Lab #0: Introduction to Python for Data Science

CS 109A, STAT 121A, AC 209A: Data Science

Fall 2016

Harvard University

LECTURE OUTLINE

What Python Looks Like

Variables and Types

Manipulating Python Data Types

Basic Control Structures

Task I: Tabular Data from File

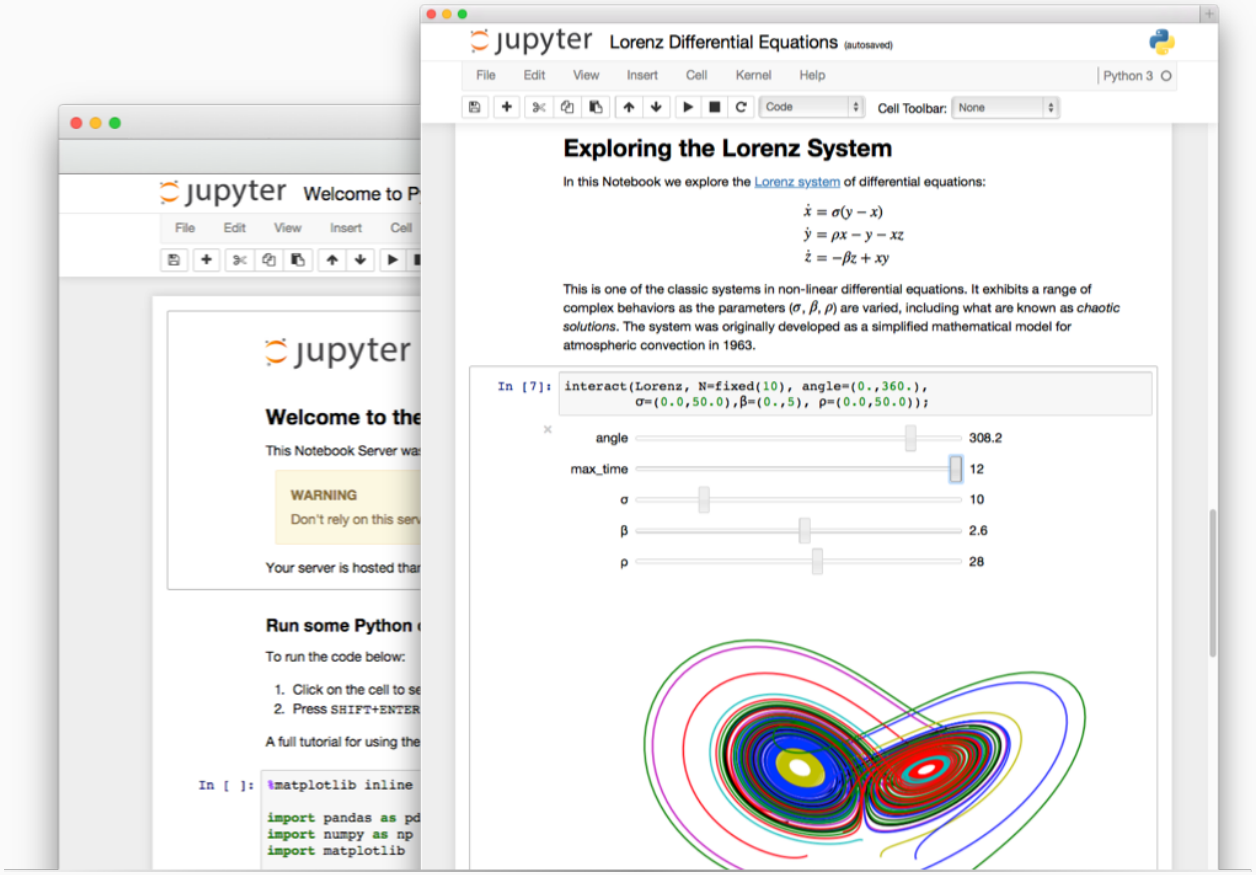
