(Python) Fundamentals

by
__Mani

overview

9:00 - 9:45	Programming basics
10:00 - 11:45	Python basics
12:00-12:45	Advanced Python
12:45-13:00	QA

... please ask questions!

Why Python?

- Why not Java, VBA, Perl, Ruby, C#, …?

Simple Task

- Read a text file and print out non-comment lines

test.csv

```
#comment
Bank,Account,Amount
BAML,12345,$1000
"Citi Bank",54321,S$500
```

```
Pseudocode:
open file test.csv
    for each line in file
        if line does not start with '#'
            print line
```

Java

```
import java.io.BufferedReader;
import java.io.FileReader;

public class CsvFile {
    public static void main(String[] args) {
        String line = null;
        try{
            BufferedReader br = new BufferedReader(new FileReader("test.csv"));
            try {
                while ((line=br.readLine()) != null) {
                    if (! line.trim().startsWith("#")) {
                        System.out.println(line);
                    }
                }
            } finally {
                br.close();
            }
        } catch (Exception e) {
            System.out.println(e);
        }
    }
}
```

Perl & Ruby

- Perl

```
use strict;
use warnings;


open(my $data, 'test.csv') or
   die "Error reading test.csv
   $!\n";
while (my $line = <$data>) {
   if ($line !~ /^#/) {
    print $line;
   }
}
```

- Ruby

```
File.open("test.csv", "r") do
   |infile|
    while (line = infile.gets)
        if !
   line.start_with?('#')
            puts "#{line}"
        end
    end
end
```

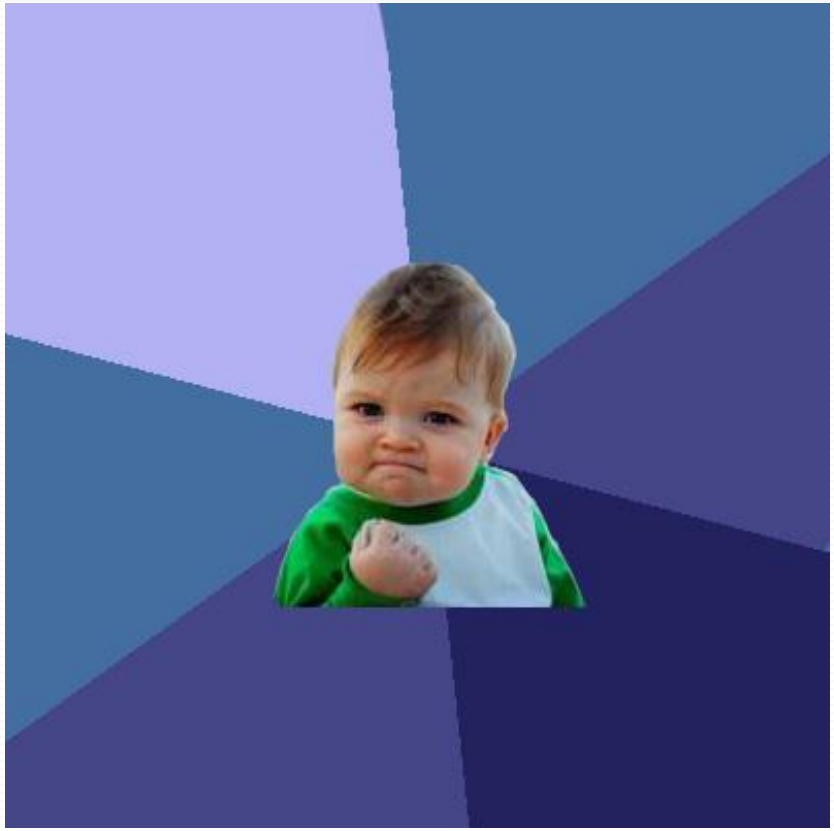
Python

- Python

```
with open('test.csv', 'r') as f:
    for l in f:
        if not l.startswith('#'):
            print l
```

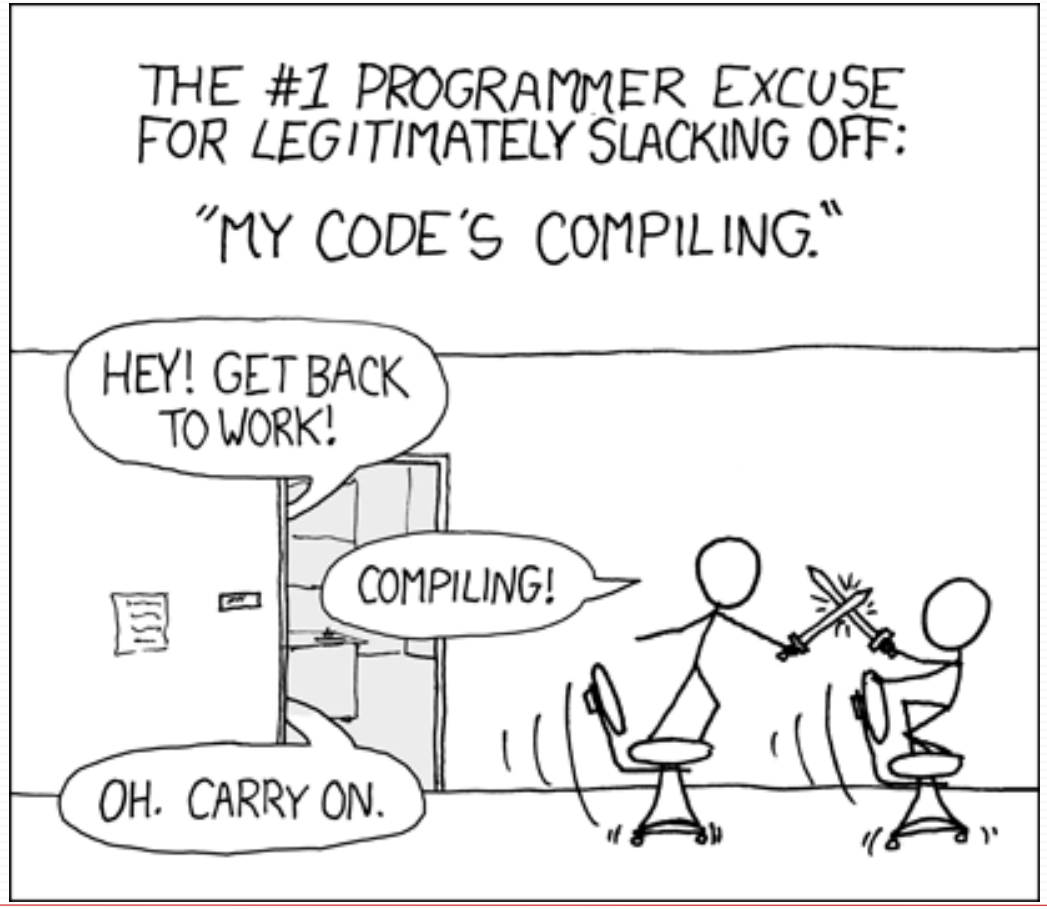
Pseudocode:

```
open file test.csv
    for each line in file
        if line does not start with '#'
            print line
```



