A Python programming tutorial

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Abstract

A tutorial for the Python programming language.

This publication is available in Web form[1] and also as a PDF document[2]. Please forward any comments to **`tcc-doc@nmt.edu`**.

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[1] http://www.nmt.edu/tcc/help/pubs/lang/pytut/
[2] http://www.nmt.edu/tcc/help/pubs/lang/pytut/pytut.pdf

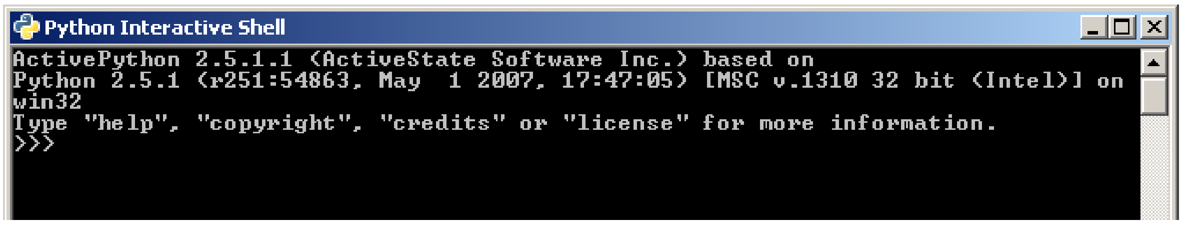
1. Introduction

This document contains some tutorials for the Python programming language. These tutorials accompany the free Python classes taught by the New Mexico Tech Computer Center. Another good tutorial is at the Python website[3].

1.1. Starting Python in conversational mode

This tutorial makes heavy use of Python's conversational mode. When you start Python in this way, you will see an initial greeting message, followed by the prompt “>>>”.

- On a TCC workstation in Windows, from the *Start* menu, select *All Programs* → *ActiveState ActivePython 2.5* → *Python Interactive Shell*. You will see something like this:



```
ActivePython 2.5.1.1 (ActiveState Software Inc.) based on
Python 2.5.1 (r251:54863, May  1 2007, 17:47:05) [MSC v.1310 32 bit (Intel)] on
win32
Type "help", "copyright", "credits" or "license" for more information.
>>>
```

- For Linux or MacOS, from a shell prompt, type:

```
python
```

You will see something like this:

```
-bash-3.1$ python
Python 2.4.2 (#1, Feb 12 2006, 03:59:46)
[GCC 4.1.0 20060210 (Red Hat 4.1.0-0.24)] on linux2
Type "help", "copyright", "credits" or "license" for more information.
>>>
```

When you see the “>>>” prompt, you can type a Python expression, and Python will show you the result of that expression. This makes Python useful as a desk calculator. For example:

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

[3] http://docs.python.org/tut/tut.html

Each section of this tutorial introduces a group of related Python features.

2. Python's numeric types

Pretty much all programs need to do numeric calculations. Python has several ways of representing numbers, and an assortment of operators to operate on numbers.

2.1. Basic numeric operations

To do numeric calculations in Python, you can write expressions that look more or less like algebraic expressions in many other common languages. The "`+`" operator is addition; "`-`" is subtraction; use "`*`" to multiply; and use "`/`" to divide. Here are some examples:

```
>>> 99 + 1
100
>>> 1 - 99
-98
>>> 7 * 5
35
>>> 81 / 9
9
```

The examples in this document will often use a lot of extra space between the parts of the expression, just to make things easier to read. However, these spaces are not required:

```
>>> 99+1
100
>>> 1-99
-98
```

When an expression contains more than one operation, Python defines the usual order of operations, so that higher-precedence operations like multiplication and division are done before addition and subtraction. In this example, even though the multiplication comes after the addition, it is done first.

```
>>> 2 + 3 * 4
14
```

If you want to override the usual precedence of Python operators, use parentheses:

```
>>> (2+3)*4
20
```

Here's a result you may not expect:

```
>>> 1 / 5
0
```

You might expect a result of 0.2, not zero. However, Python has different kinds of numbers. Any number without a decimal point is considered an *integer*, a whole number. If any of the numbers involved contain a decimal point, the computation is done using *floating point* type:

```
>>> 1.0 / 4.0
0.25
```

```
>>> 1.0 / 5.0
0.20000000000000001
```

That second example above may also surprise you. Mathematically, one-fifth is exactly 0.2. However, in Python (as in pretty much all other contemporary programming languages), many real numbers cannot be represented exactly. The representation of 1.0/5.0 has a slight error in the seventeenth decimal place. This behavior may be slightly annoying, but in conversational mode, Python doesn't know how much precision you want, so you get a ridiculous amount of precision, and this shows up the fact that some values are approximations.

You can use Python's `print` statement to display values without quite so much precision:

```
>>> print 1.0/5.0
0.2
```

It's okay to mix integer and floating point numbers in the same expression. Any integer values are coerced to their floating point equivalents.

```
>>> print 1.0/5
0.2
>>> print 1/5.0
0.2
```

Later we will learn about Python's format operator, which allows you to specify exactly how much precision to use when displaying numbers. For now, let's move on to some more of the operators on numbers.

The “`%`” operator between two numbers gives you the *modulo*. That is, the expression “`x % y`” returns the remainder when `x` is divided by `y`.

```
>>> 13 % 5
3
>>> 5.72 % 0.5
0.21999999999999975
>>> print 5.72 % 0.5
0.22
```

Exponentiation is expressed as “`x ** y`”, meaning `x` to the `y` power.

```
>>> 2 ** 8
256
>>> 2 ** 30
1073741824
>>> 2.0 ** 0.5
1.4142135623730951
>>> 10.0 ** 5.2
158489.31924611141
>>> 2.0 ** 100
1.2676506002282294e+30
```

That last number, `1.2676506002282294e+30`, is an example of *exponential* or *scientific* notation. This number is read as “1.26765... times ten to the 30th power”. Similarly, a number like `1.66e-24` is read as “1.66 times ten to the minus 24th power”.

So far we have seen examples of the integer type, which is called `int` in Python, and the floating-point type, called the `float` type in Python. Values in `int` type must be between -2,147,483,648 and 2,147,483,647 (inclusive).

There is another type called `long`, that can represent much larger integer values. Python automatically switches to this type whenever an expression has values larger than about two billion. You will see letter “`L`” appear at the end of such values, but they act just like regular integers.

```
>>> 2 ** 50
1125899906842624L
>>> 2 ** 100
1267650600228229401496703205376L
>>> 2 ** 1000
107150860718626732094842504906000181056140481170553360744375038837035105112
493612249319837881569585812759467291755314682518714528569231404359845775746
985748039345677748242309854210746050623711418779541821530464749835819412673
987675591655439460770629145711964776865421676604298316526243868372056680693
76L
```

2.2. The assignment statement

So far we have worked only with numeric constants and operators. You can attach a name to a value, and that value will stay around for the rest of your conversational Python session.

Python names must start with a letter or the underbar (_) character; the rest of the name may consist of letters, underbars, or digits. Names are case-sensitive: the name `Count` is a different name than `count`.

For example, suppose you wanted to answer the question, “how many days is a million seconds?” We can start by attaching the name `sec` to a value of a million:

```
>>> sec = 1e6
>>> sec
1000000.0
```

A statement of this type is called an *assignment statement*. To compute the number of minutes in a million seconds, we divide by 60. To convert minutes to hours, we divide by 60 again. To convert hours to days, divide by 24, and that is the final answer.

```
>>> minutes = sec / 60.0
>>> minutes
16666.666666666668
>>> hours=minutes/60
>>> hours
277.77777777777777
>>> days=hours/24.
>>> days
11.574074074074074
>>> print days, hours, minutes, sec
11.5740740741 277.777777778 16666.6666667 1000000.0
```

You can attach more than one name to a value. Use a series of names, separated by equal signs, like this.

```
>>> total = remaining = 50
>>> print total, remaining
50 50
```

The general form of an assignment statement looks like this:

```
name1 = name2 = ... = expression
```

Here are the rules for evaluating an assignment statement:

- Each `name`$_i$ is some Python variable name. Variable names must start with either a letter or the underbar (_) character, and the remaining characters must be letters, digits, or underbar characters. Examples: `skateKey`; `_x47`; `sum_of_all_fears`.
- The *`expression`* is any Python expression.
- When the statement is evaluated, first the *`expression`* is evaluated so that it is a single value. For example, if the *`expression`* is "`(2+3)*4`", the resulting single value is the integer `20`.

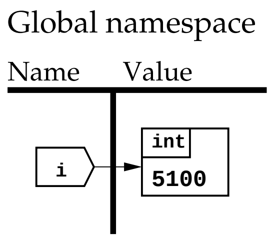
  Then all the names `name`$_i$ are *bound* to that value.

What does it mean for a name to be bound to a value? When you are using Python in conversational mode, the names and value you define are stored in an area called the *global namespace*. This area is like a two-column table, with names on the left and values on the right.

Here is an example. Suppose you start with a brand new Python session, and type this line:

```
>>> i = 5100
```

Here is what the global namespace looks like after the execution of this assignment statement.

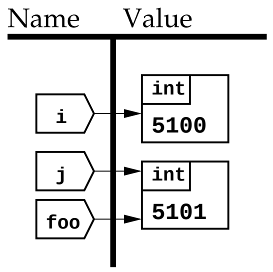


In this diagram, the value appearing on the right shows its type, `int` (integer), and the value, 5100.

In Python, values have types, but names are *not* associated with any type. A name can be bound to a value of any type at any time. So, a Python name is like a luggage tag: it identifies a value, and lets you retrieve it later.

Here is another assignment statement, and a diagram showing how the global namespace appears after the statement is executed.

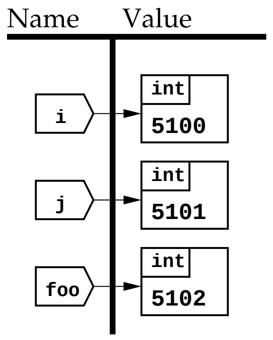
```
>>> j = foo = i + 1
```



The expression "`i + 1`" is equivalent to "`5100 + 1`", since variable `i` is bound to the integer 5100. This expression reduces to the integer value 5101, and then the names `j` and `foo` are both bound to that value. You might think of this situation as being like one piece of baggage with two tags tied to it.