Task II: Visualize Data

Task III: Web Data

Task IV: Data from Simulations

THE TOOLS

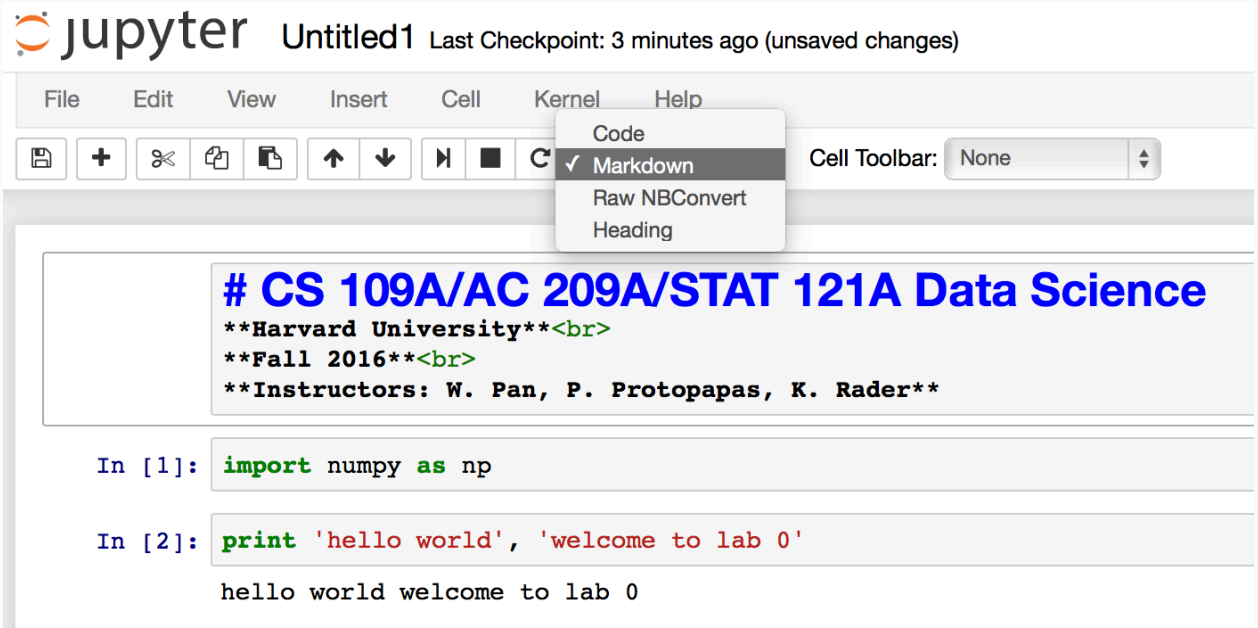
“The Jupyter Notebook is a web application that allows you to create interactive documents that contain live code, equations, visualizations and explanatory text.”



