Introduction to Python

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Outlines

- What is python?
- Versions and Python in SHARCNET
- Simple practice
- Data structure
- Data handling practice
- Libraries

Python

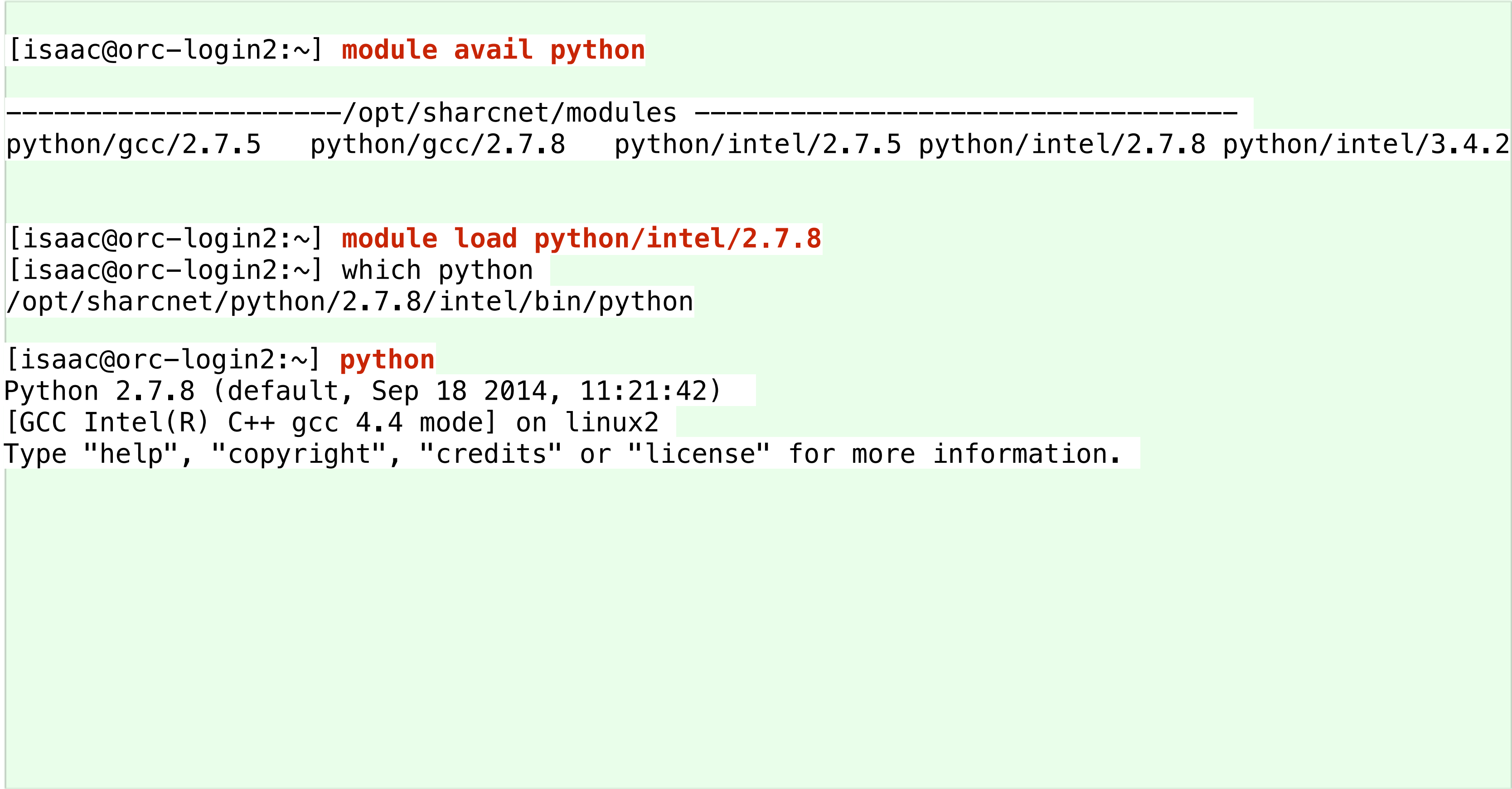
- Open source general-purpose high-level programming language.
- Interpreted language
- Object Oriented, Procedural, Functional
- Easy to interface with C/ObjC/Java/Fortran
- Simplicity but many advantages such as automatic memory management
- many libraries(NumPy, SciPy, SymPy)

Version 2.x / 3.x ?

2.x	3.x
• Released in late 2000 • Lots of web resources • Many third-party libraries	• Faster and neat • In near future all modules/libraries will be moved to 3.x versions

Note) You could use either version depending on your goal. However, it is okay for the most Python beginners to stay with 2.7.x version.

Python in SHARCNET



```
[isaac@orc-login2:~] module avail python

---------------------/opt/sharcnet/modules ----------------------------------
python/gcc/2.7.5   python/gcc/2.7.8   python/intel/2.7.5 python/intel/2.7.8 python/intel/3.4.2


[isaac@orc-login2:~] module load python/intel/2.7.8
[isaac@orc-login2:~] which python
/opt/sharcnet/python/2.7.8/intel/bin/python

[isaac@orc-login2:~] python
Python 2.7.8 (default, Sep 18 2014, 11:21:42)
[GCC Intel(R) C++ gcc 4.4 mode] on linux2
Type "help", "copyright", "credits" or "license" for more information.
```

How to install python on my PC?

- Download the installation package at

  www.python.org/download

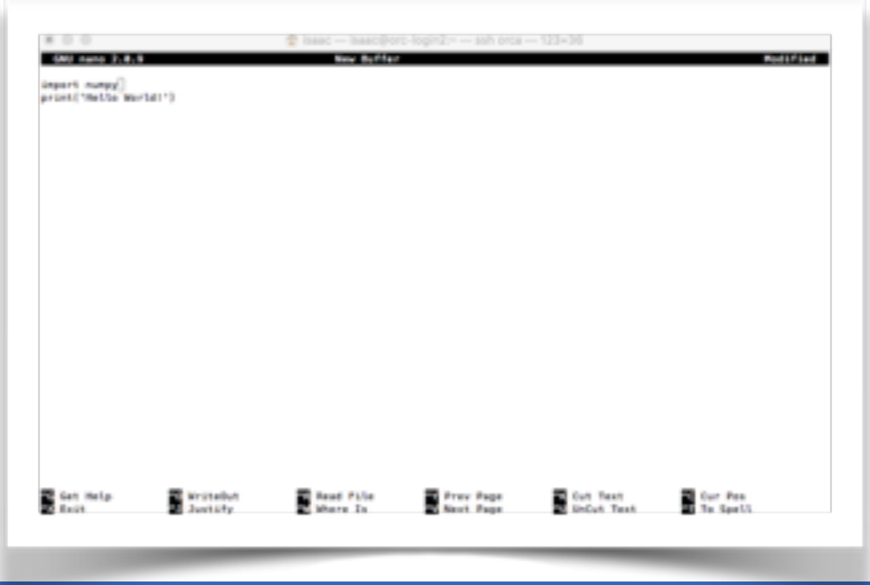
- Find the appropriate version based on your operating system in your PC (Mac OSX and LINUX have python in default)
- Or you may get ‘ANACONDA’ which has many pre-installed libraries at

  https://www.continuum.io/downloads

Setup a developing environment

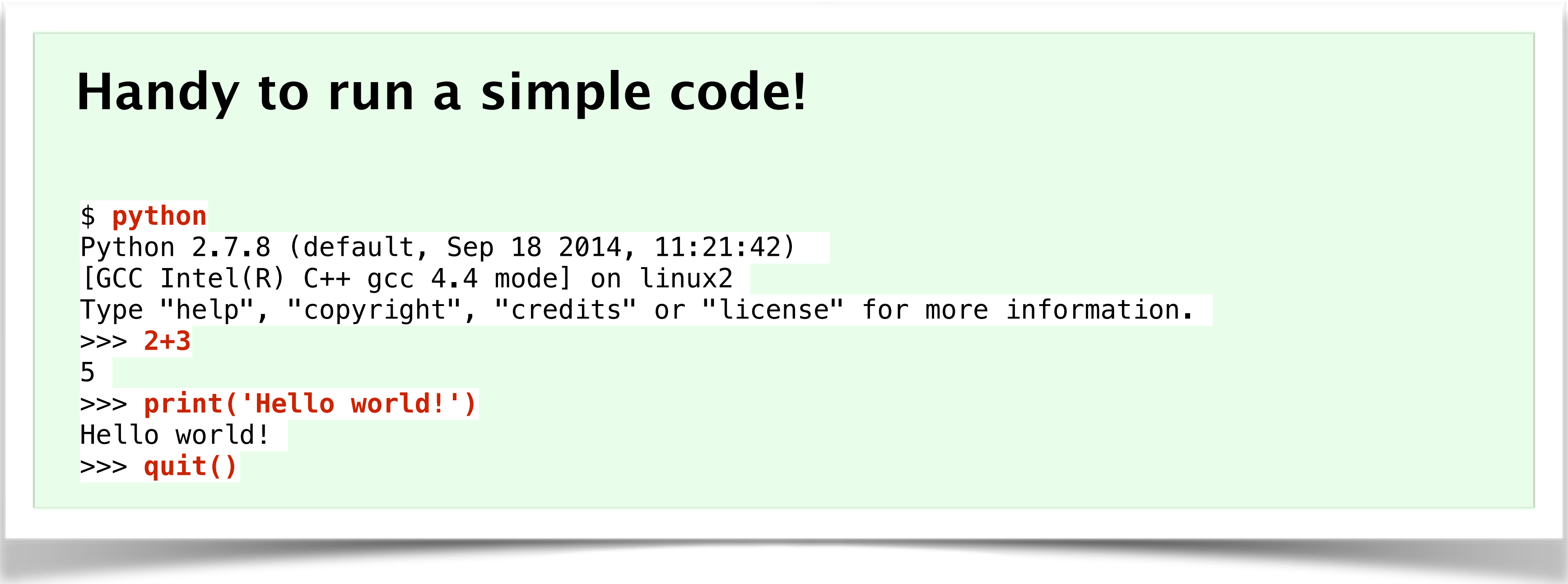
- Various options available (iPython, IDEs) but here we use ‘terminal’ which is a default environment in SHARCNET.

- The source code is edited by ‘nano’ editor in the terminal.



```
  GNU nano 2.0.9                New Buffer                        Modified

import numpy
print('Hello World!')
```

Interactive interface to Python



Handy to run a simple code!

```
$ python
Python 2.7.8 (default, Sep 18 2014, 11:21:42)
[GCC Intel(R) C++ gcc 4.4 mode] on linux2
Type "help", "copyright", "credits" or "license" for more information.
>>> 2+3
5
>>> print('Hello world!')
Hello world!
>>> quit()
```

- Python prompts with ‘>>>’
- To exit Python: ‘Ctrl+D’

Running a Script

Easy to edit/run a long code!

```
$ cat test.py
2+3
print('Hello world!')
$ python test.py
Hello world!
```

You could put the interpreter info and make it executable

```
$ cat test.py
#!/opt/sharcnet/python/2.7.8/intel/bin/python

2+3
print('Hello world!')
$ chmod 777 test.py
$ ./test.py
Hello world!
```

Simple math practice

```
$ cat test.py
a = 55
print(a)
print('double of a is:', 2.*a)

b = 2.*a
print('b is:', b)

a = 100
print('double of a is:', 2.*a)
print('b is:', b)

$ python test.py
55
('double of a is:', 110.0)
('b is:', 110.0)
('double of a is:', 200.0)
('b is:', 110.0)
```

