Python Tutorial

CS/CME/BioE/Biophys/BMI 279

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Outline

- Python2 vs Python3
- Python syntax
- Data structures
- Functions
- Debugging
- Classes
- The NumPy Library

Many examples adapted from Sam Redmond's CS41

Python2 vs Python3

- Our assignments are written for **Python2**
- You are welcome to use Python3, but you're on your own if you run into bugs; and will likely have to make some modifications to get things working
- Python2 will be maintained until **2020**

http://py3readiness.org/

Python Syntax

Variables

Python

```
x = 5
y = x + 7
z = 3.14

name = “Rishi”


1 == 1 # => True
5 > 10 # => False

True and False # => False
not False # => True
```

Variables are not statically typed!

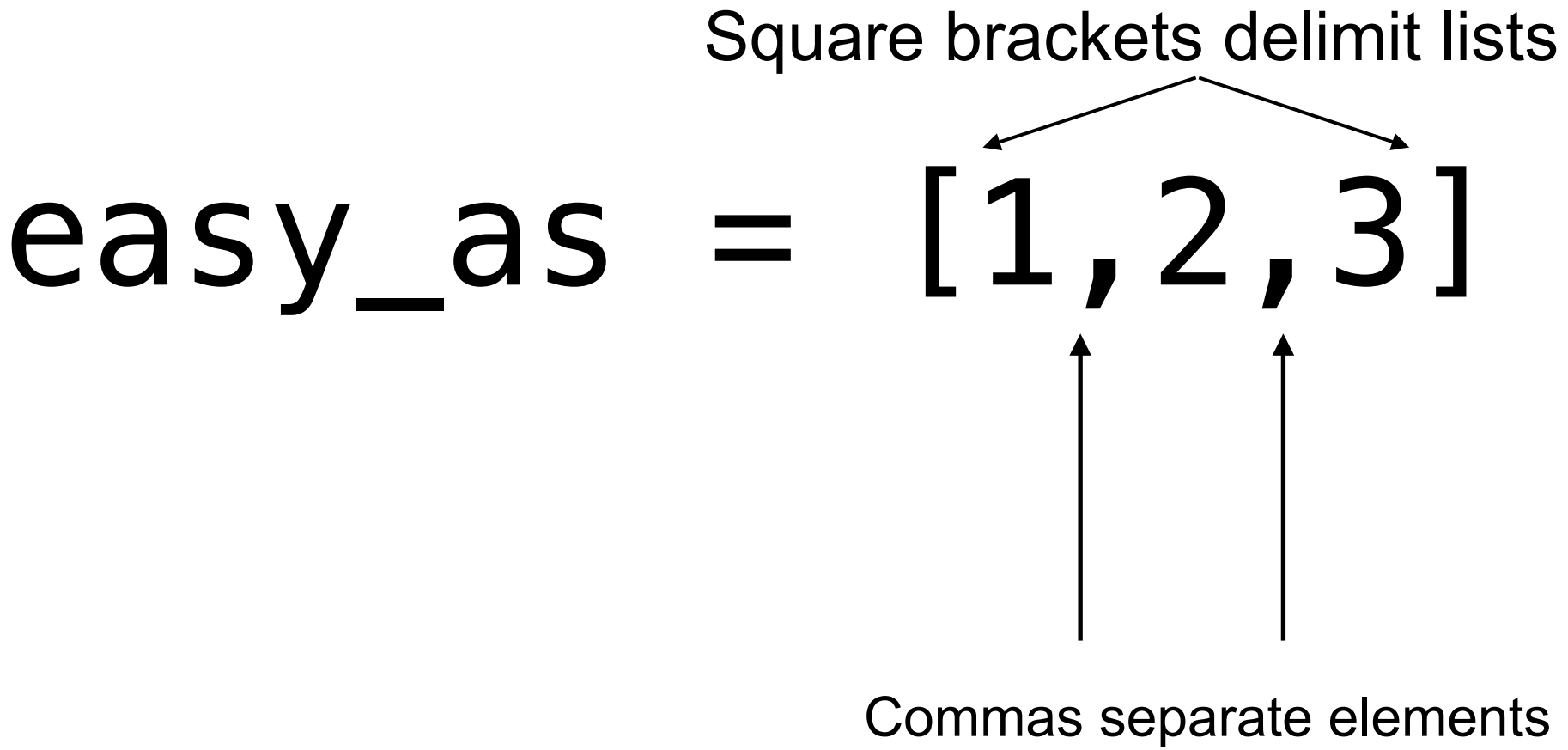
Java/C++

```
int x = 5;
int y = x + 7;
double z = 3.14;

String name = “Rishi”; // Java
string name(“Rishi”);  // C++

1 == 1 # => true
5 > 10 # => false

true && false # => false
!(false) # => true
```

