Object-Oriented Programming

- Defining new Python Classes
- Container Classes
- Overloaded Operators
- Inheritance
- User-Defined Exceptions

A new class: `Point`

Suppose we would like to have a class that represents points on a plane

- for a graphics app, say

Let's first informally describe how we would like to use this class

```
>>> point = Point()
>>> point.setx(3)
>>> point.sety(4)
>>> point.get()
(3, 4)
>>> point.move(1, 2)
>>> point.get()
(4, 6)
>>> point.setx(-1)
>>> point.get()
(-1, 6)
>>>
```

Usage	Explanation
`p.setx(xcoord)`	Sets the x coordinate of point `p` to `xcoord`
`p.sety(ycoord)`	Sets the y coordinate of point `p` to `ycoord`
`p.get()`	Returns the x and y coordinates of point `p` as a tuple (x, y)
`p.move(dx, dy)`	Changes the coordinates of point `p` from the current (x, y) to (x+dx, y+dy)

How do we create this new class `Point`?

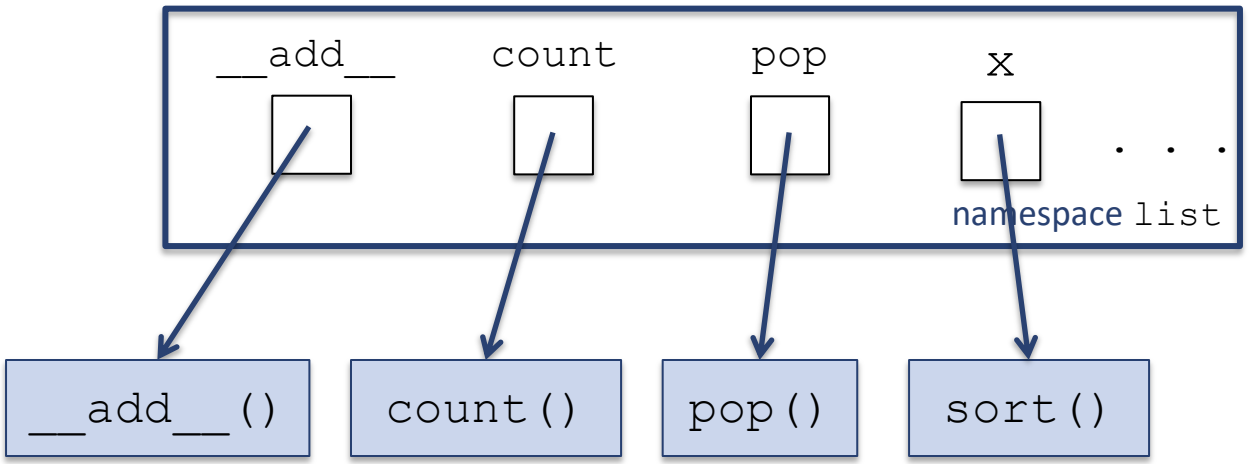
A class is a namespace (REVIEW)

A class is really a namespace

- The name of this namespace is the name of the class
- The names defined in this namespace are the class attributes (e.g., class methods)
- The class attributes can be accessed using the standard namespace notation

```
>>> list.pop
<method 'pop' of 'list' objects>
>>> list.sort
<method 'sort' of 'list' objects>
>>> dir(list)
['__add__', '__class__',
...
'index', 'insert', 'pop', 'remove',
'reverse', 'sort']
```

Function `dir()` can be used to list the class attributes



Class methods (REVIEW)

A class method is really a function defined in the class namespace; when Python executes

```
instance.method(arg1, arg2, …)
```

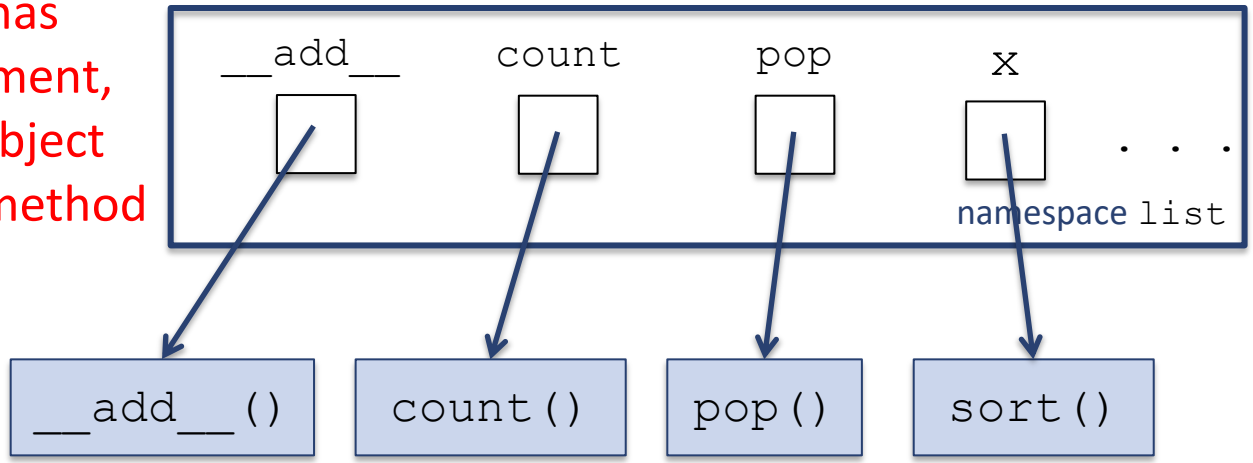
it first translates it to

```
class.method(instance, arg1, arg2, …)
```

and actually executes this last statement

The function has an extra argument, which is the object invoking the method

```
>>> lst = [9, 1, 8, 2, 7, 3]
>>> lst
[9, 1, 8, 2, 7, 3]
>>> lst.sort()
>>> lst
[1, 2, 3, 7, 8, 9]
>>> lst = [9, 1, 8, 2, 7, 3]
>>> lst
[9, 1, 8, 2, 7, 3]
>>> list.sort(lst)
>>> lst
[1, 2, 3, 7, 8, 9]
>>> lst.append(6)
>>> lst
[1, 2, 3, 7, 8, 9, 6]
>>> list.append(lst, 5)
>>> lst
[1, 2, 3, 7, 8, 9, 6, 5]
```

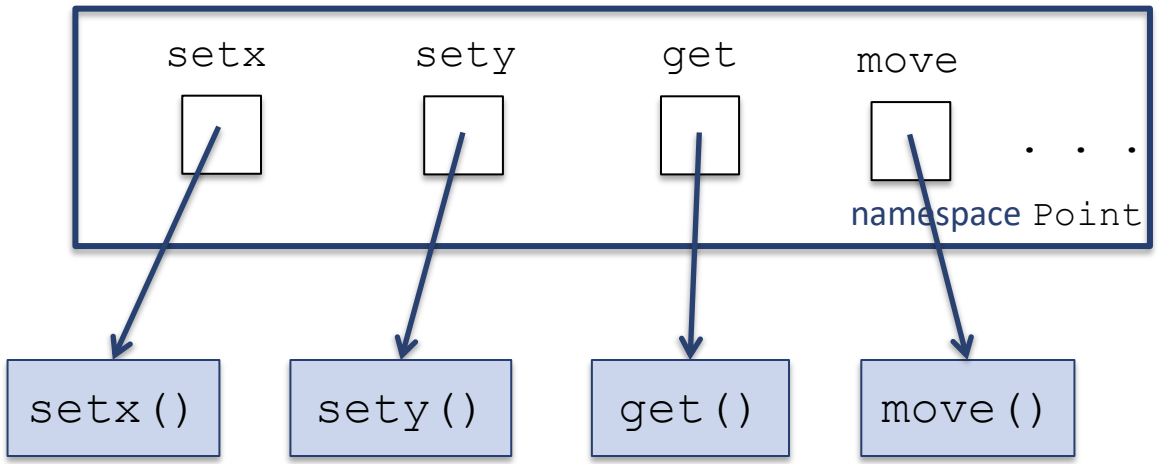


Developing the class `Point`

A namespace called `Point` needs to be defined

Namespace `Point` will store the names of the 4 methods (the class attributes)