Assign 55 to variable a

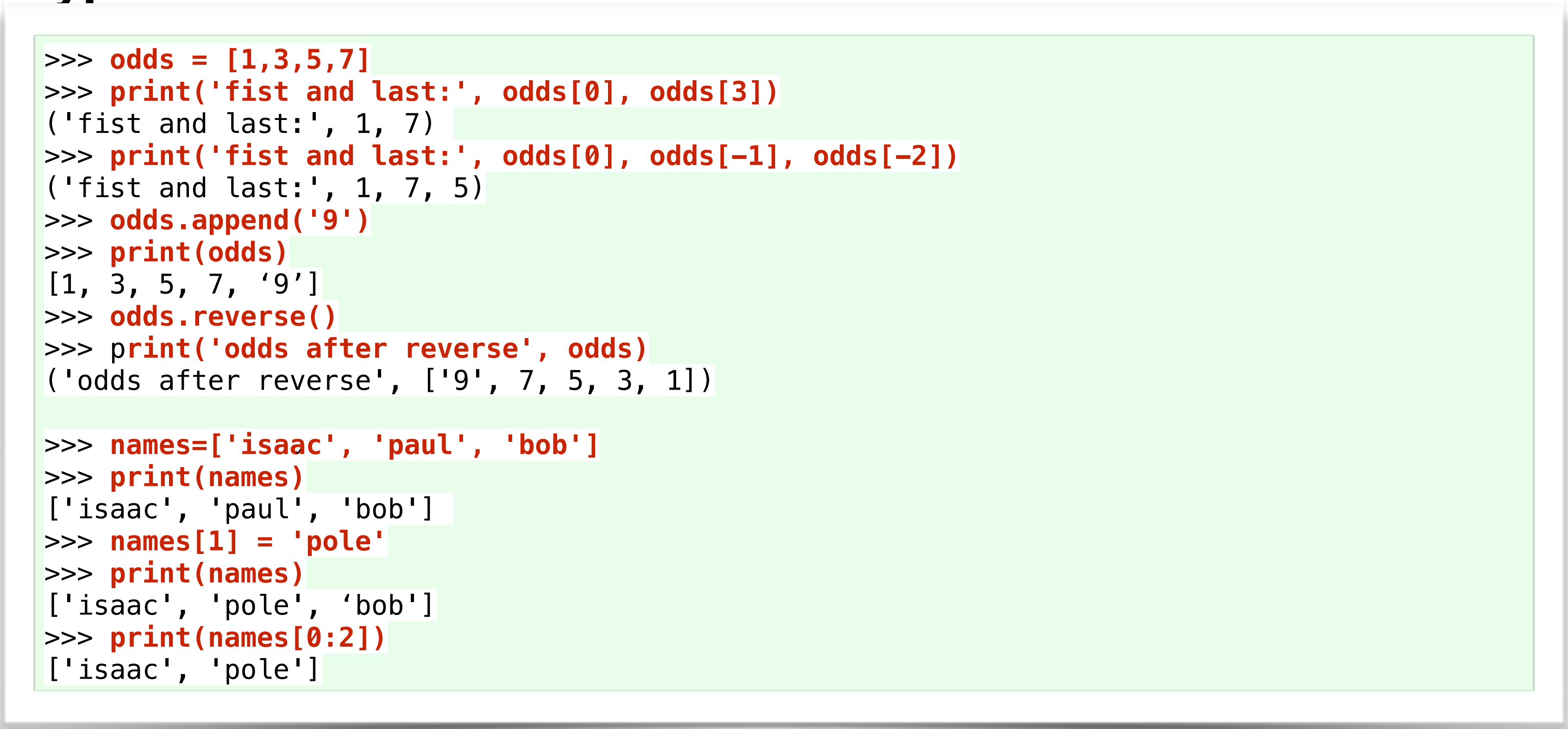
Set ‘b=2a’

Reassign 100 to a

b value is not change!

Data structures: LISTS

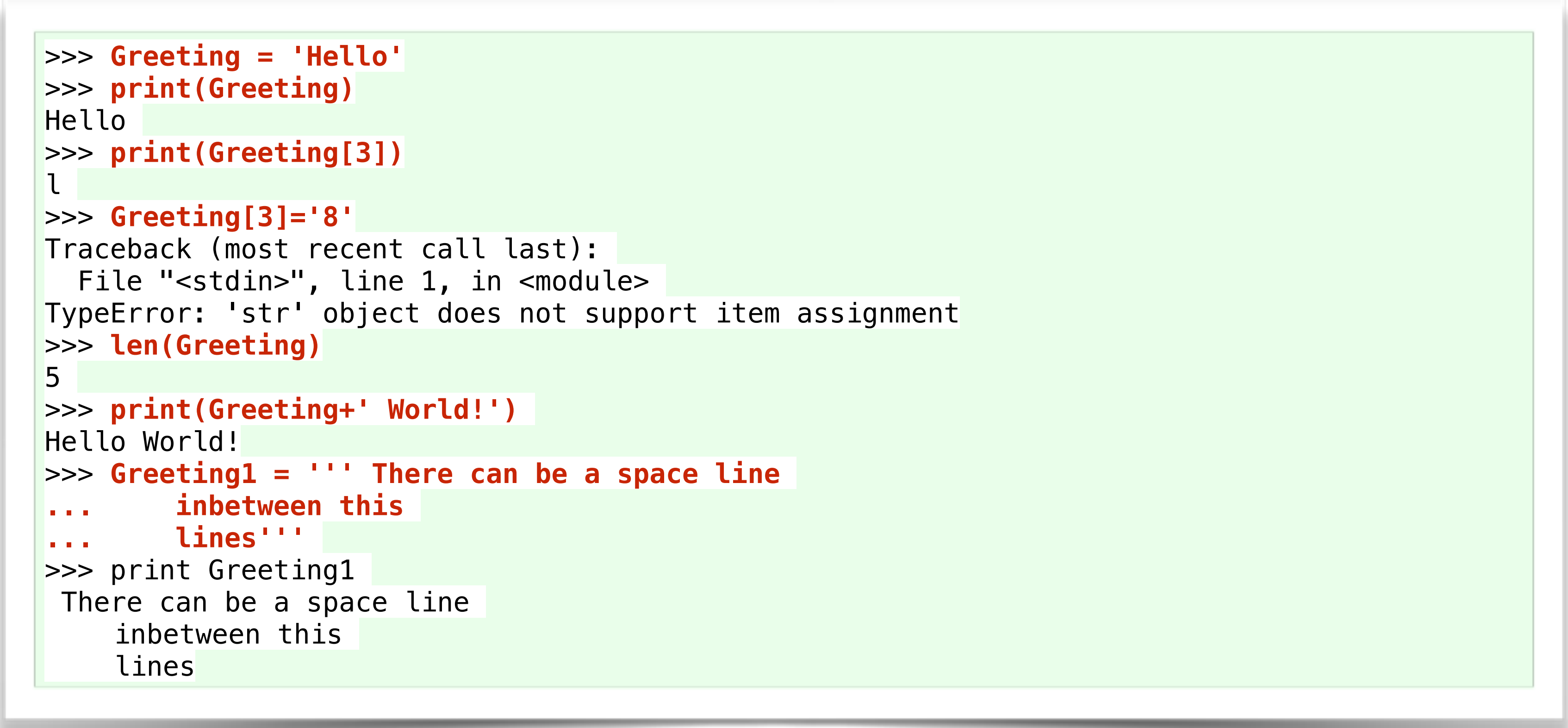
- Defined by writing a list of comma separated values in square brackets which might have different types for each item but for most of case we keep them all same type.



```
>>> odds = [1,3,5,7]
>>> print('fist and last:', odds[0], odds[3])
('fist and last:', 1, 7)
>>> print('fist and last:', odds[0], odds[-1], odds[-2])
('fist and last:', 1, 7, 5)
>>> odds.append('9')
>>> print(odds)
[1, 3, 5, 7, ‘9’]
>>> odds.reverse()
>>> print('odds after reverse', odds)
('odds after reverse', ['9', 7, 5, 3, 1])

>>> names=['isaac', 'paul', 'bob']
>>> print(names)
['isaac', 'paul', 'bob']
>>> names[1] = 'pole'
>>> print(names)
['isaac', 'pole', ‘bob']
>>> print(names[0:2])
['isaac', 'pole']
```

Data structures: STRINGS

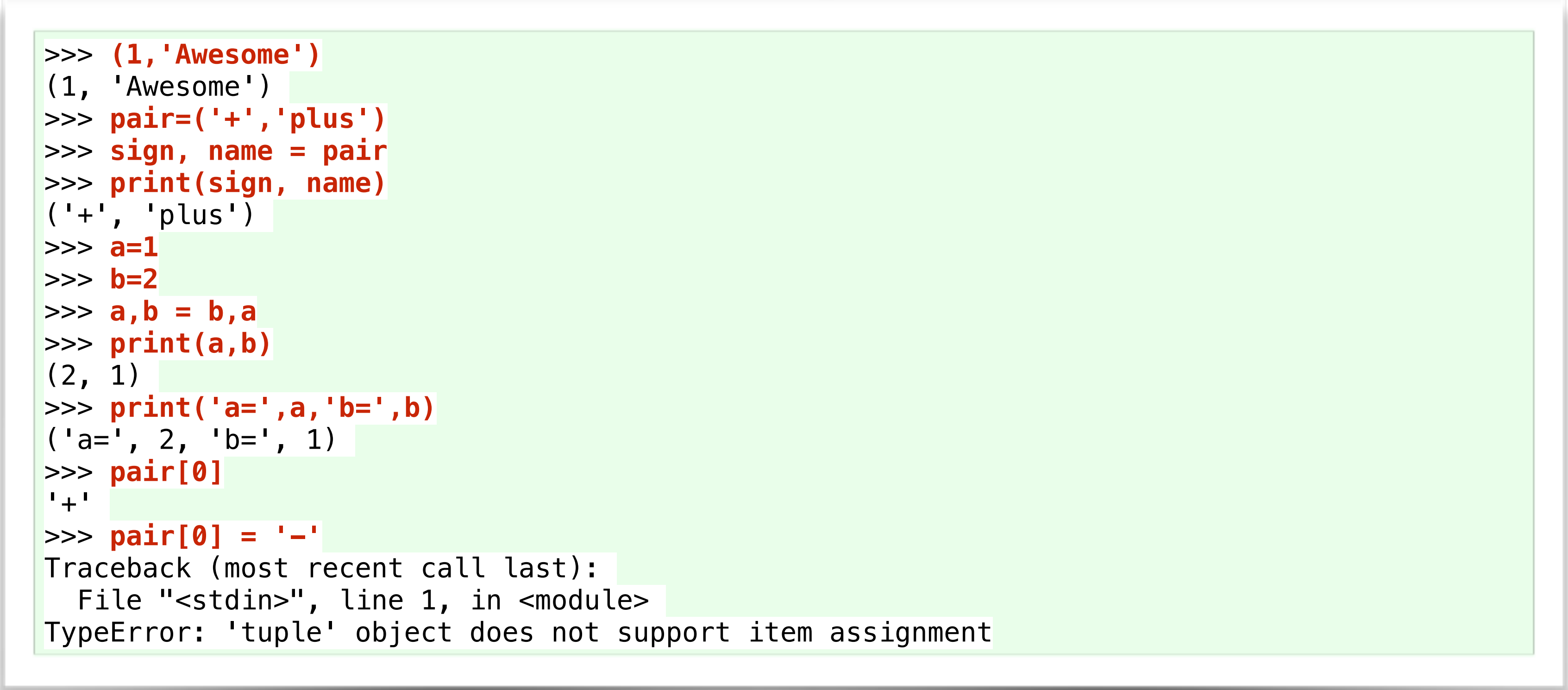
- Defined by using of single (‘) or double(“) or triple(”’) quotes. Strings are immutable so that the change of the part in strings is not permitted.



```
>>> Greeting = 'Hello'
>>> print(Greeting)
Hello
>>> print(Greeting[3])
l
>>> Greeting[3]='8'
Traceback (most recent call last):
  File "<stdin>", line 1, in <module>
TypeError: 'str' object does not support item assignment
>>> len(Greeting)
5
>>> print(Greeting+' World!')
Hello World!
>>> Greeting1 = ''' There can be a space line
...     inbetween this
...     lines'''
>>> print Greeting1
 There can be a space line
    inbetween this
    lines
```

