

Think Python (and other useful things)

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Preface

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3 Functions

3.1 Function calls

In the context of programming, a **function** is a named sequence of statements that performs a computation. To define a function, specify the name and sequence of statements. Then “call” the function by name later. Example of a **function call**:

```
>>> type(32)
<type 'int'>
```

The name of the function is `type`. The expression in parentheses is called the **argument** of the function. The result, for this function, is the type of the argument.

It is common to say that a function “takes” an argument and “returns” a result. The result is called the **return value**.

3.2 Type conversion functions

Python provides built-in functions that convert values from one type to another. The `int` function takes any value and converts it to an integer:

```
>>> int('32')
32
>>> int(3.999)
3
```

Note that decimals are truncated, not rounded.

The `float` function converts integers and strings to floating-point numbers:

```
>>> float(32)
32.0
>>> float('3.14159')
3.14159
```

The `str` function converts its argument to a string:

```
>>> str(32)
'32'
>>> str(3.14159)
'3.14159'
```

3.3 Math functions

Python has a `math` module that provides most of the familiar mathematical functions. A **module** is a file that contains a collection of related functions. Modules must be imported before they can be used (such as `>>> import math`, which creates a **module object**) named `math`. If you print the module object, you get some information about it:

```
>>> print math
<module 'math' from '/usr/lib/python2.5/lib-dynload/math.so'>
```

The module object contains the functions and variables defined in the module. To access one of the functions, you have to specify the name of the module and the name of the function, separated by a dot (this format is called **dot notation**).

```
>>> ratio = signal_power / noise_power
>>> decibels = 10 * math.log10(ratio)
```

```
>>> radians = 0.7
>>> height = math.sin(radians)
```

The first example computes the logarithm base 10 of the signal-to-noise ratio. The `math` module also provides a function called `log` that computes logarithms base `e`.

The second example finds the sine of `radians`. Trigonometric functions (`sin`, `cos`, `tan`, etc.) **take arguments in radians**.

The expression `math.pi` gets the variable `pi` from the `math` module, which is accurate to about 15 digits.

3.4 Composition

So far, we have looked at the elements of a program: variables, expressions, and statements in isolation. One of the most useful features of programming languages is their ability to take small building blocks and **compose** them. For example, the argument of a function can be any kind of expression, including arithmetic operators and function calls:

```
x = math.sin(degrees / 360.0 * 2 * math.pi)
x = math.exp(math.log(x+1))
```

3.5 Adding new functions

A **Function definition** specifies the name of a new function and the sequence of statements that execute when the function is called, e.g.:

```
def do_nothing():
    print 'Doing nothing.'
```

`def` is a keyword that indicates that this is a function definition. The name of the function is `do_nothing`. You should avoid having a variable and a function with the same name. The empty parentheses indicate that this function doesn't take any arguments.

The first line of the function definition is called the **header**; the rest is called the **body**. The header has to end with a colon and the body has to be indented. By convention, the indentation is always four spaces (see Section 3.13).

If you type a function definition in interactive mode, the interpreter prints ellipses (...) to let you know that the definition isn't complete:

```
>>> def print_lyrics():
...     print 'I'm a lumberjack, and I'm okay.'
...     print 'I sleep all night and I work all day.'
... 
```

To end the function, enter an empty line (this is not necessary in a script).

Defining a function creates a variable with the same name.

```
>>> print print_lyrics
<function print_lyrics at 0xb7e99e>
>>> type(print_lyrics)
<type 'function'>
```

The value of `print_lyrics` is a **function object**, which has type `'function'`.

The syntax for calling the new function is the same as for built-in functions:

```
>>> print_lyrics()
I'm a lumberjack, and I'm okay.
I sleep all night and I work all day.
```

Once you have defined a function, you can use it inside another function. For example, to repeat the previous refrain, we could write a function called `repeat_lyrics`:

```
def repeat_lyrics():
    print_lyrics()
    print_lyrics()
```

And then call `repeat_lyrics`:

```
>>> repeat_lyrics()
I'm a lumberjack, and I'm okay.
I sleep all night and I work all day.
I'm a lumberjack, and I'm okay.
I sleep all night and I work all day.
```

3.6 Definitions and uses

Pulling together the code fragments from the previous section, the whole program looks like this:

```
def print_lyrics():
    print 'I'm a lumberjack, and I'm okay.'
    print 'I sleep all night and I work all day.'

def repeat_lyrics():
    print_lyrics()
```

```
    print_lyrics()

repeat_lyrics()
```

This program contains two function definitions: `print_lyrics` and `repeat_lyrics`. Function definitions get executed just like other statements, but the effect is to create function objects. The statements inside the function do not get executed until the function is called, and the function definition generates no output. As you might expect, you have to create a function before you can execute it. In other words, the function definition has to be executed before the first time it is called.

3.7 Flow of execution

In order to ensure that a function is defined before its first use, you have to know the order in which statements are executed, which is called the **flow of execution**.

Execution always begins at the first statement of the program. Statements are executed one at a time, in order from top to bottom.

Function definitions do not alter the flow of execution of the program, but remember that statements inside the function are not executed until the function is called.

A function call is like a detour in the flow of execution. Instead of going to the next statement, the flow jumps to the body of the function, executes all the statements there, and then comes back to pick up where it left off.