Usage	Explanation
`p.setx(xcoord)`	Sets the x coordinate of point `p` to `xcoord`
`p.sety(ycoord)`	Sets the y coordinate of point `p` to `ycoord`
`p.get()`	Returns the x and y coordinates of point `p` as a tuple (x, y)
`p.move(dx, dy)`	Changes the coordinates of point `p` from the current (x, y) to (x+dx, y+dy)



Defining the class `Point`

A namespace called `Point` needs to be defined

Namespace `Point` will store the names of the 4 methods (the class attributes)

Each method is a function that has an extra (first) argument which refers to the object that the method is invoked on

Usage	Explanation
`setx(p, xcoord)`	Sets the x coordinate of point `p` to `xcoord`
`sety(p, ycoord)`	Sets the y coordinate of point `p` to `ycoord`
`get(p)`	Returns the x and y coordinates of point `p` as a tuple (x, y)
`move(p, dx, dy)`	Changes the coordinates of point `p` from the current (x, y) to (x+dx, y+dy)

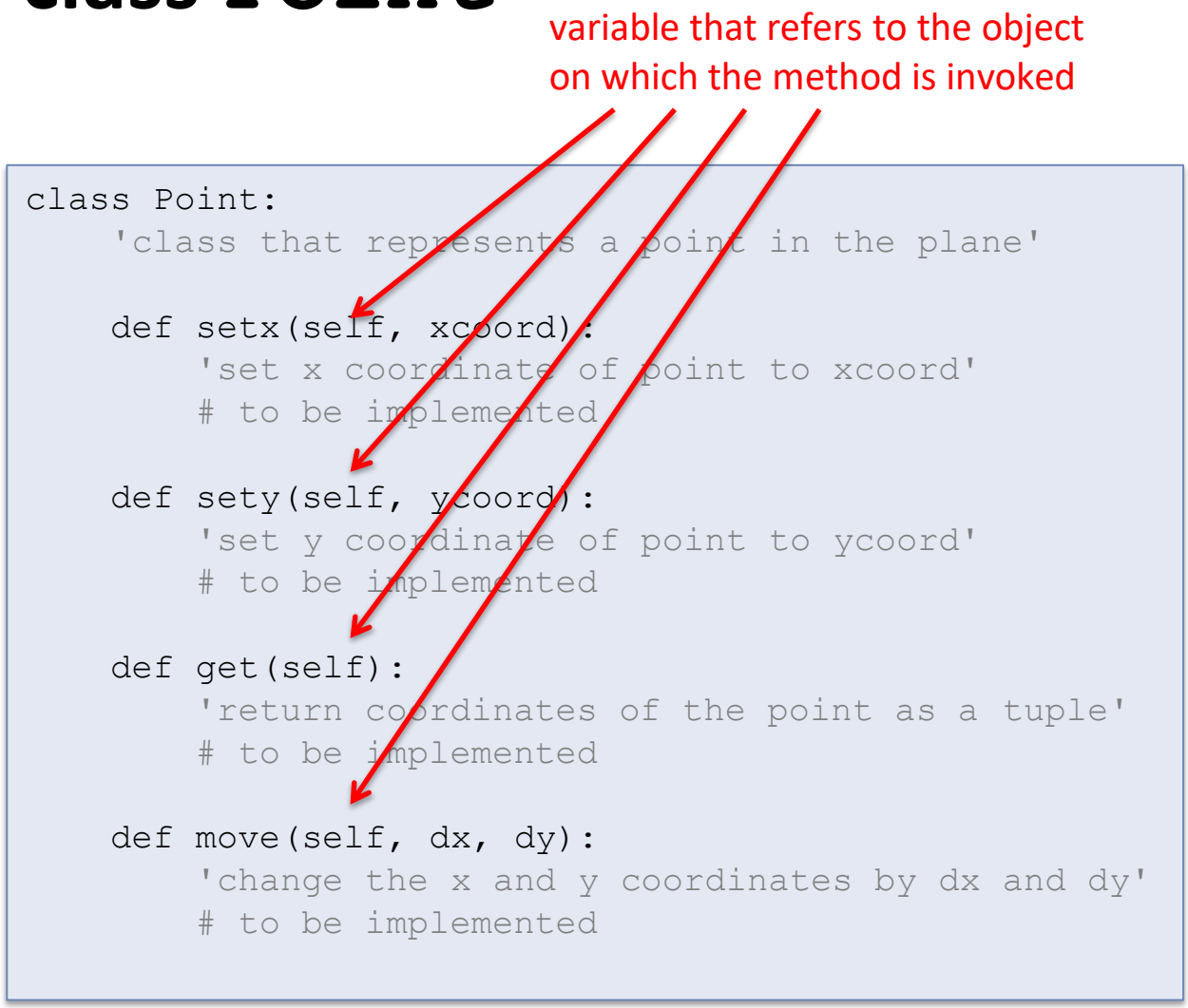
```
>>> Point.get(point)
(-1, 6)
>>> Point.setx(point, 0)
>>> Point.get(point)
(0, 6)
>>> Point.sety(point, 0)
>>> Point.get(point)
(0, 0)
>>> Point.move(point, 2, -2)
>>> Point.get(point)
(2, -2)
```

Defining the class `Point`

A namespace called `Point` needs to be defined

Namespace `Point` will store the names of the 4 methods (the class attributes)

Each method is a function that has an extra (first) argument which refers to the object that the method is invoked on



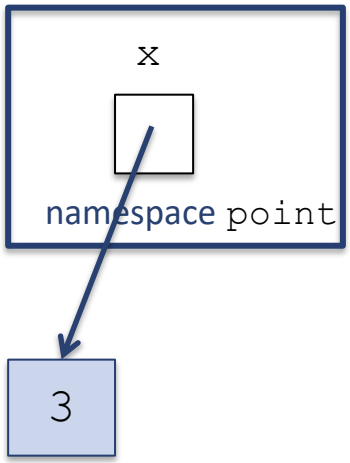
The Python `class` statement defines a new class (and associated namespace)

The object namespace

We know that a namespace is associated with every class

A namespace is also associated with every object

```
>>> point = Point()
>>> Point.setx(point, 3)
>>>
```




```
class Point:
    'class that represents a point in the plane'

    def setx(self, xcoord):
        'set x coordinate of point to xcoord'
        self.x = xcoord

    def sety(self, ycoord):
        'set y coordinate of point to ycoord'
        # to be implemented

    def get(self):
        'return coordinates of the point as a tuple'
        # to be implemented

    def move(self, dx, dy):
        'change the x and y coordinates by dx and dy'
        # to be implemented
```

The Python `class` statement defines a new class

Defining the class `Point`

A namespace called `Point` needs to be defined

Namespace `Point` will store the names of the 4 methods (the class attributes)

Each method is a function that has an extra (first) argument which refers to the object that the method is invoked on

```
class Point:
    'class that represents a point in the plane'

    def setx(self, xcoord):
        'set x coordinate of point to xcoord'
        self.x = xcoord

    def sety(self, ycoord):
        'set y coordinate of point to ycoord'
        self.y = ycoord

    def get(self):
        'return coordinates of the point as a tuple'
        return (self.x, self.y)

    def move(self, dx, dy):
        'change the x and y coordinates by dx and dy'
        self.x += dx
        self.y += dy
```