Data structures: TUPLES

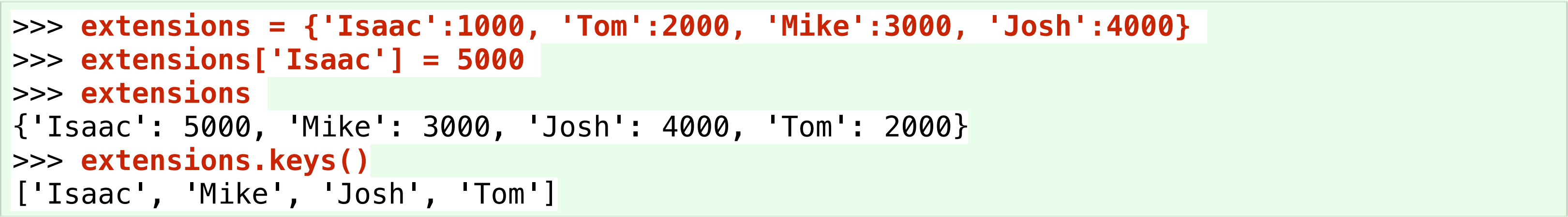
- Represented by a number of csv format. These are immutable and the output comes with nested parentheses.



```
>>> (1,'Awesome')
(1, 'Awesome')
>>> pair=('+','plus')
>>> sign, name = pair
>>> print(sign, name)
('+', 'plus')
>>> a=1
>>> b=2
>>> a,b = b,a
>>> print(a,b)
(2, 1)
>>> print('a=',a,'b=',b)
('a=', 2, 'b=', 1)
>>> pair[0]
'+'
>>> pair[0] = '-'
Traceback (most recent call last):
  File "<stdin>", line 1, in <module>
TypeError: 'tuple' object does not support item assignment
```

Data structures: DICTIONARY

- Dictionaries are another container like lists, but instead of being indexed by a number like 0 or 1 it is indexed by a key which can be almost anything. The name comes from being able to use it to represent a dictionary.



```
>>> extensions = {'Isaac':1000, 'Tom':2000, 'Mike':3000, 'Josh':4000}
>>> extensions['Isaac'] = 5000
>>> extensions
{'Isaac': 5000, 'Mike': 3000, 'Josh': 4000, 'Tom': 2000}
>>> extensions.keys()
['Isaac', 'Mike', 'Josh', 'Tom']
```

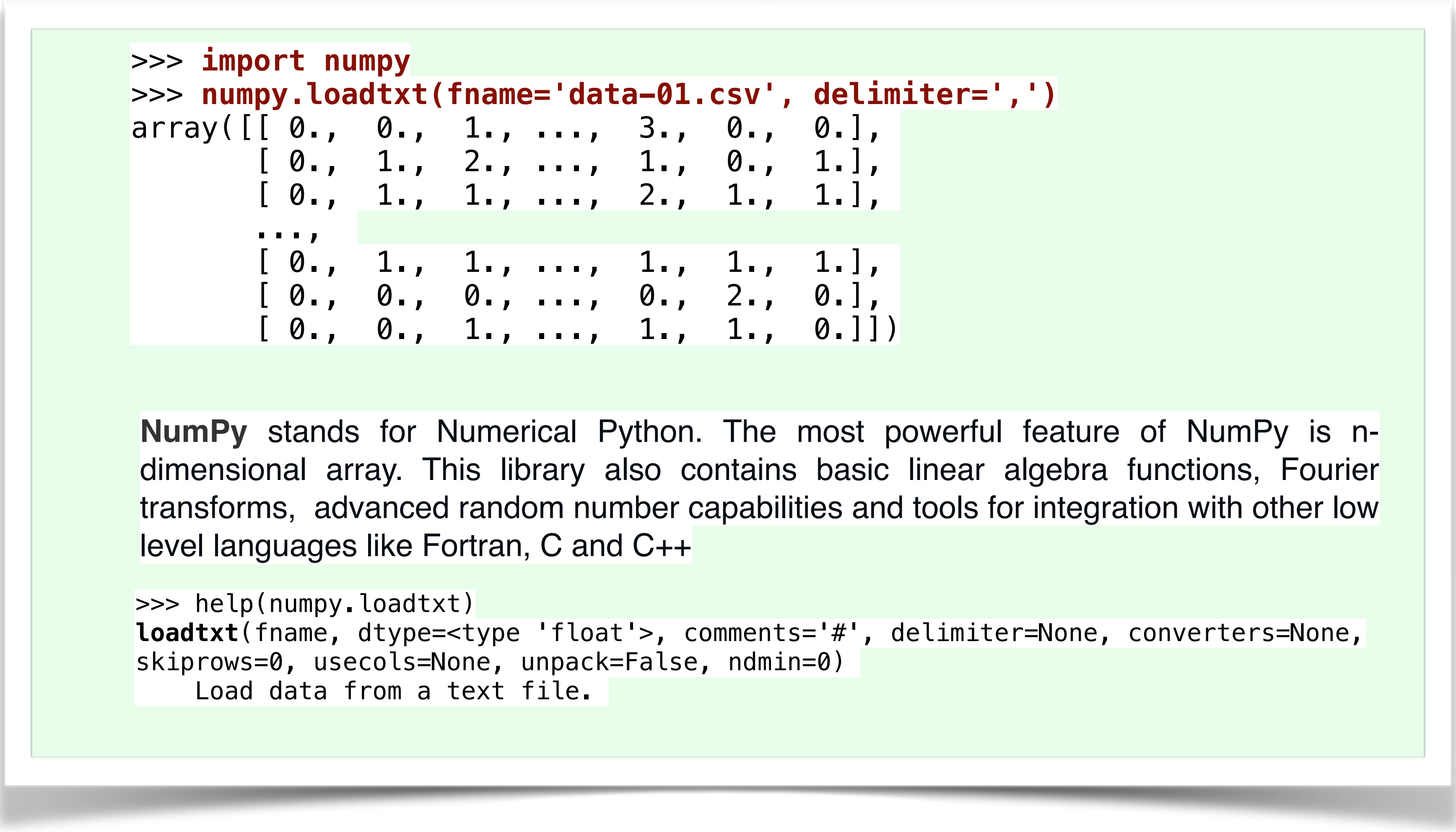
What we want to practice

- load large data (csv format) into memory
- calculate average, max, min along the column or row in the 2-D array data

```
[isaac@orc-login2:/work/isaac/swc/python/data] more data-01.csv
0,0,1,3,1,2,4,7,8,3,3,3,10,5,7,4,7,7,12,18,6,13,11,11,7,7,4,6,8,8,4,4,5,7,3,4,2,3,0,0
0,1,2,1,2,1,3,2,2,6,10,11,5,9,4,4,7,16,8,6,18,4,12,5,12,7,11,5,11,3,3,5,4,4,5,5,1,1,0,1
0,1,1,3,3,2,6,2,5,9,5,7,4,5,4,15,5,11,9,10,19,14,12,17,7,12,11,7,4,2,10,5,4,2,2,3,2,2,1,1
0,0,2,0,4,2,2,1,6,7,10,7,9,13,8,8,15,10,10,7,17,4,4,7,6,15,6,4,9,11,3,5,6,3,3,4,2,3,2,1
0,1,1,3,3,1,3,5,2,4,4,7,6,5,3,10,8,10,6,17,9,14,9,7,13,9,12,6,7,7,9,6,3,2,2,4,2,0,1,1
0,0,1,2,2,4,2,1,6,4,7,6,6,9,9,15,4,16,18,12,12,5,18,9,5,3,10,3,12,7,8,4,7,3,5,4,4,3,2,1
0,0,2,2,4,2,2,5,5,8,6,5,11,9,4,13,5,12,10,6,9,17,15,8,9,3,13,7,8,2,8,8,4,2,3,5,4,1,1,1
0,0,1,2,3,1,2,3,5,3,7,8,8,5,10,9,15,11,18,19,20,8,5,13,15,10,6,10,6,7,4,9,3,5,2,5,3,2,2,1
```

- plot the result

Loading csv format data

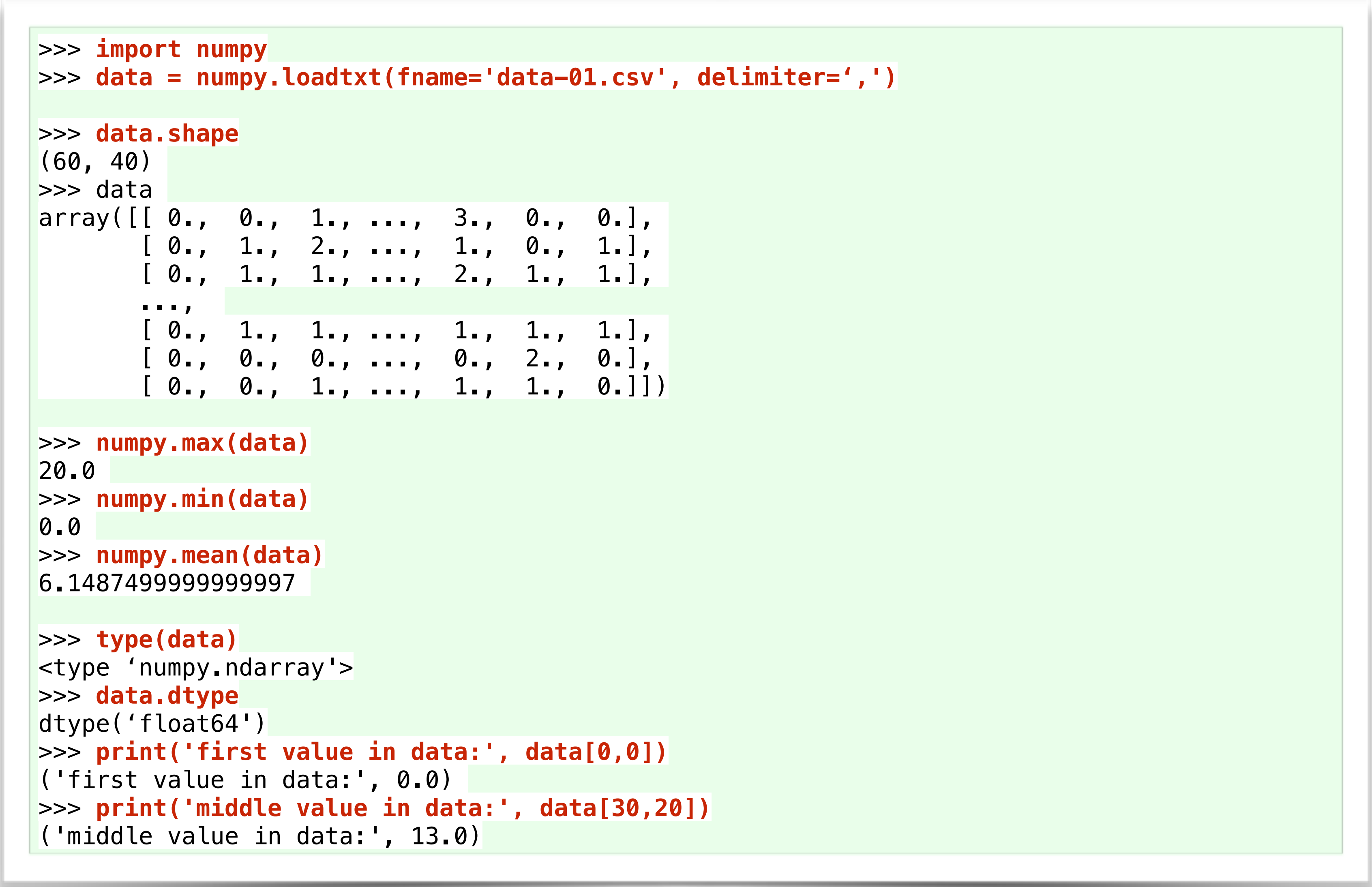


```
>>> import numpy
>>> numpy.loadtxt(fname='data-01.csv', delimiter=',')
array([[ 0.,  0.,  1., ...,  3.,  0.,  0.],
       [ 0.,  1.,  2., ...,  1.,  0.,  1.],
       [ 0.,  1.,  1., ...,  2.,  1.,  1.],
       ...,
       [ 0.,  1.,  1., ...,  1.,  1.,  1.],
       [ 0.,  0.,  0., ...,  0.,  2.,  0.],
       [ 0.,  0.,  1., ...,  1.,  1.,  0.]])
```