Let's examine the global namespace after the execution of this assignment statement:

```
>>> foo = foo + 1
```



Because `foo` starts out bound to the integer value 5101, the expression "`foo + 1`" simplifies to the value 5102. Obviously, `foo = foo + 1` doesn't make sense in algebra! However, it is a common way for programmers to add one to a value.

Note that name `j` is still bound to its old value, 5101.

2.3. More mathematical operations

Python has a number of built-in functions. To call a function in Python, use this general form:

```
f(arg1, arg2, ... )
```

That is, use the function name, followed by an open parenthesis "`(`", followed by zero or more *arguments* separated by commas, followed by a closing parenthesis "`)`".

For example, the `round` function takes one numeric argument, and returns the nearest whole number (as a `float` number). Examples:

```
>>> round ( 4.1 )
4.0
>>> round(4.9)
5.0
>>> round(4.5)
5.0
```

The result of that last case is somewhat arbitrary, since 4.5 is equidistant from 4.0 and 5.0. However, as in most other modern programming languages, the value chosen is the one further from zero. More examples:

```
>>> round (-4.1)
-4.0
>>> round (-4.9)
-5.0
>>> round (-4.5)
-5.0
```

For historical reasons, trigonometric and transcendental functions are not built-in to Python. If you want to do calculations of those kinds, you will need to tell Python that you want to use the `math` package. Type this line:

```
>>> from math import *
```

Once you have done this, you will be able to use a number of mathematical functions. For example, `sqrt(x)` computes the square root of `x`:

```
>>> sqrt(4.0)
2.0
>>> sqrt(81)
9.0
>>> sqrt(100000)
316.22776601683796
```

Importing the `math` module also adds two predefined variables, `pi` (as in π) and `e`, the base of natural logarithms:

```
>>> print pi, e
3.14159265359 2.71828182846
```

Here's an example of a function that takes more than argument. The function `atan2(dx , dy)` returns the arctangent of a line whose slope is `dy/dx`.

```
>>> atan2 ( 1.0, 0.0 )
1.5707963267948966
>>> atan2(0.0, 1.0)
0.0
>>> atan2(1.0, 1.0)
0.78539816339744828
>>> print pi/4
0.785398163397
```

For a complete list of all the facilities in the `math` module, see the *Python 2.2 quick reference*[4]. Here are some more examples; `log` is the natural logarithm, and `log10` is the common logarithm:

```
>>> log(e)
1.0
>>> log10(e)
0.43429448190325182
>>> exp ( 1.0 )
2.7182818284590451
>>> sin ( pi / 2 )
1.0
>>> cos(pi/2)
6.1230317691118863e-17
```

Mathematically, cos(π/2) should be zero. However, like pretty much all other modern programming languages, transcendental functions like this use approximations. 6.12×10^{-17} is, after all, pretty close to zero.

Two math functions that you may find useful in certain situations:

- `floor(x)` returns the largest whole number that is less than or equal to `x`.
- `ceil(x)` returns the smallest whole number that is greater than or equal to `x`.

[4] http://infohost.nmt.edu/tcc/help/pubs/python/modules.html

```
>>> floor(4.9)
4.0
>>> floor(4.1)
4.0
>>> floor(-4.1)
-5.0
>>> floor(-4.9)
-5.0
>>> ceil(4.9)
5.0
>>> ceil(4.1)
5.0
>>> ceil(-4.1)
-4.0
>>> ceil(-4.9)
-4.0
```

Note that the `floor` function always moves toward -∞ (minus infinity), and `ceil` always moves toward +∞.

3. Character string basics

Python has extensive features for handling strings of characters. There are two types:

- A `str` value is a string of zero or more 8-bit characters. The common characters you see on North American keyboards all use 8-bit characters. The official name for this character set is ASCII[5], for American Standard Code for Information Interchange.

  This character set has one surprising property: all capital letters are considered less than all lowercase letters, so the string `"Z"` sorts before string `"a"`.

- A `unicode` value is a string of zero or more 32-bit Unicode characters. The Unicode character set covers just about every written language and every special character ever invented.

We'll mainly talk about working with `str` values, but most `unicode` operations are similar or identical.

3.1. String literals

In Python, you can enclose string constants in either single-quote (`'...'`) or double-quote (`"..."`) characters.

```
>>> cloneName = 'Clem'
>>> cloneName
'Clem'
>>> print cloneName
Clem
>>> fairName = "Future Fair"
>>> print fairName
Future Fair
>>> fairName
'Future Fair'
```

[5] http://en.wikipedia.org/wiki/ASCII

When you display a string value in conversational mode, Python will usually use single-quote characters. Internally, the values are the same regardless of which kind of quotes you use. Note also that the `print` statement shows only the content of a string, without any quotes around it.

To convert an integer (`int` type) value *`i`* to its string equivalent, use the function "`str(`*`i`*`)`":

```
>>> str(-497)
'-497'
>>> str(000)
'0'
```

The inverse operation, converting a string *`s`* back into an integer, is written as "`int(`*`s`*`)`":

```
>>>
>>> int("-497")
-497
>>> int("-0")
0
>>> int ( "012this ain't no number" )
Traceback (most recent call last):
  File "<stdin>", line 1, in ?
ValueError: invalid literal for int(): 012this ain't no number
```

The last example above shows what happens when you try to convert a string that isn't a valid number.

To convert a string *`s`* number in base *`B`*, use the form "`str(`*`s`*`, `*`B`*`)`":

```
>>> int ( '0F', 16 )
15
>>> int ( "10101", 2 )
21
>>> int ( "0177776", 8 )
65534
```

To obtain the 8-bit integer code contained in a one-character string *`s`*, use the function "`ord(`*`s`*`)`". The inverse function, to convert an integer *`i`* to the character that has code *`i`*, use "`chr(`*`i`*`)`". The numeric values of each character are defined by the ASCII[6]character set.

```
>>> chr( 97 )
'a'
>>> ord("a")
97
>>> chr(65)
'A'
>>> ord('A')
65
```

In addition to the printable characters with codes in the range from 32 to 127 inclusive, a Python string can contain any of the other unprintable, special characters as well. For example, the *null character*, whose official name is `NUL`, is the character whose code is zero. One way to write such a character is to use this form:

```
'\xNN'
```

where *`NN`* is the character's code in hexadecimal (base 16) notation.

[6] http://en.wikipedia.org/wiki/ASCII

```
>>> chr(0)
'\x00'
>>> ord('\x00')
0
```

Another special character you may need to deal with is the *newline* character, whose official name is `LF` (for “line feed”). Use the special *escape sequence* “`\n`” to produced this character.

```
>>> s = "Two-line\nstring."
>>> s
'Two-line\nstring.'
>>> print s
Two-line
string.
```

As you can see, when a newline character is displayed in conversational mode, it appears as “`\n`”, but when you print it, the character that follows it will appear on the next line. The code for this character is 10:

```
>>> ord('\n')
10
>>> chr(10)
'\n'
```

Python has several other of these escape sequences. The term “escape sequence” refers to a convention where a special character, the “escape character”, changes the meaning of the characters after it. Python's escape character is backslash (`\`).

Input	**Code**	**Name**	**Meaning**
`\b`	8	BS	*backspace*
`\t`	9	HT	*tab*
`\"`	34	"	Double quote
`\'`	39	'	Single quote
`\\`	92	\	Backslash

There is another handy way to get a string that contains newline characters: enclose the string within *three* pairs of quotes, either single or double quotes.

```
>>> multi = """This string
...   contains three
...   lines."""
>>> multi
'This string\n  contains three\n  lines.'
>>> print multi
This string
  contains three
  lines.
>>> s2 = '''
... xyz
... '''
>>> s2
'\nxyz\n'
```

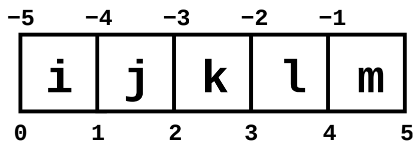
```
>>> print s2

xyz

>>>
```

Notice that in Python's conversational mode, when you press *Enter* at the end of a line, and Python knows that your line is not finished, it displays a "`...`" prompt instead of the usual "`>>>`" prompt.

3.2. Indexing strings

To extract one or more characters from a string value, you have to know how positions in a string are numbered.

Here, for example, is a diagram showing all the positions of the string `'ijklm'`.



In the diagram above, the numbers show the positions *between* characters. Position 0 is the position before the first character; position 1 is the position between the first and characters; and so on.

You may also refer to positions relative to the *end* of a string. Position -1 refers to the position before the last character; -2 is the position before the next-to-last character; and so on.

To extract from a string *s* the character that occurs just *after* position *n*, use an expression of this form:

```
s[n]
```

Examples:

```
>>> stuff = 'ijklm'
>>> stuff[0]
'i'
>>> stuff[1]
'j'
>>> stuff[4]
'm'
>>> stuff [ -1 ]
'm'
>>> stuff [-3]
'k'
>>> stuff[5]
Traceback (most recent call last):
  File "<stdin>", line 1, in ?
IndexError: string index out of range
```

The last example shows what happens when you specify a position after all the characters in the string.

3.3. String methods

Many of the operations on strings are expressed as *methods*. A method is sort of like a function that lives only inside values of a certain type. To call a method, use this syntax:

```
expr.method(arg1, arg2, ...)
```

where each `arg_i` is an argument to the method, just like an argument to a function.

For example, any string value has a method called `center` that produces a new string with the old value centered, using extra spaces to pad the value out to a given length. The general form is:

```
s.center(n)
```

This method takes one argument *n*, the size of the result. Examples:

```
>>> k = "Ni"
>>> k.center(5)
'  Ni '
>>> "<*>".center(12)
'    <*>     '
```

Note that in the first example we are asking Python to center the string `"Ni"` in a field of length 5. Clearly we can't center a 2-character string in 5 characters, so Python arbitrarily adds the extra space character before the old value.

