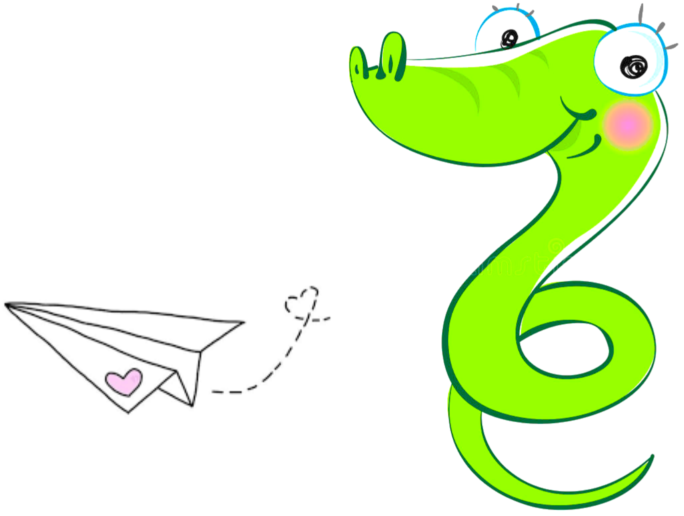
Plan For Python Lecture 2

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

For Loops and List Comprehensions



For Loops

```
for <item> in <collection>:
    <statements>
```

- If you've got an existing list, this iterates each item in it.
- You can generate a list with **Range:**
  - `list(range(5))` returns `[0,1,2,3,4]`
  - So we can say:

```
for x in range(5):
    print(x)
```

- `<item>` **can be more complex than a single variable name.**

```
for (x, y) in [('a',1), ('b',2), ('c',3), ('d',4)]:
    print(x)
```

[expression for name in list]

List Comprehensions replace loops!

```
nums = [0, 1, 2, 3, 4, 5, 6, 7, 8, 9]
# I want 'n*n' for each 'n' in nums
squares = []
for n in nums:
  for n in nums:
    squares.append(x*x)
print(squares)
```

```
squares = [x*x for x in nums]
print(squares)
```

[expression for name in list]

List Comprehensions replace loops!

```
>>> li = [3, 6, 2, 7]
>>> [elem * 2 for elem in li]
[6, 12, 4, 14]
```

```
>>> li = [('a', 1), ('b', 2), ('c', 7)]
>>> [n * 3 for (x, n) in li]
[3, 6, 21]
```

[expression for name in list if filter]

Filtered List Comprehensions

```
>>> li = [3, 6, 2, 7, 1, 9]
>>> [elem * 2 for elem in li if elem > 4]
[12, 14, 18]
```

- **Only 6, 7, and 9 satisfy the filter condition.**
- **So, only 12, 14, and 18 are produced.**

List Comprehension extra *for*

```
lst1, lst2, lst3 = [1, 2, 3], [2, 3, 4], [3, 4, 5]

res = [(x, y, z) for x in lst1 if x < 2 \
             for y in lst2 \
             for z in lst3 if x + y + z < 8]

res = [] # translation
for x in lst1:
    if x < 2:
        for y in lst2:
            for z in lst3:
                if x + y + z < 8:
                    res.append((x, y, z))

# Both value of res: [(1, 2, 3), (1, 2, 4), (1, 3, 3)]
```

Dictionary, Set Comprehensions

```
lst1 = [('a', 1), ('b', 2), ('c', 'hi')]
lst2 = ['x', 'a', 6]

d = {k: v for k,v in lst1}
s = {x for x in lst2}

d = dict() # translation
for k, v in lst1:
    d[k] = v
s = set() # translation
for x in lst:
    s.add(x)

# Both value of d: {'a': 1, 'b': 2, 'c': 'hi’}
# Both value of d: {'x', 'a', 6}
```

Iterators

Iterator Objects

- **Iterable objects can be used in a `for` loop because they have an `__iter__` magic method, which converts them to iterator objects:**

```
>>> k = [1,2,3]

>>> k.__iter__()
<list_iterator object at 0x104f8ca50>

>>> iter(k)
<list_iterator object at 0x104f8ca10>
```

