Python Fundamentals Training

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Contents

1 Getting Started **1**
1.1 Lesson Objectives . . . 1
1.2 The Interactive Interpreter . . . 1
1.3 Lab . . . 1
1.4 Lab . . . 2
1.5 *Getting Started* Follow up . . . 2

2 Simple Functions and Test Driven Labs **3**
2.1 Lesson Objectives . . . 3
2.2 Writing simple functions . . . 3
2.3 Lab . . . 3
2.4 Completing Test Driven Labs . . . 4
2.5 Lab . . . 4
2.6 *Test Driven Labs* Follow up . . . 5

3 Types and Variables **6**
3.1 Lesson objectives . . . 6
3.2 TOPIC: Types . . . 6
3.2.1 Strings . . . 6
3.2.2 Integers . . . 6
3.2.2.1 Integer Division . . . 6
3.2.3 Floats . . . 7
3.2.4 Complex . . . 7
3.3 TOPIC: Variables . . . 7
3.3.1 Definining . . . 7
3.3.2 Dynamic Typing . . . 7
3.3.3 Strong Typing . . . 8
3.3.4 Managing your types . . . 8
3.3.5 Internals . . . 9
3.4 Lab . . . 9
3.5 *Types and Variables* Follow-up . . . 9

4 Simple Expressions **10**
4.1 Lesson objectives . . . 10
4.2 Boolean Evaluation . . . 10
4.3 Truthiness . . . 11
4.4 Branching (if / elif / else) . . . 11
4.5 Block Structure and Whitespace . . . 11
4.6 Lab . . . 12
4.7 *Simple Expressions* Follow-up . . . 12

5 Advanced Types: Containers **13**
5.1 Lesson objectives . . . 13
5.2 TOPIC: Lists . . . 13
5.2.1 Lab . . . 15
5.3 TOPIC: Strings Revisited . . . 15
5.4 TOPIC: Tuples . . . 16
5.4.1 Lab . . . 18
5.5 TOPIC: Dictionaries . . . 18
5.5.1 Lab . . . 20
5.6 TOPIC: Sets . . . 20
5.7 TOPIC: Collection Transitions . . . 21
5.7.1 Lab . . . 21
5.8 *Advanced Types* Follow-up . . . 22

6 A Bit More Iteration **23**
6.1 Lesson objectives . . . 23
6.2 TOPIC: `break` and `continue` . . . 23
6.3 TOPIC: Loop-Else . . . 24
6.4 *More Iteration* Follow-up . . . 24

7 Functions **25**
7.1 Lesson objectives . . . 25
7.2 Defining . . . 25
7.3 Arguments . . . 25
7.4 Mutable Arguments and Binding of Default Values . . . 26
7.5 Accepting Variable Arguments . . . 27
7.5.1 LAB . . . 27
7.6 Unpacking Argument Lists . . . 27
7.7 Scope . . . 28
7.8 Lab . . . 29
7.9 *Functions* Follow-up . . . 29

8 Exceptions **30**
8.1 Lesson objectives . . . 30
8.2 Basic Error Handling . . . 30
8.3 Raising and re-raising exceptions . . . 31
8.3.1 Lab . . . 31
8.4 *Exceptions* Follow-up . . . 31

9 Code Organization **32**
9.1 Lesson objectives . . . 32
9.2 TOPIC: Namespaces . . . 32
9.3 TOPIC: Importing modules . . . 33
9.4 TOPIC: Creating Modules . . . 34
9.4.1 Preventing execution on import . . . 35
9.5 *Code Organization* Follow-up . . . 36

10 Working with Files **37**
10.1 Lesson objectives . . . 37
10.2 TOPIC: File I/O . . . 37
10.3 TOPIC: Iteration . . . 38
10.4 TOPIC: Context managers . . . 38
10.5 TOPIC: Duck Typing . . . 39
10.6 *Working With Files* Follow-up . . . 40

11 Interacting with the Outside World **41**
11.1 Lesson objectives . . . 41
11.2 Options . . . 41
11.3 Lab . . . 42
11.4 *Interacting with the Outside World* Follow-up . . . 42

12 Regular Expressions **43**
12.1 Lesson objectives . . . 43
12.2 The `re` module . . . 43
12.3 Lab . . . 44
12.4 *Regular Expresssions* Follow-up . . . 44

13 Functional Programming **45**
13.1 Lesson objectives . . . 45
13.2 TOPIC: Functions as Objects . . . 45
13.3 Higher-Order Functions . . . 46
13.3.1 Sorting: An Example of Higher-Order Functions . . . 46
13.3.2 More Examples: `filter`, `map`, `reduce` and friends . . . 47

13.3.2.1 `filter` . . . 47
13.3.2.2 `map` . . . 48
13.3.2.3 `reduce` . . . 49
13.3.3 Lab . . . 50
13.4 TOPIC: Anonymous Functions . . . 50
13.4.1 Lab . . . 50
13.5 *Functional Programming* Follow-up . . . 51

14 More Functional Programming **52**
14.1 Lesson objectives . . . 52
14.2 TOPIC: Nested Functions . . . 52
14.3 TOPIC: Closures . . . 53
14.3.1 Useful Function Objects: `operator` . . . 53
14.3.2 Lexical Scoping . . . 54
14.3.3 Lab . . . 55
14.4 TOPIC: Decorators . . . 55
14.4.1 Syntactic sugar with `@` . . . 56
14.4.2 Lab . . . 57
14.5 *More Functional Programming* Follow-up . . . 57

15 Advanced Iteration **58**
15.1 Lesson objectives . . . 58
15.2 TOPIC: List Comprehensions . . . 58
15.2.1 LAB . . . 59
15.3 TOPIC: Generator Expressions . . . 59
15.4 TOPIC: Generator Functions . . . 60
15.4.1 LAB . . . 61
15.5 TOPIC: Iteration Helpers: `itertools` . . . 61
15.5.1 `chain()` . . . 61
15.5.2 `izip()` . . . 62
15.6 *Advanced Iterations* Follow-up . . . 62

16 Debugging Tools **63**
16.1 Lesson objectives . . . 63
16.2 TOPIC: logging . . . 63
16.3 TOPIC: pprint . . . 65
16.4 TOPIC: pdb . . . 65
16.5 Lab . . . 65
16.6 *Debugging Tools* Follow-up . . . 66

17 Object-Oriented Programming **67**
17.1 Lesson objectives . . . 67
17.2 TOPIC: Classes . . . 67
17.2.1 Emulation . . . 69
17.2.2 `classmethod` and `staticmethod` . . . 70
17.2.3 Lab . . . 71
17.3 TOPIC: Inheritance . . . 72
17.3.1 Lab . . . 75
17.4 TOPIC: Encapsulation . . . 76
17.4.1 Intercepting Attribute Access . . . 76
17.4.2 Properties . . . 77
17.4.3 Descriptors . . . 79
17.4.4 Lab . . . 80
17.5 *Object Oriented* Follow-up . . . 80

18 UnitTest **82**
18.1 Lesson objectives . . . 82
18.2 UnitTest . . . 82
18.2.1 Lab . . . 83
18.3 *UnitTest* Follow-up . . . 83

19 Managing Your Python Environment **84**
19.1 Lesson objectives . . . 84
19.1.1 virtualenv . . . 84
19.2 PRACTICE ACTIVITY . . . 85
19.2.1 virtualenvwrapper . . . 86
19.2.2 PIP . . . 86
19.3 *Basic Tools* Follow-up . . . 86

20 Easter Eggs **87**

Chapter 1

Getting Started

1.1 Lesson Objectives

In this lesson you will learn to execute Python code in the interactive interpreter and from the shell. You'll also learn to use Python's help system to investigate objects in the interactive interpreter.

1.2 The Interactive Interpreter

The Python installation includes an interactive interpreter that you can use to execute code as you type it. This is a great tool to use to try small samples and see the result immediately without having to manage output or print statements.

1.3 Lab

Open a terminal (command prompt) and type `python`.

1. What is the version number?
2. Type `help(str)` This is a simple way to get documentation for a builtin or standard library function. You can also use the online HTML documentation.

```
>>> help(str)
Help on class str in module __builtin__:

class str(basestring)
 |  str(object) -> string
 |
 |  Return a nice string representation of the object.
 |  If the argument is a string, the return value is the same object.
 |
 |  Method resolution order:
 |      str
 |      basestring
 |      object
 |
 |  Methods defined here:
 |
 |  __add__(...)
 |      x.__add__(y) <==> x+y
 |
 ...
```

1. Note the use of methods with names with two underscores at the beginning and end of the name. These are methods that you will generally never call directly. How do you think the `__add__()` method gets executed?
2. Now try typing the following commands to see the output. Note that you don't assign a result, you get that result in the interpreter.

```
>>> 'hello world'
'hello world'
>>> _ + '!'
'hello world!'
>>> hw = _
>>> hw
'hello world!'
```

Tip
In the interactive interpreter, you can use the special variable "_" to refer to the result of the last statement. Handy in this mode, but meaningless in scripts.

Note
Throughout the rest of this courseware, the ">>>" in a listing indicates that the code is being executed in the interactive interpreter.

1.4 Lab

Enter the following into a new file "hello.py" in your text editor of choice.

```
print "hello world!"
```

Save and exit, then execute the script as shown below.

```
$ python hello.py
hello world
```

Tip
On unix, you can also use shebang (#!) notation on the first line.

1.5 *Getting Started* Follow up

In this lesson you learned to execute Python code two ways. While you will be using a text editor to save your code when writing substantial programs, the interactive interpreter allows you to "try out" code or access the built in help system. Coding in the interactive interpreter should remain part of your development process.

Chapter 2

Simple Functions and Test Driven Labs

2.1 Lesson Objectives

In this lesson you will learn to write simple functions. You will also learn how to complete the test-driven labs provided with this course.

2.2 Writing simple functions

In a later lesson in this course you'll learn all about functions, arguments, parameters and scope in Python. For now we need to show you just enough to complete some labs.

Functions are a way of identifying a section of code so that you reuse it. In Python functions are created primarily by using the `def` keyword, providing a name, and then a parameter list in parentheses. The parenthese are mandatory even if your function takes no arguments. The `def` line is terminated by a colon like the other multi-line statements you'll learn about later.

Code inside the function is indented (we'll talk more about this later) and the function can include a return statement that defines the value that results when the function is called. Functions that do not return implicitly return the value `None`.

You can call a function by saying its name followed by parentheses. You can optionally pass arguments to a function by including variable names or values in a comma separated list inside the parentheses.

```
>>> def say_hello():
...     return "Hello"
...
>>> x = say_hello()
>>> x
'Hello'
>>> def say_something(a_string):
...     print a_string
...
>>> x = say_something("test")
test
>>> x
>>>
```

2.3 Lab

Open a python prompt and try it yourself! Note that the prompt tells you with the three dots `...` when it expects an indented code block. When you are done adding an indented code block just hit enter on a line without indenting.

2.4 Completing Test Driven Labs

Throughout these lessons you'll be completing test-driven labs. These labs consist of a special kind of test supported by Python called a `doctest`. The tests look like Python code:

getting_started.py

```
"""
This is a test driven lab. Tests are the parts that look like Python
code entered in the interactive console.

>>> testing()
'Hello'

In order to run the tests execute:

$ python -m doctest getting_started.py

DO NOT EDIT THIS CODE!

Instead, add your own python code (including function definitions)
down below until all the tests pass.
"""

# Add your python code here!
```

You can run the tests from the console and see whether they pass or fail:

```
$ python -m doctest getting_started.py
**********************************************************************
File "labs/getting_started.py", line 5, in getting_started
Failed example:
    testing()
Exception raised:
    Traceback (most recent call last):
      File "/usr/lib/python2.6/doctest.py", line 1248, in __run
        compileflags, 1) in test.globs
      File "<doctest getting_started[0]>", line 1, in <module>
        testing()
    NameError: name 'testing' is not defined
**********************************************************************
1 items had failures:
   1 of   1 in getting_started
***Test Failed*** 1 failures.
```

Passing the lab simply means supplying the necessary code that makes the tests pass! Be sure to enter your code at the bottom, not inside the triply quoted `docstring`.

> **Tip**
> Docstrings are useful for all sorts of things. How do you think `help` works!

2.5 Lab

Edit the `getting_started.py` file included in your labs download. Add a function definition that makes the tests pass.

> **Tip**
> Doctest follows the unix convention that "silence is golden" and doesn't emit any output if the tests pass. If this is un-nerving try adding a -v flag when you run your tests to see "verbose" output.

2.6 *Test Driven Labs* Follow up

In this lesson you learned how to define simple functions - just enough to be able to complete the labs in later lessons. You were also introduced to the test-driven labs you'll be completing as part of the course.

Chapter 3

Types and Variables

3.1 Lesson objectives

This lesson will introduce simple numeric types and operators. You will also be introduced to creating variables with Python's dynamic yet strongly typed variable system.

3.2 TOPIC: Types

3.2.1 Strings

String literals can be defined with any of single quotes ('), double quotes (") or triple quotes (''' or """). All give the same result with two important differences.

1. If you quote with single quotes, you do not have to escape double quotes and vice-versa.
2. If you quote with triple quotes, your string can span multiple lines.

```
>>> 'hello' + " " + '''world'''
'hello world'
```

3.2.2 Integers

Integer literals are created by any number without a decimal or complex component.

```
>>> 1 + 2
3
```

3.2.2.1 Integer Division

Some programming tasks make extensive use of integer division and Python behaves in the expected manner.

```
>>> 10 / 3
3
>>> 10 % 3
1
>>> divmod(10, 3)
(3, 1)
```

3.2.3 Floats

Float literals can be created by adding a decimal component to a number.

```
>>> 1.0 / .99
1.0101010101010102
```

3.2.4 Complex

Complex literals can be created by using the notation x + yj where x is the real component and y is the imaginary component.

```
>>> 1j * 1j
(-1+0j)
```

3.3 TOPIC: Variables

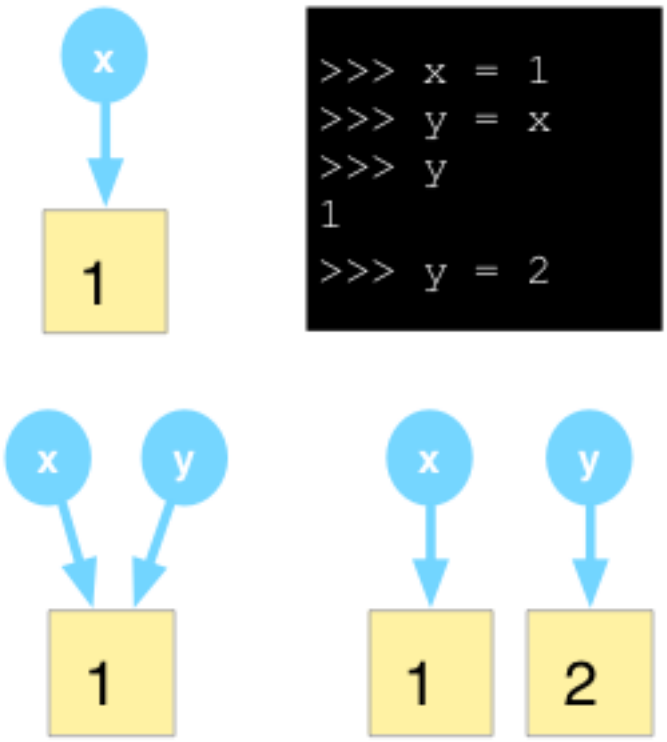
3.3.1 Definining

A variable in Python is defined through assignment. There is no concept of declaring a variable outside of that assignment.

```
>>> ten = 10
>>> ten
10
```

3.3.2 Dynamic Typing

In Python, while the value that a variable points to has a type, the variable itself has no strict type in its definition. You can re-use the same variable to point to an object of a different type. It may be helpful to think of variables as just the "labels" associated with objects.



3.3.3 Strong Typing

Caution
While Python allows you to be very flexible with your types, you must still be aware of what those types are. Certain operations will require certain types as arguments.

```
>>> 'Day ' + 1
Traceback (most recent call last):
  File "<stdin>", line 1, in <module>
  TypeError: cannot concatenate 'str' and 'int' objects
```

This behavior is different from some other loosely-typed languages. If you were to do the same thing in JavaScript, you would get a different result.

```
d8> 'Day ' + 1
Day 1
```

Programming Language Categories

Strongly Typed	Weakly Typed
Static Types	Dynamic Types
Java, Haskell	Javascript, PHP

Languages generally fall into one of these two columns. Strongly typed languages essentially care about the type associated with values while weakly typed languages don't. Strongly typed languages make you manually convert or cast your values from one type to another or may not let convert certain types at all.

Statically typed languages are languages that declare variables with an associated type. Dynamically typed languages tend to infer types from values and also allow a single variable to contain different values with different types.

Java, Pascal, OCaml, and Haskell are examples of strongly statically typed languages. On the other hand Javascript, Perl, and PHP are examples of dynamically weakly typed languages. Some languages are hybrids: Python and Ruby are both strongly dynamically typed languages.