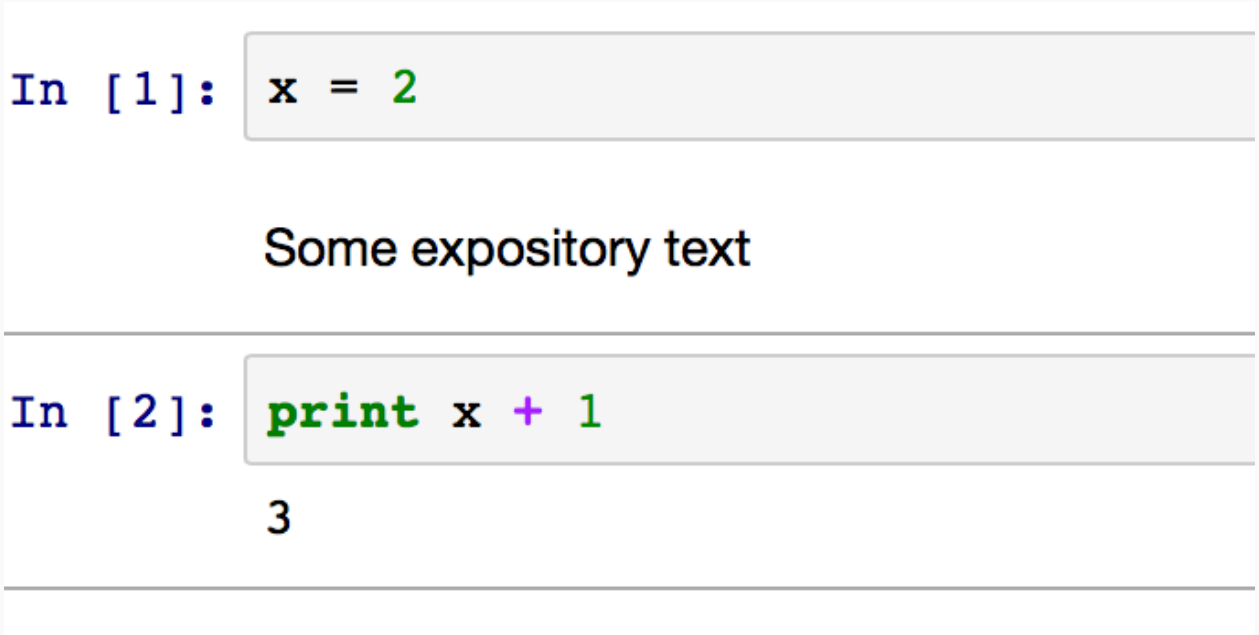
THE TOOLS

When Jupyter app loads, you see a dashboard displaying files in the Jupyter home directory (you can reset this)

Each notebook consists of blocks of cells. Each cell can display rich text elements (Markdown) or code. Code is executed by an "computational engine" called the *kernel* (IPython). The output of the code is displayed directly below.



Each cell can be executed independently, but once a block of code is executed, it lives in the memory of the kernel.



WHAT PYTHON LOOKS LIKE

Code readability is key, Python syntax itself is close to plain english.

- Your variables should be given **descriptive identifiers**!

  Identifiers for variable should be descriptive words separated by underscore (not spaces) and in all lower case

BAD	GOOD
`var6 = 25`	`age_of_mother = 25`
`AG3ofMoTh3R = 25`	`age_of_mother = 25`

PYTHON BEST PRACTICES

Code readability is key, Python syntax itself is close to plain english.

- Your variables should be given **descriptive identifiers**!
- You should use **white space** to increase readability.

BAD

```
x=[2,3,4]
v=1/3*(pi*r**2*h)
```

GOOD

```
num_list = [2, 3, 4]
v = 1/3 * (pi * r**2 * h)
```

Code readability is key, Python syntax itself is close to plain english.

- Your variables should be given **descriptive identifiers**!
- You should use **white space** to increase readability.
- You should liberally intersperse your code with **comments**!

BAD

```
v = 1/3 * (pi * r**2 * h)
```

GOOD

```
#volume of cone
v = 1/3 * (pi * r**2 * h)
```

A line of text following by # is treated as a comment.

Code readability is key, Python syntax itself is close to plain english.

- Your variables should be given **descriptive identifiers**!
- You should use **white space** to increase readability.
- You should liberally intersperse your code with **comments**!
- **Proper indentation is non-negotiable**!

BAD

```
for i in range(5):
print i
```

GOOD

```
for i in range(5):
    print i
```

Code blocks are not indicated by delimiters (e.g. `{ }`) only by indentation!

VARIABLES AND TYPES

BUILT-IN PYTHON DATA TYPES

The basic built-in Python data types we'll be using today are:

1. **integers, floating points**: `7`, `7.0`
2. **booleans**: `True`, `False` with logical operations, `and`, `or`, `not`
3. **strings**: `'hi'`, `"7.0"`
4. **lists**: sequence of data (of various types)

In Python, you do not need to *declare* the types of your variables. The type is inferred based on the valued assigned to the variable.

For example: The assignment

$$\texttt{my\_var} = 7$$

types `my_var` as an integer. Later, the assignment

$$\texttt{my\_var} =' \texttt{hello}'$$

will cause `my_var` to be typed as a string.

FUNCTIONS

Function definition follows the `def` keyword. The first line, the heading, contains the function name and the list of parameters names (you need not specify the type of each parameter). Finally, if your function returns a value, you can do so with the `return` keyword.

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

You call a function by its name with values for each parameter:

```
answer = add(1, 2)
```

Calling a function belonging to an object or library:

```
returned_val = object.method(param_1, param_2, ...)
returned_val = library.function(param_1, param_2, ...)
```

MANIPULATING PYTHON DATA TYPES

NUMERICAL OPERATORS

Python has a variety of built-in **arithmetic operators** that allows you to combine numbers.

Operator	Description	Example
`+`	adds values on either side	`1.2 + 2 = 3.2`
`-`	subtracts the right value from the left	`1.2 - 0.2 = 1.0`
`*`	multiplies values on either side	`1.2 * 2 = 2.4`
`/`	divides the left value by the right	`4 / 2 = 2.0`
`%`	divides the left value by the right and returns the remainder	`4 % 3 = 1`
`**`	exponentiate the left value by the right	`3**2 = 9`
`//`	divides the left value by the right and removes the decimal part	`3//2 = 1`

NUMERICAL OPERATORS

Python also has a variety of built-in **comparison operators** for numbers.