That sounds simple enough, until you remember that one function can call another. While in the middle of one function, the program might have to execute the statements in another function. But while executing that new function, the program might have to execute yet another function!

Fortunately, Python is good at keeping track of where it is, so each time a function completes, the program picks up where it left off in the function that called it. When it gets to the end of the program, it terminates.

Whats the moral of this sordid tale? When you read a program, you dont always want to read from top to bottom. Sometimes it makes more sense if you follow the flow of execution.

3.8 Parameters and arguments

Some of the built-in functions we have seen require arguments. For example, when you call `math.sin` you pass a number as an argument. Some functions take more than one argument: `math.pow` takes two, the base and the exponent.

Inside the function, the arguments are assigned to variables called **parameters**. Here is an example of a user-defined function that takes an argument:

```
def print_twice(bruce):
    print bruce
    print bruce
```

This function assigns the argument to a parameter named `bruce`. When the function is called, it prints the value of the parameter (whatever it is) twice.

This function works with any value that can be printed.

```
>>> print_twice('Spam')
Spam
Spam
>>> print_twice(17)
17
17
>>> print_twice(math.pi)
3.14159265359
3.14159265359
```

The same rules of composition that apply to built-in functions also apply to user-defined functions, so we can use any kind of expression as an argument for `print_twice`:

```
>>> print_twice('Spam '*4)
Spam Spam Spam Spam
Spam Spam Spam Spam
>>> print_twice(math.cos(math.pi))
-1.0
-1.0
```

The argument is evaluated before the function is called, so in the examples the expressions `'Spam '*4` and `math.cos(math.pi)` are only evaluated once.

You can also use a variable as an argument:

```
>>> michael = 'Eric, the half a bee.'
>>> print_twice(michael)
Eric, the half a bee.
Eric, the half a bee.
```

The name of the variable we pass as an argument (`michael`) has nothing to do with the name of the parameter (`bruce`). It doesn't matter what the value was called back home (in the caller); here in `print_twice`, we call everybody `bruce`.

3.9 Variables and parameters are local

When you create a variable inside a function, it is **local**, which means that it only exists inside the function. For example:

```
def cat_twice(part1, part2):
    cat = part1 + part2
    print_twice(cat)
```

This function takes two arguments, concatenates them, and prints the result twice. Here is an example that uses it:

```
>>> line1 = 'Bing tiddle '
>>> line2 = 'tiddle bang.'
>>> cat_twice(line1, line2)
Bing tiddle tiddle bang.
Bing tiddle tiddle bang.
```

When `cat_twice` terminates, the variable `cat` is destroyed. If we try to print it, we get an exception:

```
>>> print cat
NameError: name 'cat' is not defined
```

Parameters are also local. For example, outside `print_twice`, there is no such thing as `bruce`.

3.10 Stack diagrams

Meh.

3.11 Fruitful functions and void functions

Some of the functions we are using, such as the math functions, yield results; for lack of a better name, I call them **fruitful functions**. Other functions, like `print_twice`, perform an action but don't return a value. They are called **void functions**.

When you call a fruitful function, you almost always want to do something with the result; for example, you might assign it to a variable or use it as part of an expression:

```
x = math.cos(radians)
golden = (math.sqrt(5) + 1) / 2
```

When you call a function in interactive mode, Python displays the result:

```
>>> math.sqrt(5)
2.2360679774997898
```

But in a script, if you call a fruitful function all by itself, the return value is lost forever.

```
math.sqrt(5)
```

This script computes the square root of 5, but since it doesn't store or display the result, it is not very useful.

Void functions might display something on the screen or have some other effect, but they don't have a return value. If you try to assign the result to a variable, you get a special value called `None`.

```
>>> result = print_twice('Bing')
Bing
Bing
>>> print result
None
```

The value `None` is not the same as the string `'None'`. It is a special value that has its own type:

```
>>> print type(None)
<type 'NoneType'>
```

The functions we have written so far are all void. We will start writing fruitful functions in a few chapters.

3.12 Why functions?

It may not be clear why it is worth the trouble to divide a program into functions. There are several reasons:

- Creating a new function gives you an opportunity to name a group of statements, which makes your program easier to read and debug.
- Functions can make a program smaller by eliminating repetitive code. Later, if you make a change, you only have to make it in one place.
- Dividing a long program into functions allows you to debug the parts one at a time and then assemble them into a working whole.
- Well-designed functions are often useful for many programs. Once you write and debug one, you can reuse it.

3.13 Importing with `from`

Python provides two ways to import modules; we have already seen one:

```
>>> import math
>>> print math
<module 'math' (built-in)>
>>> print math.pi
3.14159265359
```

If you import `math`, you get a module object named `math`. The module object contains constants like `pi` and functions like `sin` and `exp`.

But if you try to access `pi` directly, you get an error.

```
>>> print pi
Traceback (most recent call last):
  File "<stdin>", line 1, in <module>
NameError: name 'pi' is not defined
```


As an alternative, you can import an object from a module like this:

```
>>> from math import pi
```

Now you can access pi directly, without dot notation.

```
>>> print pi
3.14159265359
```

Or you can use the star operator to import *everything* from the module:

```
>>> from math import *
>>> cos(pi)
-1.0
```

The advantage of importing everything from the math module is that your code can be more concise. The disadvantage is that there might be conflicts between names defined in different modules, or between a name from a module and one of your variables.

