr__

This is the function which is in charge of setting attributes of a class. It is provided with the name and value of the variables being assigned. Each class, of course, comes with a default __setattr__ which simply sets the value of the variable, but we can override it.

```
>>> class Unchangable:
...    def __setattr__(self, name, value):
...        print "Nice try"
...
>>> u = Unchangable()
>>> u.x = 9
Nice try
>>> u.x
```

Traceback (most recent call last): File "<stdin>", line 1, in ? AttributeError: Unchangable instance has no attribute 'x'

__getattr__

Similar to __setattr__, except this function is called when we try to access a class member, and the default simply returns the value.

```
>>> class HiddenMembers:
...     def __getattr__(self, name):
...         return "You don't get to see " + name
...
>>> h = HiddenMembers()
>>> h.anything
"You don't get to see anything"
```

__delattr__

This function is called to delete an attribute.

```
>>> class Permanent:
...     def __delattr__(self, name):
...         print name, "cannot be deleted"
...
>>> p = Permanent()
>>> p.x = 9
>>> del p.x
x cannot be deleted
>>> p.x
9
```

Operator Overloading

Operator overloading allows us to use the built-in Python syntax and operators to call functions which we define.

Binary Operators

Binary Operator Override Functions	
Function	**Operator**
__add__	A + B
__sub__	A - B
__mul__	A * B
__truediv__	A / B
__floordiv__	A // B
__mod__	A % B
__pow__	A ** B
__and__	A & B
__or__	A | B
__xor__	A ˆ B
__eq__	A == B
__ne__	A != B
__gt__	A > B
__lt__	A < B
__ge__	A >= B
__le__	A <= B
__lshift__	A << B
__rshift__	A >> B
__contains__	A in B A not in B

If a class has the __add__ function, we can use the '+' operator to add instances of the class. This will call __add__ with the two instances of the class passed as parameters, and the return value will be the result of the addition.

```
>>> class FakeNumber:
...     n = 5
...     def __add__(A,B):
...         return A.n + B.n
...
>>> c = FakeNumber()
>>> d = FakeNumber()
>>> d.n = 7
>>> c + d
12
```

To override the augmented assignment[3] operators, merely add 'i' in front of the normal binary operator, i.e. for '+=' use '__iadd__' instead of '__add__'. The function will be given one argument, which will be the object on the right side of the augmented assignment operator. The returned value of the function will then be assigned to the object on the left of the operator.

```
>>> c.__imul__ = lambda B: B.n - 6
>>> c *= d
>>> c
1
```

It is important to note that the augmented assignment[4] operators will also use the normal operator functions if the augmented operator function hasn't been set directly. This will work as expected, with "__add__" being called for "+=" and so on.

```
>>> c = FakeNumber()
>>> c += d
>>> c
12
```

3 Chapter 12.8 on page 55
4 Chapter 12.8 on page 55

Unary Operators

Unary Operator Override Functions	
Function	**Operator**
__pos__	+A
__neg__	-A
__inv__	~A
__abs__	abs(A)
__len__	len(A)

Unary operators will be passed simply the instance of the class that they are called on.

```
>>> FakeNumber.__neg__ = lambda A : A.n + 6
>>> -d
13
```

Item Operators

It is also possible in Python to override the indexing and slicing[5] operators. This allows us to use the class[i] and class[a:b] syntax on our own objects.The simplest form of item operator is __getitem__. This takes as a parameter the instance of the class, then the value of the index.

```
>>> class FakeList:
...     def __getitem__(self,index):
...         return index * 2
...
>>> f = FakeList()
>>> f['a']
'aa'
```

We can also define a function for the syntax associated with assigning a value to an item. The parameters for this function include the value being assigned, in addition to the parameters from __getitem__

```
>>> class FakeList:
...     def __setitem__(self,index,value):
...         self.string = index + " is now " + value
...
>>> f = FakeList()
>>> f['a'] = 'gone'
>>> f.string
'a is now gone'
```

We can do the same thing with slices. Once again, each syntax has a different parameter list associated with it.

```
>>> class FakeList:
...     def __getslice___(self,start,end):
...         return str(start) + " to " + str(end)
...
>>> f = FakeList()
>>> f[1:4]
'1 to 4'
```

Keep in mind that one or both of the start and end parameters can be blank in slice syntax. Here, Python has default value for both the start and the end, as show below.

```
>> f[:]
'0 to 2147483647'
```

Note that the default value for the end of the slice shown here is simply the largest possible signed integer on a 32-bit system, and may vary depending on your system and C compiler.

