03-classes

January 20, 2017

In [144]:
```
# Ignore the code in this cell!!

import svgwrite
import collections

nobinding = "nobinding"

def binding(var):
    try:
        return eval(var)
    except NameError:
        return nobinding

class listis:
    def __init__(self):
        self.lis = []
    def get(self, key):
        for k,v in self.lis:
            if key is k:
                return v
    def put(self, key, val):
        new = True
        for pair in self.lis:
            if pair[0] is key:
                pair[1].append(val)
                new = False
        if new:
            self.lis.append([key, [val]])
    def keys(self):
        return [k for k,v in self.lis]

class memgraph:
    def __init__(self, vars):
        self.vars = sorted(vars)

    def _repr_svg_(self):
        d = svgwrite.Drawing(size=(800,200))
```

```
        left = 100
        right = 260
        dy = 30
        vv = listis()
        ais = listis()

        for var in self.vars:
            val = binding(var)
            if val != nobinding:
                vv.put(val,var)
                ais.put(val, val)

        vals = ais.keys()
        vary = dict()

        y = dy
        d.add(d.text("Variables", insert=(left, y), text_anchor="end", fi
        y += dy

        for var in self.vars:
            d.add(d.text(var, insert=(left, y), text_anchor="end", fill='
            vary[var] = y
            y += dy

        y = dy
        d.add(d.text("Objects(in the Heap)", insert=(right, y), fill='blu
        y += dy

        for val in vals:
            d.add(d.text(str(val), insert=(right, y), fill='black'))

            for var in vv.get(val):
                ly = vary[var]
                d.add(d.line((left, ly ), (right, y),  stroke=svgwrite.rg
            y += dy

        return d.tostring()

    def svg(self):
        return self._repr_svg_()
```

1 Class

- classes define "templates or blueprints" for building objects
- once a class is defined, any number of objects can be "constructed", or "instantiated"
- everything in Python is an 'object'
  - not true in Java/C++

- all python objects 'live' in the 'heap'
- each object has a fixed 'type', which can be accessed via the 'type' function
- objects have attributes, which are "named objects"
- a 'method' is an attribute holding a function object, which can access and modify the object attributes
- class methods are invoked by functions, operators, and the "." syntax. examples below in 'List'

2 Numbers

- int - arbitrary precision
- float - 64 bits
- complex

```
In [146]: # numbers evaluate to themselves

          1234 # anything after a '#" is a comment and ignored by Python
```

```
Out[146]: 1234
```

```
In [147]: # Python has the usual arithmetic operators

          3*4 - 2**3
```

```
Out[147]: 4
```

```
In [148]: # a float "contaminates" an expression and
          # makes it a float

          3*4 - 2**3.2
```

```
Out[148]: 2.810413160023719
```

```
In [149]: # arbitrary precision integers
          # integer size limited only by available memory

          2**250
```

```
Out[149]: 1809251394333065553493296640760748560207343510400633813116524750123642650
```

```
In [150]: # 'type' returns the type or class name of an object

          type(2**100)
```

```
Out[150]: int
```

2.0.1 Division operators

- slightly different from most languages
- with integers

```
In [151]: # in most languages this would int 2, but in Python, it is a float

          7/2

Out[151]: 3.5

In [152]: # // is integer divide

          7//2

Out[152]: 3

In [153]: # mod or remainder

          7%2

Out[153]: 1
```

2.0.2 Division operators

- with floats

```
In [154]: 7.0 / 2.0

Out[154]: 3.5

In [155]: 7.0 // 2.0

Out[155]: 3.0

In [156]: 7.0 % 2.0

Out[156]: 1.0

In [157]: # XeY is X*10^Y

          3e3

Out[157]: 3000.0

In [158]: 2.3 * 3e3

Out[158]: 6899.999999999999
```

