

## Brief summary of basic Python syntax

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## Sources for more information and documentation

- H.P. Langtangen and G. K. Sandve: Illustrating Python via Bioinformatics Examples: PDF or HTML
- `pydoc anymodule`, `pydoc anymodule.anyfunc`
- Python Library Reference (go to *index* in the upper right corner)
- Python 2.7 Quick Reference
- Python Global Module Index
- Think Python (textbook)
- Dive Into Python (textbook)
- Think Like a Computer Scientist (textbook)
- A Gentle Introduction to Programming Using Python (MIT OpenCourseWare)
- Introduction to Computer Science and Programming (MIT OpenCourseWare m/videoer)
- Learning Python Programming Language Through Video Lectures
- Python Programming Tutorials Video Lecture Course (Learners TV)

## First Python encounter: a scientific hello world program

```
#!/usr/bin/env python
from math import sin
import sys

x = float(sys.argv[1])
print "Hello world, sin({0}) = {1}".format(x, sin(x))
```

## Running the script from the command line

Code in file `hw.py`.

Run with command:

```
> python hw.py 0.5
Hello world, sin(0.5) = 0.479426.
```

Linux alternative if file is executable (`chmod a+x hw.py`):

```
> ./hw.py 0.5
Hello world, sin(0.5) = 0.479426.
```

## Interactive Python & IPython

- Typing `python` gives you an interactive Python shell
- IPython is better, can also run scripts:  
In [1]: `run hw.py` 3.14159
- IPython is integrated with Python's `pdb` debugger
- `pdb` can be automatically invoked when an exception occurs
- IPython supports tab completion, additional help commands, and much more, ...

## Dissection of hw.py

On Unix: find out what kind of script language (interpreter) to use:

```
#!/usr/bin/env python
```

Access library functionality like the function `sin` and the list `sys.argv` (of command-line arguments):

```
from math import sin
import sys
```

Read 1st command line argument and convert it to a floating point object:

```
x = float(sys.argv[1])
```

Print out the result using a format string:

```
print "Hello world, sin({0}) = {1}".format(x, sin(x)) # v2.x
print("Hello world, sin({0}) = {1}".format(x, sin(x))) # v3.x
```

or with complete control of the formatting of floats (printf syntax):

```
print "Hello world, sin({x:g}) = {s:.3f}".format(x=x, s=sin(x)) #
print("Hello world, sin({x:g}) = {s:.3f}".format(x=x, s=sin(x))) #
```

## Python variables

Variables are not declared

**Variables hold references to objects**

```
a = 3          # ref to an int object containing 3
a = 3.0        # ref to a float object containing 3.0
a = '3.'        # ref to a string object containing '3.'
a = ['1', 2]    # ref to a list object containing
                # a string '1' and an integer 2
```

Test for a variable's type:

```
if isinstance(a, int): # int?
if isinstance(a, (list, tuple)): # list or tuple?
```

## Common types

- Numbers: int, float, complex
- Sequences: str (string), list, tuple, ndarray (NumPy array)
- Mappings: dict (dictionary/hash)
- User-defined type (via user-defined class)

## Simple Assignments

```
a = 10          # a is a variable referencing an
                # integer object of value 10

b = True        # b is a boolean variable

a = b           # a is now a boolean as well
                # (referencing the same object as b)

b = increment(4) # b is the value returned by a function

is_equal = a == b # is_equal is True if a == b
```

## Lists and tuples

```
mylist = ['a string', 2.5, 6, 'another string']
mytuple = ('a string', 2.5, 6, 'another string')
mylist[1] = -10
mylist.append('a third string')
mytuple[1] = -10 # illegal: cannot change a tuple
```

A tuple is a constant list (known as an *immutable* object)