Python, is that all you got?

- No compilation needed, no build monitor



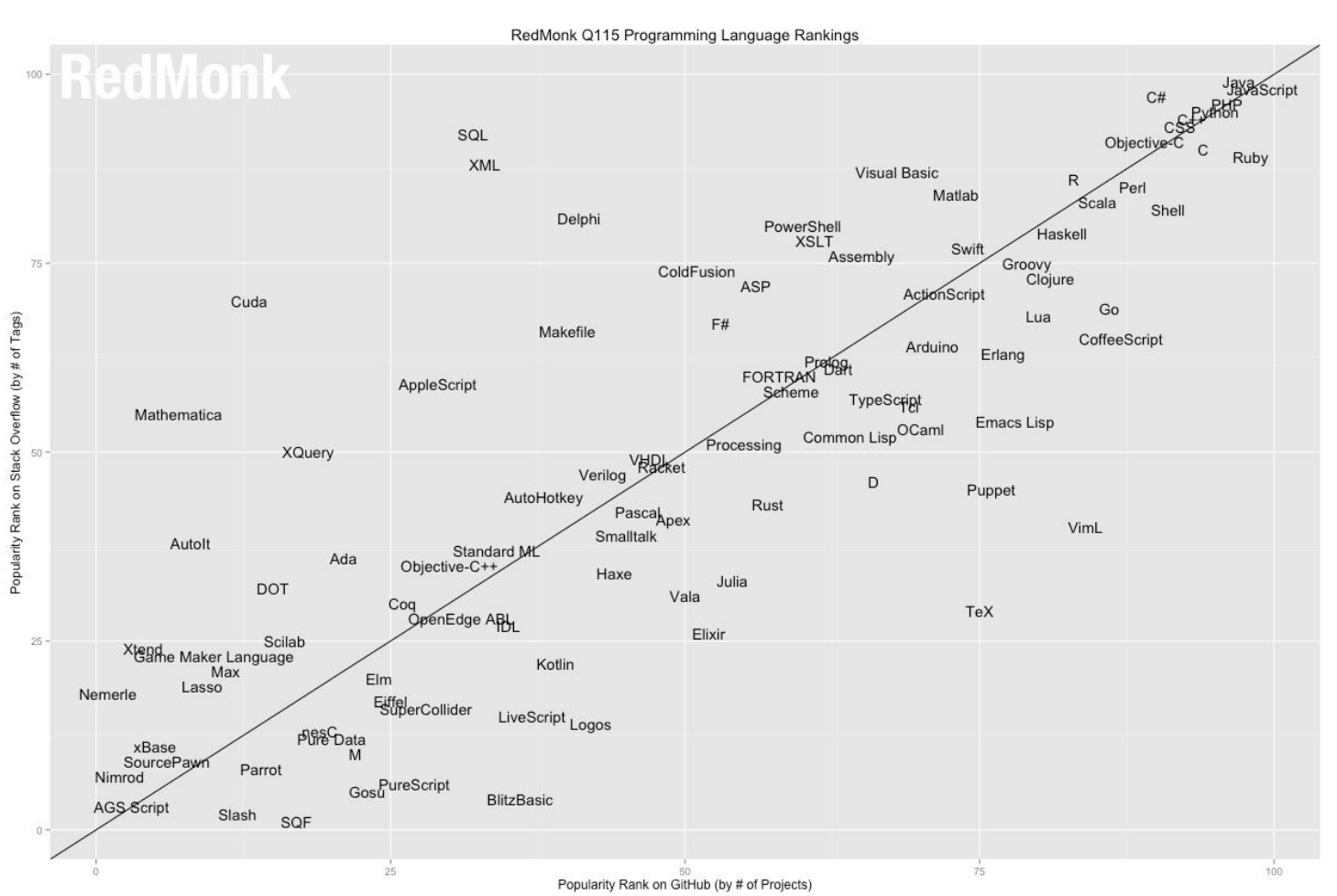
Python, is that all you got?

- Duck type

Don't check whether something IS a duck. Check whether it **QUACKS like a duck** and **WALKS like a duck**

-- Alex Martelli

Python Popularity



(Python) Fundamentals

simple data types

Values of different type allow different operations

```
12 + 3          => 15
"12" + "3"      => "123"
"12"*3          => "121212"
```

```
12 - 3          => 9
"12" - "3"      => ERROR!
```

- bool: Boolean, e.g. True, False
- int: Integer, e.g. 12, 23345
- float: Floating point number, e.g. 3.1415, 1.1e-5
- string: Character string, e.g. "This is a string"
- ...

structured types

structured data types are composed of other simple or structured types

- string: 'abc'
- list of integers: [1,2,3]
- list of strings: ['abc', 'def']
- list of lists of integers: [[1,2,3],[4,5,6]]
- ...