NumPy stands for Numerical Python. The most powerful feature of NumPy is n-dimensional array. This library also contains basic linear algebra functions, Fourier transforms, advanced random number capabilities and tools for integration with other low level languages like Fortran, C and C++

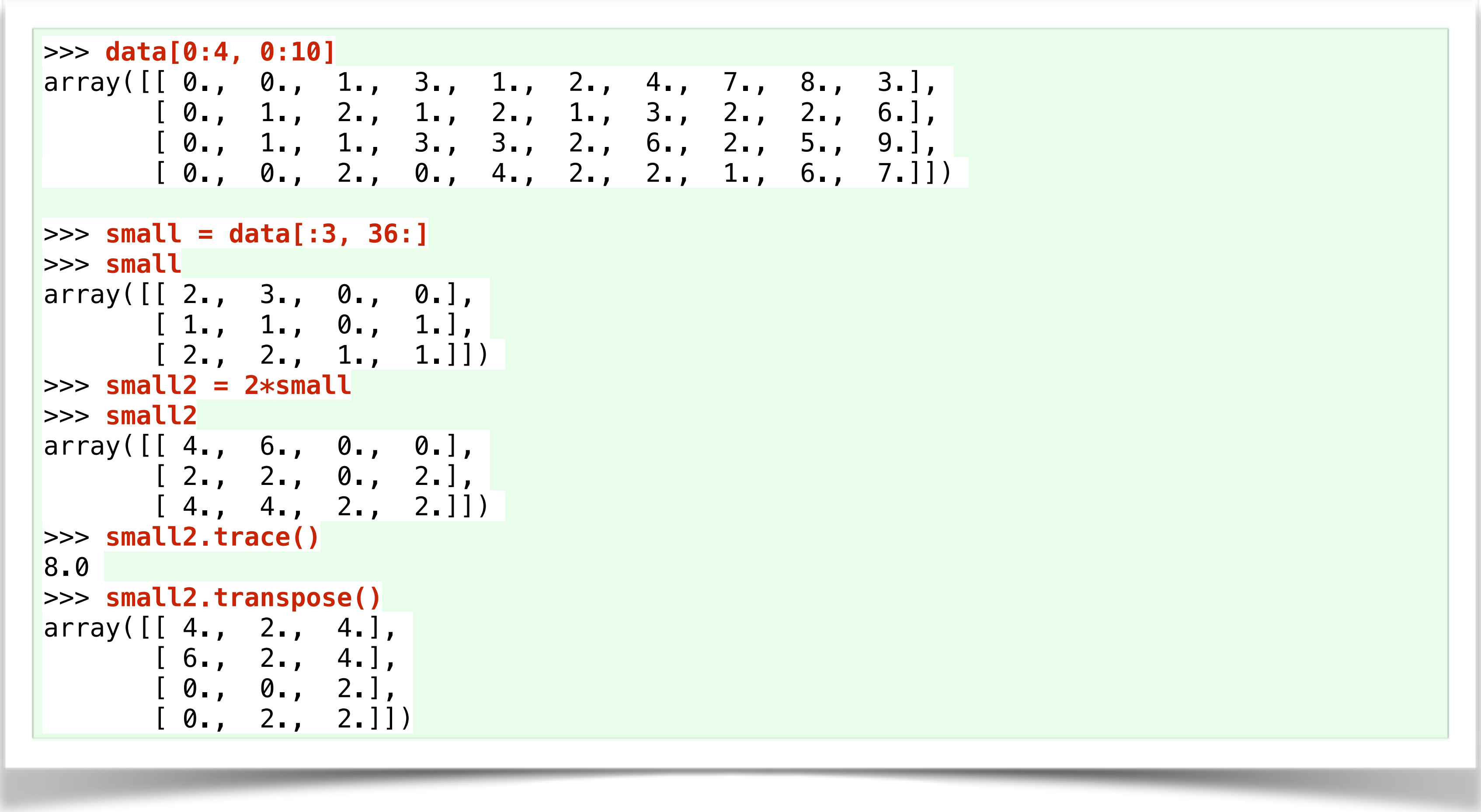
```
>>> help(numpy.loadtxt)
loadtxt(fname, dtype=<type 'float'>, comments='#', delimiter=None, converters=None,
skiprows=0, usecols=None, unpack=False, ndmin=0)
    Load data from a text file.
```

Checking loaded data



```
>>> import numpy
>>> data = numpy.loadtxt(fname='data-01.csv', delimiter=‘,')

>>> data.shape
(60, 40)
>>> data
array([[ 0.,  0.,  1., ...,  3.,  0.,  0.],
       [ 0.,  1.,  2., ...,  1.,  0.,  1.],
       [ 0.,  1.,  1., ...,  2.,  1.,  1.],
       ...,
       [ 0.,  1.,  1., ...,  1.,  1.,  1.],
       [ 0.,  0.,  0., ...,  0.,  2.,  0.],
       [ 0.,  0.,  1., ...,  1.,  1.,  0.]])

>>> numpy.max(data)
20.0
>>> numpy.min(data)
0.0
>>> numpy.mean(data)
6.1487499999999997

>>> type(data)
<type ‘numpy.ndarray'>
>>> data.dtype
dtype(‘float64')
>>> print('first value in data:', data[0,0])
('first value in data:', 0.0)
>>> print('middle value in data:', data[30,20])
('middle value in data:', 13.0)
```

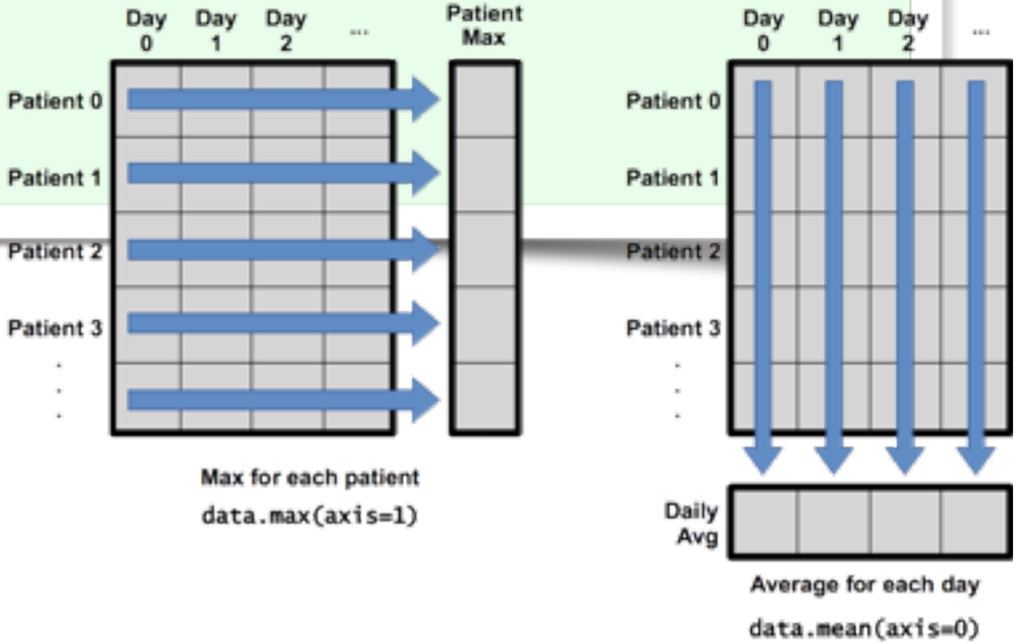
Slicing data array



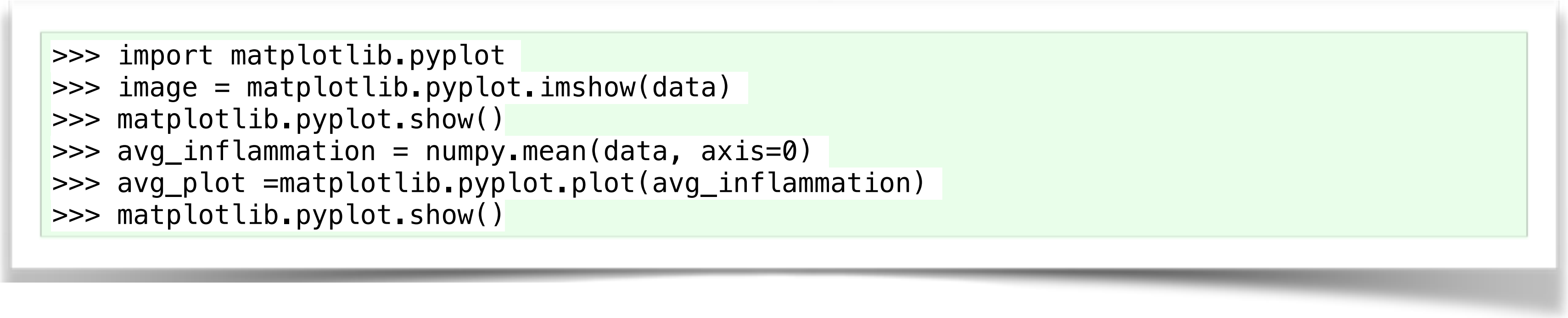
```
>>> data[0:4, 0:10]
array([[ 0.,  0.,  1.,  3.,  1.,  2.,  4.,  7.,  8.,  3.],
       [ 0.,  1.,  2.,  1.,  2.,  1.,  3.,  2.,  2.,  6.],
       [ 0.,  1.,  1.,  3.,  3.,  2.,  6.,  2.,  5.,  9.],
       [ 0.,  0.,  2.,  0.,  4.,  2.,  2.,  1.,  6.,  7.]])

>>> small = data[:3, 36:]
>>> small
array([[ 2.,  3.,  0.,  0.],
       [ 1.,  1.,  0.,  1.],
       [ 2.,  2.,  1.,  1.]])
>>> small2 = 2*small
>>> small2
array([[ 4.,  6.,  0.,  0.],
       [ 2.,  2.,  0.,  2.],
       [ 4.,  4.,  2.,  2.]])
>>> small2.trace()
8.0
>>> small2.transpose()
array([[ 4.,  2.,  4.],
       [ 6.,  2.,  4.],
       [ 0.,  0.,  2.],
       [ 0.,  2.,  2.]])
```

Handling data in array using

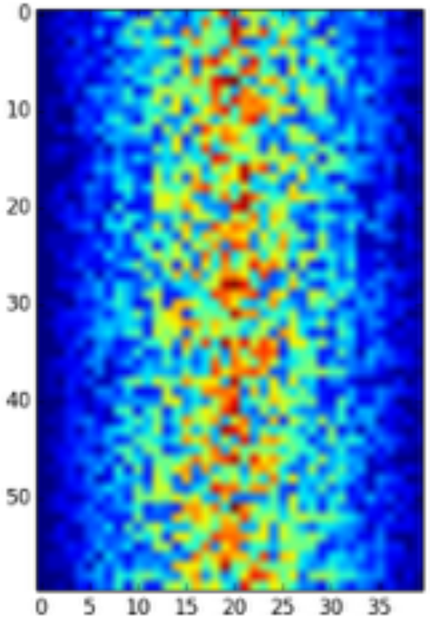
```
>>> patient0 = data[0, :]
>>> print('max inflammation for patient 0:', patient0.max())
('max inflammation for patient 0:', 18.0)
>>> patient3 = data[3, :]
>>> print('max inflammation for patient 0:', patient3.max())
('max inflammation for patient 0:', 17.0)
>>> numpy.mean(data, axis=0)
array([  0.         ,   0.45       ,   1.11666667,   …        ,   1.13333333,   0.56666667])
>>> dailymean=numpy.mean(data, axis=0)
>>> dailymean.shape
(40,)
>>> numpy.mean(data,axis=1)
array([ 5.45 ,  5.425,  6.1  ,  5.9  ,
…  5.9  ])
>>> numpy.mean(data,axis=1).shape
(60,)
```

