Ricardo Aler Mur

- This is a introductory tutorial for Python.
- There are many possibilities for using Python. In this case, and for the rest of the course, Jupyter notebooks will be used. The Anaconda environment will be used because it already contains many of the Machine Learning libraries.
- First, Python object types are introduced, including strings, lists and slicing operations. It is important to remark that numpy is not explained here.
- Then, control sentences are explained (if, while, for, …) and also higher order functions that, in some cases, can be used instead of loops.
- Files (input / output operations) are explained at the end.

A Tutorial on the Python Programming Language

by Ricardo Aler

What is Python?

- General-purpose, high-level programming language
- Code is very readable
- Includes different ways of programming:
  - Object-oriented
  - Imperative
  - Functional programming
- Python 2.x (2.7) vs. Python 3.x: most scientific packages

Languages for data analysis poll

2015 primary programming language:	
R (and its packages) (263)	51% (of 2015 votes)
Python (including scikit-learn and other libraries) (151)	29%
Other (Java, MATLAB, SAS, Scala, etc) (89)	17%
none (9)	1.8%
2014 primary programming language:	
R (and its packages) (237)	46% (of 2014 votes)
Python (including scikit-learn and other libraries) (117)	23%
Other (Java, MATLAB, SAS, Scala, etc) (118)	23%
none (40)	7.8%

Here is a more detailed analysis:

Python for Big Data

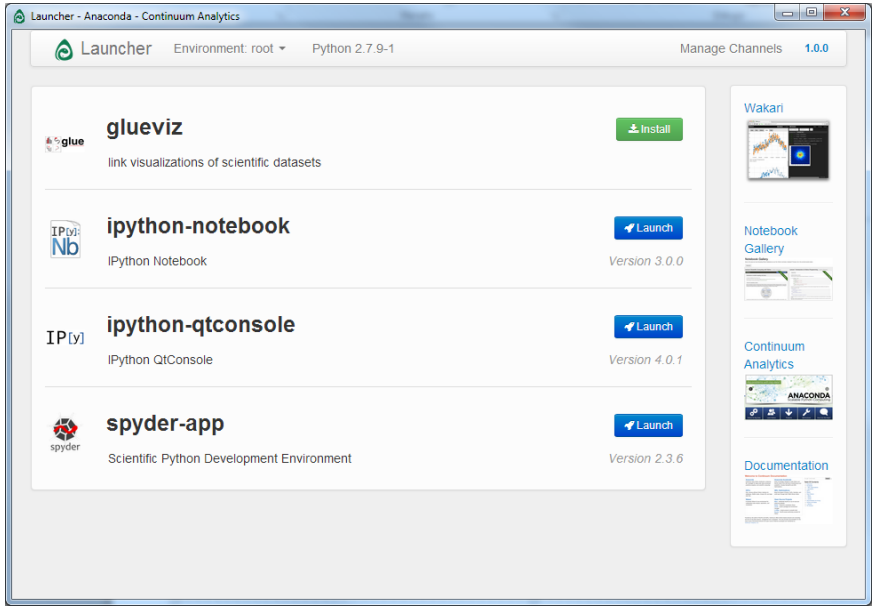
- Why Python?
- Many scientific and machine learning packages: NumPy, SciPy, scikit-learn
- Also, nice interface for Spark (pyspark)
  - R's interface is not so well developed yet

Presentation Overview

- Anaconda (Python + machine learning packages)
- Data Types
- Control Flow
- Functions
- Files
- Modules

ANACONDA

- Free Python distribution. It includes over 300 of the most popular Python packages for science, math, engineering, data analysis.
- Launcher:
  - Ipython-qtconsole
  - Ipython-notebook
  - Spyder-app:
    - edit text files containing programs
    - + console

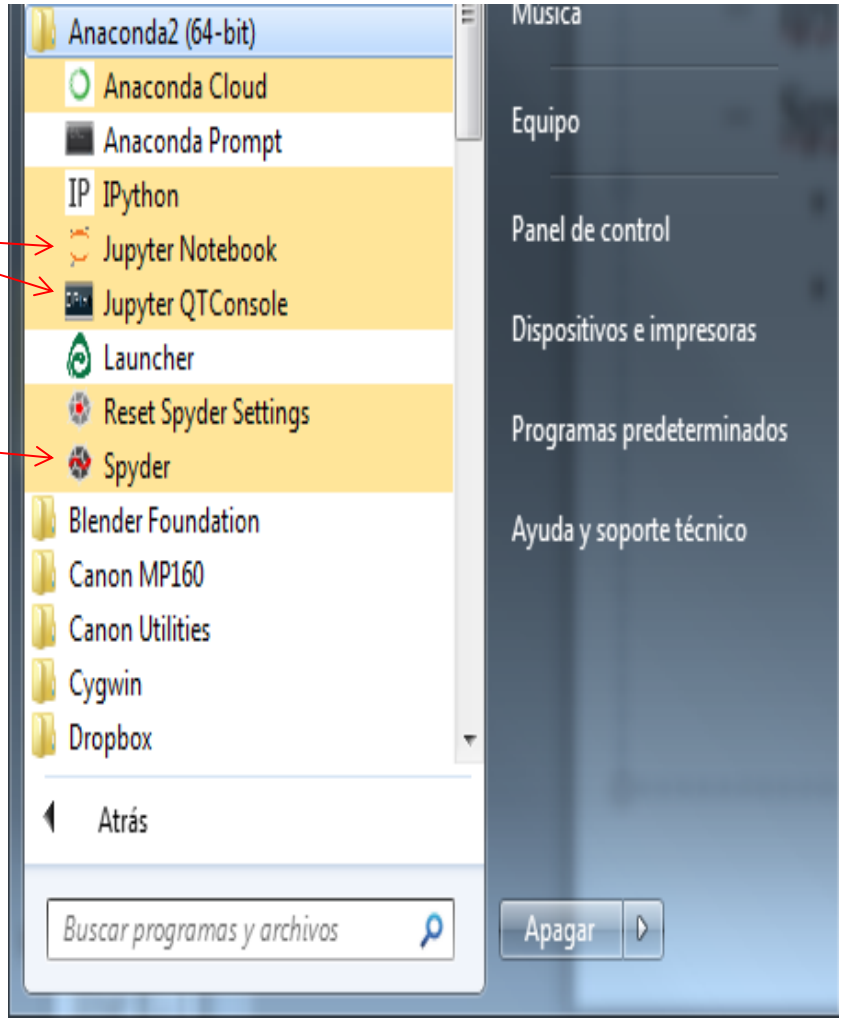


Install from: http://continuum.io/downloads

Remember to select Python 2.7!!

ANACONDA

- If Launcher does not work, start applications directly from Windows initial menu
- Ipython-qtconsole
- Ipython-notebook
  - **Jupyter**
- Spyder-app:
  - edit text files containing programs
  - + console



Interactive vs. Scripts

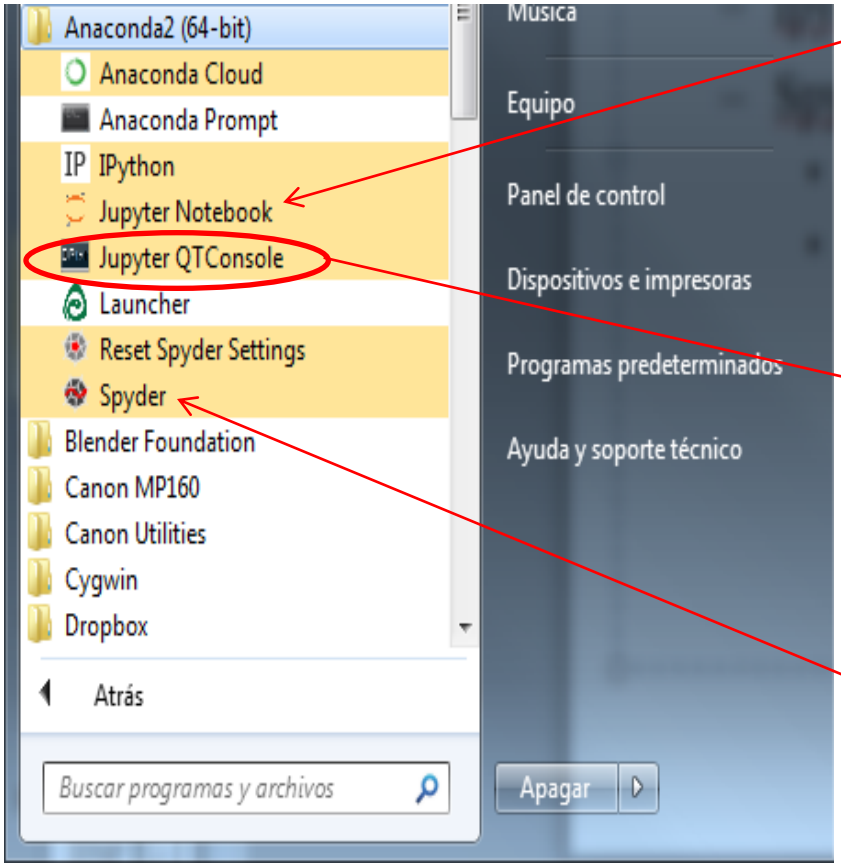
- Interactive: typing Python commands in the console (or the notebook) and obtaining an answer

- Script: a program is created using a text editor (for instance, with *spyder*)

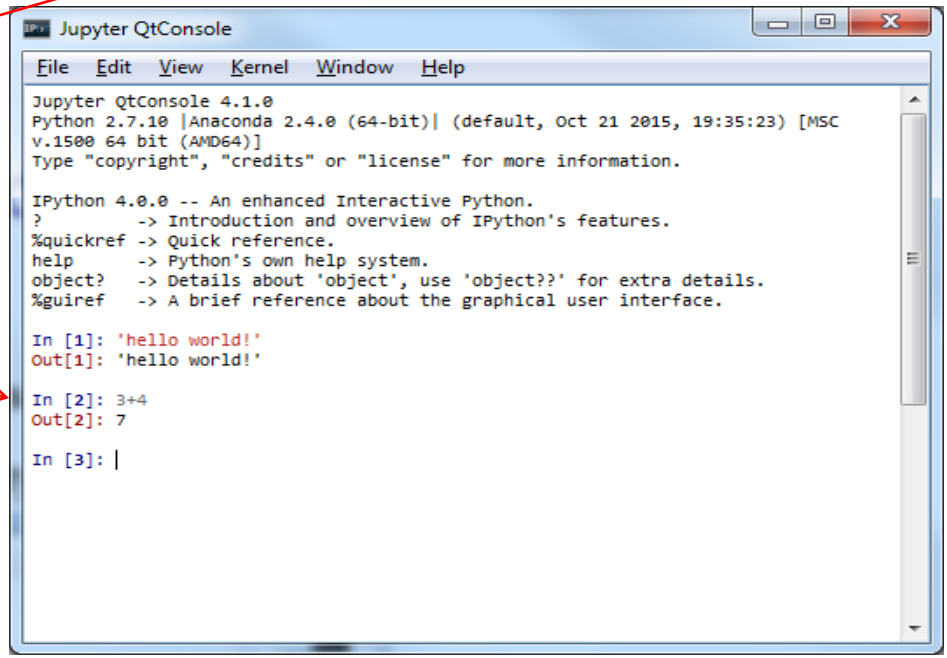
```
>>> 'hello world!'

'hello world!'
```

Interactive use: Hello World

- Open **Ipython-qtconsole** / Jupyter QTconsole
- At the prompt type ‘hello world!’