- __setslice__ has the parameters (self,start,end,value)

We also have operators for deleting items and slices.

- __delitem__ has the parameters (self,index)
- __delslice__ has the parameters (self,start,end)

Item Operator Override Functions	
Function	**Operator**
__getitem__	C[i]
__setitem__	C[i] = v
__delitem__	del C[i]
__getslice__	C[s:e]
__setslice__	C[s:e] = v
__delslice__	del C[s:e]

Other Overrides

Other Override Functions

Function	**Operator**
__cmp__	cmp(x, y)
__hash__	hash(x)
__nonzero__	bool(x)
__call__	f(x)
__iter__	iter(x)
__reversed__	reversed(x) (2.6+)
__divmod__	divmod(x, y)
__int__	int(x)
__long__	long(x)
__float__	float(x)
__complex__	complex(x)
__hex__	hex(x)
__oct__	oct(x)
__index__	
__copy__	copy.copy(x)
__deepcopy__	copy.deepcopy(x)
__sizeof__	sys.getsizeof(x) (2.6+)
__trunc__	math.trunc(x) (2.6+)
__format__	format(x, ...) (2.6+)

19.0.7 Programming Practices

The flexibility of python classes means that classes can adopt a varied set of behaviors. For the sake of understandability, however, it's best to use many of Python's tools sparingly. Try to declare all methods in the class definition, and always use the <class>.<member> syntax instead of __dict__ whenever possible. Look at classes in C++[6] and Java[7] to see what most programmers will expect from a class.

Encapsulation

Since all python members of a python class are accessible by functions/methods outside the class, there is no way to enforce encapsulation[8] short of overriding __getattr__, __setattr__ and __delattr__. General practice, however, is for the creator of a class or module to simply trust that users will use only the intended interface and avoid limiting access to the workings of the module for the sake of users who do need to access it. When using parts of a class or module other than the intended interface, keep in mind that the those parts may change in later versions of the module, and you may even cause errors or undefined behaviors in the module.since encapsulation is private.

Doc Strings

When defining a class, it is convention to document the class using a string literal at the start of the class definition. This string will then be placed in the __doc__ attribute of the class definition.

```
>>> class Documented:
...     """This is a docstring"""
...     def explode(self):
...         """
...         This method is documented, too! The coder is really serious about
...         making this class usable by others who don't know the code as well
...         as he does.
...
...         """
...         print "boom"
>>> d = Documented()
>>> d.__doc__
'This is a docstring'
```

Docstrings are a very useful way to document your code. Even if you never write a single piece of separate documentation (and let's admit it, doing so is the lowest priority for many coders), including informative docstrings in your classes will go a long way toward making them usable.

Several tools exist for turning the docstrings in Python code into readable API documentation, *e.g.* , EpyDoc[9].

6 http://en.wikibooks.org/wiki/C%2B%2B%20Programming%2FClasses
7 http://en.wikipedia.org/wiki/Class%20%28computer%20science%29%23Java
8 http://en.wikipedia.org/wiki/Information%20Hiding
9 http://epydoc.sourceforge.net/using.html

Don’t just stop at documenting the class definition, either. Each method in the class should have its own docstring as well. Note that the docstring for the method *explode* in the example class *Documented* above has a fairly lengthy docstring that spans several lines. Its formatting is in accordance with the style suggestions of Python’s creator, Guido van Rossum in PEP 8[10].