2.0.3 Complex numbers

```
In [159]: # a complex number times its conjagate is real
          # j is the square root of -1
          # type name is 'complex'

          [(3+4j)*(3-4j), type(3+4j)]

Out[159]: [(25+0j), complex]

In [160]: # int function tries to convert arg to an int

          int('2345')

Out[160]: 2345

In [161]: int(3.45)

Out[161]: 3

In [162]: # likewise for float

          float('3.45')

Out[162]: 3.45

In [163]: float(3)

Out[163]: 3.0
```

3 Object references and variables

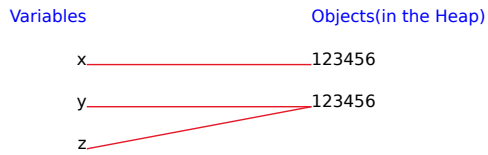
- variables hold 'references' to objects.
- variables do not have or enforce any notion of type
- a given object can have any number of references to it
- there are TWO notions of equality in Python
  - the 'is' operator is true if the two references are to the same object
  - the '==' operator is true if
    - the two references are to the same object, or two different objects "print the same way"(vague!! we will refine later)

```
In [164]: x = 123456
          y = 123456
          z = y

          # graph memory

          memgraph(['x', 'y','z'])
```

Out[164]:



In [165]:
```
# are x & y references to the same object?

x is y
```

Out[165]: False

In [166]:
```
# are y & z references to the same object?

y is z
```

Out[166]: True

In [167]:
```
# y is z => y == z

y == z
```

Out[167]: True

In [168]:
```
# are x & y 'equivalent' in some sense?
# yes - x & y are different objects, but they represent the same integer

x == y
```

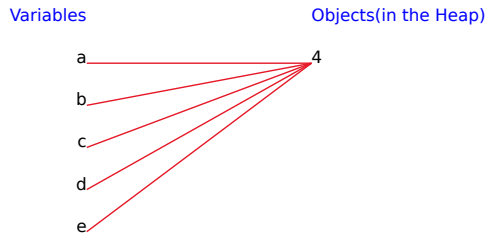
Out[168]: True

In [169]:
```
# if we try a small int, like 4, instead of 123456,
# we get a different result!

# small ints are singletons(interned) for efficiency reasons.
# so, no matter how you compute a '4', you'll get the same '4'
# object

a = 4
b = 4
c = 6 - 2
d = 2*2
e = 2**2
memgraph(['a','b','c','d','e'])
```

Out[169]:



4 Automatic memory Management

- when an object has no references to it, it becomes eligible for 'garbage collection'. the storage it uses is recycled
  - Python uses reference counting
- the user does not have to manage allocating and freeing memory, like Java, unlike C++

5 None

- Like 'null' in other languages
- Means failure or absence of a value
- is a singleton(there is only one object of class None)
- does not print at top level

```
In [170]: # no output

          None
```

```
In [171]: # explicit print will show it

          print(None)
```

```
None
```

```
In [172]: x = None
          y = None

          memgraph(['x', 'y'])
```

Out[172]:

6 Boolean

- Objects: False, True(both singletons)
- Operators: 'not', 'and', 'or'
- <.<=, etc
- unlike many languages, &, &&, |, ||, ~, are not boolean operators

```
In [173]: not(True and (True or False))

Out[173]: False

In [174]: 1234<=1234

Out[174]: True

In [175]: 123<345

Out[175]: True
```

7 Immutable vs Mutable Objects

- Immutable objects, once created, can never be modified
- Mutable objects can be modified at any time

8 Functions

- functions are "first class" objects in Python - they can be assigned as variables, passed as args
- functions are (mostly) immutable objects
- by default, functions return 'None' - you must use the 'return' statement to return a value
- note the ':' at the end of the first line, and the indenting of the function body. this is how you define a 'statement block' in python
- Java/C++ uses '{...}' for statement blocks
- much more about functions later

```
In [176]: # returns 'None'

          def add2(x):
              x + 2

          print(add2(4))
```

```
None
```

```
In [177]: # must use return

          def add2(x):
              return x + 2

          add2(3)
```

```
Out[177]: 5
```

```
In [178]: # can return multiple values by returning a list(or other data structures

          def addsub2(x):
              return [x+2, x-2]

          addsub2(10)
```

```
Out[178]: [12, 8]
```