Like the qtconsole, but for the web browser



Like the qtconsole, but with a text editor (and a whole programming environment)

The Python Interpreter

- Python is an interpreted language
- The interpreter provides an interactive environment to play with the language
- Results of expressions are printed on the screen

```
>>> 3 + 7
10
>>> 3 < 15
True
>>> 'print me'
'print me'
>>> print 'print me'
print me
>>>
```

Help

help(“print”)

Exercise

- Start the ipython-qtconsole
- Compute 3+4 and see the answer
- See the help of “print”

Importing Modules

- Sometimes, some functions are not directly available in Python
- They are included in modules
- Modules have to be imported in order to use its functions
- Example: '+' is included in base Python, but square root (*sqrt*). *sqrt* is included in module math

Importing Modules

If we try to use *sqrt*, we get an error:

```
In [1]: sqrt(2)
---------------------------------------------------------------------------
NameError Traceback (most recent call last)
<ipython-input-1-40e415486bd6> in <module>()
----> 1 sqrt(2)


NameError: name 'sqrt' is not defined
```

Importing Modules

Let's import module *math*, and use the *sqrt* function within this module, by means of the dot (.) notation

```
In [2]: import math


In [3]: math.sqrt(2)
Out[3]: 1.4142135623730951
```

The print Statement

- It can be used to print results and variables
- Elements separated by commas print with a space between them
- A comma at the end of the statement (print ‘hello’,) will not print a newline character

```
>>> print 'hello'
hello
>>> print 'hello', 'there'
hello there
```

Documentation

The ‘#’ starts a line comment

```
>>> 'this will print'
'this will print'
>>> #'this will not'
>>>
```

Exercise

- Modules contain functions, but also constants, like pi
- Import module math, assign 2*pi to variable my_pi, and print the result

```
In [29]: import math
In [30]: math.pi
Out[30]: 3.141592653589793

In [34]: my_pi = 2*math.pi
In [35]: my_pi
Out[35]: 6.283185307179586
In [36]: print(my_pi)
6.28318530718
In [37]: print(2*math.pi)
6.28318530718
```

Variables

- The variable is created the first time you assign it a value
- Everything in Python is an object

```
>>> x = 12
>>> y = " lumberjack "
>>> x
12
>>> y
’ lumberjack ’
```

Object types in Python

- Atomic: numbers, booleans (true, false), …
- Container: (contains other elements)
  - Sequences:
    - Strings: “Hello World!”
    - Lists: [1, 2, “three”]
    - Tuples: (1, 2, “three”)
  - Sets: {'a', 'b', 'c'}
  - Dictionaries: {“R”: 51, “Python”: 29}

Object types in Python with numpy module

- Container:
  - Vectors and matrices:

```
array([[1, 2, 3],
       [4, 5, 6]])
```

Object types in Python with Pandas module

- Container:
  - Dataframes:

	SepalLength	SepalWidth	PetalLength	PetalWidth	Name
0	5.1	3.5	1.4	0.2	Iris-setosa
1	4.9	3.0	1.4	0.2	Iris-setosa
2	4.7	3.2	1.3	0.2	Iris-setosa
3	4.6	3.1	1.5	0.2	Iris-setosa
4	5.0	3.6	1.4	0.2	Iris-setosa

Object types in Python

- Atomic: **numbers**, booleans (true, false), …
- Compound:
  - Sequences:
    - Strings: “Hello World!”
    - Lists: [1, 2, “three”]
    - Tuples: (1, 2, “three”)
  - Sets: {'a', 'b', 'c'}
  - Dictionaries: {“R”: 51, “Python”: 29}

Numbers

- integer: 12345, -32
- Python integer: 999999999L
- float: 1.23, 4e5, 3e-4
- octal: 012, 0456
- hex: 0xf34, 0X12FA
- complex: 3+4j, 2J, 5.0+2.5j

Operations with numbers:

- +, -, *, /
- **: power
- // integer division
- % division remainder
- …

```
>>> 123 + 222                # Integer addition
345
>>> 1.5 * 4                  # Floating-point multiplication
6.0
>>> 2 ** 100                 # 2 to the power 100
1267650600228229401496703205376
```

Object types in Python

- Atomic: numbers, **booleans (true, false),** …
- Compound:
  - Sequences:
    - Strings: “Hello World!”
    - Lists: [1, 2, “three”]
    - Tuples: (1, 2, “three”)
  - Sets: {'a', 'b', 'c'}
  - Dictionaries: {“R”: 51, “Python”: 29}

Booleans

Whether an expression is true or false

- Values: True, False

Comparisons: ==, <=, >=, !=, …

```
In [18]: 3 == 3
Out[18]: True

In [19]: 3 == 4
Out[19]: False

In [20]: 3 < 4
Out[20]: True

In [21]: "aa" < "bb"
Out[21]: True
```

Combinations: and, or, not

```
In [26]: (3 == 3) and (3 < 4)
Out[26]: True

In [27]: (3 == 3) or (3 < 4)
Out[27]: True

In [28]: not((3 == 3) or (3 < 4))
Out[28]: False
```

Booleans

- Notes:
  - 0 and None are false
  - Everything else is true
  - True and False are just aliases for 1 and 0 respectively

Object types in Python

- Atomic: numbers, booleans (true, false), …
- Container:
  - Sequences:
    - **Strings:** “Hello World!”
    - Lists: [1, 2, “three”]
    - Tuples: (1, 2, “three”)
  - Sets: {'a', 'b', 'c'}
  - Dictionaries: {“R”: 51, “Python”: 29}

String Literals

- They can be defined either with double quotes (“) or single quotes (‘)

```
In [30]: "Hello world"
Out[30]: 'Hello world'

In [31]: 'hello world'
Out[31]: 'hello world'
```

- + is overloaded to do concatenation

```
>>> x = 'hello'
>>> x = x + ' there'
>>> x
'hello there'
```

String Literals: multi-line

- Using triple quotes, strings can be defined across multiple lines

```
>>> s = """ I’m a string
much longer
than the others"""

>>> print s
 I’m a string
though I am much longer
than the others :)‘
```

Strings: some functions

- **len**(string) – returns the number of characters in the String
- **str**(object) – returns a String representation of the Object

```
In [56]: x = 'ABCDEF'
In [57]: len(x)
Out[57]: 6
In [58]: str(10.1)
Out[58]: '10.1'
```

Strings: some functions

- Some string functions are available only within a module, and the dot (.) notation must be used (similarly to *math.sqrt()*). The module for strings is called *str*. This module is imported automatically by the system.
- For instance, *lower()* and *upper()* are two such functions:

```
In [73]: x = 'It was the best of times, it was the worst of times‘

In [74]: str.lower(x.lower)            # Convert to lowercase
Out[74]: 'it was the best of times, it was the worst of times‘

In [75]: str.upper(x)                  # Convert to uppercase
Out[75]: 'IT WAS THE BEST OF TIMES, IT WAS THE WORST OF TIMES'
```

String functions

- Other string functions: *count*, *split*, *replace*

```
In [73]: x = 'It was the best of times, it was the worst of times'

In [77]: str.count(x, 'was')            # count counts how many times ‘was’ appears in x
Out[77]: 2

In [79]: print(str.split(x, ' '))       # split splits string x with space ‘ ‘ separator
['It', 'was', 'the', 'best', 'of', 'times,', 'it', 'was', 'the', 'worst', 'of', 'times']

In [80]: str.replace(x, 'was', 'is') # replace replaces ‘was’ by ‘is’ wherever it appears in x
Out[80]: 'It is the best of times, it is the worst of times'
```

String functions

IMPORTANT!!

- Typically, if you can call a function as module.function(object, other arguments), you can also use another equivalente (but shorter) syntax: object.function(other arguments)
- That is, there are two different (but equivalent) ways:
  1. object.function(arguments)
  2. module.function(object, arguments) # We already know this one
- Examples:

```
In [32]: x = 'It was the best of times, it was the worst of times'
```

```
In [33]: x.lower()
Out[33]: 'it was the best of times, it was the worst of times‘

In [34]: # is equivalent to

In [35]: str.lower(x)
Out[35]: 'it was the best of times, it was the worst of times'
```

```
In [36]: x.upper()
Out[36]: 'IT WAS THE BEST OF TIMES, IT WAS THE WORST OF TIMES‘

In [37]: # is equivalent to

In [38]: str.upper(x)
Out[38]: 'IT WAS THE BEST OF TIMES, IT WAS THE WORST OF TIMES'
```

String functions: 2 ways

IMPORTANT!!

- That is, there are two different (but equivalent) ways:
  1. object.function(arguments)
  2. module.function(object, arguments) # We already know this one
- Note: Use dir(‘ ‘) to see all methods for strings (dir(3) shows all methods for integers, etc.)
- Examples:

```
In [32]: x = 'It was the best of times, it was the worst of times'
```

```
In [39]: x.count('was')
Out[39]: 2

In [40]: # is equivalent to

In [41]: str.count(x, 'was')
Out[41]: 2
```

```
In [45]: x.replace('was', 'is')
Out[45]: 'It is the best of times, it is the worst of times'

In [46]: # is equivalent to:

In [47]: str.replace(x, 'was', 'is')
Out[47]: 'It is the best of times, it is the worst of times
```

```
In [42]: print(x.split(' '))
['It', 'was', 'the', 'best', 'of', 'times,', 'it', 'was', 'the', 'worst', 'of', 'times']

In [43]: # is equivalent to:

In [44]: print(str.split(x, ' '))
['It', 'was', 'the', 'best', 'of', 'times,', 'it', 'was', 'the', 'worst', 'of', 'times']
```

String functions: 2 ways

IMPORTANT!!

- That is, there are two different (but equivalent) ways:
  1. object.function(arguments)
  2. module.function(object, arguments) # We already know this one

```
In [39]: x.count('was')
Out[39]: 2

In [40]: # is equivalent to

In [41]: str.count(x, 'was')
Out[41]: 2
```

a) Notice that the first way is shorter and you don't need to remember the name of the module (*str*)
b) Only those methods listed with *dir*('was') can be used

Exercise: string functions

- Split a sentence *x* using both syntax cases:
  - First case: using *split* as a function of *x* (*x.split*)
  - Second case: using *split* as a function of module *str* (*str.split(x)*)

```
In [12]: x = 'It was the best of times, it was the worst of times'
In [13]: x
Out[13]: 'It was the best of times, it was the worst of times'
```

```
In [14]: # First case
In [15]: x.split(' ')
Out[15]:
['It',
'was',
'the',
'best',
'of',
'times,',
'it',
'was',
'the',
'worst',
'of',
'times']
```

```
In [16]: # Second case: split as function of module str
In [17]: str.split(x, ' ')
Out[17]:
['It',
'was',
'the',
'best',
'of',
'times,',
'it',
'was',
'the',
'worst',
'of',
'times']
```

Positive indices	0	1	2	3	4	5
s	‘0’	‘1’	‘2’	‘3’	‘4’	‘5’

Substrings (slicing)

Slicing = obtaining substrings from strings

```
>>> s = '012345'
>>> s[0]
‘0’
>>> s[1]
‘1’
>>> s[3]
'3'
>>> s[1:4]
'123'
```

- Generic slicing sentence: s[start:end:by]
  - Obtain elements from *start* to *(end-1)* with steps of “*by*”
- IMPORTANT*:*
  - *start* begins at 0!!
  - The slice (or substring) includes values from *start* to *end-1*!!!
- *start* >= 0
- *end* < *len(s)*
- *by*: step

Positive indices	0	1	2	3	4	5
Negative indices	-6	-5	-4	-3	-2	-1
s	‘0’	‘1’	‘2’	‘3’	‘4’	‘5’

Substrings (slicing)

```
>>> s = '012345'
>>> s[2:]
'2345'
>>> s[:4]
'0123'
>>> s[-1]
‘5‘
>>> s[-2]
‘4’
>>> s[-6]
‘0’
```

Generic sentence: s[start:end:by]

Excluding *start* or *end* is the same as index 0 or last index, respectively

s[2:] == s[2:6] == s[2:len(s)]
s[:4] == s[0:4]

Negative indices start at the end of the string

s[-1] == s[5] == s[len(s)-1]
s[-2] == s[4] == s[len(s)-2]
s[-6] = s[-len(s)] == s[0]

Substrings (slicing)

Slicing = obtaining sublists from strings (or from lists)

Positive indices	0	1	2	3	4	5
Negative indices	-6	-5	-4	-3	-2	-1
s	‘0’	‘1’	‘2’	‘3’	‘4’	‘5’
string2	‘A’	‘B’	‘C’	‘D’	‘E’	‘F’

```
>>> string2 = ‘ABCDEF'
>>> string2[2:]
‘CDEF'
>>> s[:4]
‘ABCDE'
```

```
>>> string2[-1]
‘F‘
>>> string2[-2]
‘E’
>>> string2[-6]
‘A’
```

Substrings (slicing)

- Generic sentence: s[start:end:**by**]
- by: step

```
>>> s = '012345'
>>> s[0:4:2]
‘02'
>>> s[0::2]
‘024'
>>> s[-1::-1]
‘543210’
>>> s[-1::-2]
‘531'
```

Get indices from 0 to 3 by 2 (even indices)

Get indices from 0 to end by 2 (even indices)

Get indices from end to beginning by -1 (reverse order)

Get indices from end to beginning by -2 (indices 5, 3, 1 (or equivalently -1, -3, -5)

Exercise

1. Create any string, for instance:

   ‘In a village of La Mancha, the name of which I have no desire to call to mind’

2. Convert it to uppercase:

   'IN A VILLAGE OF LA MANCHA, THE NAME OF WHICH I HAVE NO DESIRE TO CALL TO MIND'

3. Obtain another string by keeping one character every four characters (via slicing):

   'I L LAAHAOH ANEE L D'