Iterators

- Iterators are objects with a `__next__()` method:

```
>>> i = iter(k)
>>> next(i)
1
>>> i.__next__()
2
>>> i.next()
3
>>> i.next()
Traceback (most recent call last):
  File "<stdin>", line 1, in <module>
StopIteration
```

- Python iterators do not have a `hasnext()` method!
- Just catch the `StopIteration` exception

Iterators: The real truth about `For.. In..`

- `for <item> in <iterable>:`
  `    <statements>`

- **First line is just syntactic sugar for:**
  - 1. Initialize: Call `<iterable>.__iter__()` to create an *iterator*

  Each iteration:
  - 2. Call `iterator.__next__()` and bind `<item>`
  - 2a. Catch `StopIteration` exceptions

- **To be iterable: has `__iter__` method**
  - which returns an iterator obj
- **To be iterator: has `__next__` method**
  - which throws `StopIteration` when done

An Iterator Class

```
class Reverse:
    "Iterator for looping over a sequence backwards"
    def __init__(self, data):
        self.data = data
        self.index = len(data)

    def __next__(self):
        if self.index == 0:
            raise StopIteration
        self.index = self.index - 1
        return self.data[self.index]

    def __iter__(self):
        return self
```

```
>>> for char in Reverse('spam'):
      print(char)
```

```
m
a
p
s
```

Iterators use memory efficiently

Eg: File Objects

```
>>> for line in open("script.py"):        # returns iterator
...     print(line.upper())
...
IMPORT SYS
PRINT(SYS.PATH)
X = 2
PRINT(2 ** 3)
```

instead of

```
>>> for line in open("script.py").readlines(): #returns list
...     print(line.upper())
...
```

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):
  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
```

Generator comprehensions

- **Review**: generators are good for aggregating items.
- **For example, in Python 2, `sum(xrange(n))` was *much faster than* `sum(range(n))` *for large n***
- **Similarly,**

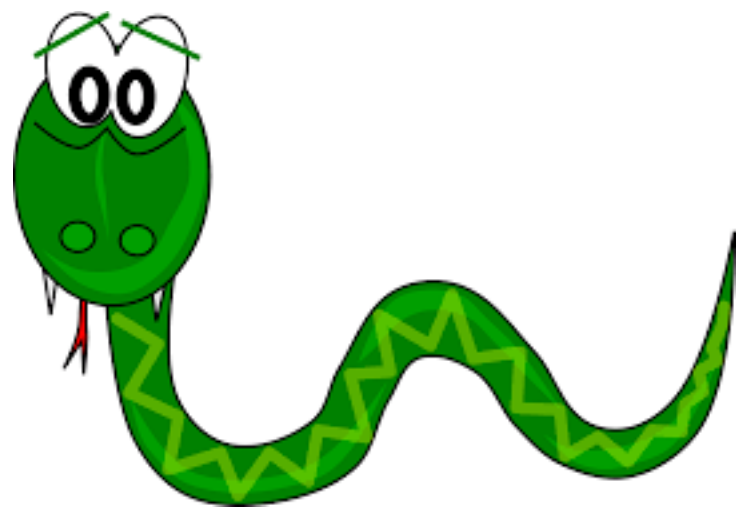
```
>>> sum(x for x in xrange(10**8) if x%5==0)
999999950000000L
```

which uses a *generator comprehension* is much faster than

```
>>> sum([x for x in xrange(10**8) if x%5==0])
999999950000000L
```

which creates the entire list before computing the sum

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 queue as Q
>>> q = Q.PriorityQueue()
>>> q.put(10)
>>> q.put(1)
>>> q.put(5)
>>> while not q.empty():
        print q.get(),
1, 5, 10
```