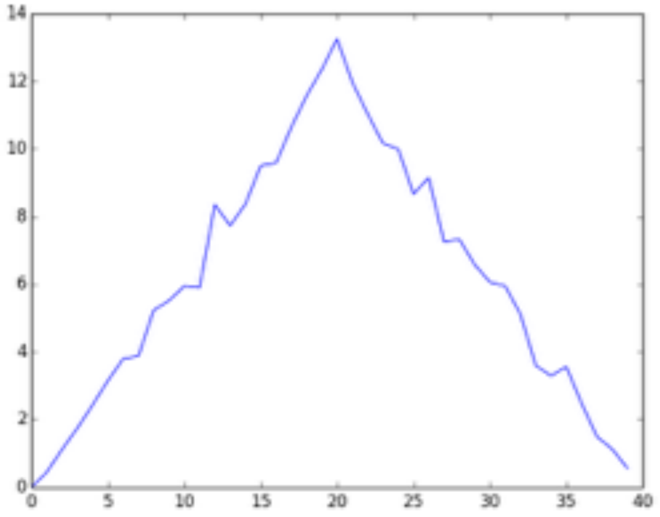


Plotting image



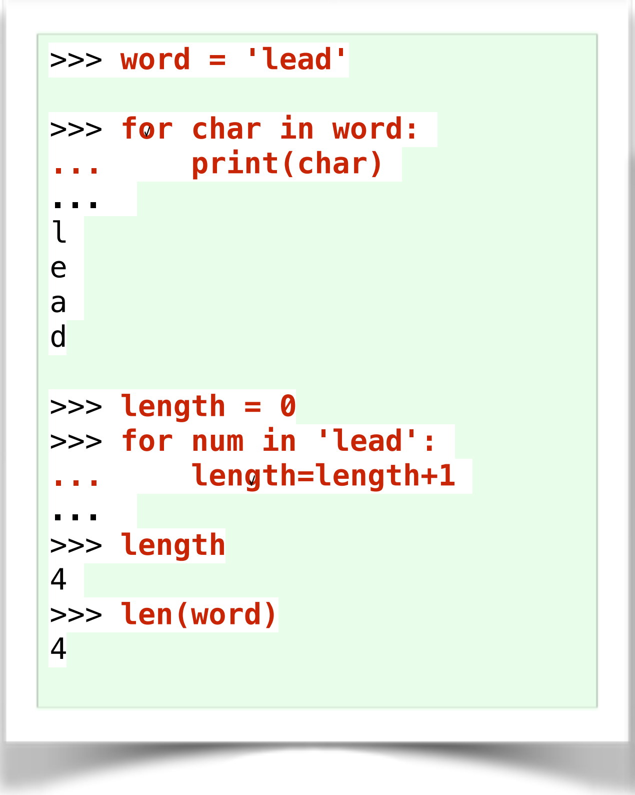
```
>>> import matplotlib.pyplot
>>> image = matplotlib.pyplot.imshow(data)
>>> matplotlib.pyplot.show()
>>> avg_inflammation = numpy.mean(data, axis=0)
>>> avg_plot =matplotlib.pyplot.plot(avg_inflammation)
>>> matplotlib.pyplot.show()
```



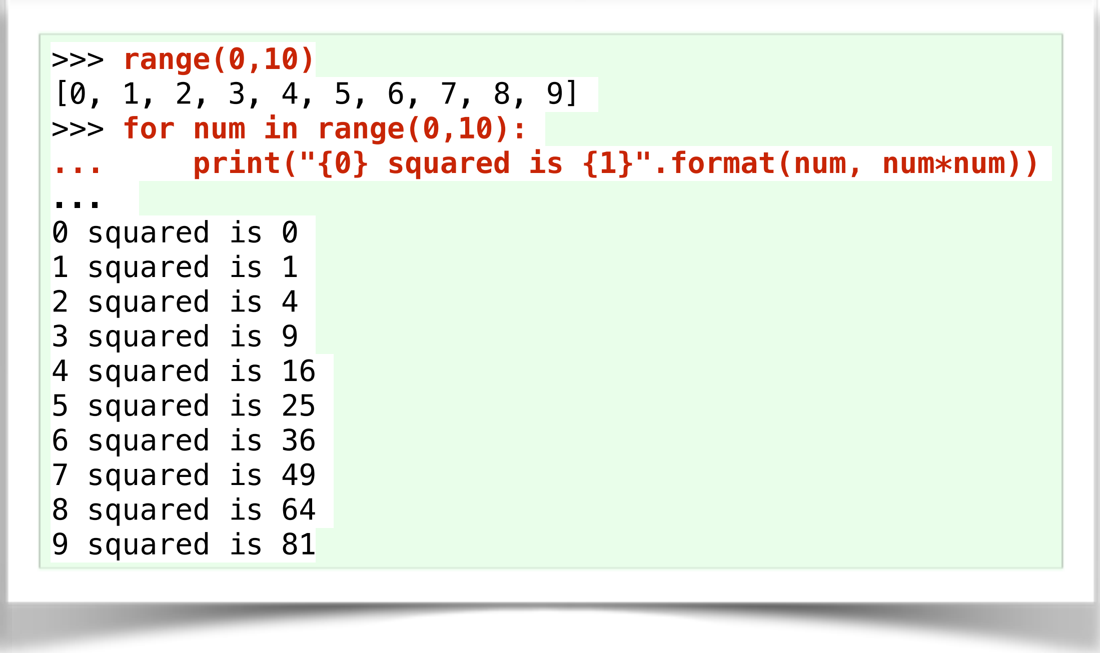


‘FOR’-loop

- For iterative work, ‘FOR’-loop is also available in Python like most languages.



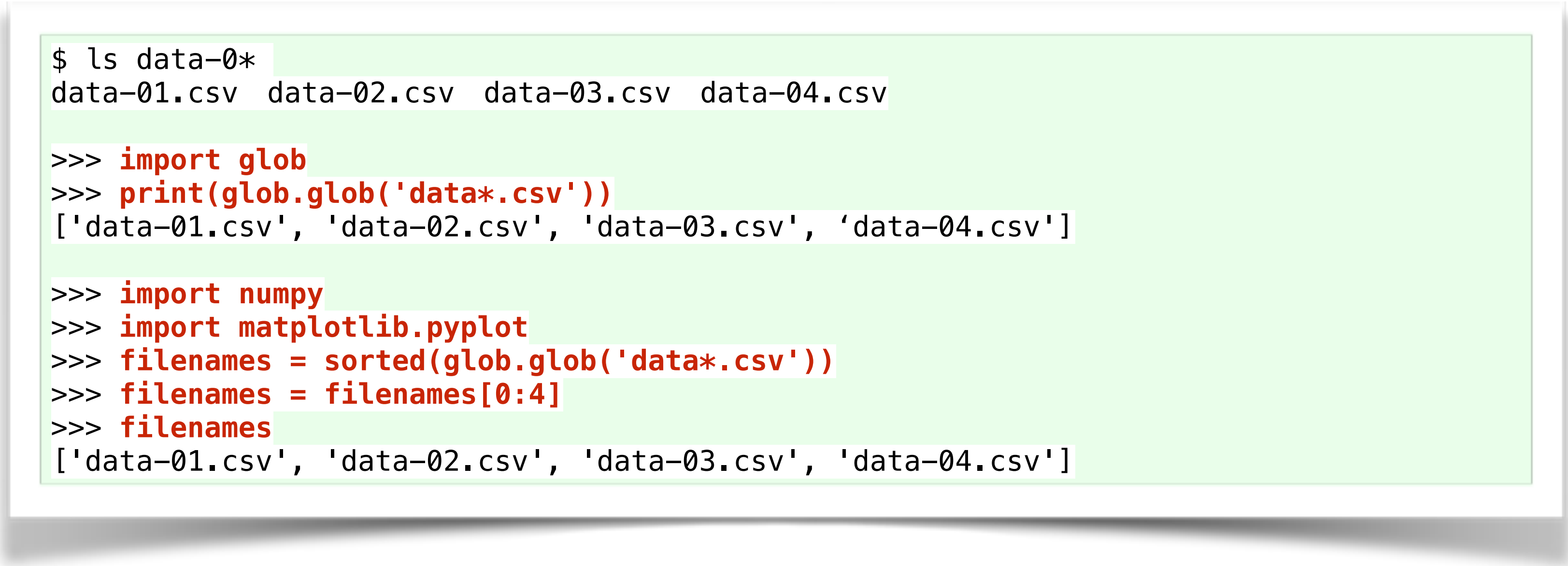
```
>>> word = 'lead'

>>> for char in word:
...     print(char)
...
l
e
a
d

>>> length = 0
>>> for num in 'lead':
...     length=length+1
...
>>> length
4
>>> len(word)
4
```



```
>>> range(0,10)
[0, 1, 2, 3, 4, 5, 6, 7, 8, 9]
>>> for num in range(0,10):
...     print("{0} squared is {1}".format(num, num*num))
...
0 squared is 0
1 squared is 1
2 squared is 4
3 squared is 9
4 squared is 16
5 squared is 25
6 squared is 36
7 squared is 49
8 squared is 64
9 squared is 81
```

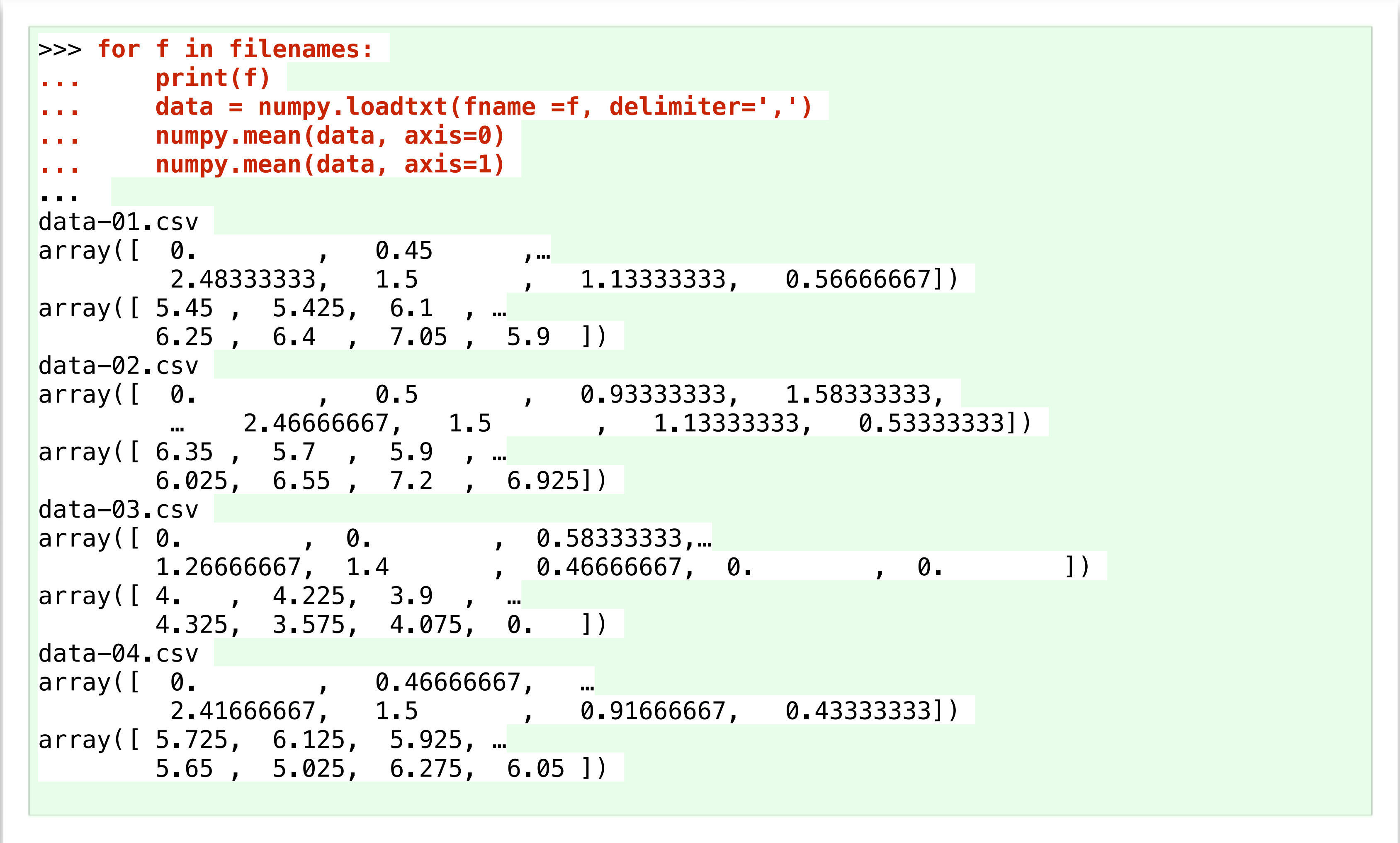
Handling multiple files

- The `glob` library contains a function, also called `glob`, that finds files and directories whose names match a pattern. We provide those patterns as strings: the character `*` matches zero or more characters, while `?` matches any one character. We can use this to get the names of all the CSV files in the current directory:



```
$ ls data-0*
data-01.csv  data-02.csv  data-03.csv  data-04.csv

>>> import glob
>>> print(glob.glob('data*.csv'))
['data-01.csv', 'data-02.csv', 'data-03.csv', ‘data-04.csv']

>>> import numpy
>>> import matplotlib.pyplot
>>> filenames = sorted(glob.glob('data*.csv'))
>>> filenames = filenames[0:4]
>>> filenames
['data-01.csv', 'data-02.csv', 'data-03.csv', 'data-04.csv']
```