Another useful string method left-justifies a value in a field of a given length. The general form:

```
s.ljust(n)
```

For any string expression *s*, this method returns a new string containing the characters from *s* with enough spaces added after it to make a new string of length *n*.

```
>>> "Ni".ljust(4)
'Ni  '
>>> "Too long to fit".ljust(4)
'Too long to fit'
```

Note that the `.ljust()` method will never return a shorter string. If the length isn't enough, it just returns the original value.

There is a similar method that right-justifies a string value:

```
s.rjust(n)
```

This method returns a string with enough spaces added before the value to make a string of length *n*. As with the `.ljust()` method, it will never return a string shorter than the original.

```
>>> "Ni".rjust(4)
'  Ni'
>>> m = "floccinaucinihilipilification"
>>> m.rjust(4)
'floccinaucinihilipilification'
```

Sometimes you want to remove whitespace (spaces, tabs, and newlines) from a string. For a string *s*, use these methods to remove leading and trailing whitespace:

- `s.strip()` returns *s* with any leading or trailing whitespace characters removed.

- `s.lstrip()` removes only leading whitespace.
- `s.rstrip()` removes only trailing whitespace.

```
>>> spaceCase = ' \n \t Moon   \t\t '
>>> spaceCase
' \n \t Moon   \t\t '
>>> spaceCase.strip()
'Moon'
>>> spaceCase.lstrip()
'Moon   \t\t '
>>> spaceCase.rstrip()
' \n \t Moon'
```

The method `s.count(t)` searches string `s` to see how many times string `t` occurs in it.

```
>>> chiq = "banana"
>>> chiq
'banana'
>>> chiq.count("a")
3
>>> chiq.count("b")
1
>>> chiq.count("x")
0
>>> chiq.count("an")
2
>>> chiq.count("ana")
1
```

Note that this method does not count overlapping occurrences. Although the string `"ana"` occurs twice in string `"banana"`, the occurrences overlap, so `"banana".count("ana")` returns only 1.

Use this method to search for a string `t` within a string `s`:

```
s.find(t)
```

If `t` matches any part of `s`, the method returns the position where the first match begins; otherwise, it returns -1.

```
>>> chiq
'banana'
>>> chiq.find ( "b" )
0
>>> chiq.find ( "a" )
1
>>> chiq.find ( "x" )
-1
>>> chiq.find ( "nan" )
2
```

If you need to find the *last* occurrence of a substring, use the similar method `s.rfind(t)`, which returns the position where the last match starts, or -1 if there is no match.

```
>>> chiq.rfind("a")
5
```

```
>>> chiq[5]
'a'
>>> chiq.rfind("n")
4
>>> chiq.rfind("b")
0
>>> chiq.rfind("Waldo")
-1
```

You can check to see if a string *s* starts with a string *t* using a method call like this:

```
s.startswith(t)
```

This method returns `True` if *s* starts with a string that matches *t*; otherwise it returns `False`.

```
>>> chiq
'banana'
>>> chiq.startswith("b")
True
>>> chiq.startswith("ban")
True
>>> chiq.startswith ( 'Waldo' )
False
```

There is a similar method `s.endswith(t)` that tests whether string *s* ends with *t*:

```
>>> chiq.endswith("Waldo")
False
>>> chiq.endswith("a")
True
>>> chiq.endswith("nana")
True
```

The special values `True` and `False` are discussed later in Section 6.1, “Conditions and the `bool` type” (p. 31).

The methods `s.lower()` and `s.upper()` are used to convert uppercase characters to lowercase, and vice versa, respectively.

```
>>> poet = 'E. E. Cummings'
>>> poet.upper()
'E. E. CUMMINGS'
>>> poet.lower()
'e. e. cummings'
```

There are string methods for testing what kinds of characters are in a string. Each of these methods is a *predicate*, that is, it asks a question and returns a value of `True` or `False`.

- `s.isalpha()` tests whether all the characters of *s* are letters.
- `s.isupper()` tests whether all the letters of *s* are uppercase.
- `s.islower()` tests whether all the characters of *s* are lowercase letters.
- `s.isdigit()` tests whether all the characters of *s* are digits.

```
>>> mixed = 'abcDEFghi'
>>> mixed.isalpha()
True
```

```
>>> mixed.isupper()
False
>>> mixed.islower()
False
>>> "ABCDGOLDFISH".isupper()
True
>>> "lmno goldfish".islower()
True
>>> paradise = "87801"
>>> paradise.isalpha()
False
>>> paradise.isdigit()
True
>>> "abc123".isdigit()
False
```

3.4. The string format operator

One of the commonest string operations is Python's format operator. Here, we want to substitute variable values into a fixed string.

For example, suppose your program wants to report how many bananas you have, and you have an `int` variable named `nBananas` that contains the actual banana count, and you want to print a string something like “We have 27 bananas” if `nBananas` has the value 27. This is how you do it:

```
>>> nBananas = 27
>>> "We have %d bananas." % nBananas
'We have 27 bananas.'
```

In general, when a string value appears on the left side of the “`%`” operator, that string is called the *format string*. Within a format string, the percent character “`%`” has special meaning. In the example above, the “`%d`” part means that an integer value will be substituted into the format string at that position. So the result of the format operator will be a string containing all the characters from the format string, except that the value on the right of the operator (`27`) will replace the “`%d`” in the format string.

Here's another example, showing the substitution of a string value.

```
>>> noSuch = "kiwis"
>>> 'We are out of %s today.' % noSuch
'We are out of kiwis today.'
```

This demonstrates the “`%s`” format code, which means that a string value is to be substituted at that position in the result.

You can substitute more than one value in a format operation, but you must enclose the values to be substituted in parentheses, separated by commas. For example:

```
>>> caseCount = 42
>>> caseContents = "peaches"
>>> print "We have %d cases of %s today." % (caseCount, caseContents)
We have 42 cases of peaches today.
```

So, in general, a format operator has this form:

“*format* % (*value*$_1$, *value*$_2$, ...)”

Wherever a format code starting with "%" appears in the *format* string, the corresponding $value_i$ is substituted for that format code.

The various format codes have a number of additional features that let you control how the values are displayed. For example, the "%s" format code always produces a value exactly as long as the string value you provide. But you may wish to produce a value of a fixed size. To do this, use a format code of the form "%*N*s", where *N* is the number of characters you want the result to occupy. Examples:

```
>>> '%s' % 'soup'
'soup'
>>> '%6s' % 'soup'
'  soup'
```

If a string shorter than *N* characters is formatted using format code "%*N*s", spaces are added before the string to fill the result out to *N* characters. If you would prefer that the extra spaces be added after the string value, use a format code of the form "%-*N*s".

```
>>> '%-6s' % 'soup'
'soup  '
```

By default, the integer format code "%d" always produces a string that is just large enough to hold the number. But if you want the number to occupy exactly *N* digits, you can use a format code of the form "%*N*d". Examples:

```
>>> "%d" % 1107
'1107'
>>> "%5d" % 1107
' 1107'
>>> '%30d' % 1107
'                          1107'
>>> '%2d' % 1107
'1107'
```

Notice in the last example that when you specify a field size that is too small for the number, Python will not truncate the number; it will take as many characters as needed to properly render the value.

When your number does not fill the field, the default is to add spaces to the left of the number as needed. If you would prefer that the extra spaces be added after the number, use a format code of the form "%-*N*d".

```
>>> '%5d' % 505
'  505'
>>> '%-5d' % 505
'505  '
```

You can ask Python to use zeroes instead of spaces to fill extra positions by using a format code of the form "%0*N*d".

```
>>> '%5d' % 42
'   42'
>>> '%05d'%42
'00042'
```

Next we'll examine Python's format code for `float` values. In its simplest form, it is just "%f".

```
>>> "%f" % 0.0
'0.000000'
```

```
>>> "%f" % 1.5
'1.500000'
>>> pi = 3.141592653589793
>>> "%f" % pi
'3.141593'
```

By default, the result will show six digits of precision after the decimal point. To specify *P* digits of precision, use a format code of the form "`%.`*P*`f`".

```
>>> "%.0f" % pi
'3'
>>> "%.15f" % pi
'3.141592653589793'
```

You can also specify the total number of characters to be used in formatting a number. A format code of the form "`%`*N*`.`*P*`f`" will try to fit the result into *N* characters, with *P* digits after the decimal point.

```
>>> "%10f" % pi
'  3.141593'
>>> "%5.1f" % pi
'  3.1'
>>> "%5.3f" % pi
'3.142'
>>> "%50.40f" % 5.33333
'        5.3333300000000001261923898709937930107117'
```

Notice in the last example above that it is possible for you to produce any number of spurious digits beyond the precision used to specify the number originally! Beware, because those extra digits are utter garbage.

When you specify a precision, the value is rounded to the nearest value with that precision.

```
>>> "%.1f" % 0.999
'1.0'
>>> "%.1f" % 0.99
'1.0'
>>> "%.1f" % 0.9
'0.9'
>>> "%.1f" % 0.96
'1.0'
>>> "%.1f" % 0.9501
'1.0'
>>> "%.1f" % 0.9499999
'0.9'
>>>
```

As with the `%s` and `%d` formats, you can use a negative field size in the `%f` format code to cause the value to be left-aligned in the field.

```
>>> "%10.2f" % pi
'      3.14'
>>> "%-10.2f" % pi
'3.14      '
```

If you would prefer to display a `float` value using the exponential format, use a format code of the form "`%`*N*`.`*P*`e`". The exponent will always occupy four or five digits depending on the size of the exponent.

```
>>> avo = 6.022e23
>>> "%e" % avo
'6.022000e+23'
>>> "%.3e" % avo
'6.022e+23'
>>> "%11.4e" % avo
' 6.0220e+23'
>>> googol = 1e100
>>> "%e" % googol
'1.000000e+100'
>>> "%e" % pi
'3.141593e+00'
```

4. Sequence types

Mathematically, a *sequence* in Python represents an ordered set.

