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`

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.

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
```

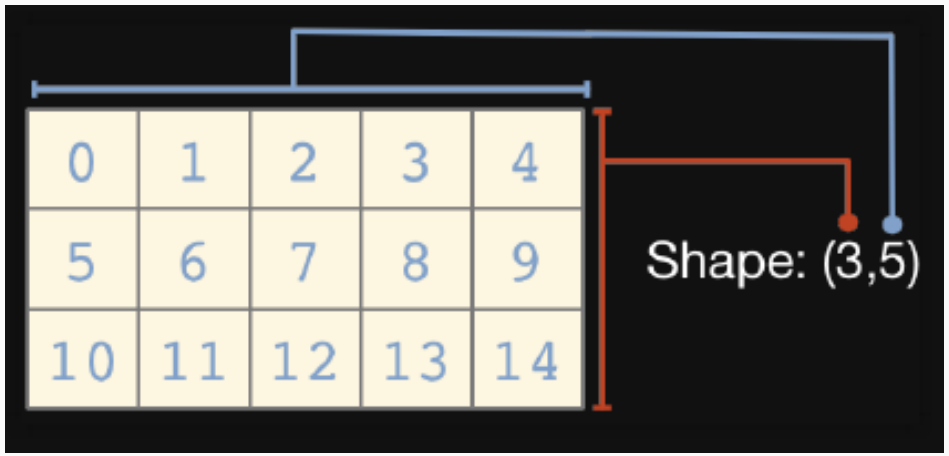
numpy ARRAYS

`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
```

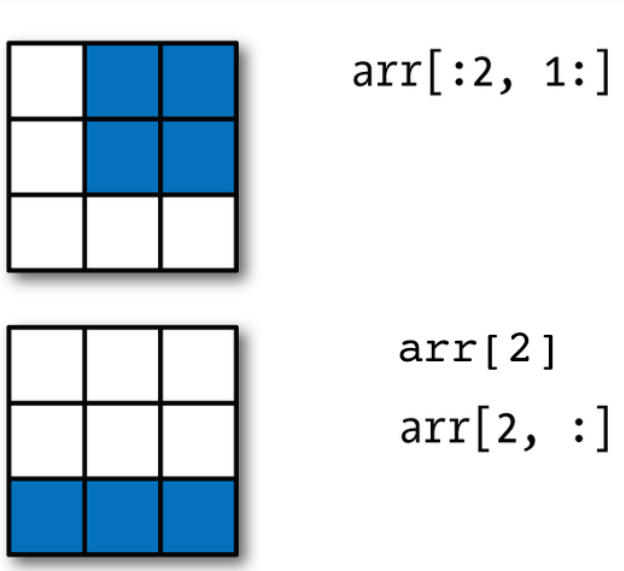
You can compute the mean by either call the mean function belonging to the array object or by applying `numpy`'s mean function to the array.