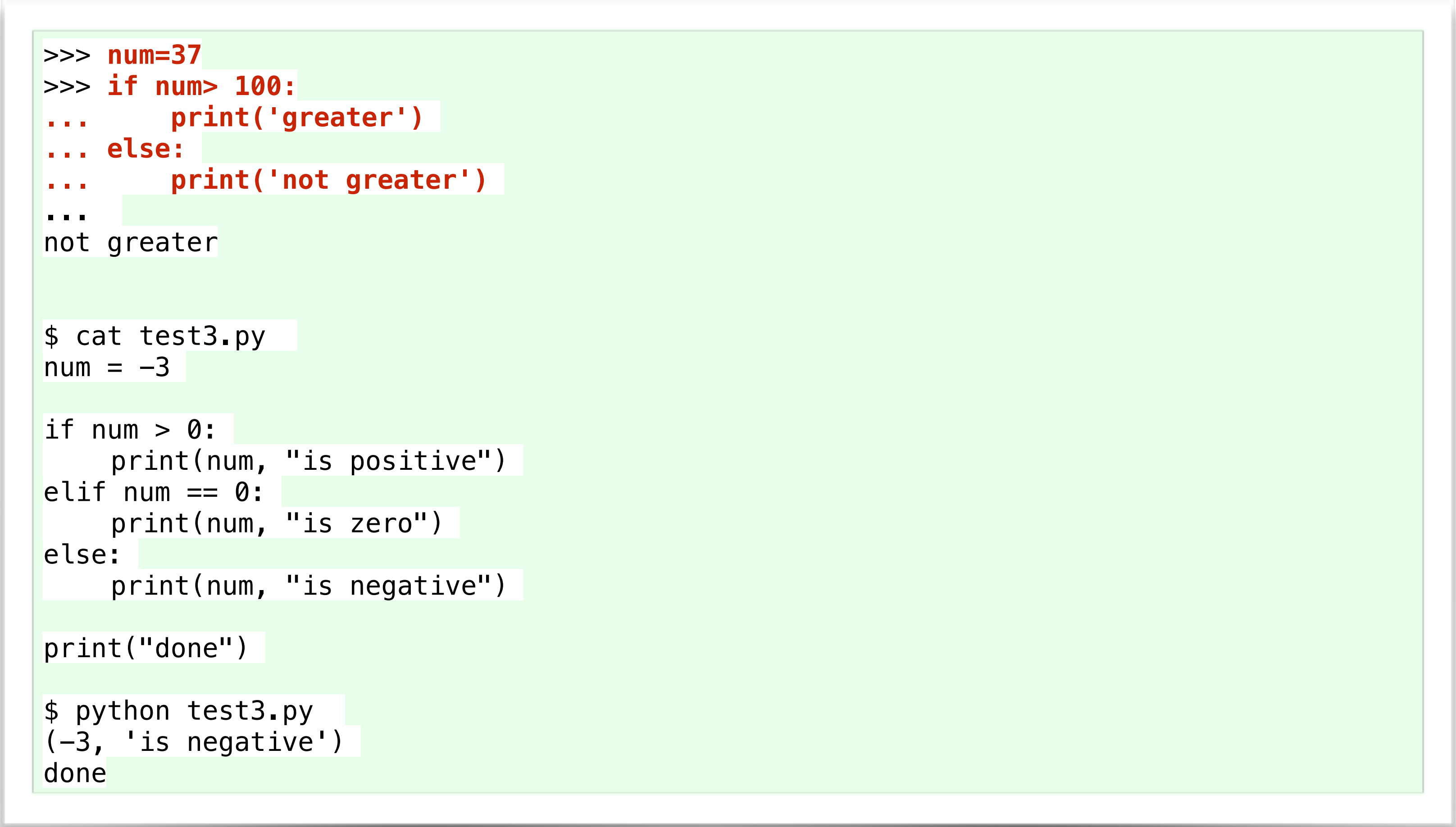
Handling multiple files (cont’d)



```
>>> for f in filenames:
...     print(f)
...     data = numpy.loadtxt(fname =f, delimiter=',')
...     numpy.mean(data, axis=0)
...     numpy.mean(data, axis=1)
...
data-01.csv
array([  0.        ,   0.45      ,…
         2.48333333,   1.5       ,   1.13333333,   0.56666667])
array([ 5.45 ,  5.425,  6.1  , …
        6.25 ,  6.4  ,  7.05 ,  5.9  ])
data-02.csv
array([  0.        ,   0.5       ,   0.93333333,   1.58333333,
         …    2.46666667,   1.5       ,   1.13333333,   0.53333333])
array([ 6.35 ,  5.7  ,  5.9  , …
        6.025,  6.55 ,  7.2  ,  6.925])
data-03.csv
array([ 0.        ,  0.        ,  0.58333333,…
        1.26666667,  1.4       ,  0.46666667,  0.        ,  0.        ])
array([ 4.   ,  4.225,  3.9  ,  …
        4.325,  3.575,  4.075,  0.   ])
data-04.csv
array([  0.        ,   0.46666667,   …
         2.41666667,   1.5       ,   0.91666667,   0.43333333])
array([ 5.725,  6.125,  5.925, …
        5.65 ,  5.025,  6.275,  6.05 ])
```

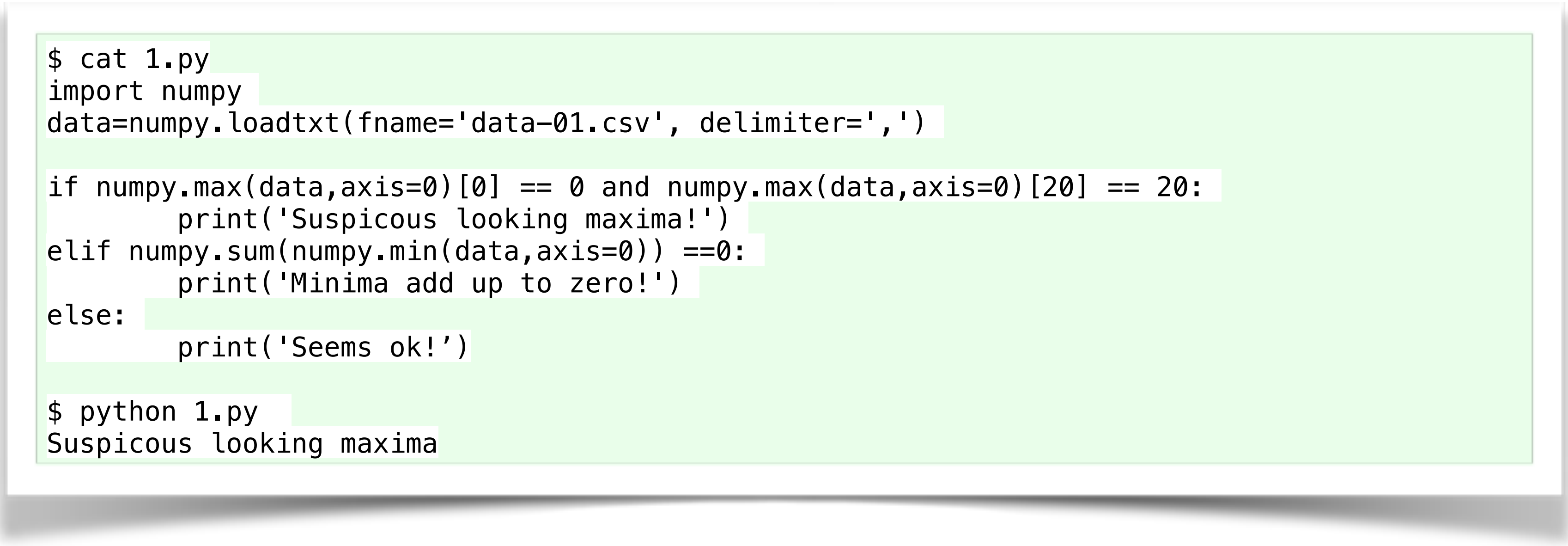
Making choices

- We can ask Python to take different actions, depending on a condition with ‘if’ statement:



```
>>> num=37
>>> if num> 100:
...     print('greater')
... else:
...     print('not greater')
...
not greater


$ cat test3.py
num = -3

if num > 0:
    print(num, "is positive")
elif num == 0:
    print(num, "is zero")
else:
    print(num, "is negative")

print("done")

$ python test3.py
(-3, 'is negative')
done
```

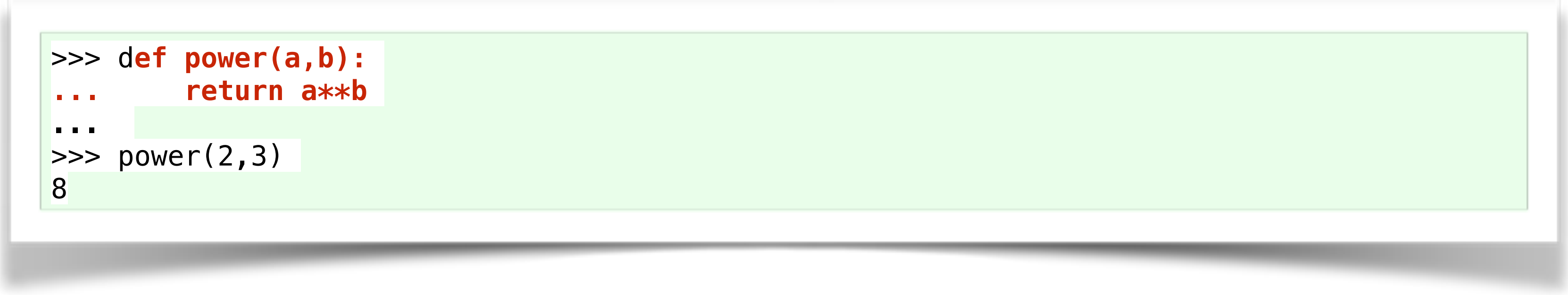
Checking the loaded data



```
$ cat 1.py
import numpy
data=numpy.loadtxt(fname='data-01.csv', delimiter=',')

if numpy.max(data,axis=0)[0] == 0 and numpy.max(data,axis=0)[20] == 20:
        print('Suspicous looking maxima!')
elif numpy.sum(numpy.min(data,axis=0)) ==0:
        print('Minima add up to zero!')
else:
        print('Seems ok!’)

$ python 1.py
Suspicous looking maxima
```

