Python

Day 1

What's This Course About? - Python 2.7

- Language Introduction
  - Installation, starting up, executing code, variables
  - Functions, modules, classes
  - Screen I/O, data types, control structures, file/socket I/O, exception handling
- Pythonic Stuff
  - Comprehensions, generators, iterators, context managers, decorators
  - Command line arguments, iterator tools, lambdas, functions-in-functions
  - Multiprocessing, utilities
- Useful Stuff
  - Unittest, cool Python API parts, code reviews

Why?

- Python 2.7 is popular
- Python is expressive!
  - Its API is massive
  - Many other projects already do what you need
  - It's great for prototyping
  - It's popular for automating things like test
- Programmers are team members
- Programmers should write code that's easy to read and maintain

Daily Structure

- 0800 - Lecture & Exercises
- 1100 - Labs & Lunch
- 1400 - Code Review
- 1500 - Code Fight Tournament

Today's Topics

- Getting Started
- Variables and Types and Such
- Control Flow
- Functions, Classes, Modules, and Packages
- Comprehensions

Quick Poll

- Who here is good at Python?
- Who here has used Python some, but not much?
- Who here has no Python experience?

Python Documentation

Installation and Startup

- Download and install...
  - apt-get install python
  - OS X has it already, but homebrew will get you an updated version
  - https://www.python.org/downloads/
- Python package managers
  - easy_install and pip
  - /usr/local/lib/python2.7/site-packages
  - pip install whatever
- Startup
  - python, python2, python2.7
  - Idle, idle2, idle2.7

- Also awesome - ipython

Writing a Script

```
#!/usr/bin/env python

from __future__ import print_function

# Print out a sober hello world
print("Hello, world.")

def diag_print(msg):
    """Print a message on a diagonal

    :param str msg: The message to print
    """
    for ind, char in enumerate(msg):
        print(" " * ind + char)

if __name__ == '__main__':
    diag_print("SUP WORLD?!?!")
```

```
f@f ~/pcp17 % vi helloworld.py
f@f ~/pcp17 % chmod +x helloworld.py
f@f ~/pcp17 % ./helloworld.py
Hello, world.
S
 U
  P


     W
      O
       R
        L
         D
          ?
           !
            ?
             !
f@f ~/pcp17 %
```

Coding Style

- Python Enhancement Proposal (PEP) 8
  - "code is read much more often than it is written" - "readability counts"
  - "know when to be inconsistent" - "use your best judgment"
  - "use 4 spaces per indentation level"
  - "limit all lines to a maximum of 79 characters"
- Using Vim - ~/.vimrc
  - :set shiftwidth=4 "vim's shifts using >> represent 4 characters
  - :set tabstop=4 "tabs you type represent four character positions
  - :set expandtab "turn any tab you type into spaces
  - :set ruler "an awesome option that
  - :set columns=79 "only display 79 characters per line
  - :syntax on "syntax highlighting
  - :filetype indent plugin on "turn on a plugin to do most of indenting based on filename

Variables

```
>>> from __future__ import print_function
>>> a = 15
>>> b = 15.4
>>> c = [a,b]
>>> print(c)
[15, 15.4]

>>> a = 24
>>> print(c)
[15, 15.4]

>>> print( (a,b) )
(24, 15.4)

>>> print = "asdf"

>>> print( (a,b) )
Traceback (most recent call last):
  File "<stdin>", line 1, in <module>
TypeError: 'str' object is not callable
```

- Variables are names with bindings
- Almost everything is an instance of a class
- Functions can be rebound...
- What types are visible here?

Types

```
>>> a=[1, 2, 3.4, 4/7, 10/7, 5/7.0, "asdf"]
>>> print(a)
[1, 2, 3.4, 0, 1, 0.7142857142857143, 'asdf']
>>> for i in a:
...  type(i)
...
<type 'int'>
<type 'int'>
<type 'float'>
<type 'int'>
<type 'int'>
<type 'float'>
<type 'str'>
>>> type(True)
<type 'bool'>
```

"The principal built-in types are numerics, sequences, mappings, files, classes, instances and exceptions."

"Some operations are supported by several object types; in particular, practically all objects can be compared, tested for truth value, and converted to a string (with the repr() function or the slightly different str() function). The latter function is implicitly used when an object is written by the print() function."

Let's just talk through what we're seeing on the left...

Integers...

```
>>> int_version = 9223372036854775807
>>> long_version = (2**63 - 1)
>>> type(int_version)
<type 'int'>
>>> type(long_version)
<type 'long'>
>>> int_version == long_version
True
>>> print(int_version, long_version)
9223372036854775807 9223372036854775807
>>> int_version, long_version
(9223372036854775807,
9223372036854775807L)
>>> int_version += 1
>>> type(int_version)
<type 'long'>
```

- Integers come in two forms - int and long
- The code on the left is from a 64 bit machine
- I have never run into an instance where this caused me a problem in practice...
- Python 3 has only one integer type and it always works

Type Conversion

```
>>> int_v = 15
>>> float(int_v)
15.0
>>> int(float(int_v))
15
>>> int_v + .15
15.15
>>> int(int_v + .15)
15
>>> int(int_v + .6)
15
>>> str(int_v)
'15'
>>> str(float(int_v))
'15.0'
>>> int("15.5")
Traceback (most recent call last):
  File "<stdin>", line 1, in <module>
ValueError: invalid literal for int() with base 10:
'15.5'
>>> int("15")
15
```

- Everything is an instance of a class...
- Even numbers...
- What do you expect to happen when you provide a class constructor with a value?
- This kind of type conversion works in most places

Sequence Types

```
>>> str = "this is a string"
>>> int_list = [1,2,3,1,2,3]
>>> int_tuple = (1,2,3,4)
>>> int_set = {1,2,3,1,2,3}
>>> str[0:4]
'this'
>>> str[:4]
'this'
>>> int_list[::2]
[1, 3, 2]
>>> int_tuple[2:]
(3, 4)
>>> int_set
set([1, 2, 3])
>>> list(int_tuple)
[1, 2, 3, 4]
>>> set(int_list)
set([1, 2, 3])
```

- We've got declarations!
- We've got slicing!
  - Implicit slicing indices...
  - Slice stepping!
- We've got type conversions!
- What's this set thing doing?

https://docs.python.org/2/library/stdtypes.html#set-types-set-frozenset

Mutability

```
>>> int_list=[1,2,3,4]
>>> initial_id = id(int_list)
>>> initial_id
4491068768
>>> int_list.append(15)
>>> int_list
[1, 2, 3, 4, 15]
>>> final_id = id(int_list)
>>> initial_id == final_id
True

>>> foobar = 4
>>> initial_id = id(foobar)
>>> initial_id
140204414349520
>>> foobar = 5
>>> final_id = id(foobar)
>>> initial_id == final_id
False
```