## List functionality

Construction	Meaning
<code>a = []</code>	initialize an empty list
<code>a = [1, 4.4, 'run.py']</code>	initialize a list
<code>a.append(elem)</code>	add <i>elem</i> object to the end
<code>a + [1,3]</code>	add two lists
<code>a.insert(i, e)</code>	insert element <i>e</i> before index <i>i</i>
<code>a[3]</code>	index a list element
<code>a[-1]</code>	get last list element
<code>a[1:3]</code>	slice: copy data to sublist (here: inc
<code>del a[3]</code>	delete an element (index 3)
<code>a.remove(e)</code>	remove an element with value <i>e</i>
<code>a.index('run.py')</code>	find index corresponding to an elem
<code>'run.py' in a</code>	test if a value is contained in the lis
<code>a.count(v)</code>	count how many elements that have
<code>len(a)</code>	number of elements in list <i>a</i>
<code>min(a)</code>	the smallest element in <i>a</i>
<code>max(a)</code>	the largest element in <i>a</i>
<code>sum(a)</code>	add all elements in <i>a</i>

## Dictionary functionality

Construction	Meaning
<code>a = {}</code>	initialize an empty dictionary
<code>a = {'point': [0,0.1], 'value': 7}</code>	initialize a dictionary
<code>a = dict(point=[2,7], value=3)</code>	initialize a dictionary
<code>a.update(b)</code>	add key-value pairs from b
<code>a.update(key1=value1, key2=value2)</code>	add key-value pairs
<code>a['hide'] = True</code>	add new key-value pair
<code>a['point']</code>	get value corresponding to key
<code>for key in a:</code>	loop over keys in unknown order
<code>for key in sorted(a):</code>	loop over keys in alphabetical order
<code>'value' in a</code>	True if string value is a key
<code>del a['point']</code>	delete a key-value pair
<code>list(a.keys())</code>	list of keys
<code>list(a.values())</code>	list of values
<code>len(a)</code>	number of key-value pairs
<code>isinstance(a, dict)</code>	is True if a is a dictionary

## String operations

```
s = 'Berlin: 18.4 C at 4 pm'
s[8:17] # extract substring
s.find(':') # index where first ':' is found
s.split(':') # split into substrings
s.split() # split wrt whitespace
'Berlin' in s # test if substring is in s
s.replace('18.4', '20')
s.lower() # lower case letters only
s.upper() # upper case letters only
s.split()[4].isdigit()
s.strip() # remove leading/trailing blanks
', '.join(list_of_words)
```

## Strings in Python use single or double quotes, or triple single/double quotes

Single- and double-quoted strings work in the same way:  
 'some string' is equivalent to "some string"  
 Triple-quoted strings can be multi line with embedded newlines:

```
text = """large portions of a text
can be conveniently placed inside
triple-quoted strings (newlines
are preserved)"""
```

Raw strings, where backslash is backslash:

```
s3 = r'\\(\\s+\\.\\d+\\)'
# in an ordinary string one must quote backslash:
s3 = '\\(\\s+\\.\\d+\\)'
```

## Simple control structures

Loops:

```
while condition:
    <block of statements>
```

Here, condition must be a boolean expression (or have a boolean interpretation), for example: `i < 10` or `!found`

```
for element in somelist:
    <block of statements>
```

Conditionals/branching:

```
if condition:
    <block of statements>
elif condition:
    <block of statements>
else:
    <block of statements>
```

## Looping over integer indices is done with range

```
for i in range(10):
    print(i)
```

Remark:

range in Python 3.x is equal to xrange in Python 2.x and generates an iterator over integers, while range in Python 2.x returns a list of integers.

## Functions and arguments

User-defined functions:

```
def split(string, char):
    position = string.find(char)
    if position > 0:
        return string[:position+1], string[position+1:]
    else:
        return string, ''

# function call:
message = 'Heisann'
print(split(message, 'i'))
# prints ('Hei', 'sann')
```

Positional arguments must appear before keyword arguments:

```
def split(message, char='i'):
    # ...
```

## eval and exec turn strings into live code

Evaluating string expressions with eval:

```
>>> x = 20
>>> r = eval('x + 1.1')
>>> r
21.1
>>> type(r)
<type 'float'>
```

Executing strings with Python code, using exec:

```
import sys
user_expression = sys.argv[1]

# Wrap user_expression in a Python function
# (assuming the expression involves x)

exec("""
def f(x):
    return %s
""" % user_expression)

# or

f = eval('lambda x: %s' % user_expression)
```