3.14 Debugging

If you are using a text editor to write your scripts, you might run into problems with spaces and tabs. The best way to avoid these problems is to use spaces exclusively (no tabs). Most text editors that know about Python do this by default, but some don't.

Tabs and spaces are usually invisible, which makes them hard to debug, so try to find an editor that manages indentation for you.

Also, don't forget to save your program before you run it. Some development environments do this automatically, but some don't. In that case the program you are looking at in the text editor is not the same as the program you are running.

Debugging can take a long time if you keep running the same, incorrect, program over and over!

Make sure that the code you are looking at is the code you are running. If you're not sure, put something like `print 'hello'` at the beginning of the program and run it again. If you don't see `hello`, you're not running the right program!

4 Case study: interface design

5 Conditionals and recursion

6 Fruitful functions

7 Iteration

8 Strings

8.1 A string is a sequence

8.2 len

8.3 Traversal with a for loop

8.4 String slices

8.5 Strings are immutable

8.6 Searching

8.7 Looping and counting

8.8 String methods

A **method** is similar to a function - it takes arguments and returns a value, but the syntax is different. For example, the method `upper` takes a string and returns a new string with all uppercase letters:

Instead of the function syntax `upper(word)`, it uses the method syntax `word.upper()`.

```
>>> word = 'banana'
>>> new_word = word.upper()
>>> print new_word
BANANA
```

This form of dot notation specifies the name of the method, `upper`, and the name of the string to apply the method to, `word`. The empty parentheses indicate that this method takes no argument.

A method call is called an **invocation**; in this case, we would say that we are invoking `upper` on the `word`.

As it turns out, there is a string method named `find` that is remarkably similar to the function we wrote:

```
>>> word = 'banana'
>>> index = word.find('a')
>>> print index
1
```

In this example, we invoke `find` on `word` and pass the letter we are looking for as a parameter.

Actually, the `find` method is more general than our function; it can find substrings, not just characters:

```
>>> word.find('na')
2
```

It can take as a second argument the index where it should start:

```
>>> word.find('na', 3)
4
```

And as a third argument the index where it should stop:

```
>>> name = 'bob'
>>> name.find('b', 1, 2)
-1
```

This search fails because `b` does not appear in the index range from `1` to `2` (not including `2`).

8.9 The `in` operator

8.10 String comparison

8.11 Debugging

9 Case study: word play

10 Lists

10.1 A list is a sequence

Like a string, a **list** is a sequence of values. In a string, the values are characters; in a list, they can be any type. The values in a list are called **elements** or sometimes **items**.

There are several ways to create a new list; the simplest is to enclose the elements in square brackets:

```
[10, 20, 30, 40]
['crunchy frog', 'ram bladder', 'lark vomit']
```

The elements of a list don't have to be the same type. The following list contains a string, a float, an integer, and (lo!) another list:

```
['spam', 2.0, 5, [10, 20]]
```

A list within another list is **nested**.

A list that contains no elements is called an *empty list*; you can create one with empty brackets, `[]`.

As you might expect, you can assign list values to variables:

```
>>> cheeses = ['Cheddar', 'Edam', 'Gouda']
>>> numbers = [17, 123]
>>> empty = []
>>> print cheeses, numbers, empty
['Cheddar', 'Edam', 'Gouda'] [17, 123] []
```

10.2 Lists are mutable

The syntax for *accessing* the elements of a list is the same as for accessing the characters of a string - the bracket operator. The expression inside the brackets specifies the index. Remember that the indices start at 0:

```
>>> print cheeses[0]
Cheddar
```

Unlike strings, lists are mutable. When the bracket operator appears on the left side of an assignment, it identifies the element of the list that will be assigned.

```
>>> numbers = [17, 123]
>>> numbers[1] = 5
>>> print numbers
[17, 5]
```

The one-eth element of numbers, which used to be 123, is now 5.

You can think of a list as a relationship between indices and elements. This relationship is called a **mapping**; each index “maps to” one of the elements.

List indices work the same way as string indices:

- Any integer expression can be used as an index.
- If you try to read or write an element that does not exist, you get an `IndexError`.
- If an index has a negative value, it counts backward from the end of the list.

The `in` operator also works on lists.

```
>>> cheeses = ['Cheddar', 'Edam', 'Gouda']
>>> 'Edam' in cheeses
True
>>> 'Brie' in cheeses
False
```

10.3 Traversing a list

The most common way to traverse the elements of a list is with a `for` loop. The syntax is the same as for strings:

```
for cheese in cheeses:
    print cheese
```

This works well if you only need to read the elements of the list. But if you want to write or update the elements, you need the indices. A common way to do that is to combine the functions `range` and `len`:

```
for i in range(len(numbers)):
    numbers[i] = numbers[i] * 2
```

This loop traverses the list and updates each element. `len` returns the number of elements in the list. `range` returns a list of indices from 0 to $n - 1$, where n is the length of the list. Each time through the loop `i` gets the index of the next element. The assignment statement in the body uses `i` to read the old value of the element and to assign the new value.