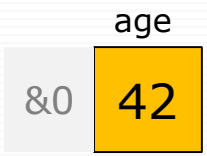
there are much more advanced data structures...

data structures are models of the objects you want to work with

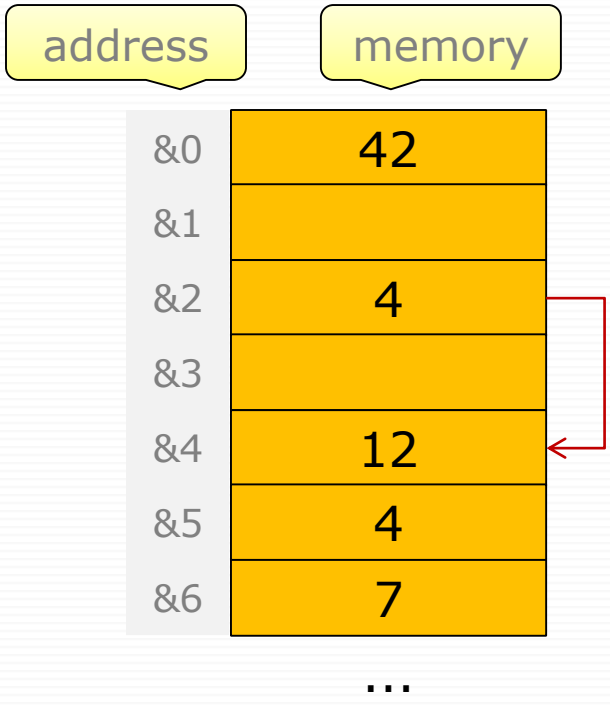
variables and references

- container for a value, name of a memory cell
- primitive values: numbers, booleans, ...
- reference values: address of a data structure, eg. a list, string, ...

```
age = 42
```




```
ages = [12,4,7]
```

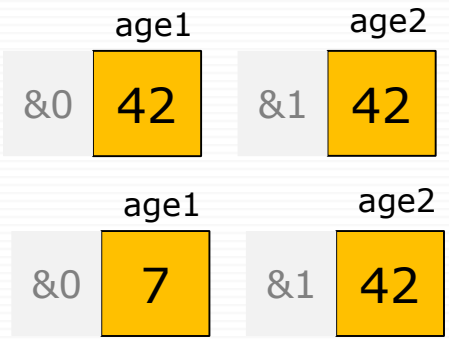


variables and references 2

```
age1 = 42
age2 = age1
```

```
age1 = 7
```

=> age2 is 42

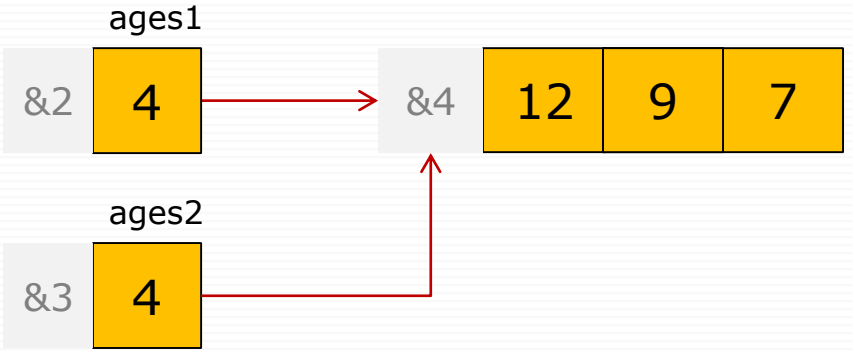



```
try:
id(age1)
id(age2)
```

```
ages1 = [12,4,7]
ages2 = ages1
```

```
ages1[1] = 9
```

=> ages2[1] is 9 !



data structures 1

- organizing data depending on task and usage pattern

- List (Array)
  - collection of (many) things
  - constant access time
  - linear search time
  - changeable (=mutable)

```
colors = ['red', 'red', 'blue']
colors[1]                    => 'red'
'blue' in colors             => True
colors[1] = “pink”
```

- Tuple
  - collection of (a few) things
  - constant access time
  - linear search time
  - not changeable (=immutable)
    => can be used as hash key

```
address = (3, 'Queen Street')
address[0]                   => 3
3 in address                 => True
address[0] = 4
```

data structures 2

- Set
  - collection of unique things
  - no random access
  - constant search time
  - no guaranteed order of values

```
even = set([2,4,6,8])
even[1]
6 in even                => True
for e in even: print e
```

- Dictionary (Hash)
  - maps keys to values
  - constant access time via key
  - constant search time for key
  - linear search time for value
  - no guaranteed order

```
tel = {'Stef':62606, 'Mel':62663}
tel['Mel']               => 62663
'Stef' in tel            => True
62663 in tel.values()    => True
for name in tel: print name
```

data structures - tips

when to use what?

- List
  - many similar items to store
    e.g, numbers, protein ids, sequences, ...
  - no need to find a specific item fast
  - fast access to items at a specific position in the list
- Tuple
  - a few (<10), different items to store
    e.g. addresses, protein id and its sequence, ...
  - want to use it as dictionary key
- Set
  - many, unique items to store
    e.g. unique protein ids
  - need to know quickly if a specific item is in the set
- Dictionary
  - map from keys to values, is a look-up table
    e.g. telephone dictionary, amino acid letters to hydrophobicity values
  - need to get quickly the value for a key

1,2,3... action

how to do something

- statement
  - executes some function or operation, e.g.

```
print 1+2
```

- condition
  - describes when something is done, e.g.

```
if number > 3:
  print "greater than 3"
```

- iteration
  - describes how to repeat something, e.g.

```
for number in [1,2,3]:
  print number
```

condition

```
if condition :
    do_something
```

```
if condition :
    do_something
else:
    do_something_else
```

```
if condition :
    do_something
elif condition2 :
    do_something_else1
else:
    do_something_else2
```

```
if x < 10:
    print "in range"
```

```
if x < 5:
    print "lower range"
else:
    print "out of range"
```

```
if x < 5:
    print "lower range"
elif x < 10:
    print "upper range"
else:
    print "out of range"
```

iteration

```
for variable in sequence :
    do_something
```

```
while condition :
    statement1
    statement2
    …
```

```
for color in ["red","green","blue"]:
    print color
```

```
i = 0
while i < 10 :
    print i
    i += 1
```