Adding methods at runtime

To a class

It is fairly easy to add methods to a class at runtime. Lets assume that we have a class called *Spam* and a function cook. We want to be able to use the function cook on all instances of the class Spam:

```
class Spam:
  def __init__(self):
    self.myeggs = 5

def cook(self):
  print "cooking %s eggs" % self.myeggs

Spam.cook = cook   #add the function to the class Spam
eggs = Spam()      #NOW create a new instance of Spam
eggs.cook()        #and we are ready to cook!
```

This will output

```
cooking 5 eggs
```

To an instance of a class

It is a bit more tricky to add methods to an instance of a class that has already been created. Lets assume again that we have a class called *Spam* and we have already created eggs. But then we notice that we wanted to cook those eggs, but we do not want to create a new instance but rather use the already created one:

```
class Spam:
  def __init__(self):
    self.myeggs = 5

eggs = Spam()

def cook(self):
  print "cooking %s eggs" % self.myeggs

import types
f = types.MethodType(cook, eggs, Spam)
eggs.cook = f
```

10 `http://www.python.org/dev/peps/pep-0008/`

```
eggs.cook()
```

Now we can cook our eggs and the last statement will output:

```
cooking 5 eggs
```

Using a function

We can also write a function that will make the process of adding methods to an instance of a class easier.

```
def attach_method(fxn, instance, myclass):
  f = types.MethodType(fxn, instance, myclass)
  setattr(instance, fxn.__name__, f)
```

All we now need to do is call the attach_method with the arguments of the function we want to attach, the instance we want to attach it to and the class the instance is derived from. Thus our function call might look like this:

```
attach_method(cook, eggs, Spam)
```

Note that in the function add_method we cannot write `instance.fxn = f` since this would add a function called fxn to the instance.

fr:Programmation Python/Programmation orienté objet[11] pt:Python/Conceitos básicos/Classes[12]

11 http://fr.wikibooks.org/wiki/Programmation%20Python%2FProgrammation%20orient%C3%A9%20objet
12 http://pt.wikibooks.org/wiki/Python%2FConceitos%20b%C3%A1sicos%2FClasses

20 Metaclasses

In Python, classes are themselves objects. Just as other objects are instances of a particular class, classes themselves are instances of a metaclass.

20.0.8 Python3

The Pep 3115[1] defines the changes to python 3 metaclasses. In python3 you have a method __prepare__ that is called in the metaclass to create a dictionary or other class to store the class members.[2] Then there is the __new__ method that is called to create new instances of that class. [3]

20.0.9 Class Factories

The simplest use of Python metaclasses is a class factory. This concept makes use of the fact that class definitions in Python are first-class objects. Such a function can create or modify a class definition, using the same syntax[4] one would normally use in declaring a class definition. Once again, it is useful to use the model of classes as dictionaries[5]. First, let's look at a basic class factory:

```
>>> def StringContainer():
...     # define a class
...     class String:
...             def __init__(self):
...                 self.content_string = ""
...             def len(self):
...                     return len(self.content_string)
...     # return the class definition
...     return String
...
>>> # create the class definition
... container_class = StringContainer()
>>>
>>> # create an instance of the class
... wrapped_string = container_class()
>>>
>>> # take it for a test drive
... wrapped_string.content_string = 'emu emissary'
>>> wrapped_string.len()
12
```

1 http://www.python.org/dev/peps/pep-3115/
2 http://www.python.org/dev/peps/pep-3115/
3 http://eli.thegreenplace.net/2011/08/14/python-metaclasses-by-example/
4 Chapter 19.0.1 on page 79
5 Chapter 19.0.3 on page 81

Of course, just like any other data in Python, class definitions can also be modified. Any modifications to attributes in a class definition will be seen in any instances of that definition, so long as that instance hasn't overridden the attribute that you're modifying.

```
>>> def DeAbbreviate(sequence_container):
...     sequence_container.length = sequence_container.len
...     del sequence_container.len
...
>>> DeAbbreviate(container_class)
>>> wrapped_string.length()
12
>>> wrapped_string.len()
 Traceback (most recent call last):
   File "<stdin>", line 1, in ?
 AttributeError: String instance has no attribute 'len'
```