A `for` loop over an *empty* list never executes the body:

```
for x in []:
    print 'This never happens.'
```

Although a list can contain another list, *the nested list still counts as a single element*. The length of this list is 4:

```
['spam', 1, ['Brie', 'Roquefort', 'Pol le Veq'], [1, 2, 3]]
```

10.4 List operations

IMPORTANT: these are not mathematical operations for lists. Convert to numpy arrays:

```
a = np.array(a)
```

The + operator concatenates lists:

```
>>> a = [1, 2, 3]
>>> b = [4, 5, 6]
>>> c = a + b
>>> print c
[1, 2, 3, 4, 5, 6]
```

Similarly, the * operator repeats a list a given number of times:

```
>>> [0] * 4
[0, 0, 0, 0]
>>> [1, 2, 3] * 3
[1, 2, 3, 1, 2, 3, 1, 2, 3]
```

The first example repeats [0] four times. The second example repeats the list [1,2,3] three times.

10.5 List slices

10.6 List methods

10.7 Map, filter, and reduce

10.8 Deleting elements

10.9 Lists and strings

10.10 Objects and values

10.11 Aliasing

10.12 List arguments

10.13 Debugging

11 Dictionaries

12 Tuples

12.1 Tuples are immutable

A tuple is a sequence of values. The values can be any type, and they are indexed by integers, so in that respect tuples are a lot like lists. *The important difference is that tuples are immutable.*

Syntactically, a tuple is a comma-separated list of values:

```
>>> t = ('a', 'b', 'c', 'd', 'e')
```

Parentheses are common, but not necessary.

To create a tuple with a single element, you have to include a final comma:

```
>>> t1 = 'a',
>>> type(t1)
<type 'tuple'>
```

A value in parentheses is not a tuple:

```
>>> t2 = ('a')
>>> type(t2)
<type 'str'>
```

Another way to create a tuple is the built-in function `tuple`. With no argument, it creates an empty tuple:

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

If the argument is a sequence (string, list or tuple), the result is a tuple with the elements of the sequence:

```
>>> t = tuple('lupins')
>>> print t
('l', 'u', 'p', 'i', 'n', 's')
```

Most list operators also work on tuples. The bracket operator indexes an element:

```
>>> t = ('a', 'b', 'c', 'd', 'e')
>>> print t[0]
'a'
```

And the slice operator selects a range of elements.

```
>>> print t[1:3]
('b', 'c')
```

But if you try to modify one of the elements of the tuple, you get an error:

```
>>> t[0] = 'A'
TypeError: object doesn't support item assignment
```

You can't modify the elements of a tuple, but you can *replace* one tuple with another:

```
>>> t = ('A',) + t[1:]
>>> print t
('A', 'b', 'c', 'd', 'e')
```

12.2 Tuple assignment

It is often useful to swap the values of two variables. With conventional assignments, you have to use a temporary variable. For example, to swap `a` and `b`:

```
>>> temp = a
>>> a = b
>>> b = temp
```

This solution is cumbersome; **tuple assignment** is more elegant:

```
>>> a, b = b, a
```

The left side is a tuple of variables; the right side is a tuple of expressions. Each value is assigned to its respective variable. All the expressions on the right side are evaluated before any of the assignments.

The number of variables on the left and the number of values on the right have to be the same:

```
>>> a, b = 1, 2, 3
ValueError: too many values to unpack
```

More generally, the right side can be any kind of sequence (string, list or tuple). For example, to split an email address into a user name and a domain, you could write:

```
>>> addr = 'monty@python.org'
>>> uname, domain = addr.split('@')
```

The return value from `split` is a list with two elements; the first element is assigned to `uname`, the second to `domain`.

```
>>> print uname
monty
>>> print domain
python.org
```


12.3 Tuples as return values

Strictly speaking, a function can only return one value, but if the value is a tuple, the effect is the same as returning multiple values. For example, if you want to divide two integers and compute the quotient and remainder, it is inefficient to compute `x/y` and then `x%y`. It is better to compute them both at the same time.

The built-in function `divmod` takes two arguments and returns a tuple of two values, the quotient and remainder. You can store the result as a tuple:

```
>>> t = divmod(7, 3)
>>> print t
(2, 1)
```

Or use tuple assignment to store the elements separately:

```
>>> quot, rem = divmod(7, 3)
>>> print quot
2
>>> print rem
1
```

Here is an example of a function that returns a tuple:

```
def min_max(t):
    return min(t), max(t)
```

`max` and `min` are built-in functions that find the largest and smallest elements of a sequence. `min_max` computes both and returns a tuple of two values.

12.4 Variable-length argument tuples

Functions can take a variable number of arguments. A parameter name that begins with **`*`** gathers arguments into a tuple. For example, `printall` takes any number of arguments and prints them:

```
def printall(*args):
    print args
```

The gather parameter can have any name you like, but `args` is conventional. Here's how the function works:

```
>>> printall(1, 2.0, '3')
(1, 2.0, '3')
```

The complement of gather is `scatter`. If you have a sequence of values and you want to pass it to a function as multiple arguments, you can use the `*` operator. For example, `divmod` takes exactly two arguments; it doesn't work with a tuple:

```
>>> t = (7, 3)
>>> divmod(t)
TypeError: divmod expected 2 arguments, got 1
```

But if you scatter the tuple, it works:

```
>>> divmod(*t)
(2, 1)
```

12.5 Lists and tuples

`zip` is a built-in function that takes two or more sequences and “zips” them into a list of tuples where each tuple contains one element from each sequence. In Python 3, `zip` returns an iterator of tuples, but for most purposes, an iterator behaves like a list.