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

```
for char in "some text":
    print char
```

functions

- break complex problems in manageable pieces
- encapsulate/generalize common functionalities

```
def function(p1,p2,...):
    do_something
    return ...
```

```
def add(a,b):
    return a+b
```

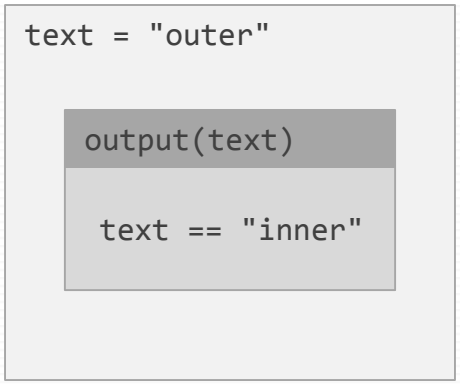
```
def divider():
    print "--------"
```

```
def divider(ch,n):
    print ch*n
```

```
def output(text):
    print text

text = "outer"
print text
output("inner")
print text
```

Scope of a variable



complete example

```
def count_gc(sequence):
    """Counts the nitrogenous bases of the given sequence.
    Ambiguous bases are counted fractionally.
    Sequence must be in upper case"""
    gc = 0
    for base in sequence:
        if   base in 'GC':     gc += 1.0
        elif base in 'YRWSKM': gc += 0.5
        elif base in 'DH':     gc += 0.33
        elif base in 'VB':     gc += 0.66
    return gc

def gc_content(sequence):
    """Calculates the GC content of a DNA sequence.
       Mixed case, gaps and ambiguity codes are permitted"""
    sequence = sequence.upper().remove('-')
    if not sequence:
        return 0
    return 100.0 * count_gc(sequence) / len(sequence)

print gc_content("actacgattagag")
```

tips

1. no tabs, use 4 spaces for indentation
2. lines should not be longer than 80 characters
3. break complex code into small functions
4. do not duplicate code, create functions instead

questions

Python Basics

let’s play

- load fasta sequences
- print name, length, first 10 symbols
- min, max, mean length
- find shortest
- plot lengths histogram
- calc GC content
- write GCs to file
- plot GC histogram
- calc correlation coefficient
- scatter plot
- scatter plot over many

survival kit

IDLE:

Python doc: F1

Auto completion: CTRL+SPACE/TAB

Call tips: CTRL+BACKSLASH

History previous: ALT+p

History next: ALT+n

http://www.quuux.com/stefan/slides.html
http://www.python.org
http://www.java2s.com/Code/Python/CatalogPython.htm
http://biopython.org
http://matplotlib.sourceforge.net/
http://www.scipy.org/Cookbook/Matplotlib
http://cheeseshop.python.org
http://www.scipy.org/Cookbook

help(...), dir(...), google

Indentation has meaning!

Always 4 spaces, never tabs!

def/if/for/while … :

#! /usr/bin/env python

$ chmod +x myscript.py

data types

```
# simple types
string  : "string"
integer : 42
long    : 4200000L
float   : 3.145
hex     : 0xFF
boolean : True
complex =:1+2j
```

```
# structured types
list = [1,2,'a']
tuple = (1,2,'a')
dict = {"pi":3.14, "e":2.17}
set([1,2,'a'])
frozenset([1,2,'a'])
func = lambda x,y: x+y
```

```
dir(3.14)
dir(float)
help(float)
help(float.__add__)
help(string)
```

all data types are objects

tuples

```
(1,2,3)
('red','green','blue')
('red',)
(1,) != (1)
()          # empty tuple


(1,2,3,4)[0]     # -> 1
(1,2,3,4)[2]     # -> 3
(1,2,3,4)[1:3]   # -> (2,3)

(a,b,c) = (1,2,3)
(a,b,c) =  1,2,3
 a,b,c  = (1,2,3)
 a,b,c  = [1,2,3]

 a,b = b,a  # swap
```

tuples are not just round brackets

tuples are immutable

```
help(())
dir(())
```

```
for i,c in [(1,'I'), (2,'II), (3,'III')]:
    print i,c

# vector addition
def add(v1, v2):
    x,y = v1[0]+v2[0], v1[1]+v2[1]
    return (x,y)
```

lists

```
[] == list()
nums = [1,2,3,4]
nums[0]
nums[:]
nums[0:2]
nums[::2]
nums[1::2]
nums[1::2] = 0
nums.append(5)
nums + [5,6]

range(5)
sum(nums)
max(nums)

[0]*5
```

lists are mutable*

lists are arrays

*since lists are mutable you cannot use them as a dictionary keys!

```
dir([]), dir(list)
help([])
help([].sort)
```

```
nums.reverse()          # in place
nums2 = reversed(nums)  # new list

nums.sort()             # in place
nums2 = sorted(nums)    # new list
```

lists examples

```
l = [('a',3), ('b',2), ('c',1)]
l.sort(key = lambda x: x[1])
l.sort(key = lambda (c,n): n)
l.sort(cmp = lambda x,y: x[1]-y[1])
l.sort(cmp = lambda (c1,n1),(c2,n2): n1-n2)
```

```
colors = ['red','green','blue']
colstr = ''
for color in colors:
    colstr = colstr+','+color

colstr = ",".join(colors)
```

```
l1 = ['a','b','c']
l2 = [1,2,3]
l3 = zip(l1,l2)
zip(*l3)

mat = [(1,2,3),
       (4,5,6)]
flip = zip(*mat)
flipback = zip(*flip)
```

slicing

```
s = "another string"

s[0:len(s)]
s[:]
s[2:7]
s[-1]
s[:-1]
s[-6:]
s[:-6]
s[::2]
s[::-1]
```

```
from numpy import array
mat = array([[1,2,3],
             [4,5,6]])

mat[1][1]
mat[:,:]
mat[1:3, 0:2]
mat[1:3, ...]
```

```
slice[start:end:stride]

start  inclusive
end    exclusive
stride optional
```