Hint: Super useful for search algorithms

Import Modules and Files

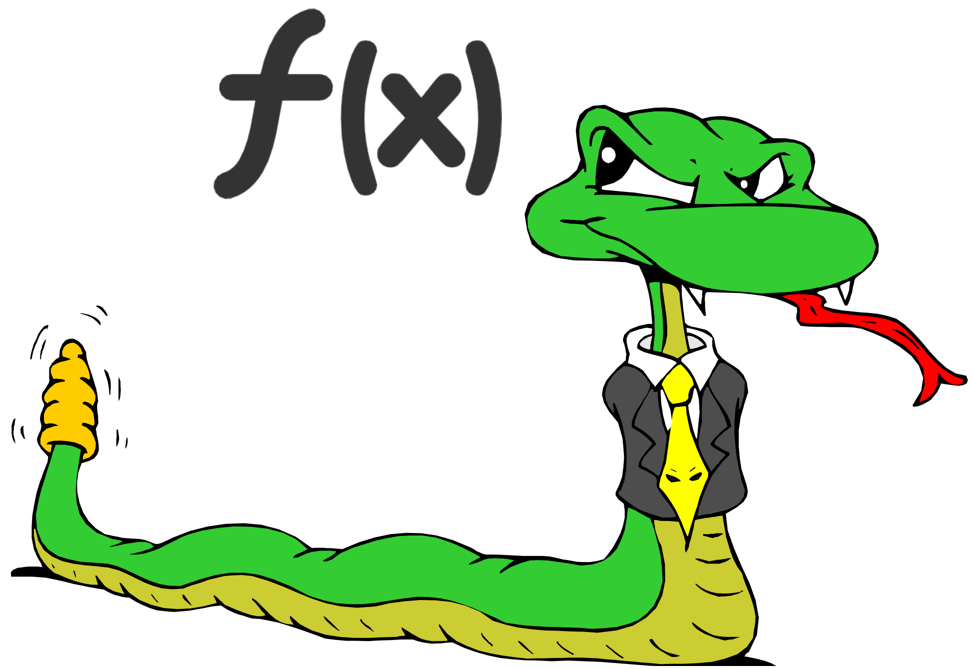
 # homework1.py

```
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 <u>types</u> 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'
```