Exercise

Add new method `getx()` to class Point

```
>>> point = Point()
>>> point.setx(3)
>>> point.getx()
3
```

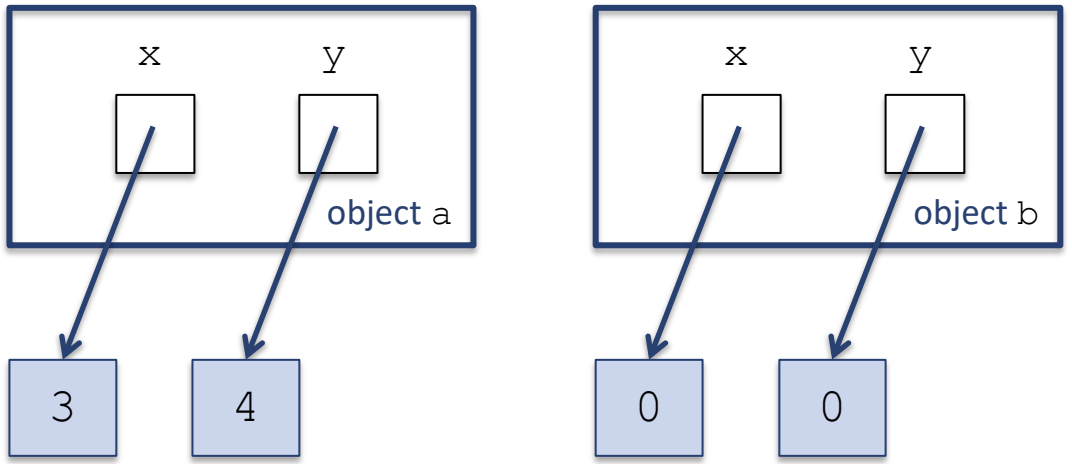
```
class Point:
    'class that represents a point in the plane'

    def setx(self, xcoord):
        'set x coordinate of point to xcoord'
        self.x = xcoord

    def sety(self, ycoord):
        'set y coordinate of point to ycoord'
        self.y = ycoord

    def get(self):
        'return coordinates of the point as a tuple'
        return (self.x, self.y)

    def move(self, dx, dy):
        'change the x and y coordinates by dx and dy'
        self.x += dx
        self.y += dy

    def getx(self):
        'return x coordinate of the point'
        return self.x
```

The instance namespaces

Variables stored in the namespace of an object (instance) are called instance variables (or instance attributes)

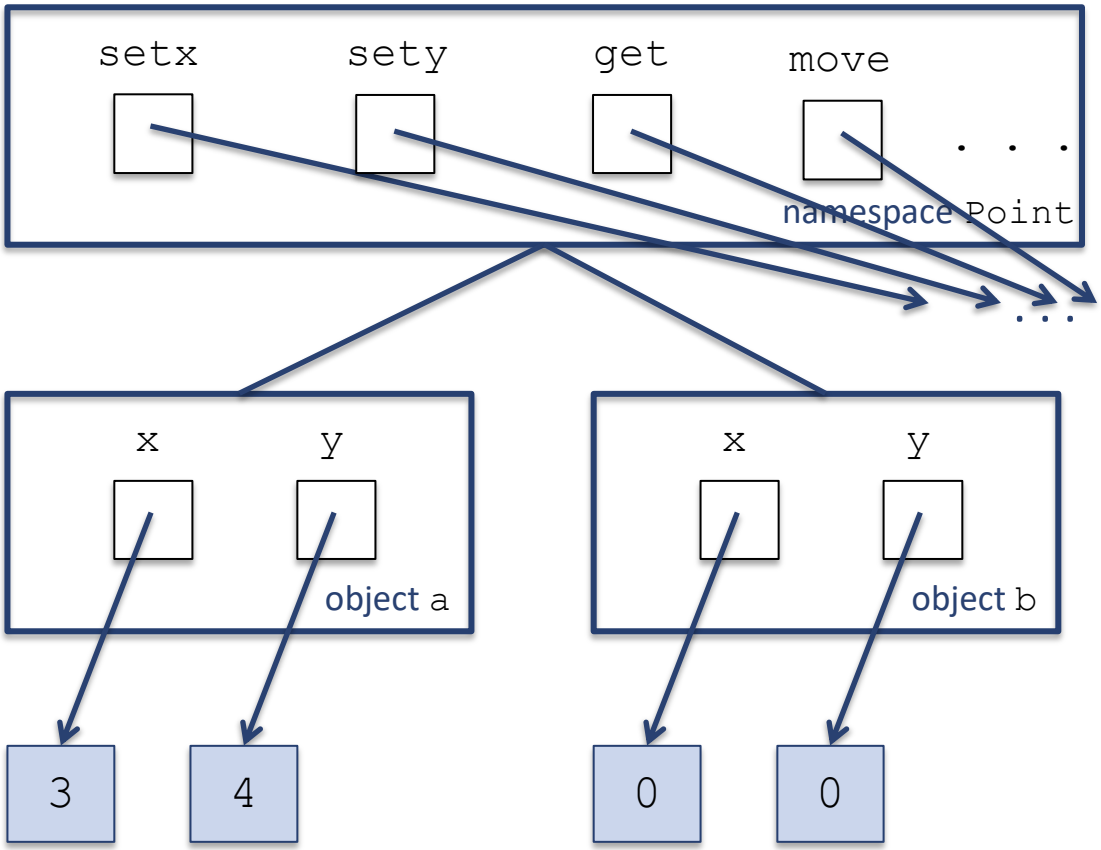
Every object will have its own namespace and therefore its own instance variables

```
>>> a = Point()
>>> a.setx(3)
>>> a.sety(4)
>>> b = Point()
>>> b.setx(0)
>>> b.sety(0)
>>> a.get()
(3, 4)
>>> b.get()
(0, 0)
>>> a.x
3
>>> b.x
0
>>>
```



The class and instance attributes

An instance of a class inherits all the class attributes




```
>>> dir(a)
['__class__', '__delattr__',
'__dict__', '__doc__',
'__eq__', '__format__',
'__ge__', '__getattribute__',
'__gt__', '__hash__',
'__init__', '__le__',
'__lt__', '__module__',
'__ne__', '__new__',
'__reduce__', '__reduce_ex__',
'__repr__', '__setattr__',
'__sizeof__', '__str__',
'__subclasshook__',
'__weakref__', 'get', 'move',
'setx', 'sety', 'x', 'y']
```

class `Point` attributes inherited by `a` instance attributes of `a`

Function `dir()` returns the attributes of an object, including the inherited ones