9 Collection Types

- hold multiple objects in various configurations
- several kinds are built into the language
- can write "collection literals"
- very easy to use

10 list

- the heart of Python
- much of the "art" of Python involves getting good at manipulating lists
- a list holds a ordered sequence of objects
- duplicates are allowed
- list objects do not have to be the same type
- lists are zero origin - index of first element is 0
- lists are mutable
- some methods, like 'index' and 'count', have no 'side effects' - they don't modify the list
- others, like reverse, modify the list
- methods that modify the list typically return 'None'
- type name is 'list'

```
In [179]: # can make a list by just typing it in

          [1,2,3]

Out[179]: [1, 2, 3]

In [180]: type([2,3,4])

Out[180]: list
```

11 range

- the 'range' form is often used to specify a list of numbers
- often used for iteration purposes
- range evaluates to itself
- range is our first example of "lazy evaluation"
  - major theme in Python 3.X

```
In [181]: range(0, 10)

Out[181]: range(0, 10)

In [182]: # to see the corresponding list, use the list function
          # note range arguments are inclusive/exclusive - there's no 10 in the lis

          list(range(0, 10))

Out[182]: [0, 1, 2, 3, 4, 5, 6, 7, 8, 9]

In [183]: # same as above, assume 0 start

          list(range(10))

Out[183]: [0, 1, 2, 3, 4, 5, 6, 7, 8, 9]

In [184]: # 3rd arg is increment

          list(range(0, 10, 2))

Out[184]: [0, 2, 4, 6, 8]

In [185]: # can go backwards too - note no 0 in list

          list(range(12, 0, -3))

Out[185]: [12, 9, 6, 3]

In [186]: # 'len' forces evaluation,
          # and returns the "length" of a collection object

          len(range(12,0, -3))
```

```
Out[186]: 4

In [187]: # order matters for lists

          [1,2,3] == [2,1,3]

Out[187]: False

In [188]: [2,1,3] == [2,1,3]

Out[188]: True

In [189]: # duplicates are ok in a list

          [1,1,2,3]

Out[189]: [1, 1, 2, 3]

In [190]: # in languages like Java/C++ would have to select a
          # 'collection' type, instantiate it, and somehow
          # 'stuff' the values in.

          # in python, can just directly "write" a list
          # the assigment statement does not print the right hand side value

          x = [0, 111.111, "zap", True, None]
          y = x
          x

Out[190]: [0, 111.111, 'zap', True, None]

In [191]: # variable by itself prints its value

          x

Out[191]: [0, 111.111, 'zap', True, None]

In [192]: # len returns the length of a list

          len(x)

Out[192]: 5

In [193]: # 'count' method returns a value, does not modify the list
          # count the number of 'True's
          # here the 'dot syntax' is used to invoke the list 'count method'

          x.count(2343)

Out[193]: 0
```

```
In [194]: # reverse returns None - a hint that it modifies the list
          # the 'reverse method' on the list class is invoked

          x.reverse()

In [195]: x

Out[195]: [None, True, 'zap', 111.111, 0]

In [196]: # what happened to y?
          # we didn't explicitly do anything to y, but
          # since y references the same object as x,
          # it 'sees' the reverse that x.reverse() did

          y

Out[196]: [None, True, 'zap', 111.111, 0]

In [197]: # common mistake
          # reverse does NOT return the reversed list
          # if you do this, you just lost your list

          z = [1,2,3,4,5,6]
          z = z.reverse()
          print(z)

None


In [198]: # Another mistake
          # leaving off the '()' just
          # returns the function object
          # the function does NOT run

          z = [1,2,3,4,5,6]
          z.reverse

Out[198]: <function list.reverse>

In [199]: # so no change to z

          z

Out[199]: [1, 2, 3, 4, 5, 6]

In [200]: x

Out[200]: [None, True, 'zap', 111.111, 0]
```

```
In [201]: # Python has very convenient techniques for accessing
          # and modifying list elements
          # can index into the list like an array,
          # and retrieve one element

          x[2]

Out[201]: 'zap'

In [202]: # negative index starts from the last list element

          x[-1]

Out[202]: 0

In [203]: # can take a subsequences (slice) of the list
          # like range, inclusive/exclusive