Exercise: solution

```
In [76]: x = 'In a village of La Mancha, the name of which I have no desire to call to mind'

In [77]: x = x.upper()

In [78]: x
Out[78]: 'IN A VILLAGE OF LA MANCHA, THE NAME OF WHICH I HAVE NO
DESIRE TO CALL TO MIND'

In [79]: y = x[0::4]

In [80]: y
Out[80]: 'I L LAAHAOH ANEE L
```

String Formatting (1): %

- Similar to C's printf
- <formatted string> % <elements to insert>
- Can usually just use %s for everything, it will convert the object to its String representation.

```
>>> "One, %d, three" % 2
'One, 2, three'
>>> "%d, two, %s" % (1,3)
'1, two, 3'
>>> "%s two %s" % (1, 'three')
'1 two three'
>>>
```

String Formatting (2): format

- <formatted string>.format(<elements to insert>)

```
>>> "One, {}, three".format(2)
'One, 2, three'
>>> “{}, two, {}".format(1,3)
'1, two, 3'
>>> "{} two {}".format(1, 'three')
'1 two three'
>>> "{0} two {1}".format(1, 'three')
'1 two three‘
>>> "{1} two {0}".format(1, 'three')
'three two 1'
```

Object types in Python

- Atomic: numbers, booleans (true, false), …
- Compound:
  - Sequences:
    - Strings: “Hello World!”
    - **Lists:** [1, 2, “three”]
    - Tuples: (1, 2, “three”)
  - Sets: {'a', 'b', 'c'}
  - Dictionaries: {“R”: 51, “Python”: 29}

Lists

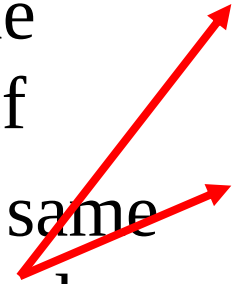
- Ordered collection of data
- Elements can be of different types
- Same subset (slicing) operations as Strings

```
>>> x = [1,'hello', (3 + 2j)]
>>> x
[1, 'hello', (3+2j)]
>>> x[2]
(3+2j)
>>> x[0:2]
[1, 'hello']
```

Lists: Modifying Content

Lists are *mutable* (i.e. they can be modified. Strings cannot)

- **x[i] = a** reassigns the ith element to the value a
- Important: variables contain references (pointers) to the object, not the object itself
- Since *x* and *y* point to the same list object, *both* are changed



```
>>> x = [1,2,3]
>>> y = x
>>> x[1] = 15
>>> x
[1, 15, 3]
>>> y
[1, 15, 3]
```

Lists: references vs. copies

- If a copy is needed instead of a reference, the copy function can be used (import copy)

Reference: x and y are the same thing

```
In [58]: x = [1, 2, 3]
In [59]: y = x

In [60]: x[1] = 15

In [61]: x
Out[61]: [1, 15, 3]
In [62]: y
Out[62]: [1, 15, 3]
```

Copy: a and b are different things

```
In [63]: import copy
In [64]: a = [1, 2, 3]
In [65]: b = copy.deepcopy(a)

In [66]: a[1] = 15

In [67]: a
Out[67]: [1, 15, 3]
In [68]: b
Out[68]: [1, 2, 3]
```

Exercise: lists modifying content

1. Create a variable called *list* with numbers 1, 10, 100, 1000, 10000, 1000000
2. Modify variable *list* via slicing so that 0 appears instead of 1000

Exercise: solution

1. Create a variable called *list* with numbers 1, 10, 100, 1000, 10000, 1000000
2. Modify variable *list* via slicing so that 0 appears instead of 1000

```
In [115]: x = [1,10,100,1000,10000, 1000000]
In [116]: x[3] = 0
In [117]: x
Out[117]: [1, 10, 100, 0, 10000, 1000000]
```

Lists: Modifying Content

Lists are *mutable* (i.e. they can be modified)

- **x[i:j:k] = b** reassigns the sublist defined by *i:j:k* to list *b*

```
In [7]: x = [0, 1, 2, 3, 4, 5]
In [8]: y = x
In [9]: x[1:3] = ['one', 'two', 'three']
In [10]: x
Out[10]: [0, 'one', 'two', 'three', 3, 4, 5]
In [11]: y
Out[11]: [0, 'one', 'two', 'three', 3, 4, 5]
```

Lists: Modifying Content

- **x.append(12)** inserts element *12* at the end of the list
- **x.extend([13, 14])** extends list [12, 13] at the end of the list
- In both cases the original list is modified!!!

```
In [14]: x = [1,2,3]
In [15]: x.append(12)
In [16]: x
Out[16]: [1, 2, 3, 12]
In [18]: x.extend([13, 14])
In [19]: x
Out[19]: [1, 2, 3, 12, 13, 14]
```

- + also concatenates lists, but it does not modify the original list

```
In [20]: y = [1, 2, 3]
In [21]: y + [13, 14]
Out[21]: [1, 2, 3, 13, 14]
In [22]: y
Out[22]: [1, 2, 3]
```

Reminder: two ways of calling functions on objects

- Let us remember that there are two ways of applying functions to lists (just as with strings):
  1. module.function(object, …)
  2. object.method(…)

```
In [27]: x = [1, 2, 3]
In [28]: list.extend(x, [13, 14])
In [29]: x
Out[29]: [1, 2, 3, 13, 14]

# is equivalent to:

In [30]: x = [1, 2, 3]
In [31]: x.extend([13, 14])
In [32]: x
Out[32]: [1, 2, 3, 13, 14]
```

Lists: deleting elements

- Function *del*:

```
In [33]: x = range(10)
In [34]: x
Out[34]: [0, 1, 2, 3, 4, 5, 6, 7, 8, 9]
In [35]: del(x[1])
In [36]: x
Out[36]: [0, 2, 3, 4, 5, 6, 7, 8, 9]
In [37]: del(x[2:4])
In [38]: x
Out[38]: [0, 2, 5, 6, 7, 8, 9]
```

Object types in Python

- Atomic: numbers, booleans (true, false), …
- Compound:
  - Sequences:
    - Strings: “Hello World!”
    - Lists: [1, 2, “three”]
    - **Tuples:** (1, 2, “three”)
  - Sets: {'a', 'b', 'c'}
  - Dictionaries: {“R”: 51, “Python”: 29}

Tuples

- Tuples are *immutable* versions of lists
- One strange point is the format to make a tuple with one element:

  ‘,’ is needed to differentiate from the mathematical expression (2)

```
>>> x = (1,2,3)
>>> x[1:]
(2, 3)
>>> y = (2,)
>>> y
(2,)
>>>
```

Object types in Python

- Atomic: numbers, booleans (true, false), …
- Compound:
  - Sequences:
    - Strings: “Hello World!”
    - Lists: [1, 2, “three”]
    - Tuples: (1, 2, “three”)
  - Sets: {'a', 'b', 'c'}
  - **Dictionaries:** {“R”: 51, “Python”: 29}

Dictionaries

- A set of key-value pairs
- Dictionaries are *mutable*
- Example number of bottles of different drinks
- Access and modification by key

```
In [47]: d = {'milk': 3, 'beer': 21, 'olive oil':
2}
In [48]: d
Out[48]: {'beer': 21, 'milk': 3, 'olive oil': 2}
In [49]: d['milk']
Out[49]: 3
In [50]: d['milk'] = 4
In [51]: d
Out[51]: {'beer': 21, 'milk': 4, 'olive oil': 2}
```

Dictionaries: Add/Delete

- Assigning to a key that does not exist adds an entry:

```
In [52]: d['coffee'] = 3
In [53]: d
Out[53]: {'beer': 21, 'coffee': 3, 'milk': 4, 'olive oil': 2}
```

- Elements can be deleted with *del* (like with lists)

```
In [54]: del(d['beer'])
In [55]: d
Out[55]: {'coffee': 3, 'milk': 4, 'olive oil': 2}
```

Copying Dictionaries and Lists

- The built-in **list** function will copy a list
- The dictionary has a method called **copy**

```
>>> l1 = [1]
>>> l2 = list(l1)
>>> l1[0] = 22
>>> l1
[22]
>>> l2
[1]
```

```
>>> d = {1 : 10}
>>> d2 = d.copy()
>>> d[1] = 22
>>> d
{1: 22}
>>> d2
{1: 10}
```

Data Type Summary

- Lists, Tuples, and Dictionaries are containers that can store any type (including other lists, tuples, and dictionaries!)
- Only lists and dictionaries are mutable
- All variables are references, but copies can be made

A Tutorial on the Python Programming Language

by Ricardo Aler

The print Statement

- It can be used to print results and variables
- Elements separated by commas print with a space between them
- A comma at the end of the statement (print ‘hello’,) will not print a newline character

```
>>> print 'hello'
hello
>>> print 'hello', 'there'
hello there
```