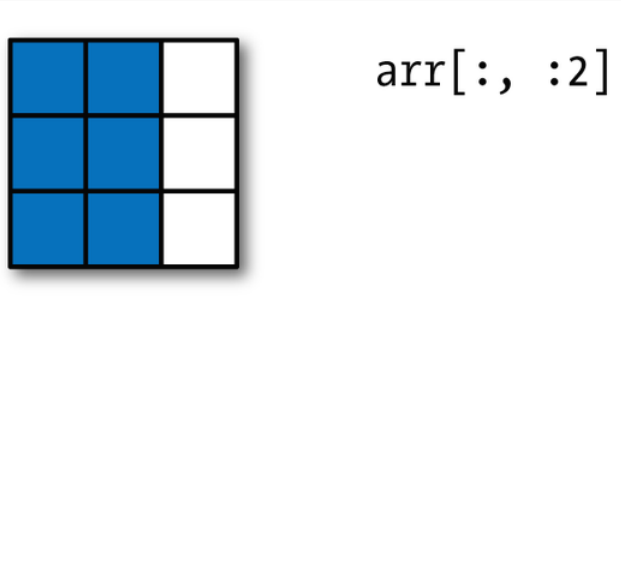
numpy 2D ARRAYS

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)
```

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?

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.

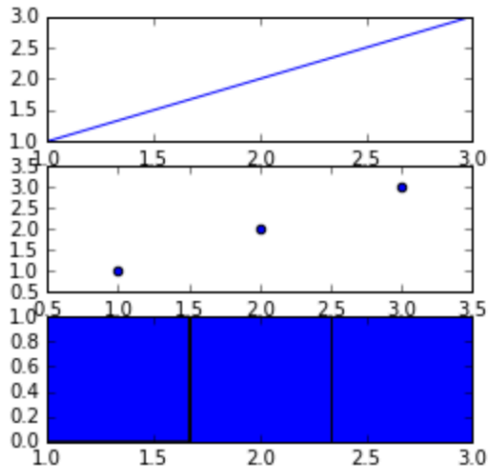
Function	Input	Result
`plt.figure()`	(optional) figure size	returns a new figure
`figure.add_subplot(n, m, k)`	row, column, subplot number	returns an axes for the *k*-th subplot in the *nxm*-grid column
`figure.add_subplot(n, m, k, projection='3d')`	row, column, subplot number, projection type	returns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

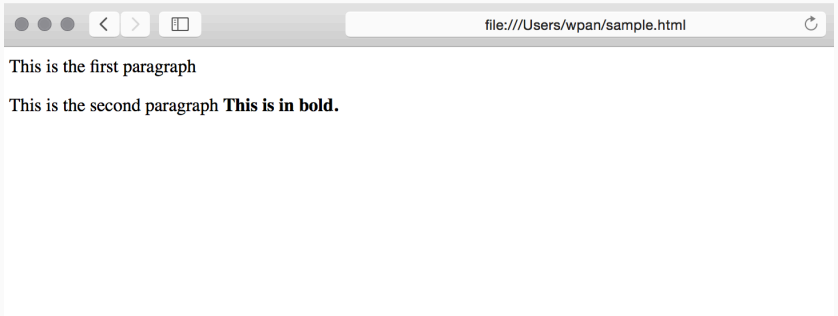
```
In [72]: fig = plt.figure(figsize=(4, 4))

         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()
```



TASK III: WEB DATA

beautifulsoup

An importance source of data is web data,
where simple displays you see on screen are specified complex syntax.



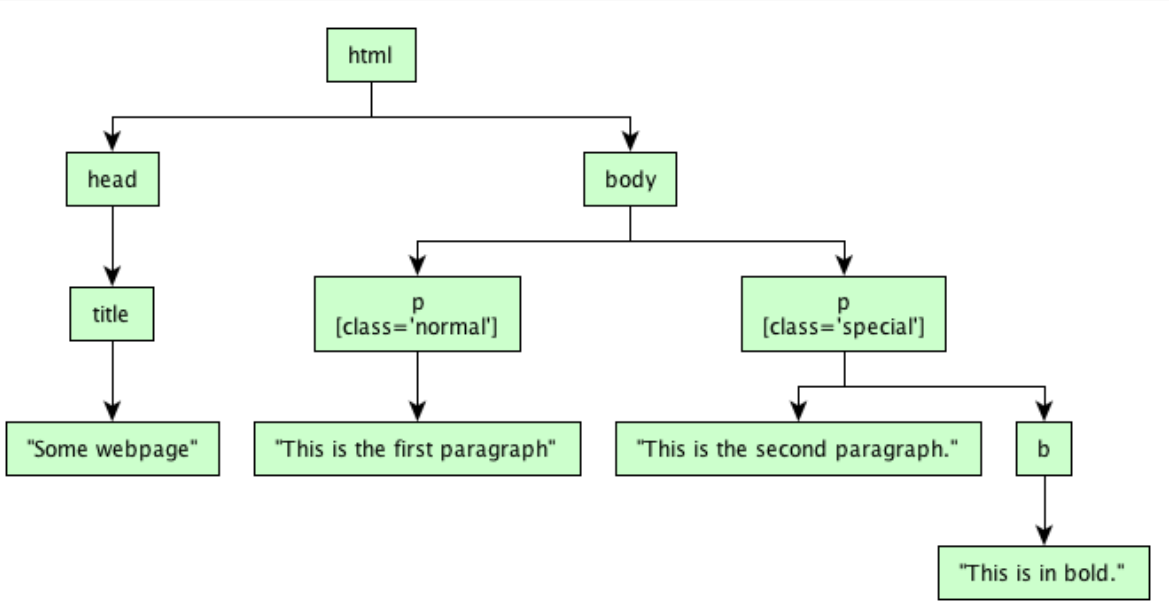

```
1
2  <html>
3      <head>
4
5          <title>Some webpage</title>
6
7      </head>
8
9      <body>
10
11         <p class="normal">
12             This is the first paragraph
13         </p>
14
15         <p class="special">
16             This is the second paragraph
17             <b>
18     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

BeautifulSoup is a Python package that will represent the information in an html file in a simple to access data structure, along with many useful functions to manipulate this structure.

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.contents`
`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.children`
`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]
```

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`!