Operator	Description	Example
`==`	checks if values on either side are equal	`1 == 2` is `False`
`!=`	checks if values on either side are unequal	`1 != 2` is `True`
`>`	checks if left value is greater	`1 > 2` is `False`
`<`	checks if left value is smaller	`1 < 2` is `True`
`>=`	checks if left value is greater or equal	`2 >= 2` is `True`
`<=`	checks if left value is smaller or equal	`1 <= 2` is `True`

STRING DATA TYPE

String literals in Python are a set of characters enclosed by either single or double quotation marks.

For example: The following are two equivalent assignments

```
my_str = ”Hello World!”
my_str = ’Hello World!’
```

STRING OPERATORS

Python has a variety of built-in operator for string manipulation.

Let's say `s = 'Hi!'`.

Operator	Description	Example
`==`	checks if strings on either side are equal	`s == 'hi!'` is `False`
`!=`	checks if strings on either side are unequal	`s != 'hi!'` is `True`
`+`	appends right string to end of left	`'Hi' + '!'` is `'Hi!'`
`[n]`	returns the *n*-th character	`s[0]` is `'H'`
`[n:m]`	returns the substring from *n* up to *m*	`s[0:1]` is `'H'`
`[n:]`	returns the substring from *n* on	`s[1:]` is `'i!'`
`[:n]`	returns the substring up to *n*	`s[:2]` is `'Hi'`

Note: Python enumerates starting from **zero**!

LIST DATA TYPE

Lists in Python are collections of items of possibly **different types**. Lists are created and displayed with items separated by commas and enclosed by square brackets. The empty list is denoted by `[]`.

For example: The following list contains both numerical and string data types.

```
>>> ['hi', 70, 2.1, ':(', '<3']
```

LIST OPERATORS

Python has a variety of built-in operator for list manipulation (they look just like the string operators).

Let's set `lst = ['hi', 7, 'c']`.

Operator	Description	Example
`+`	appends right list to end of left	`['H'] + [2]` is `['H', 2]`
`[n]`	returns the *n*-th item	`lst[0]` is `'hi'`
`[n:m]`	returns items from *n* up to *m*	`lst[0:1]` is `['hi']`
`[n:]`	returns items from *n* on	`lst[1:]` is `[7, 'c']`
`[:n]`	returns items up to *n*	`lst[:2]` is `['hi', 7]`

BASIC CONTROL STRUCTURES

SELECTION: ‘IF’, ‘ELIF’, ‘ELSE’

In Python, selection is implemented using the `if, elif, else` constructions.

For example: Our holistic 0-5 homework grading scheme might translate into:

```
if grade == 5:
    print “Everything was outstanding!”
elif grade == 4:
    print “Everything was good with no major mistakes”
elif grade == 3 or grade == 2:
    print “Good with some major mistakes”
elif grade == 1:
    print “Hmm...there seem to be lots of missing solutions”
elif grade == 0:
    print “Oops! You forgot to submit this one!”
else:
    print “That’s not a valid grade!”
```

ITERATING OVER LISTS

We can directly **iterate over the items in a list** (from 0-th index to end).

```
In [9]: my_list = [1, 2, 3, 4]

        for val in my_list:
            print val
```

```
1
2
3
4
```

ITERATING OVER RANGES OF NUMBERS

We can **iterate over a range of numbers**.

```
In [10]: my_list = [1, 2, 3, 4]

         for index in range(4):
             print my_list[index]

1
2
3
4
```

ITERATING OVER RANGES OF NUMBERS

Variations on `range()`:

- `range(10)` produces a list-like of numbers 0 thru 9:

  0, 1, 2, 3, 4, 5, 6, 7, 8, 9

- `range(5, 10)` will produce a list-like of numbers starting at 5 and thru 9

  5, 6, 7, 8, 9

- `range(0, 10, 2)` will produce a list-like of numbers between 0 and 9 counting by 2:

  0, 2, 4, 6, 8

Task I: Tabular data from file

CSV FILES

A comma-separated values (CSV) file stores tabular data in plain text. Each line of the file is a single record. Each record consists of one or more values, numeric or text, separated, typically, by commas.

```
1,0.455,0.365,0.095,0.514,0.2245,0.101,0.15,13
1,0.35,0.265,0.09,0.2255,0.0995,0.0485,0.07,5
2,0.53,0.42,0.135,0.677,0.2565,0.1415,0.21,7
1,0.44,0.365,0.125,0.516,0.2155,0.114,0.155,8
0,0.33,0.255,0.08,0.205,0.0895,0.0395,0.055,5
0,0.425,0.3,0.095,0.3515,0.141,0.0775,0.12,6
2,0.53,0.415,0.15,0.7775,0.237,0.1415,0.33,18
2,0.545,0.425,0.125,0.768,0.294,0.1495,0.26,14
1,0.475,0.37,0.125,0.5095,0.2165,0.1125,0.165,7
2,0.55,0.44,0.15,0.8945,0.3145,0.151,0.32,17
2,0.525,0.38,0.14,0.6065,0.194,0.1475,0.21,12
1,0.43,0.35,0.11,0.406,0.1675,0.081,0.135,8
1,0.49,0.38,0.135,0.5415,0.2175,0.095,0.19,9
2,0.535,0.405,0.145,0.6845,0.2725,0.171,0.205,8
2,0.47,0.355,0.1,0.4755,0.1675,0.0805,0.185,8
1,0.5,0.4,0.13,0.6645,0.258,0.133,0.24,10
```

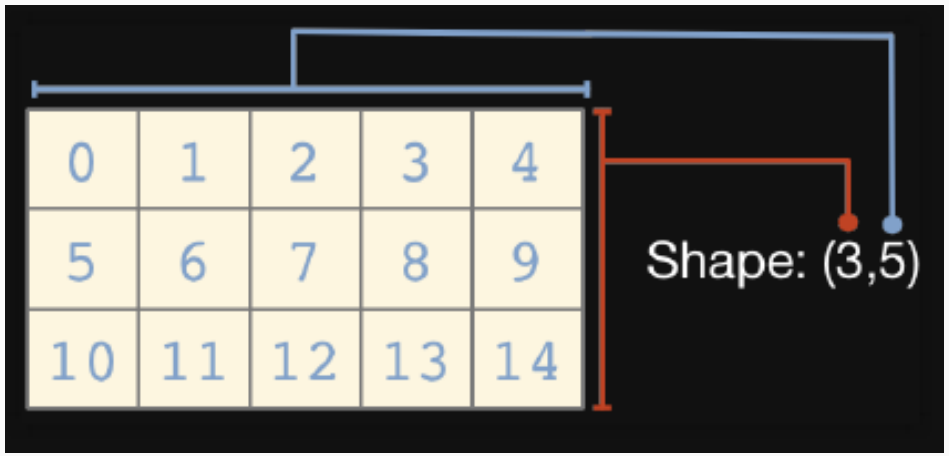
numpy ARRAYS

`numpy` is a useful package for scientific computation. `numpy` is typically imported as `np`.

Notably, `numpy` provides an multi-dimensional array object which optimizes storing and manipulating data.

`numpy` also provides a number of way to load csv data into arrays (through `loadtxt` or `genfromtxt`).

Each array has a shape, recorded as a tuple $(n, m, \ldots)$.



numpy 1D ARRAYS

Creating 1D arrays:

```
In [19]: my_array = np.array([1, 2, 3, 4])
         print my_array.shape

         (4,)
```

Note: indexing with 1D arrays work just like with lists and strings!

Computations with 1D arrays:

```
In [21]: print my_array.mean()
         print np.mean(my_array)

         2.5
         2.5
```

You can compute the mean by either call the mean function belonging to the array object or by applying `numpy`'s mean function to the array.