Sequences are an example of *container classes*: values that contain other values inside them.

Mutability: You can't change *part* of an immutable value. For example, you can't change the first character of a string from `'a'` to `'b'`. It is, however, easy to build a new string out of pieces of other strings.

Type name	Contains	Examples	Mutable?
`str`	8-bit characters	`"abc" 'abc' "" '' '\n' '\x00'`	No
`unicode`	32-bit characters	`u'abc' u'\u000c'`	No
`list`	Any values	`[23, "Fred", 69.8] []`	Yes
`tuple`	Any values	`(23, "Fred", 69.8) () (44,)`	No

- `int` and `unicode` are used for strings.
- `list` and `tuple` are used for sequences of zero or more values of any type. Use a `list` if the contents of the sequence may change; use a `tuple` if the contents will not change, and in certain places where tuples are required.
- To create a list, use an expression of the form

  ```
  [ expr1, expr1, ... ]
  ```

  with a list of zero or more values between *square brackets*, "`[…]`".
- To create a tuple, use an expression of the form

  ```
  ( expr1, expr1, ... )
  ```

  with a list of zero or more values enclosed in *parentheses*, "`(…`").

  To create a tuple with only one element *v*, use the special syntax "`(v,)`". For example, `(43+1,)` is a one-element tuple containing the integer 44. The trailing comma is used to distinguish this case from the expression "`(43+1)`", which yields the integer 44, not a tuple.

Here are some calculator-mode examples. First, we'll create a string named `s`, a list named `L`, and a tuple named `t`:

```
>>> s = "abcde"
>>> L = [0, 1, 2, 3, 4, 5]
>>> t = ('x', 'y')
>>> s
'abcde'
>>> L
[0, 1, 2, 3, 4, 5]
>>> t
('x', 'y')
```

4.1. Functions and operators for sequences

The built-in function `len(S)` returns the number of elements in a sequence *S*.

```
>>> print len(s), len(L), len(t)
5 6 2
```

Function `max(S)` returns the largest value in a sequence *S*, and function `min(S)` returns the smallest value in a sequence *S*.

```
>>> max(L)
5
>>> min(L)
0
>>> max(s)
'e'
>>> min(s)
'a'
```

To test for set membership, use the “`in`” operator. For a value *v* and a sequence *S*, the expression `v in S` returns the Boolean value `True` if there is at least one element of *S* that equals *v*; it returns `False` otherwise.

```
>>> 2 in L
True
>>> 77 in L
False
```

There is an inverse operator, `v not in S`, that returns `True` if *v* does not equal any element of *S*, `False` otherwise.

```

>>> 2 not in L
False
>>> 77 not in L
True
```

The “`+`” operator is used to concatenate two sequences of the same type.

```
>>> s + "xyz"
'abcdexyz'
>>> L + L
[0, 1, 2, 3, 4, 5, 0, 1, 2, 3, 4, 5]
```

```
>>> t + ('z',)
('x', 'y', 'z')
```

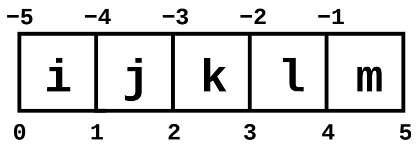
When the "*" operator occurs between a sequence *S* and an integer *n*, you get a new sequence containing *n* repetitions of the elements of *S*.

```
>>> "x" * 5
'xxxxx'
>>> "spam" * 8
'spamspamspamspamspamspamspamspam'
>>> [0, 1] * 3
[0, 1, 0, 1, 0, 1]
```

4.2. Indexing the positions in a sequence

Positions in a sequence refer to locations *between* the values. Positions are numbered from left to right starting at 0. You can also refer to positions in a sequence using negative numbers to count from right to left: position -1 is the position before the last element, position -2 is the position before the next-to-last element, and so on.

Here are all the positions of the string `"ijklm"`.



To extract a single element from a sequence, use an expression of the form `S[i]`, where `S` is a sequence, and `i` is an integer value that selects the element just *after* that position.

```
>>> s[0]
'a'
>>> s[4]
'e'
>>> s[5]
Traceback (most recent call last):
  File "<stdin>", line 1, in ?
IndexError: string index out of range
```

The last line is an error; there is nothing after position 5 in string `s`.

```
>>> L[0]
0
>>> t[0]
'x'
```

4.3. Slicing sequences

For a sequence *S*, and two positions *B* and *E* within that sequence, the expression `S [ B : E ]` produces a new sequence containing the elements of S between those two positions.

```
>>> L
[0, 1, 2, 3, 4, 5]
```

```
>>> L[2]
2
>>> L[4]
4
>>> L[2:4]
[2, 3]
>>> s = 'abcde'
>>> s[2]
'c'
>>> s[4]
'e'
>>> s[2:4]
'cd'
```

Note in the example above that the elements are selected from position 2 to position 4, which does *not* include the element `L[4]`.

You may omit the starting position to slice elements from at the beginning of the sequence up to the specified position. You may omit the ending position to specify a slice that extends to the end of the sequence. You may even omit both in order to get a copy of the whole sequence.

```
>>> L[:4]
[0, 1, 2, 3]
>>> L[4:]
[4, 5]
>>> L[:]
[0, 1, 2, 3, 4, 5]
```

You can replace part of a list by using a slicing expression on the *left-hand* side of the "`=`" in an assignment statement, and providing a list of replacement elements on the right-hand side of the "`=`". The elements selected by the slice are deleted and replaced by the elements from the right-hand side.

In slice assignment, it is not necessary that the number of replacement elements is the same as the number of replaced elements. In this example, the second and third elements of `L` are replaced by the five elements from the list on the right-hand side.

```
>>> L
[0, 1, 2, 3, 4, 5]
>>> L[2:4]
[2, 3]
>>> L[2:4] = [93, 94, 95, 96, 97]
>>> L
[0, 1, 93, 94, 95, 96, 97, 4, 5]
```

You can even delete a slice from a sequence by assigning an an empty sequence to a slice.

```
>>> L
[0, 1, 93, 94, 95, 96, 97, 4, 5]
>>> L[3]
94
>>> L[7]
4
>>> L[3:7] = []
>>> L
[0, 1, 93, 4, 5]
```

Similarly, you can insert elements into a sequence by using an empty slice on the left-hand side.

```
>>> L
[0, 1, 93, 4, 5]
>>> L[2]
93
>>> L[2:2] = [41, 43, 47, 53]
>>> L
[0, 1, 41, 43, 47, 53, 93, 4, 5]
```

Another way to delete elements from a sequence is to use Python's `del` statement.

```
>>> L
[0, 1, 41, 43, 47, 53, 93, 4, 5]
>>> L[3:6]
[43, 47, 53]
>>> del L[3:6]
>>> L
[0, 1, 41, 93, 4, 5]
```

4.4. List methods

We have already seen how all string values have methods. For example, if variable `p` contains the string `"Path"`, the expression `p.upper()` returns a new string with all lowercase characters uppercased:

```
>>> p = "Path"
>>> p.upper()
'PATH'
```

Similarly, all list instances support several useful methods. For example, for any list instance *`L`*, the `.append(`*`v`*`)` method appends a new value *`v`* to that list.

```
>>> menu1 = ['kale', 'tofu']
>>> menu1
['kale', 'tofu']
>>> menu1.append ( 'sardines' )
>>> menu1
['kale', 'tofu', 'sardines']
>>>
```

To insert a single new value *`V`* into a list *`L`* at an arbitrary position *`P`*, use this method:

```
L.insert(P, V)
```

To continue the example above:

```
>>> menu1
['kale', 'tofu', 'sardines']
>>> menu1.insert(0, 'beans')
>>> menu1
['beans', 'kale', 'tofu', 'sardines']
>>> menu1[3]
'sardines'
>>> menu1.insert(3, 'trifle')
>>> menu1
['beans', 'kale', 'tofu', 'trifle', 'sardines']
```

To find the position of a value *V* in a list *L*, use this method:

```
L.index(V)
```

This method returns the position of the first element of *L* that equals *V*. , or `-1` i If no elements of *L* are equal, Python raises a `ValueError` exception.

```
>>> menu1
['beans', 'kale', 'tofu', 'trifle', 'sardines']
>>> menu1.index("kale")
1
>>> menu1.index("spam")
Traceback (most recent call last):
  File "<stdin>", line 1, in ?
ValueError: list.index(x): x not in list
```

The method `L.count(V)` method returns the number of elements of *L* that are equal to *V*.

```
>>> menu1[2:2] = ['spam'] * 3
>>> menu1
['beans', 'kale', 'spam', 'spam', 'spam', 'tofu', 'trifle', 'sardines']
>>> menu1.count('gravy')
0
>>> menu1.count('spam')
3
```

The method `L.remove(V)` removes the first element of *L* that equals *V*, if there is one. If no elements equal *V*, the method raises a `ValueError` exception.

```
>>> menu1
['beans', 'kale', 'spam', 'spam', 'spam', 'tofu', 'trifle', 'sardines']
>>> menu1.remove('spam')
>>> menu1
['beans', 'kale', 'spam', 'spam', 'tofu', 'trifle', 'sardines']
>>> menu1.remove('spam')
>>> menu1
['beans', 'kale', 'spam', 'tofu', 'trifle', 'sardines']
>>> menu1.remove('gravy')
Traceback (most recent call last):
  File "<stdin>", line 1, in ?
ValueError: list.remove(x): x not in list
```

The `L.sort()` method sorts the elements of a list into ascending order.

```
>>> menu1
['beans', 'kale', 'spam', 'tofu', 'trifle', 'sardines']
>>> menu1.sort()
>>> menu1
['tofu', 'beans', 'kale', 'sardines', 'spam', 'trifle']
```

Note that the `.sort()` method itself does not return a value; it sorts the values of the list in place. A similar method is `.reverse()`, which reverses the elements in place:

```
>>> menu1
['tofu', 'beans', 'kale', 'sardines', 'spam', 'trifle']
>>> menu1.reverse()
>>> menu1
['trifle', 'spam', 'sardines', 'kale', 'beans', 'tofu']
```

4.5. The `range()` function: creating arithmetic progressions

The term *arithmetic progression* refers to a sequence of numbers such that the difference between any two successive elements is the same. Examples: [1, 2, 3, 4, 5]; [10, 20, 30, 40]; [88, 77, 66, 55, 44, 33].