The class and instance attributes

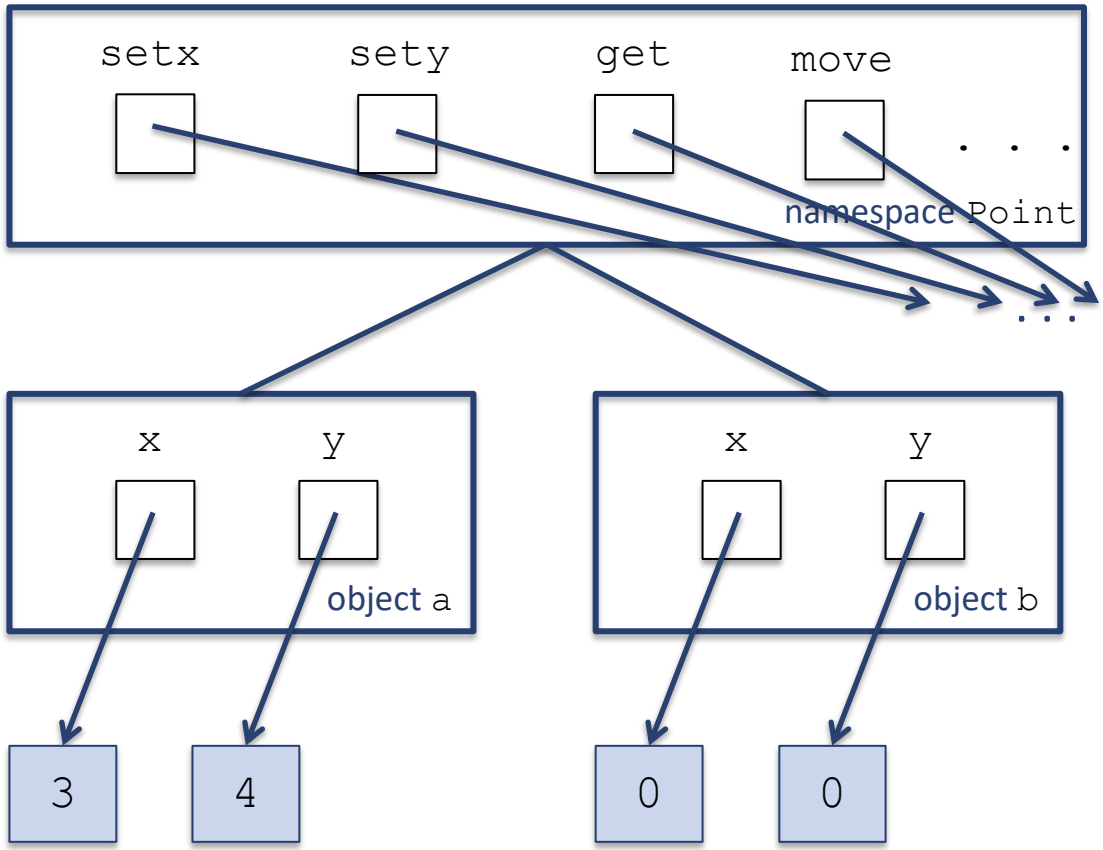
Method names `setx`, `sety`, `get`, and `move` are defined in namespace `Point`

- not in namespace `a` or `b`.

Python does the following when evaluating expression `a.setx`:

1. It first attempts to find name `setx` in object (namespace) a.

2. If name `setx` does not exist in namespace a, then it attempts to find `setx` in namespace `Point`



Class definition, in general

```
class Point:

    def setx(self, xcoord):
        self.x = xcoord

    def sety(self, ycoord):
        self.y = ycoord

    def get(self):
        return (self.x, self.y)

    def move(self, dx, dy):
        self.x += dx
        self.y += dy
```

Note: no documentation

(No) class documentation

```
>>> help(Point)
Help on class Point in module __main__:

class Point(builtins.object)
 |  Methods defined here:
 |
 |  get(self)
 |
 |  move(self, dx, dy)
 |
 |  setx(self, xcoord)
 |
 |  sety(self, ycoord)
 |
 |  ----------------------------------------------------------------------
-
 |  Data descriptors defined here:
 |
 |  __dict__
 |      dictionary for instance variables (if defined)
 |
 |  __weakref__
 |      list of weak references to the object (if defined)
```

Class documentation

```
class Point:
    'class that represents a point in the plane'

    def setx(self, xcoord):
        'set x coordinate of point to xcoord'
        self.x = xcoord

    def sety(self, ycoord):
        'set y coordinate of point to ycoord'
        self.y = ycoord

    def get(self):
        'return coordinates of the point as a tuple'
        return (self.x, self.y)

    def move(self, dx, dy):
        'change the x and y coordinates by dx and dy'
        self.x += dx
        self.y += dy
```

Class documentation

```
>>> help(Point)
Help on class Point in module __main__:

class Point(builtins.object)
 |  class that represents a point in the plane
 |
 |  Methods defined here:
 |
 |  get(self)
 |      return a tuple with x and y coordinates of the point
 |
 |  move(self, dx, dy)
 |      change the x and y coordinates by dx and dy
 |
 |  setx(self, xcoord)
 |      set x coordinate of point to xcoord
 |
 |  sety(self, ycoord)
 |      set y coordinate of point to ycoord
 |
 |  ----------------------------------------------------------------
-
 |  Data descriptors defined here:
...
```

Exercise

Develop class `Animal` that supports methods:

- `setSpecies(species)`
- `setLanguage(language)`
- `speak()`

```
>>> snoopy = Animal()
>>> snoopy.setpecies('dog')
>>> snoopy.setLanguage('bark')
>>> snoopy.speak()
I am a dog and I bark.
```

```
class Animal:
    'represents an animal'

    def setSpecies(self, species):
        'sets the animal species'
        self.spec = species

    def setLanguage(self, language):
        'sets the animal language'
        self.lang = language

    def speak(self):
        'prints a sentence by the animal'
        print('I am a {} and I {}.'.format(self.spec, self.lang))
```

Overloaded constructor

called by Python each time a `Point` object is created

It takes 3 steps to create a `Point` object at specific x and y coordinates

```
>>> a = Point()
>>> a.setx(3)
>>> a.sety(4)
>>> a.get()
(3, 4)
>>>
```

It would be better if we could do it in one step

```
>>> a = Point(3, 4)
>>> a.get()
(3, 4)
>>>
```

```
class Point:
    'class that represents a point in the plane'

 def __init__(self, xcoord, ycoord):
        'initialize coordinates to (xcoord, ycoord)'
        self.x = xcoord
        self.y = ycoord

    def setx(self, xcoord):
        'set x coordinate of point to xcoord'
        self.x = xcoord

    def sety(self, ycoord):
        'set y coordinate of point to ycoord'
        self.y = ycoord

    def get(self):
        'return coordinates of the point as a tuple'
        return (self.x, self.y)

    def move(self, dx, dy):
        'change the x and y coordinates by dx and dy'
        self.x += dx
        self.y += dy
```

Default constructor

xcoord is set to 0 if the argument is missing

ycoord is set to 0 if the argument is missing

Problem: Now we can't create an uninitialized point

Built-in types support default constructors

Want to augment class Point so it supports a default constructor

```
>>> a = Point()
Traceback (most recent call
  File "<pyshell#0>", line 1
    a = Point()
TypeError: __init__() takes
>>>
```

```
>>> a = Point()
>>> a.get()
(0, 0)
>>>
```

```
>>> n
0
>>>
```

```
class Point:
    'class that represents a point in the plane'

 def __init__(self, xcoord=0, ycoord=0):
        'initialize coordinates to (xcoord, ycoord)'
        self.x = xcoord
        self.y = ycoord

    def setx(self, xcoord):
        'set x coordinate of point to xcoord'
        self.x = xcoord

    def sety(self, ycoord):
        'set y coordinate of point to ycoord'
        self.y = ycoord

    def get(self):
        'return coordinates of the point as a tuple'
        return (self.x, self.y)

    def move(self, dx, dy):
        'change the x and y coordinates by dx and dy'
        self.x += dx
        self.y += dy
```

Exercise

Modify the class `Animal` we developed in the previous section so it supports a two, one, or no input argument constructor

```
>>> snoopy = Animal('dog', 'bark')
```

```
class Animal:
    'represents an animal'

    def __init__(self, species='animal', language='make sounds'):
        self.species = species
        self.language = language

    def setSpecies(self, species):
        'sets the animal species'
        self.spec = species

    def setLanguage(self, language):
        'sets the animal language'
        self.lang = language

    def speak(self):
        'prints a sentence by the animal'
        print('I am a {} and I {}.'.format(self.spec, self.lang))
```

Example: class `Card`

Goal: develop a class `Card` class to represent playing cards.