slicing works the same for lists and tuples (<= sequences)

sets

```
set([3,2,2,3,4])
frozenset([3,2,2,3,4])

s = "my little string"
set(s)

s.remove('t')
s.pop()

s1 = set([1,2,3,4])
s2 = set([3,4,5])
s1.union(s2)
s1.difference(s2)
s1 - s2
s1 or s2
s1 and s2
```

sets are mutable

frozensets are immutable

```
dir(set())
help(set)
help(set.add)
help(frozenset)

s = set([2,3,3,34,51,1])
max(s)
min(s)
sum(s)
```

dictionaries

```
d = {}
d = dict()
d = {'pi':3.14, 'e':2.7}
d = dict(pi=3.14, e=2.7)
d = dict([('pi',3.14),('e',2.7)])
```

directories are hashes

only immutables are allowed as keys

```
d['pi']
d['pi'] = 3.0
d['zero'] = 0.0
d[math.pi] = "pi"
d[(1,2)] = "one and two"
```

```
dir({})
help({})
help(dict)
help(dict.values)
help(dict.keys)
```

```
d.get('two', 2)
d.setdefault('one', 1)
d.has_key('one')
'one' in d
```

```
mat = [[0,1], [1,3], [2,0]]
sparse = dict([((i,j),e)
          for i,r in enumerate(mat)
          for j,e in enumerate(r) if e])
```

data structures - tips

when to use what?

- List
  - many similar items to store
    e.g, numbers, protein ids, sequences, ...
  - no need to find a specific item fast
  - fast access to items at a specific position in the list
- Tuple
  - a few (<10), different items to store
    e.g. addresses, protein id and its sequence, ...
  - want to use it as dictionary key
- Set
  - many, unique items to store
    e.g. unique protein ids
  - need to know quickly if a specific item is in the set
- Dictionary
  - map from keys to values, is a look-up table
    e.g. telephone dictionary, amino acid letters to hydrophobicity values
  - need to get quickly the value for a key

boolean logic

False: False, 0, None, [], (,)

True: everything else, e.g.: 1, True, ['blah'], ...

```
A = 1
B = 2

A and B
A or B
not A

1 in [1,2,3]
"b" in "abc"

all([1,1,1])
any([0,1,0])
```

```
l1 = [1,2,3]
l2 = [4,5]

if not l1:
    print "list is empty or None"

if l1 and l2:
    print "both lists are filled"
```

comparisons

```
(1, 2, 3) < (1, 2, 4)
[1, 2, 3] < [1, 2, 4]
'C' < 'Pascal' < 'Perl' <'Python'
(1, 2, 3, 4) < (1, 2, 4)
(1, 2) < (1, 2, -1)
(1, 2, 3) == (1.0, 2.0, 3.0)
(1, 2, ('aa', 'ab')) < (1, 2, ('abc', 'a'), 4)
```

comparison of complex objects

chained comparisons

```
s1 = "string1"
s2 = "string2"
s1 = s3

s1 == s2     # same content
s1 is s3     # same reference
```

Java people watch out!

if

```
if 1 < x < 10:
    print "in range"
```

indentation has meaning
there is no switch() statement

```
if 1 < x < 5:
    print "lower range"
elif 5 < x < 10:
    print "upper range"
else:
    print "out of range"
```

```
if condition :
    do_something
elif condition2 :
    do_something_else1
else:
    do_something_else2
```

```
# conditional expression
frac = 1/x if x>0 else 0
```

```
# one-line if
if condition : statement
```

```
result = statement if condition else alternative
```

for

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

for i in xrange(10,0,-1):
    print i

for ch in "mystring":
    print ch

for e in ["red","green","blue"]:
    print e

for line in open("myfile.txt"):
    print line
```

```
for variable in sequence :
    statement1
    statement2
    …
```

```
help(range)
help(xrange)
```

more for

```
for i in xrange(10):
    if 2<i<5 :
        continue
    print i
```

```
for ch in "this is a string":
    if ch == ' ':
        break
    print ch
```

```
i = 0
for ch in "mystring":
    print i,ch
    i = i + 1
```

```
nums = [1,2,3,4,5]
for i in nums:
    if i==3: del nums[3]
    print i
```

Don't modify list while iterating over it!

```
for i,ch in enumerate("mystring"):
    print i,ch
```

```
for i,line in enumerate(open("myfile.txt")):
    print i,line
```

while

```
i = 0
while i < 10 :
    print i
    i += 1
```

```
while condition :
    statement1
    statement2
    …
```

```
i = 0
while 1 :
    print i
    i += 1
    if i >= 10:
        break
```

```
i = 0
while 1 :
    i += 1
    if i < 5:
        continue
    print i
```

strings

```
"quotes"
'apostrophes'
'You can "mix" them'
'or you \'escape\' them'
"a tab \t and a newline \n"
```

```
"""Text over
multiple lines"""
```

```
'''Or like this,
if you like.'''
```

strings are immutable

```
r"(a-z)+\.doc"
```

```
# äöü
u"\xe4\xf6\xfc"
```

```
"a"+" "+"string"
```

```
"repeat "*3
```

if you code in C/C++/Java/... as well, I suggest apostrophes for characters and quotes for strings, e.g: 'c' and "string"

string formatting

```
print "new line"
print "same line",


"height=",12," meters"
"height="+str(12)+" meters"
"height=%d meters" % 12
"%s=%.3f meters or %d cm" % ("height", 1.0, 100)


# template strings
dic = {"prop1":"height", "len":100, "color":"green"}
"%(prop1)s = %(len)d cm" % dic
"The color is %(color)s" % dic
```

format codes (%d, %s, %f, …) similar to C/C++/Java

string methods

```
s = " my little string "

len(s)
s.find("string")
s.count("t")
s.strip()
s.replace("my", "your")

s[4]
s[4:10]