3.3.4 Managing your types

In Python it is possible to change the type of a value through builtin functions.

```
>>> 'Day ' + str(1)
'Day 1'
```

This type conversion can be a necessity to get the outcome that you want. For example, to force float division instead of integer division. Without an explicit conversion, the division of two integers will result in a third integer.

```
>>> 10 / 3
3
```

By converting one of the operands to a float, Python will perform float division and give you the result you were looking for (at least within floating point precision).

```
>>> float(10) / 3
3.3333333333333335
>>> 10 / float(3)
3.3333333333333335
```

You can also force the initial value to be a float by including a decimal point.

```
>>> 10.0 / 3
3.3333333333333335
```

Make sure to account for order of operations, though. If you convert the result of integer division, it will be too late to get the precision back.

```
>>> float(10 / 3)
3.0
```

3.3.5 Internals

Each object in Python has three key attributes: a type, a value, and an id. The type and the id can be examined using the `type()` and `id()` functions respectively. The id is implementation-dependent, but in most standard Python interpreters represents the location in memory of the object.

```
>>> a = 1
>>> type(a)
<type 'int'>
>>> id(a)
4298185352
>>> b = 2
>>> type(b)
<type 'int'>
>>> id(b)
4298185328
```

Multiple instances of the same immutable may be optimized by the interpreter to, in fact, be the same instance with multiple labels. The next example is a continuation of the previous. Notice that by subtracting 1 from `b`, it's value becomes the same as `a` and so does its id. So rather than changing the value at the location to which `b` points, `b` itself is changed to point to a location that holds the right value. This location may be the location of an already existing object or it may be a new location. That choice is an optimization made by the interpreter.

```
>>> b = b - 1
>>> b
1
>>> id(b)
4298185352
```

Python uses reference counting to track how many of these labels are currently pointing to a particular object. When that count reaches 0, the object is marked for garbage collection after which it may be removed from memory.

3.4 Lab

Edit the `variables.py` file included in your labs download. Add variables and function definitions that makes the tests pass.

3.5 *Types and Variables* Follow-up

In this lesson you learned to create value literals for basic types in Python. You also learned to create variables - in Python variables are simply labels attached to values. Finally you learned about Python's dynamic yet strongly typed nature.

Chapter 4

Simple Expressions

4.1 Lesson objectives

This lesson will demonstrate simple expressions used to control program flow. Simple and compound boolean statements result in True or False and you will learn to use Python's truth value testing for non-Boolean types.

4.2 Boolean Evaluation

Boolean expressions are created with the the boolean operators represented by the keywords `and`, `or`, `not` and `is`. For example:

```
>>> True and False
False
>>> True or False
True
>>> not True
False
>>> not False
True
>>> True is True
True
>>> True is False
False
>>> 'a' is 'a'
True
```

Compound boolean evaluations shortcut and return the last expression evaluated. In other words:

```
>>> False and 'a' or 'b'
'b'
>>> True and 'a' or 'b'
'a'
```

Up until Python 2.6, this mechanism was the simplest way to implement a "ternary if" (a = expression ? if_true : if_false) statement. As of Python 2.6, it is also possible to use:

```
>>> 'a' if True else 'b'
'a'
>>> 'a' if False else 'b'
'b'
```

4.3 Truthiness

Many of the types in Python have truth values that can be used implicitly in boolean checks. However, it is important to note that this behavior is different from C where almost everything ends up actually being a zero. True, False and None in Python are all singleton objects and comparisons are best done with the `is` keyword.

Table 4.1: Truthiness values

Value	truthy	None	True	False
`None`	N	Y	N	N
`0`	N	N	N	N
`1`	Y	N	N	N
`'hi'`	Y	N	N	N
`True`	Y	N	Y	N
`False`	N	N	N	Y
`[]`	N	N	N	N
`[0]`	Y	N	N	N

4.4 Branching (if / elif / else)

Python provides the `if` statement to allow branching based on conditions. Multiple `elif` checks can also be performed followed by an optional `else` clause. The `if` statement can be used with any evaluation of truthiness.

```
>>> i = 3
>>> if i < 3:
...     print 'less than 3'
... elif i < 5:
...     print 'less than 5'
... else:
...     print '5 or more'
...
less than 5
```

Tip
Python does not have a switch or case statement. Multiple cases can be handled with an *if-elif-else* structure and you can use as many elif's as you need. Later lessons will show how to use container types to pick between many choices.

4.5 Block Structure and Whitespace

The code that is executed when a specific condition is met is defined in a "block." In Python, the block structure is signalled by changes in indentation. Each line of code in a certain block level must be indented equally and indented more than the surrounding scope. The standard (defined in PEP-8) is to use 4 spaces for each level of block indentation. Statements preceding blocks generally end with a colon (:).

Because there are no semi-colons or other end-of-line indicators in Python, breaking lines of code requires either a continuation character (\ as the last char) or for the break to occur inside an unfinished structure (such as open parentheses).

4.6 Lab

Edit *hello.py* to pass all its tests.

Tip
you might need the string format "%" operator. Put a format string on one side and a value on the other to do simple string interpolation. (eg `"Test %s" % 1`)

4.7 *Simple Expressions* Follow-up

In this lesson you learned to use Python's boolean operators to create boolean expressions. You learned simple flow-control statements like if/elif statements to conditionally execute code blocks and learned about one of Python's most unique features: whitespace delimted code blocks. You also learned about "truthiness" - Python's ability to evaluate any type for truth values in boolean expressions. In the following sections we'll learn to take advantage of truthiness to write succint boolean expressions with container types.

Chapter 5

Advanced Types: Containers

5.1 Lesson objectives

In this lesson you will explore Python's rich system of advanced types. Python has built in types for lists, hashtables, unique lists, immutable lists and you will learn to create and manipulate each of these types and convert one type to another. You will also learn Python's very handy mini-language on container types that support positional indexing. Finally you'll spend a little time exploring typical usage and built in methods on each container type.

One of the great advantages of Python as a programming language is the ease with which it allows you to manipulate containers. Containers (or collections) are an integral part of the language and, as you'll see, built in to the core of the language's syntax. As a result, thinking in a Pythonic manner means thinking about containers.

5.2 TOPIC: Lists

The first container type that we will look at is the list. A list represents an ordered, mutable collection of objects. You can mix and match any type of object in a list, add to it and remove from it at will.

Creating Empty Lists To create an empty list, you can use empty square brackets or use the `list()` function with no arguments.

```
>>> l = []
>>> l
[]
>>> l = list()
>>> l
[]
```

Initializing Lists You can initialize a list with content of any sort using the same square bracket notation. The `list()` function also takes an iterable as a single argument and returns a shallow copy of that iterable as a new list. A list is one such iterable as we'll see soon, and we'll see others later.

```
>>> l = ['a', 'b', 'c']
>>> l
['a', 'b', 'c']
>>> l2 = list(l)
>>> l2
['a', 'b', 'c']
```

A Python string is also a sequence of characters and can be treated as an iterable over those characters. Combined with the `list()` function, a new list of the characters can easily be generated.

```
>>> list('abcdef')
['a', 'b', 'c', 'd', 'e', 'f']
```

Adding You can append to a list very easily (add to the end) or insert at an arbitrary index.

```
>>> l = []
>>> l.append('b')
>>> l.append('c')
>>> l.insert(0, 'a')
>>> l
['a', 'b', 'c']
```

Note
While inserting at position 0 will work, the underlying structure of a list is not optimized for this behavior. If you need to do it a lot, use `collections.deque`, which is optimized for this behavior (at the expense of some pointer overhead) and has an `appendleft()` function.

Iterating Iterating over a list is very simple. All iterables in Python allow access to elements using the `for ... in` statement. In this structure, each element in the iterable is sequentially assigned to the "loop variable" for a single pass of the loop, during which the enclosed block is executed.

```
>>> for letter in l:
...     print letter,
...
a b c
```

Note
The `print` statement adds a newline character when called. Using a trailing "," in the `print` statement prevents a newline character from being automatically appended.

Iterating with while It is also possible to use a `while` loop for this iteration. A `while` loop is most commonly used to perform an iteration of unknown length, either checking a condition on each entry or using a `break` statement to exit when a condition is met.

For the simplicity of the example, here we will use the `list.pop()` method to consume the list entries from the right.

```
>>> l = ['a', 'b', 'c']
>>> while len(l):
...     print l.pop(),
...
c b a
```

Iterating with an Index In some instances, you will actually want to know the index of the item that you are accessing inside the for loop. You can handle this in a traditional form using the builtin `len()` and `range()` functions.

```
>>> len(l)
3
>>> range(3)
[0, 1, 2]

>>> for i in range(len(l)):
...     print i, l[i]
...
0 a
1 b
2 c
```

However, with a little more foundation, we will see a better way.

Access and Slicing Accessing individual items in a list is very similar to accessing the elements of an array in many languages, often referred to as subscripting, or more accurately, using the subscript operator. One less common, but very useful addition, is the ability to use negative indexing, where `alist[-1]` returns the last element of `alist`. Note that 0 represents the first item in a list while -1 represents the last.

Slices are another extension of this subscripting syntax providing access to subsets of the list. The slice is marked with one or two colons (:) within the square bracket subscript.

In the single colon form, the first argument represents the starting index (inclusive) and the second argument represents the end index (exclusive). If the first is omitted (e.g. `l[:2]`), the start index is the beginning of the list. If the second argument is omitted (e.g. `l[2:]`) the end index is the last item in the list.

In the double colon form, the first two arguments are unchanged and the third represents *stride*. For example, `l[::2]` would take every second item from a list.

```
>>> l = list('abcdefgh')
>>> l
['a', 'b', 'c', 'd', 'e', 'f', 'g', 'h']

>>> l[3]
'd'
>>> l[-3]
'f'

>>> l[1:4]
['b', 'c', 'd']

>>> l[1:-1]
['b', 'c', 'd', 'e', 'f', 'g']

>>> l[1:-1:2]
['b', 'd', 'f']
```

5.2.1 Lab

Edit `containers/slices.py` and make all the tests pass.

Presence and Finding Checking for the presence of an object in a list is performed with the `in` keyword. The `index()` method of a list returns the actual location of the object.

```
>>> chars = list('abcdef')
>>> chars
['a', 'b', 'c', 'd', 'e', 'f']
>>> 'g' in chars
False
>>> 'c' in chars
True
>>> chars.index('c')
2
```

5.3 TOPIC: Strings Revisited

Python's string object not only acts as a sequence but has many useful methods for moving back and forth to other types of sequences. A very common use case in data processing is splitting strings into substrings based on a delimiter. This is done with the `split()` method, which returns a list of the components.

```
>>> s = 'abc.def'

>>> parts = s.split('.')
>>> parts
['abc', 'def']
```

The converse method to `split()` is `join()` which joins a list together separating each element by the contents of the string on which the method was called.

This method looks backwards to many people when they first see it (thinking that `.join()` should be a method of the list object). It is also important to realize that a string literal in Python is just another instance of a string object.

Using '/' from the following example, that string is a string object and the `.join()` method can be called on it. There is no point assigning it to a variable before using it, because it is of no value after that single call.

```
>>> new_string = '/'.join(parts)
>>> new_string
'abc/def'
```

Other standard sequence operations also apply.

```
>>> s = 'hello world'
>>> len(s)
11
>>> s[4]
'o'
>>> s[2:10:2]
'lowr'
```

A less sequence-oriented, but still quite common method for dealing with strings is trimming whitespace with the `strip()` method and its relatives: `lstrip()` and `rstrip()`.

```
>>> s = '   abc   '
>>> s.strip()
'abc'
```

5.4 TOPIC: Tuples

A tuple is like an immutable list. It is slightly faster and smaller than a list, so it is useful. Tuples are also commonly used in core program features, so recognize them.

Creating Similar to lists, empty tuples can be created with an empty pair of parentheses, or with the `tuple()` builtin function.

```
>>> t = ()
>>> t
()
>>> tuple()
()
```

Tuples can also be initialized with values (and generally are, since they are immutable). There is one important distinction to make due to the use of parentheses, which is that a 1-tuple (tuple with one item) requires a trailing comma to indicate that the desired result is a tuple. Otherwise, the interpreter will see the parentheses as nothing more than a grouping operation.

```
>>> t = ('Othello')
>>> t
'Othello'
>>> t = ('Othello',)
>>> t
('Othello',)
```

The behavior for a 2-tuple and beyond is nothing new. Note that the parentheses become optional at this point. The implication that any comma-separated list without parentheses becomes a tuple is both useful and important in Python programming.

```
>>> t = ('Othello', 'Iago')
>>> t
('Othello', 'Iago')
>>> t = 'Othello', 'Iago'
>>> t
('Othello', 'Iago')
```

Tuples can also be created by passing an iterable to the `tuple()` function.

```
>>> l = ['Othello', 'Iago']
>>> tuple(l)
('Othello', 'Iago')
```

Unpacking A very common paradigm for accessing tuple content in Python is called unpacking. It can be used on lists as well, but since it requires knowledge of the size of the container, it is far more common with tuples.

By assigning a tuple to a list of variables that matches the count of items in the tuple, the variables are individually assigned ordered values from the tuple.

```
>>> t = ('Othello', 'Iago')
>>> hero, villain = t
>>> hero
'Othello'
>>> villain
'Iago'
```

An interesting and valuable side-effect of the natural use of tuples is the ability to elegantly swap variables.

```
>>> t = ('Othello', 'Iago')
>>> t
('Othello', 'Iago')

>>> hero, villain = t

>>> hero
'Othello'
>>> villain
'Iago'

>>> hero, villain = villain, hero

>>> hero
'Iago'
>>> villain
'Othello'
```

Accessing and Slicing Tuples can be accessed and sliced in the same manner as lists. Note that tuple slices are tuples themselves.

```
>>> t[0]
'Othello'
>>> t = ('Othello', 'Iago', 'Desdemona')
>>> t[0::2]
('Othello', 'Desdemona')
```

Iterating Tuples are iterable, in exactly the same manner as lists.

```
>>> t = ('Othello', 'Iago')
>>> for character in t:
...     print character
```

```
...
Othello
Iago
```

Since a tuple is iterable, a mutable copy is easily created using the `list()` builtin.

```
>>> t = ('Othello', 'Iago')
>>> list(t)
['Othello', 'Iago']
```

Indexed List Iteration Revisited Now that you know how to unpack tuples, you can see a better way to iterate lists with an index. The builtin `enumerate()` function takes a single argument (an iterable) and returns an iterator of 2-tuples. Each 2-tuple contains an index and an item from the original iterable. These 2-tuples can be unpacked into separate loop variables as part of the `for` statement.

```
>>> l = ['a', 'b', 'c']
>>> for i, letter in enumerate(l):
...     print i, letter
...
0 a
1 b
2 c
```

5.4.1 Lab

Update `containers/lists-1.py` to pass all the tests.

5.5 TOPIC: Dictionaries

A dictionary is an implementation of a key-value mapping that might go by the name "hashtable" or "associative array" in another language. Dictionaries are the building blocks of the Python language itself, so they are quite prevalent and also quite efficient.

Warning
Dictionary order is undefined and implementation-specific. It can be different across interpreters, versions, architectures, and more. Even multiple executions in the same environment.

Creating Following the analogy of the other container types, dictionaries are created using braces, i.e. `{}`. There is also a `dict()` builtin function that accepts an arbitrary set of keyword arguments.

Note
Unlike some similar languages, string keys in Python must always be quoted.

```
>>> characters = {'hero': 'Othello', 'villain': 'Iago', 'friend': 'Cassio'}
>>> characters
{'villain': 'Iago', 'hero': 'Othello', 'friend': 'Cassio'}

>>> characters = dict(hero='Othello', villain='Iago', friend='Cassio')
>>> characters
{'villain': 'Iago', 'hero': 'Othello', 'friend': 'Cassio'}
```

Accessing Dictionary values can be accessed using the subscript operator except you use the key instead of an index as the subscript argument. The presence of keys can also be tested with the *in* keyword.

```
>>> if 'villain' in characters:
...     print characters['villain']
...
Iago
```

Adding A new entry can be created where there is no existing key using the same subscripting notation and assignment.

```
>>> characters['beauty'] = 'Desdemona'
```

Modifying Existing entries are modified in exactly the same manner.

```
>>> characters['villain'] = 'Roderigo'

>>> characters
{'villain': 'Roderigo', 'hero': 'Othello', 'beauty': 'Desdemona', 'friend': 'Cassio'}
```

Failed Lookups If you use the subscript operator and the key is not found, a `KeyError` will be raised. If this behavior is not desired, using the `get()` method of the dictionary will return a supplied default value when the key is not found. If no default is provided, `None` is returned when the key is not found. The `get()` method does not alter the contents of the dictionary itself.

```
>>> characters['horse']
Traceback (most recent call last):
  File "<stdin>", line 1, in <module>
  KeyError: 'horse'
>>> characters.get('horse', 'Ed')
'Ed'
>>> characters
{'villain': 'Roderigo', 'hero': 'Othello', 'friend': 'Cassio', 'beauty': 'Desdemona'}
>>> characters.get('horse')
>>>
```

You can also set the value in the case that it wasn't found using the `setdefault()` method.

```
>>> characters
{'villain': 'Roderigo', 'hero': 'Othello', 'friend': 'Cassio', 'beauty': 'Desdemona'}
>>> characters.setdefault('horse', 'Ed')
'Ed'
>>> characters
{'villain': 'Roderigo', 'horse': 'Ed', 'hero': 'Othello', 'friend': 'Cassio', 'beauty': ' ↩
    Desdemona'}
```

Iterating Because the dictionary has both keys and values, iterating has a few more options. A simple *for* ... *in* statement will iterate over the keys, which is one method to access both.

```
>>> for role in characters:
...     print role, characters[role]
...
villain Roderigo
hero Othello
beauty Desdemona
friend Cassio
```

However, the `items()` method will return 2-tuples of key, value pairs, which can be unpacked in the for loop.

```
>>> characters.items()
[('villain', 'Roderigo'), ('hero', 'Othello'), ('friend', 'Cassio'), ('beauty', 'Desdemona ↩
    ')]
>>> for role, name in characters.items():
...     print role, name
...
villain Roderigo
```

```
hero Othello
friend Cassio
beauty Desdemona
```

Note
The `.items()` method returns a newly allocated list full of newly allocated tuples, that exists only for the duration of the iteration. Whenever possible, it is preferable to use the `.iteritems()` method, which returns a generator. This generator holds a reference to the original dictionary and produces individual 2-tuples on demand. The downside of the iterator is that it expects the state of the dictionary to remain consistent during iteration.

```
>>> characters.iteritems()
<dictionary-itemiterator object at 0x100473b50>
>>> for role, name in characters.iteritems():
...     print role, name
...
villain Roderigo
hero Othello
friend Cassio
beauty Desdemona
```

5.5.1 Lab

- Edit *containers/dict-1.py* so that it passes all its tests.
- Revisit `hello.py`. Is there a way to use a `dict` or a `list` to
- replace the if/elif/else code you may have written?