The class Card should support methods:

- `Card(rank, suit)`: Constructor that initializes the rank and suit of the card
- `getRank()`: Returns the card's rank
- `getSuit()`: Returns the card's suit

```
>>> card = Card('3', '\u2660')
>>> card.getRank()
'3'
>>> card.getSuit()
'♠'
>>>
```

```
class Card:
    'represents a playing card'

    def __init__(self, rank, suit):
        'initialize rank and suit of card'
        self.rank = rank
        self.suit = suit

    def getRank(self):
        'return rank'
        return self.rank

    def getSuit(self):
        'return suit'
        return self.suit
```

Container class: class `Deck`

Goal: develop a class `Deck` to represent a standard deck of 52 playing cards.

The class `Deck` should support methods:

- `Deck()`: Initializes the deck to contain a standard deck of 52 playing cards
- `shuffle()`: Shuffles the deck
- `dealCard()`: Pops and returns the card at the top of the deck

```
>>> deck = Deck()
>>> deck.shuffle()
>>> card = deck.dealCard()
>>> card.getRank(), card.getSuit()
('2', '♠')
>>> card = deck.dealCard()
>>> card.getRank(), card.getSuit()
('Q', '♣')
>>> card = deck.dealCard()
>>> card.getRank(), card.getSuit()
('4', '♢')
>>>
```

Container class: class Deck

```
class Deck:
    'represents a deck of 52 cards'

    # ranks and suits are Deck class variables
    ranks = {'2','3','4','5','6','7','8','9','10','J','Q','K','A'}

    # suits is a set of 4 Unicode symbols representing the 4 suits
    suits = {'\u2660', '\u2661', '\u2662', '\u2663'}

    def __init__(self):
        'initialize deck of 52 cards'
        self.deck = []          # deck is initially empty

        for suit in Deck.suits: # suits and ranks are Deck
            for rank in Deck.ranks: # class variables
                # add Card with given rank and suit to deck
                self.deck.append(Card(rank,suit))


    def dealCard(self):
        'deal (pop and return) card from the top of the deck'
        return self.deck.pop()

    def shuffle(self):
        'shuffle the deck'
        shuffle(self.deck)
```

Container class: class Queue

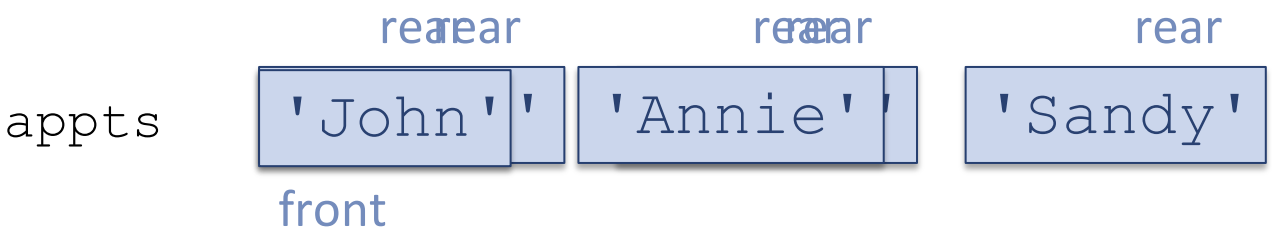
Goal: develop a class `Queue` , an ordered collection of objects that restricts insertions to the rear of the queue and removal from the front of the queue

The class `Queue` should support methods:

- `Queue()` : Constructor that initializes the queue to an empty queue
- `enqueue()` : Add item to the end of the queue
- `dequeue()` : Remove and return the element at the front of the queue
- `isEmpty()` : Returns True if the queue is empty, False otherwise

```
>>> appts = Queue()
>>> appts.enqueue('John')
>>> appts.enqueue('Annie')
>>> appts.enqueue('Sandy')
>>> appts.dequeue()
'John'
>>> appts.dequeue()
'Annie'
>>> appts.dequeue()
'Sandy'
>>> appts.isEmpty()
True
```

Container class: class Queue




```
>>> appts = Queue()
>>> appts.enqueue('John')
>>> appts.enqueue('Annie')
>>> appts.enqueue('Sandy')
>>> appts.dequeue()
'John'
>>> appts.dequeue()
'Annie'
>>> appts.dequeue()
'Sandy'
>>> appts.isEmpty()
True
```

Container class: class Queue

```
class Queue:
    'a classic queue class'

    def __init__(self):
        'instantiates an empty list'
        self.q = []

    def isEmpty(self):
        'returns True if queue is empty, False otherwise'
        return (len(self.q) == 0)

    def enqueue (self, item):
        'insert item at rear of queue'
        return self.q.append(item)

    def dequeue(self):
        'remove and return item at front of queue'
        return self.q.pop(0)
```

Our classes are not user-friendly

```
>>> a = Point(3, 4)
>>> a
<__main__.Point object at 0x10278a690>
```

```
>>> a = Point(3, 4)
>>> a
Point(3, 4)
```

```
>>> a = Point(3,4)
>>> b = Point(1,2)
>>> a+b
Traceback (most recent call last):
  File "<pyshell#44>", line 1, in <module>
    a+b
TypeError: unsupported operand type(s) for
+: 'Point' and 'Point'
```

```
>>> a = Point(3,4)
>>> b = Point(1,2)
>>> a+b
Point(4, 6)
```

What would we prefer?

(x and y coordinates are added, respectively)

```
>>> appts = Queue()
>>> len(appts)
Traceback (most recent call last):
  File "<pyshell#40>", line 1, in <module>
    len(appts)
TypeError: object of type 'Queue' has no len()
```

```
>>> appts = Queue()
>>> len(appts)
0
```

```
>>> deck = Deck()
>>> deck.shuffle()
>>> deck.dealCard()
<__main__.Card object at 0x10278ab90>
```

```
>>> deck = Deck()
>>> deck.shuffle()
>>> deck.dealCard()
Card('2', '♠')
```

Python operators

```
>>> 'he' + 'llo'
'hello'
>>> [1,2] + [3,4]
[1, 2, 3, 4]
>>> 2+4
6
```

```
>>> 'he'.__add__('llo')
'hello'
>>> [1,2].__add__([3,4])
[1, 2, 3, 4]
>>> int(2).__add__(4)
6
```

Operator + is defined for multiple classes; it is an overloaded operator.

- For each class, the definition—and thus the meaning—of the operator is different.
  - integer addition for class `int`
  - list concatenation for class `list`
  - string concatenation for class `str`
- How is the behavior of operator + defined for a particular class?

Class method `__add__()` implements the behavior of operator + for the class

When Python evaluates

`object1 + object 2`

… it first translates it to method invocation …

`object1.__add__(object2)`

… and then evaluates the method invocation

Python operators

In Python, all expressions involving operators are translated into method calls

```
>> '!'.__mul__(10)
'!!!!!!!!!!'
>>> [1,2,3].__eq__([2,3,4])
False
>>> int(2).__lt__(5)
True
>>> 'a'.__le__('a')
True
>>> [1,1,2,3,5,8].__len__()
6
```

```
>>> [1,2,3].__repr__()
'[1, 2, 3]'
>>> int(193).__repr__()
'193'
>>> set().__repr__()
'set()'
```

Operator	Method
x + y	x.__add__(y)
x - y	x.__sub__(y)
x * y	x.__mul__(y)
x / y	x.__truediv__(y)
x // y	x.__floordiv__(y)
x % y	x.__mod__(y)
x == y	x.__eq__(y)
x != y	x.__ne__(y)
x > y	x.__gt__(y)
x >= y	x.__ge__(y)
x < y	x.__lt__(y)
x <= y	x.__le__(y)
repr(x)	x.__repr__()
str(x)	x.__str__()
len(x)	x.__len__()
<type>(x)	<type>.__init__(x)