":".join(["red","green","blue"])

str(3.14); float("3.14"); int("3")
```

```
dir("")
dir(str)
help("".count)
help(str)
```

references

```
v1 = 10
v2 = v1         -> v2 = 10   # content copied
v1 = 50         -> v2 = 10   # as expected


l1 = [10]
l2 = l1         -> l2 = [10] # address copied
l1[0] = 50      -> l2 = [50] # oops


l1 = [10]
l2 = l1[:]      -> l2 = [10] # content copied
l1[0] = 50      -> l2 = [10] # that's okay now
```

```
import copy
help(copy.copy)
help(copy.deepcopy)
```

same for sets (and dictionaries) but not for tuples, strings or frozensets (<- immutable)

list comprehension

```
[expression for variable in sequence if condition]
```

condition is optional

```
[x*x for x in xrange(10)]                # square

[x for x in xrange(10) if not x%2]       # even numbers

[(b,a) for a,b in [(1,2), (3,4)]]        # swap

s = "mary has a little lamb"
[ord(c) for c in s]
[i for i,c in enumerate(s) if c==' ']

# what's this doing?
[p for p in xrange(100) if not [x for x in xrange(2,p) if not p%x]]
```

generators

```
(expression for variable in sequence if condition)
```

```
(x*x for x in xrange(10))
```

```
for n in (x*x for x in xrange(10)):
    print n
```

```
sum(x*x for x in xrange(10))
```

```
"-".join(c for c in "try this")
```

```
def xrange1(n):
    return (x+1 for x in xrange(n))
```

```
def my_xrange(n):
    i = 0
    while i<n :
        i += 1
        yield i
```

```
def my_range(n):
    l = []
    i = 0
    while i<n :
        i += 1
        l.append(i)
    return l
```

functions

```
def add(a, b):
    return a+b


def inc(a, b=1):
    return a+b
```

```
help(add)
```

```
def add(a, b):
    """adds a and b"""
    return a+b

def list_add(l):
    return sum(l)

def list_add(l1, l2):
    return [a+b for a,b in zip(l1,l2)]
```

```
def function(p1,p2,...):
    """ doc string """
    ...
    return ...
```

```
# duck typing
add(1,2)
add("my", "string")
add([1, 2], [3, 4])
```

functions - args

```
def function(p1,p2,...,*args,*kwargs):
    return ...
```

```
def add(*args):
    """example: add(1,2,3)"""
    return sum(args)
```

```
def scaled_add(c, *args):
    """example: scaled_add(2, 1,2,3)"""
    return c*sum(args)
```

```
def super_add(*args, **kwargs):
    """example: super_add(1,2,3, scale=2)"""
    scale  = kwargs.get('scale', 1)
    offset = kwargs.get('offset', 0)
    return offset + scale * sum(args)
```

variable arguments are lists or dictionaries

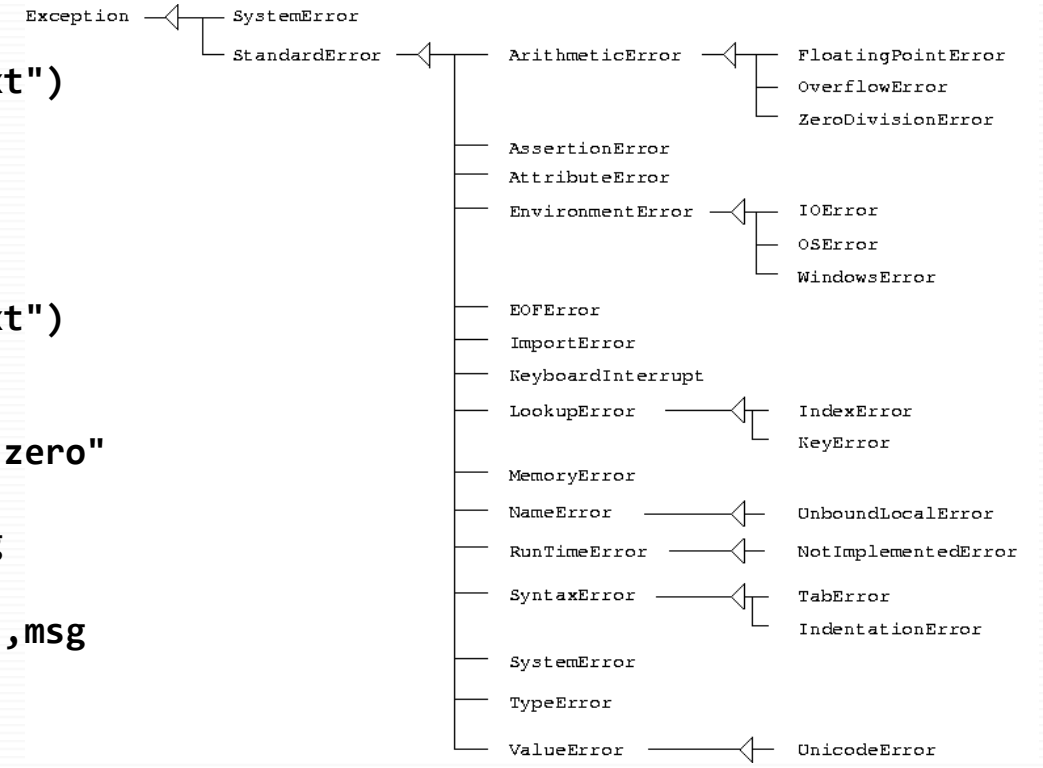
```
def showme(*args):
    print args
```

```
def showmemore(**kwargs):
    print kwargs
```

Exceptions - handle

```
try:
     f = open("c:/somefile.txt")
except:
     print "cannot open file"


try:
     f = open("c:/somefile.txt")
     x = 1/y
except ZeroDivisionError:
     print "cannot divide by zero"
except IOError, msg:
     print "file error: ",msg
except Exception, msg:
     print "ouch, surprise: ",msg
else:
     x = x+1
finally:
     f.close()
```



Exceptions - raise