Function

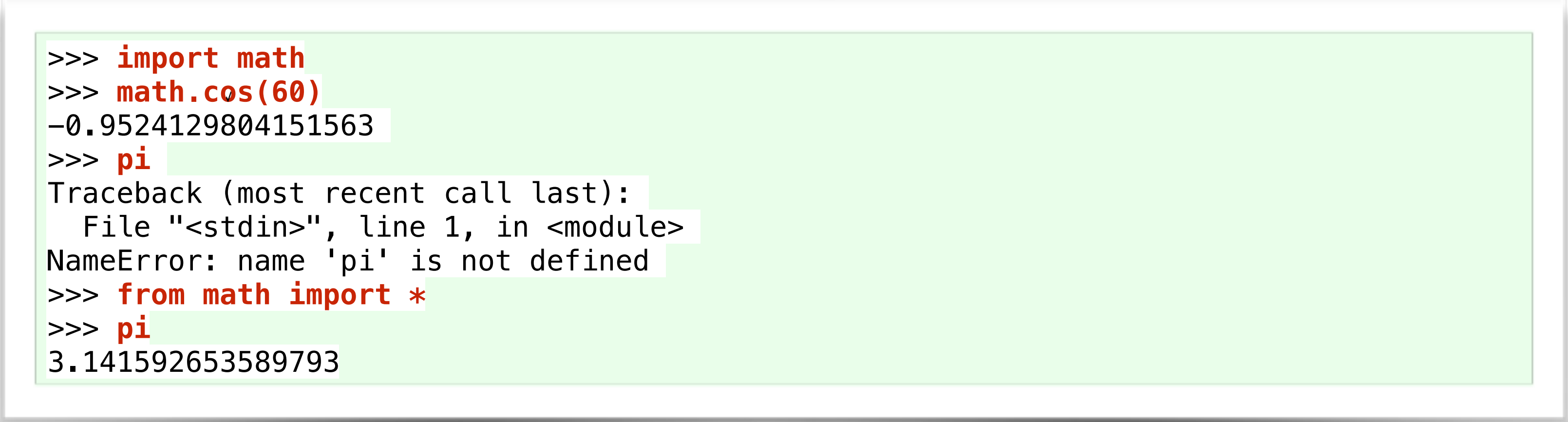
- `def` is the keyword to define a function. `add` in the above example is the name. All functions require a parameter list surrounded by an open bracket "(" and close bracket ")" even if there are no parameters. `return` is also a keyword which is required return a value. If it isn't provided `None` is returned. Function bodies are block like if statements and for loops.



```
>>> def power(a,b):
...     return a**b
...
>>> power(2,3)
8
```

Libraries

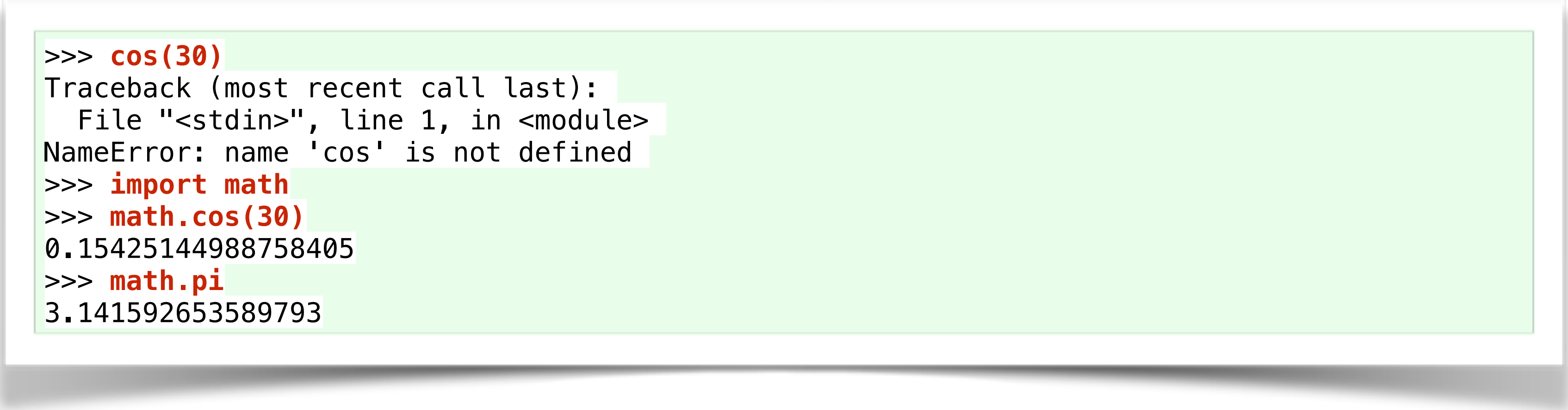
>>> import math	>>> from math import *
• Loading 'math' library which has various functions. It must be used by referencing it like 'math.cos()'	• Importing entire namespace in math library so it can be used without reference like 'cos()'



```
>>> import math
>>> math.cos(60)
-0.9524129804151563
>>> pi
Traceback (most recent call last):
  File "<stdin>", line 1, in <module>
NameError: name 'pi' is not defined
>>> from math import *
>>> pi
3.141592653589793
```

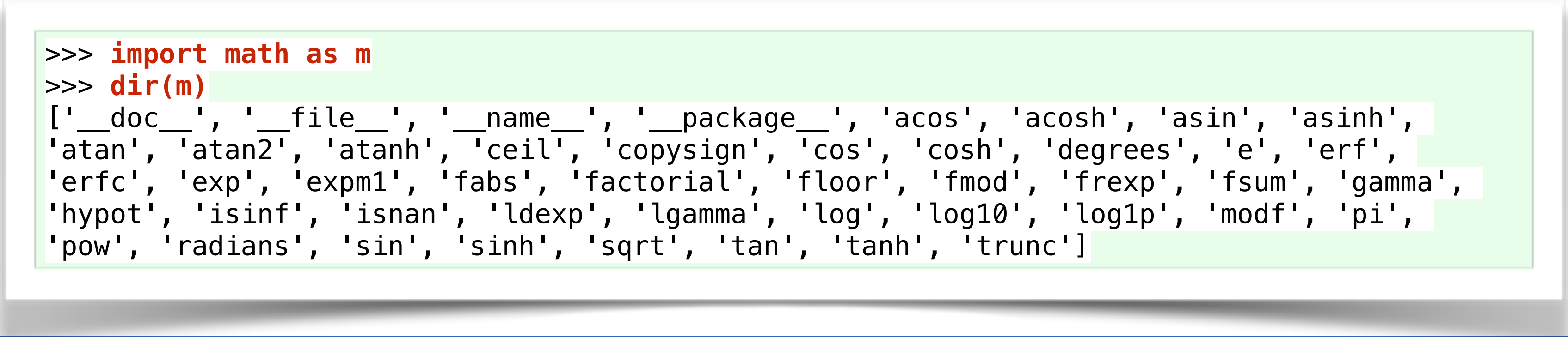
Library: Math

- This module is always available. It provides access to the mathematical functions defined by the C standard.



```
>>> cos(30)
Traceback (most recent call last):
  File "<stdin>", line 1, in <module>
NameError: name 'cos' is not defined
>>> import math
>>> math.cos(30)
0.15425144988758405
>>> math.pi
3.141592653589793
```

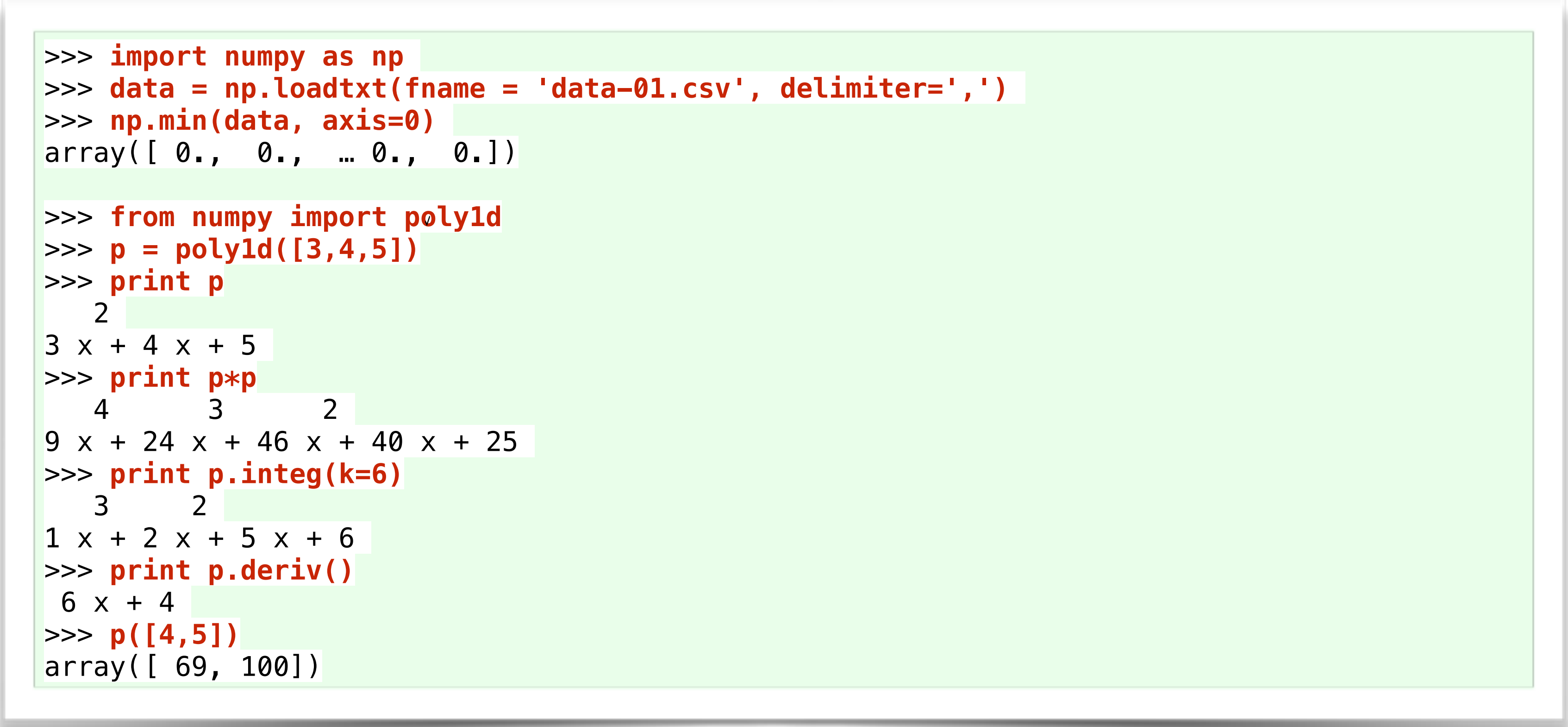
- A long library name can be shorten as an alias



```
>>> import math as m
>>> dir(m)
['__doc__', '__file__', '__name__', '__package__', 'acos', 'acosh', 'asin', 'asinh',
'atan', 'atan2', 'atanh', 'ceil', 'copysign', 'cos', 'cosh', 'degrees', 'e', 'erf',
'erfc', 'exp', 'expm1', 'fabs', 'factorial', 'floor', 'fmod', 'frexp', 'fsum', 'gamma',
'hypot', 'isinf', 'isnan', 'ldexp', 'lgamma', 'log', 'log10', 'log1p', 'modf', 'pi',
'pow', 'radians', 'sin', 'sinh', 'sqrt', 'tan', 'tanh', 'trunc']
```