- Previously modifying a variable cause the variable name to be reassigned
- Will that work well with lists?
- Consider changing only one element of the list...
- So - lists are mutable! Sets, dictionaries too, but not integers, strings, tuples...
- You cannot change just one letter in a string

What about binary and unicode?

```
>>> a=list()
>>> for i in range(256):
...       a.append(chr(i))
...
>>> a
['\x00', '\x01', '\x02', '\x03', '\x04', '\x05', '\x06', '\x07', '\x08', '\t', '\n', '\x0b', '\x0c', '\r', '\x0e', '\x0f', '\x10', '\x11',
'\x12', '\x13', '\x14', '\x15', '\x16', '\x17', '\x18', '\x19', '\x1a', '\x1b', '\x1c', '\x1d', '\x1e', '\x1f', ' ', '!', '"', '#', '$',
'%', '&', "'", '(', ')', '*', '+', ',', '-', '.', '/', '0', '1', '2', '3', '4', '5', '6', '7', '8', '9', ':', ';', '<', '=', '>', '?', '@', 'A', 'B', 'C', 'D',
'E', 'F', 'G', 'H', 'I', 'J', 'K', 'L', 'M', 'N', 'O', 'P', 'Q', 'R', 'S', 'T', 'U', 'V', 'W', 'X', 'Y', 'Z', '[', '\\', ']', '^', '_', '`', 'a', 'b',
'c', 'd', 'e', 'f', 'g', 'h', 'i', 'j', 'k', 'l', 'm', 'n', 'o', 'p', 'q', 'r', 's', 't', 'u', 'v', 'w', 'x', 'y', 'z', '{', '|', '}', '~', '\x7f', '\x80',
'\x81', '\x82', '\x83', '\x84', '\x85', '\x86', '\x87', '\x88', '\x89', '\x8a', '\x8b', '\x8c', '\x8d', '\x8e', '\x8f', '\x90',
'\x91', '\x92', '\x93', '\x94', '\x95', '\x96', '\x97', '\x98', '\x99', '\x9a', '\x9b', '\x9c', '\x9d', '\x9e', '\x9f', '\xa0',
'\xa1', '\xa2', '\xa3', '\xa4', '\xa5', '\xa6', '\xa7', '\xa8', '\xa9', '\xaa', '\xab', '\xac', '\xad', '\xae', '\xaf', '\xb0',
'\xb1', '\xb2', '\xb3', '\xb4', '\xb5', '\xb6', '\xb7', '\xb8', '\xb9', '\xba', '\xbb', '\xbc', '\xbd', '\xbe', '\xbf', '\xc0',
'\xc1', '\xc2', '\xc3', '\xc4', '\xc5', '\xc6', '\xc7', '\xc8', '\xc9', '\xca', '\xcb', '\xcc', '\xcd', '\xce', '\xcf', '\xd0', '\xd1',
'\xd2', '\xd3', '\xd4', '\xd5', '\xd6', '\xd7', '\xd8', '\xd9', '\xda', '\xdb', '\xdc', '\xdd', '\xde', '\xdf', '\xe0', '\xe1',
'\xe2', '\xe3', '\xe4', '\xe5', '\xe6', '\xe7', '\xe8', '\xe9', '\xea', '\xeb', '\xec', '\xed', '\xee', '\xef', '\xf0', '\xf1', '\xf2',
'\xf3', '\xf4', '\xf5', '\xf6', '\xf7', '\xf8', '\xf9', '\xfa', '\xfb', '\xfc', '\xfd', '\xfe', '\xff']
>>> type(u"asdfasdf")
<type 'unicode'>
```

Mappings

```
>>> foo={
...       "a key": "a value",
...       "key 2": 15.3,
...       (2,1)  : [1,2,3,4,5]
... }

>>> type(foo)
<type 'dict'>

>>> foo["a key"]
'a value'

>>> foo[(2,1)]
[1, 2, 3, 4, 5]

>>> foo["lucky number"] = 13
>>> foo[0] = "zombo.com"

>>> foo
{0: 'zombo.com', 'key 2': 15.3, 'a key': 'a value',
(2, 1): [1, 2, 3, 4, 5], 'lucky number': 13}
```

- Dictionaries are _the_ mapping type
- They are a hash map
- Every key must be unique, values don't have to be

Mappings Continued

```
>>> foo[ ["a","b"] ] = 27
Traceback (most recent call last):
  File "<stdin>", line 1, in <module>
TypeError: unhashable type: 'list'

>>> foo[0] = ["a","b"]

>>> foo
{0: ['a', 'b'], 'key 2': 15.3, 'a key': 'a value', (2, 1):
[1, 2, 3, 4, 5], 'lucky number': 13}
```

- "Unhashable" types cannot be dictionary keys

- A good rule of thumb - if a type is mutable then it is not hashable

How does hashing work?

```
>>> foobar = "asdf"; hash(foobar)
-2835731962866600674

>>> foobar = 49; hash(foobar)
49

>>> foobar = 37.2; hash(foobar)
2107415142

>>> foobar = (15,); hash(foobar)
3430017387552

>>> foobar = [15,16,17]; hash(foobar)
Traceback (most recent call last):
  File "<stdin>", line 1, in <module>
TypeError: unhashable type: 'list'
```

- What type is the builtin hash function returning?
- What happens when you hash something unhashable?
- How does the hash function know when something is hashable?

- You can often use a semicolon to put multiple things on one line

HOW DOES IT KNOW!?!?!?!

```
>>> dir((1,2))
['__add__', '__class__', '__contains__',
'__delattr__', '__doc__', '__eq__', '__format__',
'__ge__', '__getattribute__', '__getitem__',
'__getnewargs__', '__getslice__', '__gt__',
'__hash__', '__init__', '__iter__', '__le__',
'__len__', '__lt__', '__mul__', '__ne__',
'__new__', '__reduce__', '__reduce_ex__',
'__repr__', '__rmul__', '__setattr__', '__sizeof__',
'__str__', '__subclasshook__', 'count', 'index']
```

- The builtin dir function displays all attributes and functions of an instance
- Hashable instances have a __hash__ function
- The hash builtin calls this function and returns the value
- Can you define __hash__ when you create your own classes and instances?
- So - do list objects have a __hash__?

