Elements Of Data Science - S2022

# Week 2: Python Intro/Review and Numpy

1/25/2022

# TODOs

- **Review** Selections from PDSH Chapter 2
- **Read** Selections from PDSH Chapter 3
- **Skim** Selections from PDSH Chapter 4
- **Read** Chapter 2 from HOML
- Complete Week 2 Quiz

# TODOs

- Ch 2. Introduction to NumPy
    - Understanding Data Types in Python
    - The Basics of NumPy Arrays
    - Computation on NumPy Arrays: Universal Functions
    - Aggregations: Min, Max, and Everything In Between
    - Computation on Arrays: Broadcasting
    - Comparisons, Masks, and Boolean Logic
    - Fancy Indexing
    - Sorting Arrays
    - Structured Data: NumPy's Structured Arrays

# TODOs

- Ch 3. Data Manipulation with Pandas
    - Introducing Pandas Objects
    - Data Indexing and Selection
    - Operating on Data in Pandas
    - Handling Missing Data
    - Hierarchical Indexing
    - Combining Datasets: Concat and Append
    - Combining Datasets: Merge and Join
    - Aggregation and Grouping
    - Pivot Tables
    - Vectorized String Operations
    - Working with Time Series
    - High-Performance Pandas: eval() and query()

# TODOs

- Ch 4. Visualization with Matplotlib
    - Simple Line Plots
    - Simple Scatter Plots
    - Visualizing Errors
    - Density and Contour Plots
    - Histograms, Binnings, and Density
    - Customizing Plot Legends
    - Customizing Colorbars
    - Multiple Subplots
    - Text and Annotation
    - Customizing Ticks
    - Customizing Matplotlib: Configurations and Stylesheets
    - Three-Dimensional Plotting in Matplotlib
    - Geographic Data with Basemap

- Visualization with Seaborn

# Getting Changes from Git

```
terminal
$ cd [to your cloned repository directory, eg: ~/proj/eods-f21]
$ git pull
```

Questions?

# TODAY

- Tools Review
- Getting "Help" Documentation
- Python (Review?)
- Numpy
- Pandas

# Tools Review

- Starting Jupyter
- Notebooks and virtual environments

# Getting "Help" Documentation in Python

In [1]:

```
help(print)
```

```
Help on built-in function print in module buil
tins:

print(...)
    print(value, ..., sep=' ', end='\n', file=
sys.stdout, flush=False)

    Prints the values to a stream, or to sys.s
tdout by default.
    Optional keyword arguments:
    file:  a file-like object (stream); defaul
ts to the current sys.stdout.
    sep:   string inserted between values, def
```

```
ault a space.
    end:   string appended after the last valu
e, default a newline.
    flush: whether to forcibly flush the strea
m.
```

Also, in ipython/jupyter:

```
terminal
print?            # show docstring
print??           # show code as well
print([SHIFT+TAB] # get help in a popup
```

# Python (Review?)

- Dynamic Typing
- Whitespace Formatting
- Basic Data Types
- Functions
- String Formatting
- Exceptions and Try-Except
- Truthiness
- Comparisons and Logical Operators
- Control Flow
- Assert
- Sorting
- List/Dict Comprehensions
- Importing Modules
- collections Module

- Object Oriented Programming

# Dynamic Typing

- don't need to specify type at variable creation (though they'll get one at runtime)

In [2]:

```
x = 3
x = 3.14
x = 'apple'
x
```

Out[2]:

```
'apple'
```

In [3]:

```
# to determine the current variable type
type(x)
```

Out[3]:

```
str
```

# Basic Python Data Types

- **int** (integer): `42`
- **float** : `4.2`, `4e2`
- **bool** (boolean): `True`, `False`
- **str** (string) : `'num 42'`, `"num 42"`
- **None** (null): `None`
- also `long`, `complex`, `bytes`, etc.

# Whitespace Formatting

- Instead of braces or brackets to delimit blocks, use whitespace

```
# The pound sign marks the start of a comment. Python itself
# ignores the comments, but they're helpful for anyone reading the code.
for i in [1, 2, 3, 4, 5]:
    print(i)                    # first line in "for i" block
    for j in [1, 2, 3, 4, 5]:
        print(j)                # first line in "for j" block
        print(i + j)            # last line in "for j" block
    print(i)                    # last line in "for i" block
print("done looping")
```

- 4 space indentations are conventional
- Style Guide : PEP 8 (**https://www.python.org/dev/peps/pep-0008/**)

# Functions

In [4]:

```
def add_two(x):
    """Adds 2 to the number passed in."""
    return x+2


add_two(2)
```

Out[4]:

4

In [5]:

```
help(add_two)
```

```
Help on function add_two in module __main__:

add_two(x)
    Adds 2 to the number passed in.
```

Also in ipython/jupyter:

- `add_two?  # show docstring`
- `add_two??  # show code as well`
- `add_two([SHIFT+TAB] # get help in a popup`

# Function Arguments

- can assign defaults

In [6]:

```
def increment(x,amount=1):
    """Increment a value, default by 1."""
    return x+amount

increment(2)
```

Out[6]:

3

In [7]:

```
increment(2,amount=2)
```

Out[7]:

4

# Function Arguments Cont.

- **positional arguments** must be entered in order

In [8]:

```
def subtract(x,y):
    return x-y

subtract(3,1)
```

Out[8]:

2

- **keyword arguments** must follow positional
- can be called in any order

In [9]:

```
def proportion(numer,denom,precision=2):
    return round(numer/denom,precision)

proportion(2,precision=2,denom=3)
```

Out[9]:

0.67

# String Formatting

In [10]:

```
x = 3.1415

'the value of x is ' + str(x)
```

Out[10]:

```
'the value of x is 3.1415'
```

In [11]:

```
'the value of x is %0.2f' % x
```

Out[11]:

```
'the value of x is 3.14'
```

In [12]:

```
'the value of x is {:0.10f}'.format(x)
```

Out[12]:

```
'the value of x is 3.1415000000'
```

In [13]:

```
f'the value of x is {x:0.2f}'
```

Out[13]:

```
'the value of x is 3.14'
```

- often print variable values for debugging

In [14]:

```
f'x = {x:0.2f}'
```

Out[14]:

```
'x = 3.14'
```

In [15]:

```
f'{x = :0.2f}' # new in 3.8
```

Out[15]:

```
'x = 3.14'
```

# String Formatting Cont.

In [16]:

```
"""This is a multiline string.
The value of x is {}.""".format(x)
```

Out[16]:

```
'This is a multiline string.\nThe value of x i
s 3.1415.'
```

In [17]:

```
print("""This is a multiline string.
The value of x is {}.""".format(x))
```

```
This is a multiline string.
The value of x is 3.1415.
```

- common specifiers: `%s strings, %d integers, %f floats`

In [18]:

```
x='apple'
f'the plural of {x:>10s} is {x+"s"}'
```

Out[18]:

```
'the plural of      apple is apples'
```

In [19]:

```
x = 3
f'the square of {x:10d} is {x**2}'
```

Out[19]:

```
'the square of          3 is 9'
```

- to learn more **https://realpython.com/python-string-formatting/**

# Python Data Types Continued: `list`

In [20]:

```
# elements of a python list do not all have to be of the same type
x = [42,'e',2.0]
x
```

Out[20]:

```
[42, 'e', 2.0]
```

In [21]:

```
x[0] # indexing
```

Out[21]:

```
42
```

In [22]:

```
x[-3] # reverse indexing
```

Out[22]:

```
42
```

In [23]:

```
x[2] = 4 # assignment
x
```

Out[23]:

```
[42, 'e', 4]
```

In [24]:

```
x.append('a') # add a value to list
x
```

Out[24]:

```
[42, 'e', 4, 'a']
```

In [25]:

```
value_at_1 = x.pop(1) # remove/delete at index
x
```

Out[25]:

```
[42, 4, 'a']
```

# Python Data Types Continued: `dict` (Dictionary)

- Stores key:value pairs

In [26]:

```
x = {'b':[2,1],'a':1,'c':4}
# or x = dict(b=[2,1],a=1,c=4)
x # NOTE: order is not guaranteed!
```

Out[26]:

```
{'b': [2, 1], 'a': 1, 'c': 4}
```

In [27]:

```
# index into dictionary using key
x['b']
```

Out[27]:

```
[2, 1]
```

In [28]:

```
# assign a value to a (new or existing) key
x['d'] = 3
x
```

Out[28]:

```
{'b': [2, 1], 'a': 1, 'c': 4, 'd': 3}
```

In [29]:

```
# remove/delete
# can specify a return a value if key does not exist (here it's None), otherwise throws an exception
x.pop('d',None)
```

Out[29]:

```
3
```

In [30]:

```
x
```

Out[30]:

```
{'b': [2, 1], 'a': 1, 'c': 4}
```

# Python Data Types Continued: `dict` Cont.

In [31]:

```
# using the same dictionary
x
```

Out[31]:

```
{'b': [2, 1], 'a': 1, 'c': 4}
```

In [32]:

```
# get a set of keys
x.keys()
```

Out[32]:

```
dict_keys(['b', 'a', 'c'])
```

In [33]:

```
# get a set of values
x.values()
```

Out[33]:

```
dict_values([[2, 1], 1, 4])
```

In [34]:

```
# get a set of (key,value) tuples
x.items()
```

Out[34]:

```
dict_items([('b', [2, 1]), ('a', 1), ('c', 4)])
```

In [35]:

```
# get a list of (key,value) pairs
list(x.items())
```

Out[35]:

```
[('b', [2, 1]), ('a', 1), ('c', 4)]
```

# Python Data Types Continued: `tuple`

- like a list, but **immutable**

In [36]:

```
x = (2,'e',3,4)
x
```

Out[36]:

```
(2, 'e', 3, 4)
```

In [37]:

```
x[0] # indexing
```

Out[37]:

```
2
```

In [38]:

```
x[0] = 3 # assignment? Nope, error: immutable`
```

```
---------------------------------------------------------------------------
TypeError                                 Traceback (most recent call last)
/tmp/ipykernel_5904/3594152884.py in <module>
----> 1 x[0] = 3 # assignment? Nope, error: immutable`

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

# Python Data Types Continued: `set`

In [39]:

```
x = {2,'e','e'} # or set([2,'e','e'])
x
```

Out[39]:

```
{2, 'e'}
```

In [40]:

```
x.add(1) # insert
x
```

Out[40]:

```
{1, 2, 'e'}
```

In [41]:

```
x.remove('e') # remove/delete
x
```

Out[41]:

```
{1, 2}
```

In [42]:

```
x.intersection({2,3})
```

Out[42]:

{2}

In [43]:

```
x.difference({2,3})
```

Out[43]:

{1}

In [44]:

```
x[0] # cannot index into a set
```

```
---------------------------------------------------------------------------
TypeError                                 Traceback (most recent call last)
/tmp/ipykernel_5904/3791443751.py in <module>
----> 1 x[0] # cannot index into a set
```

```
TypeError: 'set' object is not subscriptable
```

# Determining Length with `len`

In [45]:

```
len([1,2,3])
```

Out[45]:

3

In [46]:

```
len({'a':1,'b':2,'c':3})
```

Out[46]:

3

In [47]:

```
len('apple')
```

Out[47]:

5

In [48]:

```
len(True)
```

```
---------------------------------------------------------------------------
TypeError                                 Traceback (most recent call last)
/tmp/ipykernel_5904/1402046054.py in <module>
----> 1 len(True)

TypeError: object of type 'bool' has no len()
```

# Exceptions

In [49]:

```
'a' + 2
```

```
---------------------------------------------------------------------------
TypeError                                 Traceback (most recent call last)
/tmp/ipykernel_5904/2408715624.py in <module>
----> 1 'a' + 2

TypeError: can only concatenate str (not "int") to str
```

Common exceptions:

- SyntaxError
- IndentationError
- ValueError
- TypeError
- IndexError
- KeyError
- and many more **https://docs.python.org/3/library/exceptions.html**

# Catching Exceptions with `try-except`

In [50]:

```
try:
    'a' + 2
except TypeError as e:
    print(f"We did this on purpose, and here's what's wrong:\n{e}")
```

```
We did this on purpose, and here's what's wron
g:
can only concatenate str (not "int") to str
```

In [51]:

```
try:
    set([1,2,3])[0]
except SyntaxError as e:
    print(f"Print this if there's a syntax error")
except Exception as e:
    print(f"Print this for any other error")
```

```
Print this for any other error
```

# Truthiness

- boolean: `True`, `False`
- These all translate to `False`:
    - `None`
    - `[]` (empty list)
    - `{}` (empty dictionary)
    - `''` (empty string)
    - `set()`
    - `0`
    - `0.0`

# Comparison Operators

- equality: `==`
- inequality: `!=`

In [52]:

```
3 == 3
```

Out[52]:

```
True
```

In [53]:

```
3 != 4
```

Out[53]:

```
True
```

- less than: `<`
- greater than: `>`
- '(less than/greater than) or equal to: `<=` , `>=`

In [54]:

```
3 < 4
```

Out[54]:

True

# Logical Operators

- logical operators: `and`, `or`, `not`

In [55]:

```
( (3 > 5) or ((3 < 4) and (5 > 4)) ) and not (3 == 5)
```

Out[55]:

```
True
```

- `any()`: at least one element is true

In [56]:

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

Out[56]:

```
True
```

- `all()`: all elements are true

In [57]:

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

Out[57]:

```
False
```

- **bitwise operators** (we'll see these in numpy and pandas) : `&` (and), `|` (or), `~` (not)

# Assert

- use `assert` to test anything we know should be true
- simple unit test
- raises exception when assertion is false, otherwise nothing

In [58]:

```
assert 2+2 == 4
```

In [59]:

```
assert 1 == 0
```

```
---------------------------------------------------------------------------
AssertionError                                            Traceback (most recent call last)
/tmp/ipykernel_5904/351952524.py in <module>
----> 1 assert 1 == 0
```

```
AssertionError:
```

In [60]:

```
# can add an error message
assert 1 == 0, "1 does not equal 0"
```

```
---------------------------------------------------------------------------
AssertionError                                            Traceback (most recent call last)
/tmp/ipykernel_5904/1347466644.py in <module>
      1 # can add an error message
----> 2 assert 1 == 0, "1 does not equal 0"