## File reading

Reading a file:

```
infile = open(filename, 'r')
for line in infile:
    # process line

lines = infile.readlines()
for line in lines:
    # process line

for i in xrange(len(lines)):
    # process lines[i] and perhaps next line lines[i+1]

fstr = infile.read() # fstr contains the entire file
fstr = fstr.replace('some string', 'another string')
for piece in fstr.split(';'):
    # process piece (separated by ;)

infile.close()
```

## File writing

```
outfile = open(filename, 'w') # new file or overwrite
outfile = open(filename, 'a') # append to existing file

outfile.write("Some string")
...
outfile.writelines(list_of_lines)

outfile.close()
```

## Using modules

Import module:

```
import sys
x = float(sys.argv[1])
```

Import module member argv into current namespace:

```
from sys import argv
x = float(argv[1])
```

Import everything from sys (not recommended)

```
from sys import *
x = float(argv[1])

flags = ''
# Oops, flags was also imported from sys, this new flags
# name overwrites sys.flags!
```

Import argv under an alias:

```
from sys import argv as a
x = float(a[1])
```

## Making your own Python modules

- Reuse scripts by wrapping them in classes or functions
- Collect classes and functions in library modules
- How? just put classes and functions in a file MyMod.py
- Put MyMod.py in one of the directories where Python can find it (see next slide)

Examples:

```
import MyMod
# or
import MyMod as M # M is a short form
# or
from MyMod import *
# or
from MyMod import myspecialfunction, myotherspecialfunction
```

## How Python can find your modules?

Python has some "official" module directories, typically

```
/usr/lib/python2.7
/usr/lib/python2.7/site-packages
/usr/lib/python3.4
/usr/lib/python3.4/site-packages
```

+ current working directory

The environment variable PYTHONPATH may contain additional directories with modules

```
> echo $PYTHONPATH
/home/me/python/mymodules:/usr/lib/python3.4:/home/you/yourlibs
```

Python's sys.path list contains the directories where Python searches for modules, and sys.path contains "official" directories, plus those in PYTHONPATH

## Packages

- A class of modules can be collected in a *package*
- Normally, a package is organized as module files in a directory tree
- Each subdirectory has a file `__init__.py` (can be empty)

Can import modules in the tree like this:

```
from MyMod.numerics.pde.grids import fdm_grids

grid = fdm_grids()
grid.domain(xmin=0, xmax=1, ymin=0, ymax=1)
...
```

Here, class `fdm_grids` is in module `grids` (file `grids.py` in the directory `MyMod/numerics/pde`)

## Test block in a module

Module files can have a test/demo section at the end:

```
if __name__ == '__main__':
    infile = sys.argv[1]; outfile = sys.argv[2]
    for i in sys.argv[3:]:
        create(infile, outfile, i)
```

- The block is executed *only* if the module file is run as a program
- The tests at the end of a module often serve as good examples on the usage of the module

## Installing modules

- Python has its own tool, Distutils, for distributing and installing modules
- Installation is based on the script `setup.py`

Standard command:

```
> sudo python setup.py install
```

## Writing your own setup.py script

Suppose you have a module in `mymod.py` that you want to distribute to others such that they can easily install it by `setup.py install`.

```
from distutils.core import setup
name='mymod'

setup(name=name,
      version='0.1',
      py_modules=[name], # modules to be installed
      scripts=[name+'.py'], # executable programs to be installed
)
```

Now, `setup.py` will be installed both as a module and as an executable script (if it has a test block for sensible code). Can easily be extended to install a package of modules, see the introduction to Distutils

## Use doc strings in functions, classes, and modules!

Doc strings = first string in a function, class, or file (module)

```
def ignorecase_sort(a, b):
    """Compare strings a and b, ignoring case."""
    return cmp(a.lower(), b.lower())
```

Doc strings in modules are a (often long multi-line) string starting in the top of the file

```
"""
This module is a fake module
for exemplifying multi-line
doc strings.
"""
import sys
import collections

def somefunc():
    ...
```

## Doc strings serve many purposes

- documentation in the source code
- online documentation (Sphinx can automatically produce manuals with doc strings)
- balloon help in sophisticated GUIs (e.g., IDLE)
- automatic testing with the `doctest` module