Overloading `repr()`

In Python, operators are translated into method calls

To add an overloaded operator to a user-defined class, the corresponding method must be implemented

To get this behavior

```
>>> a = Point(3, 4)
>>> a
Point(3, 4)
```

```
>>> a = Point(3, 4)
>>> a.__repr__()
Point(3, 4)
```

method `__repr__()` must be implemented and added to class `Point`

`__repr__()` should return the (canonical) string representation of the point

```
class Point:

    # other Point methods here

    def __repr__(self):
        'canonical string representation Point(x, y)'
        return 'Point({}, {})'.format(self.x, self.y)
```

Overloading operator +

To get this behavior

```
>>> a = Point(3,4)
>>> b = Point(1,2)
>>> a+b
Point(4, 6)
```

```
>>> a = Point(3,4)
>>> b = Point(1,2)
>>> a.__add__(b)
Point(4, 6)
```

method `__add__()` must be implemented and added to class `Point`

`__add__()` should return a new `Point` object whose coordinates are the sum of the coordinates of `a` and `b`

Also, method `__repr__()` should be implemented to achieve the desired display of the result in the shell

```
class Point:

    # other Point methods here

    def __add__(self, point):
        return Point(self.x+point.x, self.y+point.y)

    def __repr__(self):
        'canonical string representation Point(x, y)'
        return 'Point({}, {})'.format(self.x, self.y)
```

Overloading operator `len()`

To get this behavior

```
>>> appts = Queue()
>>> len(appts)
0
```

```
>>> appts = Queue()
>>> appts.__len__()
0
```

method `__len__()` must be implemented and added to class `Queue`

`__len__()` should return the number of objects in the queue

- i.e., the size of list `self.q`

We use the fact that `len()` is implemented for class `list`

```
class Queue:
    def __init__(self):
        self.q = []

    def isEmpty(self):
        return (len(self.q) == 0)

    def enqueue (self, item):
        return self.q.append(item)

    def dequeue(self):
        return self.q.pop(0)

    def __len__(self):
        return len(self.q)
```

Exercise

Modify `Deck` and/or `Card` to get this behavior

```
>>> deck = Deck()
>>> deck.shuffle()
>>> deck.dealCard()
Card('2', '♠')
```

```
class Card:
    'represents a playing card'

    def __init__(self, rank, suit):
        'initialize rank and suit of card'
        self.rank = rank
        self.suit = suit

    def getRank(self):
        'return rank'
        return self.rank

    def getSuit(self):
        'return suit'
        return self.suit

 def __repr__(self):
        'return formal representation'
        return "Card('{}', '{}')".format(self.rank, self.suit)
```

```
'10','J','Q','K','A'}
u2663'}

tially empty
anks are Deck
ariables
it))
```

str() vs repr()

Built-in function `repr()` returns the canonical string representation of an object

- This is the representation printed by the shell when evaluating the object

Built-in function `str()` returns the "pretty" string representation of an object

- This is the representation printed by the `print()` statement and is meant to be readable by humans

```
>>> str([1,2,3])
'[1, 2, 3]'
>>> str(193)
'193'
>>> str(set())
'set()'
```

Operator	Method
x + y	x.__add__(y)
x - y	x.__sub__(y)
x * y	x.__mul__(y)
x / y	x.__truediv__(y)
x // y	x.__floordiv__(y)
x % y	x.__mod__(y)
x == y	x.__eq__(y)
x != y	x.__ne__(y)
x > y	x.__gt__(y)
x >= y	x.__ge__(y)
x < y	x.__lt__(y)
x <= y	x.__le__(y)
repr(x)	x.__repr__()
str(x)	x.__str__()
len(x)	x.__len__()
<type>(x)	<type>.__init__(x)

str() vs repr()

Built-in function `repr()` returns the canonical string representation of an object

- This is the representation printed by the shell when evaluating the object

```
>>> r = Representation()
>>> r
canonical string representation
>>> print(r)
Pretty string representation.
>>>
```

Built-in function `str()` returns the "pretty" string representation of an object

- This is the representation printed by the `print()` statement and is meant to be readable by humans

```
class Representation(object):
    def __repr__(self):
        return 'canonical string representation'
    def __str__(self):
        return 'Pretty string representation.'
```

Canonical string representation

Built-in function `repr()` returns the canonical string representation of an object

- This is the representation printed by the shell when evaluating the object
- Ideally, this is also the string used to construct the object
  - e.g., `'[1, 2, 3]'`, `'Point(3, 5)'`
- In other words, the expression
  `eval(repr(o))`
  should give back an object equal to the original object `o`

```
>>> repr([1,2,3])
'[1, 2, 3]'
>>> [1,2,3]
[1, 2, 3]
>>> eval(repr([1,2,3]))
[1, 2, 3]
>>> [1,2,3] == eval(repr([1,2,3]))
True
```

Problem: operator ==

```
>>> repr(Point(3,5))
'Point(3, 5)'
>>> eval(repr(Point(3,5)))
Point(3, 5)
>>> Point(3,5) == eval(repr(Point(3,5)))
False
```

Contract between the constructor and operator `repr()`

Overloading operator ==

For user-defined classes, the default behavior for operator == is to return `True` only when the two objects are the same object.

```
>>> a = Point(3,5)
>>> b = Point(3,5)
>>> a == b
False
>>> a == a
True
```

Usually, that is not the desired behavior

- It also gets in the way of satisfying the contract between constructor and `repr()`

For class `Point`, operator == should return `True` if the two points have the same coordinates

contract between constructor and `repr()` is now satisfied

```
class Point:

    # other Point methods here

    def __eq__(self, other):
        'self == other if they have the same coordinates'
        return self.x == other.x and self.y == other.y
    def __repr__(self):
        'return canonical string representation Point(x, y)'
        return 'Point({}, {})'.format(self.x, self.y)`
```

Exercise

We have already modified class `Card` to support function `repr()`. Now
equal.

```
class Card:
    'represents a playing card'

    def __init__(self, rank, suit):
        'initialize rank and suit of card'
        self.rank = rank
        self.suit = suit

    def getRank(self):
        'return rank'
        return self.rank

    def getSuit(self):
        'return suit'
        return self.suit

    def __repr__(self):
        'return formal representation'
        return "Card('{}', '{}')".format(self.rank, self.suit)

    def __eq__(self, other):
        'self == other if rank and suit are the same'
        return self.rank == other.rank and self.suit == other.suit
```

```
card1 =
('4', '\u2662')
card2 =
('4', '\u2662')
card1 == card2
```

Inheritance

Code reuse is a key software engineering goal

- One benefit of functions is they make it easier to reuse code
- Similarly, organizing code into user-defined classes makes it easier to later reuse the code
  - E.g., classes `Card` and `Deck` can be reused in different card game apps

A class can also be reused by extending it through inheritance

Example: Suppose that we find it convenient to have a class that behaves just like the built-in class `list` but also supports a method called `choice()` that returns an item from the list, chosen uniformly at random.

```
>>> mylst = MyList()
>>> mylst.append(2)
>>> mylst.append(3)
>>> mylst.append(5)
>>> mylst.append(7)
>>> len(mylst)
4
>>> mylst.index(5)
2
>>> mylst.choice()
7
>>> mylst.choice()
3
>>>
```

Implementing class `MyList`

Approach 1: Develop class `MyList` from scratch

- Just like classes `Deck` and `Queue` Huge amount of work!

Approach 2: Develop class `MyList` by inheritance from class `list`

```
import random
class MyList(list):
    'a subclass of list that implements method choice'

    def choice(self):
        'return item from list chosen uniformly at random'
        return random.choice(self)
```

```
ial = []):
        self.lst = initial

    def __len__(self):
        return len(self.lst)

    def append(self, item):
        self.lst.append(self, item)

    # implementations of remaining "list" methods

    def choice(self):
        return random.choice(self.lst)
```

Implementing class `MyList`

Approach 1: Develop class `MyList` from scratch

- Just like classes `Deck` and `Queue` Huge amount of work!