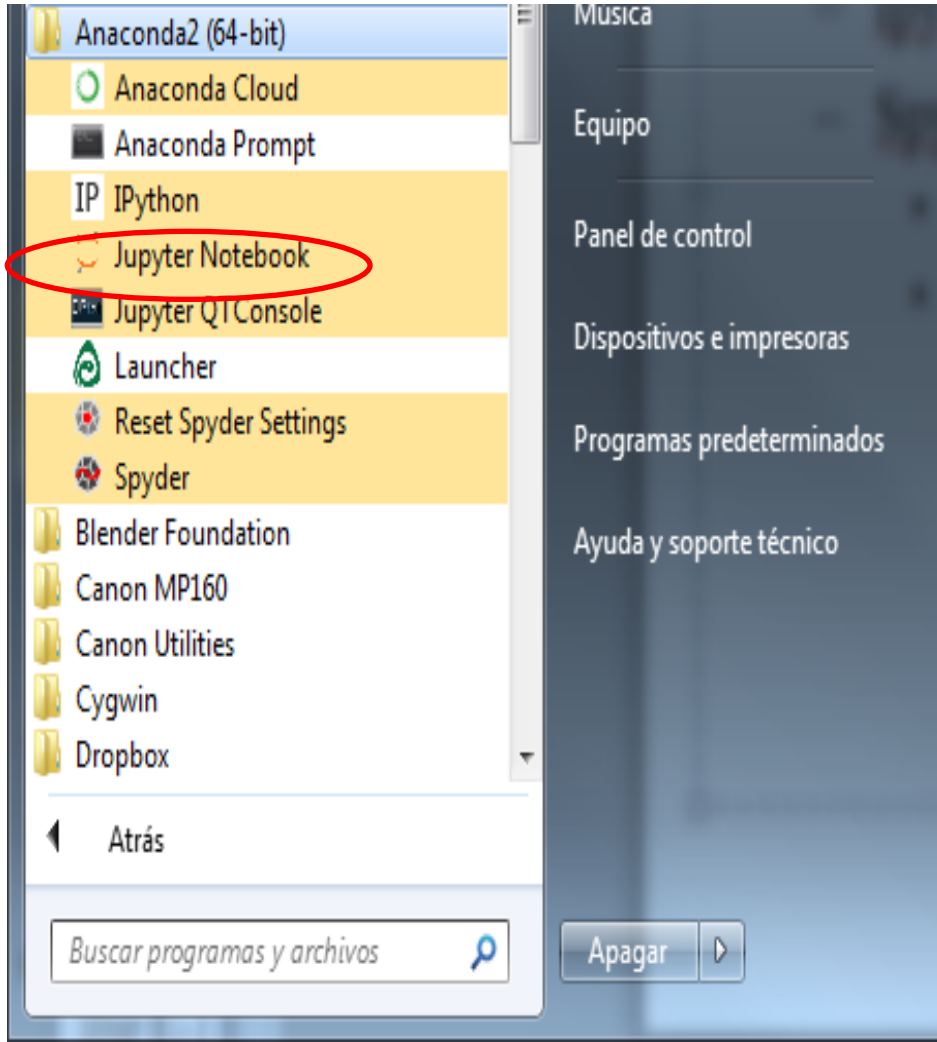
Comments

The ‘#’ starts a line comment

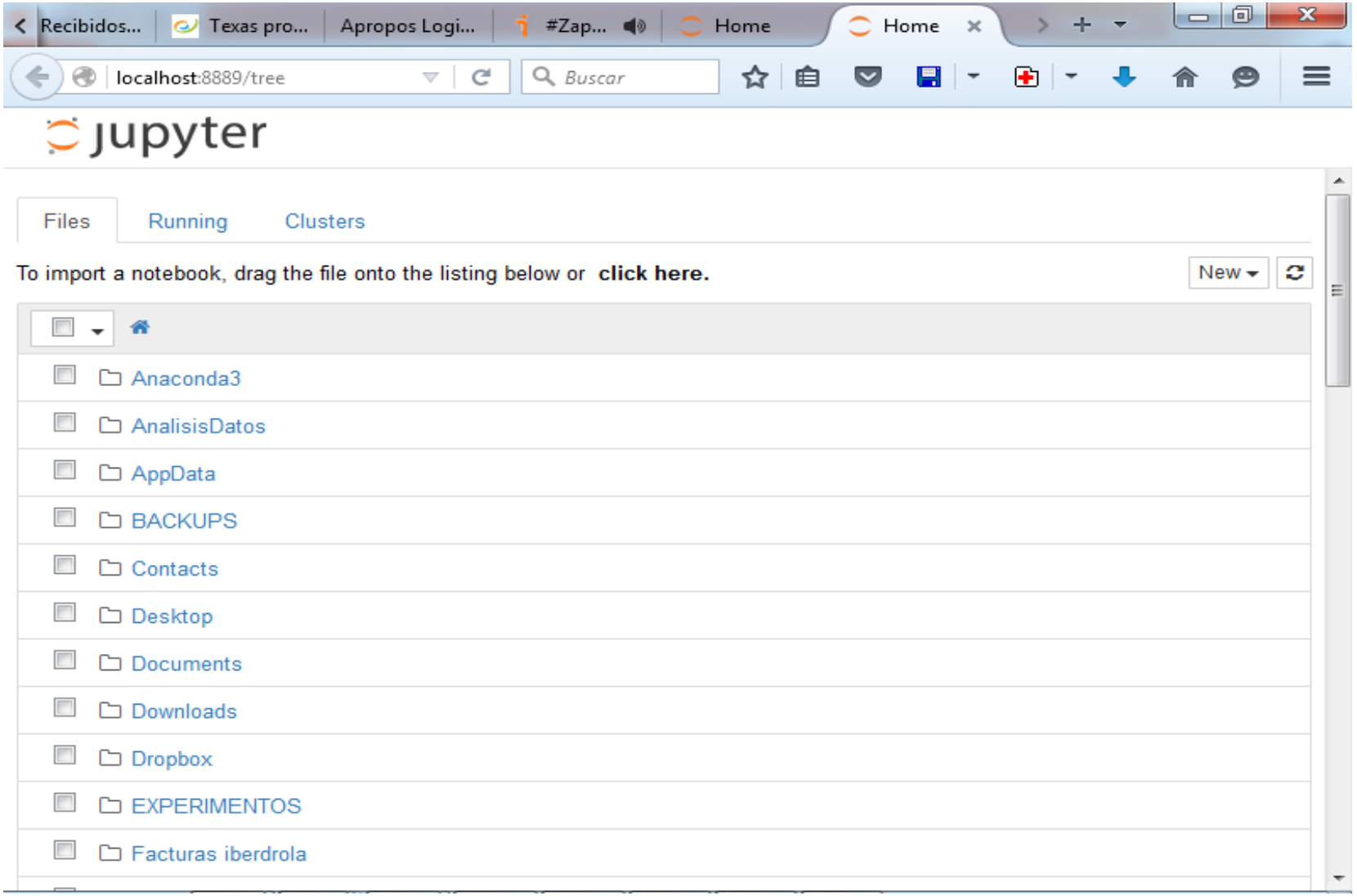
```
>>> 'this will print'
'this will print'
>>> #'this will not'
>>>
```

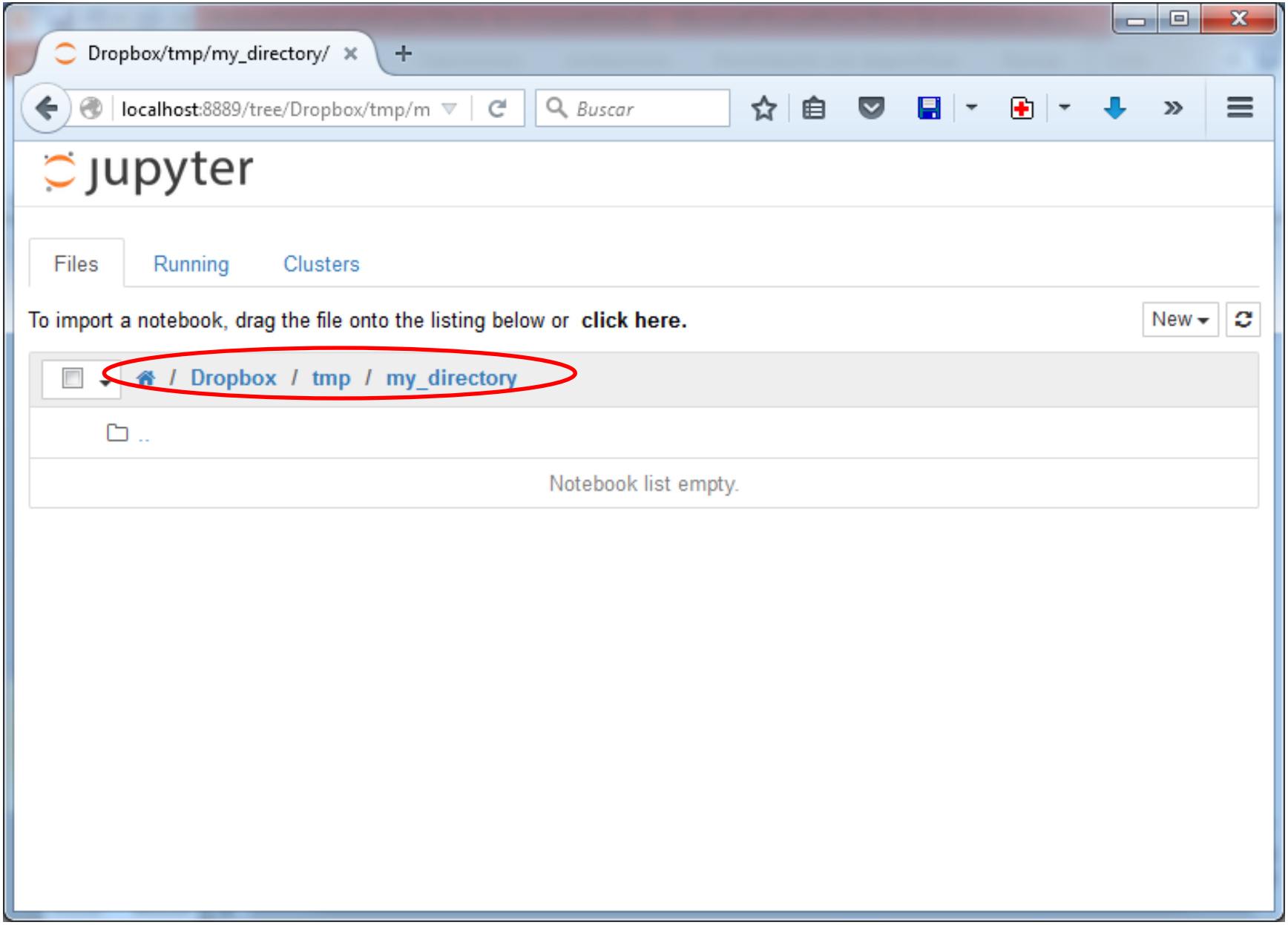
Using the ipython-notebook

- We already know how to use the qt-console
- The ipython-notebook is similar, but works in the **browser**, and allows to keep a record of the Python session

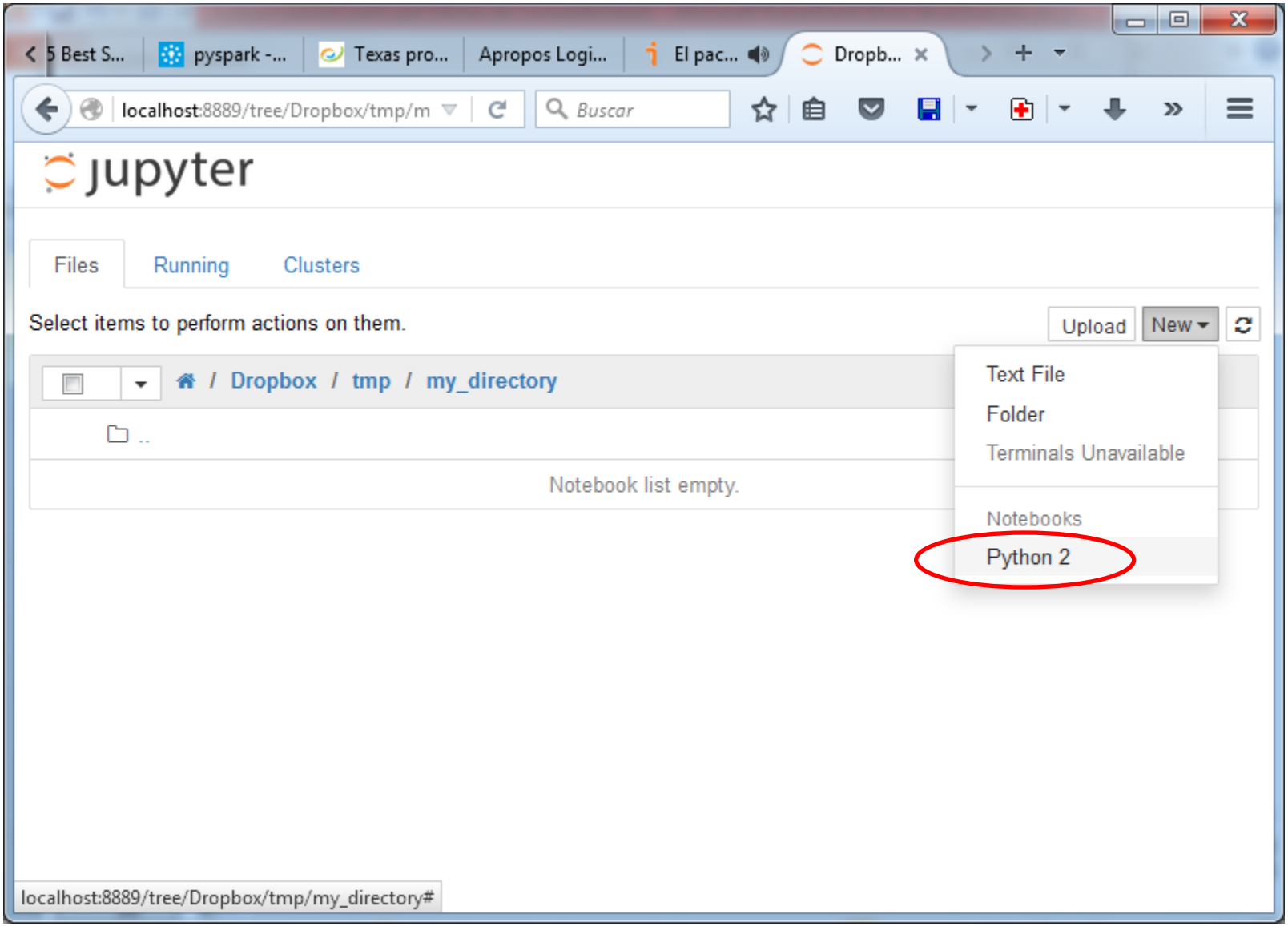


- A new tab will open in your default browser
- Now, you have to go to your directory