HOW DOES IT KNOW!?!?!?!

```
>>> dir([1,2])
['__add__', '__class__', '__contains__',
'__delattr__', '__delitem__', '__delslice__',
'__doc__', '__eq__', '__format__', '__ge__',
'__getattribute__', '__getitem__', '__getslice__',
'__gt__', '__hash__', '__iadd__', '__imul__',
'__init__', '__iter__', '__le__', '__len__', '__lt__',
'__mul__', '__ne__', '__new__', '__reduce__',
'__reduce_ex__', '__repr__', '__reversed__',
'__rmul__', '__setattr__', '__setitem__',
'__setslice__', '__sizeof__', '__str__',
'__subclasshook__', 'append', 'count', 'extend',
'index', 'insert', 'pop', 'remove', 'reverse', 'sort']
```

- DANG IT! This list has a __hash__!
- HOW DOES THE HASH BUILTIN KNOW?!?!?!?!

Let's investigate...

```
>>> (1,2,3).__hash__
<method-wrapper '__hash__' of tuple object at
0x10baed910>

>>> (1,2,3).__hash__()
2528502973977326415

>>> hash((1,2,3))
2528502973977326415

>>> [1,2,3].__hash__

>>> [1,2,3].__hash__ is None
True

>>> [1,2,3] is [1,2,3]
False
>>> [1,2,3] == [1,2,3]
True
```

- So - on the tuple, __hash__ is a method-wrapper
  - This is some kind of fancy object-oriented hell they've done - it's a function
- When we call it, we get an int
- On the list, __hash__ is "None"
- Wait - KARL - WHAT THE HECK IS "is" and "None" !?!?!?!

Time for some exercises...

For 15 minutes, on the Python console write...

- A for loop that calculates the first 20 numbers of the Fibonacci sequence
- A list of the primary colors red, blue, and yellow
  - Then, use functions on the list instance to add "purple", "green", and "orange" to their proper position between the primary colors
  - We did not discuss the function you need - look it up in the Python documentation

Also - take a break

Also - save your exercises - some get reused for later exercises...

Solutions

```
>>> i, j = 0, 1
>>> for cnt in range(20):
...       i, j = j, i+j
...       print i

>>> colors=["red","blue","yellow"]
>>> colors.insert(1,"purple")
>>> colors.insert(3,"green")
>>> colors.insert(0,"orange")
>>> colors.append("orange")
>>> colors
['orange', 'red', 'purple', 'blue', 'green', 'yellow', 'orange']
```

Control Flow: if/elif/else

```
bar = 10
foo = 5 if bar >= 10 else 10

if foo == 10:
    print('foo = 10')
elif foo == 5:
    print('foo = 5')
else:
    print('foo != 10 or 5')
```

- If, elif and else work how you'd expect...
- Watch indentation!
- Check out that awesome ternary operator!

Control Flow - While

```
>>> foo_list = ["up", "you", "give",
                "gonna", "never", "foo", "bar",
                "bar", "foo", "foo", "bar"
                ]

>>> while "foo" in foo_list:
...     print foo_list.pop()
...
bar
foo
foo
bar
bar
foo
```

- Does while work exactly how you hoped?
- Yes it does. Don't lie to me.

- Ok - so how about "in"? Why didn't we get Rick Rolled?

- How about "pop"? Pretty awesome, huh?

Control Flow - Break, Continue, Pass

```
>>> known_primes = []
>>> for i in range(100):
...     if i == 0 or i == 1:
...       continue
...     is_prime = True
...     for prime in known_primes:
...       if i % prime == 0:
...         is_prime = False
...         break
...     if is_prime:
...       known_primes.append(i)
...     else:
...       pass
...
>>> print known_primes
[2, 3, 5, 7, 11, 13, 17, 19, 23, 29, 31, 37, 41, 43,
47, 53, 59, 61, 67, 71, 73, 79, 83, 89, 97]
```

- Continue skips execution of the rest of the iteration of the loop, moving to the next
- Break ends all execution of the loop...
- Pass is useful when Python requires an indented block, but you don't have one
  - For example, for stub code
  - Was there any reason for me to put in the else and pass here?
- Why did we skip 0 and 1 at the beginning of the loop? Was there a better way to do that?
- Are continue and break different than "goto"? Why is that good or bad? DISCUSS

Functions

```
>>> def this_is_a_func(arg1, arg2, *args,
**kwargs):
...     print "arg1 was {}".format(arg1)
...     print "arg2 was {}".format(arg2)
...     print "args was {}".format(args)
...     print "kwargs was {}".format(kwargs)
...     return arg1 + arg2
...
>>> retval =
this_is_a_func(15,22,"first","second",key1="foo",
key2="bar")
arg1 was 15
arg2 was 22
args was ('first', 'second')
kwargs was {'key2': 'bar', 'key1': 'foo'}
>>> print retval
37
```

- Line indentation after the "def" must be consistent
- *args becomes a list of positional arguments that were left over
- **kwargs becomes a dictionary of keyword arguments that were left over

- But, it doesn't have to be this way...

Functions

```
>>> def this_is_a_func(arg1, arg2, *args,
**kwargs):
...   print "arg1 was {}".format(arg1)
...   print "arg2 was {}".format(arg2)
...   print "args was {}".format(args)
...   print "kwargs was {}".format(kwargs)
...   return arg1 + arg2
...
>>> retval = this_is_a_func(arg2=10, arg1=15,
foo="bar")
arg1 was 15
arg2 was 10
args was ()
kwargs was {'foo': 'bar'}
```

- Here - we've used keyword arguments out of order, and left args empty

NO PROBLEM MON!

Classes

```
#!/usr/bin/env python
"""test.py"""

class my_base_class(object):
    class_var = 20

    def __init__(self, special_num):
        self.special_num = special_num

    def print_special(self):
        print "My special num is {}".format(self.special_num)

class child_class(my_base_class):
    def __init__(self, special_num):
        super(child_class, self).__init__(special_num * 2)

if __name__ == "__main__":
    ch = child_class(11)
    ch.print_special()
```

- Base classes in Python 2 should inherit from "object"
- The __init__ function is called like a constructor
- Self is the first argument in almost every case - this is a convention...
- How about multiple inheritance?

- "Super" is super confusing, but less-so in python 3...

- What will executing ./test.py produce?