Data Structures

- Lists
- Tuples
- Dictionaries
- Iteration
- List Comprehensions

Lists


Square brackets delimit lists
easy_as = [1,2,3]
Commas separate elements

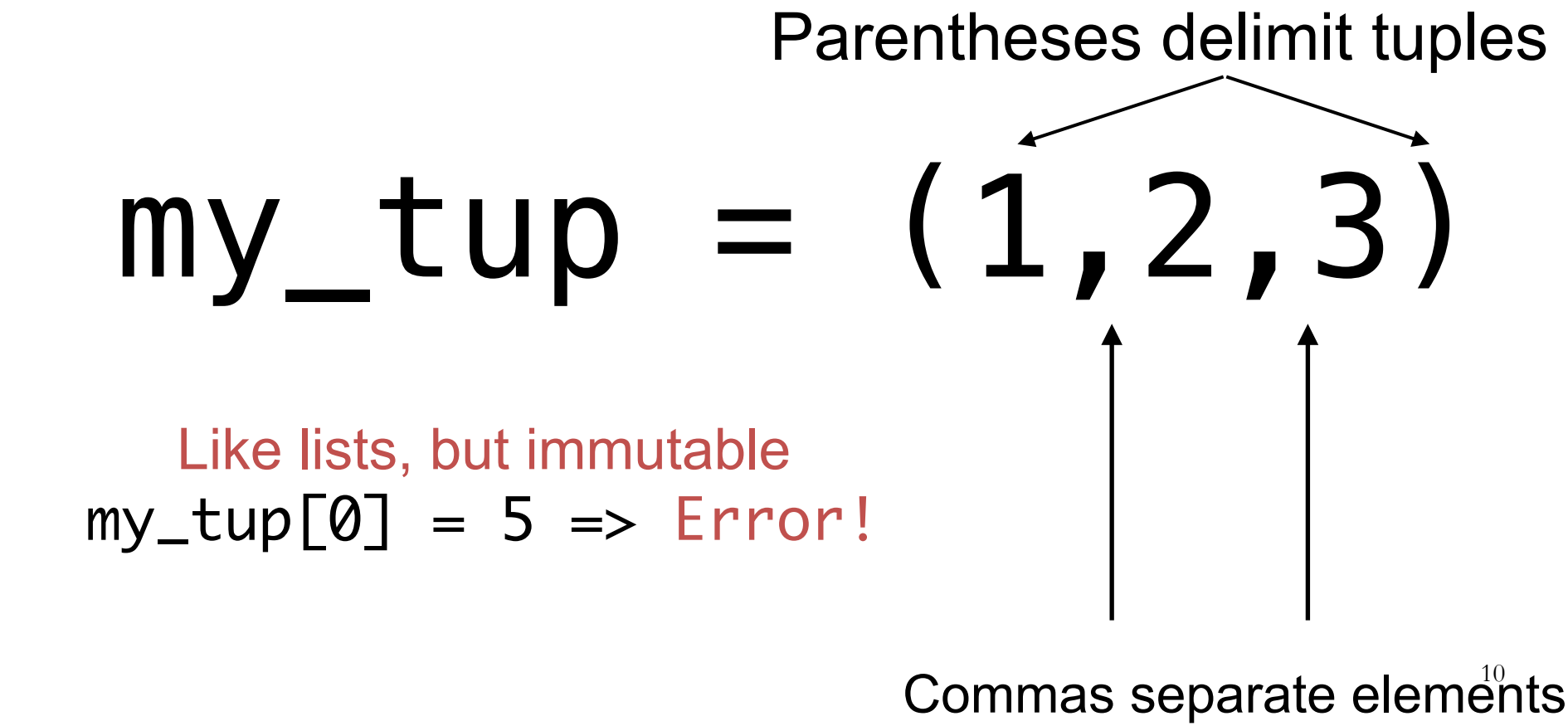
Lists

```
# Create a new list
empty = []
letters = ['a', 'b', 'c', 'd']
numbers = [2, 3, 5]

# Lists can contain elements of different types
mixed = [4, 5, "seconds"]

# Append elements to the end of a list
numbers.append(7)   # numbers == [2, 3, 5, 7]
numbers.append(11)  # numbers == [2, 3, 5, 7, 11]
```