AssertionError: 1 does not equal 0
```

# Control Flow: `if`:`elif`:`else`

- `if` then `elif` then `else`

In [61]:

```
x = 3
if x > 0:
    print('x > 0')
elif x < 0:
    print('x < 0')
else:
    print('x == 0')
```

```
x > 0
```

- single-line `if` then `else`

In [62]:

```
print("x < 0") if (x < 0) else print("x >= 0")
```

```
x >= 0
```

# More Control Flow: `for` and `while`

- `for` each element of an iterable: do something

In [63]:

```
a = []
for x in [0,1,2]:
    a.append(x)
a
```

Out[63]:

```
[0, 1, 2]
```

- `while` something is true

In [64]:

```
x = 0
while x < 3:
    x += 1
x
```

Out[64]:

```
3
```

# More Control Flow: `break` and `continue`

- `break` : break out of current loop

In [65]:

```
x = 0
while True:
    x += 1
    if x == 3:
        print(x)
        break
```

```
3
```

- `continue` : continue immediately to next iteration of loop

In [66]:

```
for x in range(3):
    if x == 1:
        continue
    print(x)
```

```
0
2
```

# Generate a Range of Numbers: `range`

In [67]:

```
# create list of integers from 0 up to but not including 4
a = []
for x in range(4):
    a.append(x)
a
```

Out[67]:

```
[0, 1, 2, 3]
```

In [68]:

```
list(range(4))
```

Out[68]:

```
[0, 1, 2, 3]
```

In [69]:

```
list(range(3,5)) # with a start and end+1
```

Out[69]:

```
[3, 4]
```

In [70]:

```
list(range(0,10,2)) # with start, end+1 and step-size
```

Out[70]:

```
[0, 2, 4, 6, 8]
```

# Keep track of list index or for-loop iteration: `enumerate`

In [71]:

```
for i,x in enumerate(['a','b','c']):
    print(i,x)
```

```
0 a
1 b
2 c
```

In [72]:

```
list(enumerate(['a','b','c']))
```

Out[72]:

```
[(0, 'a'), (1, 'b'), (2, 'c')]
```

# Sorting

Two ways to sort a list:

1. by changing the list itself: `list.sort()`

In [73]:

```
x = [4,1,2,3]
x.sort()
assert x == [1,2,3,4]
```

1. without changing the list: `sorted()`

In [74]:

```
x = [4,1,2,3]
y = sorted(x)
assert x == [4,1,2,3]
assert y == [1,2,3,4]
```

# Sorting Cont.

- To sort descending, use `reverse=True`:

In [75]:

```
assert sorted([1,2,3,4], reverse=True) == [4,3,2,1]
```

- Pass a `lambda` function to 'key=' to specify what to sort by:

In [76]:

```
# for example, to sort a dictionary by value
d = {'a':3,'b':5,'c':1}

# recall that .items() returns a set of key,value tuples
s = sorted(d.items(), key=lambda x: x[1])

assert s == [('c', 1), ('a', 3), ('b', 5)]
```

# List Comprehensions

- Like a single line for loop over a list or other iterable

In [77]:

```
# which integers between 0 and 3 inclusive are divisible by 2?
is_even = []
for x in range(0,4):
    is_even.append(x%2 == 0)
is_even
```

Out[77]:

```
[True, False, True, False]
```

In [78]:

```
[x%2 == 0 for x in range(0,4)] # using a list comprehension
```

Out[78]:

```
[True, False, True, False]
```

In [79]:

```
# what are the indices of the vowels in 'apple'?
vowels = ['a','e','i','o','u']
[i for i,x in enumerate('apple') if x in vowels]
```

Out[79]:

```
[0, 4]
```

# Dictionary Comprehension

- list comprehension but for (key,value) pairs
- can add logic to dictionary creation

In [80]:

```
pairs = [(1,'e'),(2,'f'),(3,'g')]
```

In [81]:

```
dict(pairs)
```

Out[81]:

```
{1: 'e', 2: 'f', 3: 'g'}
```

In [82]:

```
# modify value and only include odd keys
{key:'value_'+str(val) for key,val in pairs if key%2 == 1}
```

Out[82]:

```
{1: 'value_e', 3: 'value_g'}
```

# Object Oriented Programming

In [85]:

```
class MyClass:
    """A descriptive docstring."""

