Plan For Python Lecture 2

- **Generators**
- **Imports**
- **Functions**
  - *args, **kwargs, first class functions
- **Classes**
  - inheritance
  - “magic” methods (objects behave like built-in types)
- **Profiling**
  - timeit
  - cProfile
- **Idioms**

Generators

Generators: using `yield`

- **Generators are iterators (with `__next()__` method)**
- **Creating Generators: `yield`**
  - Functions that contain the `yield` keyword ***automatically*** return a generator when called

```
>>> def f(n):
...     yield n
...     yield n+1
...
>>>
>>> type(f)
<class 'function'>
>>> type(f(5))
<class 'generator'>
>>> [i for i in f(6)]
[6, 7]
```

Generators: What does `yield` do?

- Each time we call the `__next__` method of the generator, the method runs until it encounters a `yield` statement, and then it stops and returns the value that was yielded. Next time, it resumes where it left off.

```
>>> gen = f(5) # no need to say f(5).__iter__()
>>> gen
<generator object f at 0x1008cc9b0>
>>> gen.__next__()
5
>>> next(gen)
6
>>> gen.__next__()
Traceback (most recent call last):
  File "<stdin>", line 1, in <module>
StopIteration
```

Generators

- **`xrange(n)` vs `range(n)` in Python 2**
  - `xrange` acts like a generator
  - `range(n)` keeps all n values in memory before starting a loop *even if n is huge*: `for k in range(n)`
  - `sum(xrange(n))` much faster than `sum(range(n))` for large `n`

- **In Python 3**
  - `xrange(n)` is removed
  - `range(n)` acts similar to the old `xrange(n)`
  - Can use list() to get similar behavior as in Python 2
  - Python 3's range is more powerful than Python 2's xrange

Generators

- **Benefits of using generators**
  - Less code than writing a standard iterator
  - Maintains local state automatically
  - Values are computed one at a time, as they’re needed
  - Avoids storing the entire sequence in memory
  - Good for aggregating (summing, counting) items. One pass.
  - Crucial for infinite sequences
  - Bad if you need to inspect the individual values

Using generators: merging sequences

- **Problem: merge two sorted lists, using the output as a stream (i.e. not storing it).**

```
def merge(l, r):
  """Merge two sorted lists."""
  llen, rlen, i, j = len(l), len(r), 0, 0
  while i < llen or j < rlen:
    if j == rlen or (i < llen and l[i] < r[j]):
      yield l[i]
      i += 1
    else:
      yield r[j]
      j += 1
```

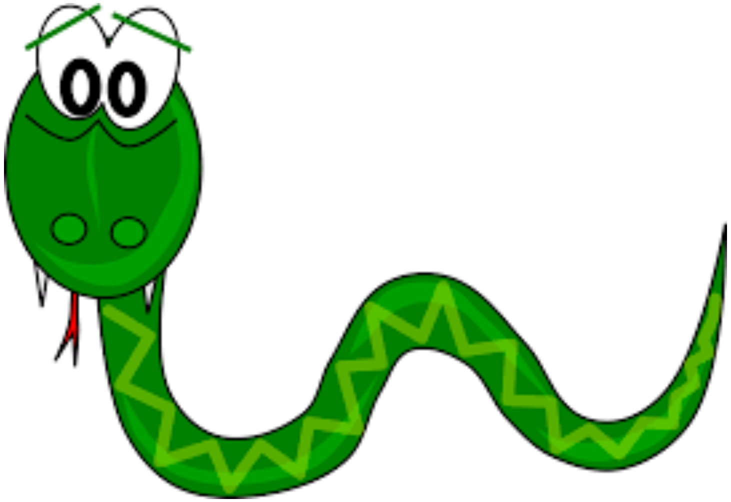
Using generators

```
>>> g = merge([2,4], [1, 3, 5]) #g is an iterator
>>> while True:
...    print(g.__next__())
...
1
2
3
4
5
Traceback (most recent call last):
  File "<stdin>", line 2, in <module>
StopIteration

>>> [x for x in merge([1,3,5],[2,4])]
[1, 2, 3, 4, 5]
```

Generators and exceptions

```
>>> g = merge([2,4], [1, 3, 5])
>>> while True:
...    try:
...      print(g.__next__())
...    except StopIteration:
...      print('Done')
...      break
...
1
2
3
4
5
Done
```