Library: NumPy

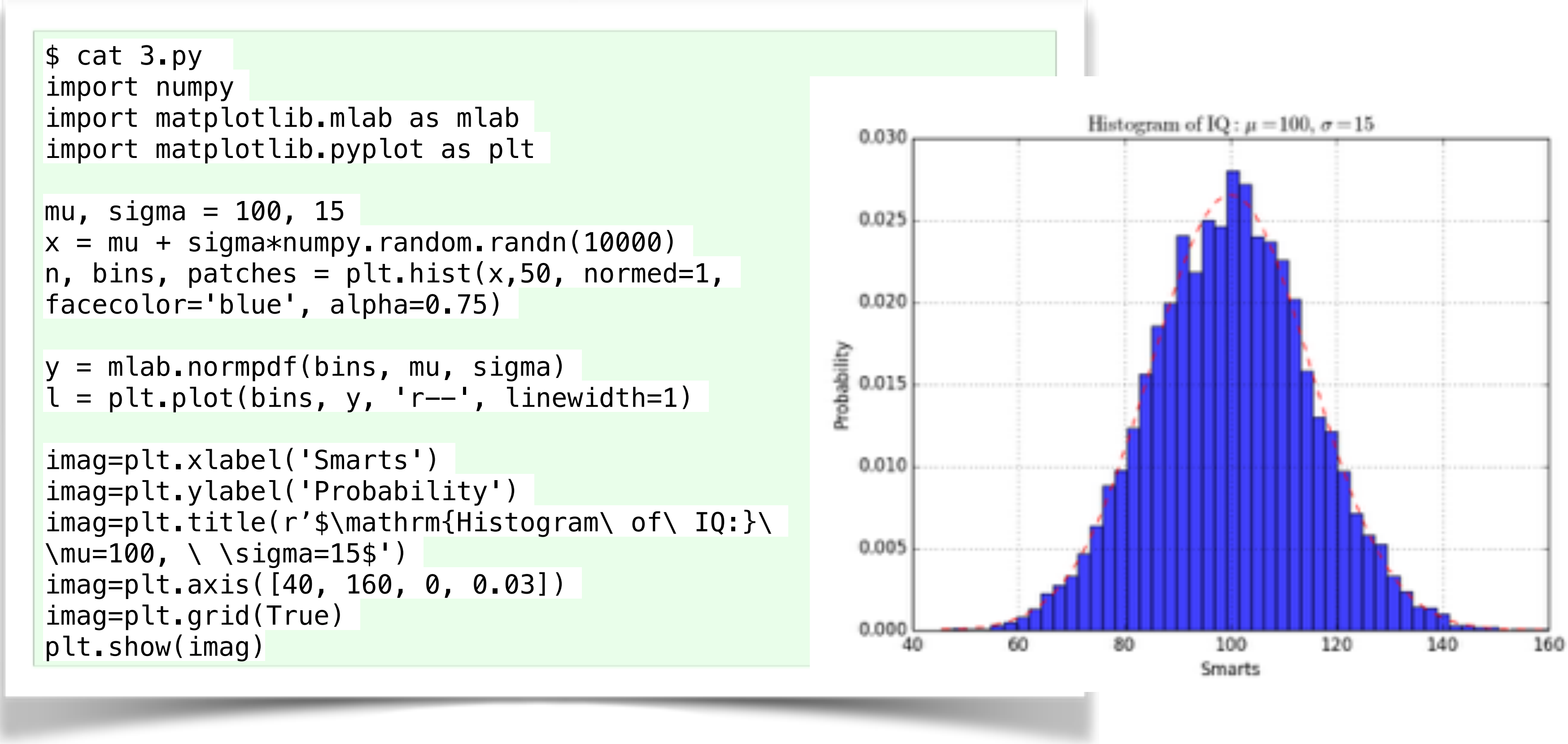
- Offers Matlab-ish capabilities within Python
- Fast array operations
- 2D arrays, multi-D arrays, linear algebra



```
>>> import numpy as np
>>> data = np.loadtxt(fname = 'data-01.csv', delimiter=',')
>>> np.min(data, axis=0)
array([ 0.,  0.,  … 0.,  0.])

>>> from numpy import poly1d
>>> p = poly1d([3,4,5])
>>> print p
   2
3 x + 4 x + 5
>>> print p*p
   4      3      2
9 x + 24 x + 46 x + 40 x + 25
>>> print p.integ(k=6)
   3     2
1 x + 2 x + 5 x + 6
>>> print p.deriv()
 6 x + 4
>>> p([4,5])
array([ 69, 100])
```

Matplotlib

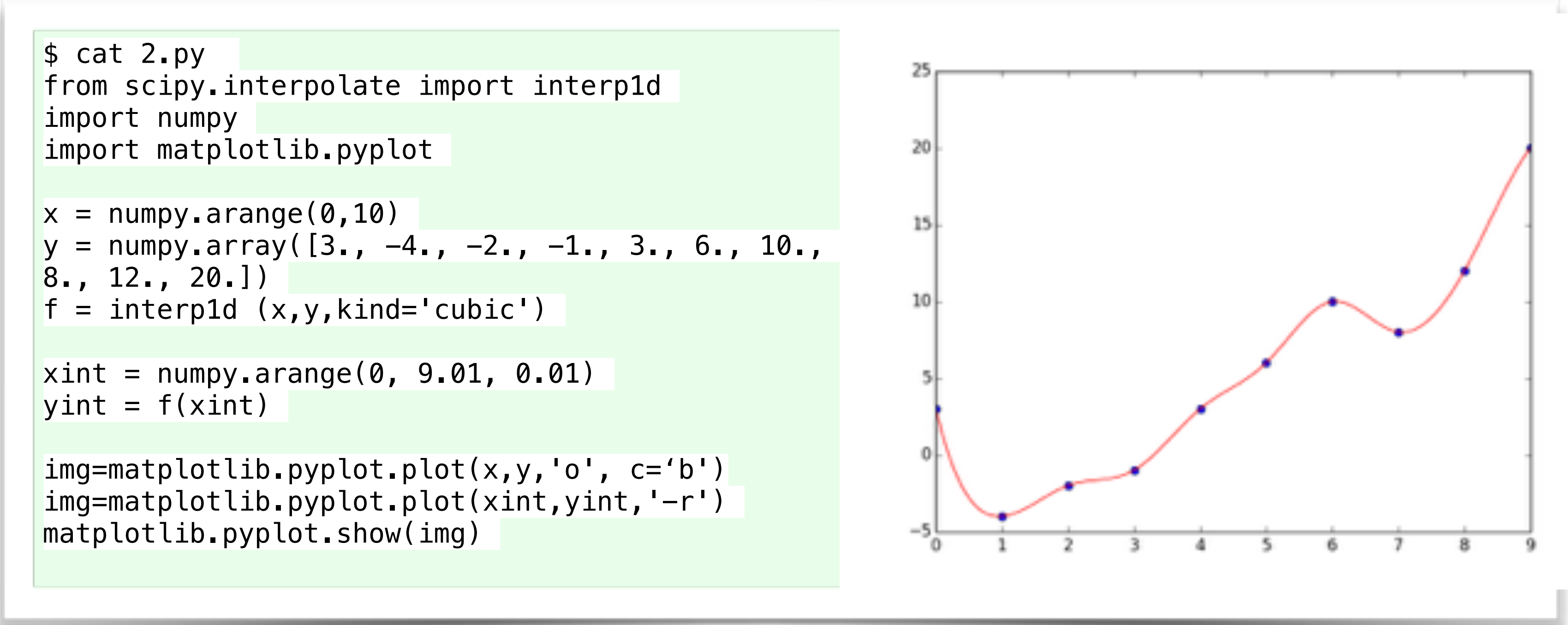
- Plotting vast variety of graphs, starting from histograms to line plots to heat plots. You can also use Latex commands to add math to your plot.



```
$ cat 3.py
import numpy
import matplotlib.mlab as mlab
import matplotlib.pyplot as plt

mu, sigma = 100, 15
x = mu + sigma*numpy.random.randn(10000)
n, bins, patches = plt.hist(x,50, normed=1,
facecolor='blue', alpha=0.75)

y = mlab.normpdf(bins, mu, sigma)
l = plt.plot(bins, y, 'r--', linewidth=1)

imag=plt.xlabel('Smarts')
imag=plt.ylabel('Probability')
imag=plt.title(r’$\mathrm{Histogram\ of\ IQ:}\
\mu=100, \ \sigma=15$')
imag=plt.axis([40, 160, 0, 0.03])
imag=plt.grid(True)
plt.show(imag)
```

SciPY

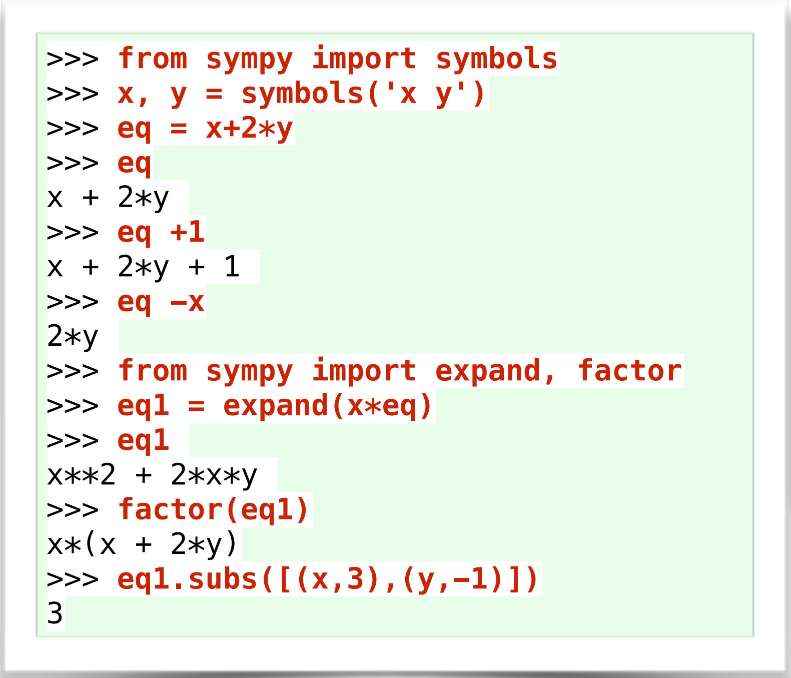
- SciPy contains additional routines needed in scientific work: for example, routines for computing integrals numerically, solving differential equations, optimization, and sparse matrices (note: Scipy sub-packages need to be imported separately)



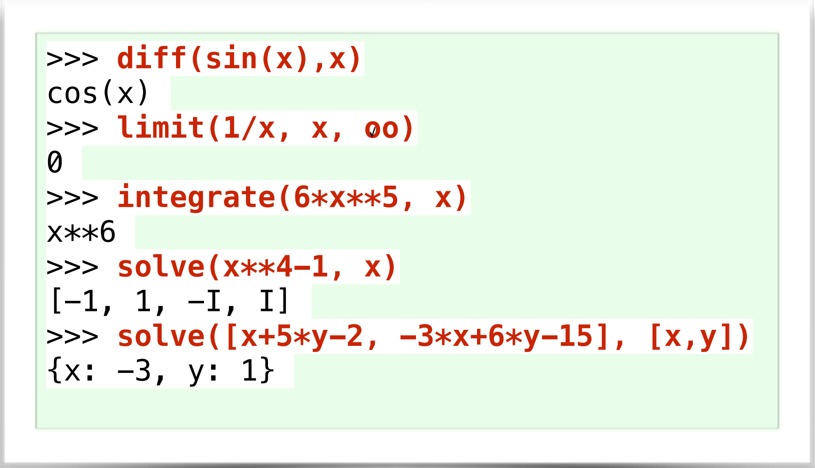
```
$ cat 2.py
from scipy.interpolate import interp1d
import numpy
import matplotlib.pyplot

x = numpy.arange(0,10)
y = numpy.array([3., -4., -2., -1., 3., 6., 10.,
8., 12., 20.])
f = interp1d (x,y,kind='cubic')

xint = numpy.arange(0, 9.01, 0.01)
yint = f(xint)

img=matplotlib.pyplot.plot(x,y,'o', c=‘b')
img=matplotlib.pyplot.plot(xint,yint,'-r')
matplotlib.pyplot.show(img)
```

SymPy

- SymPy is a Python library for symbolic mathematics. Symbolic computation deals with the computation of mathematical objects symbolically. This means that the mathematical objects are represented exactly. (note: It is an extra feature so that you may need to install it)



```
>>> from sympy import symbols
>>> x, y = symbols('x y')
>>> eq = x+2*y
>>> eq
x + 2*y
>>> eq +1
x + 2*y + 1
>>> eq -x
2*y
>>> from sympy import expand, factor
>>> eq1 = expand(x*eq)
>>> eq1
x**2 + 2*x*y
>>> factor(eq1)
x*(x + 2*y)
>>> eq1.subs([(x,3),(y,-1)])
3
```



```
>>> diff(sin(x),x)
cos(x)
>>> limit(1/x, x, oo)
0
>>> integrate(6*x**5, x)
x**6
>>> solve(x**4-1, x)
[-1, 1, -I, I]
>>> solve([x+5*y-2, -3*x+6*y-15], [x,y])
{x: -3, y: 1}
```

compute | calcul
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Thank you!