    # constructor
    def __init__(self,myvalue = 0):  # what happens when created
        # attributes
        self.myvalue = myvalue

    def __repr__(self):   # what gets printed out (string repr.)
        return f'MyClass(myvalue={self.myvalue})'

    # any other methods
    def get_value(self):
        """Return the value in myvalue."""
        return self.myvalue
```

In [86]:

```
x = MyClass(100)            # instantiate object

assert x.myvalue == 100     # access object attribute

assert x.get_value() == 100 # use object method
```

# Importing Modules

- Want to import a module/library? Use `import`

In [87]:

```
import math
math.sqrt(2)
```

Out[87]:

```
1.4142135623730951
```

- Want to import a submodule or function from a module? Use `from`

In [88]:

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

```
1.4142135623730951
1
```

# Importing Modules Cont.

- Want to import a module using an alias? Use 'as'

In [89]:

```
import math as m
m.sqrt(2)
```

Out[89]:

```
1.4142135623730951
```

- Don't do: `import *`

```
from math import *
# for example, what if there is a math.print() function?
# what happens when we then call print()?
```

# `collections` Module

In [90]:

```
from collections import Counter, defaultdict, OrderedDict
```

- `Counter` : useful for counting hashable objects
- `defaultdict` : create dictionaries without checking keys
- `OrderedDict` : key,value pairs returned in order added
- others : **https://docs.python.org/3.7/library/collections.html**

# `collections` Module: `Counter`

In [91]:

```
c = Counter(['red', 'blue', 'red', 'green', 'blue', 'blue'])
c
```

Out[91]:

```
Counter({'red': 2, 'blue': 3, 'green': 1})
```

In [92]:

```
c = Counter()
for word in ['red', 'blue', 'red', 'green', 'blue', 'blue']:
    c[word] += 1
```

In [93]:

```
c.most_common()
```

Out[93]:

```
[('blue', 3), ('red', 2), ('green', 1)]
```

# `collections` Module Cont. : `defaultdict`

In [94]:

```
%xmode Minimal
# reduce the amount printed when an exception is thrown
```

```
Exception reporting mode: Minimal
```

In [95]:

```
# create mapping from length of word to list of words
colors = ['red', 'blue', 'purple', 'gold', 'orange']
d = {}
for word in colors:
    d[len(word)].append(word)
```

```
KeyError: 3
```

In [96]:

```
d = {}
for word in colors:
    if len(word) in d:
        d[len(word)].append(word)
    else:
        d[len(word)] = [word]
d
```

Out[96]:

```
{3: ['red'], 4: ['blue', 'gold'], 6: ['purpl
e', 'orange']}
```

In [97]:

```
d = defaultdict(list)
for word in colors:
     d[len(word)].append(word)
d
```

Out[97]:

```
defaultdict(list, {3: ['red'], 4: ['blue', 'go
ld'], 6: ['purple', 'orange']})
```

# Contexts

- a context is like applying a scope with helper functions
- For example: open and write to a file

In [98]:

```
with open('tmp_context_example.txt','w') as f:
    f.write('test')
```

In [99]:

```
# instead of
f = open('tmp_context_example.txt','w')
f.write('test')
f.close() # this is easy to forget to do
```

In [100]:

```
# remove the example file we just created
%rm tmp_context_example.txt
```

# Python (Review?)

- Dynamic Typing
- Whitespace Formatting
- Basic Data Types
- Functions
- String Formatting
- Exceptions and Try-Except
- Truthiness
- Comparisons and Logical Operators
- Control Flow
- Assert
- Sorting
- List/Dict Comprehensions
- Importing Modules
- collections Module

- Object Oriented Programming

Questions?

# Working with Data

Want to:

- transform and select data quickly (numpy)
- manipulate datasets: load, save, group, join, etc. (pandas)
- keep things organized (pandas)

# Intro to NumPy


Provides (from numpy.org):

- a powerful N-dimensional array object
- sophisticated (broadcasting) functions
- linear algebra and random number capabilities
- (Fourier transform, tools for integrating C/C++ and Fortran code, etc.)

# Python Dynamic Typing

In [101]:

```
x = 5
x = 'five'
```

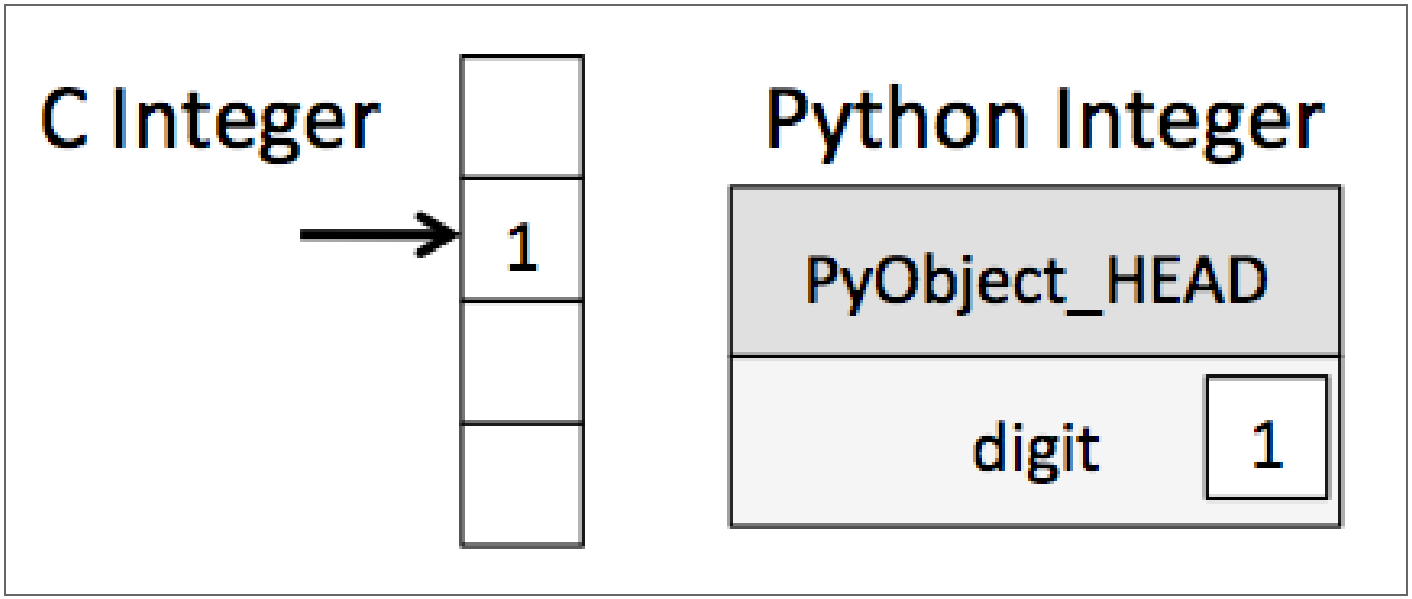
- Note: still *strongly* typed

In [102]:

```
x,y = 5,'five'
x+y
```

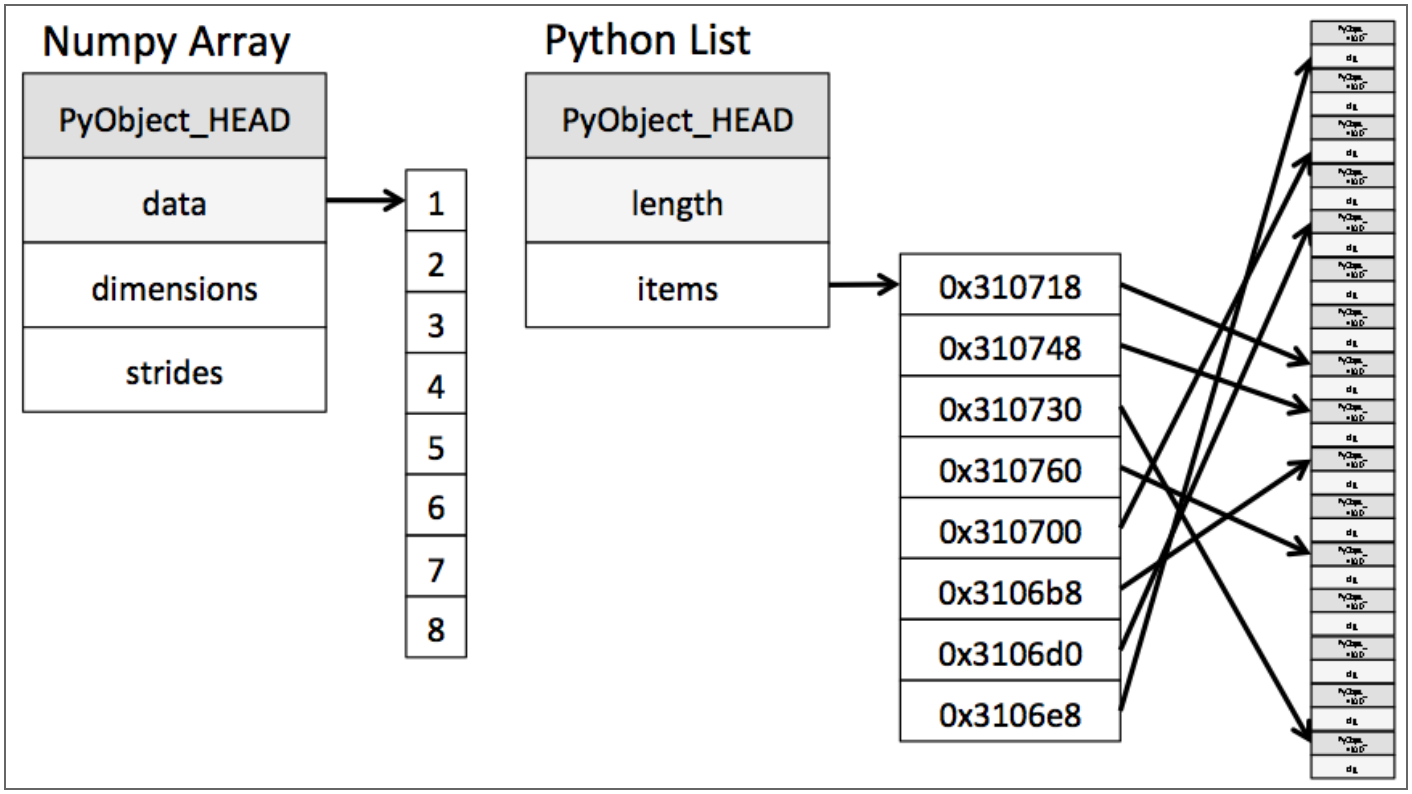
```
TypeError: unsupported operand type(s) for +:
 'int' and 'str'
```

# Python Dynamic Typing




**PDHS Chap 2.**

# NumPy Array vs Python List



# PDHS Chap 2.

# Importing NumPy

## Often imported as alias `np`

In [103]:

```
import numpy as np

np.random.randint(10,size=5)
```

Out[103]:

```
array([9, 5, 3, 7, 6])
```

# NumPy Datatypes

```
bool_       Boolean (True or False) stored as a byte
int_        Default integer type (same as C long; normally either int64 or
int32)
intc        Identical to C int (normally int32 or int64)
intp        Integer used for indexing (same as C ssize_t; normally either
int32 or int64)
int8        Byte (-128 to 127)
int16       Integer (-32768 to 32767)
int32       Integer (-2147483648 to 2147483647)
int64       Integer (-9223372036854775808 to 9223372036854775807)
uint8       Unsigned integer (0 to 255)
uint16      Unsigned integer (0 to 65535)
uint32      Unsigned integer (0 to 4294967295)
uint64      Unsigned integer (0 to 18446744073709551615)
float_      Shorthand for float64.
float16     Half precision float: sign bit, 5 bits exponent, 10 bits mantissa
float32     Single precision float: sign bit, 8 bits exponent, 23 bits
```

</font>

# NumPy Arrays

In [104]:

```
x = np.array([1,2,3])
x
```

Out[104]:

```
array([1, 2, 3])
```

In [105]:

```
type(x)
```

Out[105]:

```
numpy.ndarray
```

In [106]:

```
# use dtype to show the datatype of the array
x.dtype
```

Out[106]:

```
dtype('int64')
```

In [107]:

```
# np arrays can only contain one datatype and default to the most flexible type
x = np.array([1,'two',3])
x
```

Out[107]:

```
array(['1', 'two', '3'], dtype='<U21')
```

In [108]:

```
x.dtype
```

Out[108]:

```
dtype('<U21')
```

In [109]:

```
# many different ways to create numpy arrays
np.ones(5,dtype=float)
```

Out[109]:

```
array([1., 1., 1., 1., 1.])
```

# NumPy Array Indexing

- For single indices, works the same as list

In [110]:

```
x = np.arange(1,6)
x
```

Out[110]:

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

In [111]:

```
x[0], x[-1], x[-2]
```

Out[111]:

```
(1, 5, 4)
```

# NumPy Array Slicing

In [112]:

```
x = np.arange(5) # note that in numpy it's arange instead of range
x
```

Out[112]:

```
array([0, 1, 2, 3, 4])
```

In [113]:

```
# return first two items, start:end (exclusive)
x[0:2]
```

Out[113]:

```
array([0, 1])
```

In [114]:

```
# missing start implies position 0
x[:2]
```

Out[114]:

```
array([0, 1])
```

In [115]:

```
# missing end implies length of array
x[2:]
```

Out[115]:

```
array([2, 3, 4])
```

In [116]:

```
# return last two items
x[-2:]
```

Out[116]:

```
array([3, 4])
```

# NumPy Array Slicing with Steps

In [117]:

```
x
```

Out[117]:

```
array([0, 1, 2, 3, 4])
```

In [118]:

```
# return every other item from position 1 to 4 exclusive
# start:end:step_size
x[1:4:2]
```

Out[118]:

```
array([1, 3])
```

# Reverse array with step-size of -1

In [119]:

```
x
```

Out[119]:

```
array([0, 1, 2, 3, 4])
```

In [120]:

```
x[::-1]
```

Out[120]:

```
array([4, 3, 2, 1, 0])
```

# NumPy Fancy Indexing

- Accessing multiple, non-consective indices at once using a list

In [121]:

```
x = np.arange(5,10)
x
```

Out[121]:

```
array([5, 6, 7, 8, 9])
```

In [122]:

```
x[[0,3]]
```

Out[122]:

```
array([5, 8])
```

In [123]:

```
x[[0,2,-1]]
```

Out[123]:

```
array([5, 7, 9])
```

# Boolean Indexing using a Boolean Mask

In [124]:

```
x
```

Out[124]:

```
array([5, 6, 7, 8, 9])
```

In [125]:

```
# Which indices have a value divisible by 2?
# mod operator % returns remainder of division
x%2 == 0
```

Out[125]:

```
array([False,  True, False,  True, False])
```

In [126]:

```
# Which values are divisible by 2?
x[x%2 == 0]
```

Out[126]:

```
array([6, 8])
```

In [127]:

```
# Which values are greater than 6?
x[x > 6]
```

Out[127]:

```
array([7, 8, 9])
```

# Boolean Indexing And Bitwise Operators

In [128]:

```
x
```

Out[128]:

```
array([5, 6, 7, 8, 9])
```

In [129]:

```
(x%2 == 0)
```

Out[129]:

```
array([False,  True, False,  True, False])
```

In [130]:

```
(x > 6)
```

Out[130]:

```
array([False, False,  True,  True,  True])
```

In [131]:

```
# Which values are divisible by 2 AND greater than 6?
# 'and' expexts both elements be boolean, not arrays of booleans!
(x%2 == 0) and (x > 6)
```

```
ValueError: The truth value of an array with more than one element is ambiguous. Us
e a.any() or a.all()
```

In [132]:

```
# & compares each element pairwise
(x%2 == 0) & (x > 6)
```

Out[132]:

```
array([False, False, False,  True, False])
```

In [133]:

```
x[(x%2 == 0) & (x > 6)]
```

Out[133]:

```
array([8])
```

# Boolean Indexing And Bitwise Operators

- and : `&` (ampersand)

In [134]:

```
# Which values are even AND greater than 6?
x[(x%2 == 0) & (x > 6)]
```

Out[134]:

```
array([8])
```

- or : `|` (pipe)

In [135]:

```
# which values are even OR greater than 6?
x[(x%2 == 0) | (x > 6)]
```

Out[135]:

```
array([6, 7, 8, 9])
```

- not : `~` (tilde)

In [136]:

```
# which values are NOT (even OR greater than 6)
x[~( (x%2 == 0) | (x > 6) )]
```

Out[136]:

```
array([5])
```

- see **PDHS** for more info

# Indexing Review

- standard array indexing (including reverse/negative)
- slicing [start:end:step-size]
- fancy indexing (list/array of indices)
- boolean indexing (list/array of booleans)

# Multidimensional Lists

In [137]:

```
x = [[1,2,3],[4,5,6]] # list of lists
x
```

Out[137]:

```
[[1, 2, 3], [4, 5, 6]]
```

In [138]:

```
# return first row
x[0]
```

Out[138]:

```
[1, 2, 3]
```

In [139]:

```
# return first row, second column
x[0][1]
```

Out[139]:

```
2
```

In [140]:

```
# return second column?
[row[1] for row in x]
```

Out[140]:

```
[2, 5]
```

# NumPy Multidimensional Arrays

In [141]:

```
x = np.array([[1,2,3],[4,5,6]])
x
```

Out[141]:

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

In [142]:

```
x[0,1] # first row, second column
```

Out[142]:

```
2
```

In [143]:

```
x[0,0:3] # first row
```

Out[143]:

```
array([1, 2, 3])
```

In [144]:

```
x[0,:] # first row (first to last column)
```

Out[144]:

```
array([1, 2, 3])
```

In [145]:

```
x[:,1] # second column (first to last row)
```

Out[145]:

```
array([2, 5])
```

# NumPy Array Attributes

In [146]:

```
x = np.array([[1,2,3],[4,5,6]])
```

In [147]:

```
x.ndim # number of dimensions
```

Out[147]:

```
2
```

In [148]:

```
x.shape # shape in each dimension
```

Out[148]:

```
(2, 3)
```

In [149]:

```
x.size # total number of elements
```

Out[149]:

```
6
```

# NumPy Operations (UFuncs)

In [150]:

```
x = [1,2,3]
y = [4,5,6]
```

In [151]:

```
x+y
```

Out[151]:

```
[1, 2, 3, 4, 5, 6]
```

In [152]:

```
x = np.array([1,2,3])
y = np.array([4,5,6])
```

In [153]:

```
x+y
```

Out[153]:

```
array([5, 7, 9])
```

# NumPy Broadcasting

## Allows for vectorized computation on arrays of different sizes

In [154]:

```
# square every element in a list
x = [1,2,3]
```

In [155]:

```
x**2
```

```
TypeError: unsupported operand type(s) for ** or pow(): 'list' and 'int'
```

In [156]:

```
[y**2 for y in x]
```

Out[156]:

```
[1, 4, 9]
```

In [157]:

```
# square every element in a numpy array
x = np.array([1,2,3])
```

In [158]:

```
x**2
```

Out[158]:

```
array([1, 4, 9])
```

# NumPy `random` Submodule

Provides many random sampling functions

```
from numpy.random import ...
```

- `rand` : random floats
- `randint` : random integers
- `randn` : standard normal distribution
- `permutation` : random permutation
- `normal` : Gaussian normal distribution
- `seed` : seed the random generator

Questions?