5.6 TOPIC: Sets

A set is a mutable, unordered, unique collection of objects. It is designed to reflect the properties and behavior of a true mathematical set. A *frozenset* has the same properties as a set, except that it is immutable.

Creating A new set is created using the `set()` builtin. This function without any parameters will return a new, empty set. It will also accept a single argument of an iterable, in which case it will return a new set containing one element for each unique element in the iterable.

```
>>> s = set()
>>> s
set([])
>>> s = set(['Beta', 'Gamma', 'Alpha', 'Delta', 'Gamma', 'Beta'])
>>> s
set(['Alpha', 'Beta', 'Gamma', 'Delta'])
```

Accessing Sets are not designed for indexed access, so it is not possible to use subscript notation. Like a list, we can use the `.pop()` method to consume elements, but note that the order will be undefined.

```
>>> s
set(['Alpha', 'Beta', 'Gamma', 'Delta'])
>>> while len(s):
...     print s.pop(),
...
Alpha Beta Gamma Delta
```

Set Operations Not surprisingly, the real value of sets shows itself in set operations. Sets use sensibly overloaded operators to calculate unions and intersections of sets. You can also call these methods by name.

```
>>> s1 = set(['Beta', 'Gamma', 'Alpha', 'Delta', 'Gamma', 'Beta'])
>>> s2 = set(['Beta', 'Alpha', 'Epsilon', 'Omega'])
>>> s1
set(['Alpha', 'Beta', 'Gamma', 'Delta'])
>>> s2
set(['Alpha', 'Beta', 'Omega', 'Epsilon'])

>>> s1.union(s2)
set(['Epsilon', 'Beta', 'Delta', 'Alpha', 'Omega', 'Gamma'])
>>> s1 | s2
set(['Epsilon', 'Beta', 'Delta', 'Alpha', 'Omega', 'Gamma'])

>>> s1.intersection(s2)
set(['Alpha', 'Beta'])
>>> s1 & s2
set(['Alpha', 'Beta'])

>>> s1.difference(s2)
set(['Gamma', 'Delta'])
>>> s1 - s2
set(['Gamma', 'Delta'])

>>> s1.symmetric_difference(s2)
set(['Epsilon', 'Delta', 'Omega', 'Gamma'])
>>> s1 ^ s2
set(['Epsilon', 'Delta', 'Omega', 'Gamma'])
```

5.7 TOPIC: Collection Transitions

As you saw previously, `dict.items()` returns a list of 2-tuples representing key-value pairs. Inversely, a list of 2-tuples can be passed to the `dict()` factory function to create a dictionary using the first item from each tuple as a key and the second item as the value. `zip()` takes n lists and returns one list of n-tuples.

```
>>> roles = characters.keys()
>>> roles
['villain', 'hero', 'beauty', 'friend']
>>> names = characters.values()
>>> names
['Roderigo', 'Othello', 'Desdemona', 'Cassio']

>>> tuples = zip(roles, names)
>>> tuples
[('villain', 'Roderigo'), ('hero', 'Othello'), ('beauty', 'Desdemona'), ('friend', 'Cassio ↩
    ')]

>>> new_characters = dict(tuples)
>>> new_characters
{'villain': 'Roderigo', 'hero': 'Othello', 'friend': 'Cassio', 'beauty': 'Desdemona'}
```

5.7.1 Lab

Optionally: take a look at intro-1-lunch.py. This is another test drive lab. Solving it might involve knowledge of `dict` and `list` methods, the `set` type, and perhaps the use of `collections.Counter`!

5.8 *Advanced Types* Follow-up

In this lesson you learned about Python's container types. Learning to code "Pythonically" has a lot to do with learning when and how to use lists, tuples, dicts, sets and strings. You practiced iterating through different data structures and learned Python's simple iteration syntax and the details of iterating by index as well as value on lists or by value as well as key on dicts.

Chapter 6

A Bit More Iteration

6.1 Lesson objectives

This lesson will demonstrate a few additional features of iteration in Python. Python loops support the usual `break` and `continue` features but also include support for an unusual `else` clause.

6.2 TOPIC: `break` and `continue`

Within loops the `break` keyword immediately ceases iteration. This might be used to stop looping when a condition is met:

```
>>> for val in range(10):
...     if val > 5:
...         break
>>> print val
6
```

Note
While some languages allow an optional argument to control the level of nesting `break` in Python only breaks out of the immediately enclosing loop.

Python also supports the `continue` keyword. Using `continue` in a loop doesn't stop iteration but instead immediately begins the next cycle of iteration on the enclosing loop. This might be used to skip the body of a loop based on a conditional check.

```
>>> tail = []
>>> for val in range(10):
...     if val < 8:
...         continue
...     tail.append(val)
>>> print tail
[8, 9]
```

Tip
Consider using `continue` to invert the logic of complex loops and flatten the body of the loop. Instead of having the body of the loop nested behind complex conditionals, test the opposite case and continue. You can think about this pattern as being similar to putting an early return in a function to simplify the function body's logic.

6.3 TOPIC: Loop-Else

An addition to both *for* and *while* loops in Python that is not common to all languages is the availability of an *else* clause. The *else* block after a loop is executed in the case where **no** *break* occurs inside the loop.

The most common paradigm for using this clause occurs when evaluating a dataset for the occurences of a certain condition and breaking as soon as it is found. Rather than setting a flag when found and checking after to see the result, the else clause simplifies the code.

In the following example, if a multiple of 5 is found, the break exits the for loop without executing the *else* clause.

```
>>> for x in range(1,5):
...     if x % 5 == 0:
...         print '%d is a multiple of 5' % x
...         break
... else:
...     print 'No multiples of 5'
...
No multiples of 5

>>> for x in range(11,20):
...     if x % 5 == 0:
...         print '%d is a multiple of 5' % x
...         break
... else:
...     print 'No multiples of 5'
...
15 is a multiple of 5
```

Without this feature, the code would look something like:

```
>>> found = False
>>> for x in range(1,5):
...     if x % 5 == 0:
...         print '{0} is a multiple of 5'.format(x)
...         found = True
...         break
...
>>> if not found:
...     print 'No multiples of 5'
...
No multiples of 5
```

6.4 *More Iteration* Follow-up

In this lesson you learned about Python's `break` and `continue` keywords that allow you to control flow in your loops. You also learned about the optional `else` clause which allows you to check whether the loop was terminated with a `break`. These features may not be used frequently but when needed can simplify your code and make your intentions more explicit.

Chapter 7

Functions

7.1 Lesson objectives

This lesson covers defining and calling functions in Python. After covering the basics you'll learn about declaring default values for arguments to functions and passing and accepting variable arguments. We'll also begin to learn about how Python handles variable scope.

7.2 Defining

A function in Python is defined with the `def` keyword. Functions do not have declared return types. A function without an explicit `return` statement returns `None`. In the case of no arguments and no return value, the definition is very simple.

Calling the function is performed by using the call operator `()` after the name of the function.

```
>>> def hello_function():
...     print 'Hello World, it\'s me.  Function.'
...

>>> hello_function()
Hello World, it's me.  Function.
```

7.3 Arguments

The arguments of a function are defined within the `def` statement. Like all other variables in Python, there is no explicit type associated with the function arguments. This fact is important to consider when making assumptions about the types of data that your function will receive.

Function parameters can optionally be defined with a default value. The default value will be assigned in the case that the argument is not present in the call to the function. All parameters without default values must be listed before arguments with default values in the function definition.

Any argument can be passed either implicitly by position or explicitly by name, regardless of whether or not it has a default value defined.

```
>>> def record_score(name, score=0):
...     print '%s scored %s' % (name, score)
...

>>> record_score('Jill', 4)
Jill scored 4
```

```
>>> record_score('Jack')
Jack scored 0

>>> record_score(score=3, name='Pail')
Pail scored 3

>>> record_score(2)
2 scored 0

>>> record_score(score=2)
Traceback (most recent call last):
  File "<stdin>", line 1, in <module>
  TypeError: record_score() takes at least 1 non-keyword argument (0 given)

>>> record_score()
Traceback (most recent call last):
  File "<stdin>", line 1, in <module>
  TypeError: record_score() takes at least 1 argument (0 given)
```

Note
Look carefully at the example above. There is an asymmetry in the use of the = sign for defining vs. passing arguments that can be confusing to beginners. An argument with a default value can be passed using only position and an argument without a default can be passed using a keword.

Tip
Python has two kinds of arguments and two kinds of parameters: 1. mandatory positional parameters, referred to as `args` 2. optional, default value, named parameters referred to as keyword args or `kwargs`

7.4 Mutable Arguments and Binding of Default Values

When defining default arguments, take special care with mutable data types. The instance of the default value is bound at the time the function is defined. Consequently, there is a single instance of the mutable object that will be used across all calls to the function.

```
>>> def add_items(new_items, base_items=[]):
...     for item in new_items:
...         base_items.append(item)
...     return base_items
...

>>> add_items((1, 2, 3))
[1, 2, 3]

>>> add_items((1, 2, 3))
[1, 2, 3, 1, 2, 3]
```

As a result, it is best to use default value of `None` as a flag to signify the absense of the argument and handle the case inside the function body.

```
>>> def add_items(new_items, base_items=None):
...     if base_items is None:
...         base_items = []
...     for item in new_items:
...         base_items.append(item)
```

```
...     return base_items
...

>>> add_items((1, 2, 3))
[1, 2, 3]

>>> add_items((1, 2, 3))
[1, 2, 3]
```

7.5 Accepting Variable Arguments

In addition to named arguments, functions can accept two special collections of arguments.

The first is a variable-length, named tuple of any additional positional arguments received by the function. This special argument is identified by prefixing it with a single asterisk (*).

The second is a variable-length dictionary containing all keyword arguments passed to the function that were not explicitly defined as part of the function arguments. This argument is identified by prefixing it with two asterisks (**).

It is not required, but conventional and therefore highly recommended, to name these two arguments args and kwargs, respectively.

The use of these two arguments is illustrated in the following set of examples.

```
>>> def variable_function(*args, **kwargs):
...     print 'args:', args
...     print 'kwargs:', kwargs
...

>>> variable_function('simple')
args: ('simple',)
kwargs: {}

>>> variable_function(type='Complex')
args: ()
kwargs: {'type': 'Complex'}

>>> def mixed_function(a, b, c=None, *args, **kwargs):
...     print '(a, b, c):', (a, b, c)
...     print 'args:', args
...     print 'kwargs:', kwargs
...

>>> mixed_function(1, 2, 3, 4, 5, d=10, e=20)
(a, b, c): (1, 2, 3)
args: (4, 5)
kwargs: {'e': 20, 'd': 10}
```

7.5.1 LAB

Edit functions1.py and make the tests pass.

7.6 Unpacking Argument Lists

It is also possible to construct argument lists (positional or keyword) and pass them into a function.

For positional arguments, insert them into a tuple / list and prepend with an asterisk (*) in the function call.

For keyword arguments, use a dictionary and prepend with two asterisks (**).

```
>>> def printer(a, b, c=0, d=None):
...     print 'a: {0}, b: {1}, c: {2}, d: {3}'.format(a, b, c, d)
...
>>> printer(2, 3, 4, 5)
a: 2, b: 3, c: 4, d: 5

>>> ordered_args = (5, 6)
>>> keyword_args = {'c': 7, 'd': 8}

>>> printer(*ordered_args, **keyword_args)
a: 5, b: 6, c: 7, d: 8
```

Note
The example above shows another potentially confusing asymmetry in Python. You can pass arguments using the regular style to a function defined using variable arguments, and you can pass unpacked variable argument lists to a function defined without variable arguments.

7.7 Scope

Each function evaluation creates a local namespace that is manipulated at any level within the function. As a result, variables can be initially defined at a seemingly lower level of scope than they are eventually used.

```
>>> def deep_scope():
...     if True:
...         if True:
...             if True:
...                 x = 5
...     return x
...

>>> deep_scope()
5
```

Warning
This model for scope can simplify your code, but pay attention. If you don't anticipate all code paths, you can end up referencing undefined variables.

```
>>> def oops(letter):
...     if letter == 'a':
...         out = 'A'
...     return out
...

>>> oops('a')
'A'

>>> oops('b')
Traceback (most recent call last):
  File "<stdin>", line 1, in <module>
  File "<stdin>", line 4, in oops
UnboundLocalError: local variable 'out' referenced before assignment
```

Variables created in a function are created in the local namespace of the function. Variable access, however, checks the current namespace and then any enclosing namespaces until it finds a corresponding label. This can be confusing so Python warns us if we mix access and creation:

```
>>> count = 1
>>> def output_count():
...     print "Count is: %s" % count # count is defined in the global namespace
...     count = 2 # but this would create a local variable
>>> output_count()
UnboundLocalError: local variable 'count' referenced before assignment
```

Note
We can use the `global` declaration in our function to allow assignment to variables in the global namespace.

7.8 Lab

Take a look at `functions/functions2.py`. This is another test-driven lab. See if you can get all the tests to pass (sorry: you can't!) Be sure to understand when the use of the `global` keyword is required and how Python's scope mechanisms work.

7.9 *Functions* Follow-up

Understanding functions, including scope rules and `*args` and `**kwargs`, is foundational to writing and understanding Pythonic code. I've sometimes joked that the ability to accept and pass variable arguments is a swiss-army chainsaw's worth of functionality and it can be overwhelming at first. Be sure to practice these concepts, however, as we will be using them in functional and object oriented programming.

Chapter 8

Exceptions

8.1 Lesson objectives

In this lesson you will learn the five keywords used to raise and handle exceptions. You will also understand how exceptions alter the control flow of your program.

8.2 Basic Error Handling

Exception handling in Python follows a similar pattern to many other languages with this construct. The statements with exception handling are contained in a `try` block, followed by one or more `except` blocks. The `except` keyword is analogous to `catch` in some other languages.

The body of the `try` block is executed up to and including whatever statement raises (throws) an exception. At that point, the first except clause with an associated type that either matches, or is a supertype of, the exception raised will execute.

Important
If no except clause matches, execution will exit the current scope and the process will continue back up the stack until the exception is handled or program execution terminates.

Regardless of whether the exception is caught at the current execution level, the optional `finally` clause will execute if present. The `finally` clause will also execute if no exception is raised and is ideally suited for resource cleanup.

If no exception is raised, the optional `else` block will be executed. The idea of an `else` block in exceptions is less common and designed to limit the contents of the `try` block, such that the types of exceptions being tested are quite explicit.

```
>>> characters = {'hero': 'Othello', 'villain': 'Iago', 'friend': 'Cassio'}
>>> def get_char(role):
...     try:
...         name = characters[role]
...     except KeyError, e: # KeyError is the type, e is the instance
...         result = 'This play has no %s' % role
...     else:
...         result = '%s is the %s' % (name, role)
...     finally:
...         result += ' and it\'s a great play'
...     return result
...
>>> get_char('champion')
"This play has no champion and it's a great play"
```

```
>>> get_char('friend')
"Cassio is the friend and it's a great play"
```

8.3 Raising and re-raising exceptions

We can use exceptions in our own code to indicate error conditions and Python provides a rich family of built-in Exceptions to meet various error conditions. Raising an exception allows us to force calling code to handle errors rather than allowing them to pass silently (eg: by failing to check return values, etc). Sometimes however calling code may not be able to successfully handle error conditions and must simply re-raise the error. This can be accomplished with the bare `raise` keyword inside an except block.

```
>>> def proportion(x, y):
...     if y == 0:
...        raise ArithmeticError("y must be greater than 0")
...     return x/float(y)
>>> try:
...     result = proportion(5,0)
... except ArithmeticError as e: # "as" valid in Python >= 2.6
...     result = 0 # handle the error
... except: # a bare exception clause matches all exceptions
...     print "An inexplicable error occured"
...     raise  # re-raise the current exception
>>> print result
0
```

8.3.1 Lab

Optionally: make the tests in `exceptions1.py` pass.

8.4 *Exceptions* Follow-up

Python itself uses exceptions to communicate error conditions and understanding how to handle exceptions is a necessary part of writing Pythonic code. Be sure to explore the `__builtin__` module to see the list of built in exception classes.

Now that you understand how to use exceptions, keep in mind the "better to ask for forgiveness than permission" model of programming - it may help you as you work through the rest of the lab assignments.

Chapter 9

Code Organization

9.1 Lesson objectives

In this lesson you'll learn some of the tools you need as your scripts get to be bigger than just the contents of a single file. Python's module system gives us a valuable organizational pattern for organizing our programs. After this session you'll understand

- namespaces
- how to import modules
- how to write your own modules and packages

9.2 TOPIC: Namespaces

Inside a single python module (file) there are multiple namespaces. The global namespace represents the full contents of the file, while inside each function there is a local namespace. The contents of these namespaces can be accessed as dictionaries using the functions `globals()` and `locals()` respectively.

When objects (variables, functions, etc) are defined in the file, they manipulate the global namespace. Anything defined inside a function manipulates its local namespace. Notice in the example below that the namespace is manipulated as the file is read. In other words, the first print statement occurs before the interpreter is aware of the presence of the function definition.