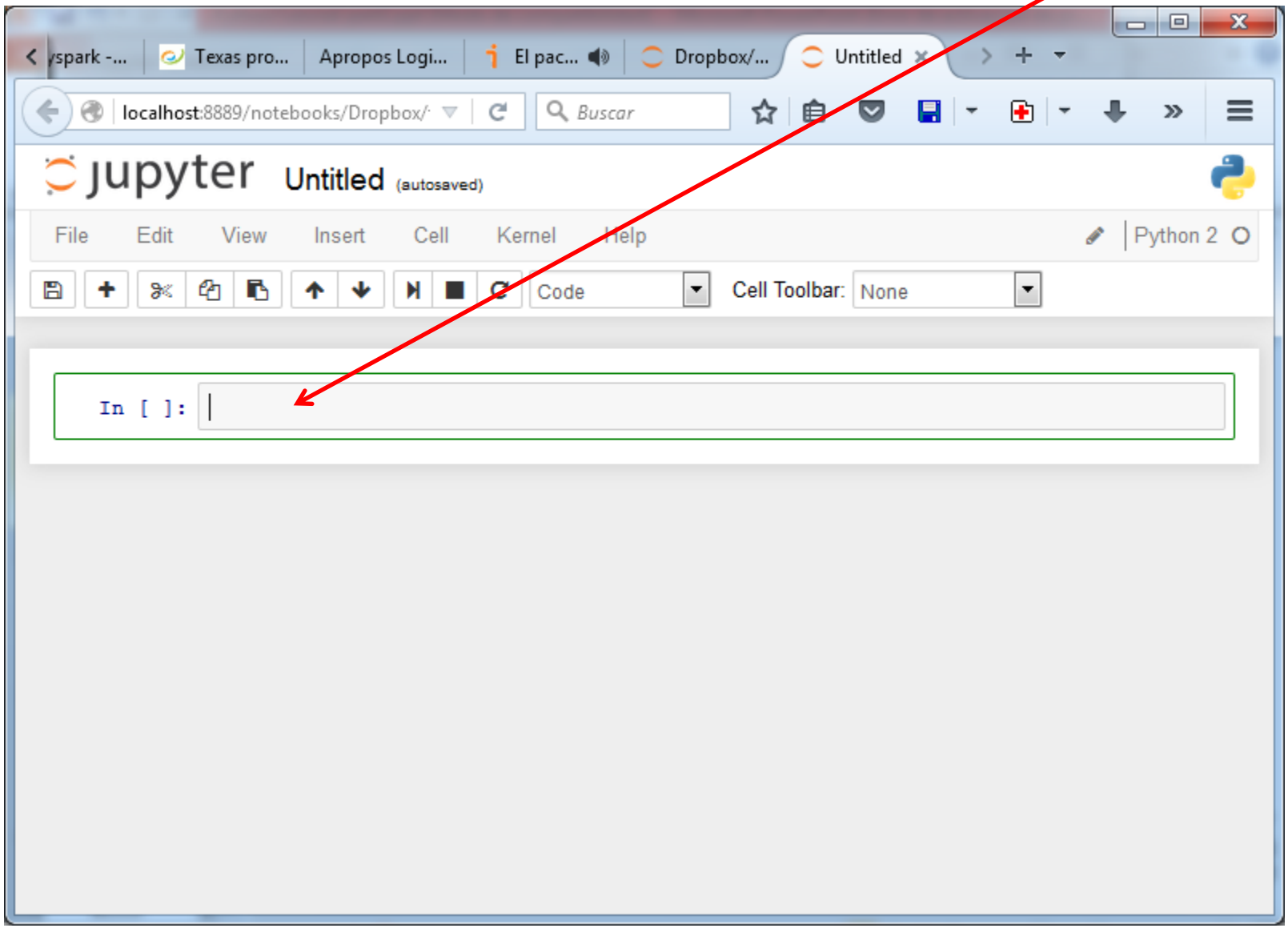



Dropbox/tmp/my_directory/
localhost:8889/tree/Dropbox/tmp/m
Buscar
jupyter
Files
Running
Clusters
To import a notebook, drag the file onto the listing below or click here.
New
/ Dropbox / tmp / my_directory
..
Notebook list empty.

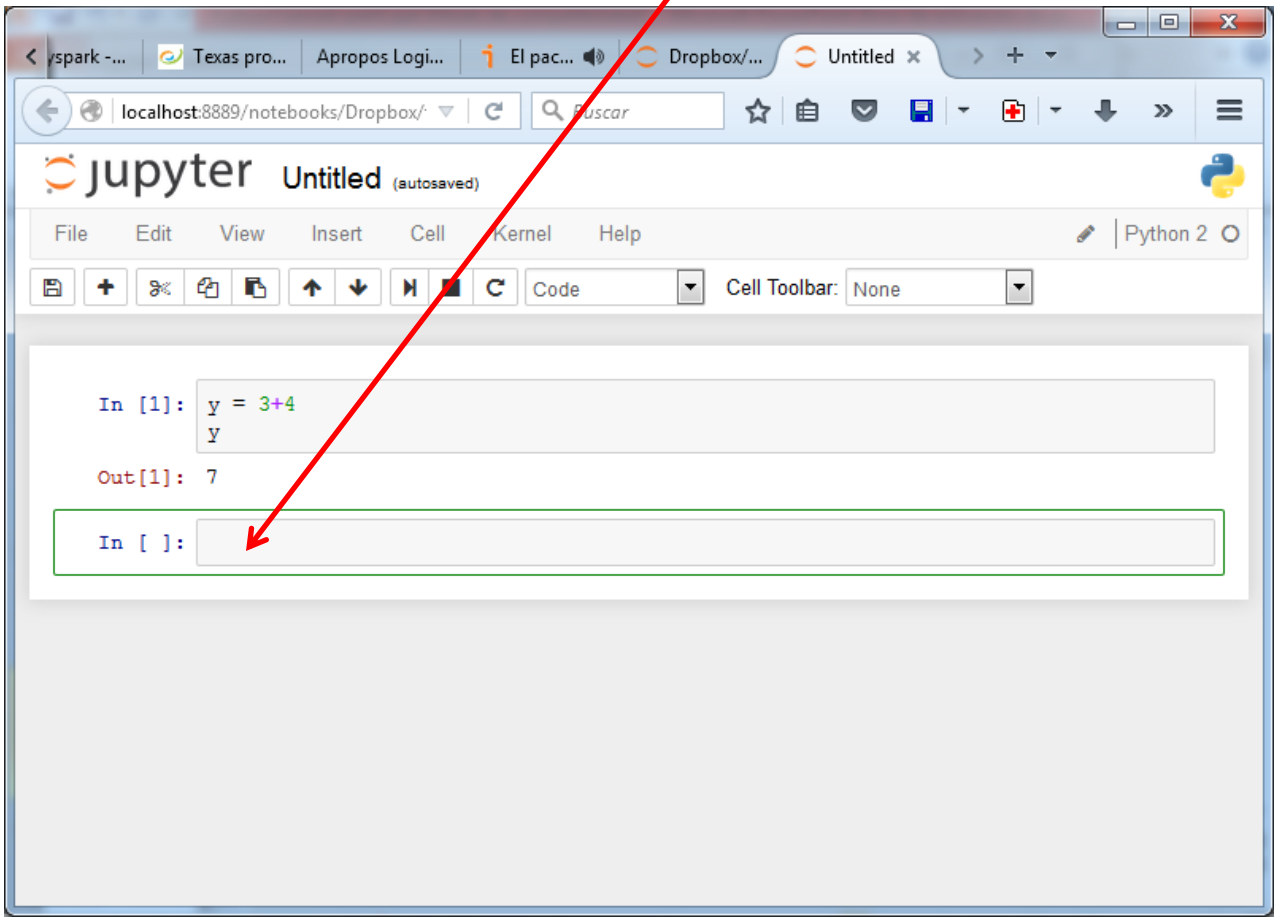
- Start a Python 2 notebook



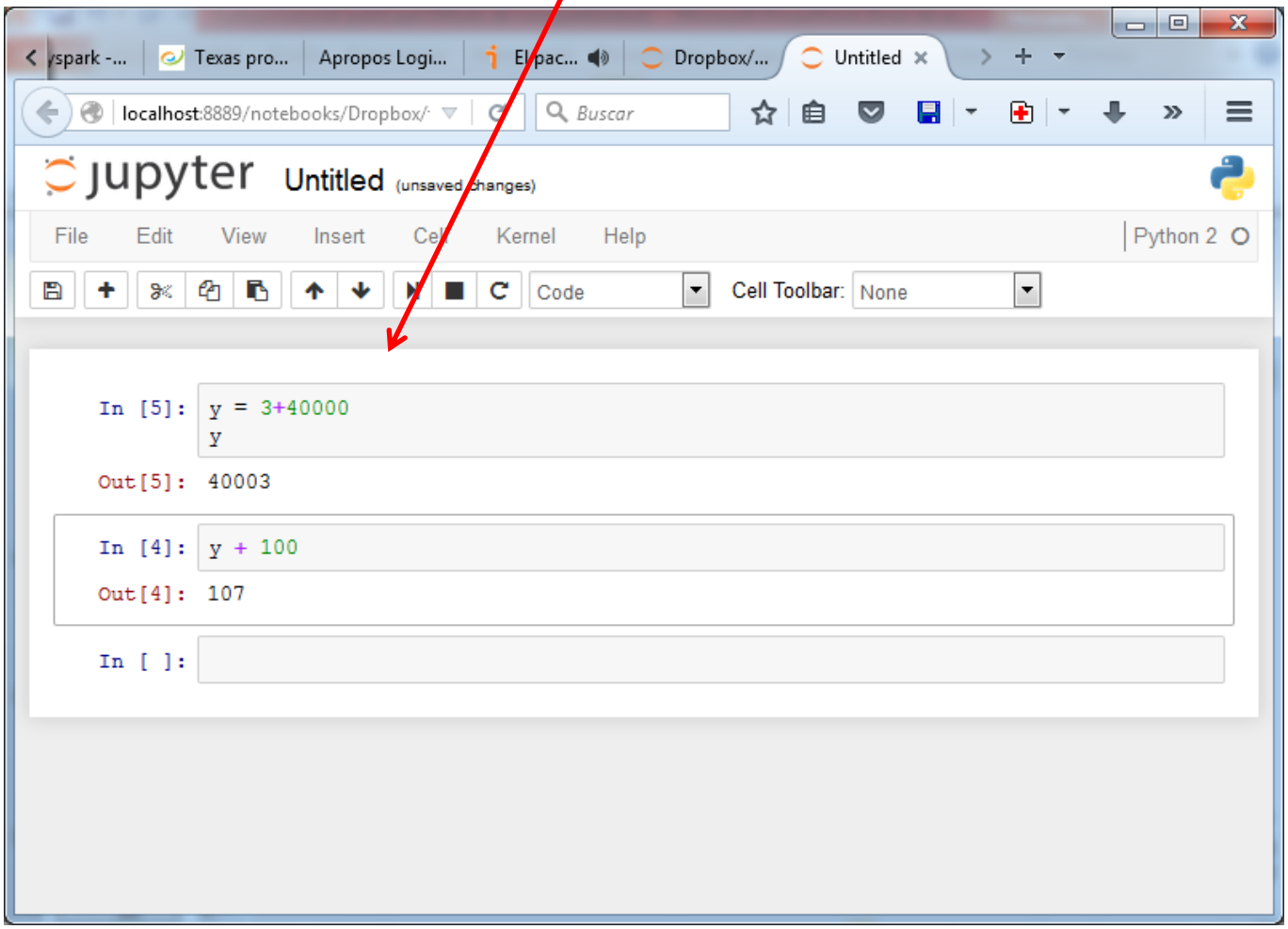
- You can type python commands in the cell



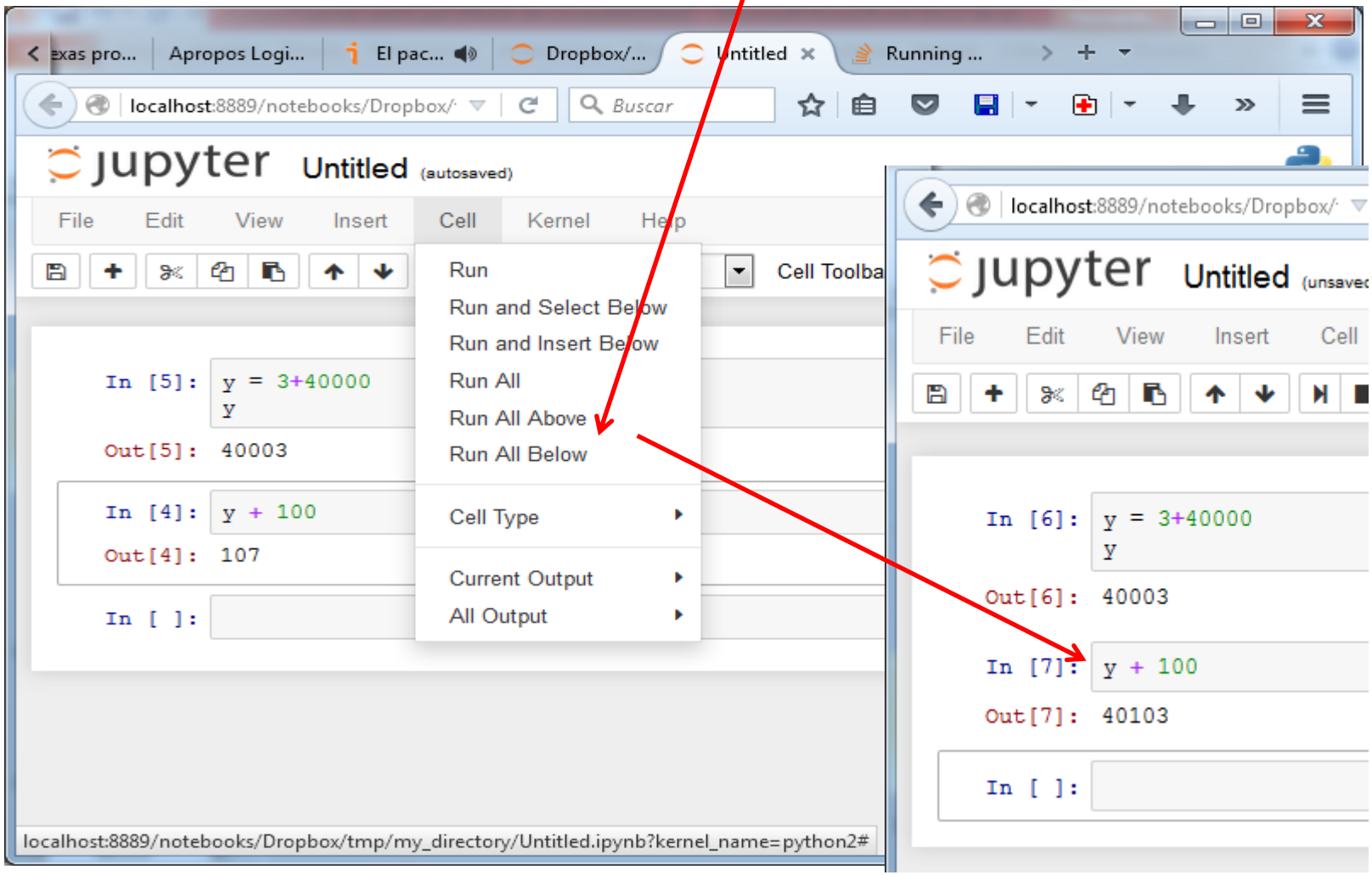
- Important:
  - "Enter" changes to a new line WITHIN the cell
  - In order to execute the commands in the cell, you have to type shift+enter
  - Once you type shift+enter, a new cell is created. You can type new commands