Modules and Packages

- mkdir my_module/
- mv test.py my_module/
- vi my_module/__init__.py

from my_module.test import child_class

- python2

```
>>> import my_module
>>> my_module.child_class(22).print_special()
My special num is 44
>>> dir(my_module.child_class(22))
['__class__', '__delattr__', '__dict__', '__doc__',
'__format__', '__getattribute__', '__hash__',
'__init__', '__module__', '__new__',
'__reduce__', '__reduce_ex__', '__repr__',
'__setattr__', '__sizeof__', '__str__',
'__subclasshook__', '__weakref__', 'class_var',
'print_special', 'special_num']
```

- Modules are files containing python code
- Every time we've written code in a file, that has created a module

- Packages are directories containing modules, including one named __init__.py

- __init__.py is usually empty, but if it's not empty, things imported into it are imported whenever the package is imported

- What are the two different ways to use import?

EXERCISE!!!

Make a package called "school", with modules "high", "middle" and "elementary".
Each module should have functions:

- Function "add_class" that takes one argument, a string that names the class
- Function "list_classes" that returns a list of all classes defined so far
- Property "name" that gives a school name that may be set

Create a script that demonstrates this functionality.

BONUS - also do this where high, middle and elementary are classes... Maybe "school" becomes a module instead of a package?

EXERCISE!!!

EXERCISE!!!

```
% ls school
__init__.py    elementary.py  high.py   middle.py
__init__.pyc elementary.pyc high.pyc middle.pyc

-------- high.py, middle.py, elementary.py --------

class_list = list()
name = ""

def add_class(class_name):
    class_list.append(class_name)

def list_classes():
    return class_list

------------------  init.py ------------------
import school.high as high
import school.middle as middle
import school.elementary as elementary
```

```
------------------- run_schools.py ------------------
#!/usr/bin/env python

import school

if __name__ == "__main__":
    class_names = ["english","spanish","opera",
         "math","science"]
    schools = {
            "John Booker High": school.high,
            "James Knight Middle": school.middle,
            "Little Tykes Elementary": school.elementary,
            }

    for school_name, school_type in schools.items():
        school_type.name = school_name
        for name in class_names:
            school_type.add_class(name)

    for school_type in schools.values():
        print "Classes at {}:".format(school_type.name)
        for course in school_type.list_classes():
            print "\t{}".format(course)
```

Comprehensions

```
>>> [i*5 for i in range(10)]
[0, 5, 10, 15, 20, 25, 30, 35, 40, 45]

>>> {i % 5 for i in range(5000)}
set([0, 1, 2, 3, 4])

>>> import random
>>> ".".join(str(random.randrange(256)) for i in
range(4))

>>> (i*5 for i in range(10))
<generator object <genexpr> at 0x107988960>
>>> next((i*5 for i in range(10)))
0
>>> next((i*5 for i in range(10)))
0
>>> gen=(i*5 for i in range(10))
>>> next(gen)
0
>>> next(gen)
5
>>> tuple(i*5 for i in range(10))
```

- Comprehensions are a handy way to build a list, set, dictionary, or tuple from another iterable type
- The join function on strings can be handy for turning a comprehension into a string
- What did we get when we tried to build a tuple the naive way?
  - Generators only produce the input they need right before they need it...
  - If generating the input means holding a large data structure in memory, this can be useful
  - We'll cover generators in more detail later, but this basic usage is pretty awesome

Dictionary Comprehensions...

```
>>> {divisor:
        {numerator for numerator in range(20) if (numerator % divisor == 0)}
        for divisor in range(1,20)
        }
```

```
{1: set([0, 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19]),
2: set([0, 2, 4, 6, 8, 10, 12, 14, 16, 18]),
3: set([0, 3, 6, 9, 12, 15, 18]),
4: set([0, 8, 4, 12, 16]),    5: set([0, 10, 5, 15]),    6: set([0, 18, 12, 6]),
7: set([0, 14, 7]),           8: set([0, 8, 16]),        9: set([0, 9, 18]),
10: set([0, 10]),             11: set([0, 11]),          12: set([0, 12]),
13: set([0, 13]),             14: set([0, 14]),          15: set([0, 15]),
16: set([0, 16]),             17: set([0, 17]),          18: set([0, 18]),
19: set([0, 19])}
```

EXERCISE!

1. Write a script that produces all three letter strings where the sum of their letter indices is divisible by X, where X = 73 (Note: remember chr and ord)

   Letter indices are: a=0, b=1, ... z=25 (case doesn't matter, only ASCII letters)
   You should get: ['aaa', 'xzz', 'yyz', 'yzy', 'zxz', 'zyy', 'zzx']

2. Modify it to produce all three letter strings where the sum of indices is divisible by, in turn, X = 10, 20, ... 100 (also do 0 for bonus points)
3. Modify it to answer the question: Which values of X (in X=1, 2, ... 100) produce fewer than 10 divisible three letter strings?
4. Modify it to produce a list describing how many three letter strings are divisible by, in turn, X = 1, 2, ... 100

EXERCISE!!!

Lunch 'n Lab

Python

Day 2

Daily Structure

- 0800 - Lecture & Exercises
- 1100 - Labs & Lunch
- 1400 - Code Review
- 1500 - Code Fight Tournament

Today's Topics

- Screen/File/Socket I/O
- Exceptions
- Logging
- Unit Testing

Screen I/O

```
>>> print "hello world!"
hello world!

>>> class foobar:
...  def __str__(self):
...   return "whatever man!"
...  def __repr__(self):
...   return "a representation of the parts"
...

>>> print foobar
__main__.foobar

>>> print foobar()
whatever man!

>>> [foobar(), foobar()]
[a representation of the parts, a representation
of the parts]
```

- We've seen print, and we've seen future print...
- How does Python know how to print classes?
- Sometimes it's printing them nicely after conversion to string...
- Sometimes it's printing them as part of another data structure...
- You've undoubtedly seen these representations in error messages...

Screen Formatting

```
>>> "An int {} a str {} and a list {} walk into a |".format(
        1, "1", [1,1,1]
        )
'An int 1 a str 1 and a list [1, 1, 1] walk into a |'


>>> "An int %i a str %s and a list %s walk into a |" % \
        (1, "1",
              "[" + ",".join(  str(i) for i in [1,1,1]  ) + "]"
        )
'An int 1 a str 1 and a list [1,1,1] walk into a |'
```

Recommendation:

- Use ".format" whenever possible
- Remember how to read % formatting...

Why? Some things you wish you could simply print aren't easy to print with %...

https://docs.python.org/2/library/stdtypes.html#string-formatting-operations

https://docs.python.org/2/library/stdtypes.html#str.format

https://pyformat.info/

Screen I/O

```
>>> foobar = raw_input("Who is your daddy and what does he do?")

Who is your daddy and what does he do?

>>> He's a bad bad man!

>>> print foobar.split(" ")
['', "He's", 'a', 'bad', 'bad', 'man!']

>>> print "Times two it's {}".format(
        int(raw_input("Enter a number: ")) * 2
        )
Enter a number: 22
Times two it's 44
```

- Don't use input()!
  - Unless you're in python3, then:
  - ONLY USE input() !
- raw_input returns a string...