```
try:
    # do something and raise an exception
    raise IOError, "Something went wrong"
except IOError, error_text:
     print error_text
```

doctest

```
def add(a, b):
    """Adds two numbers or lists
    >>> add(1,2)
    3
    >>> add([1,2], [3,4])
    [1, 2, 3, 4]
    """
    return a+b


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

unittest

```
import unittest

def add(a,b): return a+b
def mult(a,b): return a*b

class TestCalculator(unittest.TestCase):
    def test_add(self):
        self.assertEqual( 4, add(1,3))
        self.assertEqual( 0, add(0,0))
        self.assertEqual(-3, add(-1,-2))
    def test_mult(self):
        self.assertEqual( 3, mult(1,3))
        self.assertEqual( 0, mult(0,3))


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

import

```
import math
math.sin(3.14)

from math import sin
sin(3.14)
math.cos(3.14)

from math import sin, cos
sin(3.14)
cos(3.14)

from math import *    # careful!
sin(3.14)
cos(3.14)

import math as m
m.sin(3.14)
m.cos(m.pi)
```

```
import module
import module as m
from module import f1, f2
from module import *
```

```
import math
help(math)
dir(math)
help(math.sin)
```

import example

```
# module calculator.py

def add(a,b):
    return a+b

if __name__ == "__main__":
    print add(1,2)    # test
```

```
# module do_calcs.py

import calculator

def main():
    print calculator.add(3,4)

if __name__ == "__main__":
    main()
```

package example

```
calcpack/__init__.py
calcpack/calculator.py
calcpack/do_calcs.py
```

```
# in a different package

from calcpack.calculator import add
x = add(1,2)

from calcpack.do_calcs import main
main()
```

template

```
""" This module implements
some calculator functions
"""

def add(a,b):
    """Adds two numbers
    a -- first number
    b -- second number
    returns the sum """
    return a+b

def main():
    """Main method. Adds 1 and 2"""
    print add(1,2)

if __name__ == "__main__":
    main()
```

regular expressions

```
import re

text = "date is 24/07/2008"
re.findall(r'(..)/(..)/(....)', text)
re.split(r'[\s/]', text)
re.match(r'date is (.*)', text).group(1)
re.sub(r'(../)(../)', r'\2\1', text)


# compile pattern if used multiple times
pattern = compile(r'(..)/(..)/(....)')
pattern.findall(text)
pattern.split(...)
pattern.match(...)
pattern.sub(...)
```

Perl addicts:

only use regex if there is no other way.
Tip: string methods and data structures

file reading/writing

```
f = open(fname)
for line in f:
    print line
f.close()
```

```
open(fname).read()
open(fname).readline()
open(fname).readlines()
```

```
dir(file)
help(file)
```

```
f = open(fname, 'w')
f.write("blah blah")
f.close()
```

```
#skip header and first col
f = open(fname)
f.next()
for line in f:
    print line[1:]
f.close()
```

```
def write_matrix(fname, mat):
    f = open(fname, 'w')
    f.writelines([' '.join(map(str, row))+'\n' for row in mat])
    f.close()

def read_matrix(fname):
    return [map(float, line.split()) for line in open(fname)]
```

file handling

```
import os.path as path
path.split("c:/myfolder/test.dat")
path.join("c:/myfolder", "test.dat")
```

```
import os
os.listdir('.')
os.getcwd()
```

```
import glob
glob.glob("*.py")
```

```
import os
dir(os)
help(os.walk)
```

```
import os.path
dir(os.path)
```

```
import shutil
dir(shutil)
help(shutil.move)
```

file processing examples

```
def number_of_lines(fname):
    return len(open(fname).readlines())

def number_of_words(fname):
    return len(open(fname).read().split())

def enumerate_lines(fname):
    return [t for t in enumerate(open(fname))]

def shortest_line(fname):
    return min(enumerate(open(fname)), key=lambda (i,l): len(l))

def wordiest_line(fname):
   return max(enumerate(open(fname)), key=lambda (i,l): len(l.split()))
```

system

```
import sys
if __name__ == "__main__":
    args = sys.argv
    print "script name: ", args[1]
    print "script args: ", args[1:]
```

```
import os
# run and wait
os.system("mydir/blast -o %s" % fname)
```

```
import subprocess
# run and do not wait
subprocess.Popen("mydir/blast -o %s" % fname, shell=True)
```

```
import sys
dir(sys)
sys.version
sys.path

import os
dir(os)

help(os.sys)
help(os.getcwd)
help(os.mkdir)
```

last famous words

1. line length < 80
2. complexity < 10
3. no code duplication
4. value-adding comments
5. use language idioms
6. automated tests

questions

Advanced Python

overview

- Functional programming
- Object oriented programming

Functional programming

Functional Programming is a programming paradigm that emphasizes the application of functions and avoids state and mutable data, in contrast to the imperative programming style, which emphasizes changes in state.

- makes some things easier
- limited support in Python

Functions can be treated like any other type of data

```
def timeFormat(date):
  return "%2d:%2d" % (date.hour,date.min)

def dayFormat(date):
  return "Day: %sd" % (date.day)

def datePrinter(dates, format):
  for date in dates:
    print format(date)

datePrinter(dates, timeFormat)
```

```
def add(a,b):
  return a+b
plus = add
plus(1,2)
```

```
def inc_factory(n):
    def inc(a):
        return n+a
    return inc
inc2 = inc_factory(2)
inc3 = inc_factory(3)
inc3(7)
```

FP - lambda functions

Lambda functions are anonymous functions.
Typically for very short functions that are used only once.