Note
The following example makes use of `import`, which will be explained in the next section. It also uses `pprint.pformat` which converts a dictionary into a string in a manner that is more easily read when printed.

organization-1-namespaces.py

```
'''Some documentation for this file.'''
import pprint

print 'globals before def: %s\n' % pprint.pformat(globals(), indent=4)

def simple():
  print 'locals before a: %s\n' % locals()
  a = 'simple'
  print 'locals after a: %s\n' % locals()
  return a

print 'globals after def: %s\n' % pprint.pformat(globals(), indent=4)

simple()
```

```
$ python organization-1-namespaces.py
globals before def: {   '__builtins__': <module '__builtin__' (built-in)>,
    '__doc__': 'Some documentation for this file.',
    '__file__': 'samples/organization-1-namespaces.py',
    '__name__': '__main__',
    '__package__': None,
    'pprint': <module 'pprint' from '/usr/lib/python2.6/pprint.pyc'>}

globals after def: {   '__builtins__': <module '__builtin__' (built-in)>,
    '__doc__': 'Some documentation for this file.',
    '__file__': 'samples/organization-1-namespaces.py',
    '__name__': '__main__',
    '__package__': None,
    'pprint': <module 'pprint' from '/usr/lib/python2.6/pprint.pyc'>,
    'simple': <function simple at 0x40404aac>}

locals before a: {}

locals after a: {'a': 'simple'}
```

9.3 TOPIC: Importing modules

Have another look at an example similar to the one above. Notice that the modules that are imported are present in the global namespace.

organization-2-imports.py

```
import collections
import pprint

d = collections.deque()
d.append('a')
d.appendleft('b')

pprint.pprint(globals())
```

```
$ python organization-2-imports.py
{'__builtins__': <module '__builtin__' (built-in)>,
 '__doc__': None,
 '__file__': 'samples/organization-2-imports.py',
 '__name__': '__main__',
 '__package__': None,
 'collections': <module 'collections' from '/usr/lib/python2.6/collections.pyc'>,
 'd': deque(['b', 'a']),
 'pprint': <module 'pprint' from '/usr/lib/python2.6/pprint.pyc'>}
```

Objects from this module are accessed using dotted notation.

Alternatively, you can import the specific element from the module, using the `from ... import` syntax.

organization-3-import-submodule.py

```
from collections import deque
from pprint import pprint

d = deque()
d.append('a')
d.appendleft('b')

pprint(globals())
```

```
$ python organization-3-import-submodule.py
{'__builtins__': <module '__builtin__' (built-in)>,
 '__doc__': None,
 '__file__': 'samples/organization-3-import-submodule.py',
 '__name__': '__main__',
 '__package__': None,
 'd': deque(['b', 'a']),
 'deque': <type 'collections.deque'>,
 'pprint': <function pprint at 0x40404c6c>}
```

It is also possible to import an entire namespace. This should be done with caution, as it can lead to unexpected elements in your namespace and conflicts in naming.

organization-4-import-all.py

```
from collections import *
from pprint import pprint

d = deque()
d.append('a')
d.appendleft('b')

pprint(globals())
```

```
$ python organization-4-import-all.py
{'Callable': <class '_abcoll.Callable'>,
 'Container': <class '_abcoll.Container'>,
 'Hashable': <class '_abcoll.Hashable'>,
 'ItemsView': <class '_abcoll.ItemsView'>,
 'Iterable': <class '_abcoll.Iterable'>,
 'Iterator': <class '_abcoll.Iterator'>,
 'KeysView': <class '_abcoll.KeysView'>,
 'Mapping': <class '_abcoll.Mapping'>,
 'MappingView': <class '_abcoll.MappingView'>,
 'MutableMapping': <class '_abcoll.MutableMapping'>,
 'MutableSequence': <class '_abcoll.MutableSequence'>,
 'MutableSet': <class '_abcoll.MutableSet'>,
 'Sequence': <class '_abcoll.Sequence'>,
 'Set': <class '_abcoll.Set'>,
 'Sized': <class '_abcoll.Sized'>,
 'ValuesView': <class '_abcoll.ValuesView'>,
 '__builtins__': <module '__builtin__' (built-in)>,
 '__doc__': None,
 '__file__': 'samples/organization-4-import-all.py',
 '__name__': '__main__',
 '__package__': None,
 'd': deque(['b', 'a']),
 'defaultdict': <type 'collections.defaultdict'>,
 'deque': <type 'collections.deque'>,
 'namedtuple': <function namedtuple at 0x404004fc>,
 'pprint': <function pprint at 0x40404c6c>}
```

9.4 TOPIC: Creating Modules

Once your code starts to get bigger than a script, you will want to start organizing it into modules. Unlike some other languages (Java for example) each file in Python is a module. Directories can also be used as a further layer of organization with some care.

Using the file-only model, functions can be created in another file in the same directory (or somewhere in the $PYTHONPATH) and imported using the filename and the function name.

tools.py

```
def shorten(toolong):
    return toolong[:2]
```

complexity-4-file-module.py

```
from tools import shorten

print shorten('abcdef')
```

```
$ python complexity-4-file-module.py
ab
```

As code starts to require even more organization, perhaps with multiple types of utility functions, this file could be moved to a subdirectory. In order to use a directory as a module, it is required that the special file `__init__.py` be present in the directory, which can be empty. Hierarchical modules like this - modules that contain modules - are called packages.

```
$ ls tools2
tools2/__init__.py
tools2/strings.py
```

tools2/strings.py

```
def shorten(toolong):
    return toolong[:2]
```

complexity-5-directory-module.py

```
from tools2 import strings

print strings.shorten('abcdef')
```

```
$ python complexity-5-directory-module.py
ab
```

9.4.1 Preventing execution on import

You might pay attention to the special variable `__name__`. In the code samples above `__name__` appears as a variable in `globals()` and has the value "*main*". Python provides this variable and automatically sets it to one of two values depending on the execution context.

testmodule.py

```
print __name__
if __name__ == '__main__':
   print "Run program"
```

If we run this file directly the value of `__name__` is the string "*main*".

```
$ python testmodule.py
__main__
Run program
```

However if we import this file as a module the value of the variable `__name__` is set to the string value of the containing module. This means our `if` statement doesn't evaluate to `True` and any code hidden behind the if statement doesn't run. It is Python convention to end every script with an `if __name__` block to ensure that importing your script has no side effects.

```
$ python
Python 2.6.5
>>> import testmodule
testmodule
```

9.5 *Code Organization* Follow-up

Unfortunately most of the labs in this course are not substantial enough to give you real world experience with structuring your code in packages. It's worth noting, however, that you have been creating modules each time you create a new .py file. Be sure to name your python files using valid Python identifiers so they can be imported.

You also learned about the special `__name__` variable and how to use it to execute Python code only when run directly. Be sure to use this idiom to hide the main body of your scripts hidden from execution when your script is imported as a module.

Chapter 10

Working with Files

10.1 Lesson objectives

In this lesson you'll learn to read and write to text files using Python's low level file IO api. You'll also learn about several important topics in Python - iteration - duck typing - context managers

10.2 TOPIC: File I/O

Getting data into and out of files in Python feels a lot like using the low-level methods of C, but it has all the ease of Python layered on top.

For example, to open a file for writing use the builtin (and very C-like) `open()` function. But then write the contents of a list with a single call. The `open()` function returns an open file object and closing the file is done by calling the `close()` method of that object.

Note
the `writelines()` and `readlines()` methods in Python do not handle EOL characters on your behalf, making the naming a bit confusing. In this example, note the inclusion of the *\n* character in the elements of the list.

```
>>> colors = ['red\n', 'yellow\n', 'blue\n']
>>> f = open('colors.txt', 'w')
>>> f.writelines(colors)
>>> f.close()
```

By default, the `open()` function returns a file open for reading. Individual lines can be read with the `readline()` method, which will return an empty string. Since the zero-length string has is not truthy, it makes a simple marker.

```
>>> f = open('colors.txt')
>>> f.readline()
'red\n'
>>> f.readline()
'yellow\n'
>>> f.readline()
'blue\n'
>>> f.readline()
''
>>> f.close()
```

Alternatively, all of the lines of the file can be read into a list with one method call and then iterated over from there.

```
>>> f = open('colors.txt')
>>> f.readlines()
['red\n', 'yellow\n', 'blue\n']
>>> f.close()
```

Important: Be sure to investigate the help on the `file` object (which is what the `open` method returns) to see important information about file modes and how to write or append to files.

10.3 TOPIC: Iteration

For large files, reading the contents into memory can be impractical. So it is best to use the file object itself as an iterator, which will consume content from the file as needed with no intermediary memory requirement.

```
>>> f = open('colors.txt')
>>> for line in f:
...     print line,
...
red
yellow
blue
>>> f.close()
```

Python allows objects to provide iterable behavior - notice that we are iterating directly on the file object itself. This is a common idiom in Python code and when you learn how to create your own types you'll also learn how to provide iterable behavior.

10.4 TOPIC: Context managers

In order to ensure that the files in the above examples were properly closed, they should have been safe-guarded against an abnormal exit (by Exception or other unexpected return) using a `finally` statement. See the following example, where you can see in the final `seek()` that the file is closed in the case of proper execution.

```
>>> f = open('colors.txt')
>>> try:
...     lines = f.readlines()
... finally:
...     f.close()
...
>>> lines
['red\n', 'yellow\n', 'blue\n']

>>> f.seek(0)
Traceback (most recent call last):
  File "<stdin>", line 1, in <module>
ValueError: I/O operation on closed file
```

In the next example, the code path fails attempting to write to a file opened for reading. The file is still closed in the *finally* clause.

```
>>> f = open('colors.txt')
>>> try:
...     f.writelines('magenta\n')
... finally:
...     f.close()
...
Traceback (most recent call last):
  File "<stdin>", line 2, in <module>
IOError: File not open for writing
```

```
>>> f.seek(0)
Traceback (most recent call last):
  File "<stdin>", line 1, in <module>
ValueError: I/O operation on closed file
```

As of Python 2.6, there is a builtin syntax for handling this paradigm, using the `with` keyword. `with` creates a context and regardless of how that context is exited, calls the `__exit__()` method of the object being managed. In the following example, that object is the file `f`, but this model works for any file-like object (objects with the basic methods of files). Again - when you learn to create your own types you can add support for the `with` statement to your own objects.

Once again, performing an operation on the file outside of that context shows that it has been closed - but this is much cleaner than the explicit try/finally block.

```
>>> with open('colors.txt') as f:
...     for line in f:
...         print line,
...
red
yellow
blue

>>> f.seek(0)
Traceback (most recent call last):
  File "<stdin>", line 1, in <module>
ValueError: I/O operation on closed file
```

10.5 TOPIC: Duck Typing

As mentioned above, file-like objects are objects that look and feel like files. In Python, there is no strict inheritance requirement in order to use an object as if it were another. Pythonistas call this idea "duck typing" - instead of checking an inheritance tree for an object we simply call methods. In other words: if it quacks like a duck… it is a duck.

`StringIO` is an example of a file-like object that manages its contents in memory instead of on disk. It is important to be conscious of the file-like behavior here. Note that a seek is required after writing to get back to the beginning and read. Attempting to run the same iterator twice results in no values the second time through.

`StringIO.getvalue()` returns a newly created string object with the full contents of the `StringIO` buffer.

```
>>> colors = ['red\n', 'yellow\n', 'blue\n']
>>> from StringIO import StringIO
>>> buffer = StringIO()
>>> buffer.writelines(colors)
>>> buffer.seek(0)

>>> for line in buffer:
...     print line,
...
red
yellow
blue

>>> for line in buffer:
...     print line,
...

>>> buffer.getvalue()
'red\nyellow\nblue\n'
```

10.6 *Working With Files* Follow-up

In this lesson you learned how to use the built in file objects to read and write to text files. You also saw some of the features of the built in objects in Python that allow them to be used in an elegant but powerful manner. Iteration in particular is a fundamental topic in Python and you're now prepared to explore it further in future lessons.

Chapter 11

Interacting with the Outside World

11.1 Lesson objectives

In this lesson you'll learn to accept command line arguments and create "user friendly" command line programs using Python's built in optparse module.

11.2 Options

Each script invoked from the command line in Python has access to any arguments in the `sys.argv` list. While the contents of this list are quite predictable, it is rarely necessary to handle them directly. The preferred option is to use the `optparse` module and the `OptionParser` class from that module.

An instance of OptionParser has methods for adding options (long and short flags) and including parameters with those options (if desired). The action to be taken when an option is encountered is also configurable, including setting a boolean flag, storing a value, or executing a callback function.

Defaults and help text are also covered, as well as error handling. Here is a basic example using the standard features.

The call to `parse_args()` returns a two-tuple. The first item in the tuple is an options object containing any parameters or boolean values captured from the command line. The second item is a list containing any additional arguments passed at the end of the command line.

```
from optparse import OptionParser

p = OptionParser()

p.add_option('-d', '--debug', action='store_true',
dest='debug', help='Turn on debugging')

p.add_option('-s', '--speed', action='store',
type='int', dest='speed',
   help='Use a bigger number to go faster')

p.add_option('-u', '--username', action='store',
type='string', dest='user',
   help='Provide your username')

p.set_defaults(debug=False, speed=0)

options, args = p.parse_args()

if options.user is None:
```

```
    p.error('Username is required')

print 'debug option is: %s' % options.debug
print 'speed option is: %s' % options.speed
print 'args are: %s' % args
```

```
$ python options.py
Usage: options.py [options]

options.py: error: Username is required
```

Unless modified in the creation, each instance of OptionParser adds a -h option to print help for the user.

```
$ python options.py -h
Usage: options.py [options]

Options:
  -h, --help            show this help message and exit
  -d, --debug           Turn on debugging
  -s SPEED, --speed=SPEED
                        Use a bigger number to go faster
  -u USER, --username=USER
                        Provide your username
```

In the output below, note the value *myfile.txt*, which was not associated with any flag. In OptParse terminology `options` are the key/value pairs indicated by flags and `args` are the trailing values.

```
$ python options.py -u me -s 9 myfile.txt
debug option is: False
speed option is: 9
args are: ['myfile.txt']
```

11.3 Lab

Rename optparse-speed.py to speed.py and edit to provide the following:

1. Accept the following command-line options:
    a. -s, --speed integer speed to travel
    b. -l, --list list the possible destination cities and exit
2. Accept a city name as a command line argument and validate
3. given a valid speed and city name, print the number of hours required

11.4 *Interacting with the Outside World* Follow-up

In this lesson you learned to use Python's `optparse` module to accept command line options and arguments. Any command-line scripts you write should have a user friendly front-end that provides instruction and help in running your program - your users will thank you!

Chapter 12

Regular Expressions

12.1 Lesson objectives

In this lesson you'll learn to slice and dice text with Python's regular expression support.

Important: Regular Expressions are a mini-language used for pattern matching. The syntax of regular expressions can be complex and teaching you to write and understand your own patterns is beyond the scope of this class. However students who are familiar with regexp from other languages like Perl will quickly learn the `re` API.

12.2 The `re` module

While regular expression handling is very complete in Python, regular expressions are not a first-class language element as they are in Perl or JavaScript. Regular expression handling is found in the `re` module.

At the simplest level, there are module-level functions in `re` that can be used to search for regular expresssions. In many cases, calling the `search()` function and checking for the presence of a return value is enough. `search()` returns `None` if the pattern was not found.

Note
It is customary in Python regular expressions to pass the patterns as raw strings (`r'pattern'`) to avoid escaping the special characters that are likely included in the pattern.

```
>>> text = 'All your base are belong to us.'

>>> re.search(r'o\s?u', text) # matches "o u" or "ou"
<_sre.SRE_Match object at 0x10041f718>
```

Take note of the `match()` function, which specifically only matches the beginning of the text being matched and does not search throughout for the pattern.

```
>>> re.match(r'o\s?u', text)
>>> re.match('All', text)
<_sre.SRE_Match object at 0x10041f718>
```

Regular expressions can also be used to split strings in more advanced ways than the `string.split()` method.

```
>>> re.split(r'o\s?u', text)
['All y', 'r base are belong t', 's.']
```

Using the `findall()` or `finditer()` methods, it is possible to process all the matching groups. `findall()` returns a list while `finditer()` returns an iterator.

```
>>> re.findall(r'o\s?u', text)
['ou', 'o u']

>>> re.finditer(r'o\s?u', text)
<callable-iterator object at 0x100516610>
```

If you need to use the same pattern multiple times, you can improve performance by compiling the regex and then using the methods of the regex object, rather than the module-level functions.

If groups are defined in the pattern, they can be accessed using the `group()` method of the returned Match object. Note that they are 1-indexed to conform to most other regex utilities.

```
>>> text = 'All your base are belong to us.'

>>> pattern = re.compile(r'you[r]?\s*(\S*)\s*are belong to us')

>>> match = pattern.search(text)

>>> match.group(1)
'base'
```

12.3 Lab

1. Rename complexity-1-fileutil.py to fileutil.py
2. Implement fileutil.py to pass the doctests
3. Create a second file grep.py that accepts command line arguments and calls the function in grep.py
4. Accept the following command-line args:
    a. -v, --invert-match select non-matching lines
    b. -E, --extended-regexp PATTERN is an extended regular expression
    c. And a list of files

12.4 *Regular Expresssions* Follow-up

This lesson explored the `re` module. Be sure to review all the functions in the `re` module so that you understand the differences between, for example, `match`, `search`, and `findall`. If you're experienced solving problems with regular expressions you shouldn't have much trouble using regular expressions with Python.

Chapter 13

Functional Programming

13.1 Lesson objectives

In this lesson you'll learn to apply some basic functional programming techniques to Python. This means

- learning to pass functions as data
- using `lambda` to create anonymous functions
- applying the idea of higher order functions with Python builtins

When it comes to functional programming, Python is classified as a "hybrid" language. It supports the functional programming paradigm, but equally supports imperative paradigms (both procedural and object-oriented). You can (mostly) use functional techniques if you want to - but Python also has other approaches to many functional problems that may be easier to read and write. If the following material on higher order functions feels difficult don't despair! You'll learn some other techniques in the following sections on advanced iteration.