- Why should you almost always avoid code like my "times two" example?

File I/O

```
>>> with open("/tmp/terrible_secret","w") as fdes:
...         fdes.write("The terrible secret of space")
...

>>> with open("/tmp/terrible_secret","r") as fdes:
...         print fdes.read() + "<DONE>"
...
The terrible secret of space<DONE>

>>> fdes = open("/tmp/terrible_secret","a")
>>> fdes.write("\n")
>>> fdes.close()

>>> with open("/tmp/terrible_secret","r") as fdes:
...          print fdes.read() + "<DONE>"
...
The terrible secret of space
<DONE>
```

- ALRIGHT CORAL WHAT THE HECK IS THIS WITH THING!?!?!?!
- "with" begins a context!
- Python guarantees that, upon exiting the context, it will properly close the context...
- In the case of a file descriptor given in the "as", it will close it
- Although - you don't have to use with...
- Write - doesn't add a newline...
- Read - by default reads the whole file...
- Check out the modes!
    - There's also the "b" mode addon...
    - https://docs.python.org/2/tutorial/inputoutput.html#reading-and-writing-files

File I/O

```
>>> with open("/tmp/secrets","w") as f:
...  for line in ["kfc recipe","coke
ingredient","password"]:
...   f.write(line + "\n")
...

>>> type(f)
<type 'file'>

>>> with open("/tmp/secrets","r") as f:
...  for line in f:
...   print "The secret {}".format(line)
...
The secret kfc recipe

The secret coke ingredient

The secret password
```

- Check out what happens when you just iterate over the file descriptor variable!
- Note the double newlines in the output...

- Also - note that f is still defined after the block

File I/O

```
>>> with open("/tmp/secrets","w") as f:
...  for line in f:
...   print "This is borked!"
...
Traceback (most recent call last):
  File "<stdin>", line 2, in <module>
IOError: File not open for reading

>>> type(f)
<type 'file'>

>>> f.write("asdf")
Traceback (most recent call last):
  File "<stdin>", line 1, in <module>
ValueError: I/O operation on closed file
```

- Here's an example of when "with" is handy
- Despite the error, the file closed!

- Note that f still exists after the "with"

Other File Awesomeness

Tempfile - https://docs.python.org/2/library/tempfile.html

The os Package

os.path - https://docs.python.org/2/library/os.path.html

os.walk - https://docs.python.org/2/library/os.html#os.walk

os.listdir - https://docs.python.org/2/library/os.html#os.listdir

Pickle - https://docs.python.org/2/library/pickle.html

JSON - https://docs.python.org/2/library/json.html

EXERCISE!!!

- Consider a simple tree data structure - a list of lists of lists of lists of...
  - The outermost list is the root
  - Branches are lists containing more branches and leaves, arbitrarily
  - Leaves are strings
- Input an arbitrary tree from a user, print it, save it to a file, and read it back again
- Consider just using json for the "save it to a file and read it" part...

Let's take 30 minutes for this one...

EXERCISE!!!

What solutions did you guys come up with?

Maybe check out the reference solution...

EXERCISE!!!

This one is just if time is going well...

Modify the "all three letter strings w/index sums divisible by X" to handle "all words in the dictionary"

You can find a dictionary in /usr/share/dict/

Just do the first and last part - which words are divisible by 73, and how many are divisible by X for X in [1, 100]

Socket I/O - TCP Client for IPV4 and IPV6, Simply

```
>>> import socket

>>> sock = socket.create_connection(("localhost",8080))

>>> sock.sendall("This is a test")

>>> sock.recv(4096)
'This is a response\n'

>>> sock.close()
```

- Making a TCP connection is too easy...
- The socket module exposes lots of C-like functionality
- Additionally, this "just handles" Windows situations
- Use sendall to ensure all data is sent
- Specify a maximum amount of data to recv

- There's a select module too, if you want it, and it's very similar to C's

Socket I/O - TCP and UDP Clients

```
>>> s=socket.socket(socket.AF_INET, socket.SOCK_STREAM)
>>> s.connect(("localhost",8080))
>>> s.send("asdf")
4
>>> s.recv(4096)
'qwer\n'
>>> s.close()
```

- Just like in C:
  - AF_INET specifies IPV4
  - SOCK_STREAM - TCP
  - SOCK_DGRAM - UDP
  - Note - those are defined within "socket", so you must use "socket." before them...

```
>>> s=socket.socket(socket.AF_INET, socket.SOCK_DGRAM)
>>> s.connect(("localhost",8080))
>>> s.sendall("asdf")
>>> s.recv(4096)
'qwer\n'
>>> s.close()
```

- "send" is not guaranteed to send all data you gave it, so it returns the number of bytes actually sent

Socket I/O - TCP Server

```
>>> sock = socket.socket(socket.AF_INET, socket.SOCK_STREAM)
>>> sock.setsockopt(socket.SOL_SOCKET, socket.SO_REUSEADDR, 1)
>>> sock.bind(("",8080))
>>> sock.listen(10)

>>> client = sock.accept()
>>> print(client)
(<socket._socketobject object at 0x10b796ad0>, ('127.0.0.1', 51691))

>>> client[0].sendall("Here's some data")
>>> client[0].recv(4096)
"Here's a response\n"
>>> client[0].close()

>>> new_client = sock.accept()
>>> new_client[0].sendall("Here's some data")
>>> new_client[0].recv(4096)
'This is repetitive suckah!\n'
>>> new_client[0].close()

>>> sock.close()
```

- This looks a lot like C...
- Bind takes a tuple
  - First part specifies the address to bind to
  - Second part is port...
- Listen takes the number of connections to hold in backlog
  - The max value here is system dependent
  - It's usually maxed at 5
- Accept returns a tuple containing a tuple...

- Also - REUSEADDR...

Socket I/O - UDP Server

```
>>> import socket

>>> sock = socket.socket(socket.AF_INET, socket.SOCK_DGRAM)
>>> sock.bind(("",8080))

>>> data, addr = sock.recvfrom(4096)
>>> data
"Here's some UDP test data\n"

>>> addr
('127.0.0.1', 61350)

>>> sock.sendto("Here's a response", addr)
17

>>> sock.close()
```

- Don't "listen"... recvfrom
- Watch out for "sendto" not sending all the data...