Python's built-in `range()` function returns a list containing an arithmetic progression. There are three different ways to call this function.

To generate the sequence [0, 1, 2, ..., *n*-1], use the form `range(n)`.

```
>>> range(6)
[0, 1, 2, 3, 4, 5]
>>> range(2)
[0, 1]
>>> range(0)
[]
```

Note that the sequence will never include the value of the argument *n*; it stops one value short.

To generate a sequence [*i*, *i*+1, *i*+2, ..., *n*-1], use the form `range(i, n)`:

```
>>> range(5,11)
[5, 6, 7, 8, 9, 10]
>>> range(1,5)
[1, 2, 3, 4]
```

To generate an arithmetic progression with a difference *d* between successive values, use the three-argument form `range(i, n, d)`. The resulting sequence will be [*i*, *i*+*d*, *i*+2**d*, ...], and will stop before it reaches a value equal to *n*.

```
>>> range ( 10, 100, 10 )
[10, 20, 30, 40, 50, 60, 70, 80, 90]
>>> range ( 100, 0, -10 )
[100, 90, 80, 70, 60, 50, 40, 30, 20, 10]
>>> range ( 8, -1, -1 )
[8, 7, 6, 5, 4, 3, 2, 1, 0]
```

4.6. A list surprise

Now it is time for one of Python's little surprises. The author has found Python pretty predictable for the most part, but there are some behaviors that might surprise programmers familiar with other languages. Here is one of them.

We start by creating a list of two strings and binding two names to that list.

```
>>> menu1 = menu2 = ['kale', 'tofu']
>>> menu1
['kale', 'tofu']
```

```
>>> menu2
['kale', 'tofu']
```

Then we make a new list using a slice that selects all the elements of `menu1`:

```
>>> menu3 = menu1 [ : ]
>>> menu3
['kale', 'tofu']
```

Now watch what happens when we modify `menu1`'s list:

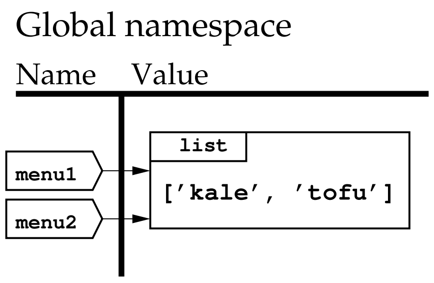
```
>>> menu1.append ( 'sardines' )
>>> menu1
['kale', 'tofu', 'sardines']
>>> menu2
['kale', 'tofu', 'sardines']
>>> menu3
['kale', 'tofu']
```

If we appended a third string to `menu1`, why does that string also appear in list `menu2`? The answer lies in the definition of Python's assignment statement:

> To evaluate an assignment statement of the form
>
> $V_1 = V_2 = \ldots = expr$
>
> where each V_i is a variable, and *expr* is some expression, first reduce *expr* to a single value, then bind each of the names v_i to that value.

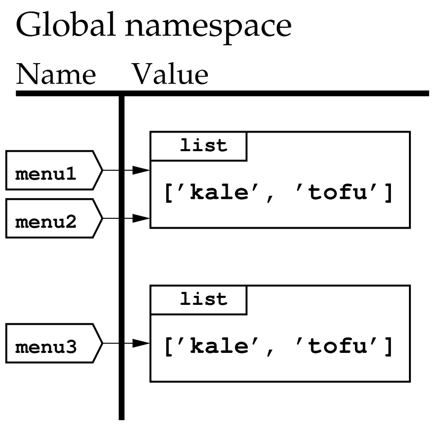
So let's follow the example one line at a time, and see what the global namespace looks like after each step. First we create a list instance and bind two names to it:

```
>>> menu1=menu2=['kale', 'tofu']
```



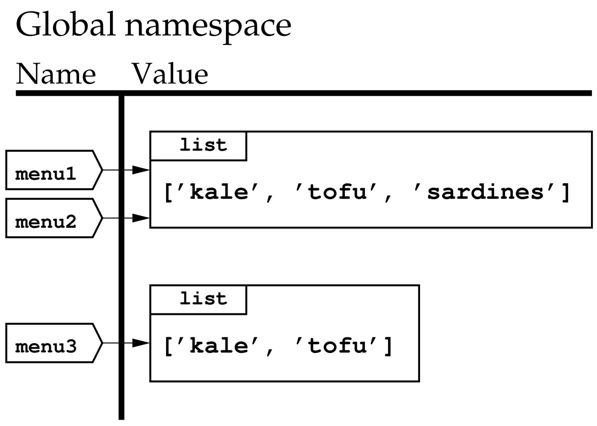
Two different names, `menu1` and `menu2`, point to the same list. Next, we create an element-by-element copy of that list and bind the name `menu3` to the copy.

```
>>> menu3 = menu1[:]
>>> menu3
['kale', 'tofu']
```



So, when we add a third string to `menu1`'s list, the name `menu2` is still bound to that same list.

```
>>> menu1.append ( 'sardines' )
>>> menu1
['kale', 'tofu', 'sardines']
>>> menu2
['kale', 'tofu', 'sardines']
```



This behavior is not often a problem in practice, but it is important to know that two or more names can be bound to the same value.

5. Dictionaries

Python's dictionary type is useful for many applications involving table lookups. In mathematical terms:

> A Python dictionary is a set of zero or more ordered pairs (*`key`*, *`value`*) such that:
>
> - The *`value`* can be any type.
> - Each *`key`* may occur only once in the dictionary.
> - No *`key`* may be a list or dictionary.

The idea is that you store values in a dictionary associated with some key, so that later you can use that key to retrieve the associated value.

5.1. Operations on dictionaries

The general form used to create a new dictionary in Python looks like this:

```
{k1: v1,  k2: v2,  ...}
```

To retrieve the value associated with key *k* from dictionary *d*, use an expression of this form:

```
d[k]
```

Here are some conversational examples:

```
>>> numberNames = {0:'zero', 1:'one', 10:'ten', 5:'five'}
>>> numberNames[10]
'ten'
>>> numberNames[0]
'zero'
>>> numberNames[999]
Traceback (most recent call last):
  File "<stdin>", line 1, in ?
KeyError: 999
```

Note that when you try to retrieve the value for which no key exists in the dictionary, Python raises a `KeyError` exception.

To add or replace the value for a key *k* in dictionary *d*, use an assignment statement of this form:

```
d[k] = v
```

For example:

```
>>> numberNames[2] = "two"
>>> numberNames[2]
'two'
>>> numberNames
{0: 'zero', 1: 'one', 10: 'ten', 2: 'two', 5: 'five'}
```

Note

The ordering of the pairs within a dictionary is undefined. Note that in the example above, the pairs do not appear in the order they were added.

You can use strings, as well as many other values, as keys:

```
>>> nameNo={"one":1, "two":2, "forty-leven":4011}
>>> nameNo["forty-leven"]
4011
```

You can test to see whether a key *k* exists in a dictionary *d* with the "`in`" operator, like this:

```
k in d
```

This operation returns `True` if *k* is a key in dictionary *d*, `False` otherwise.

The construct "*k* `not in` *d*" is the inverse test: it returns `True` if *k* is *not* a key in *d*, `False` if it *is* a key.

```
>>> 1 in numberNames
True
>>> 99 in numberNames
False
>>> "forty-leven" in nameNo
True
>>> "eleventeen" in nameNo
False
>>> "forty-leven" not in nameNo
False
>>> "eleventeen" not in nameNo
True
```

Python's `del` (delete) statement can be used to remove a key-value pair from a dictionary.

```
>>> numberNames
{0: 'zero', 1: 'one', 10: 'ten', 2: 'two', 5: 'five'}
>>> del numberNames[10]
>>> numberNames
{0: 'zero', 1: 'one', 2: 'two', 5: 'five'}
>>> numberNames[10]
Traceback (most recent call last):
  File "<stdin>", line 1, in ?
KeyError: 10
```

5.2. Dictionary methods

A number of useful methods are defined on any Python dictionary. To test whether a key *`k`* exists in a dictionary *`d`*, use this method:

```
d.has_key(k)
```

This is the equivalent of the expression "*`k`* `in` *`d`*": it returns `True` if the key is in the dictionary, `False` otherwise.

```
>>> numberNames
{0: 'zero', 1: 'one', 2: 'two', 5: 'five'}
>>> numberNames.has_key(2)
True
>>> numberNames.has_key(10)
False
```

To get a list of all the keys in a dictionary *`d`*, use this expression:

```
d.keys()
```

To get a list of the values in a dictionary *`d`* , use this expression:

```
d.values()
```

You can get all the keys and all the values at the same time with this expression, which returns a list of 2-element tuples, in which each tuple has one key and one value as `(`*`k`*`, `*`v`*`)`.

```
d.items()
```

Examples:

```
>>> numberNames
{0: 'zero', 1: 'one', 2: 'two', 5: 'five'}
>>> numberNames.keys()
[0, 1, 2, 5]
>>> numberNames.values()
['zero', 'one', 'two', 'five']
>>> numberNames.items()
[(0, 'zero'), (1, 'one'), (2, 'two'), (5, 'five')]
>>> nameNo
{'forty-leven': 4011, 'two': 2, 'one': 1}
>>> nameNo.keys()
['forty-leven', 'two', 'one']
>>> nameNo.values()
[4011, 2, 1]
>>> nameNo.items()
[('forty-leven', 4011), ('two', 2), ('one', 1)]
```

Here is another useful method:

```
d.get(k)
```

If *k* is a key in *d*, this method returns `d[k]`. However, if *k* is not a key, the method returns the special value `None`. The advantage of this method is that if the *k* is not a key in *d*, it is not considered an error.

```
>>> nameNo.get("two")
2
>>> nameNo.get("eleventeen")
>>> huh = nameNo.get("eleventeen")
>>> print huh
None
```

Note that when you are in conversational mode, and you type an expression that results in the value `None`, nothing is printed. However, the `print` statement will display the special value `None` visually as the example above shows.