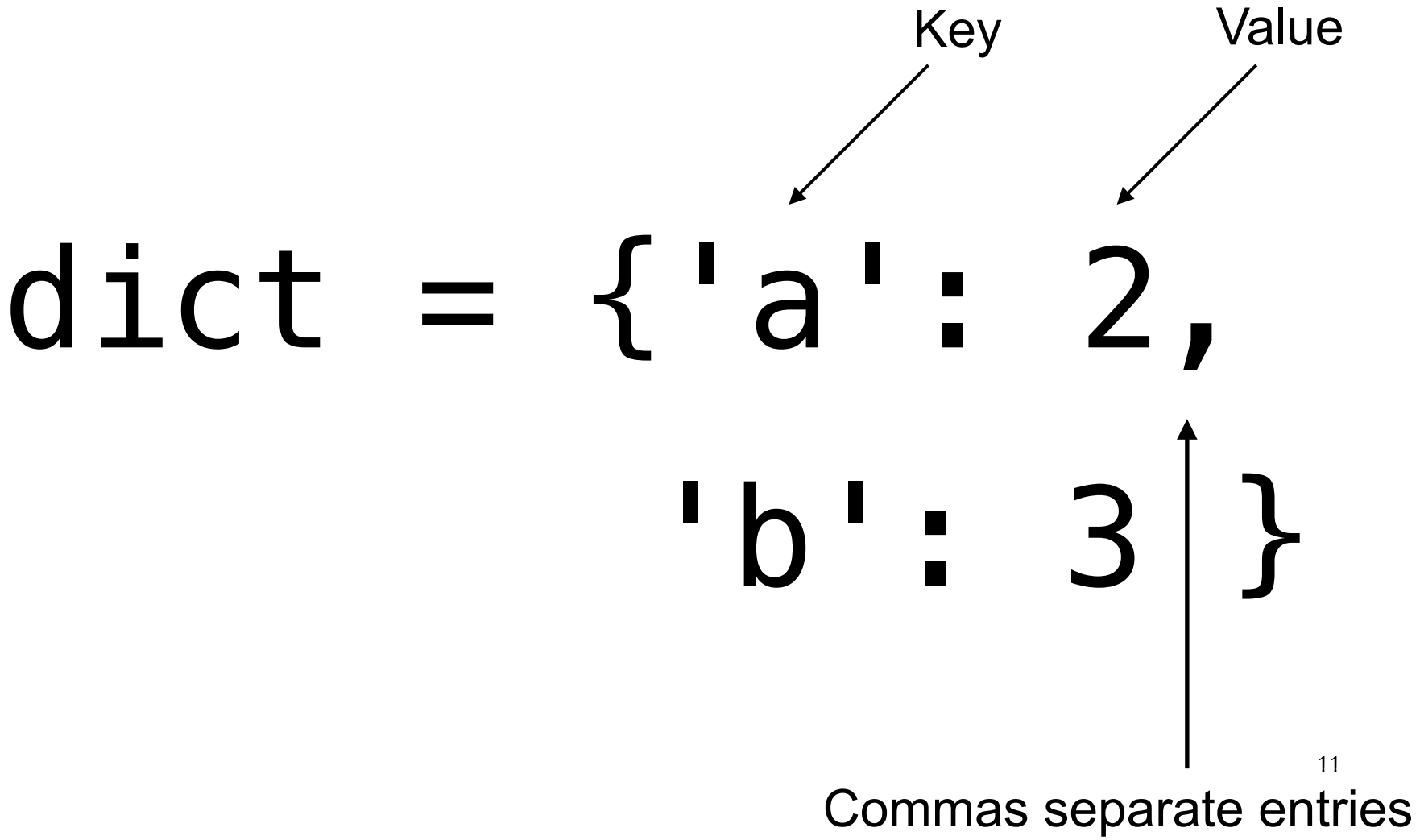
Lists

```
# Access elements at a particular index
numbers[0]  # => 2
numbers[-1]  # => 11

# You can also slice lists - the same rules apply
letters[:3]  # => ['a', 'b', 'c']
numbers[1:-1]  # => [3, 5, 7]

# Lists really can contain anything - even other lists!
x = [letters, numbers]
x  # => [['a', 'b', 'c', 'd'], [2, 3, 5, 7, 11]]
x[0]  # => ['a', 'b', 'c', 'd']
x[0][1]  # => 'b'
x[1][2:]  # => [5, 7, 11]
```