          # slices always COPY the original list

          x[0:2]

Out[203]: [None, True]

In [204]: # missing second index means continue slice to the end of the list

          x[3:]

Out[204]: [111.111, 0]

In [205]: # missing first index means start slice at begining  of the list

          x[:2]

Out[205]: [None, True]

In [206]: # can add a index increment to a slice

          x[0:8:2]

Out[206]: [None, 'zap', 0]

In [207]: # index missing on both sides of ":" - slice
          # is the whole list.
          # common python shorthand for copying
          # an entire list

          x2 = x[:]

          # reverse modifies x2, but x will not be changed, because
          # x and x2 are referencing different objects
```

```
          # reverse() returns 'None'

          print(x2)
          print(x2.reverse())
          print(x2)
          print(x)
```

```
[None, True, 'zap', 111.111, 0]
None
[0, 111.111, 'zap', True, None]
[None, True, 'zap', 111.111, 0]
```

```
In [208]: # can set list elements

          x[0] = -1
          x
```

```
Out[208]: [-1, True, 'zap', 111.111, 0]
```

```
In [209]: # can set slices

          x[3:5] = [2**8, False]
          x
```

```
Out[209]: [-1, True, 'zap', 256, False]
```

```
In [210]: #  'in' operator - is an element in the list somewhere?
          # uses == to test

          ['zap' in x, 55 in x]
```

```
Out[210]: [True, False]
```

```
In [211]: # where is the element?
          # 'index' is a 'method' on the list class

          x.index('zap')
```

```
Out[211]: 2
```

```
In [212]: # index throws an error if it doesn't find anything
          # we will learn more about errors later

          x.index("not in there")
```

```
---------------------------------------------------------------------------

ValueError                                Traceback (most recent call last)
```

```
        <ipython-input-212-83c8fd21a8b8> in <module>()
          2 # we will learn more about errors later
          3
    ----> 4 x.index("not in there")


        ValueError: 'not in there' is not in list
```

```
In [213]: # + concatenates lists
          # note: what '+' actually does depends on the type of its arguments

          x = list(range(5))
          x + x

Out[213]: [0, 1, 2, 3, 4, 0, 1, 2, 3, 4]

In [214]: x

Out[214]: [0, 1, 2, 3, 4]

In [215]: # add one element at the end

          x.append([22,33])
          x

Out[215]: [0, 1, 2, 3, 4, [22, 33]]

In [216]: # add N elements at the end

          x.extend([22,33])
          x

Out[216]: [0, 1, 2, 3, 4, [22, 33], 22, 33]

In [217]: # add one element anywhere

          x.insert(2, 5)
          x

Out[217]: [0, 1, 5, 2, 3, 4, [22, 33], 22, 33]

In [218]: # pop method removes and returns a
          # list element, by default the last element

          print(x.pop())
          print(x)
```

```
33
[0, 1, 5, 2, 3, 4, [22, 33], 22]
```

```
In [219]: # but can specify which element to pop

          print(x.pop(2))
          print(x)
```

```
5
[0, 1, 2, 3, 4, [22, 33], 22]
```

```
In [220]: # remove first 4 found

          x.remove(4)
          print(x)
```

```
[0, 1, 2, 3, [22, 33], 22]
```

```
In [221]: # sort modifies the list

          x = [34,3,5,22]
          x.sort()
          x
```

```
Out[221]: [3, 5, 22, 34]
```

```
In [222]: # can preserve original list by using 'sorted'
          # sorted makes a copy of the input list

          x = [34,3,5,22]
          y = sorted(x)
          [x, y]
```

```
Out[222]: [[34, 3, 5, 22], [3, 5, 22, 34]]
```

```
In [223]: # dir shows the methods defined on a class
          # __XYZ__ are "special" methods - ignore them for now

          dir(list)
```

```
Out[223]: ['__add__',
           '__class__',
           '__contains__',
           '__delattr__',
           '__delitem__',
           '__dir__',
```

```
'__doc__',
'__eq__',
'__format__',
'__ge__',
'__getattribute__',
'__getitem__',
'__gt__',
'__hash__',
'__iadd__',
'__imul__',
'__init__',
'__iter__',
'__le__',
'__len__',
'__lt__',
'__mul__',
'__ne__',
'__new__',
'__reduce__',
'__reduce_ex__',
'__repr__',
'__reversed__',
'__rmul__',
'__setattr__',
'__setitem__',
'__sizeof__',
'__str__',
'__subclasshook__',
'append',
'clear',
'copy',
'count',
'extend',
'index',
'insert',
'pop',
'remove',
'reverse',
'sort']
```