This example zips a string and a list:

```
>>> s = 'abc'
>>> t = [0, 1, 2]
>>> zip(s, t)
[('a', 0), ('b', 1), ('c', 2)]
```

The result is a list of tuples where each tuple contains a character from the string and the corresponding element from the list.

If the sequences are not the same length, the result has the length of the shorter one.

```
>>> zip('Anne', 'Elk')
[('A', 'E'), ('n', 'l'), ('n', 'k')]
```

You can use tuple assignment in a `for` loop to traverse a list of tuples:

```
t = [('a', 0), ('b', 1), ('c', 2)]
for letter, number in t:
    print number, letter
```

Each time through the loop, Python selects the next tuple in the list and assigns the elements to `letter` and `number`. The output of this loop is:

```
0 a
1 b
2 c
```

If you combine `zip`, `for` and tuple assignment, you get a useful idiom for traversing two (or more) sequences at the same time. For example, `has_match` takes two sequences, `t1` and `t2`, and returns `True` if there is an index `i` such that `t1[i] == t2[i]`:

```
def has_match(t1, t2):
    for x, y in zip(t1, t2):
        if x == y:
            return True
    return False
```

If you need to traverse the elements of a sequence and their indices, you can use the built-in function `enumerate`:

```
for index, element in enumerate('abc'):
    print index, element
```

The output of this loop is:

```
0 a
1 b
2 c
```

Again.

12.6 Dictionaries and tuples

Dictionaries have a method called `items` that returns a list of tuples, where each tuple is a key-value pair.

```
>>> d = {'a':0, 'b':1, 'c':2}
>>> t = d.items()
>>> print t
[('a', 0), ('c', 2), ('b', 1)]
```

As you should expect from a dictionary, the items are in no particular order. In Python 3, `items` returns an iterator, but for many purposes, iterators behave like lists.

Going in the other direction, you can use a list of tuples to initialize a new dictionary:

```
>>> t = [('a', 0), ('c', 2), ('b', 1)]
>>> d = dict(t)
>>> print d
{'a': 0, 'c': 2, 'b': 1}
```

Combining `dict` with `zip` yields a concise way to create a dictionary:

```
>>> d = dict(zip('abc', range(3)))
>>> print d
{'a': 0, 'c': 2, 'b': 1}
```

The dictionary method `update` also takes a list of tuples and adds them, as key-value pairs, to an existing dictionary.

Combining `items`, tuple assignment and `for`, you get the idiom for traversing the keys and values of a dictionary:

```
for key, val in d.items():
    print val, key
```

The output of this loop is:

```
0 a
2 c
1 b
```

Again. It is common to use tuples as keys in dictionaries (primarily because you cant use lists). For example, a telephone directory might map from last-name, first-name pairs to telephone numbers. Assuming that we have defined `last`, `first` and `number`, we could write:

```
directory[last,first] = number
```

The expression in brackets is a tuple. We could use tuple assignment to traverse this dictionary.

```
for last, first in directory:
    print first, last, directory[last,first]
```

This loop traverses the keys in `directory`, which are tuples. It assigns the elements of each tuple to `last` and `first`, then prints the name and corresponding telephone number.

12.7 Comparing tuples

The relational operators work with tuples and other sequences; Python starts by comparing the first element from each sequence. If they are equal, it goes on to the next elements, and so on, until it finds elements that differ. Subsequent elements are not considered (even if they are really big).

```
>>> (0, 1, 2) < (0, 3, 4)
True
>>> (0, 1, 2000000) < (0, 3, 4)
True
```

The `sort` function works the same way. It sorts primarily by first element, but in the case of a tie, it sorts by second element, and so on.

This feature lends itself to a pattern called **DSU** for

Decorate a sequence by building a list of tuples with one or more sort keys preceding the elements from the sequence,

Sort the list of tuples, and

Undecorate by extracting the sorted elements of the sequence.

For example, suppose you have a list of words and you want to sort them from longest to shortest:

```
def sort_by_length(words):
    t = []
    for word in words:
        t.append((len(word), word))

    t.sort(reverse=True)

    res = []
    for length, word in t:
        res.append(word)
    return res
```

The first loop builds a list of tuples, where each tuple is a word preceded by its length.

`sort` compares the first element, length, first, and only considers the second element to break ties. The keyword argument `reverse=True` tells `sort` to go in decreasing order.

The second loop traverses the list of tuples and builds a list of words in descending order of length.

12.8 Sequences of sequences

I have focused on lists of tuples, but almost all of the examples in this chapter also work with lists of lists, tuples of tuples, and tuples of lists. To avoid enumerating the possible combinations, it is sometimes easier to talk about sequences of sequences.

In many contexts, the different kinds of sequences (strings, lists and tuples) can be used interchangeably. So how and why do you choose one over the others?