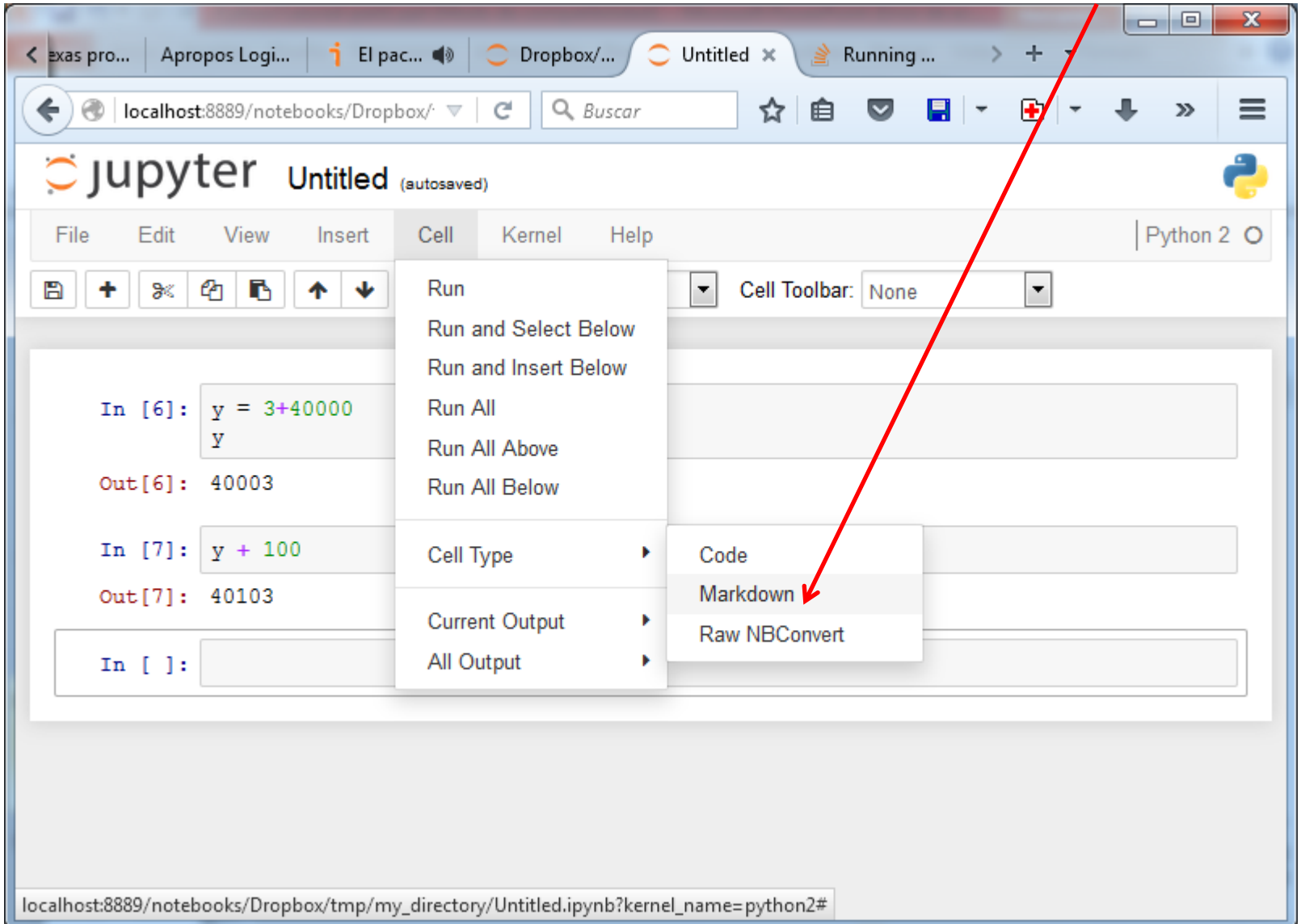
- You can return to a previous cell and change it. You need to re-execute it with shift+enter (or ctrl+enter)



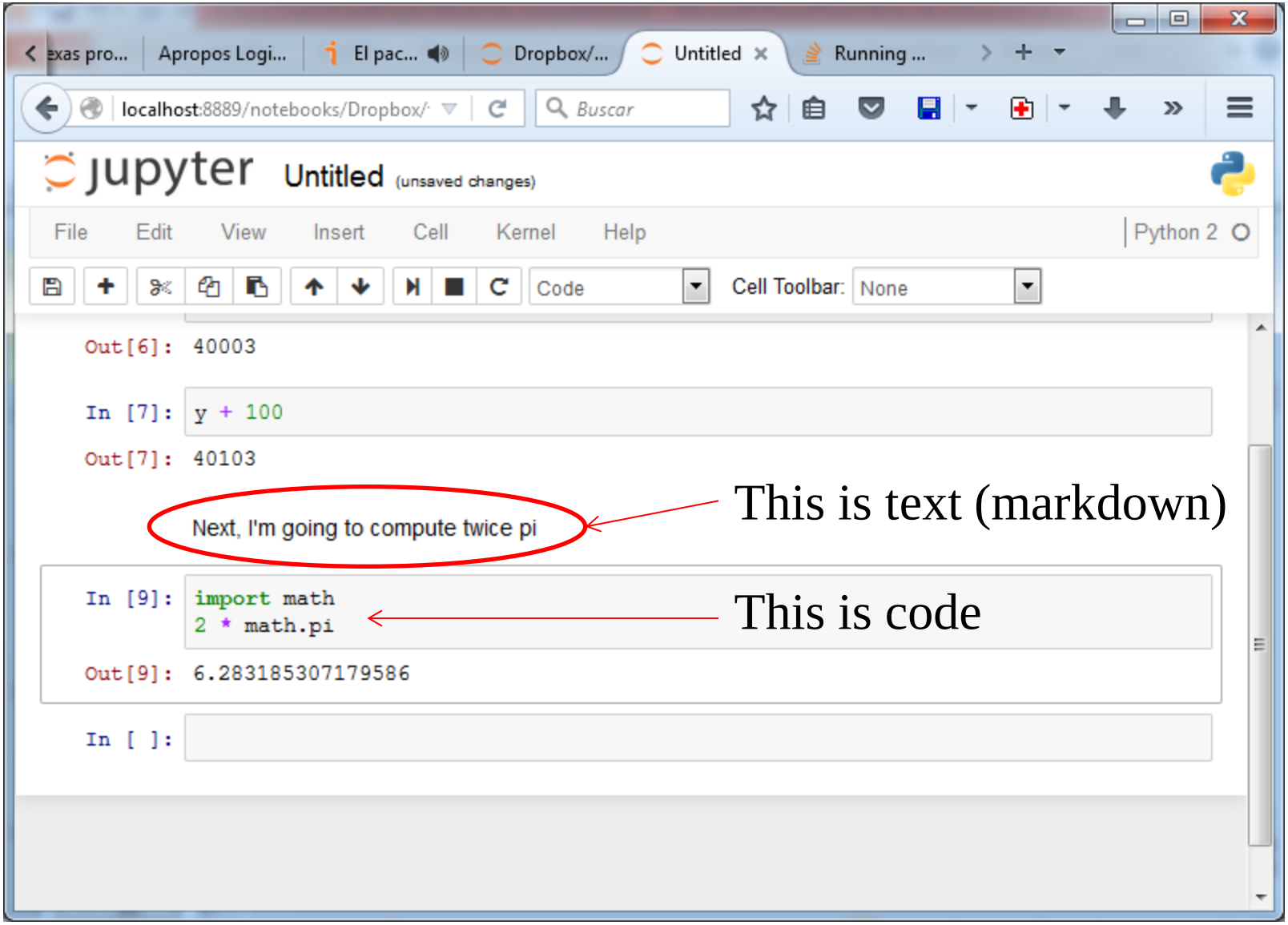
- If you want the changes to propagate to the following cells, you have to execute all of them again.



- In a Python notebook, you can mix text, python commands and results, by changing the cell type