13.2 TOPIC: Functions as Objects

Functions are first-class objects in Python, meaning they have attributes and can be referenced and assigned to variables.

```
>>> def i_am_an_object(myarg):
...     '''I am a really nice function.
...        Please be my friend.'''
...     return myarg
...
>>> i_am_an_object(1)
1

>>> an_object_by_any_other_name = i_am_an_object
>>> an_object_by_any_other_name(2)
2

>>> i_am_an_object
<function i_am_an_object at 0x100432aa0>

>>> an_object_by_any_other_name
<function i_am_an_object at 0x100432aa0>

>>> i_am_an_object.__doc__ # functions have attributes!
'I am a really nice function.\n       Please be my friend.'
```

13.3 Higher-Order Functions

Python also supports higher-order functions, meaning that functions can accept other functions as arguments and return functions to the caller. There is no special syntax for this because in Python functions are objects, just like everything else.

```
>>> i_am_an_object(i_am_an_object)
<function i_am_an_object at 0x100519848>
```

13.3.1 Sorting: An Example of Higher-Order Functions

In order to define non-default sorting in Python, both the `sorted()` function and the list's `.sort()` method accept a `key` argument. The value passed to this argument needs to be a function object that returns the sorting key for any item in the list or iterable.

For example, given a list of tuples, Python will sort by default on the first value in each tuple. In order to sort on a different element from each tuple, a function can be passed that returns that element.

```
>>> def second_element(t):
...     return t[1]
...
>>> zepp = [('Guitar', 'Jimmy'), ('Vocals', 'Robert'), ('Bass', 'John Paul'), ('Drums', ' ↩
    John')]

>>> sorted(zepp)
[('Bass', 'John Paul'), ('Drums', 'John'), ('Guitar', 'Jimmy'), ('Vocals', 'Robert')]

>>> sorted(zepp, key=second_element)
[('Guitar', 'Jimmy'), ('Drums', 'John'), ('Bass', 'John Paul'), ('Vocals', 'Robert')]
```

This is a level of indirection that might be confusing. You need to write a `key` function which accepts **one** argument while `sorted` will be in charge of applying your function to each item in the list. You won't call your key function, `sorted` will! But your key function defines the value `sorted` will be using to compare items, so you're customising the process of sorting by providing the function.

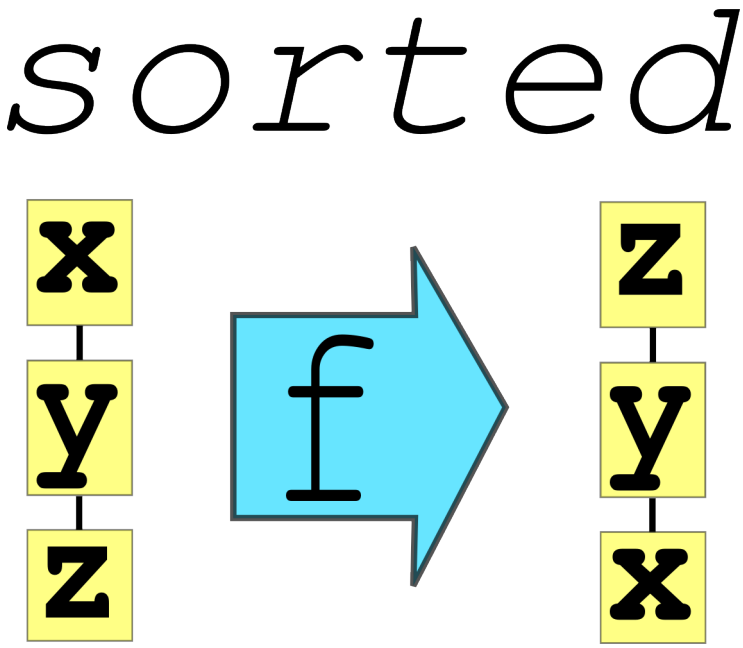


Figure 13.1: sorted produces a re-ordered list

13.3.2 More Examples: `filter`, `map`, `reduce` and friends

This idea - that we can customize how builtins work by passing them a function - is actually pretty common. Python includes several list-processing builtins whose behavior can be customized in this way.

13.3.2.1 `filter`

One example is `filter`.

```
>>> help(filter)
Help on built-in function filter in module __builtin__:

filter(...)
    filter(function or None, sequence) -> list, tuple, or string

    Return those items of sequence for which function(item) is true.  If
    function is None, return the items that are true.  If sequence is a tuple
    or string, return the same type, else return a list.
```

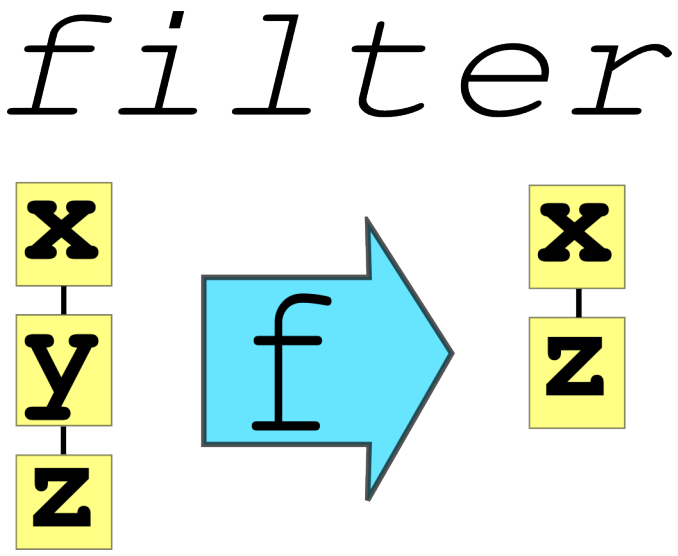


Figure 13.2: filter produces a filtered list

`filter` is a tool for taking an input list and **selecting** which items make it to the output list. We can customize what "which items" means by providing a function `f` so that value `x` makes it on the list if `f(x)==True`. The output list may be shorter, but it has got exactly the same items in exactly the same order.

If we pass `None` to `filter` it just relies on Python's implicit truthiness conversions to select items.

```
>>> filter(None, [0, 1, 2, 3]) # filter out the zeros
[1, 2, 3]
>>> filter(None, ["red", "green", "", "blue"]) # filter out the zero-length strings
['red', 'green', 'blue']
```

The default behavior of `filter` is useful enough. But what if we want to customise the idea of truthiness? `filter` lets us pass a function as the first argument. The function should return `True` or `False` and accept one item from the list. A `True` return value means the item should be included in the output list and a `False` return value means the input value should be excluded. For example

```
>>> def long_enough(word):
...     return len(word) > 4
```

```
...
>>> filter(long_enough, ['red', 'green', 'blue'])
['green']
```

13.3.2.2 map

Another example is `map`.

```
>>> help(map)
Help on built-in function map in module __builtin__:

map(...)
    map(function, sequence[, sequence, ...]) -> list

    Return a list of the results of applying the function to the items of
    the argument sequence(s).  If more than one sequence is given, the
    function is called with an argument list consisting of the corresponding
    item of each sequence, substituting None for missing values when not all
    sequences have the same length.  If the function is None, return a list of
    the items of the sequence (or a list of tuples if more than one sequence).
```

You're still here, right? Ok maybe the `help` for `map` is is a little bit dense. Would some pictures help?

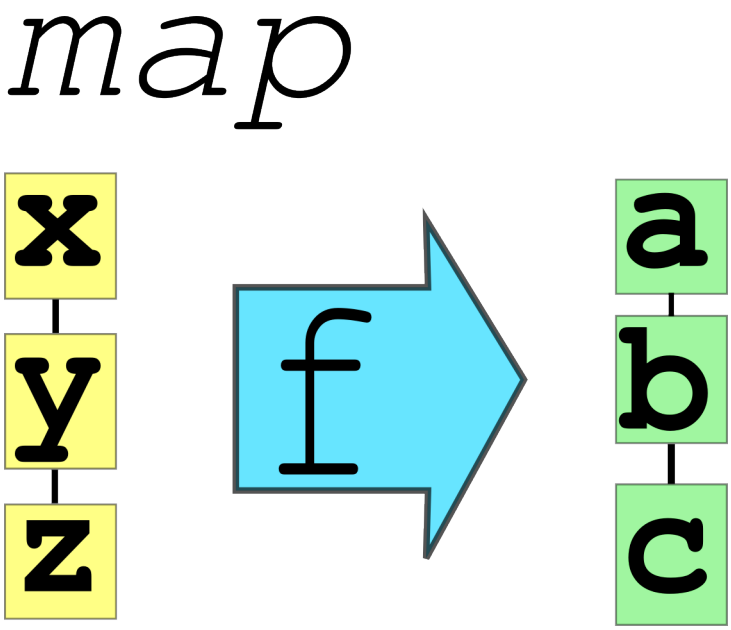


Figure 13.3: map produces a list with calculated values

`map` is a tool for taking an input list and creating an output list of **modified** elements. We define the modification by providing a function so that for input value `x` the corresponding value on the output list is `f(x)`. The output list is the same length, with the same order, but modified values.

This can come in handy when we want to apply builtins to a list of values instead of one at a time.

```
>>> map(str, [1, 2, 3]) # create a list of strings from a list of numbers
['1', '2', '3']
>>> map(str.lower, ["Red", "greeN", "Blue"]) # create a list of lowercase strings
['red', 'green', 'blue']
```

Of course we can define our own kinds of transformations by supplying a custom function.

```
>>> def negative_times_2(val):
...     if val < 0:
...             return val * 2
...     else:
...             return val
...
>>> map(negative_times_2, [3, -2, -1, 10])
[3, -4, -2, 10]
```

13.3.2.3 reduce

`reduce` is another "functional" function but `reduce` is a bit different. Where `sorted`, `map`, and `filter` all take input lists and produce output lists, `reduce` is a tool to produce a single value from a list of input values. Of course you supply the function that customises the process.

```
reduce(...)
    reduce(function, sequence[, initial]) -> value

    Apply a function of two arguments cumulatively to the items of a sequence,
    from left to right, so as to reduce the sequence to a single value.
```

The idea is simple enough.

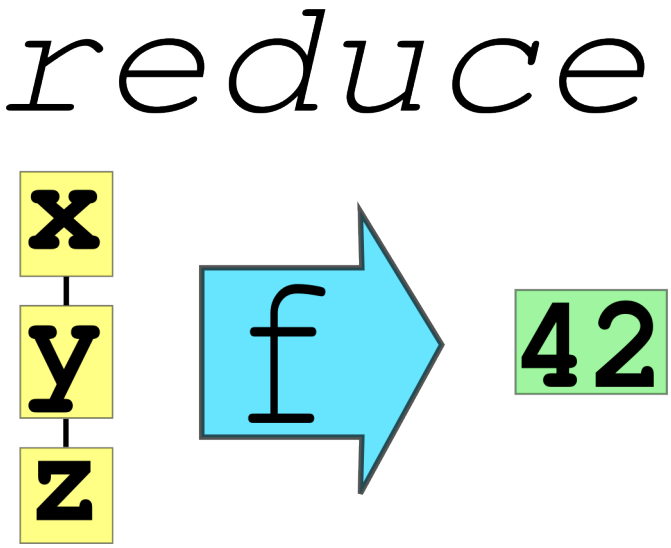


Figure 13.4: reduce calculates a single value from a list

But the function you write is a little more complicated. Think of it this way: you supply a function that can reduce two values down to one. `reduce` replaces the first two values of the input list with one value and repeats until there is only one value on the list. The single value is the output.

Let's walk through a simple example together. Given a function `add` that works just like the builtin + operator and a list of `[1, 2, 3, 4]`, `reduce` would reduce the list down to a single value like so:

```
[1, 2, 3, 4] # initial data
[3, 3, 4]    # first two elements replaced by result of add(1, 2)
[6, 4]       # first two elements replace by result of add(3, 3)
10           # reduced down to a single value!
```

Tip
The `operator` module has replacements for all the operators (punctuation) in Python. Don't write a function called `add`!

```
>>> import operator
>>> operator.add(4, 5)
9
>>> reduce(operator.add, [1, 2, 3, 4])
10
```

Tip
Don't stop here! Python has other useful "functional" functions. Be sure to check out `max`, `min`, and the `itertools` module.

13.3.3 Lab

Tackle `fp/functional1.py`. Make all the tests pass - don't be afraid to add helper functions for use with `map`, `filter`, `sorted`, and so on.

13.4 TOPIC: Anonymous Functions

Anonymous functions in Python are created using the `lambda` statement. This approach is most commonly used when passing a simple function as an argument to another function. The syntax is shown in the next example and consists of the `lambda` keyword followed by a list of arguments, a colon, and the expression to evaluate and return.

```
>>> f = lambda x, y: x + y
>>> f
<function <lambda> at 0xb73fbca4>
>> f(3, 4)
7
>>> zepp = [('Guitar', 'Jimmy'), ('Vocals', 'Robert'), ('Bass', 'John Paul'), ('Drums', ' ↩
    John')]
>>> sorted(zepp, key=lambda row: row[1]) # lambda function returns the 1th element
[('Guitar', 'Jimmy'), ('Drums', 'John'), ('Bass', 'John Paul'), ('Vocals', 'Robert')]
```

Anonymous functions via `lambda` are frequently used with higher order functions. It can be convenient to define your simple function inline with the `sorted/map/filter/reduce` call. But avoid `lambda` if:

There's a builtin that can do the job
Whenever you find yourself writing a simple anonymous function, check for a builtin first. The `operator` module is a good place to start - you ought to learn to know it well!

Using a `lambda` impairs readability
This is especially a concern when nesting multiple higher order functions.

```
map(lambda x: (x + 2) ** 2, filter(lamba x: x > 5, range(10)) # what?
```

There's nothing wrong with adding a `def`!

13.4.1 Lab

Revisit `fp/functional1.py`. Replace your helper functions with `lambda` statements? How do you feel about the readability of your code? Can you formulate any guidlines for using `lambda`?

13.5 *Functional Programming* Follow-up

Functional programming as a way of thinking about problems is a huge topic and we've just scratched the surface. Learning to think about how to compose and apply functional elements takes time but learning the syntax in Python is easy.

You've discovered that (like everything else in Python) functions are really objects. You've gained experience in passing functions along as arguments - "higher-order" functions. You've also learned to create little "anonymous" functions inline with the `lambda` keyword

Be sure to explore the built in help for `map`, `filter`, `max` and `reduce` as well. Practicing using functions that take functions as arguments will help you learn to think functionally.

Chapter 14

More Functional Programming

14.1 Lesson objectives

In this lesson you'll learn to apply some more advanced functional programming techniques to Python. This means

- understanding Python's scoping rules
- understanding functional closures
- understanding decorators

This may be a tall order! But don't worry - if this is your first exposure to advanced functional techniques we won't make you write too much code. Most important is gaining a general understanding of how decorators work. Decorators, as we'll see, are a cool meta-programming feature in Python that can be a little complicated to write but incredibly easy to use!

14.2 TOPIC: Nested Functions

In Python functions can be defined within the scope of another function. If this type of function definition is used, the inner function is only in scope inside the outer function. This can be useful when making little single-purpose functions you don't want re-used.

```
>>> def find_words(lst):
...     def long_enough(word): # define a nested def
...         return len(word) > 5
...     return filter(long_enough, lst)
>>> long_enough() # the nested function is not in scope!
Traceback (most recent call last):
 ...
NameError: name 'long_enough' is not defined
```

However it is also useful to defined nested functions when the inner function is being returned, moving it to the outer scope.

Notice that in the below example, a new instance of the function `inner()` is created on each call to `outer()`. That is because it is defined during the execution of `outer()`. The creation of the second instance has no impact on the first.

```
>>> def outer():
...     def inner(a):
...         return a
...     return inner
...
>>> f = outer()
>>> f
```

```
<function inner at 0x1004340c8>

>>> f2 = outer()
>>> f2
<function inner at 0x1004341b8>
>>> f is f2 # They're not the same function!
False
```

14.3 TOPIC: Closures

A nested function has access to the environment in which it was defined. Remember from above that the definition occurs during the execution of the outer function. Therefore, it is possible to return an inner function that remembers the state of the outer function, even after the outer function has completed execution and all of its local variables have been discarded. This model is referred to as a closure.

```
>>> def outer():
...     x = 1
...     def inner():
...         return x
...     return inner
>>> f = outer()
>>> f() # But x is only defined while outer is running!
1
>>> f.func_closure # aha! Nested functions store the containing scope!
(<cell at 0x9084584: int object at 0x8bded68>,)
```

So lets use this behavior to do something cool! We can use closures to make functions that remember their calling environment and therefore have a "hard-coded variable", so to speak.

```
>>> def adder(x):
...     def inner(y):
...         return x + y
...     return inner
>>> add2 = adder(2)
>>> add5 = adder(5)
>>> add2(5)
7
>>> add5(5)
10
```

Closures provide us with function factories - a way to manufacture custom functions.

14.3.1 Useful Function Objects: `operator`

There are many builtin functions in Python that accept functions as arguments. An example is the `filter()` function that was used previously. However, there are some basic actions that use operators instead of functions (like + or the subscript `[]` or dot `.` operators).

The `operator` module provides function versions of these operators.

```
>>> import operator
>>> operator.add(1, 2)
3
```

Using closures, it's possible to create functions dynamically that can, for example, know **which** item to get from a list. The `operator` module has a function which does this:

```
>>> get_second = operator.itemgetter(1) # returns a function with a hard coded index
>>> get_second(['a', 'b', 'c', 'd']) # function always returns the 1th element
'b'
```

The `itemgetter()` function will return a tuple if it is given more than one index.

```
>>> get_02 = operator.itemgetter(0, 2)
>>> get_02(['a', 'b', 'c', 'd'])
('a', 'c')
```

A typical use for the `itemgetter()` function is as the `key` argument to a list sort.

```
>>> import operator
>>> zepp = [('Guitar', 'Jimmy'), ('Vocals', 'Robert'), ('Bass', 'John Paul'), ('Drums', ' ↩
    John')]

>>> sorted(zepp)
[('Bass', 'John Paul'), ('Drums', 'John'), ('Guitar', 'Jimmy'), ('Vocals', 'Robert')]

>>> sorted(zepp, key=operator.itemgetter(1))
[('Guitar', 'Jimmy'), ('Drums', 'John'), ('Bass', 'John Paul'), ('Vocals', 'Robert')]
```

14.3.2 Lexical Scoping

A common pattern that occurs while attempting to use closures, and leads to confusion, is attempting to encapsulate an internal variable using an immutable type. When it is re-assigned in the inner scope, it is interpreted as a new variable and fails because it hasn't been defined.

```
>>> def outer():
...     count = 0
...     def inner():
...         count += 1
...         return count
...     return inner
...

>>> counter = outer()

>>> counter()
Traceback (most recent call last):
  File "<stdin>", line 1, in <module>
  File "<stdin>", line 4, in inner
UnboundLocalError: local variable 'count' referenced before assignment
```

The standard workaround for this issue is to use a mutable datatype like a list and manage state within that object.

```
>>> def better_outer():
...     count = [0]
...     def inner():
...         count[0] += 1
...         return count[0]
...     return inner
...
>>> counter = better_outer()
>>> counter()
1
>>> counter()
2
>>> counter()
3
```

Tip
If you find yourself building complicated closures and struggling to maintain state, consider using object oriented solutions instead!