There is another way to call the `.get()` method, with two arguments:

```
d.get(k, default)
```

In this form, if key *k* exists, the corresponding value is returned. However, if *k* is not a key in *d*, it returns the *`default`* value.

```
>>> nameNo.get("two", "I have no idea.")
2
>>> nameNo.get("eleventeen", "I have no idea.")
'I have no idea.'
```

Here is another useful dictionary method. This is similar to the two-argument form of the `.get()` method, but it goes even further: if the key is not found, it stores a default value in the dictionary.

```
d.setdefault(k, default)
```

If key *k* exists in dictionary *d*, this expression returns the value `d[k]`. If *k* is not a key, it creates a new dictionary entry as if you had said “`d[k] = default`”.

```
>>> nameNo.setdefault("two", "Unknown")
2
>>> nameNo["two"]
2
>>> nameNo.setdefault("three", "Unknown")
'Unknown'
>>> nameNo["three"]
'Unknown'
```

To merge two dictionaries `d1` and `d2`, use this method:

```
d1.update(d2)
```

This method adds all the key-value pairs from `d2` to `d1`. For any keys that exist in both dictionaries, the value after this operation will be the value from `d2`.

```
>>> colors = { 1: "red", 2: "green", 3: "blue" }
>>> moreColors = { 3: "puce", 4: "taupe", 5: "puce" }
>>> colors.update ( moreColors )
>>> colors
{1: 'red', 2: 'green', 3: 'puce', 4: 'taupe', 5: 'puce'}
```

Note in the example above that key `3` was in both dictionaries, but after the `.update()` method call, key `3` is related to the value from `moreColors`.

6. Branching

By default, statements in Python are executed sequentially. *Branching* statements are used to break this sequential pattern.

- Sometimes you want to perform certain operations only in some cases. This is called a *conditional branch*.
- Sometimes you need to perform some operations repeatedly. This is called *looping*.

Before we look at how Python does conditional branching, we need to look at Python's Boolean type.

6.1. Conditions and the `bool` type

Boolean algebra is the mathematics of true/false decisions. Python's `bool` type has only two values: `True` and `False`.

A typical use of Boolean algebra is in comparing two values. In Python, the expression `x < y` is `True` if `x` is less than `y`, `False` otherwise.

```
>>> 2 < 5
True
>>> 2 < 2
False
>>> 2 < 0
False
```

Here are the six comparison operators:

Math symbol	**Python**	**Meaning**
<	<	Less than
≤	<=	Less than or equal to
>	>	Greater than
≥	>=	Greater than or equal to
≡	==	Equal to
≠	!=	Not equal to

The operator that compares for equality is "`==`". (The "`=`" symbol is not an operator: it is used only in the assignment statement.)

Here are some more examples:

```
>>> 2 <= 5
True
>>> 2 <= 2
True
>>> 2 <= 0
False
>>> 4.9 > 5
False
>>> 4.9 > 4.8
True
>>> (2-1)==1
True
>>> 4*3 != 12
False
```

Python has a function `cmp(`*`x`*`, `*`y`*`)` that compares two values and returns:

- Zero, if *`x`* and *`y`* are equal.
- A negative number if *`x`*` < `*`y`*.
- A positive number if *`x`*` > `*`y`*.

```
>>> cmp(2,5)
-1
>>> cmp(2,2)
0
>>> cmp(2,0)
1
```

The function `bool(`*`x`*`)` converts any value *`x`* to a Boolean value. The values in this list are considered `False`; any other value is considered `True`:

- Any numeric zero: `0`, `0L`, or `0.0`.
- Any empty sequence: `""` (an empty string), `[]` (an empty list), `()` (an empty tuple).
- `{}` (an empty dictionary).
- The special unique value `None`.

```
>>> print bool(0), bool(0L), bool(0.0), bool(''), bool([]), bool(())
False False False False False False
>>> print bool({}), bool(None)
False False
```

```
>>> print bool(1), bool(98.6), bool('Ni!'), bool([43, "hike"])
True True True True
```

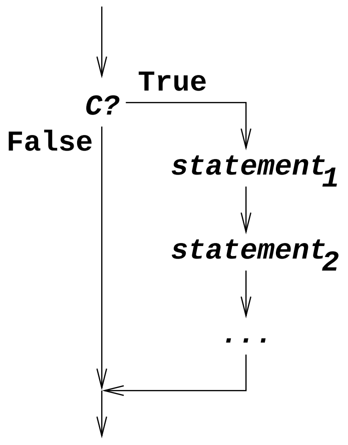
6.2. The `if` statement

The purpose of an `if` statement is to perform certain actions only in certain cases.

Here is the general form of a simple “one-branch” `if` statement. In this case, if some condition *C* is true, we want to execute some sequence of statements, but if *C* is not true, we don't want to execute those statements.

```
if C:
    statement1
    statement2
    ...
```

Here is a picture showing the flow of control through a simple `if` statement. Old-timers will recognize this as a *flowchart*.



There can be any number of statements after the `if`, but they must all be indented, and all indented the same amount. This group of statements is called a *block*.

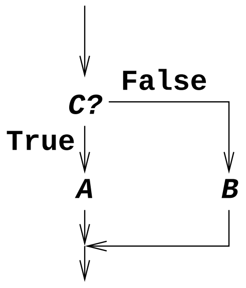
When the `if` statement is executed, the condition *C* is evaluated, and converted to a `bool` value (if it isn't already Boolean). If that value is `True`, the block is executed; if the value is `False`, the block is skipped.

Here's an example:

```
>>> half = 0.5
>>> if half > 0:
...     print "Half is better than none."
...     print "Burma!"
...
Half is better than none.
Burma!
```

Sometimes you want to do some action *A* when `C` is true, but perform some different action *B* when `C` is false. The general form of this construct is:

```
if C:
    block A
    ...
else:
    block B
    ...
```



As with the single-branch `if`, the condition *`C`* is evaluated and converted to Boolean. If the result is `True`, *`block A`* is executed; if `False`, *`block B`* is executed instead.

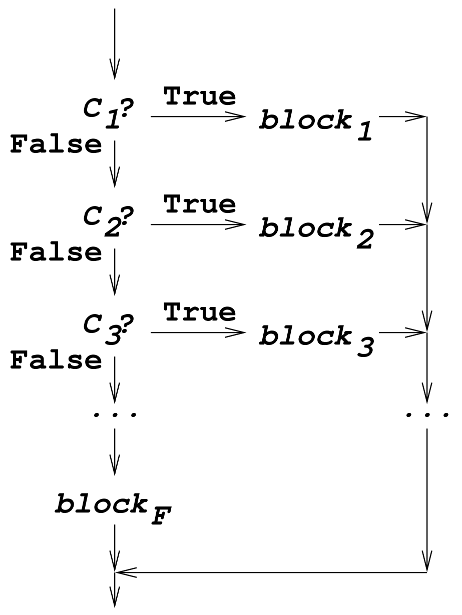
```
>>> half = 0.5
>>> if half > 0:
...     print "Half is more than none."
... else:
...     print "Half is not much."
...     print "Ni!"
...
Half is more than none.
```

Some people prefer a more "horizontal" style of coding, where more items are put on the same line, so as to take up less vertical space. If you prefer, you can put one or more statements on the same line as the `if` or `else`, instead of placing them in an indented block. Use a semicolon "`;`" to separate multiple statements. For example, the above example could be expressed on only two lines:

```
>>> if half > 0: print "Half is more than none."
... else: print "Half is not much."; print "Ni!"
...
Half is more than none.
```

Sometimes you want to execute only one out of three or four or more blocks, depending on several conditions. For this situation, Python allows you to have any number of "`elif` clauses" after an `if`, and before the `else` clause if there is one. Here is the most general form of a Python `if` statement:

```
if C1:
    block1
elif C2:
    block2
elif C3:
    block3
...
else:
    blockF
    ...
```



So, in general, an `if` statement can have zero or more `elif` clauses, optionally followed by an `else` clause. Example:

```
>>> i = 2
>>> if i==1: print "One"
... elif i==2: print "Two"
... elif i==3: print "Three"
... else: print "Many"
...
Two
```

You can have blocks within blocks. Here is an example:

```
>>> x = 3
>>> if  x >= 0:
...     if (x%2) == 0:
...         print "x is even"
...     else:
...         print "x is odd"
... else:
...     print "x is negative"
...
x is odd
```

6.3. A word about indenting your code

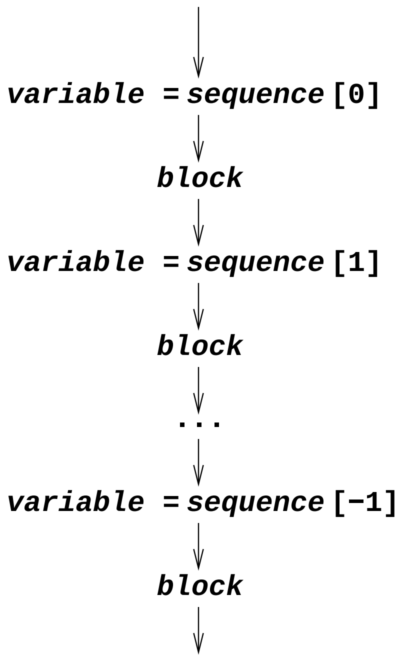
One of the most striking innovations of Python is the use of indentation to show the structure of the blocks of code, as in the `if` statement. Not everyone is thrilled by this feature. However, it is generally good practice to indent subsidiary clauses; it makes the code more readable. Those who argue that they should be allowed to violate this indenting practice are, in the author's opinion, arguing against what is generally regarded as a good practice.