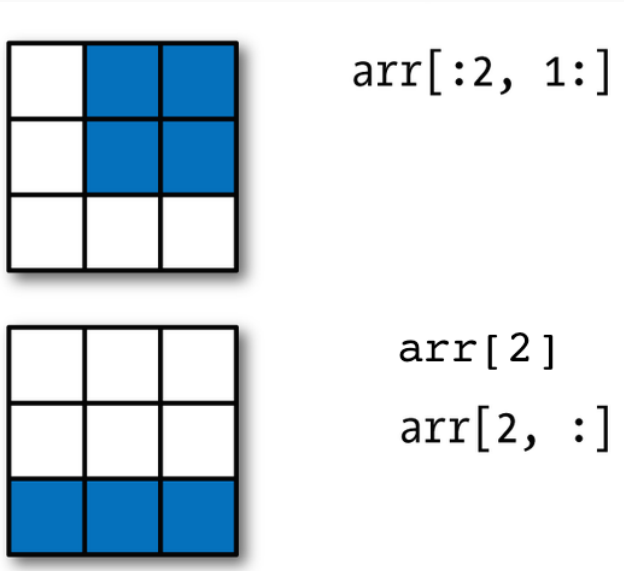
numpy 2D ARRAYS

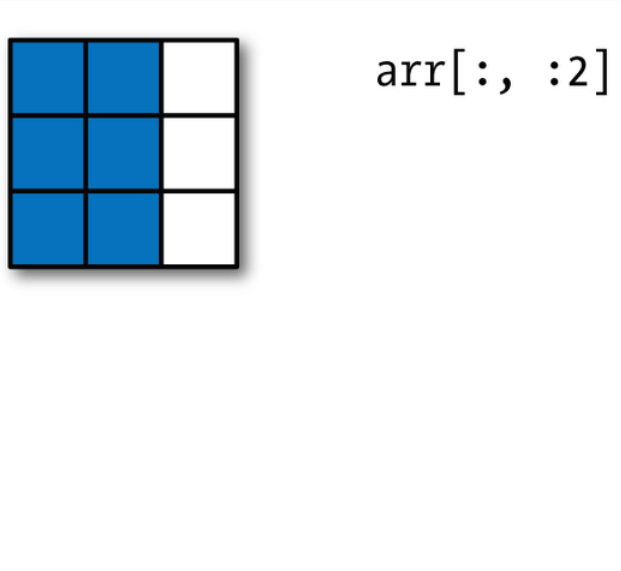
Creating 2D arrays: we can make 2-D arrays out of a list of rows, each row is a list of values.

```
In [24]: my_array = np.array([[1, 2], [3, 4]])
         print my_array

         [[1 2]
          [3 4]]

In [25]: print my_array.shape

         (2, 2)
```

numpy 2D ARRAYS

Indexing 2D arrays: The element at the *n*-th row and the *m*-th column is indexed as `[n, m]`. Just like lists, you can also get multiple array values at a time:





Finally, you can get a "list" rows: `arr[[0, 1]]` or `arr[[0, 1], :]`

numpy 2D ARRAYS

Filtering 2D arrays: Even more sophisticated, you can get values from an array that satisfy a bunch of criteria!

```
In [24]: my_array = np.array([[1, 2], [3, 4]])
         print my_array

         [[1 2]
          [3 4]]

In [44]: my_array = np.array([[1, 2], [3, 4]])
         print my_array[:, 0] == 1

         [ True False]

In [34]: print my_array[my_array[:, 0] == 1]

         [[1 2]]

In [37]: print my_array[(my_array[:, 0] == 1) | (my_array[:, 0] == 3)]

         [[1 2]
          [3 4]]
```

Question: how do you get the values that are greater than one? What is the shape of this array of filtered values?

PROBLEM SOLVING

Let's process some tabular data!

Download files for lab 0 at: https://github.com/cs109Alabs/lab_files

Do problem 1, parts a and b

TASK II: VISUALIZE DATA

matplotlib

`matplotlib` is a plotting library, the `pyplot` module contains a set of functions especially useful for generating a wide range of simple plots. `pyplot` is typically imported as `plt`.

Plotting function	Input	Result
`plt.plot(x, y)`	*x*-coords and *y*-coords	curve defined by the set of x, y coords
`plt.scatter(x, y)`	*x*-coords and *y*-coords	scatter plot defined by the set of x, y coords
`plt.hist(vals)`	an array or list of values	histogram of the list of values
`plt.title(plot_title)`	a string	adds title
`plt.show()`	none	displays all figures

FANCIER PLOTTING: 3D, SUBPLOTS

To generate a group of 3 plots in a 3×1 grid, say. We want to explicitly create a figure and add subplots to particular positions of the grid.