12 Iterating over Lists

- Many ways to iterate, we'll look at the two most important here, 'for' and 'list comprehensions'
- Python does NOT have C++/Java style loops, like:

for(int j = 0; j<5; j++) { }

13 for loop

- Python version of C++/Java loop above
- Python loops are simpler
- note trailing ':', and indented print statements - defines a statement block
- Python uses idents and ':' to define blocks, unlike C/Java, which uses '{}'

```
In [224]: for j in range(10,15):
              print(j)
              print(j+10)
          print('loop finished')

10
20
11
21
12
22
13
23
14
24
loop finished


In [225]: # to sum up a list of numbers
          # use zn 'acculumation variable'

          sum = 0

          for j in range(5):
              sum += j

          sum

Out[225]: 10

In [226]: # add 10 to every element of a list
          # use list acculumation variable

          a10 = []

          for j in range(5):
              a10.append(10+j)

          a10

Out[226]: [10, 11, 12, 13, 14]
```

14 list comprehension

- above technique is not conidered 'pythonic'
- syntax is a little odd at first glance
- no accum var needed
- can optionally do filtering

```
In [227]: # add 10 again

          [j+10 for j in range(5)]

Out[227]: [10, 11, 12, 13, 14]

In [228]: # filter - add 10 only to even ints
          # '%' is mod operator

          [j+10 for j in range(5) if j % 2 == 0]

Out[228]: [10, 12, 14]
```

15 Tuples

- like lists, but immutable - can't be modified after creation
  - however, objects that the tuple refers to can still be modified
- useful for functional programming
- 'tuple' is the type name

```
In [232]: # len returns length of top level elements

          t = (1,[5,6],4)
          [t , len(t), type(t)]

Out[232]: [(1, [5, 6], 4), 3, tuple]

In [233]: len(t)

Out[233]: 3

In [234]: # can retrieve

          t[0]

Out[234]: 1

In [235]: # but can't modify

          t[0] = 3
```

```
---------------------------------------------------------------------------

TypeError                                 Traceback (most recent call last)

<ipython-input-235-5ac5b4647ba0> in <module>()
  1 # but can't modify
  2
----> 3 t[0] = 3


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

```
In [236]: t
```

```
Out[236]: (1, [5, 6], 4)
```

```
In [237]: # but - objects the tuple refers to are NOT made immutable

          t[1][0] = 45
          t
```

```
Out[237]: (1, [45, 6], 4)
```

```
In [238]: # tuples loop like lists

          for x in (1,2,3):
              print(x)
```

```
1
2
3
```

16 Iterables

- 'iterables' are objects you can iterate over
- lists and tuples are iterables

17 Strings

- immutable - once created, cannot be modified
- in Python version 3.X, strings are unicode
- many useful methods
- the 're' module provides regular expression pattern matching
- three types of string literals 'foo', "foo", and '"foo"'
- triple quotes can include multiple lines

- unlike other languages, there is no 'character' type
- a Python 'character' is just a length 1 string
- 'str' is the type name

```
In [239]: # len returns number of characters

          ['foobar', 'foo"bar', type('foobar'), len('foobar')]

Out[239]: ['foobar', 'foo"bar', str, 6]