The amount by which you indent each level is a matter of personal preference. You can use a *tab* character for each level of indention; tab stops are assumed to be every 8th character. Beware mixing tabs with spaces, however; the resulting errors can be difficult to diagnose.

6.4. The `for` statement: Looping

Use Python's “`for`” construct to do some repetitive operation for each member of a sequence. Here is the general form:

```
for variable in sequence:
    block
    ...
```



- The *`sequence`* can be any expression that evaluates to a sequence value, such as a list or tuple. The `range()` function is often used here to generate a sequence of integers.
- For each value in the *`sequence`* in turn, the *`variable`* is set to that value, and the *`block`* is executed.

  As with the `if` statement, the block consists of one or more statements, indented the same amount relative to the `if` keyword.

This example prints the cubes of all numbers from 1 through 5.

```
>>> for  n in range(1,6):
...     print "The cube of %d is %d." % (n, n**3)
...
The cube of 1 is 1.
The cube of 2 is 8.
The cube of 3 is 27.
The cube of 4 is 64.
The cube of 5 is 125.
```

You may put the body of the loop—that is, the statements that will be executed once for each item in the sequence—on the same line as the "`for`" if you like. If there are multiple statements in the body, separate them with semicolons.

```
>>> for  n in range(1,6): print "%d**3=%d" % (n, n**3),
...
1**3=1 2**3=8 3**3=27 4**3=64 5**3=125
```

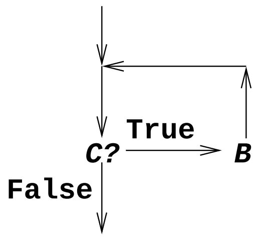
Here is an another example. In this case, the sequence is a specific list.

```
>>> for  s in ['a', 'e', 'i', 'o', 'u']:
...     word  =  "st" + s + "ck"
...     print  "Pick up the", word
...
Pick up the stack
Pick up the steck
Pick up the stick
Pick up the stock
Pick up the stuck
```

6.5. The `while` statement

Use this statement when you want to perform a block *B* as long as a condition *C* is true:

```
while C:
    B
    ...
```



Here is how a `while` statement is executed.

1. Evaluate *C*. If the result is true, go to step 2. If it is false, the loop is done, and control passes to the statement after the end of *B*.
2. Execute block *B*.
3. Go back to step 1.

Here is an example of a simple `while` loop.

```
>>> i = 1
>>> while i < 100:
...     print i,
...     i = i * 2
...
1 2 4 8 16 32 64
```

This construct has the potential to turn into an *infinite loop*, that is, one that never terminates. Be sure that the body of the loop does something that will eventually make the loop terminate.

6.6. Special branch statements: `break` and `continue`

Sometimes you need to exit a `for` or `while` loop without waiting for the normal termination. There are two special Python branch statements that do this:

- If you execute a `break` statement anywhere inside a `for` or `while` loop, control passes out of the loop and on to the statement after the end of the loop.
- A `continue` statement inside a `for` loop transfers control back to the top of the loop, and the variable is set to the next value from the sequence if there is one. (If the loop was already using the last value of the sequence, the effect of `continue` is the same as `break`.)

Here are examples of those statements.

```
>>> i = 0
>>> while  i < 100:
...     i  =  i + 3
...     if  ( i % 5 ) == 0:
...         break
...     print i,
...
3 6 9 12
```

In the example above, when the value of `i` reaches 15, which has a remainder of 0 when divided by 5, the `break` statement exits the loop.

```
>>> for  i in range(500, -1, -1):
...     if (i % 100) != 0:
...         continue
...     print i,
...
500 400 300 200 100 0
```

7. How to write a self-executing Python script

So far we have used Python's conversational mode to demonstrate all the features. Now it's time to learn how to write a complete program.

Your program will live in a file called a *script*. To create your script, use your favorite text editor (*emacs*, *vi*, *Notepad*, whatever), and just type your Python statements into it.

How you make it executable depends on your operating system.

- On Windows platforms, be sure to give your script file a name that ends in “`.py`”. If Python is installed, double-clicking on any script with this ending will use Python to run the script.
- Under Linux and MacOS X, the first line of your script must look like this:

  ```
  #!pythonpath
  ```

  The *`pythonpath`* tells the operating system where to find Python. This path will usually be “`/usr/local/bin/python`”, but you can use the “`which`” shell command to find the path on your computer:

```
bash-3.1$ which python
/usr/local/bin/python
```

Once you have created your script, you must also use this command to make it executable:

```
chmod +x your-script-name
```

Here is a complete script, set up for a typical Linux installation. This script, `powersof2`, prints a table showing the values of 2^n and 2^{-n} for n in the range 1, 2, ..., 12.

```
#!/usr/local/bin/python
print "Table of powers of two"
print
print "%10s %2s %-15s" % ("2**n", "n", "2**(-n)")
for n in range(13):
    print "%10d %2d %.15f" % (2**n, n, 2.0**(-n))
```

Here we see the invocation of this script under the `bash` shell, and the output:

```
bash-3.1$ ./powersof2
Table of powers of two

      2**n  n 2**(-n)
         1  0 1.000000000000000
         2  1 0.500000000000000
         4  2 0.250000000000000
         8  3 0.125000000000000
        16  4 0.062500000000000
        32  5 0.031250000000000
        64  6 0.015625000000000
       128  7 0.007812500000000
       256  8 0.003906250000000
       512  9 0.001953125000000
      1024 10 0.000976562500000
      2048 11 0.000488281250000
      4096 12 0.000244140625000
```

8. `def`: Defining functions

You can define your own functions in Python with the `def` statement.

- Python functions can act like mathematical functions such as `len(s)`, which computes the length of `s`. In this example, values like `s` that are passed to the function are called *parameters* to the function.
- However, more generally, a Python function is just a container for some Python statements that do some task. A function can take any number of parameters, even zero.

Here is the general form of a Python function definition. It consists of a `def` statement, followed by an indented block called the *body* of the function.

```
def name ( arg0, arg1, ... ):
    block
```

The parameters that a function expects are called *arguments* inside the body of the function.

Here's an example of a function that takes no arguments at all, and does nothing but print some text.

```
>>> def pirateNoises():
...     for arrCount in range(7):
...         print "Arr!",
...
>>>
```

To call this function:

```
>>> pirateNoises()
Arr! Arr! Arr! Arr! Arr! Arr! Arr!
>>>
```

To call a function in general, use an expression of this form:

```
name ( param0, param1, ... )
```

- The name of the function is followed by a left parenthesis "`(`", a list of zero or more *parameter* values separated by commas, then a right parenthesis "`)`".
- The parameter values are substituted for the corresponding arguments to the function. The value of parameter *`param`*$_0$ is substituted for argument *`arg`*$_0$; *`param`*$_1$ is substituted for *`arg`*$_1$; and so forth.

Here's a simple example showing argument substitution.

```
>>> def grocer(nFruits, fruitKind):
...     print "We have %d cases of %s today." % (nFruits, fruitKind)
...
>>> grocer ( 37, 'kale' )
We have 37 cases of kale today.
>>> grocer(0,"bananas")
We have 0 cases of bananas today.
>>>
```

8.1. `return`: Returning values from a function

So far we have seen some simple functions that take arguments or don't take arguments. How do we define functions like `len()` that return a value?

Anywhere in the body of your function, you can write a `return` statement that terminates execution of the function and returns to the statement where it was called.

Here is the general form of this statement:

```
return expression
```

The *`expression`* is evaluated, and its value is returned to the caller.

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

```
>>> def square(x):
...     return x**2
...
>>> square(9)
81
>>> square(2.5)
```

```
6.25
>>>
```

- You can omit the `expression`, and just use a statement of this form:

  ```
  return
  ```

  In this case, the special placeholder value `None` is returned.

- If Python executes your function body and never encounters a `return` statement, the effect is the same as a `return` with no value: the special value `None` is returned.

Here is another example of a function that returns a value. This function computes the factorial of a positive integer:

> The factorial of *n*, denoted *n*!, is defined as the product of all the integers from 1 to *n* inclusive.

For example, 4! = 1×2×3×4 = 24.

We can define the factorial function *recursively* like this:

- If *n* is 0 or 1, *n*! is 1.
- If *n* is greater than 1, *n*! = n × (n-1)!.

And here is a recursive Python function that computes the factorial, and a few examples of its use.

```
>>> def fact(n):
...     if n <= 1:
...         return 1
...     else:
...         return n * fact(n-1)
...
>>> for i in range(5):
...     print i, fact(i)
...
0 1
1 1
2 2
3 6
4 24
>>> fact(44)
2658271574788448768043625811014615890319638528000000000L
>>>
```

8.2. Function argument list features

The general form of a `def` shown in Section 8, "`def`: Defining functions" (p. 39) is over-simplified. In general, the argument list of a function is a sequence of four kinds of arguments:

1. If the argument is just a name, it is called a *positional* argument. There can be any number of positional arguments, including zero.
2. You can supply a default value for the argument by using the form "`name=value`". Such arguments are called *keyword* arguments. See Section 8.3, "Keyword arguments" (p. 42).

   A function can have any number of keyword arguments, including zero.

All keyword arguments must follow any positional arguments in the argument list.

3. Sometimes it is convenient to write a function that can accept any number of positional arguments. To do this, use an argument of this form:

   ```
   * name
   ```

   A function may have only one such argument, and it must follow any positional or keyword arguments. For more information about this feature, see Section 8.4, “Extra positional arguments” (p. 43).

4. Sometimes it is also convenient to write a function that can accept any number of keyword arguments, not just the specific keyword arguments. To do this, use an argument of this form:

   ```
   ** name
   ```

   If a function has an argument of this form, it must be the last item in the argument list. For more information about this feature, see Section 8.5, “Extra keyword arguments” (p. 44).