You can also delete class definitions, but that will not affect instances of the class.

```
>>> del container_class
>>> wrapped_string2 = container_class()
Traceback (most recent call last):
  File "<stdin>", line 1, in ?
NameError: name 'container_class' is not defined
>>> wrapped_string.length()
12
```

20.0.10 The type Metaclass

The metaclass for all standard Python types is the "type" object.

```
>>> type(object)
<type 'type'>
>>> type(int)
<type 'type'>
>>> type(list)
<type 'type'>
```

Just like list, int and object, "type" is itself a normal Python object, and is itself an instance of a class. In this case, it is in fact an instance of itself.

```
>>> type(type)
<type 'type'>
```

It can be instantiated to create new class objects similarly to the class factory example above by passing the name of the new class, the base classes to inherit from, and a dictionary defining the namespace to use.

For instance, the code:

```
>>> class MyClass(BaseClass):
...     attribute = 42
```

Could also be written as:

```
>>> MyClass = type("MyClass", (BaseClass,), {'attribute' : 42})
```

20.0.11 Metaclasses

It is possible to create a class with a different metaclass than type by setting its __metaclass__ attribute when defining. When this is done, the class, and its subclass will be created using your custom metaclass. For example

```
class CustomMetaclass(type):
    def __init__(cls, name, bases, dct):
        print "Creating class %s using CustomMetaclass" % name
        super(CustomMetaclass, cls).__init__(name, bases, dct)

class BaseClass(object):
    __metaclass__ = CustomMetaclass

class Subclass1(BaseClass):
    pass
```

This will print

```
Creating class BaseClass using CustomMetaclass
Creating class Subclass1 using CustomMetaclass
```

By creating a custom metaclass in this way, it is possible to change how the class is constructed. This allows you to add or remove attributes and methods, register creation of classes and subclasses creation and various other manipulations when the class is created.

20.0.12 More resources

- Wikipedia article on Aspect Oriented Programming[6]
- Unifying types and classes in Python 2.2[7]
- O'Reilly Article on Python Metaclasses[8]

20.0.13 References

6 http://en.wikipedia.org/wiki/Aspect-oriented_programming
7 http://www.python.org/2.2/descrintro.html
8 http://www.onlamp.com/pub/a/python/2003/04/17/metaclasses.html

21 Reflection

A Python script can find out about the type, class, attributes and methods of an object. This is referred to as **reflection** or **introspection** . See also ../Metaclasses/[1].

Reflection-enabling functions include type(), isinstance(), callable(), dir() and getattr().

21.1 Type

The type method enables to find out about the type of an object. The following tests return True:

- type(3) is int
- type('Hello') is str
- type([1, 2]) is list
- type([1, [2, 'Hello']]) is list
- type({'city': 'Paris'}) is dict

21.2 Isinstance

Determines whether an object is an instance of a class.

The following returns True:

- isinstance(3, int)
- isinstance([1, 2], list)

Note that isinstance provides a weaker condition than a comparison using #Type[2].

21.3 Duck typing

Duck typing provides an indirect means of reflection. It is a technique consisting in using an object as if it was of the requested type, while catching exceptions resulting from the object not supporting some of the features of the class or type.

1 Chapter 20 on page 105
2 Chapter 21.1 on page 109

21.4 Callable

For an object, determines whether it can be called. A class can be made callable by providing a __call__() method.

Examples:

- callable(2)
  - Returns False. Ditto for callable("Hello") and callable([1, 2]).
- callable([1,2].pop)
  - Returns True, as pop without "()" returns a function object.
- callable([1,2].pop())
  - Returns False, as [1,2].pop() returns 2 rather than a function object.

21.5 Dir

Returns the list of attributes of an object, which includes methods.