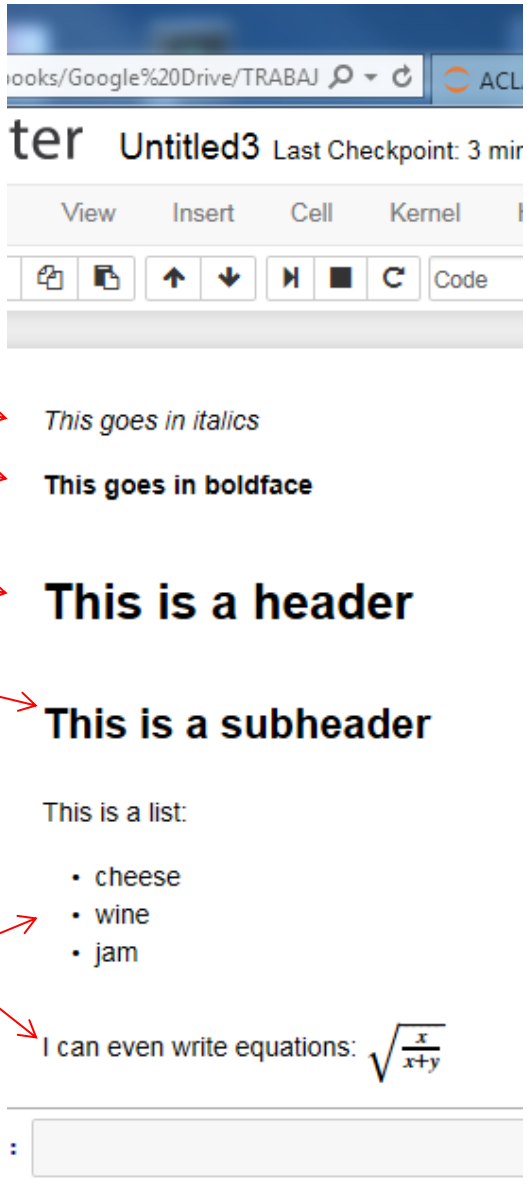
- Text mixed with code



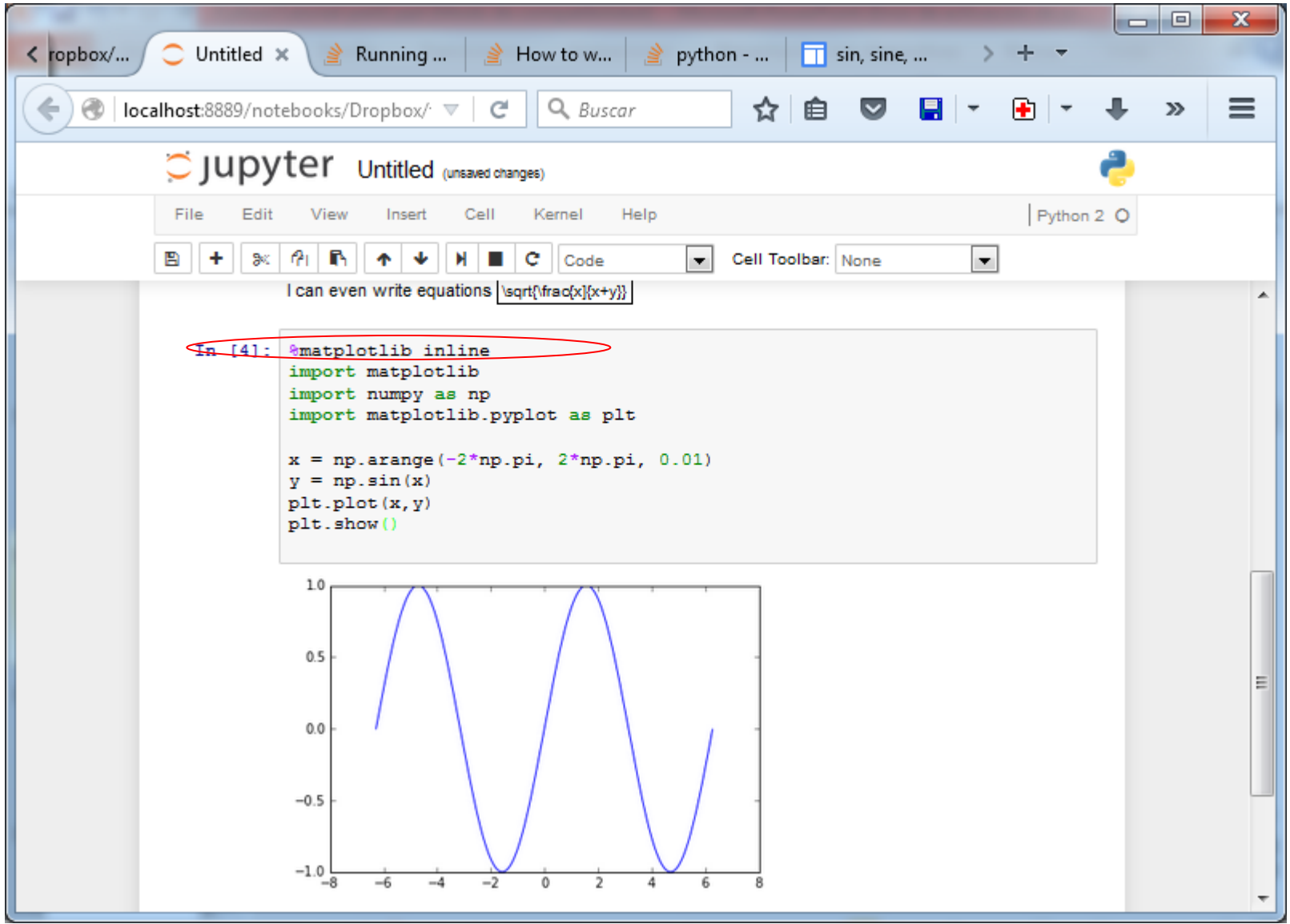
Markdown

- Markdown is a language to format text:
  - *this goes in italics*
  - **this goes in boldface**
  - #This is a header
  - ##This is a subheader
  - I can even write equations (in LaTeX):
    - $\sqrt{\frac{x}{x+y}}$

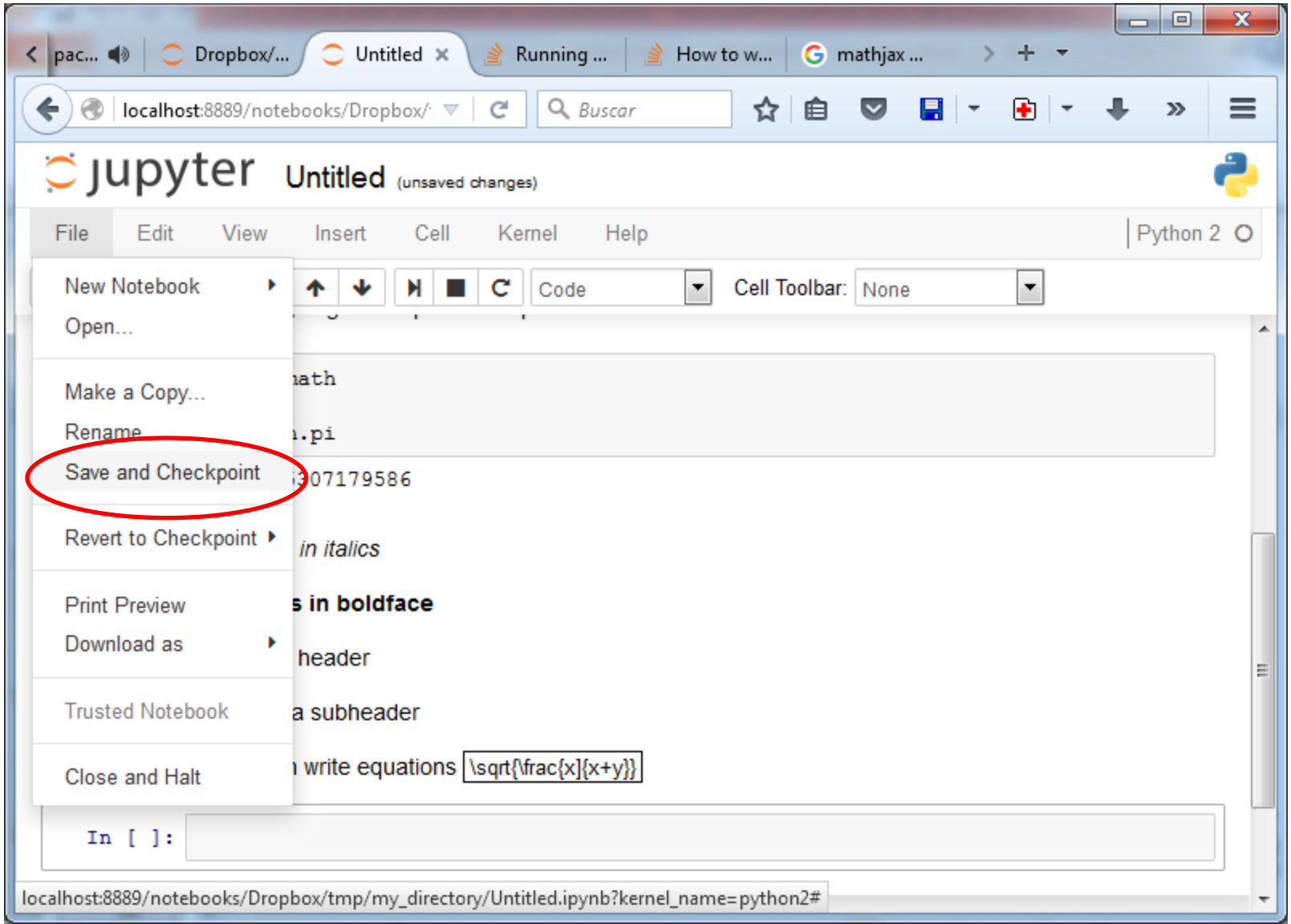
This is a list:
- Cheese
- Wine
- Jam



You can even embed plots

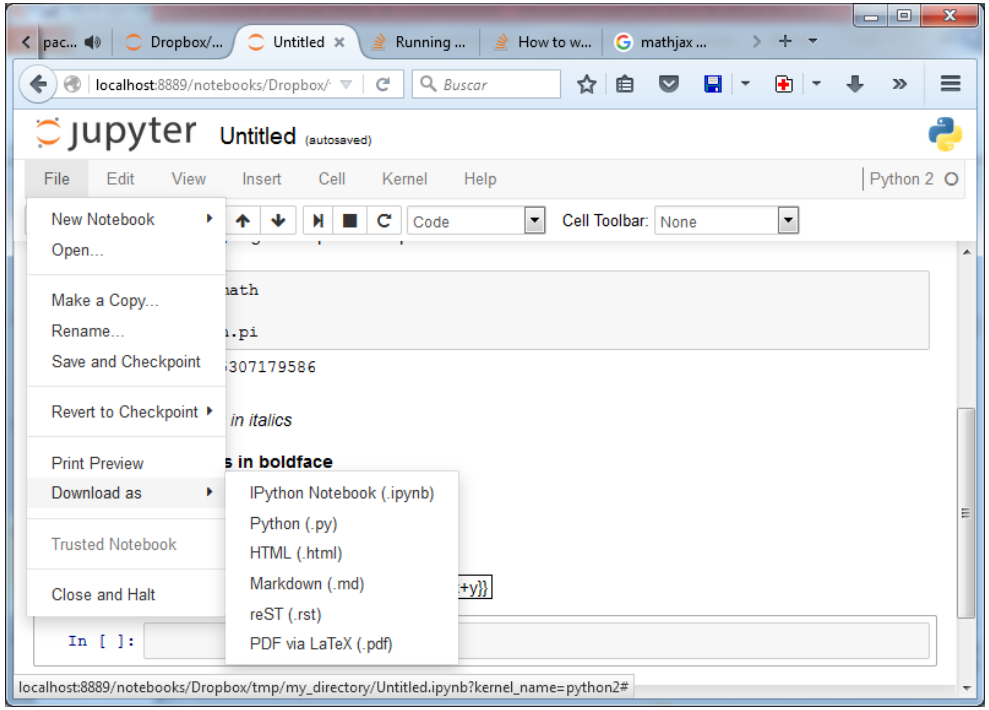


Saving the notebook



Download the notebook

- In several formats: (filename can be changed in File/Rename)
  - Python notebook: it can be loaded again as a notebook
  - Python script: this is a text file containing the sequence of Python commands. Text is also stored as comments (#)
  - html: it can be loaded later in a browser
  - pdf (it might not work because it requires LaTeX)



Etc.

- In order to finish the notebook:
  - File / close and halt
- Jupyter notebooks have more options but you can explore them yourselves

Exercise

- Try to get something similar to:

COMPUTING THE LENGTH OF A CIRCUMFERENCE

The length of a circunference with radius r is $l = 2\pi r$

In [10]:
```
import math
r = 3

l = 2*math.pi*r
print "Length is: {}".format(r)
```

```
Length is: 3
```

HINT

```
# COMPUTING THE LENGTH OF A CIRCUMFERENCE

The length of a circunference with radius *r* is $l = 2 \pi r$
```

Topics

1. If … then … else
2. Loops:
   - While condition …
   - For …
3. Functions
4. High-level functions (map, filter, reduce)

If Statements

```
if condition :
    sentence1
    sentence2
    …
next sentence
```

```
if condition :
    sentence1
    sentence2
    …
else :
   sentencea
   sentenceb
   …
next sentence
```

```
if condition :
    sentence1
    sentence2
    …
elif condition3 :
   sentencea
   sentenceb
   …
else :
   sentencex
   sentencey
   …
next sentence
```

Example:

```
x = 30
if x <= 15 :
   y = x + 15
elif x <= 30 :
   y = x + 30
else :
   y = x
print 'y = ', y
```

Indentation

Sentence that follows the "if" (outside of the "if" block)

Result is: ?

If Statements

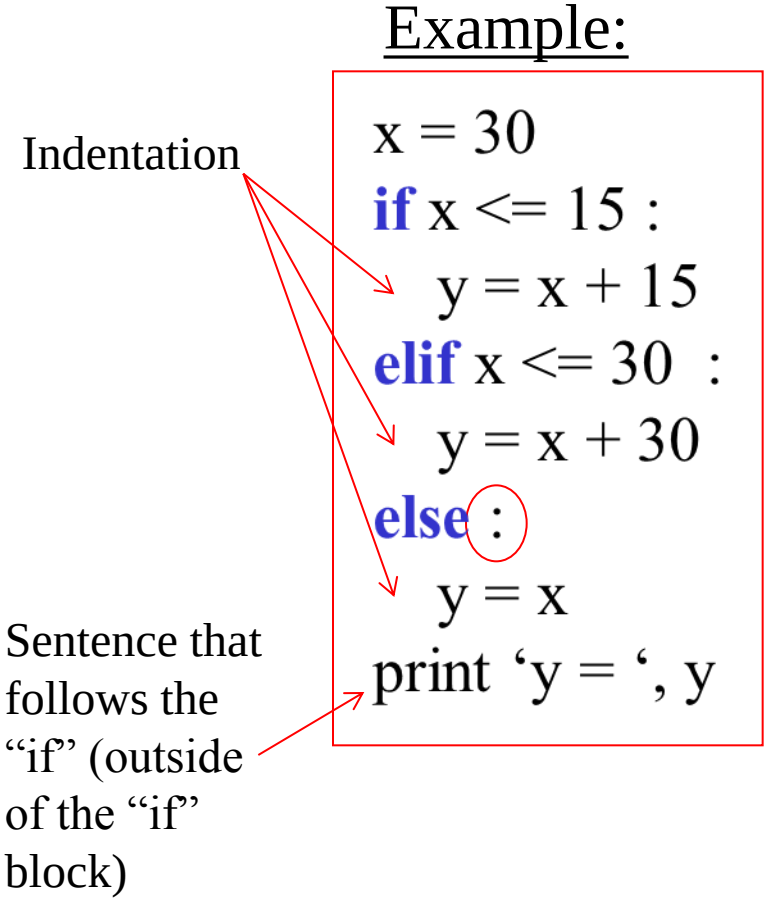
Example:

```
x = 30
if x <= 15 :
    y = x + 15
elif x <= 30 :
    y = x + 30
else :
    y = x
print 'y = ', y
```