Tuples


Parentheses delimit tuples
my_tup = (1,2,3)
Like lists, but immutable
my_tup[0] = 5 => Error!
Commas separate elements

Dictionaries



Dictionaries

```
d = {"one": 1, "two": 2, "three": 3}

len(d.keys())  # => 3

print d['one']   # => 1
print d['five']  # => ERROR!

d['five'] = 5    # => OK, creates new key

d.keys()        # iterator over k
d.values()      # iterator over v
d.items()       # iterator over (k, v) pairs
```

Iteration

Most data structures can be iterated over in the same way:

```
mylist = ['a', 'b', 'c']
for item in mylist:
    print item
```

```
mytuple = ('a', 'b', 'c')
for item in mytuple:
    print item
```

Note we don't need the index of the element to access it.

```
dict = {'a': 10, 'b': 15}
for key in dict:
    print key, dict[key]
```

When iterating over a dictionary like this, we iterate over the keys.

Iteration

We can also iterate over indices:

```
for i in range(4):
    print i,                                    # 0 1 2 3

for i in range(1, 10, 2):
    print i,                                    # 1 3 5 7 9

mylist = ['a', 'b', 'c']                        #  0 'a'
for i in range(len(mylist):                     #  1 'b'
    print i, mylist[i]                          #  2 'c'


mylist = ['a', 'b', 'c']                        #  0 'a'
for idx, item in enumerate(mylist):             #  1 'b'
    print idx, item                             #  2 'c'
```

List Comprehensions

Input: `nums = [1, 2, 3, 4, 5]`

Goal: `sq_nums = [1, 4, 9, 16, 25]`

Here's how we could already do this:

```
sq_nums = []
for n in nums:
    sq_nums.append(n**2)
```

Or… we could use a comprehension:

```
sq_nums = [n ** 2 for n in nums]
```

square brackets show we're making a list

apply some operation to the loop variable

loop over the specified iterable

More List Comprehensions

```
Template:
    new_list = [f(x) for x in iterable]
```

```
words = ['hello', 'this', 'is', 'python']
caps  = [word.upper() for word in words]
```

```
powers  = [(x**2, x**3, x**4) for x in range(10)]
```

Remember this doesn't have to be a list! Can be any iterable.