When Things Go Wrong

```
>>> int("0x10")
Traceback (most recent call last):
  File "<stdin>", line 1, in <module>
ValueError: invalid literal for int() with base 10: '0x10'

>>> try:
...     int("0x10")
... except ValueError as e:
...     print("You did a bad bad thing")
... else:
...     print("You did a good good thing!")
... finally:
...     print("This always happens")
...
You did a bad bad thing
This always happens
```

- When Python hits something it can't handle, it raises an exception
- Many API functions specify which exceptions they'll throw
- In _nearly all_ cases, catch only the exceptions you expect
  - Don't try to catch and handle them all
  - Unless - handling is to "print and die"

- If an exception is not caught, the function dies and raises the exception to the caller

- Except, else and finally should be at the same indentation as try

When You Make Things Go Wrong

```
>>> def throw_stuff():
...   selection = raw_input("0, 1, or 2? ")
...   exceptions = [ValueError, RuntimeError,
                    ReferenceError]
...   raise exceptions[int(selection)]("Message here...")

>>> def catch_stuff():
...   try:
...     throw_stuff()
...   except ValueError as e:
...     print "There was a value error {}".format(e)
...   except RuntimeError as e:
...     print "Runtime error this time {}".format(e)
...   except ReferenceError as e:
...     print "Reference error now fool! {}".format(e)
...   except Exception as e:
...     print "Some other exception dude {}".format(e)
...   except BaseException as e:
...     print "Oooh!  We fell all the way back {}".format(e)
...   print "Still did this..."
```

Let's consider raising exceptions...

We'll define two functions:

- throw_stuff raises exceptions
  - Based on user input...
  - What if user input is not in the expected format
- catch_stuff calls throw_stuff
  - The programmer wanted to handle throw_stuff's exceptions
  - Programmer caught all exceptions...
- Running this is on the next slide...

When You Make Things Go Wrong

```
>>> catch_stuff()
0, 1, or 2? 0
There was a value error Message here...
Still did this...
>>> catch_stuff()
0, 1, or 2? 1
Runtime error this time Message here...
Still did this...
>>> catch_stuff()
0, 1, or 2? 2
Reference error now fool! Message here...
Still did this...
>>> catch_stuff()
0, 1, or 2? 3
Some other exception dude list index out of range
Still did this...
>>> catch_stuff()
0, 1, or 2? sdlfkj
There was a value error invalid literal for int() with base 10: 'sdlfkj'
Still did this...
```

- First - let's try expected inputs
- Then - try "3" - an invalid input
- Then - try "sdlfkj" - also invalid input, but one with an exception that was expected
  - If your code raises specific exceptions, try to use them for their expected purposes
  - Consider writing your own exception extending the "Exception" class

- What if the programmer had just written catch_stuff wrong? Like - "throw_stiff()" instead of "throw_stuff()"?
- https://docs.python.org/2/library/exceptions.html

Practical Exception Handling... Demo!!!

Sample_tcp_server.py is the tree exercise, over TCP!

- However, leaves must be integers...

We'll step through the code quickly...

It is broken in a few places we'll have to debug...

There are several ways to break it just using common network comms...

- Killing comms from the client's side...
- Server's port is already taken...
- Not giving an int as a leaf...

EXERCISE!!!

Modify your tree program to get input and output over the network.

Handle the error cases you expect.

Logging

```
>>> import logging
>>> logging.basicConfig()
>>> logging.debug("Debug output")
>>> logging.info("Info output")
>>> logging.warning("Warning output")
WARNING:root:Warning output
>>> logging.error("Error output")
ERROR:root:Error output
>>> logging.critical("Critical output")
CRITICAL:root:Critical output
```

- The logging module offers simplicity or complexity
- basicConfig offers a variety of formatting options
- Other modules that use logging will automatically use whatever format you specify
- Want debug output and higher to a file, but info and higher to the screen? No problem.
- Worried about output issues during threading? Don't be.
- Want a simple way to annotate errors with the module they came in? Yeah, that's in there.

- Check out the tutorial, it's awesome:
- https://docs.python.org/2/howto/logging.html

Unit Testing

```
""" to_test.py """

def multiply(one, two):
    return one * two

def add(one, two):
    return one + two

def subtract(one, two):
    return one - two
```

```
#!/usr/bin/env python
""" simple_tester.py """

import unittest

from to_test import add, multiply, subtract

class try_tests(unittest.TestCase):
    def test_uno(self):
        self.assertEquals(multiply(4,3), 12)
        self.assertEquals(multiply(9,15), 135)
        self.assertEquals(multiply("asdf", 4), "asdfasdfasdfasdf")

    def test_dos(self):
        self.assertAlmostEqual(multiply(5.0, 3.1394), 15.697, 6)
        self.assertEqual(add(5.1, 3.1394), 8.2394)

if __name__ == "__main__":
    unittest.main()
```

Unit Testing

Step through more_complex_tester...

https://docs.python.org/2/library/unittest.html

Lunch 'n Lab

Python

Day 3

Daily Structure

- 0800 - Lecture & Exercises
- 1100 - Labs & Lunch
- 1400 - Code Review
- 1500 - Code Fight Tournament

Today's Topics

- Generators and Iterators
- Lambdas and Func-ception
- Multithreading and Multiprocessing

Generators and Iterators

Proceeding through lists, dictionary items, and strings with "for" is permitted because they are iterable

Iterable items require an __iter__ function and a next function:

https://docs.python.org/2/library/stdtypes.html#iterator-types

There are three ways to implement this:

separate_container_iterator_iterable.py

same_container_iterator_iterable.py

generator_iterable.py

Generators and Iterators - Case Study: Tuples

```
>>> tup = (1,2,3)
>>> type(tup)
<type 'tuple'>
>>> hasattr(tup, "__iter__")
True
>>> hasattr(tup, "next")
False
>>> tupiter = iter(tup)
>>> type(tupiter)
<type 'tupleiterator'>
>>> hasattr(tupiter, "__iter__")
True
>>> hasattr(tupiter, "next")
True
>>> [next(tupiter), next(tupiter), next(tupiter)]
[1, 2, 3]
>>> next(tupiter)
Traceback (most recent call last):
  File "<stdin>", line 1, in <module>
StopIteration
```

- Tuples have an __iter__, but no next
- Passing iter() a tuple will return a "tupleiterator"
- The tupleiterator has both the iter and the next...
- Calling next on the tupleiterator will exhaust it eventually

Generators and Iterators - Case Study: Strings

```
>>> str = "test str"
>>> hasattr(str,"__iter__")
False
>>> hasattr(str,"next")
False
>>> hasattr(str,"__getitem__")
True
>>> striter = iter(str)
>>> type(striter)
<type 'iterator'>
>>> hasattr(striter,"__iter__")
True
>>> hasattr(striter,"next")
True
>>> next(striter), next(striter), next(striter)
('t', 'e', 's')
```