14.3.3 Lab

Look at `fp/functional2.py`. This is a test driven lab and the code to satisfy the tests should be shorter than the tests - but it's tricky! You don't have to use `reduce` but you do have to have closure...

14.4 TOPIC: Decorators

A powerful and common, albeit potentially more complex, paradigm in Python is the use of function decorators. The usual role of decorators is to reduce repetition in code by consolidating common elements of setup and teardown in functions.

Understanding decorators requires some foundation, so the first building block is a straightforward function that does nothing out of the ordinary.

```
>>> def sub(x, y):
...     return x + y
...
>>> sub(9, 4)
5
```

The second building block is a closure. Remember that a nested or inner function in Python has access to the environment in which it was defined. If that environment happens to include another function, then the closure will have access to that function.

```
>>> def logit(func):
...     def wrapper(*args, **kwargs):
...         print 'function %s called with args %s, %s' % (func, args, kwargs)
...         func(*args, **kwargs) # call func with whatever we got
...     return wrapper
```

Now, calling `logit()` and passing the function object `sub` as the argument returns us a new function with a reference to `sub`. The returned function is easily assigned to a new variable, and then called.

```
>>> logged_sub = logit(sub)

>>> logged_sub(9, 4)
function <function sub at 0x100414de8> called with args (4, 5)
5
```

At this point, `logged_sub` is, in effect, a modified version of the original function that had the name `sub`. More often than not, the goal is to require the use of the modified version, so it makes sense to remove the ability to call the original function. To accomplish this task, assign the newly returned function to the original variable name `sub`. Remember, function names are just variables pointing to function objects (labels on values!).

This technique looks like the following:

```
>>> sub = logit(sub)
```

Now, calling `sub` is actually calling the inner `wrapper` function from `logit`, which has a reference to the function that was originally referenced by `sub`. In other words, the only way that the original function object can be called at this point is through the wrapper which supplies additional behavior!

```
>>> sub(6, 2)
function <function sub at 0x100414de8> called with args (6, 2)
4
```

Logging is a very common example of a task that can be accomplished in a decorator, but the options are extensive. Decorators can:

1. intercept and modify arguments
2. do stuff before the decorated function runs
3. intercept and modify the return value
4. do stuff after the decorated function runs
5. or even - not run the original function at all!

Most commonly: If there is any common functionality that happens (or can happen) at the beginning or end of multiple function bodies, then a decorator is tool we can use to reduce duplication of effort.

14.4.1 Syntactic sugar with `@`

The decorator paradigm is so common in Python that there is a special syntax using the `@` symbol that allows the name of the decorating function to be placed immediately above the function definition line.

This syntax, while it stands out, tends to lead to some confusion because it is less explicit than the previous format. So it is important to remember that the `@` symbol notation does exactly the same thing under the covers as re-assigning the function variable name after the function definition. We could rewrite the example above as:

```
>>> @loggit
... def sub(x, y):
...     return x + y
...
>>> sub(6, 2)
function <function sub at 0x100414de8> called with args (6, 2)
4
```

You can see the usefulness of the `@decorator` style application (and a really simple decorator) in the following code sample.

```
include::samples/registry.py
```

Remember that

```
@registry
def function():
    pass
```

is the same thing as

```
def function():
    pass

function = registry(function)
```

Since `registry` is a decorator that just returns unmodified the functions it decorates, each of the labels still points to the original unmodified function. But: as a side-effect the decorator is putting each function decorated into a `dict` as a way of keeping track of which functions are legal for the end user to call, perhaps from an html templating language.

```
>>> legal_functions
{'nl2li': <function nl2li at 0x9459e9c>, 'nl2br': <function nl2br at 0x9459e64>}
```

The high visibility of the `@decorator` syntax makes it easy to tell at a glance which functions are going to be "legal" to call and which aren't.

Tip
Writing decorators can be a challenge - and we haven't yet discussed writing configurable decorators or using classes and objects to implement decorators. See http://simeonfranklin.com/blog/2012/jul/1/python-decorators-in-12-steps/ for more resources and explanation.

14.4.2 Lab

Optionally complete `fp/functional-2-decorate.py`. Your instructor will walk you through this lab - to make the test pass you need to supply two decorators and then implement the function bodies.

14.5 *More Functional Programming* Follow-up

This chapter covers some of the most challenging material in learning Python. Thinking generically about functions -dynamically creating and returning functions with closures or substituting wrappers in place of the original function with decorators - can be complex and feel intimidating.

Exposure and practice helps a lot here. With time these techniques can feel as comfortable as manipulating lists or writing flow-control code. The good news, however, is that while writing a decorator might be a bit challenging, **using** decorators is really simple. We'll explore the use of some builtin decorators Python provides when we tackle object oriented programming.

Chapter 15

Advanced Iteration

15.1 Lesson objectives

This lesson will explore list comprehensions and generators. List comprehensions are a great feature in Python, allowing us to filter and transform lists in succint but readable fashion. Generator expressions and generator functions allow us more efficient iteration or the ability to chaining multiple iterations into one operations. And finally we'll explore the `itertools` module to see some tools that help us with advanced iteration.

15.2 TOPIC: List Comprehensions

Python provides list comprehension syntax to simplify the task of generating new lists from existing lists (or from any other iterable data type). A list comprehension is simply a 3 part expression inside square braces that produces a new list from an old one. The three parts are

1. an item in the new list
2. a for loop that defines the old list
3. an optional if statement that filters the original list

In the earlier example of writing to a file, the `\n` character was stored with each color in the list so that it could be passed to the `writelines()` method of the file object. Storing the data in this way would make other processing challenging, so a more common model would be to create a list with line feeds based on a list without them.

Without list comprehensions, this operation would look something like the following:

```
>>> colors = ['red', 'yellow', 'blue']
>>> color_lines = []
>>> for color in colors:
...     color_lines.append('{0}\n'.format(color))
...
>>> color_lines
['red\n', 'yellow\n', 'blue\n']
```

We could use the `map()` function to perform this task. Map takes a function that maps values from an original list to a new list.

```
>>> colors = ['red', 'yellow', 'blue']
>>> color_lines = map(lambda c: '{0}\n'.format(c), colors)
>>> color_lines
['red\n', 'yellow\n', 'blue\n']
```

List comprehensions perform this task equally well, but provide additional functionality in an easier package. To accomplish the same task with a list comprehension, use the following syntax:

```
>>> colors = ['red', 'yellow', 'blue']
>>> color_lines = [color + "\n" for color in colors]
>>> color_lines
['red\n', 'yellow\n', 'blue\n']
```

A conditional filter can also be included in the creation of the new list, like so:

```
>>> colors = ['red', 'yellow', 'blue']
>>> color_lines = [color + "\n' for color in colors if 'l' in color]
>>> color_lines
['yellow\n', 'blue\n']
```

Read the list comprehension aloud - it should read naturally. Can you tell what the expression is doing? It should be more easily understandable than the equivalent nested `map` and `filter` calls while remaining much more succint than the `for` loop and nested `if` equivalent.

More than one list can be iterated over, as well, which will create a pass for each combination in the lists.

```
>>> colors = ['red', 'yellow', 'blue']
>>> clothes = ['hat', 'shirt', 'pants']

>>> colored_clothes = ['{0} {1}'.format(color, garment) for color in colors for garment in ↩
    clothes]

>>> colored_clothes
['red hat', 'red shirt', 'red pants', 'yellow hat', 'yellow shirt', 'yellow pants', 'blue ↩
    hat', 'blue shirt', 'blue pants']
```

Nesting list comprehensions typically diminishes their readability and should be approached with caution.

15.2.1 LAB

Copy your earlier completion of functional1.py to a new file called listcomp1.py. Modify any examples that use `map` or `filter` to use a list comprehension instead. You may be able to get rid of the lambda functions you used with map and filter.

15.3 TOPIC: Generator Expressions

Storing a new list as the output of a list comprehension is not always optimal behavior. Particularly in a case where that list is intermediary or where the total size of the contents is quite large.

For such cases, a slightly modified syntax (replacing square brackets with parentheses) leads to the creation of a generator instead of a new list. The generator will produce the individual items in the list as each one is requested, which is generally while iterating over that new list.

```
>>> colors = ['red', 'yellow', 'blue']
>>> color_lines = ("\n" + color for color in colors)
>>> color_lines
<generator object <genexpr> at 0x10041ac80>
>>> color_lines.next()
'red\n'
>>> color_lines.next()
'yellow\n'
>>> color_lines.next()
'blue\n'
>>> color_lines.next()
Traceback (most recent call last):
  File "<stdin>", line 1, in <module>
StopIteration
```

It's important to realise that a generator does not produce a list, it is a promise to produce a list in the future! Until you iterate on a generator nothing has happened besides the creation of your generator object.

Even when the generator does run - instead of creating a single list from the loop and conditions it produces a single value and a position. For each call to `.next()` it produces a single value and updates the current position.

There are downsides - you can't index a generator and you can only iterate over it once. But the performance implications (particularly memory usage) can be dramatic. Code that uses a list comprehension that produces a new list from an original (large) list takes twice the memory of the same code that simply changes the square brackets in the list comprehension to parentheses to make a generator expression instead.

15.4 TOPIC: Generator Functions

The type of object created by the generator expression in the previous section is unsurprisingly called a generator. This is a term for a type of iterator that generates values on demand.

While the generator expression notation is very compact, there may be cases where there is more logic to be performed than can be effectively expressed with this notation. For such cases, a generator function can be used.

A generator function uses the `yield` statement in place of `return` and usually does so inside a loop. When the interpreter sees this statement, it will actually return a generator object from the function. Each time the `next()` function is called on the generator object, the function will be executed up to the next `yield`. When the function completes, the interpreter will raise a StopIteration error to the caller.

```
>>> def one_color_per_line():
...     colors = ['red', 'yellow', 'blue']
...     for color in colors:
...         yield '{0}\n'.format(color)
...
>>> gen = one_color_per_line()
>>> gen
<generator object one_color_per_line at 0x10041acd0>
>>> gen.next()
'red\n'
>>> gen.next()
'yellow\n'
>>> gen.next()
'blue\n'
>>> gen.next()
Traceback (most recent call last):
  File "<stdin>", line 1, in <module>
StopIteration
```

Note that a second call to the same generator function will return a new generator object (shown at a different address) as each generator should be capable of maintaining its own state.

```
>>> gen = one_color_per_line()
>>> gen
<generator object one_color_per_line at 0x10041ad20>
```

Of course, the more typical use case would be to allow the calls to `next()` to be handled by a `for ... in` loop.

```
>>> for line in one_color_per_line():
...     print line,
...
red
yellow
blue
```

You might be wondering why you would ever use generators. Most answers tend to revolve around performance. The potential memory efficiency is most obvious but you can also often improve the execution speed by using generators to interleave CPU and IO bound work.

Aside from performance, however, the coolest thing about generators is the way they let you reshape iteration with trivial amounts of code. Consider writing a function that takes an arbitrary number of iterable data sources and returns a single object that can be iterated over to produce one record at a time. You could do this by:

1. Iterating over all the data sources and accumulate each record in an output list, then returning the output list.

or you could:

1. Build an iterable object that loops over the data sources and uses `yield` to return one object at a time.

This is likely to be less code, as well as more efficient.

15.4.1 LAB

Make all the tests in `mychain.py` pass. Warning: thanks to yield this will be an almost trivial amount of code! If you have more than a few lines, you're doing it wrong!

Tip
and of course as we'll see there are already builtins `xrange` and `itertools.chain`.

15.5 TOPIC: Iteration Helpers: `itertools`

Iteration is a big part of the flow of Python and aside from the builtin syntax, there are some handy tools in the itertools package to make things easier. They also tend to make things run faster.

15.5.1 `chain()`

The `chain()` method accepts an arbitrary number of iterable objects as arguments and returns an iterator that will iterate over each iterable in turn. Once the first is exhausted, it will move onto the next.

Without the `chain()` function, iterating over two lists would require creating a copy with the contents of both or adding the contents of one to the other.

```
>>> l1 = ['a', 'b', 'c']
>>> l2 = ['d', 'e', 'f']
>>> l1.extend(l2)
>>> l1
['a', 'b', 'c', 'd', 'e', 'f']
```

It's much more efficient to use the `chain()` function which only allocates additional storage for some housekeeping data in the iterator itself.

```
>>> import itertools
>>> l1 = ['a', 'b', 'c']
>>> l2 = ['d', 'e', 'f']

>>> chained = itertools.chain(l1, l2)
>>> chained
<itertools.chain object at 0x100431250>

>>> [l for l in chained]
['a', 'b', 'c', 'd', 'e', 'f']
```

15.5.2 `izip()`

`izip()` is almost identical to the `zip()` builtin, in that it pairs up the contents of two lists into an iterable of 2-tuples. However, where `zip()` allocates a new list, `izip()` only returns an iterator.

```
>>> name = ['Jimmy', 'Robert', 'John Paul', 'John']
>>> instruments = ['Guitar', 'Vocals', 'Bass', 'Drums']

>>> zepp = zip(name, instruments)
>>> zepp
[('Jimmy', 'Guitar'), ('Robert', 'Vocals'), ('John Paul', 'Bass'), ('John', 'Drums')]

>>> zepp = itertools.izip(name, instruments)
>>> zepp
<itertools.izip object at 0x100430998>

>>> [musician for musician in zepp]
[('Jimmy', 'Guitar'), ('Robert', 'Vocals'), ('John Paul', 'Bass'), ('John', 'Drums')]
```

15.6 *Advanced Iterations* Follow-up

In this lesson you learned how to use list comprehensions to filter or modify lists. Practice list comprehensions until you are very comfortable writing and reading them. Generator functions and generator expressions might be used less - but they give us important efficiency gains and you'll use generators later on when you enable iteration on our own types.

Chapter 16

Debugging Tools

16.1 Lesson objectives

In this lesson you will review two modules that can help you trace that path of your code's execution and format the output of large or complicated data structures. You will also be introduced to `pdb`: the Python Debugger Module which allows interactive debugging of your programs from the command-line.

16.2 TOPIC: logging

The `logging` module in the Python standard libraries is similar in function to log4j and all of its derivatives in other languages. Logging configuration is hierarchical and can range from very simple to very complex to suit application needs.

Here is an example of a very standard logging configuration and its usage.

Note that you should ideally find a place in your application that will only be executed once in order to configure the logging.

logconfig.py

```
import logging
from logging import handlers

def config():
    logger = logging.getLogger('app')
    logger.setLevel(logging.ERROR)
    handler = handlers.RotatingFileHandler(
            'debug.log',
            maxBytes=(1024*1024),
            backupCount=5
            )
    formatter = logging.Formatter('%(asctime)s - %(levelname)s - %(message)s')
    handler.setFormatter(formatter)
    logger.addHandler(handler)

    logger = logging.getLogger('app.othersub')
    logger.setLevel(logging.DEBUG)
```

debug-1-logging.py

```
import logging

from logconfig import config

config()
```

```
logger = logging.getLogger('app.sub')
logger.debug('something interesting just happened')
logger.error('something horrible just happened')

logger2 = logging.getLogger('app.othersub')
logger2.debug('HMM> something interesting just happened')
logger2.setLevel(logging.DEBUG)
logger2.error('UH-OH> something horrible just happened')

class YouCantDoThatException(Exception):
    pass

class ThatsABadThingException(Exception):
    pass

def dobrokenstuff():
    d = {}
    e = {}
    key = 'missingkey'
    try:
        # val = d[key]
        # raise YouCantDoThatException
        raise KeyError('badkey')
    except KeyError, ke:
        d[key] = 'samplestring'
        logger2.exception('two exceptions')
    else:
        val = val.reverse()
        print val
        val = val.lower()
        finalval = e[val]
        logger2.debug('ELSE: HERE I AM')
    finally:
        logger2.debug('FINALLY: HERE I AM')

def dostuff():
    try:
        dobrokenstuff()
    except YouCantDoThatException, e:
        logger2.exception('Don\'t do that')

try:
    dostuff()
except:
    logger.exception("How did this happen?")
```

```
$ cat debug.log
2010-08-01 21:03:28,074 - DEBUG - something interesting just happened
2010-08-01 21:03:28,074 - ERROR - something horrible just happened
```

The logging module is complex with decoupled Loggers, Handlers, Formatters all communicating via channels. It can be used to create arbitrarily complex logging scenarios where, for example, ERRORs are emailed, WARNINGs go to the database, INFO goes to a file, and so on. The simplest case, however, lets us easily choose how many debugging messages we want to emit. Consider using logging statements liberally in your labs and adding a command line switch that configures a handler to print out a particular debug level. Invoking your progrogram with

```
$ python myprogram.py -d INFO
```

would produce verbose output while

```
$ python myprogram.py -d ERROR
```

would only display error messages.