Imports



Import Modules and Files

```
>>> import math
>>> math.sqrt(9)
3.0
```

Not as good to do this:

```
>>> from math import *
>>> sqrt(9)   # unclear where function defined
```

Import Modules and Files

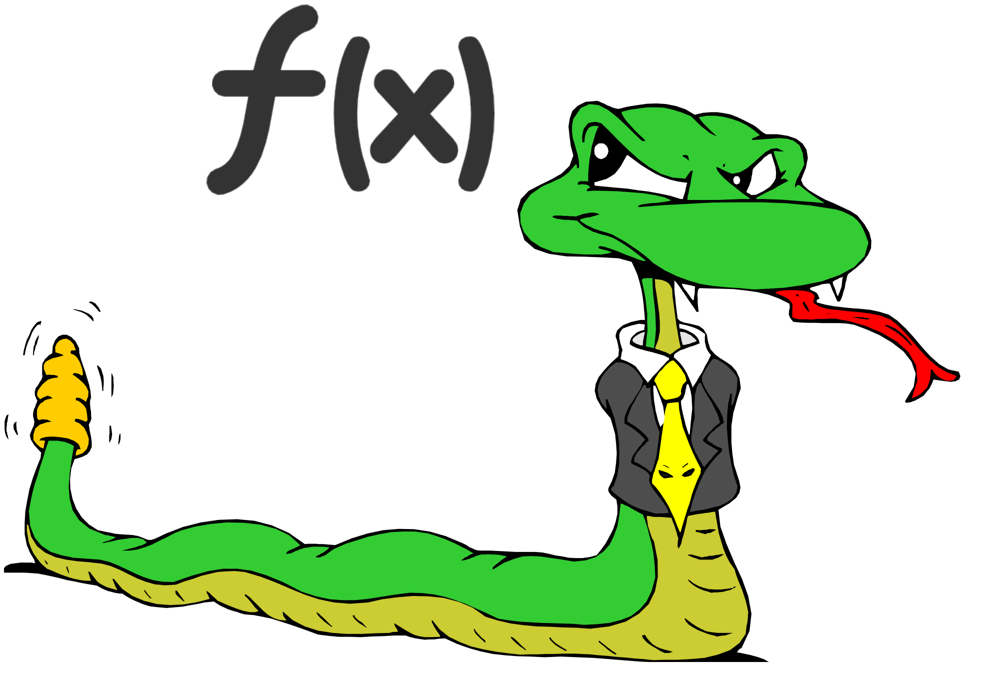
 # homework1.py

```
def concatenate(seqs):
    return [seq for seq in seqs] # This is wrong
```

 # run python interactive interpreter (REPL) in directory of homework1.py

```
>>> import homework1
>>> assert homework1.concatenate([[1, 2], [3, 4]]) == \
        [1, 2, 3, 4]
Traceback (most recent call last):
  File "<stdin>", line 1, in <module>
AssertionError

>>> import importlib        #after fixing homework1
>>> importlib.reload(homework1)
```

Functions



Defining Functions

Function definition begins with **def**.

Function name and its arguments.

```
def get_final_answer(filename):
    """Documentation String"""
    line1
    line2
    return total_counter
...
```

Colon

First line with less indentation is considered to be outside of the function definition.

'return' indicates the value to be sent back to the caller.

No declaration of types of arguments or result.

Function overloading? No.

- **There is no function overloading in Python 2**
  - Unlike Java, a Python function is specified by its name alone
  - Two different functions can't have the same name, even if they have different numbers, order, or names of arguments
  - *But **operator** overloading – overloading +, ==, -, etc. – is possible using special methods on various classes*
- **In Python 3.4, partial support**
  - Python 3 – Function Overloading with singledispatch

Default Values for Arguments

- You can provide **default** values for a function's arguments
- These arguments are optional when the function is called

```
>>> def myfun(b, c=3, d="hello"):
        return b + c

>>> myfun(5,3,"bob")
8
>>> myfun(5,3)
8
>>> myfun(5)
8
```

- Non-default argument should always follows default arguments; otherwise, it reports `SyntaxError`