To start with the obvious, strings are more limited than other sequences because the elements have to be characters. They are also immutable. If you need the ability to change the characters in a string (as opposed to creating a new string), you might want to use a list of characters instead.

Lists are more common than tuples, mostly because they are mutable. But there are a few cases where you might prefer tuples:

1. In some contexts, like a `return` statement, it is syntactically simpler to create a tuple than a list. In other contexts, you might prefer a list.
2. If you want to use a sequence as a dictionary key, you have to use an immutable type like a tuple or string.
3. If you are passing a sequence as an argument to a function, using tuples reduces the potential for unexpected behavior due to aliasing.

Because tuples are immutable, they don't provide methods like `sort` and `reverse`, which modify existing lists. But Python provides the built-in functions `sorted` and `reversed`, which take any sequence as a parameter and return a new list with the same elements in a different order.

12.9 Debugging

Lists, dictionaries and tuples are known generically as **data structures**; in this chapter we are starting to see compound data structures, like lists of tuples, and dictionaries that contain tuples as keys and lists as values. Compound data structures are useful, but they are prone to what I call **shape errors**; that is, errors caused when a data structure has the wrong type, size or composition. For example, if you are expecting a list with one integer and I give you a plain old integer (not in a list), it won't work.

To help debug these kinds of errors, I have written a module called `structshape` that provides a function, also called `structshape`, that takes any kind of data structure as an argument and returns a string that summarizes its shape. You can download it from <http://thinkpython.com/code/structshape.py>

Here's the result for a simple list:

```
>>> from structshape import structshape
>>> t = [1,2,3]
>>> print structshape(t)
list of 3 int
```

A fancier program might write "list of 3 ints," but it was easier not to deal with plurals. Here's a list of lists:

```
>>> t2 = [[1,2], [3,4], [5,6]]
>>> print structshape(t2)
list of 3 list of 2 int
```

If the elements of the list are not the same type, `structshape` groups them, in order, by type:

```
>>> t3 = [1, 2, 3, 4.0, '5', '6', [7], [8], 9]
>>> print structshape(t3)
list of (3 int, float, 2 str, 2 list of int, int)
```

Here's a list of tuples:

```
>>> s = 'abc'
>>> lt = zip(t, s)
>>> print structshape(lt)
list of 3 tuple of (int, str)
```

And here's a dictionary with 3 items that map integers to strings.

```
>>> d = dict(1t)
>>> print structshape(d)
dict of 3 int->str
```

If you are having trouble keeping track of your data structures, `structshape` can help.

13 Case study: data structure selection

14 Files

<http://www.greenteapress.com/thinkpython/html/thinkpython015.html>

14.1 Persistence

Most of the programs we have seen so far are transient in the sense that they run for a short time and produce some output, but when they end, their data disappears. If you run the program again, it starts with a clean slate.

Other programs are **persistent**: they run for a long time (or all the time); they keep at least some of their data in permanent storage (a hard drive, for example); and if they shut down and restart, they pick up where they left off.

Examples of persistent programs are operating systems, which run pretty much whenever a computer is on, and web servers, which run all the time, waiting for requests to come in on the network.

One of the simplest ways for programs to maintain their data is by reading and writing text files. We have already seen programs that read text files; in this chapter we will see programs that write them.

An alternative is to store the state of the program in a database. In this chapter I will present a simple database and a module, `pickle`, that makes it easy to store program data.

14.2 Reading and writing

```
file:
f=open('file.txt','rwa') [read,write,append]
s=f.readline()
f.close(),
alternatively:
for line in f:
    print line
```

A text file is a sequence of characters stored on a permanent medium like a hard drive, flash memory, or CD-ROM. We saw how to open and read a file in Section 9.1.

To write a file, you have to open it with mode 'w' as a second parameter:

```
>>> fout = open('output.txt', 'w')
>>> print fout
<open file 'output.txt', mode 'w' at 0xb7eb2410>
```

If the file already exists, opening it in write mode clears out the old data and starts fresh, so be careful! If the file doesn't exist, a new one is created.

The `write` method puts data into the file.

```
>>> line1 = 'This here's the wattle,\n'
>>> fout.write(line1)
```

Again, the file object keeps track of where it is, so if you call `write` again, it adds the new data to the end.

```
>>> line2 = "the emblem of our land.\n"
>>> fout.write(line2)
```

When you are done writing, you have to close the file.

```
>>> fout.close()
```

14.3 Format operator

```
'''
Formatted output
> print 'the number is {:.#e|:nd|:n.nf|:ns}'.format(x)
    exponential, integer, float, string
General syntax:
'''
template.format(var_1,var_2,...var_n)
# template:
#'[field]![conversion]:[spec]}'
field = index of variables listed in .format()
conversion = int, float, string, etc.
spec = specifier
[[fill]align][sign][#][0][minwidth][.prec][type]
align:
<(left,default)
>(right)
=(padding after sign, before digits)
^(center)
0: zero padding (same as '=' and fill char of 0)
type: e,f,g(general)

# Including text:
print 'Variable 2 is {1} and variable 1 is {0}'.format(var_1,var_2)
```



```
'{:8d}asdfad{:8.2f}'.format(i,f)
formats: {:nd},{:n.nf},{:ns}
#    n-number (width.precision), d-integer, f-float, s-string
#----- How to use a variable for width?? -----#
```

The argument of `write` has to be a string, so if we want to put other values in a file, we have to convert them to strings. The easiest way to do that is with `str`:

```
>>> x = 52
>>> fout.write(str(x))
```

An alternative is to use the **format operator**, `%`. When applied to integers, `%` is the modulus operator. But when the first operand is a string, `%` is the format operator.