8.3. Keyword arguments

If you want to make some of the arguments to your function optional, you must supply a default value. In the argument list, this looks like “*name*=*value*”.

Here's an example of a function with one argument that has a default value. If you call it with no arguments, the name `mood` has the string value `'bleah'` inside the function. If you call it with an argument, the name `mood` has the value you supply.

```
>>> def report(mood='bleah'):
...     print "My mood today is", mood
...
>>> report()
My mood today is bleah
>>> report('hyper')
My mood today is hyper
>>>
```

If your function has multiple arguments, and the caller supplies multiple parameters, here is how they are matched up:

- The function call must supply at least as many parameters as the function has positional arguments.
- If the caller supplies more positional parameters than the function has positional arguments, parameters are matched with keyword arguments according to their position.

Here are some examples showing how this works.

```
>>> def f(a, b="green", c=3.5):
...     print a, b, c
...
>>> f()
Traceback (most recent call last):
  File "<stdin>", line 1, in ?
TypeError: f() takes at least 1 argument (0 given)
>>> f(47)
47 green 3.5
>>> f(47, 48)
47 48 3.5
```

```
>>> f(47, 48, 49)
47 48 49
>>> f(47, 48, 49, 50)
Traceback (most recent call last):
  File "<stdin>", line 1, in ?
TypeError: f() takes at most 3 arguments (4 given)
>>>
```

Here is another feature: the caller of a function can supply what are called *keyword parameters* of the form "`name=value`". If the function has an argument with a matching keyword, that argument will be set to `value`.

- If a function's caller supplies both positional and keyword parameters, all positional parameters must precede all keyword parameters.
- Keyword parameters may occur in any order.

Here are some examples of calling a function with keyword parameters.

```
>>> def g(p0, p1, k0="K-0", k1="K-1"):
...     print p0, p1, k0, k1
...
>>> g(33,44)
33 44 K-0 K-1
>>> g(33,44,"K-9","beep")
33 44 K-9 beep
>>> g(55,66,k1="whirr")
55 66 K-0 whirr
>>> g(7,8,k0="click",k1="clank")
7 8 click clank
>>>
```

8.4. Extra positional arguments

You can declare your function in such a way that it will accept any number of positional parameters. To do this, use an argument of the form "`*name`" in your argument list.

- If you use this special argument, it must follow all the positional and keyword arguments in the list.
- When the function is called, this name will be bound to a tuple containing any positional parameters that the caller supplied, over and above parameters that corresponded to other parameters.

Here is an example of such a function.

```
>>> def h(i, j=99, *extras):
...     print i, j, extras
...
>>> h(0)
0 99 ()
>>> h(1,2)
1 2 ()
>>> h(3,4,5,6,7,8,9)
3 4 (5, 6, 7, 8, 9)
>>>
```

8.5. Extra keyword arguments

You can declare your function in such a way that it can accept any number of keyword parameters, in addition to any keyword arguments you declare.

To do this, place an argument of the form "`**name`" last in your argument list.

When the function is called, that name is bound to a dictionary that contains any keyword-type parameters that are passed in that have names that don't match your function's keyword-type arguments. In that dictionary, the keys are the names used by the caller, and the values are the values that the caller passed.

Here's an example.

```
>>> def k(p0, p1, nickname='Noman', *extras, **extraKeys):
...     print p0, p1, nickname, extras, extraKeys
...
>>> k(1,2,3)
1 2 3 () {}
>>> k(4,5)
4 5 Noman () {}
>>> k(6, 7, hobby='sleeping', nickname='Sleepy', hatColor='green')
6 7 Sleepy () {'hatColor': 'green', 'hobby': 'sleeping'}
>>> k(33, 44, 55, 66, 77, hometown='McDonald', eyes='purple')
33 44 55 (66, 77) {'hometown': 'McDonald', 'eyes': 'purple'}
>>>
```

8.6. Documenting function interfaces

Python has a preferred way to document the purpose and usage of your functions. If the first line of a function body is a string constant, that string constant is saved along with the function as the *documentation string*. This string can be retrieved by using an expression of the form `f.__doc__`, where `f` is the function name.

Here's an example of a function with a documentation string.

```
>>> def pythag(a, b):
...     """Returns the hypotenuse of a right triangle with sides a and b.
...     """
...     return (a*a + b*b)**0.5
...
>>> pythag(3,4)
5.0
>>> pythag(1,1)
1.4142135623730951
>>> print pythag.__doc__
Returns the hypotenuse of a right triangle with sides a and b.

>>>
```

9. Input and output

Python makes it easy to read and write files. To work with a file, you must first open it using the built-in `open()` function. If you are going to read the file, use the form "`open(filename)`", which returns a *file object*. Once you have a file object, you can use a variety of methods to perform operations on the file.

9.1. Reading files

For example, for a file object `F`, the method `F.readline()` attempts to read and return the next line from that file. If there are no lines remaining, it returns an empty string.

Let's start with a small text file named `trees` containing just three lines:

```
yew
oak
alligator juniper
```

Suppose this file lives in your current directory. Here is how you might read it one line at a time:

```
>>> treeFile = open ( 'trees' )
>>> treeFile.readline()
'yew\n'
>>> treeFile.readline()
'oak\n'
>>> treeFile.readline()
'alligator juniper\n'
>>> treeFile.readline()
''
```

Note that the newline characters (`'\n'`) are included in the return value. You can use the string `.rstrip()` method to remove trailing newlines, but beware: it also removes any other trailing whitespace.

```
>>> 'alligator juniper\n'.rstrip()
'alligator juniper'
>>> 'eat all my trailing spaces         \n'.rstrip()
'eat all my trailing spaces'
```

Use the `.close()` method once you are done processing the file. Once you have closed a file, you can't perform any operations on it.

```
>>> treeFile.close()
>>> treeFile.readline()
Traceback (most recent call last):
  File "<stdin>", line 1, in ?
ValueError: I/O operation on closed file
```

To read all the lines in a file at once, use the `.readlines()` method. This returns a list whose elements are strings, one per line.

```
>>> treeFile=open("trees")
>>> treeFile.readlines()
['yew\n', 'oak\n', 'alligator juniper\n']
>>> treeFile.close()
```

A more general method for reading files is the `.read()` method. Used without any arguments, it reads the entire file and returns it to you as one string.

```
>>> treeFile = open ("trees")
>>> treeFile.read()
'yew\noak\nalligator juniper\n'
>>> treeFile.close()
```

To read exactly *N* characters from a file *F*, use the method `F.read(N)`. If *N* characters remain in the file, you will get them back as an *N*-character string. If fewer than *N* characters remain, you will get the remaining characters in the file (if any).

```
>>> treeFile = open ( "trees" )
>>> treeFile.read(1)
'y'
>>> treeFile.read(5)
'ew\noa'
>>> treeFile.read(50)
'k\nalligator juniper\n'
>>> treeFile.read(80)
''
>>> treeFile.close()
```

9.2. File positioning for random-access devices

For random-access devices such as disk files, there are methods that let you find your current position within a file, and move to a different position.

- *F*.tell() returns your current position in file *F*.
- `F.seek(N)` moves your current position to *N*, where a position of zero is the beginning of the file.
- `F.seek(N, 1)` moves your current position by a distance of *N* characters, where positive values of *N* move toward the end of the file and negative values move toward the beginning.

  For example, `F.seek(80, 1)` would move the file position 80 characters further from the start of the file.
- `F.seek(N, 2)` moves to a position *N* characters relative to the end of the file. For example, `F.seek(0, 2)` would move to the end of the file; `F.seek(-200, 2)` would move your position to 200 bytes before the end of the file.

```
>>> treeFile = open ( "trees" )
>>> treeFile.tell()
0L
>>> treeFile.read(6)
'yew\noa'
>>> treeFile.tell()
6L
>>> treeFile.seek(1)
>>> treeFile.tell()
1L
>>> treeFile.read(5)
'ew\noa'
>>> treeFile.tell()
6L
>>> treeFile.seek(1, 1)
>>> treeFile.tell()
7L
```

```
>>> treeFile.seek(-3, 1)
>>> treeFile.tell()
4L
>>> treeFile.seek(0, 2)
>>> treeFile.tell()
26L
>>> treeFile.seek(-3, 2)
>>> treeFile.tell()
23L
>>> treeFile.read()
'er\n'
>>> treeFile.close()
```

9.3. Writing files

To create a disk file, open the file using a statement of this general form:

```
F = open ( filename, "w" )
```

The second argument, `"w"`, specifies write access. If possible, Python will create a new, empty file by that name. If there is an existing file by that name, and if you have write permission to it, the existing file will be deleted.

To write some content to the file you are creating, use this method:

```
F.write(s)
```

where *s* is any string expression.

```
>>> sports = open ( "sportfile", "w" )
>>> sports.write ( "tennis\nrugby\nquoits\n" )
>>> sports.close()
>>> sportFile = open ( "sportfile" )
>>> sportFile.readline()
'tennis\n'
>>> sportFile.readline()
'rugby\n'
>>> sportFile.readline()
'quoits\n'
>>> sportFile.readline()
''
```

Warning

The data you have sent to a file with the `.write()` method may not actually appear in the disk file until you close it.

This is due to a mechanism called *buffering*. Python accumulates the data you have sent to the file, until a certain amount is present, and then it “flushes” that data to the physical file by writing it. Python also flushes the data to the file when you close it.

If you would like to make sure that the data you have written to the file is actually physically present in the file without closing it, call the `.flush()` method on the file object.

Here is a lengthy example demonstrating the action of the `.flush()` method.

```
>>> sporting = open('sports', 'w')
>>> sporting.write('golf\n')
>>> echo = open('sports')
>>> echo.read()
''
>>> echo.close()
>>> sporting.flush()
>>> echo = open('sports')
>>> echo.read()
'golf\n'
>>> echo.close()
>>> sporting.write('soccer')
>>> sporting.close()
>>> open('sports').read()
'golf\nsoccer'
```

Note that you must explicitly provide newline characters in the arguments to `.write()`.