```
l = [('a',3), ('b',2), ('c',1)]
```

```
#without lambda functions
def key(x): return x[1]
l.sort(key = key)

def cmp(x,y): return x[1]-y[1]
l.sort(cmp = cmp)
```

```
#with lambda functions
l.sort(key = lambda (c,n): n)
l.sort(cmp = lambda x,y: x[1]-y[1])
```

functional programming

map applies a function to the elements of a sequence

```
map(str, [1,2,3,4,5])
```

```
l = []
for n in [1,2,3,4,5]:
  l.append(str(n))
```

filter extracts elements from a sequence depending on a predicate function

```
filter(lambda x: x>3, [1,2,3,4,5])
```

```
l = []
for x in [1,2,3,4,5]:
  if x>3: l.append(n)
```

reduce iteratively applies a binary function, reducing a sequence to a single element

```
reduce(lambda a,b: a*b, [1,2,3,4,5])
```

```
prod = 1
for x in [1,2,3,4,5]:
  prod = prod * x
```

FP - example

Problem

sum over matrix rows stored in a file

File

```
1 2 3
4 5 6
```

List

```
6
15
```

Imperative

```
rowsums = []
for row in open(fname):
    elems = row.split()
    rowsum = 0
    for e in elems:
        rowsum += float(e)
    rowsums.append(rowsum)
```

Functional

```
rowsums = [sum(map(float,row.split())) for row in open(fname)]
```

Extra Functional ;-)

```
rowsums  = map(sum,map(lambda row:map(float,row.split()),open(fname)))
```

Numpy

```
rowsums = sum(loadtxt(fname),axis=1)
```

FP - more examples

```
numbers = [1,2,3,4]
numstr  = ",".join(map(str,numbers))
numbers = map(int,numstr.split(','))
```

```
v1 = [1,2,3]
v2 = [3,4,5]
dotprod = sum(map(lambda (x,y): x*y, zip(v1,v2)))
dotprod = sum(x*y for x,y in zip(v1,v2))
```

Object Oriented Programming

Object-oriented programming (OOP) is a programming paradigm that uses "objects" – data structures consisting of data fields and associated methods.

- brings data and functions together
- helps to manage complex code
- limited support in Python

Dot notation

```
object.attribute
object.method()
```

Class
- attributes
+ methods

Car
- color
- brand
+ consumption(speed)

Examples

```
text = "some text"
text.upper()
len(text) #not a method call
text.__len__()

f = open(filename)
if not f.closed :
  lines = f.readlines()
f.close()
```

```
try:
dir(file)
help(file)
```

OO motivation

Problem

for some genes print out name, length and GC content

Non-OO approach

```
genes = [
  ['gatA', 2108, 3583, 'agaccta'],
  ['yfgA', 9373, 9804, 'agaaa'],
  ...
]
```

```
def gc_content(seq):
  …
  return gc
```

```
for gene in genes:
  print gene[0], gene[2]-gene[1], gc_content(gene[3])
```

Object oriented

```
for gene in genes:
  print gene.name(), gene.length(), gene.gc_content()
```

OO definitions

Class: a template that defines attributes and functions of something,
e.g.

Car
- brand
- color
- calc_fuel_consumption(speed)

Attributes, Fields, Properties: things that describe an object,
e.g. Brand, Color

Methods, Operations, Functions: something that an object can do
e.g. calc_fuel_consumption(speed)

Instance: an actual, specific object created from the template/class
e.g. red BMW M5

Object: some unspecified class instance

Decorators

- Minor Syntax tweak but…
  - Syntax matters, often in unexpected ways
- they modify functions, and in the case of *class decorators*, entire classes

```
@foo
def bar: pass
```

Same as

```
bar = foo(bar)
```

```
def foo(): pass
foo = staticmethod(foo)
```

```
@staticmethod
def foo(): pass
```

Decorators

- Function based decorators

```
def trace(f):
  def new_f(*args)
     print 'Entering %s%s' % (f.__name__, args)
     result = f(*args, **kwargs)
     print 'Exiting %s%s with %s' % (f.__name__, args,result)
     return result
  return new_f


@trace
def sum(n, m):
    return n + m
```

Further Reading

- http://wiki.python.org/moin/PythonDecoratorLibrary
  - More examples of decorators. Note the number of these examples that use classes rather than functions as decorators.
- http://scratch.tplus1.com/decoratortalk
  - Matt Wilson's *Decorators*

Metaprogramming

- Every class statement uses a metaclass
  - Mostly type (or types.ClassType)
  - No hassle, no problem, no issue
- However, you can make a custom metaclass

```
class SimpleMeta1(type):
    def __init__(cls, name, bases, nmspc):
        super(SimpleMeta1, cls).__init__(name, bases, nmspc)
        cls.uses_metaclass = lambda self : "Yes!"

class Simple1(object):
    __metaclass__ = SimpleMeta1
    def foo(self): pass
    @staticmethod
    def bar(): pass

simple = Simple1()
```

Metaprogramming

- Metaprogramming involves hooking our own operations into the creation of class objects
  - `__init__`
  - `__new__`
  - `__call__`
- **Further Reading**
  - Excellent step-by-step introduction to metaclasses: http://cleverdevil.org/computing/78/
  - Metaclass intro and comparison of syntax between Python 2.x and 3.x: http://mikewatkins.ca/2008/11/29/python-2-and-3-metaclasses/

The Pattern Concept

- “Design patterns help you learn from others’ successes instead of your own failures”
  - Creational
  - Structural
  - Behavioral

- **Further Reading**
  - Alex Martelli’s Video Lectures on Design Patterns in Python: http://www.catonmat.net/blog/learning-python-design-patterns-through-video-lectures/

Unit Testing & Test-Driven Development

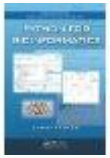
- TBD

questions

links

- Wikipedia – Python
  http://en.wikipedia.org/wiki/Python
- Learn Python Hard way
  http://learnpythonthehardway.org/
- Python Beginner
  https://www.python.org/about/gettingstarted/
- Instant Python
  http://hetland.org/writing/instant-python.html
- Dive into Python
  http://www.diveintopython.org/
- Hitchhiker Guide to Python
  http://docs.python-guide.org/en/latest/intro/learning/
- Python Magic Method
  http://www.rafekettler.com/magicmethods.html

books



Learn Python the Hard Way
By Zed A. Shaw
2009

Expert Python Programming
By Tarek Ziade
2008

Thank You

Design is not what it look like & feels like.

Design is how it works.

- Steve Jobs