The first operand is the **format string**, which contains one or more **format sequences**, which specify how the second operand is formatted. The result is a string.

For example, the format sequence `'%d'` means that the second operand should be formatted as an integer (`d` stands for “decimal”):

```
>>> camels = 42
>>> '%d' % camels
'42'
```

The result is the string `'42'`, which is not to be confused with the integer value 42.

A format sequence can appear anywhere in the string, so you can embed a value in a sentence:

```
>>> camels = 42
>>> 'I have spotted %d camels.' % camels
'I have spotted 42 camels.'
```

If there is more than one format sequence in the string, the second argument has to be a tuple. Each format sequence is matched with an element of the tuple, in order.

The following example uses `'%d'` to format an integer, `'%g'` to format a floating-point number, and `'%s'` to format a string:

```
>>> 'In %d years I have spotted %g %s.' % (3, 0.1, 'camels')
'In 3 years I have spotted 0.1 camels.'
```

The number of elements in the tuple has to match the number of format sequences in the string. Also, the types of the elements have to match the format sequences:

```
>>> '%d %d %d' % (1, 2)
TypeError: not enough arguments for format string
>>> '%d' % 'dollars'
TypeError: illegal argument type for built-in operation
```

In the first example, there aren't enough elements; in the second, the element is the wrong type.

The format operator is powerful, but it can be difficult to use. You can read more about it at <http://docs.python.org/2/library/stdtypes.html#string-formatting>.

14.4 Filenames and paths

15 Classes and objects

16 Classes and functions

17 Classes and methods

18 Inheritance

19 Case study: Tkinter

20 Debugging

21 Analysis of Algorithms

22 Lumpy

Glossary

accumulator A variable used in a loop to add up or accumulate a result.

aliasing A circumstance where two or more variables refer to the same object.

argument A value provided to a function when the function is called. This value is assigned to the corresponding parameter in the function.

augmented assignment A statement that updates the value of a variable using an operator like `+=`.

body The sequence of statements inside a function definition.

composition Using an expression as part of a larger expression, or a statement as part of a larger statement.

data structure A collection of related values, often organized in lists, dictionaries, tuples, etc.

delimiter A character or string used to indicate where a string should be split.

dot notation The syntax for calling a function in another module by specifying the module name followed by a dot (period) and the function name.

DSU Abbreviation of “decorate-sort-undecorate,” a pattern that involves building a list of tuples, sorting, and extracting part of the result.

element One of the values in a list (or other sequence), also called items.

equivalent Having the same value.

filter A processing pattern that traverses a list and selects the elements that satisfy some criterion.

flow of execution The order in which statements are executed during a program run.

frame A box in a stack diagram that represents a function call. It contains the local variables and parameters of the function.

fruitful function A function that returns a value.

function A named sequence of statements that performs some useful operation. Functions may or may not take arguments and may or may not produce a result.

function call A statement that executes a function. It consists of the function name followed by an argument list.

function definition A statement that creates a new function, specifying its name, parameters, and the statements it executes.

function object A value created by a function definition. The name of the function is a variable that refers to a function object.

gather The operation of assembling a variable-length argument tuple.

header The first line of a function definition.

identical Being the same object (which implies equivalence).

import statement A statement that reads a module file and creates a module object.

index An integer value that indicates an element in a list.

list A sequence of values.

list traversal The sequential accessing of each element in a list.

local variable A variable defined inside a function. A local variable can only be used inside its function.

map A processing pattern that traverses a sequence and performs an operation on each element.

mapping A relationship in which each element of one set corresponds to an element of another set. For example, a list is a mapping from indices to elements.

module A file that contains a collection of related functions and other definitions.

module object A value created by an `import` statement that provides access to the values defined in a module.

nested list A list that is an element of another list.

object Something a variable can refer to. An object has a type and a value.

parameter A name used inside a function to refer to the value passed as an argument.

reduce A processing pattern that traverses a sequence and accumulates the elements into a single result.

reference The association between a variable and its value.

return value The result of a function. If a function call is used as an expression, the return value is the value of the expression.

scatter The operation of treating a sequence as a list of arguments.

shape (of a data structure) A summary of the type, size and composition of a data structure.

stack diagram A graphical representation of a stack of functions, their variables, and the values they refer to.

traceback A list of the functions that are executing, printed when an exception occurs.

tuple An immutable sequence of elements.

tuple assignment An assignment with a sequence on the right side and a tuple of variables on the left. The right side is evaluated and then its elements are assigned to the variables on the left.