Keyword Arguments

- Functions can be called with arguments out of order
- These arguments are specified in the call
- Keyword arguments can be used after all other arguments.

```
>>> def myfun(a, b, c):
        return a - b

>>> myfun(2, 1, 43)         # 1
>>> myfun(c=43, b=1, a=2)   # 1
>>> myfun(2, c=43, b=1)     # 1
>>> myfun(a=2, b=3, 5)
  File "<stdin>", line 1
SyntaxError: positional argument follows keyword argument
```

*args 

- Suppose you want to accept a variable number of non-keyword arguments to your function.

```
def print_everything(*args):
    """args is a tuple of arguments passed to the fn"""
    for count, thing in enumerate(args):
        print('{0}. {1}'.format(count, thing))
>>> lst = ['a', 'b', 'c']
>>> print_everything('a', ’b', 'c')
0. a
1. b
2. c
>>> print_everything(*lst) # Same results as above
```

**kwargs

- Suppose you want to accept a variable number of keyword arguments to your function.

```
def print_keyword_args(**kwargs):
    # kwargs is a dict of the keyword args passed to the fn
    for key, value in kwargs.items(): #.items() is list
        print("%s = %s" % (key, value))

>>> kwargs = {'first_name': 'Bobby', 'last_name': 'Smith'}
>>> print_keyword_args(**kwargs)
first_name = Bobby
last_name = Smith
>>> print_keyword_args(first_name="John", last_name="Doe")
first_name = John
last_name = Doe
```

Python uses dynamic scope

- **Function sees the most current value of variables**

```
>>> i = 10
>>> def add(x):
        return x + i

>>> add(5)
15
>>> i = 20
>>> add(5)
25
```

Default Arguments & Memoization

- ***Default parameter values are evaluated only when the `def` statement they belong to is first executed.***
- **The function uses the same default object each call**

```
def fib(n, fibs={}):
    if n in fibs:
        print('n = %d exists' % n)
        return fibs[n]
    if n <= 1:
        fibs[n] = n # Changes fibs!!
    else:
        fibs[n] = fib(n-1) + fib(n-2)
    return fibs[n]
```

```
>>> fib(3)
n = 1 exists
2
```

Functions are “first-class” objects

- **First class object**
  - An entity that can be dynamically created, destroyed, passed to a function, returned as a value, and have all the rights as other variables in the programming language have
- **Functions are “first-class citizens”**
  - Pass functions as arguments to other functions
  - Return functions as the values from other functions
  - Assign functions to variables or store them in data structures
- **Higher order functions: take functions as input**

```
def compose (f, g, x):
    return f(g(x))
```

```
>>> compose(str, sum, [1, 2, 3])
'6'
```