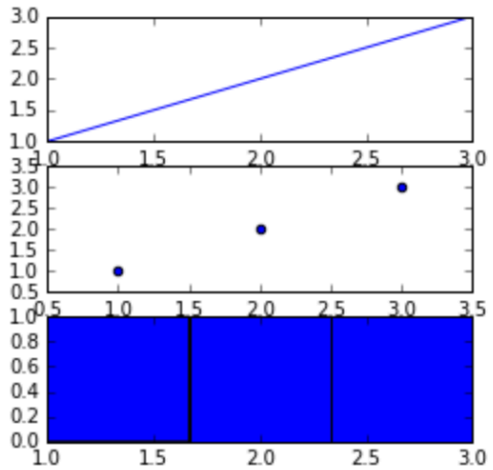
Function	Input	Result
`plt.figure()`	(optional) figure size	returns a new figure
`figure.add_subplot(n, m, k)`	row, column, subplot number	returns an axes for the *k*-th subplot in the *nxm*-grid column
`figure.add_subplot(n, m, k, projection='3d')`	row, column, subplot number, projection type	returns an axes for the *k*-th subplot in the *nxm*-grid column

You can do all your favorite plotting on the axes of each subplot.

FANCIER PLOTTING: 3D, SUBPLOTS

To generate a group of 3 plots in a 3×1 grid, say. We want to explicitly create a figure and add subplots to particular positions of the grid.

```
In [72]: fig = plt.figure(figsize=(4, 4))

         ax1 = fig.add_subplot(311)
         ax1.plot([1, 2, 3], [1, 2, 3])

         ax2 = fig.add_subplot(312)
         ax2.scatter([1, 2, 3], [1, 2, 3])

         ax3 = fig.add_subplot(313)
         ax3.hist([1, 2, 3], bins=3)

         fig.tight_layout()
         plt.show()
```



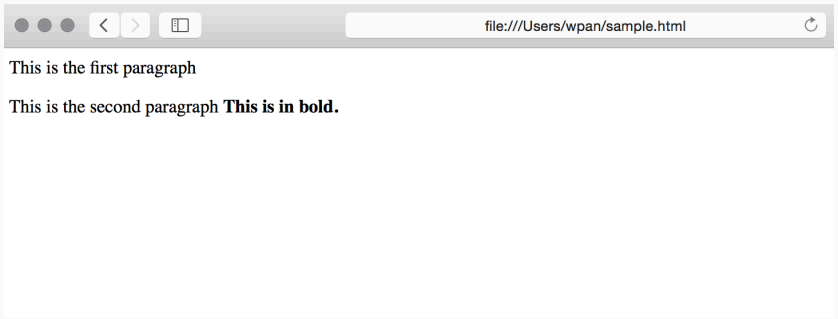
PROBLEM SOLVING

Let’s do some simple data-visualization!

Do problem 1, parts c and d

TASK III: WEB DATA

beautifulsoup

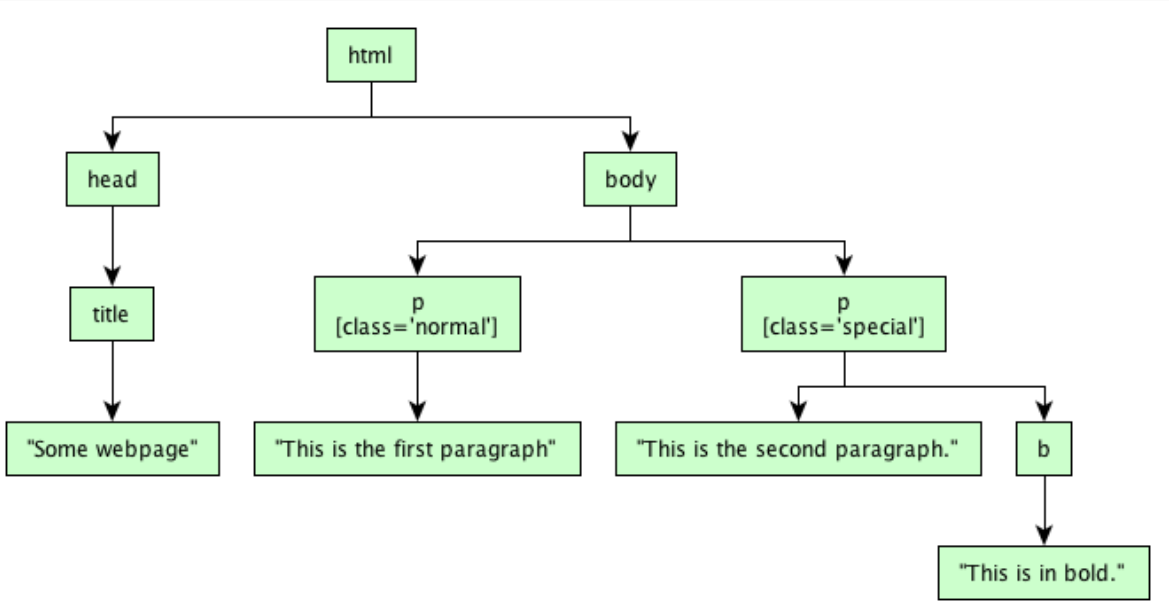



```
1
2  <html>
3      <head>
4
5          <title>Some webpage</title>
6
7      </head>
8
9      <body>
10
11         <p class="normal">
12             This is the first paragraph
13         </p>
14
15         <p class="special">
16             This is the second paragraph
17             <b>
18                 This is in bold.
19             </b>
20         </p>
21
22     </body>
23
24 </html>
```