void function A function that doesn't return a value.

```
#export PYTHONPATH="${PYTHONPATH}:/new/path

# not compiled, execute with cl> python program_name.py
#   or cl> ./program_name.py IF you have the top line in your program
#       (must be the first line, literally)

# Resources
astropy.org
stackoverflow
regex

# 'pickle' is the equivalent of IDL's 'save'

# To allow import:
def main():
    # program statements
    print "hello world."
if __name__=="__main__": # flexible way of running routines
    main()

# Things to import (packages?)
import math [as shortername]
print math.sqrt(4)
circumference = 2*math.pi*radius
print math.exp(2) --> get e^2

import pdb
pdb.set_trace() #equivalent of 'STOP' in IDL

# line continuation:
implicit continuation using expression in parentheses...?

# variables: not declared
```

Lists

lists are similar to arrays, but can't do mathematical operations

```
x = [0,1,2,3,4]
```

```

x = range(5) # Same as above... note that there are 5 elements, not
              # including the number 5

array.append(newValue)
A = [1,2,3] # --> [1,2,3]
print A*2 # --> [1,2,3,1,2,3]... not [2,4,6] as expected
B = np.array([1,2,3]) # --> [1 2 3]
B*2 # --> [2 4 6]
<<<<<<< HEAD

```

numerical arrays

```

import numpy as np
np.zeros(n,m)
np.array(n) # creates an array that consists of n, NOT LENGTH n
np.array([a,b,c,d][e,f,g])
np.arange(n) # [0,1,2,...,n-1]
np.ndarray(...) # two-dimensional array
np.argmax(x) # returns INDEX of max value of x array
np.append(array,what_to_append)
np.linspace(0,9,100) #0-9 with 100 increments
np.logspace
np.sum(array)
np.roll(x,2) # (~IDL's SHIFT); shifts array elements 2 to the right
--> [3,4,0,1,2] # note x is still the same, unless do x = np.roll(...)

y1 = x**2
# just like with the math package, can't simply do sqrt(x). Need
# np.sqrt (or math.sqrt if not dealing with arrays).
y2 = np.sqrt(x)
# Also this doesn't work:
x = [1,2,3]
y = x**2
# because x is a list, not an array... even though it's just numbers.

>>>>>> e65b08cb7892365af863d0202be5fe03115aa38c

>>> A = np.array([1,2,3])
>>> A + 1
      [2,3,4]

num_elements = len(Array)

# dynamic memory allocation

```

```

# structures
(dictionaries, see also lists)
var={'name':'test', ra:1.}
print var['name'], var['test']
dicname = { 'A':[1,2,3], 'B':[2,4,6], 'C':[3,9,15] }
print dicname
# dictionaries are indexed by keys, rather than numbers.
# Keys can be any immutable type. Can't use lists, since they can be modified.
profile = {'density':rho_r, 'mass':mass, ...}
density = np.array(profile['density'])

# structure arrays
sarray = np.zeros(nelem,
    dtype=[('name','a12'),('ra','f4'),('dec','f4')])
sarray=np.zeros(nelem,
    dtype={'names': ('name', 'ra', 'dec'),
    'formats': ('S12','f4','f4')})

# operators (add, subtract, multiply, divide, exponent)
+,-,*,/,**,+,-,*,/,**,+,-,*,/,**,+,-,*,/,**
# bitwise operators (and, or, xor, not)
&,&,^,!
# string operators
+, str[i1:i2] (string slice, but string is immutable)

#matrix operations

# conditionals
if (condition):
    statements
else:
    statements
    (extent of conditional statements specified by indentation)
    pass # need to have 'something' here.
if (condition):
    break
else:
    continue
''' Conditions (logical operators) '''
==, !=, >, >=, <, <=, and, or, not

```

Looping

```

for i in (list): i = value in list, NOT the index of each value
for i in range(1,x): ... ~ IDL> for i=1,x-1... i IS the index here

```

PYTHON IS NOT INCLUSIVE!

```
''' Looping with condition '''
while (condition):
    statements

''' Simple output '''
print 'characters', string, variable

# simple reading from terminal and file
terminal:
s=raw_input('prompt')

# higher level file reading routines
data = numpy.loadtxt(file,
    dtype=[('name', 'a12'), ('ra', f4), ('dec', 'f4')])

data = astropy.io.ascii(file)
```

Plotting

<http://latexcolor.com/>

???

```
>>> import matplotlib.pyplot as plt
.csv file --> ?
pyplot.show()
pyplot.savefig('tmp.pdf')
--> rewritten each time!
plt.xlabel('labelname', fontsize=14, color='red')
color='#eeefff'
```

???

axes objects

Whole figure:

```
fig = plt.figure()
fig.suptitle('bold figure suprtitle', fontsize=14, fontweight='bold')
plt.xlabel('xlabel') # whole figure
plt.ylabel('xlabel') # whole figure
```

Simpler?:

```
fig, ax = plt.subplots()
```

Individual axes:

```
ax.set_xlabel('labelname',
              fontsize = 14,
              )
ax.tick_params(axis=['x'|'y'|'both'],
              labelsizе='large')
ax.ticklabel_format(style='sci',

for i in range(0,some_number):
    ax = fig.add_subplot(n,m,i+1)
    # n - vertical; m - horizontal; i+1 - plot being defined as 'ax'
```

Legend

```
ax.plot(x,y1, 'k--', label='line 1')
ax.plot(x,y2, 'k:', label='line 2')
ax.plot(x,y3, 'k', label='line 3')
legend = ax.legend(loc='upper center', shadow=True)
legend = ax.legend(loc='lower left')
```

'k' is black.