Approach 2: Develop class `MyList` by inheritance from class `list`

Class `MyList` inherits all the attributes of class `list`

Example: Suppose that we find it convenient to have a class that behaves just like the built-in class `list` but also supports a method called `choice()` that returns an item from the list, chosen uniformly at random.

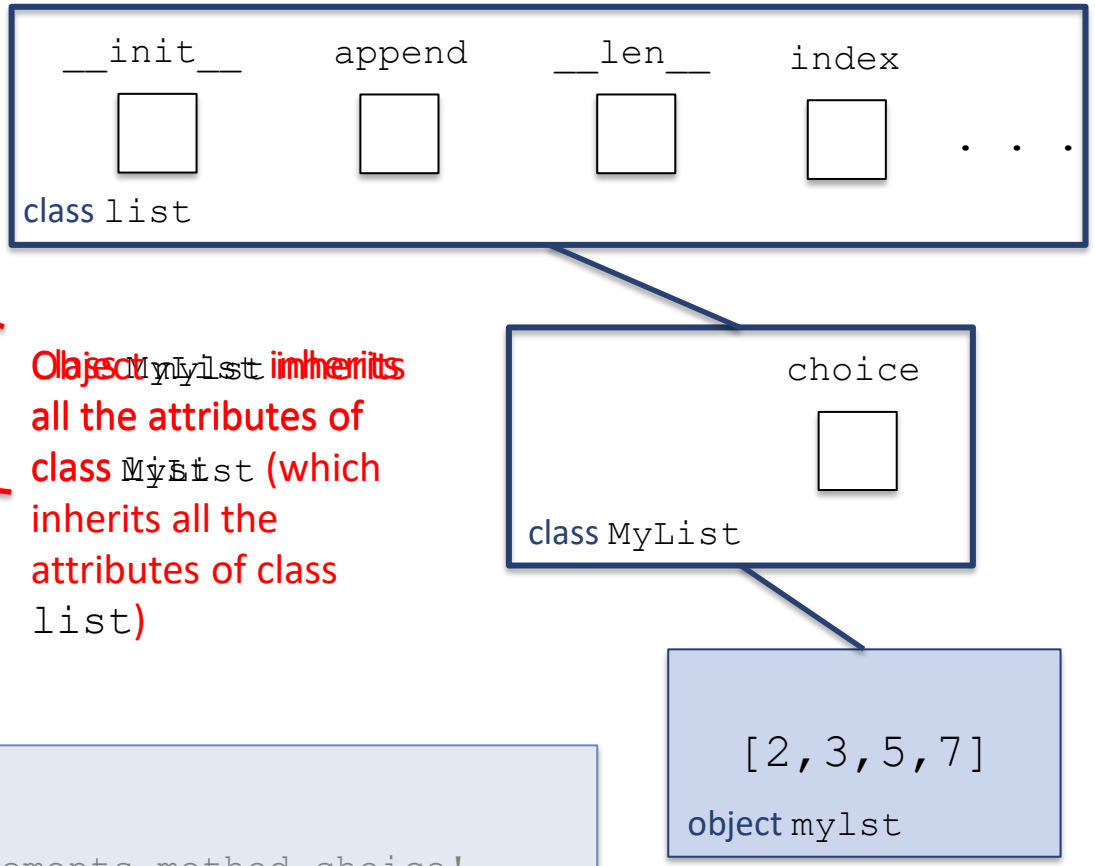
```
>>> mylst = MyList()
>>> mylst.append(2)
>>> mylst.append(3)
>>> mylst.append(5)
>>> mylst.append(7)
>>> len(mylst)
4
>>> mylst.index(5)
2
>>> mylst.choice()
7
>>> mylst.choice()
3
>>> mylst.choice()
3
>>> mylst.choice()
5
>>> mylst.choice()
3
```

A `MyList` object should behave just like a list

A `MyList` object should also support method `choice()`

Class `MyList` by inheritance

```
>>> dir(MyList)
['__add__', '__class__',
. . .
'choice', 'count', 'extend',
'index', 'insert', 'pop',
'remove', 'reverse', 'sort']
>>> dir(mylst)
['__add__', '__class__',
. . .
 'choice', 'count', 'extend',
'index', 'insert', 'pop',
'remove', 'reverse', 'sort']
>>>
```



Object `mylst` inherits all the attributes of class `MyList` (which inherits all the attributes of class `list`)

```
import random
class MyList(list):
    'a subclass of list that implements method choice'

    def choice(self):
        'return item from list chosen uniformly at random'
        return random.choice(self)
```

Class definition, in general

A class can be defined "from scratch" using: `class <Class Name>:`

A class can also be derived from another class, through inheritance

```
class <Class Name>(<Super Class>):
```

`class <Class Name>:` is a shorthand for `class <Class Name>(object):`

`object` is a built-in class with no attributes; it is the class that all classes inherit from, directly or indirectly

```
>>> help(object)
Help on class object in module builtins:

class object
 |  The most base type
```

A class can also inherit attributes from more than one superclass

```
class <Class Name>(<Super Class 1>, <Super Class 2>, …):
```

Overriding superclass methods

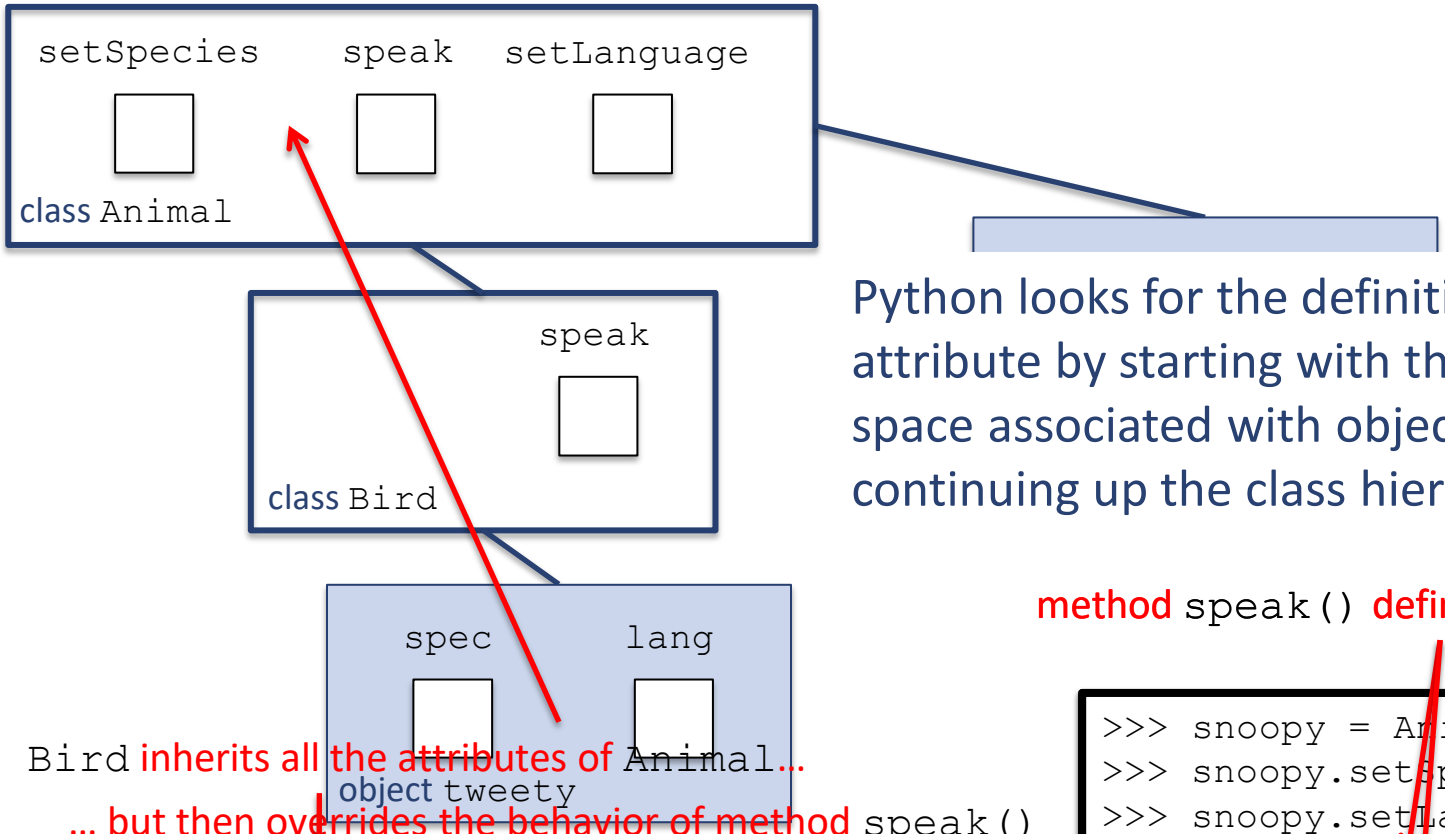
Sometimes we need to develop a new class that can almost inherit attributes from an existing class… but not quite.