beautifulsoup

```
page = urllib.urlopen("some_page.html").read()
soup = BeautifulSoup(page, "lxml")
```

```
<html>
    <head>

        <title>Some webpage</title>

    </head>

    <body>

        <p class="normal">
            This is the first paragraph
        </p>

        <p class="special">
            This is the second paragraph
            <b>
                This is in bold.
            </b>
        </p>

    </body>

</html>
```



The function `soup.prettify()` will turn the tree into a nicely formatted string (like the HTML file we wrote).

The function `soup.get_text()` will turn all the displayed text on the page as a string.

beautifulsoup

Code	Result	Example
`soup.tag`	returns the first instance of tag	`soup.b`
`parent.child_tag`	access the tag named 'child_tag' from it's parent tag	`soup.html.head`
`tag.contents`	returns all content (text and descendent tags)	`soup.html.head.children`
`tag.string`	returns any strings in the tag, not belonging to child tags	`soup.html.head.string`
`tag.children`	returns a "list" of all child tags	`soup.html.head.string`
`soup.find_all(tag_name)`	returns a "list" of all tags named "tag_name"	`soup.find_all('b')`

Let’s do some simple web-scrapping!

Do problem 2, parts a, b and c

MUTABLE VS IMMUTABLE TYPES

In Python, strings are **immutable**!

In [1]:
```
my_list = [0, 1, 'hi', 3, 4, 5]
my_list[2] = 1
print my_list
```

```
[0, 1, 1, 3, 4, 5]
```

In [2]:
```
my_string = 'hello'
my_string[0] = 'H'
```

```
---------------------------------------------------------------------------
TypeError                                 Traceback (most recent call last)
<ipython-input-2-e25a76cbc7ac> in <module>()
      1 my_string = 'hello'
----> 2 my_string[0] = 'H'

TypeError: 'str' object does not support item assignment
```

In [3]:
```
my_string = 'H' + my_string[1:]
print my_string
```

```
Hello
```

The Python string object has many useful functions.

`string = 'Hi world'`, `substr = 'world'`, `newstr='World'`, `sep=' '`.

Function	Returned Value	Example
`len(string)`	length of string*	`11`
`string.replace(substr, newstr)`	`string` with `substr` replaced with `newstr`	`'Hello World'`
`string.split(sep)`	a list of substrings of `string` separated by `sep`	`['Hi', 'world']`
`string.find(substr)`	the first position where `substr` occurs in `string`	`3`
`' '.join(string, newstr)`	two strings concatenated separated by a space	`'Hello World World'`

* Note: `len()` also takes lists as input.

more on lists

The Python list object also has many useful functions. For example, the `.append()` function allows us to build lists from scratch.

```
In [11]: my_list = []

         for num in range(10):
             my_list.append(num)

         print my_list
```

```
[0, 1, 2, 3, 4, 5, 6, 7, 8, 9]
```

problem solving

Let's do some text analysis on The Metamorphosis!

Do problem 2, parts d and e.

TASK IV: DATA FROM SIMULATIONS

`numpy.random`

`numpy` has a library/module called `random` that is great for sampling (generating) random numbers. Read the documentation for `random`!

problem solving

Let's simulate a simple queue!

Do problem 3, part a.