- Strings, in python 2, don't have __iter__ or next, yet, we've definitely iterated over them...
- They do have "__getitem__", which takes an index and returns the character at that index
- Python's "iter" is able to use this to return something following the iterator protocol

Lambdas

```
>>> ops = { "add": lambda a, b: a + b,
... "subtract": lambda a, b: a - b,
... "multiply": lambda a, b: a * b,
... "divide": lambda a, b: a / b
... }
>>> ops["multiply"](1,2)
2
>>> ops["multiply"](3,4)
12
>>> ops["add"](3,4)
7
>>> foo=[1,2,3,4,5,6,7,8]
>>> map(lambda i: i * 2, foo)
[2, 4, 6, 8, 10, 12, 14, 16]
>>> filter(lambda i: i > 5, foo)
[6, 7, 8]
>>> reduce(lambda i, total: i * 2 + total, foo)
502
>>> reduce(lambda total, i: i * 2 + total, foo)
71
```

- Lambda lets you write a simple function without giving it a name
- Many functions take functions as an argument
- For simple functionality, a lambda can be useful

- Lambdas are best when you don't want anyone else to understand your code!

Lambdas - Partial Evaluation

```
>>> import re

>>> re.search("e h","This is line one")
>>> re.search("e h","Line two be here, peeps")
<_sre.SRE_Match object at 0x109328bf8>
>>> re.search("e h","Dis be line tres, homes")

>>> def partial_eval_search(patt):
...  return lambda s: re.search(patt, s)
...

>>> canada_func = partial_eval_search("e h")
>>> canada_func("This is line one")
>>> canada_func("Line two be here, peeps")
<_sre.SRE_Match object at 0x109328b90>
>>> canada_func("Dis be line tres, homes")
```

- Lambdas can be useful when you'd like partial function evaluation...
- WHAT DAT?
- It lets you specify some parameters at one point, then the others later
- What if you want to provide a function to a function, but you want to provide some state from outside that function?

- Do you even functional bruh?
- This is a practical example, except Python's re module provides a "compile" function

Functions in Functions (Nested Functions/Closures)

```
>>> import os
>>> def enumerate_subdirs(top_dir):
...       def yield_name_cnt():
...         for name, subdirs, contents in os.walk(top_dir):
...           yield name, len(subdirs)+len(contents)
...
...       for name, size in yield_name_cnt():
...         print name, size
...
>>> enumerate_subdirs(".")
. 2
./Day1 3
./Day1/school 8
./Day2 12
>>> enumerate_subdirs("../")
../ 5
../.git 10
../.git/hooks 10
...
```

- Helpful to organize a small bit of code with limited use
- Provides well-defined functionality with very limited scope

- This ain't Kernighan & Ritchie's Python

EXERCISE!!!

Build some things that represent the entire set:

- Of even numbers
- Of the Fibonacci sequence
- Of prime numbers

Before the end of the universe.

I don't think a list is going to work for you...

EXERCISE!!!

EXERCISE!!!

Why didn't we want to use a list? Are these really infinite?

What can we do with the tools we built? What functions can we pass them to? What operations can we perform?

Could we have done something similar in C, or in a more procedural Python style?

What are some more practical uses of the technique? Can you imagine taking "infinite" input from a socket, stdin, or file? How would that change your program's structure?

The result is typically a more functional style, which can look simpler.

Multiprocessing

```
>>> import logging
>>> import threading
>>> import time
>>> import random
>>> logging.basicConfig(level=logging.INFO)
>>> def try_threads(num_threads):
...       def thread_target(index):
...         time.sleep(random.randint(1,5))
...         logging.info("Thread index {} finishing".format(index))
...
...       thread_list = list()
...       for i in range(num_threads):
...         thread_list.append(
...             threading.Thread(target=thread_target, args=(i,))
...           )
...         thread_list[-1].start()
...       for thr in thread_list:
...         thr.join()
...         logging.info("Joined a thread!")
...       logging.info("Joined all threads.")
...
```

- Two popular multiprocessing modules:
  - threading
  - multiprocessing

- https://docs.python.org/2/library/threading.html

- In CPython, there's only one thread...

- Why use threads, then?
  - When slow things (I/O...) are the limiting factor, not CPU

Multiprocessing

```
>>> import logging
>>> import threading
>>> import time
>>> import random
>>> logging.basicConfig(level=logging.INFO)
>>> def try_threads(num_threads):
...       def thread_target(index):
...         time.sleep(random.randint(1,5))
...         logging.info("Thread index {} finishing".format(index))
...
...       thread_list = list()
...       for i in range(num_threads):
...         thread_list.append(
...             threading.Thread(target=thread_target, args=(i,))
...           )
...         thread_list[-1].start()
...       for thr in thread_list:
...         thr.join()
...         logging.info("Joined a thread!")
...       logging.info("Joined all threads.")
...
```

```
>>> try_threads(4)
INFO:root:Thread index 3 finishing
INFO:root:Thread index 0 finishing
INFO:root:Joined a thread!
INFO:root:Thread index 1 finishing
INFO:root:Joined a thread!
INFO:root:Thread index 2 finishing
INFO:root:Joined a thread!
INFO:root:Joined a thread!
INFO:root:Joined all threads.

>>> try_threads(4)
INFO:root:Thread index 2 finishing
INFO:root:Thread index 0 finishing
INFO:root:Thread index 1 finishing
INFO:root:Joined a thread!
INFO:root:Joined a thread!
INFO:root:Joined a thread!
INFO:root:Thread index 3 finishing
INFO:root:Joined a thread!
INFO:root:Joined all threads.
```

Multiprocessing

```
>>> def sync_test(lock, sem, event):
...   logging.info("Beginning test")
...   with lock:
...     logging.info("Lock held!")
...   sem.acquire()
...   logging.info("First sem acq")
...   with sem:
...     logging.info("Second sem acq")
...   logging.info("Third sem acq")
...   while not event.wait(1):
...     logging.info("Event not set...")
...   logging.info("Event set!  Done!")
...
>>> l = threading.Lock()
>>> s = threading.Semaphore(2)
>>> e = threading.Event()
>>> l.acquire()
True

>>> threading.Thread(target=sync_test, args=(l,s,e)).start()
```

- Threading synchronization tools:
  - Lock
  - RLock
  - Condition
  - Semaphore
  - Event
  - Timer
- Lock:
  - "acquire" and "release"
  - Entering/exiting using with calls those
  - It's a semaphore with value 1
- Semaphore:
  - May be acquired and released multiple times
  - Acquiring decrements an internal counter, releasing increments
  - Useful when a resource supports multiple access
- Event:
  - "set" / "clear, "is_set" / "wait"
  - Waiting supports a timeout!
  - Useful when one thread wants to signal another
- These are all similar... Why choose one? Readability.