Examples:

- dir(3)
- dir("Hello")
- dir([1, 2])

21.6 Getattr

Returns the value of an attribute of an object, given the attribute name passed as a string.

An example:

- getattr(3, "imag")

The list of attributes of an object can be obtained using #Dir[3].

21.7 External links

- 2. Built-in Functions[4], docs.python.org
- How to determine the variable type in Python?[5], stackoverflow.com
- Differences between isinstance() and type() in python[6], stackoverflow.com
- W:Reflection (computer_programming)#Python[7], Wikipedia
- W:Type introspection#Python[8], Wikipedia

3 Chapter 21.5 on page 110
4 `http://docs.python.org/2/library/functions.html`
5 `http://stackoverflow.com/questions/402504/how-to-determine-the-variable-type-in-python`
6 `http://stackoverflow.com/questions/1549801/differences-between-isinstance-and-type-in-python`
7 `http://en.wikipedia.org/wiki/Reflection%20%28computer_programming%29%23Python`
8 `http://en.wikipedia.org/wiki/Type%20introspection%23Python`

22 Regular Expression

Python includes a module for working with regular expressions on strings. For more information about writing regular expressions and syntax not specific to Python, see the regular expressions[1] wikibook. Python's regular expression syntax is similar to Perl's[2]

To start using regular expressions in your Python scripts, import the ”re” module:

```
import re
```

22.1 Overview

Regular expression functions in Python at a glance:

```
import re
if re.search("l+","Hello"):        print 1  # Substring match suffices
if not re.match("ell.","Hello"):   print 2  # The beginning of the string has to
 match
if re.match(".el","Hello"):        print 3
if re.match("he..o","Hello",re.I): print 4  # Case-insensitive match
print re.sub("l+", "l", "Hello")            # Prints "Helo"; replacement AKA
 substitution
print re.sub(r"(.*)\1", r"\1", "HeyHey")    # Prints "Hey"; backreference
for match in re.findall("l+.", "Hello Dolly"):
  print match                               # Prints "llo" and then "lly"
for match in re.findall("e(l+.)", "Hello Dolly"):
  print match                               # Prints "llo"; match picks group 1
matchObj = re.match("(Hello|Hi) (Tom|Thom)","Hello Tom Bombadil")
if matchObj is not None:
  print matchObj.group(0)                   # Prints the whole match
 disregarding groups
  print matchObj.group(1) + matchObj.group(2) # Prints "HelloTom"
```

22.2 Matching and searching

One of the most common uses for regular expressions is extracting a part of a string or testing for the existence of a pattern in a string. Python offers several functions to do this.

The match and search functions do mostly the same thing, except that the match function will only return a result if the pattern matches at the beginning of the string being searched, while search will find a match anywhere in the string.

1 http://en.wikibooks.org/wiki/regular%20expressions
2 http://en.wikibooks.org/wiki/Perl%20Programming%2FRegular%20Expressions%20Reference

```
>>> import re
>>> foo = re.compile(r'foo(.{,5})bar', re.I+re.S)
>>> st1 = 'Foo, Bar, Baz'
>>> st2 = '2. foo is bar'
>>> search1 = foo.search(st1)
>>> search2 = foo.search(st2)
>>> match1 = foo.match(st1)
>>> match2 = foo.match(st2)
```

In this example, match2 will be `None` , because the string `st2` does not start with the given pattern. The other 3 results will be Match objects (see below).

You can also match and search without compiling a regexp:

```
>>> search3 = re.search('oo.*ba', st1, re.I)
```

Here we use the search function of the re module, rather than of the pattern object. For most cases, its best to compile the expression first. Not all of the re module functions support the flags argument and if the expression is used more than once, compiling first is more efficient and leads to cleaner looking code.

The compiled pattern object functions also have parameters for starting and ending the search, to search in a substring of the given string. In the first example in this section, `match2` returns no result because the pattern does not start at the beginning of the string, but if we do:

```
>>> match3 = foo.match(st2, 3)
```

it works, because we tell it to start searching at character number 3 in the string.