In [240]: # various ways to embed quotes

          ['foo"bar', "foo'bar", 'foo\'bar']

Out[240]: ['foo"bar', "foo'bar", "foo'bar"]

In [241]: # use triple quotes to define multi-line strings

          '''
          foo'
          bar"
          '''

Out[241]: '\nfoo\'\nbar"\n'

In [242]: # Strings are iterables

          for s in 'FooBar':
              print(s)

F
o
o
B
a
r


In [243]: # string methods that return a string always return a NEW string.
          # the original string is NEVER modified

          s = 'FooBar'
          ls = [s, s.lower(), s.upper(), s.replace('o','X'), s.swapcase()]

In [244]: # first element of list is the original 'FooBar' - has not
          # been modified by any of the methods run above
          # rest of list contains 4 NEW string objects, derived from the
          # original 'FooBar'

          ls
```

```
Out[244]: ['FooBar', 'foobar', 'FOOBAR', 'FXXBar', 'fOObAR']

In [245]: # join is a very handy method

          [','.join(ls), '|'.join(ls), '---'.join(ls)]

Out[245]: ['FooBar,foobar,FOOBAR,FXXBar,fOObAR',
           'FooBar|foobar|FOOBAR|FXXBar|fOObAR',
           'FooBar---foobar---FOOBAR---FXXBar---fOObAR']

In [246]: # the inverse, split, creates a list of tokens

          s = "foo,bar,34,zap"
          s.split(",")

Out[246]: ['foo', 'bar', '34', 'zap']

In [247]: # strip can remove chars at the begining(left) and/or end(right) of a str
          # Note middle 'X' is not removed
          # Most commonly used to remove new lines from a string

          s = 'XXfooXbarXXX'
          [s.strip('X'), s.lstrip('X'), s.rstrip('X')]

Out[247]: ['fooXbar', 'fooXbarXXX', 'XXfooXbar']

In [248]: # '+' concatenates strings as well as lists
          # the operation '+' performs depends on the type of the arguments

          s + s

Out[248]: 'XXfooXbarXXXXXfooXbarXXX'

In [249]: # can repeat strings

          [2*"abc", "xyz"*4]

Out[249]: ['abcabc', 'xyzxyzxyzxyz']

In [250]: # 'in' looks for substrings
          # case sensitive compares

          s = 'zappa'
          ['pa' in s, 'Za' in s, s.count('p'), s.count('ap')]

Out[250]: [True, False, 2, 1]

In [251]: # search for a substring with 'find' or 'index'

          [s.find('pa'), s.index('pa')]
```

```
Out[251]: [3, 3]

In [252]: # on a miss, 'find' returns -1

          s.find('32')

Out[252]: -1

In [253]: # but index throws an error

          s.index('32')


        ---------------------------------------------------------------------------

        ValueError                                Traceback (most recent call last)

        <ipython-input-253-ca1c8ab7d822> in <module>()
          1 # but index throws an error
          2
    ----> 3 s.index('32')


        ValueError: substring not found


In [254]: # 'ord' and 'chr' do character-number conversions

          [ord('A'), chr(65)]

Out[254]: [65, 'A']

In [255]: # make the lower case chars, a-z
          # somewhat terse one liner -
          # in Python you can do alot with a little code,
          # but can be hard to read

          lc= ''.join([chr(c) for c in range(ord('a'), ord('z')+1)])
          lc

Out[255]: 'abcdefghijklmnopqrstuvwxyz'

In [256]: # let's break it into separate steps:
          # get the ascii codes for 'a' and 'z'

          a = ord('a')
          z = ord('z')
          [a,z]

Out[256]: [97, 122]
```

```
In [257]: # now we have all the codes for 'a' to 'z'
          # note the z+1 - need the +1 to get the z code

          codes = [c for c in range(a,z+1)]
          print(codes)
```

```
[97, 98, 99, 100, 101, 102, 103, 104, 105, 106, 107, 108, 109, 110, 111, 112, 113,
```