For example, a class `Bird` that supports the same methods class `Animal` supports (`setSpecies()`, `setLanguage()`, and `speak()`) but with a different behavior for method `speak()`

```
class Animal:
    'represents an animal'

    def setSpecies(self, species):
        'sets the animal species'
        self.spec = species

    def setLanguage(self, language):
        'sets the animal language'
        self.lang = language

    def speak(self):
        'prints a sentence by the animal'
        print('I am a {} and I {}.'.format(self.spec, self.lang))
```

```
>>> snoopy = Animal()
>>> snoopy.setSpecies('dog')
>>> snoopy.setLanguage('bark')
>>> snoopy.speak()
I am a dog and I bark.
>>> tweety = Bird()
>>> tweety.setSpecies('canary')
>>> tweety.setLanguage('tweet')
>>> tweety.speak()
tweet! tweet! tweet!
```

Overriding superclass methods



Python looks for the definition of an attribute by starting with the name-space associated with object and continuing up the class hierarchy.

`Bird` inherits all the attributes of `Animal`...

... but then overrides the behavior of method `speak()`

```
class Bird(Animal):
    'represents a bird'

    def speak(self):
        'prints bird sounds'
        print('{}! '.format(self.lang) * 3)
```

method `speak()` defined in `Animal` is used

```
>>> snoopy = Animal()
>>> snoopy.setSpecies('dog')
>>> snoopy.setLanguage('bark')
>>> snoopy.speak()
I am a dog and I bark.
>>> tweety = Bird()
>>> tweety.setSpecies('canary')
>>> tweety.setLanguage('tweet')
>>> tweety.speak()
tweet! tweet! tweet!
```

Extending superclass methods

A superclass method can be inherited as-is, overridden, or extended.

```
class Super:
    'a generic class with one method'
    def method(self):                       # the Super method
        print('in Super.method')

class Inheritor(Super):
    'class that inherits method'
    pass

class Replacer(Super):
    'class that overrides method'
    def method(self):
        print('in Replacer.method')

class Extender(Super):
    'class that extends method'
    def method(self):
        print('starting Extender.method')
        Super.method(self)                  # calling Super method
        print('ending Extender.method')
```

Object-Oriented Programming (OOP)

Code reuse is a key benefit of organizing code into new classes; it is made possible through abstraction and encapsulation.

Abstraction: The idea that a class object can be manipulated by users through method invocations alone and without knowledge of the implementation of these methods.

- Abstraction facilitates software development because the programmer works with objects abstractly (i.e., through "abstract", meaningful method names rather than "concrete", technical code).

Encapsulation: In order for abstraction to be beneficial, the "concrete" code and data associated with objects must be encapsulated (i.e., made "invisible" to the program using the object).

- Encapsulation is achieved thanks to the fact that (1) every class defines a namespace in which class attributes live, and (2) every object has a namespace, that inherits the class attributes, in which instance attributes live.

OOP is an approach to programming that achieves modular code through the use of objects and by structuring code into user-defined classes.

An encapsulation issue

The current implementation of class Queue does not completely encapsulate its implementation

```
>>> queue = Queue()
>>> queue.dequeue()
Traceback (most recent call last):
  File "<pyshell#76>", line 1, in <module>
    queue.dequeue()
  File "/Users/me/ch8.py", line 120, in dequeue
    raise EmptyQueueError('dequeue from empty queue')
EmptyQueueError: dequeue from empty queue
```

We need to be able to define user-defined exceptions

But first, we need to learn how to "force" an exception to be raised

What is the problem?

The user of class `Queue` should not have to know the implementation detail that a list stores the items in a `Queue` object

What should be output instead?

Raising an exception

By typing Ctrl-C, a user can force a `KeyboardInterrupt` exception to be raised

Any exception can be raised within a program with the `raise` statement

- `ValueError`, like all exception types, is a class
- `ValueError()` uses the default constructor to create an exception (object)
- statement `raise` switches control flow from normal to exceptional
- The constructor can take a "message" argument to be stored in the exception object

```
>>> while True:
        pass

Traceback (most recent call last):
  File "<pyshell#53>", line 2, in <module>
    pass
KeyboardInterrupt
>>> raise ValueError()
Traceback (most recent call last):
  File "<pyshell#54>", line 1, in <module>
    raise ValueError()
ValueError
>>> raise ValueError('Just joking...')
Traceback (most recent call last):
  File "<pyshell#55>", line 1, in <module>
    raise ValueError('Just joking...')
ValueError: Just joking...
>>> try:
        raise ValueError()
except:
        print('Caught exception.')


Caught exception.
>>>
```

User-defined exceptions

Every built-in exception type is a subclass of class `Exception`.

A new exception class should be a subclass, either directly or indirectly, of `Exception`.

```
>>> help(Exception)
Help on class Exception in module builtins:

class Exception(BaseException)
 |  Common base class for all non-exit exceptions.
 |
 |  Method resolution order:
 |      Exception
 |      BaseException
 |      object
. . .
```

Class Queue, revisited

Our goal was to encapsulate class Queue better:

```
>>> queue = Queue()
>>> queue.dequeue()
Traceback (most recent call last):
  File "<pyshell#76>", line 1, in <module>
    queue.dequeue()
  File "/Users/me/ch8.py", line 120, in dequeue
    raise EmptyQueueError('dequeue from empty queue')
EmptyQueueError: dequeue from empty queue
```

To achieve this behavior, we:

1. Need to create exception class `EmptyQueueError`
2. Modify `Queue` method `dequeue` so an `EmptyQueueError` exception is raised if an attempt to `dequeue` an empty queue is made

Class Queue, revisited

```
class EmptyQueueError(Exception):
    pass

class Queue:
    'a classic queue class'

    def __init__(self):
        'instantiates an empty list'
        self.q = []

    def isEmpty(self):
        'returns True if queue is empty, False otherwise'
        return (len(self.q) == 0)

    def enqueue (self, item):
        'insert item at rear of queue'
        return self.q.append(item)

    def dequeue(self):
        'remove and return item at front of queue'
        if self.isEmpty():
            raise EmptyQueueError('dequeue from empty queue')
        return self.q.pop(0)
```