What if we want to search for multiple instances of the pattern? Then we have two options. We can use the start and end position parameters of the search and match function in a loop, getting the position to start at from the previous match object (see below) or we can use the findall and finditer functions. The findall function returns a list of matching strings, useful for simple searching. For anything slightly complex, the finditer function should be used. This returns an iterator object, that when used in a loop, yields Match objects. For example:

```
>>> str3 = 'foo, Bar Foo. BAR FoO: bar'
>>> foo.findall(str3)
[', ', '. ', ': ']
>>> for match in foo.finditer(str3):
...     match.group(1)
...
', '
'. '
': '
```

If you're going to be iterating over the results of the search, using the finditer function is almost always a better choice.

22.2.1 Match objects

Match objects are returned by the search and match functions, and include information about the pattern match.

The group function returns a string corresponding to a capture group (part of a regexp wrapped in `()`) of the expression, or if no group number is given, the entire match. Using the `search1` variable we defined above:

```
>>> search1.group()
'Foo, Bar'
>>> search1.group(1)
', '
```

Capture groups can also be given string names using a special syntax and referred to by `matchobj.group('name')` . For simple expressions this is unnecessary, but for more complex expressions it can be very useful.

You can also get the position of a match or a group in a string, using the start and end functions:

```
>>> search1.start()
0
>>> search1.end()
8
>>> search1.start(1)
3
>>> search1.end(1)
5
```

This returns the start and end locations of the entire match, and the start and end of the first (and in this case only) capture group, respectively.

22.3 Replacing

Another use for regular expressions is replacing text in a string. To do this in Python, use the sub function.

sub takes up to 3 arguments: The text to replace with, the text to replace in, and, optionally, the maximum number of substitutions to make. Unlike the matching and searching functions, sub returns a string, consisting of the given text with the substitution(s) made.

```
>>> import re
>>> mystring = 'This string has a q in it'
>>> pattern = re.compile(r'(a[n]? )(\w) ')
>>> newstring = pattern.sub(r"\1'\2' ", mystring)
>>> newstring
"This string has a 'q' in it"
```

This takes any single alphanumeric character (\w in regular expression syntax) preceded by ”a” or ”an” and wraps in in single quotes. The `\1` and `\2` in the replacement string are backreferences to the 2 capture groups in the expression; these would be group(1) and group(2) on a Match object from a search.

The subn function is similar to sub, except it returns a tuple, consisting of the result string and the number of replacements made. Using the string and expression from before:

```
>>> subresult = pattern.subn(r"\1'\2' ", mystring)
>>> subresult
("This string has a 'q' in it", 1)
```

Replacing without constructing and compiling a pattern object:

```
>>> result = re.sub(r"b.*d","z","abccde")
>>> result
'aze'
```

22.4 Splitting

The split function splits a string based on a given regular expression:

```
>>> import re
>>> mystring = '1. First part 2. Second part 3. Third part'
>>> re.split(r'\d\.', mystring)
['', ' First part ', ' Second part ', ' Third part']
```

22.5 Escaping

The escape function escapes all non-alphanumeric characters in a string. This is useful if you need to take an unknown string that may contain regexp metacharacters like `(` and `.` and create a regular expression from it.

```
>>> re.escape(r'This text (and this) must be escaped with a "\" to use in a
 regexp.')
'This\\ text\\ \\(and\\ this\\)\\ must\\ be\\ escaped\\ with\\ a\\ \\"\\\\\\"\\
 to\\ use\\ in\\ a\\ regexp\\.'
```

22.6 Flags

The different flags use with regular expressions:

Abbreviation	Full name	Description
`re.I`	`re.IGNORECASE`	Makes the regexp case-insensitive[3]
`re.L`	`re.LOCALE`	Makes the behavior of some special sequences (`\w, \W, \b, \B, \s, \S`) dependent on the current locale[4]
`re.M`	`re.MULTILINE`	Makes the `^` and `$` characters match at the beginning and end of each line, rather than just the beginning and end of the string
`re.S`	`re.DOTALL`	Makes the `.` character match every character *including* newlines.
`re.U`	`re.UNICODE`	Makes `\w, \W, \b, \B, \d, \D, \s, \S` dependent on Unicode character properties

3 `http://en.wikipedia.org/wiki/case%20sensitivity`
4 `http://en.wikipedia.org/wiki/locale`

Abbreviation	Full name	Description
`re.X`	`re.VERBOSE`	Ignores whitespace except when in a character class or preceded by an non-escaped backslash, and ignores `#` (except when in a character class or preceded by an non-escaped backslash) and everything after it to the end of a line, so it can be used as a comment. This allows for cleaner-looking regexps.

22.7 Pattern objects

If you're going to be using the same regexp more than once in a program, or if you just want to keep the regexps separated somehow, you should create a pattern object, and refer to it later when searching/replacing.

To create a pattern object, use the compile function.

```
import re
foo = re.compile(r'foo(.{,5})bar', re.I+re.S)
```

The first argument is the pattern, which matches the string ”foo”, followed by up to 5 of any character, then the string ”bar”, storing the middle characters to a group, which will be discussed later. The second, optional, argument is the flag or flags to modify the regexp's behavior. The flags themselves are simply variables referring to an integer used by the regular expression engine. In other languages, these would be constants, but Python does not have constants. Some of the regular expression functions do not support adding flags as a parameter when defining the pattern directly in the function, if you need any of the flags, it is best to use the compile function to create a pattern object.

The `r` preceding the expression string indicates that it should be treated as a raw string. This should normally be used when writing regexps, so that backslashes are interpreted literally rather than having to be escaped.

22.8 External links

- Python `re` documentation[5] - Full documentation for the re module, including pattern objects and match objects

fr:Programmation Python/Regex[6]

5 `http://docs.python.org/library/re.html`
6 `http://fr.wikibooks.org/wiki/Programmation%20Python%2FRegex`

23 GUI Programming

There are various GUI toolkits to start with.

23.1 Tkinter

Tkinter, a Python wrapper for Tcl/Tk[1], comes bundled with Python (at least on Win32 platform though it can be installed on Unix/Linux and Mac machines) and provides a cross-platform GUI. It is a relatively simple to learn yet powerful toolkit that provides what appears to be a modest set of widgets. However, because the Tkinter widgets are extensible, many compound widgets can be created rather easily (e.g. combo-box, scrolled panes). Because of its maturity and extensive documentation Tkinter has been designated as the de facto GUI for Python.

To create a very simple Tkinter window frame one only needs the following lines of code:

```
import Tkinter

root = Tkinter.Tk()
root.mainloop()
```

From an object-oriented perspective one can do the following:

```
import Tkinter

class App:
    def __init__(self, master):
        button = Tkinter.Button(master, text="I'm a Button.")
        button.pack()

if __name__ == '__main__':
    root = Tkinter.Tk()
    app = App(root)
    root.mainloop()
```

To learn more about Tkinter visit the following links:

- `http://www.astro.washington.edu/users/rowen/TkinterSummary.html` <- A summary
- `http://infohost.nmt.edu/tcc/help/lang/python/tkinter.html` <- A tutorial
- `http://www.pythonware.com/library/tkinter/introduction/` <- A reference

1 `http://en.wikibooks.org/wiki/Programming%3ATcl%20`

23.2 PyGTK

See also book PyGTK For GUI Programming[2]

PyGTK[3] provides a convenient wrapper for the GTK+[4] library for use in Python programs, taking care of many of the boring details such as managing memory and type casting. The bare GTK+ toolkit runs on Linux, Windows, and Mac OS X (port in progress), but the more extensive features — when combined with PyORBit and gnome-python — require a GNOME[5] install, and can be used to write full featured GNOME applications.