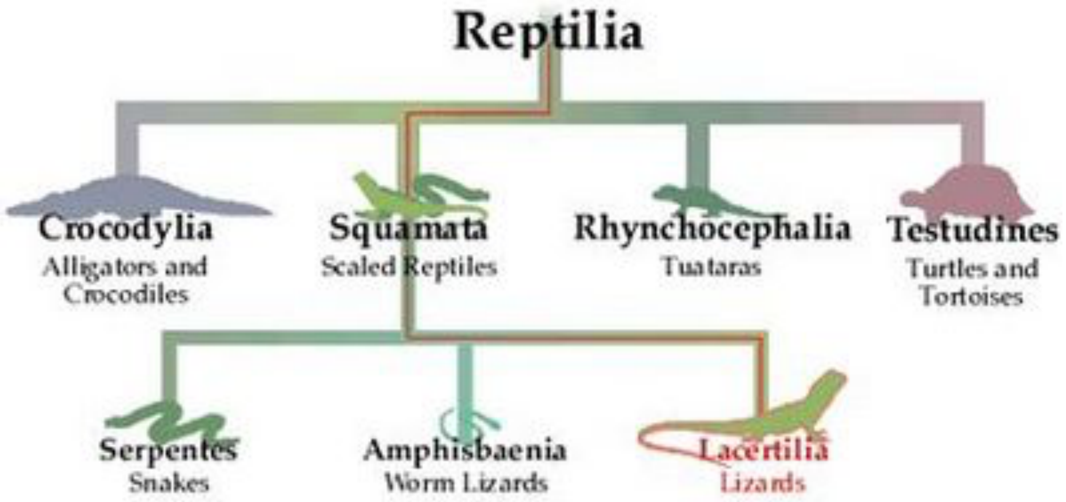
Higher Order Functions: Map, Filter

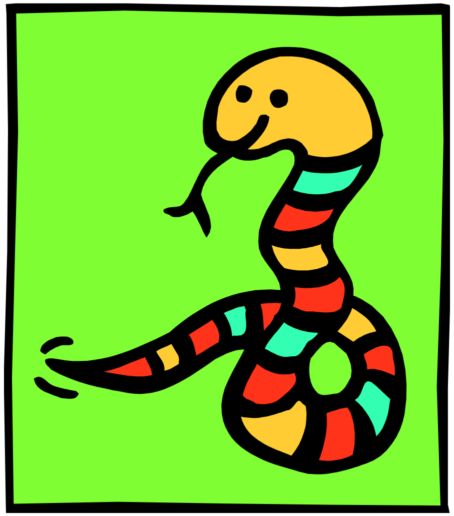
```
>>> [int(i) for i in ['1', '2']]
[1, 2]
>>> list(map(int, ['1', '2']))    #equivalent to above

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:

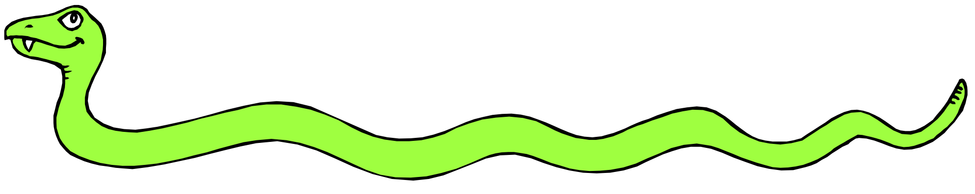
```
parentClass.__init__(self, x, y)
```

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!
```

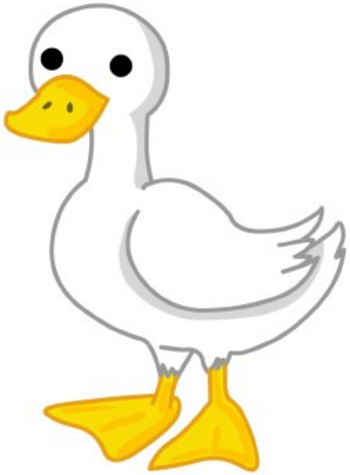
Special Built-In Methods and Attributes



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

```python
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

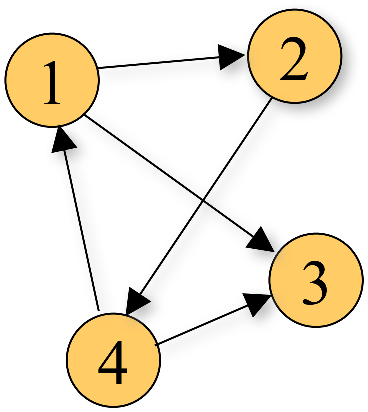
- **Used to implement operator overloading**
  - Most operators trigger a special method, dependent on class

`__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.**

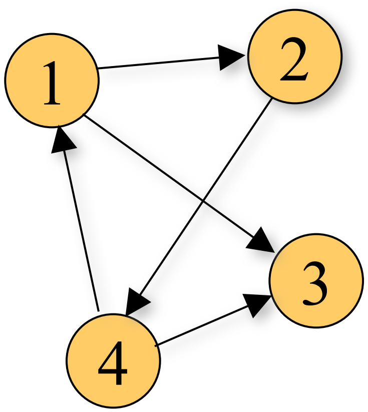
A directed graph class

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



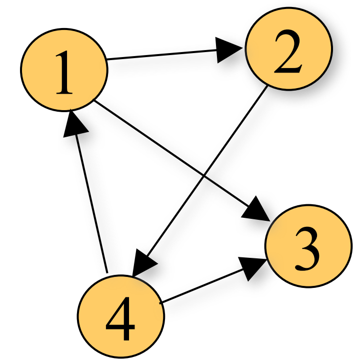
A directed graph class

```
>>> 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"

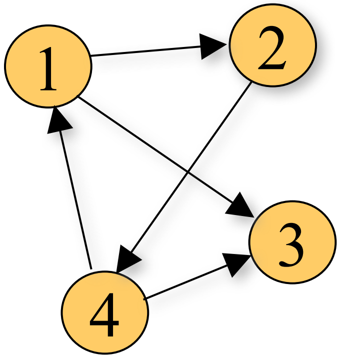
The DiGraph constructor




```
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/**