16.3 TOPIC: pprint

In conjunction with the `logging` module, the `pprint` (pretty print) module can be very helpful. It is easy to include a list or dictionary in a log statement, but it can be hard to read when debugging. In the `pprint` module, the `pprint` function prints to standard out while the `pformat` function returns a string that is more likely to be useful in logging or for other custom output requirements.

```
>>> import pprint
>>> deep = [{'letter': let, 'index': i, 'extended': let*i}
...         for i, let in enumerate(list('abcdefg'))]
>>> deep
[{'index': 0, 'extended': '', 'letter': 'a'}, {'index': 1, 'extended': 'b', 'letter': 'b'}, ↩
     {'index': 2, 'extended': 'cc', 'letter': 'c'}, {'index': 3, 'extended': 'ddd', 'letter ↩
    ': 'd'}, {'index': 4, 'extended': 'eeee', 'letter': 'e'}, {'index': 5, 'extended': ' ↩
    fffff', 'letter': 'f'}, {'index': 6, 'extended': 'gggggg', 'letter': 'g'}]

>>> pprint.pprint(deep)
[{'extended': '', 'index': 0, 'letter': 'a'},
 {'extended': 'b', 'index': 1, 'letter': 'b'},
 {'extended': 'cc', 'index': 2, 'letter': 'c'},
 {'extended': 'ddd', 'index': 3, 'letter': 'd'},
 {'extended': 'eeee', 'index': 4, 'letter': 'e'},
 {'extended': 'fffff', 'index': 5, 'letter': 'f'},
 {'extended': 'gggggg', 'index': 6, 'letter': 'g'}]
```

16.4 TOPIC: pdb

Python also includes a module that supplies a command-line interactive debugger. Your instructor walk you through using debugger commands and the various ways of entering the debugger. Most frequently used is:

Starting the Debugger

```
# large script ...
import pdb;pdb.set_trace() # debugger starts when this line executes
-> import pdb;pdb.set_trace()
(Pdb) ?quit
q(uit) or exit - Quit from the debugger.
The program being executed is aborted.
(Pdb)
```

Once the `set_trace()` call is executed the `pdb` console appears as indicated by the "(Pdb)" prompt. You can enter debugger commands like `step`, `next`, `quit` and also any valid Python code that doesn't conflict with a debugger command. Try launching `pdb` and typing "?" at the prompt for a listing of possible commands. Prefixing a command with a question mark will display help for that command as demonstrated in the code sample above.

16.5 Lab

1. Create a simple script with three loggers 'app', 'app.sub', 'app.sub.sub'.
2. Log a debug and critical message for each.

3. Set ‘app’ to CRITICAL and ‘app.sub.sub’ to DEBUG. What messages do you get?
4. Include a timestamp and the log level in your messages.
5. raise an Exception and log it with .exception()

16.6 *Debugging Tools* Follow-up

This lesson quickly demonstrated several tools you’ll use as a Python developer and you gained experience using the somewhat complicated `logging` module. Using `logging` (and `pdb`) well will take more experience but be sure to practice - figuring out errors in our code can be hard and any tools that make the process easier should be embraced.

Chapter 17

Object-Oriented Programming

17.1 Lesson objectives

This lesson will review Python's support for object oriented programming. Some topics in OOP are beyond the scope of this class but you will learn

- how to create your own types with `class`
- how to support Python operators and protocols (like emulation or indexing) on your custom types
- how to create static functions as part of your Classes
- how to use inheritance and `super`
- how to separate the interface from implementation in your classes

17.2 TOPIC: Classes

A class is defined in Python using the `class` statement. The syntax of this statement is `class <ClassName>(superclass)`. In the absence of anything else, the superclass should always be `object`, the root of all classes in Python.

Note
`object` is technically the root of "new-style" classes in Python, but new-style classes today are as good as being the only style of classes.

Here is a basic class definition for a class with one method. There are a few things to note about this method:

1. The single argument of the method is `self`, which is a reference to the object instance upon which the method is called, is explicitly listed as the first argument of the method. In the example, that instance is `a`. This object is commonly referred to as the "bound instance."
2. However, when the method is called, the `self` argument is inserted implicitly by the interpreter — it does not have to be passed by the caller.
3. The attribute `__class__` of `a` is a reference to the class object `A`
4. The attribute `__name__` of the class object is a string representing the name, as given in the class definition.

Also notice that "calling" the class object (`A`) produces a newly instantiated object of that type (assigned to `a` in this example). You can think of the class object as a factory that creates objects and gives them the behavior described by the class definition.

```
>>> class A(object):
...     def whoami(self):
...         return self.__class__.__name__
...

>>> a = A()

>>> a
<__main__.A object at 0x100425d90>

>>> a.whoami()
'A'
```

The most commonly used special method of classes is the `__init__()` method, which is an initializer for the object. The arguments to this method are passed in the call to the class object.

Notice also that the arguments are stored as object attributes, but those attributes are not defined anywhere before the initializer.

Attempting to instantiate an object of this class without those arguments will fail.

```
>>> class Song(object):
...     def __init__(self, title, artist):
...         self.title = title
...         self.artist = artist
...     def get_title(self):
...         return self.title
...     def get_artist(self):
...         return self.artist
...

>>> unknown = Song()
Traceback (most recent call last):
  File "<stdin>", line 1, in <module>
TypeError: __init__() takes exactly 3 arguments (1 given)
```

Notice again that one argument was actually provided (`self`) and only title and artist are considered missing.

So, calling `Song` properly gives an instance of Song with an artist and title. Calling the `get_title()` method returns the title, but so does just referencing the `title` attribute. It is also possible to directly write the instance attribute. Using boilerplate getter / setter methods is generally considered unnecessary. There are ways to create encapsulation that will be covered later.

```
>>> leave = Song('Leave', 'Glen Hansard')

>>> leave
<__main__.Song object at 0x100431050>

>>> leave.get_title()
'Leave'

>>> leave.title
'Leave'

>>> leave.title = 'Please Leave'

>>> leave.title
'Please Leave'
```

One mechanism that can be utilized to create some data privacy is a preceding double-underscore on attribute names. However, it is possible to find and manipulate these variables if desired, because this approach simply mangles the attribute name with the class name. The goal in this mangling is to prevent clashing between "private" attributes of classes and "private" attributes of their superclasses.

```
>>> class Song(object):
...     def __init__(self, title, artist):
...         self.__title = title
...         self.__artist = artist
...     def get_title(self):
...         return self.__title
...     def get_artist(self):
...         return self.__artist
...
>>> leave = Song('Leave', 'Glen Hansard')

>>> leave.get_title()
'Leave'

>>> leave.__title
Traceback (most recent call last):
  File "<stdin>", line 1, in <module>
AttributeError: 'Song' object has no attribute '__title'

>>> leave._Song__title
'Leave'
```

17.2.1 Emulation

Python provides many special methods on classes that can be used to emulate other types, such as functions, iterators, containers and more.

Functions In order to emulate a function object, a class must define the method `__call__()`. If the call operator `()` is used on an instance of the class, this method will be called behind the scenes. Here is an example that performs the same task as the adding closure in the functional programming section.

```
>>> class Adder(object):
...     def __init__(self, extra):
...         self.extra = extra
...     def __call__(self, base):
...         return self.extra + base
...
>>> add2 = Adder(2)
>>> add2(3)
5
>>> add5 = Adder(5)
>>> add5(3)
8
>>> add2(1)
3
```

Iterators When an object is used in a `for ... in` statement, the object's `__iter__()` method is called and the returned value should be an iterator. At that point, the interpreter iterates over the result, assigning each object returned from the iterator to the loop variable in the `for ... in` statement.

This example class implements the `__iter__()` method and returns a generator expression based on whatever arguments were passed to the initializer.

```
>>> class Lister(object):
...     def __init__(self, *args):
...         self.items = tuple(args)
...     def __iter__(self):
...         return (i for i in self.items)
...
```

```
>>> l = Lister('a', 'b', 'c')

>>> for letter in l:
...     print letter,
...
a b c
```

Here is the same example using a generator function instead of a generator expression.

```
>>> class Lister(object):
...     def __init__(self, *args):
...         self.items = tuple(args)
...     def __iter__(self):
...         for i in self.items:
...              yield i
...

>>> l = Lister('a', 'b', 'c')

>>> for letter in l:
...     print letter,
...
a b c
```

17.2.2 `classmethod` and `staticmethod`

A class method in Python is defined by creating a method on a class in the standard way, but applying the `classmethod` decorator to the method.

Notice in the following example that instead of `self`, the class method's first argument is named `cls`. This convention is used to clearly denote the fact that in a class method, the first argument received is not a bound instance of the class, but the class object itself.

As a result, class methods are useful when there may not be an existing object of the class type, but the type of the class is important. This example shows a "factory" method, that creates Song objects based on a list of tuples.

Also notice the use of the `__str__()` special method in this example. This method returns a string representation of the object when the object is passed to `print` or the `str()` builtin.

```
>>> class Song(object):
...     def __init__(self, title, artist):
...         self.title = title
...         self.artist = artist

...     def __str__(self):
...         return ('"%(title)s" by %(artist)s' %
...                 self.__dict__)

...     @classmethod
...     def create_songs(cls, songlist):
...         for artist, title in songlist:
...             yield cls(title, artist)
...
>>> songs = (('Glen Hansard', 'Leave'),
...         ('Stevie Ray Vaughan', 'Lenny'))

>>> for song in Song.create_songs(songs):
...     print song
...
"Leave" by Glen Hansard
"Lenny" by Stevie Ray Vaughan
```

Static methods are very similar to class methods and defined using a similar decorator. The important difference is that static methods receive neither an instance object nor a class object as the first argument. They only receive the passed arguments.

As a result, the only real value in defining static methods is code organization. But in many cases a module-level function would do the same job with fewer dots in each call.

```
>>> class Song(object):
...     def __init__(self, title, artist):
...         self.title = title
...         self.artist = artist

...     def __str__(self):
...         return ('"%(title)s" by %(artist)s' %
...                 self.__dict__)

...     @staticmethod
...     def create_songs(songlist):
...         for artist, title in songlist:
...             yield Song(title, artist)
...
>>> songs = (('Glen Hansard', 'Leave'),
...         ('Stevie Ray Vaughan', 'Lenny'))

>>> for song in Song.create_songs(songs):
...     print song
...
"Leave" by Glen Hansard
"Lenny" by Stevie Ray Vaughan
```

17.2.3 Lab

oop-1-parking.py

```
'''
>>> # Create a parking lot with 2 parking spaces
>>> lot = ParkingLot(2)
'''



'''
>>> # Create a car and park it in the lot
>>> car = Car('Audi','R8', '2010')
>>> lot.park(car)
>>> car = Car('VW', 'Vanagon', '1981')
>>> lot.park(car)
>>> car = Car('Buick','Regal', '1988')
>>> lot.park(car)
'Lot Full'
>>> lot.spaces = 3
>>> lot.park(car)
>>> car.make
'Buick'
>>> car.model
'Regal'
>>> car.year
'1988'
>>> for c in lot:
...     print c
2010 Audi R8
1981 VW Vanagon
1988 Buick Regal
```

```
>>> for c in lot.cars_by_age():
...     print c
1981 VW Vanagon
1988 Buick Regal
2010 Audi R8
>>> for c in lot:
...     print c
2010 Audi R8
1981 VW Vanagon
1988 Buick Regal
'''



if __name__ == '__main__':
    import doctest
    doctest.testmod()
```

17.3 TOPIC: Inheritance

As noted in the first class definition example above, a class defines a superclass using the parentheses list in the class definition. The model for overloading methods is very similar to most other languages: define a method in the child class with the same name as that in the parent class and it will be used instead.

oop-1-inheritance.py

```
class Instrument(object):
    def __init__(self, name):
        self.name = name
    def has_strings(self):
        return True

class PercussionInstrument(Instrument):
    def has_strings(self):
        return False

guitar = Instrument('guitar')
drums = PercussionInstrument('drums')

print 'Guitar has strings: {0}'.format(guitar.has_strings())
print 'Guitar name: {0}'.format(guitar.name)
print 'Drums have strings: {0}'.format(drums.has_strings())
print 'Drums name: {0}'.format(drums.name)
```

```
$ python oop-1-inheritance.py
Guitar has strings: True
Guitar name: guitar
Drums have strings: False
Drums name: drums
```

Calling Superclass Methods Python has a `super()` builtin function instead of a keyword and it makes for slightly clunky syntax. The result, however, is as desired, which is the ability to execute a method on a parent or superclass in the body of the overloading method on the child or subclass.

In this example, an overloaded `__init__()` is used to hard-code the known values for every guitar, saving typing on every instance.

oop-2-super.py

```
class Instrument(object):
    def __init__(self, name):
        self.name = name
    def has_strings(self):
        return True

class StringInstrument(Instrument):
    def __init__(self, name, count):
        super(StringInstrument, self).__init__(name)
        self.count = count

class Guitar(StringInstrument):
    def __init__(self):
        super(Guitar, self).__init__('guitar', 6)

guitar = Guitar()

print 'Guitar name: {0}'.format(guitar.name)
print 'Guitar count: {0}'.format(guitar.count)
```

```
python oop-2-super.py
Guitar name: guitar
Guitar count: 6
```

There is an alternate form for calling methods of the superclass by calling them against the unbound class method and explicitly passing the object as the first parameter. Here is the same example using the direct calling method.

oop-3-super-alt.py

```
class Instrument(object):
    def __init__(self, name):
        self.name = name
    def has_strings(self):
        return True

class StringInstrument(Instrument):
    def __init__(self, name, count):
        Instrument.__init__(self, name)
        self.count = count

class Guitar(StringInstrument):
    def __init__(self):
        StringInstrument.__init__(self, 'guitar', 6)

guitar = Guitar()

print 'Guitar name: {0}'.format(guitar.name)
print 'Guitar count: {0}'.format(guitar.count)
```

```
python oop-3-super-alt.py
Guitar name: guitar
Guitar count: 6
```

Multiple Inheritance Python supports multiple inheritance using the same definition format as single inheritance. Just provide an ordered list of superclasses to the class definition. The order of superclasses provided can affect method resolution in the case of conflicts, so don't treat it lightly.

The next example shows the use of multiple inheritance to add some functionality to a class that might be useful in many different kinds of classes.

oop-4-multiple.py

```
class Instrument(object):
    def __init__(self, name):
        self.name = name
    def has_strings(self):
        return True


class Analyzable(object):
    def analyze(self):
        print 'I am a {0}'.format(self.__class__.__name__)


class Flute(Instrument, Analyzable):
    def has_strings(self):
        return False


flute = Flute('flute')
flute.analyze()
print flute.__class__.__mro__
```

```
$ python oop-4-multiple.py
I am a Flute
(<class '__main__.Flute'>, <class '__main__.Instrument'>, <class '__main__.Analyzable'>, < ↩
    type 'object'>)
```

Abstract Base Classes Python recently added support for abstract base classes. Because it is a more recent addition, its implementation is based on existing capabilities in the language rather than a new set of keywords. To create an abstract base class, override the metaclass in your class definition (metaclasses in general are beyond the scope of this course, but they define how a class is created). Then, apply the `abstractmethod` decorator to each abstract method. Note that both `ABCMeta` and `abstractmethod` need to be imported.

Here is a simple example. Notice that the base class cannot be instantiated, because it is incomplete.

oop-5-abc.py

```
from abc import ABCMeta, abstractmethod
import sys
import traceback

class Instrument(object):
    __metaclass__ = ABCMeta
    def __init__(self, name):
        self.name = name
    @abstractmethod
    def has_strings(self):
        pass


class StringInstrument(Instrument):
    def has_strings(self):
        return True


guitar = StringInstrument('guitar')
print 'Guitar has strings: {0}'.format(guitar.has_strings())
try:
    guitar = Instrument('guitar')
except:
    traceback.print_exc(file=sys.stdout)
```

```
$ python oop-5-abc.py
Guitar has strings: True
Traceback (most recent call last):
  File "samples/oop-5-abc.py", line 22, in <module>
    guitar = Instrument('guitar')
TypeError: Can't instantiate abstract class Instrument with abstract methods has_strings
```

One feature of abstract methods in Python that differs from some other languages is the ability to create a method body for an abstract method. This feature allows common, if incomplete, functionality to be shared between multiple subclasses. The abstract method body is executed using the `super()` method in the subclass.

oop-6-abcbody.py

```
from abc import ABCMeta, abstractmethod

class Instrument(object):
    __metaclass__ = ABCMeta

    def __init__(self, name):
        self.name = name

    @abstractmethod
    def has_strings(self):
        print 'checking for strings in %s' % \
            self.name


class StringInstrument(Instrument):

    def has_strings(self):
        super(StringInstrument,
                self).has_strings()
        return True


guitar = StringInstrument('guitar')
print 'Guitar has strings: {0}'.format(guitar.has_strings())
```

```
$ python oop-6-abcbody.py
checking for strings in guitar
Guitar has strings: True
```

17.3.1 Lab

oop-2-pets.py

```
'''
>>> cat = Cat('Spike')
>>> cat.speak()
'Spike says "Meow"'
>>> dog = Dog('Bowzer')
>>> cat.can_swim()
False
>>> dog.can_swim()
True
>>> dog.speak()
'Bowzer says "Woof"'
>>> fish = Fish('Goldie')
>>> fish.speak()
```

```
"Goldie can't speak"
>>> fish.can_swim()
True
>>> generic = Pet('Bob')
Traceback (most recent call last):
    ...
TypeError: Can't instantiate abstract class Pet with abstract methods can_swim
'''

if __name__ == '__main__':
    import doctest
    doctest.testmod()
```

17.4 TOPIC: Encapsulation

As mentioned previously, while Python does not support declarations of attribute visibility (public, private, etc), it does provide mechanisms for encapsulation of object attributes. There are three approaches with different levels of capability that can be used for this purpose.

17.4.1 Intercepting Attribute Access

When an attribute of an object is accessed using dot-notation, there are three special methods of the object that may get called along the way.