Functions

```
def fn_name(param1, param2):
    value = do_something()
    return value
```

```
def isEven(num):
    return (num % 2 == 0)

myNum = 100
if isEven(myNum):
    print str(myNum) + " is even"
```

- `def` starts a function definition
- `return` is optional
  - if either return or its value are omitted, implicitly returns `None`
- Parameters have no explicit types

Putting Functions and List Comprehensions Together

Goal: given a list of numbers, generate a list that contains True for every even number and False for every odd number

```
def isEven(num):
    return (num % 2 == 0)
```

Template:

```
new_list = [f(x) for x in iterable]
```

```
numbers  = [5, 18, 7, 9, 2, 4, 0]
isEvens  = [isEven(num) for num in numbers]

## isEvens = [False, True, False, False, True, True, True]
```

Importing Modules

```
from math import exp
from random import random
```

Imports only the selected function(s) from the module; in this case, `exp` from `math` and `random` from `random`

Can now do:

`exp(0.5)` to compute $e^{0.5}$

`random()` to generate uniform random number over [0,1]

But if we had imported the whole modules, like this…

```
import math
import random
```

Then we would call the functions like this:

```
math.exp(0.5)
random.random()
```

Debugging Tricks

- "print line debugging"
  - At various points in your code, insert print statements that log the state of the program
- You will probably want to print some strings with some variables
  - You could just join things together like this:
    ```
    print 'Variable x is equal to ' + str(x)
    ```
  - … but that gets unwieldy pretty quickly
  - The **format** function is much nicer:

```
print 'x, y, z are equal to {}, {}, {}'.format(x,y,z)
```

Python Debugger (pdb)

- Python Debugger: pdb
  - insert the following in your program to set a breakpoint
  - when your code hits these lines, it'll stop running and launch an interactive prompt for you to inspect variables, step through the program, etc.

```
import pdb
pdb.set_trace()
```

n to step to the next line in the current function
s to step into a function
c to continue to the next breakpoint
you can also run any Python command, like in the interpreter

Classes

```
class Predictor(object):
    def __init__(self, nIters, name):
        self.nIters = nIters
        self.name = name

    def predict(self, start):
        raise NotImplementedError("Predictor should not be instantiated")

class MonteCarloPredictor(Predictor):
    def predict(self, start):
        ## Do some stuff
        for x in self.nIters:
            # do some stuff
            pass
```

`__init__` gets called when you instantiate an object

Need to refer to member variables with `self.` prefix inside the class

…but outside the class, refer to member variables/functions using the object's name

```
myPredictor = MonteCarloPredictor(nIters=1000, name='myPred')
myPredictor.predict(pose)
```

Numeric Computing using NumPy

- Python's built-in datatypes are very flexible
- They aren't optimized for fast numerical calculations, especially on large multi-dimensional matrices
- NumPy is a widely-used 3rd party package which adds such support to Python
- Sister library for scientific computing: SciPy

NumPy Example

```
>>> import numpy as np
>>> mat = np.ones((3,3))
>>> print mat
[[ 1.  1.  1.]
 [ 1.  1.  1.]
 [ 1.  1.  1.]]
>>> mat[1,1] = 5
>>> print mat
[[ 1.  1.  1.]
 [ 1.  5.  1.]
 [ 1.  1.  1.]]
>>> vec = np.array([1, 2, 3])
>>> np.dot(mat, vec)
array([  6.,  14.,   6.])
```

I can rename my module when I import it for convenience

It looks a lot like a list of lists!

Create arrays using `np.array`

Support for various linear algebra operations like dot products

NumPy Example

Are the absolute values of all elements in the array less than 5?

```
>>> a = np.array([1, -2, 3])
>>> b = np.array([1, 2, -6])
>>> np.all(np.abs(a) < 5)
True
>>> np.all(np.abs(b) < 5)
False
```

Can apply operations like absolute value element-wise

`np.all` checks whether all elements evaluate to `True`