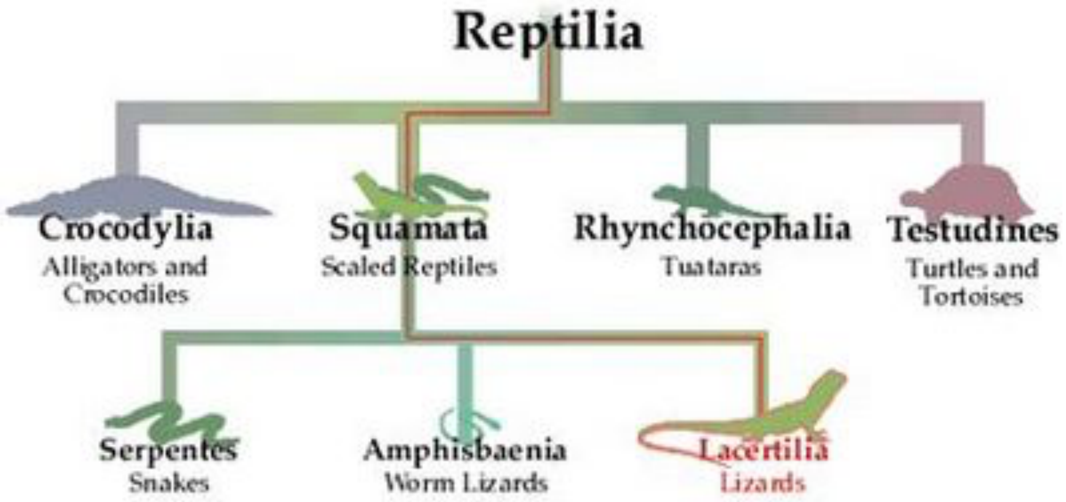
Higher Order Functions: Map, Filter

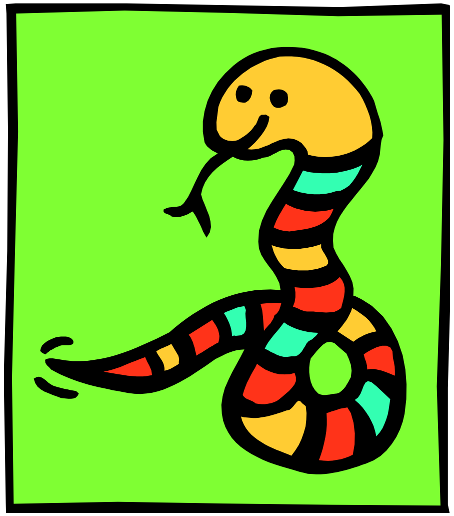
```
>>> [int(i) for i in ['1', '2']]
[1, 2]
>>> list(map(int, ['1', '2']))    #equivalent to above

def is_even(x):
    return x % 2 == 0
>>> [i for i in [1, 2, 3, 4, 5] if is_even(i)]
[2, 4]
>>> list(filter(is_even, [1, 2, 3, 4, 5])) #equivalent

>>> t1 = (0, 10)
>>> t2 = (100, 2)
>>> min([t1, t2], key=lambda x: x[1])
(100, 2)
```

Sorted list of n-grams

```
from operator import itemgetter

def calc_ngram(inputstring, nlen):
    ngram_list = [inputstring[x:x+nlen] for x in \
        range(len(inputstring)- nlen + 1)]
    ngram_freq = {}    # dict for storing results
    for n in ngram_list: # collect the distinct n-grams and count
        if n in ngram_freq:
            ngram_freq[n] += 1
        else:
            ngram_freq[n] = 1 # human counting numbers start at 1
    # Can set reverse to change order of sort
    # (reverse=True for ascending; reverse=False for descending)
    return sorted(ngram_freq.items(), \
            key=itemgetter(1), reverse=True)
```

Classes and Inheritance





Creating a class

```
Class Student:
    univ = "upenn" # class attribute

    def __init__(self, name, dept):
        self.student_name = name
        self.student_dept = dept

    def print_details(self):
        print("Name: " + self.student_name)
        print("Dept: " + self.student_dept)


student1 = Student("john", "cis")
student1.print_details()
Student.print_details(student1)
Student.univ
```

Called when an object is instantiated

Every method begins with the variable **self**

Another member method

Creating an instance, note no **self**

Calling methods of an object

Subclasses

- **A class can *extend* the definition of another class**
  - Allows use (or extension) of methods and attributes already defined in the previous one.
  - New class: *subclass*. Original: *parent*, *ancestor* or *superclass*
- **To define a subclass, put the name of the superclass in parentheses after the subclass's name on the first line of the definition.**

```
class AiStudent(Student):
```

- **Python has no 'extends' keyword like Java.**
- **Multiple inheritance is supported.**

Redefining Methods

- **Very similar to over-riding methods in Java**

- **To *redefine a method* of the parent class, include a new definition using the same name in the subclass.**
  - The old code in the parent class won't get executed.

- **To execute the method in the parent class *in addition to* new code for some method, explicitly call the parent's version of the method.**

```
parentClass.methodName(self, a, b, c)
```

  - **The only time you ever explicitly pass `self` as an argument is when calling a method of an ancestor.**

    So use `myOwnSubClass.methodName(a,b,c)`

Constructors: __init__

- Very similar to Java
- Commonly, the ancestor's `__init__` method is executed in addition to new commands
- *Must be done explicitly*
- You'll often see something like this in the `__init__` method of subclasses:

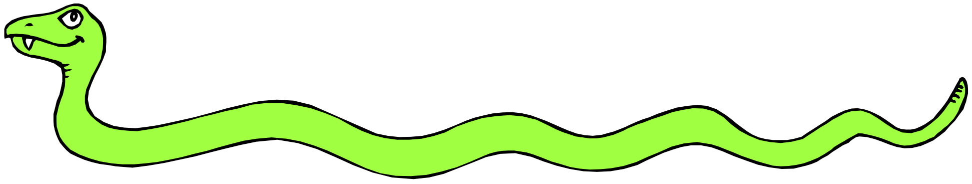
```
parentClass.__init__(self, x, y)
```

where parentClass is the name of the parent's class

Multiple Inheritance can be tricky

```
class A(object):
    def foo(self):
        print('Foo!')
class B(object):
    def foo(self):
        print('Foo?')
    def bar(self):
        print('Bar!')

class C(A, B):
    def foobar(self):
        super().foo() # Foo!
        super().bar() # Bar!
```

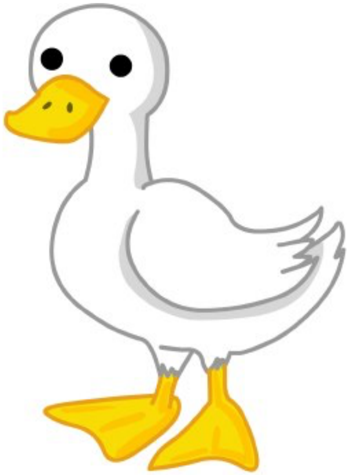
Special Built-In Methods and Attributes



Magic Methods and Duck Typing

- ***Magic Methods*** **allow user-defined classes to behave like built in types**

- ***Duck typing*** **establishes suitability of an object by determining presence of methods**
  - Does it swim like a duck and quack like a duck? It’s a duck
  - Not to be confused with ‘rubber duck debugging’



Magic Methods and Duck Typing

```
class Duck:
    def fly(self):
        print("Duck flying")

class Airplane:
    def fly(self):
        print("Airplane flying")

class Whale:
    def swim(self):
        print("Whale swimming")

def lift_off(entity):
    entity.fly()

duck = Duck()
airplane = Airplane()
whale = Whale()

lift_off(duck) # prints `Duck flying`
lift_off(airplane) # prints `Airplane flying`
lift_off(whale) # Throws the error `'Whale' object has no attribute 'fly'`
```

Example Magic Method

```
class Student:
   def __init__(self, full_name, age):
        self.full_name = full_name
        self.age = age

   def __str__(self):
        return "I'm named " + self.full_name + " - age: "
   +  str(self.age)
   ...

>>> f = Student("Bob Smith", 23)

>>> print(f)
I'm named Bob Smith - age: 23
```

Other "Magic" Methods

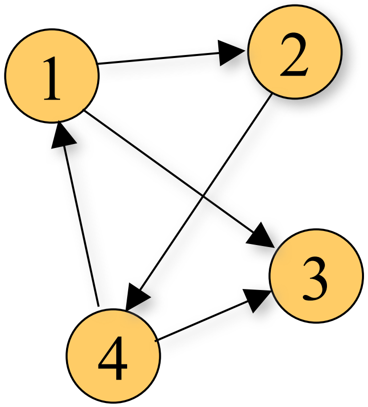
- **Used to implement operator overloading**
  - Most operators trigger a special method, dependent on class

`__init__`: The constructor for the class.
`__len__` : Define how **`len(`** obj **`)`** works.
`__copy__`: Define how to copy a class.
`__cmp__` : Define how == works for class.
`__add__` : Define how **+** works for class
`__neg__` : Define how unary negation works for class

- **Other built-in methods allow you to give a class the ability to use [ ] notation like an array or ( ) notation like a function call.**

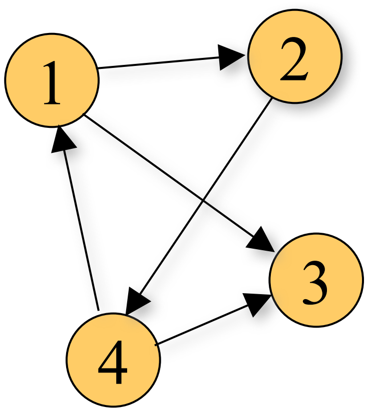
A directed graph class

```
>>> d = DiGraph([(1,2),(1,3),(2,4),(4,3),(4,1)])
>>> print(d)
1 -> 2
1 -> 3
2 -> 4
4 -> 3
4 -> 1
```