For lookups, two separate methods are called: `__getattribute__(self, name)` is called first, passing the name of the attribute that is being requested. Overriding this method allows for the interception of requests for any attribute. By contrast, `__getattr__()` is only called when `__getattribute__()` fails to return a value. So this method is useful if only handling undefined cases.

For setting attributes only one method, `__setattr__(self, name, value)` is called. Note that inside this method body, calling `self.name = value` will lead to infinite recursion. Use the superclass `object.__setattr__(self, name, value)` instead.

The following example shows a course with two attributes `capacity` and `enrolled`. A third attribute `open` is calculated based on the other two. However, setting it is also allowed and forces the enrolled attribute to be modified.

oop-7-intercept.py

```
import traceback
import sys

class Course(object):
    def __init__(self, capacity):
        self.capacity = capacity
        self.enrolled = 0

    def enroll(self):
        self.enrolled += 1

    def __getattr__(self, name):
        if name == 'open':
            return self.capacity - self.enrolled
        else:
            raise AttributeError('%s not found', name)

    def __setattr__(self, name, value):
        if name == 'open':
            self.enrolled = self.capacity - value
        else:
```

```
            object.__setattr__(self, name, value)

    def __str__(self):
        return 'Enrolled: \t{0}\nCapacity:\t{1}\nOpen:\t{2}'.format(
                self.enrolled, self.capacity, self.open)

course = Course(12)
course.enroll()
course.enroll()

print course

course.open = 8

print course
```

```
$ python oop-7-properties.py
Enrolled:   2
Capacity: 12
Open: 10
Enrolled:   4
Capacity: 12
Open: 8
```

17.4.2 Properties

For the simple case of defining a calculated property as shown in the above example, the more appropriate (and simpler) model is to use the `property` decorator to define a method as a propery of the class.

Here is the same example again using the `property` decorator. Note that this approach does not handle setting this property. Also notice that while `open()` is initially defined as a method, it cannot be accessed as a method.

oop-8-properties.py

```
import traceback
import sys

class Course(object):
    def __init__(self, capacity):
        self.capacity = capacity
        self.enrolled = 0

    def enroll(self):
        self.enrolled += 1

    @property
    def open(self):
        return self.capacity - self.enrolled

course = Course(12)
course.enroll()
course.enroll()

print 'Enrolled: \t{0}\nCapacity:\t{1}\nOpen:\t{2}'.format(course.enrolled,
        course.capacity, course.open)

print
try:
    course.open()
except:
```

```
    traceback.print_exc(file=sys.stdout)

print
try:
    course.open = 9
except:
    traceback.print_exc(file=sys.stdout)
```

```
$ python oop-8-properties.py
Enrolled:   2
Capacity: 12
Open: 10

Traceback (most recent call last):
  File "samples/oop-8-properties.py", line 25, in <module>
    course.open()
TypeError: 'int' object is not callable

Traceback (most recent call last):
  File "samples/oop-8-properties.py", line 31, in <module>
    course.open = 9
AttributeError: can't set attribute
```

Using the property mechanism, setters can also be defined. A second decorator is dynamically created as `<attribute name>.setter` which must be applied to a method with the **exact same name** but an additional argument (the value to be set).

In this example, we use this additional functionality to encapsulate the speed of a car and enforce a cap based on the type of car being manipulated.

oop-9-propertysetters.py

```
class Car(object):
    def __init__(self, name, maxspeed):
        self.name = name
        self.maxspeed = maxspeed
        self.__speed = 0

    @property
    def speed(self):
        return self.__speed

    @speed.setter
    def speed(self, value):
        s = int(value)
        s = max(0, s)
        self.__speed = min(self.maxspeed, s)

car = Car('Lada', 32)
car.speed = 100
print 'My {name} is going {speed} mph!'.format(name=car.name, speed=car.speed)

car.speed = 24
print 'My {name} is going {speed} mph!'.format(name=car.name, speed=car.speed)
```

```
$ python oop-9-propertysetters.py
My Lada is going 32 mph!
My Lada is going 24 mph!
```

17.4.3 Descriptors

The final mechanism for encapsulating the attributes of a class uses descriptors. A descriptor is itself a class and it defines the type of an attribute. When using a descriptor, the attribute is actually declared at the class level (not in the initializer) because it is adopting some type information that must be preserved.

The descriptor class has a simple protocol with the methods `__get__()`, `__set__()` and `__delete__()` being called on attribute access and manipulation. Notice that the descriptor does not store instance attributes on itself, but rather on the instance. The descriptor is only instantiated once at class definition time, so any values stored on the descriptor object will be common to all instances.

The following example tackles the speed-limit problem using descriptors.

oop-10-descriptors.py

```
class BoundsCheckingSpeed(object):
    def __init__(self, maxspeed):
        self.maxspeed = maxspeed

    def __get__(self, instance, cls):
        return instance._speed

    def __set__(self, instance, value):
        s = int(value)
        s = max(0, s)
        instance._speed = min(self.maxspeed, s)


class Animal(object):
    speed = BoundsCheckingSpeed(0)

    def __init__(self, name):
        self.name = name

    @property
    def speed_description(self):
        return '{name} the {type} is going {speed} mph!'.format(name=self.name,
            type=self.__class__.__name__.lower(), speed=self.speed)


class Squirrel(Animal):
    speed = BoundsCheckingSpeed(12)


class Cheetah(Animal):
    speed = BoundsCheckingSpeed(70)


squirrel = Squirrel('Jimmy')
squirrel.speed = 20
print squirrel.speed_description

squirrel.speed = 10
print squirrel.speed_description

cheetah = Cheetah('Fred')
cheetah.speed = 100
print cheetah.speed_description
```

```
$ python oop-10-descriptors.py
Jimmy the squirrel is going 12 mph!
Jimmy the squirrel is going 10 mph!
Fred the cheetah is going 70 mph!
```

Tip
Notice that values of the descriptor can be set for all instances of a certain class, while being different in different uses. The descriptor allows for the creation of a generic field "type" that can be shared in a configurable fashion across unrelated classes. It is more complex to use than properties, but can provide more flexibility in a complex object hierarchy.

17.4.4 Lab

oop-3-portfolio.py

```
'''
>>> p = Portfolio()
>>> stocks = (('APPL', 1000, 251.80, 252.73),
...           ('CSCO', 5000, 23.09, 23.74),
...           ('GOOG', 500, 489.23, 491.34),
...           ('MSFT', 2000, 24.63, 25.44))
...
>>> for stock in stocks:
...     p.add(Investment(*stock))
>>> print p['APPL']
1000 shares of APPL worth 252730.00
>>> p['GOOG'].quantity
500
>>> p['GOOG'].close
491.33999999999997
>>> p['GOOG'].open
489.23000000000002
>>> for stock in p:
...     print stock
1000 shares of APPL worth 252730.00
5000 shares of CSCO worth 118700.00
500 shares of GOOG worth 245670.00
2000 shares of MSFT worth 50880.00
>>> for stock in p.sorted('open'):
...     print stock.name
CSCO
MSFT
APPL
GOOG
>>> p['MSFT'].gain
0.81000000000000227
>>> p['CSCO'].total_gain
3249.9999999999927
>>> 'GOOG' in p
True
>>> 'YHOO' in p
False
'''

if __name__ == '__main__':
    import doctest
    doctest.testmod()
```

17.5 *Object Oriented* Follow-up

This chapter covered the major concepts of Object Oriented programming in Python. You've gained experience writing classes and using Python's emulation features to use your objects in an intuitive and Pythonic manner. You've also explored how inheritance works and used more advanced concepts like the `@property` decorator to separate the details of your implementation

from the interface to your objects. This should be enough coverage to enable you to use object oriented thinking and design to solve real world problems in your own programs.

Chapter 18

UnitTest

18.1 Lesson objectives

In this lesson you will learn to write tests with the builtin UnitTest module. UnitTest allows you to write more robust tests that require setup or cleanup.

18.2 UnitTest

The `unittest` module may feel a little verbose and "un-pythonic". This is probably a reflection of it's origin as a straight port of the JUnit testing framework written for the Java programming language. Tests written with the help of unittest must be written inside of classes - Java, unlike Python, does not allow purely procedural code and unittest reflects this.

Why might we want to use the more cumbersome `unittest` module? You've probably written enough doctests by now to recognize some of their limitations: output parsing can be a little fragile due to embedding strings inside of docstrings, there isn't any way to structure your test suite (each line of code is a test), and you're limited by readability constraints. It probably wouldn't be very friendly to put 20 lines of doctest on a 5 line function - but sometimes that is what you need to test all the edge cases. Some functions also depend on their environment - and a doctest that has 10 lines of setup and 1 line of actual test isn't necessarily contributing much to the intended documentation purpose of docstrings.

The unittest module provides a runner to execute our tests, means of grouping tests into logical units, and the concept of setup and teardown to provide a consistent environment for our tests. Let's see how all these concepts work by looking at a simple example:

unitttest1.py

```
import unittest

class ObviousTest(unittest.TestCase):

    def setUp(self):
        self.num = 1

    def test_math(self):
        self.assertEqual(self.num, 1)

    def test_divides_by_zero(self):
        self.assertRaises(ZeroDivisionError, lambda : 1/0)

if __name__ == '__main__':
    unittest.main()
```

Let's review the OOP concepts you will need to write `UnitTests`.

- A TestCase is a class that inherits from `unittest.TestCase`. In Python we create inheritance by passing a list of parent classes in parentheses after the name of our class.
- The actual tests must be methods of our class whose names start with "test". Functions defined inside a class are by default `bound methods` and therefore require a mandatory first parameter conventionally named `self`.

We can run our tests by running the script - when run as a script the provided `unittest.main()` function takes care of finding all the TestCase subclasses, calling their `setUp` method first if provided, calling a methods whose name starts with *test*, finally calling a `tearDown` method if provided. This process is repeated for each `test*` method. The default test runner prints out dots for sucessful tests, `E` if a test contains an error and `F` if call to an assertion method fails.

```
$ python unitest1.py
..
----------------------------------------------------------------------
Ran 2 tests in 0.000s

OK
```

We currently have two passing tests.

Our test class has three methods, but `setUp` is not a test. The `setUp` method allows us to prepare the environment in which our tests will be run - if we need to create files, prepare data, etc then `setUp` is the place to do it. Next we have our "test" methods. When writing doctests each line of code was a test but in unittest you will define your tests as functions.

Each test can contain whatever Python code it likes - but usually calls convenience methods supplied by the unittest.TestCase base class. You can access these methods by dereferencing `self` and methods exist to assert that two values are equal or inequal, or even "almost" equal, that a value is False or True, or even to check that a callable raises an exception.

```
>>> import unittest
>>> [method for method in dir(unittest.TestCase) if "assert" in method]
['assertAlmostEqual', 'assertAlmostEquals', 'assertEqual', 'assertEquals', 'assertFalse', ' ↩
    assertNotAlmostEqual', 'assertNotAlmostEquals', 'assertNotEqual', 'assertNotEquals', ' ↩
    assertRaises', 'assertTrue', 'assert_']
```

The tests in our `ObviousTest` class aren't doing anything very profound - `test_divides_by_zero` confirms that an anonymous function that attempts to divide by zero does in fact raise an exception. In this case we are testing a failure condition and the test passes if the failure occurs as expected. In `test_math` we are testing that two numeric values are equal and as expected these tests pass.

18.2.1 Lab

Earlier you completed a short lab that tested using functional programming constructs like map, filter, and sorted. You've already written doctests for this code - now remove any doctests that don't improve the documentation of your functions and create a new file `unittest1.py`. Copy and paste the unittest example above and write new methods to test the functions in functional1.py. How many tests should you write? How can you tell when you've exhaustively tested your code?

18.3 *UnitTest* Follow-up

Doctests are quick to write and may improve your documentation. They also make sense when you need code samples for your documentation and want to make sure that the documentation doesn't lie. Use unittests, however, whenever you need to thoroughly test something. And the Python community has developed a whole ecosystem of test runners, reports, plugins, and tools all of which work well with tests written using `unittest`.

Chapter 19

Managing Your Python Environment

19.1 Lesson objectives

Despite Python's "batteries included" philosophy we frequently want to install 3rd party packages for use in our Python programs. Python (on most operating systems) comes with a facility for automatically installing modules but all packages are installed globally and on some systems it requires adminstrative privileges. We can use standard tools to create isolated Python environments and install 3rd party packages into them.

19.1.1 virtualenv

Virtualenv is a tool that has swiftly become a community standard in the Python world - so much so that official support for virtualenv shipped with Python 3.3. Consider the typical ways in which you might install a Python package or application

Django installation

```
$ tar xzvf Django-1.5.tar.gz
$ cd Django-1.5
$ sudo python setup.py install
```

The disadvantage of this approach is that Django ends up installed globally. The built-in installer uses a system called setuptools and places the django directory containing importable code in your shared system packages directory. On Windows, for example, this might be in `C:\Python2.7\Lib\site-packages`.

Using a single global location to install Python modules means that it is impossible to to have more than one version of your package installed. It also means that you have to have administrative permissions to install Python modules. Fortunately there's a better way to manage installation of Python modules.

> VIRTUALENV
>
> `virtualenv` is a tool to create isolated Python environments.
>
> — cite http://pypi.python.org/pypi/virtualenv

Ian Bicking's tool virtualenv allows us to create Python environments that are isolated from one another. It supports all three major OS platforms (Windows/Mac/Linux) and has become a defacto standard with integration in other tools such as mod_wsgi and the pip installer.

To install virtualenv we can use `easy_install`, the installer provided by setuptools. This should be automatically installed with Python on Mac and Linux but Windows users may have to download and run the setuptools installer for your version of Python - you can find it at http://pypi.python.org/pypi/setuptools

Installing virtualenv

```
$ easy_install virtualenv
```

`virtualenv` works by creating a Python environment, copying or symnlinking your Python executable and creating a local directory in which to install Python modules. This is best demonstrated by example:

Let's make a virtualenv

```
$ virtualenv PROJ1
New python executable in PROJ1/bin/python
Installing setuptools.............done.
$ which python              # The virtual env is not yet activated
/usr/bin/python
$ source PROJ1/bin/activate # Activate using the source command
(PROJ1)$ which python       # Notice the prompt indicates the active env
/home/simeon/PROJ1/bin/python
```

The `virtualenv` command is used to create a virtualenvironment in the directory specified. Virtualenvironments are just directories with a Python environment - they can be activated by running the activate script using the `source` command on the activate script on Mac/Linux or by running the `activate.bat` on windows.

The prompt is modified to show the currently active virtualenvironment and now running commands like `python` or `easy_install` runs a local copy in the `bin` directory of the virtualenvironment instead of the global shared executable.

Install Nose

```
(PROJ1)$ easy_install nose
Searching for nose
Reading http://pypi.python.org/simple/nose/
Reading http://somethingaboutorange.com/mrl/projects/nose/
Reading http://readthedocs.org/docs/nose/
Best match: nose 1.1.2
Downloading http://pypi.python.org/packages/source/n/nose/nose-1.1.2.tar.gz#md5=144 ↩
    f237b615e23f21f6a50b2183aa817
Processing nose-1.1.2.tar.gz
... snip ...
Processing dependencies for nose
Finished processing dependencies for nose
```

Notice that easy_install was not run with administrative permissions. Not only is the Python code put in the right place (the site-packages directory of the currently activated virtualenv) but utilities like the *nosetests* test runner are put in a `bin` folder in the currently activated environment as well.

19.2 PRACTICE ACTIVITY

1. Make sure your environment is all set up. Go ahead and install setuptools if on Windows - other OS's should already have setuptools installed. You can check by running the `easy_install` command in your shell - if you've got it you already have setuptools installed.
2. Install virtualenv using easy_install.
3. Create a virtualenv called `nose`. Install `nose` in it using easy_install. Go ahead and easy_install the "coverage" module as we'll be needing that too.
4. You can check to make sure nose is installed correctly by opening a Python console and running `import nose`.

Tip
Mac users who have recently upgraded to Lion seem to have a variety of problems with `virtualenv` and `easy_install`. Most of these problems seem to be resolved by running all updates for xcode.

19.2.1 virtualenvwrapper

Doug Hellman's `virtualenvwrapper` is a set of helper commands for managing virtualenvs. It is written in bash so unfortunately is not available for Windows - although Windows users might check out https://github.com/davidmarble/virtualenvwrapper-win for an implementation in batch scripts.

The idea behind virtualenvwrapper is to store all virtualenvs in a specific place (by default `~/.virtualenv` but configurable) and add utility commands for creating, activating, manually adding locations, and listing the contents of a particular virtualenv. We won't be covering installation and usage of virtualenvwrapper in this course as it doesn't modify the functionality of the underlying `virtualenv` tool, but many Python hackers find virtualenvwrapper an indispensable part of their toolkit to manage their development environment.

19.2.2 PIP

You might also be interested in replacing `easy_install` with `pip`. Pip is another Ian Bicking tool that has become an indispensable part of many Python devopers toolkit. You can install it with `easy_install` - but if you use a `virtualenv` it will be automatically installed for you!

Using pip at a basic level is nearly identical to `easy_install`. Pip includes features like default .egg unzipping, uninstallation, listing installed packages, native support for virtual environments, installing directly from source control, building a new environment from a requirements file and much more. See http://www.pip-installer.org/en/latest/index.html for more details.

19.3 *Basic Tools* Follow-up

This lesson introduced tools that should become part of your basic workflow as a Python developer. The ability to create isolated Python environments, try out different versions of packages, and easily recreate a given Python environment is important. If nothing else, however, the tools make it easy to quickly install 3rd party libraries you're interested in playing with.

Chapter 20

Easter Eggs

The `__future__` module contains new features of the language backported to older versions. Perhaps if you prefer to `{}` instead of indentation you should try:

```
>>> from __future__ import braces
```

Note the exception message!

You might also try:

```
>>> import antigravity
```

and

```
>>> import this
```