Home Page[6]

23.3 PyQt

PyQt is a wrapper around the cross-platform Qt C++ toolkit[7]. It has many widgets and support classes[8] supporting SQL, OpenGL, SVG, XML, and advanced graphics capabilities. A PyQt hello world example:

```
from PyQt4.QtCore import *
from PyQt4.QtGui import *

class App(QApplication):
    def __init__(self, argv):
        super(App, self).__init__(argv)
        self.msg = QLabel("Hello, World!")
        self.msg.show()

if __name__ == "__main__":
    import sys
    app = App(sys.argv)
    sys.exit(app.exec_())
```

PyQt[9] is a set of bindings for the cross-platform Qt[10] application framework. PyQt v4 supports Qt4 and PyQt v3 supports Qt3 and earlier.

2 http://en.wikibooks.org/wiki/PyGTK%20For%20GUI%20Programming
3 http://www.pygtk.org/
4 http://www.gtk.org
5 http://www.gnome.org
6 http://www.pygtk.org/
7 http://www.trolltech.com/products/qt
8 http://www.riverbankcomputing.com/static/Docs/PyQt4/html/classes.html
9 http://www.riverbankcomputing.co.uk/pyqt/
10 http://en.wikibooks.org/wiki/Qt

23.4 wxPython

Bindings for the cross platform toolkit wxWidgets[11]. WxWidgets is available on Windows, Macintosh, and Unix/Linux.

```
import wx

class test(wx.App):
    def __init__(self):
        wx.App.__init__(self, redirect=False)

    def OnInit(self):
        frame = wx.Frame(None, -1,
                         "Test",
                         pos=(50,50), size=(100,40),
                         style=wx.DEFAULT_FRAME_STYLE)
        button = wx.Button(frame, -1, "Hello World!", (20, 20))
        self.frame = frame
        self.frame.Show()
        return True

if __name__ == '__main__':
        app = test()
        app.MainLoop()
```

- wxPython[12]

23.5 Dabo

Dabo is a full 3-tier application framework. Its UI layer wraps wxPython, and greatly simplifies the syntax.

```
import dabo
dabo.ui.loadUI("wx")

class TestForm(dabo.ui.dForm):
        def afterInit(self):
                self.Caption = "Test"
                self.Position = (50, 50)
                self.Size = (100, 40)
                self.btn = dabo.ui.dButton(self, Caption="Hello World",
                      OnHit=self.onButtonClick)
                self.Sizer.append(self.btn, halign="center", border=20)

        def onButtonClick(self, evt):
                dabo.ui.info("Hello World!")

if __name__ == '__main__':
        app = dabo.ui.dApp()
        app.MainFormClass = TestForm
        app.start()
```

- Dabo[13]

11 http://www.wxwidgets.org/
12 http://wxpython.org/
13 http://dabodev.com/

23.6 pyFltk

pyFltk[14] is a Python wrapper for the FLTK[15], a lightweight cross-platform GUI toolkit. It is very simple to learn and allows for compact user interfaces.

The ”Hello World” example in pyFltk looks like:

```
from fltk import *

window = Fl_Window(100, 100, 200, 90)
button = Fl_Button(9,20,180,50)
button.label("Hello World")
window.end()
window.show()
Fl.run()
```

23.7 Other Toolkits

- PyKDE[16] - Part of the kdebindings package, it provides a python wrapper for the KDE libraries.
- PyXPCOM[17] provides a wrapper around the Mozilla XPCOM[18] component architecture, thereby enabling the use of standalone XUL[19] applications in Python. The XUL toolkit has traditionally been wrapped up in various other parts of XPCOM, but with the advent of libxul and XULRunner[20] this should become more feasible.

fr:Programmation Python/L’interface graphique[21] pt:Python/Programação com GUI[22]

14 http://pyfltk.sourceforge.net/
15 http://www.fltk.org/
16 http://www.riverbankcomputing.co.uk/pykde/index.php
17 http://developer.mozilla.org/en/docs/PyXPCOM
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