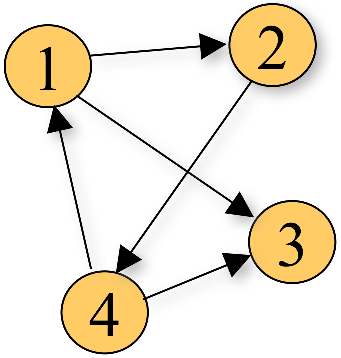
A directed graph class

```
>>> d = DiGraph([(1,2),(1,3),(2,4),(4,3),(4,1)])
>>> [v for v in d.search(1, set())]
[1, 2, 4, 3]
>>> [v for v in d.search(4, set())]
[4, 3, 1, 2]
>>> [v for v in d.search(2, set())]
[2, 4, 3, 1]
>>> [v for v in d.search(3, set())]
[3]
```



`search` method returns a *generator* for the nodes that can be reached from a given node by following arrows "from tail to head"

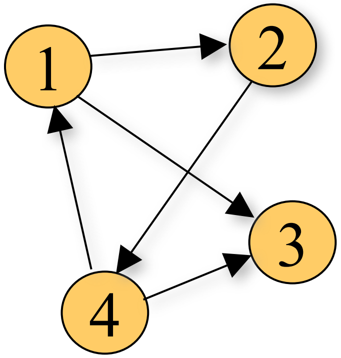
The DiGraph constructor




```
class DiGraph:
  def __init__(self, edges):
    self.adj = {}
    for u, v in edges:
        if u not in self.adj: self.adj[u] = [v]
        else: self.adj[u].append(v)

  def __str__(self):
    return '\n'.join(['%s -> %s'%(u,v) \
                              for u in self.adj for v in self.adj[u]])

>>> d = DiGraph([(1,2),(1,3),(2,4),(4,3),(4,1)])
>>> d.adj
{1: [2, 3], 2: [4], 4: [3, 1]}
```

The constructor builds a dictionary (`self.adj`) mapping each node name to a list of node names that can be reached by following one edge (an "adjacency list")

The search method




```
class DiGraph:
  ...

  def search(self, u, visited):
    # If we haven't already visited this node...
    if u not in visited:
      # yield it
      yield u
      # and remember we've visited it now.
      visited.add(u)
      # Then, if there are any adjacent nodes...
      if u in self.adj:
        # for each adjacent node...
        for v in self.adj[u]:
          # search for all nodes reachable from *it*...
          for w in self.search(v, visited):
            # and yield each one.
            yield w
```

Profiling, function level

- **Rudimentary**

```
>>> import time
>>> t0 = time.time()
>>> code_block
>>> t1 = time.time()
>>> total = t1-t0
```

- **Timeit (more precise)**

```
>>> import timeit
>>> t = timeit.Timer(″<statement to time>",
″<setup code>")
>>> t.timeit()
```

  - The second argument is usually an import that sets up a virtual environment for the statement
  - `timeit` calls the statement 1 million times and returns the total elapsed time, `number` argument specifies number of times to run it.

Profiling, script level 1

```
# to_time.py

def get_number():
    for x in range(500000):
        yield x

def exp_fn():
    for x in get_number():
        i = x ^ x ^ x
    return 'some result!'

if __name__ == '__main__':
    exp_fn()
```

Profiling, script level 2

```
# python interactive interpreter (REPL)

$ python -m cProfile to_time.py
500004 function calls in 0.203 seconds
Ordered by: standard name
ncalls tottime  percall  cumtime  percall filename:lineno(function)
1       0.000    0.000    0.203    0.203   to_time.py:1(<module>)
500001 0.071    0.000    0.071    0.000   to_time.py:1(get_number)
1       0.133    0.133    0.203    0.203   to_time.py:5(exp_fn)
1       0.000    0.000    0.000    0.000   {method 'disable' of
'_lsprof.Profiler' objects}
```

- For details see https://docs.python.org/3.7/library/profile.html

Idioms

- **Many frequently-written tasks should be written Python-style even though you could write them Java-style in Python**
- **Remember beauty and readability!**

- **See http://safehammad.com/downloads/python-idioms-2014-01-16.pdf**
- **A list of anti-patterns: http://lignos.org/py_antipatterns/**