```
In [258]: # now we have a list of the lower case characters

          chars = [chr(c) for c in codes]
          print(chars)
```

```
['a', 'b', 'c', 'd', 'e', 'f', 'g', 'h', 'i', 'j', 'k', 'l', 'm', 'n', 'o', 'p', 'q
```

```
In [259]: # last step - using the 'join' method on string,
          # merge the chars into one string

          ''.join(chars)
```

```
Out[259]: 'abcdefghijklmnopqrstuvwxyz'
```

```
In [260]: # now that we have suffered, there is an easier way
          # string package has useful constants

          import string
          string.ascii_lowercase
```

```
Out[260]: 'abcdefghijklmnopqrstuvwxyz'
```

```
In [261]: # can slice strings too

          [len(lc), lc[10:20], lc[10:20:2], lc[10:11]]
```

```
Out[261]: [26, 'klmnopqrst', 'kmoqs', 'k']
```

```
In [262]: # unlike a list, a string is immutable - you can't change anything

          s = 'foobar'
          s[0] = 't'
```

```
---------------------------------------------------------------------------

TypeError                                 Traceback (most recent call last)

<ipython-input-262-28c99246d7b8> in <module>()
  2
```

```
      3 s = 'foobar'
----> 4 s[0] = 't'


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

```
In [263]: # unlike list objects, string objects don't have a reverse method
          # but you can reverse with a slice
          # works with lists as well

          s = '1234'
          z = [1,2,3,4]
          [s[::-1], z[::-1]]
```

```
Out[263]: ['4321', [4, 3, 2, 1]]
```

```
In [264]: # startswith, endwith string methods are sometimes
          # convenient alternatives to regular expressions

          a = "foo.txt"

          [a.startswith('foo'), a.endswith('txt'), a.endswith('txt2')]
```

```
Out[264]: [True, True, False]
```

```
In [265]: # 'str' converts objects to strings

          [str(234), str(3.34), str([1,2,3])]
```

```
Out[265]: ['234', '3.34', '[1, 2, 3]']
```

```
In [266]: # 'list' converts a string into a list of
          # characters(length one strings)

          list('foobar')
```

```
Out[266]: ['f', 'o', 'o', 'b', 'a', 'r']
```

18 'printf' style string formatting - old way

- still works, but deprecated

```
In [267]: 'int %d float %f string %s' % (3, 5.5, 'printf')
```

```
Out[267]: 'int 3 float 5.500000 string printf'
```

19 'printf' style string formatting - new way

- preferred method
- looks at the type of the arg, so don't have to specify type in control string
- details

```
In [268]: 'int {} float {} string {}'.format(3, 5.5, 'printf')

Out[268]: 'int 3 float 5.5 string printf'

In [269]: # lots of methods on strings

          dir(str)

Out[269]: ['__add__',
           '__class__',
           '__contains__',
           '__delattr__',
           '__dir__',
           '__doc__',
           '__eq__',
           '__format__',
           '__ge__',
           '__getattribute__',
           '__getitem__',
           '__getnewargs__',
           '__gt__',
           '__hash__',
           '__init__',
           '__iter__',
           '__le__',
           '__len__',
           '__lt__',
           '__mod__',
           '__mul__',
           '__ne__',
           '__new__',
           '__reduce__',
           '__reduce_ex__',
           '__repr__',
           '__rmod__',
           '__rmul__',
           '__setattr__',
           '__sizeof__',
           '__str__',
           '__subclasshook__',
           'capitalize',
           'casefold',
           'center',
```

```
'count',
'encode',
'endswith',
'expandtabs',
'find',
'format',
'format_map',
'index',
'isalnum',
'isalpha',
'isdecimal',
'isdigit',
'isidentifier',
'islower',
'isnumeric',
'isprintable',
'isspace',
'istitle',
'isupper',
'join',
'ljust',
'lower',
'lstrip',
'maketrans',
'partition',
'replace',
'rfind',
'rindex',
'rjust',
'rpartition',
'rsplit',
'rstrip',
'split',
'splitlines',
'startswith',
'strip',
'swapcase',
'title',
'translate',
'upper',
'zfill']
```