Result is: **y = 60**

Note on indentation

- Python uses indentation instead of braces (or curly brackets) to determine the scope of expressions
- All lines must be indented the same amount to be part of the scope (or indented more if part of an inner scope)
- This forces the programmer to use proper indentation since the indenting is part of the program!
- Indentation made of four spaces is recommended



While Loops

While *condition* is true, execute sentences in the *while block* (*sentence1*, *sentence2*, …)

```
while condition :
    sentence1
    sentence2
    …
Next sentence
(outside while block)
```

```
phrase = ['Somewhere', 'in', 'La', 'Mancha']
index = 0
while index < len(phrase) :
    print phrase[index]
    index = index + 1
print '** Words printed, while finished!!'
```

```
Somewhere
in
La
Mancha
** Words printed, while finished!!
```

For Loops

variable takes succesive values in the *sequence*

```
for variable in sequence :
    sentence1
    sentence2
    …
Next sentence (outside for block)
```

```
phrase = ['Somewhere', 'in', 'La', 'Mancha']
index = 0
for word in phrase :
    print word
print '** Words printed, "for loop" finished!!'
```

```
Somewhere
in
La
Mancha
** Words printed, "for loop" finished!!
```

Exercise

- Create a list of numbers [0, 1, 3, 4, 5, 6]
- Iterate over this list by using a for loop
  - For each element in the list, print “even” if the number is even and “odd” if the number is odd
- Reminder: a number *x* is even if the remainder of the division by 2 is zero. That is: (x % 2 == 0)
- Once you are done, try with another list:

  [1, 7, 3, 2, 0]

Solution

In [13]:
```
# This is equivalent to myList = [0, 1, 2, 3, 4, 5, 6]
myList = range(7)

for element in myList:
    if (element % 2 == 0):
        print("Even")
    else:
        print("Odd")
```

```
Even
Odd
Even
Odd
Even
Odd
Even
```

Function Definition

"return x" returns the value and ends the function exectution

```
def functionName(argument1, argument2, …) :
    sentence1
    sentence2
    …
```

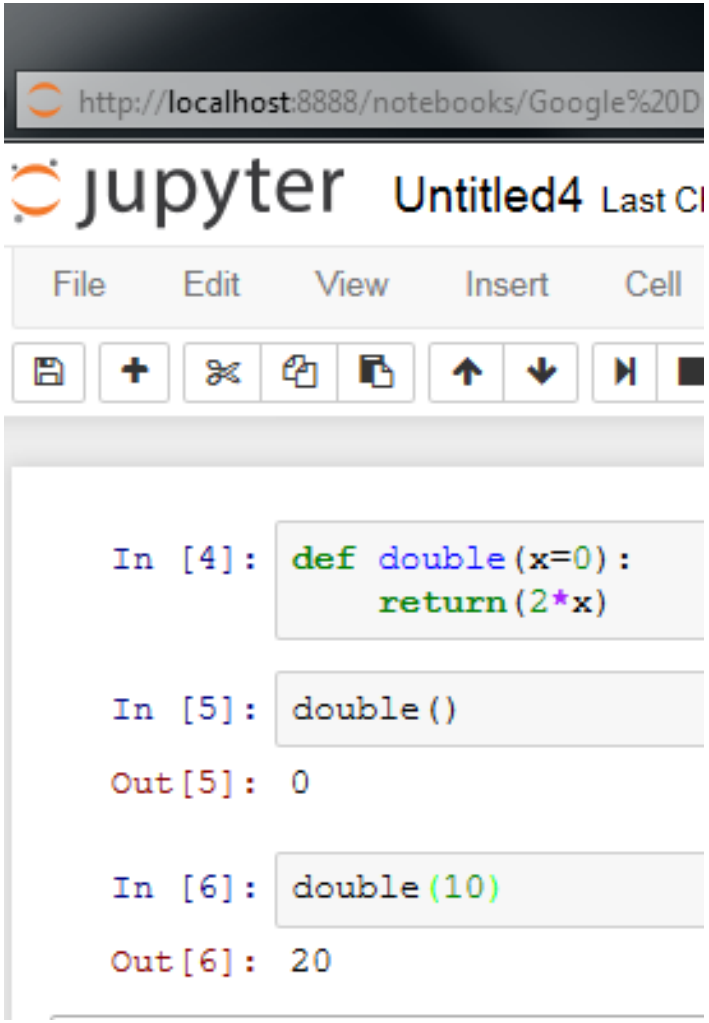
```
def max(x,y) :
    if x < y :
        return x
    else :
        return y
```

```
max(3,5)
```

```
3
```

Parameters: Defaults

- Parameters can be assigned default values
- They are overridden if a parameter is given for them



Parameters: Named

- Call by name
- Any positional arguments must come before named ones in a call

```
In [7]: def myPrint(a,b,c):
            print a,b,c

In [8]: myPrint(c=10, a=2, b=14)
        2 14 10

In [9]: myPrint(3, c=2, b=19)
        3 19 2
```

Exercise

- Define a function *myDif* that returns:
  - If (a-b)>0 then (a-b)
  - Otherwise b-a
- Both *a* and *b* should have default values of 0
- You need to use *if*
- Try the following function calls and see what happens:
  - myDif(1,2)
  - myDif(2,1)
  - myDif(2)
  - myDif(b=2,a=1)

Solution

In [18]:
```
def myDif(a=0, b=0):
    result = a-b
    if (result>0):
        return(result)
    else:
        return(-result)

print(myDif(1,2))
print(myDif(2,1))
print(myDif(2))
print(myDif(b=2,a=1))
```

```
1
1
2
1
```

In [ ]:

Higher-Order Functions

map(func,seq) – for all i, applies func(seq[i]) and returns the corresponding sequence of the calculated results.

filter(boolfunc,seq) – returns a sequence containing all those items in seq for which boolfunc is True.

Notice that a function is passed as argument!!

```
def double(x):
    """It multiplies x by 2"""
    return 2*x

def even(x):
    """It checks whether x is even. It returns True or False"""
    return x % 2 == 0

lst = range(10)
print "Applying double to all elements in {}".format(lst)
print map(double, range(10))
print "Filtering / selecting even elements in {}".format(lst)
print filter(even, range(10))
```

```
Applying double to all elements in [0, 1, 2, 3, 4, 5, 6, 7, 8, 9]
[0, 2, 4, 6, 8, 10, 12, 14, 16, 18]
Filtering / selecting even elements in [0, 1, 2, 3, 4, 5, 6, 7, 8, 9]
[0, 2, 4, 6, 8]
```

Higher-Order Functions

reduce(func,seq) – applies func to the items of seq, from left to right, two-at-time, to reduce the seq to a single value.

Example: reduce(addition, [1,2,3,4]) = 1+2+3+4 = 10

```
def addition(x,y):
    return x+y

lst = range(10)
print "Adding all numbers in {}".format(lst)
print reduce(addition, lst)
```

```
Adding all numbers in [0, 1, 2, 3, 4, 5, 6, 7, 8, 9]
45
```

Higher-Order Functions with lambda functions

map(func,seq) – for all i, applies func(seq[i]) and returns the corresponding sequence of the calculated results.

filter(boolfunc,seq) – returns a sequence containing all those items in seq for which boolfunc is True.

```
lst = range(10)
print "Applying double to all elements in {}".format(lst)
print map(lambda x: x*2, range(10))
print "Filtering / selecting even elements in {}".format(lst)
print filter(lambda x: x % 2 == 0, range(10))
```

```
Applying double to all elements in [0, 1, 2, 3, 4, 5, 6, 7, 8, 9]
[0, 2, 4, 6, 8, 10, 12, 14, 16, 18]
Filtering / selecting even elements in [0, 1, 2, 3, 4, 5, 6, 7, 8, 9]
[0, 2, 4, 6, 8]
```

Higher-Order Functions with lambda functions

reduce(func,seq) – applies func to the items of seq, from left to right, two-at-time, to reduce the seq to a single value.

```
lst = range(10)
print "Adding all numbers in {}".format(lst)
print reduce(lambda x,y: x+y , lst)
```

```
Adding all numbers in [0, 1, 2, 3, 4, 5, 6, 7, 8, 9]
45
```

Exercise

- Use a higher-order function (*map*) with lambda-function that adds 2 to every number in a list
- Apply it to this list: [1, 5, 7]

Solution

```
In [19]: map(lambda x: x+2, [1, 5, 7])

Out[19]: [3, 7, 9]
```

Modules: Imports

```
# Different ways of importing modules
########################
# import moduleName ##
########################
# In this case, functions must be called as:
# moduleName.functionName(...)
import math
print math.sqrt(2)

#################################
# import moduleName as otherName   ##
#################################
# In this case, functions must be called as:
# otherName.functionName(...)
import numpy as npy
print npy.arange(2)

#################################
# from module import function otherName   ##
#################################
# In this case, functions can be called as:
# functionName(...)

from math import sqrt
print sqrt(2)
```

```
1.41421356237
[0 1]
1.41421356237
```

Writing and reading files

In [20]:
```
mySentence = "Number three is {}".format(3)
print(mySentence)
# Now, we open file "myFile.txt" for writing
mf = open("myFile.txt", "w")
# Then we write the sentence
mf.write(mySentence)
# Finally, we close the file
mf.close()

# Now, we open the file for reading
mf = open("myfile.txt", "r")
# We read the whole file into variable sentenceFromFile
sentenceFromFile = mf.read()
# We close the file
mf.close()

# And print the sentence, in order to checke whether it is the original sentence
print(sentenceFromFile)
```

```
Number three is 3
Number three is 3
```

Files: Input

inflobj = open(‘data’, ‘r’)	Open the file ‘data’ for input.
S = inflobj.read()	Read whole file into one String
S = inflobj.read(N)	Reads N bytes (N >= 1)
L = inflobj.readlines()	Returns a list of line strings

Files: Output

outflobj = open(‘data’, ‘w’)	Open the file ‘data’ for writing
outflobj.write(S)	Writes the string S to file
outflobj.writelines(L)	Writes each of the strings in list L to file
outflobj.close()	Closes the file

EXTRA MATERIAL: LOOPS AND LIST COMPREHENSIONS

Loop Control Statements

break	Jumps out of the closest enclosing loop (or while)
continue	Jumps to the top of the closest enclosing loop (or while)
pass	Does nothing, empty statement placeholder

The Loop Else Clause

- The optional **else** clause runs only if the loop exits normally (not by break)

```
while condition :
    sentence1
    sentence2
    …
else:
    sentencea
    sentenceb
Next sentence
(outside while block)
```

```
for variable in sequence :
    sentence1
    sentence2
    …
else:
    sentencea
    sentenceb
Next sentence (outside
for block)
```

The Loop Else Clause

- The optional **else** clause runs only if the loop exits normally (not by break)

```
number = 14
factor = 2
while factor < number :
    if number % factor == 0 :
        print "Number {} is not a prime number".format(number)
        break
    else:
        factor = factor + 1
else:
    print "Number {} is prime".format(number)
```

```
Number 14 is not a prime number
```

The Loop Else Clause

- The optional **else** clause runs only if the loop exits normally (not by break)

```
number = 13
# Note: range(a,b) produces a list of numbers from a to n-1
print range(2, number)
for factor in range(2,number) :
    if number % factor == 0 :
        print "Number {} is not a prime number".format(number)
        break
else: # this block is executed when the loop for exits without break
    print "Number {} is prime".format(number)
```

```
[2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12]
Number 13 is prime
```

Higher-Order Functions with list comprehensions

```
lst = range(10)
print "The following is equivalent to map(double, lst)"
print [double(a) for a in lst]
print "The following is equivalent to filter(even, lst)"
print [a for a in lst if even(a)]
```

```
The following is equivalent to map(double, lst)
[0, 2, 4, 6, 8, 10, 12, 14, 16, 18]
The following is equivalent to filter(even, lst)
[0, 2, 4, 6, 8]
```

Higher-Order Functions with list comprehensions

reduce(func,seq) – applies func to the items of seq, from left to right, two-at-time, to reduce the seq to a single value.

```
lst = range(10)
print "Adding all numbers in {}".format(lst)
print reduce(lambda x,y: x+y , lst)
```

```
Adding all numbers in [0, 1, 2, 3, 4, 5, 6, 7, 8, 9]
45
```

Functions are first class objects

- Can be assigned to a variable

  x = max
- Can be passed as a parameter
- Can be returned from a function
- Functions are treated like any other variable in Python, the **def** statement simply assigns a function to a variable

Anonymous Functions

- A lambda expression returns a function object
- The body can only be a simple expression, not complex statements

```
>>> f = lambda x,y : x + y
>>> f(2,3)
5
```