Multiprocessing

```
>>> def sync_test(lock, sem, event):
...   logging.info("Beginning test")
...   with lock:
...     logging.info("Lock held!")
...   sem.acquire()
...   logging.info("First sem acq")
...   with sem:
...     logging.info("Second sem acq")
...   logging.info("Third sem acq")
...   while not event.wait(1):
...     logging.info("Event not set...")
...   logging.info("Event set!  Done!")
...
>>> l = threading.Lock()
>>> s = threading.Semaphore(2)
>>> e = threading.Event()
>>> l.acquire()
True

>>> threading.Thread(target=sync_test, args=(l,s,e)).start()
```

```
INFO:root:Beginning test
>>> l.release()
>>> INFO:root:Lock held!
INFO:root:First sem acq
INFO:root:Second sem acq
INFO:root:Third sem acq
INFO:root:Event not set...
INFO:root:Event not set...
INFO:root:Event not set...
INFO:root:Event not set...
eINFO:root:Event not set...
.set()INFO:root:Event not set...

>>> INFO:root:Event set!  Done!
l.acquire()
True
>>>
```

Multiprocessing

```
>>> def long_running_calc(inputs):
...         time.sleep(15)
...
>>> input_data_sets = [(1,2,3), (14,16,18), (20,10,3)]

>>> now = time.time(); \
        outputs = [long_running_calc(indat) for \
                indat in input_data_sets]; \
        print time.time() - now;
45.0066490173

>>> now = time.time(); \
        outputs = map(long_running_calc,
                input_data_sets); \
        print time.time() - now;
45.0073480606
```

- Multiple Python processes can act in parallel - true multitasking (compared to the threading module)
- The multiprocessing module makes parallelizing functional programming tasks so easy!
- Multiprocessing provides its own sync primitives, but it's best not to introduce side-effects, and therefore not to need them
- Create a pool of processes, then map a function and inputs to them
- Pool's default constructor value is the number of CPUs you have :-)

```
>>> import multiprocessing
>>> p=multiprocessing.Pool(4)
>>> now = time.time(); \
        outputs = p.map(long_running_calc, input_data_sets); \
        print time.time() - now;
15.002751112
```

Lunch 'n Lab

Python

Day 4

Daily Structure

- 0800 - Lecture & Exercises
- 1100 - Labs & Lunch
- 1400 - Code Review
- 1500 - Code Fight Tournament

Today's Topics

- Command Line Arguments
- Itertools
- HTTP Classes

Argparse

Let's step through the lecture code...

https://docs.python.org/2/library/argparse.html

Other cool stuff - subparsers, argument groups, mutual exclusion...

Itertools

We discussed some of these in the argparse example...

https://docs.python.org/2/library/itertools.html

Other cool stuff: combinatoric generators, recipes

EXERCISE!!!

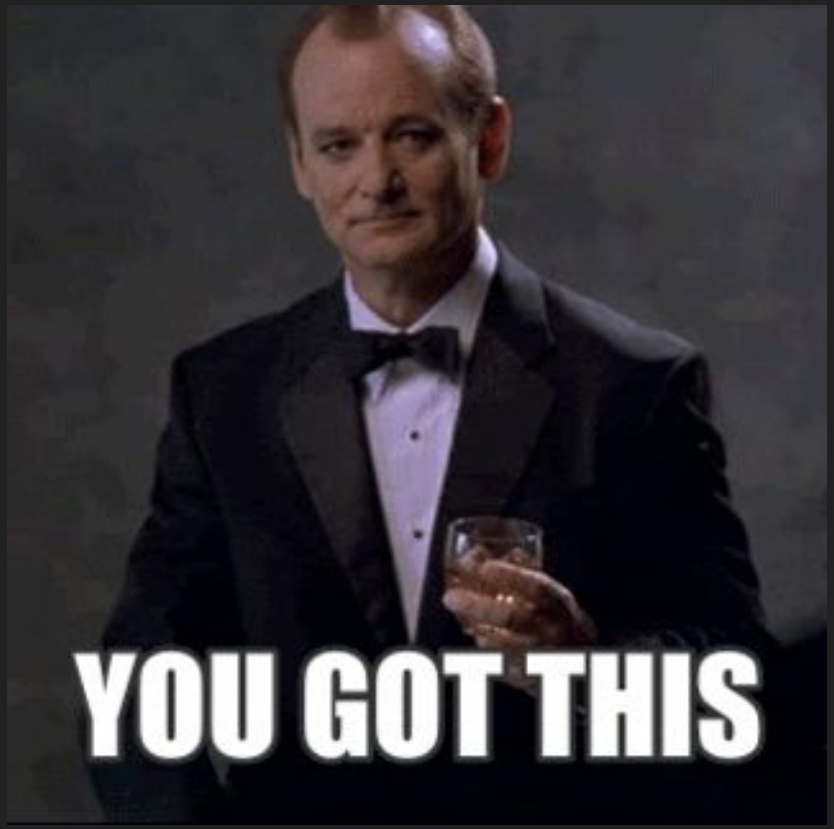
Remember those infinite generators we created before?

Output the 1000th, 1002th, ... 1098th prime numbers

Sum the 10000th through 10100th even numbers that are also divisible by 57

Output the 10 values from the Fibonacci sequence starting with the first value that contains the substring "01234567"

EXERCISE!!!



EXERCISE!!!

```
>>> list(it.islice(it.ifilter(lambda x: x%2, ij.prime_seq()), 1000, 1100, 2))

[7933, 7949, 7963, 8009, 8017, 8053, 8069, 8087, 8093 ...

>>> sum(it.islice(it.ifilter(lambda x: x % 57 == 0, ij.even_numbers()), 10000, 10100))

114575700

>>> list(it.islice(it.dropwhile(lambda x: "01234567" not in str(x), ij.fib_seq()),10))
```

BIG NUMBERS...

HTTP Classes

https://docs.python.org/2/library/internet.html

Handy file server - "python -m SimpleHTTPServer"

Let's go through the webserver.py lecture code

Other Important Stuff

2to3 - A utility included with python that does most of the work in converting Python 2 code to Python 3 code

Pylint - A separate tool that will check your code style against PEP8, and lots of other stuff

Lunch 'n Lab