19. Introduction to Classes

Topics:

- Class Definitions and Objects
- Accessing Attributes
- Copying Objects
- Functions and classes
- Lists of Objects

Motivation

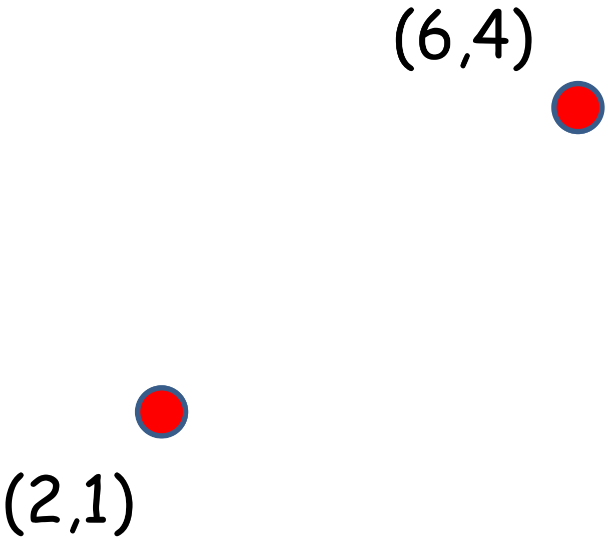
What a Simple Class Definition Looks Like

```
class Point:
    """
    Attributes:
        x: float, the x-coordinate of a point
        y: float, the y-coordinate of a point
    """
    def __init__(self,x,y):
        self.x = x
        self.y = y
```

A class can be used to ``package" related data

One Reason for classes:
They Elevate the Level Thinking

```
>>> P = Point(2,1)
>>> Q = Point(6,4)
>>> d = dist(P,Q)
>>> print d
5
```



Here, dist is a function that takes two Points and computes the distance between them.

One Reason for classes:
They Elevate the Level Thinking

```
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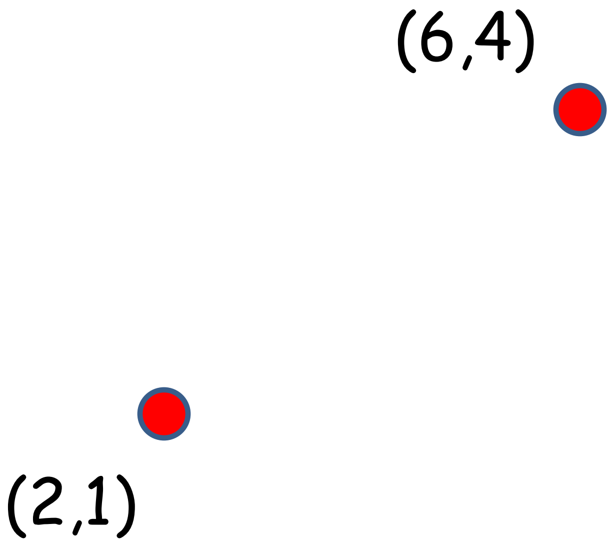

By having a Point class we can think at the “point level” instead of at the “xy level”

Classes and Types

Recall that a type is a set of values and operations that can be performed on those values.

The four basic "built-in" types:

```
int, float, str, bool
```

Classes are a way to define new types

Examples

By suitably defining a rectangle class, we could say something like

```
if R1.intersect(R2):
   print ‘Rectangles R1 and R2 intersect’
```

Examples

By suitably defining a polynomial class, we could perform operations like

```
p = q + r
```

where q and r are polynomials that are added together to produce a polynomial p

How to Define a Class

A Point Class

```
class Point:
    """
    Attributes:
        x: float, the x-coordinate of a point
        y: float, the y-coordinate of a point
    """
    def __init__(self,x,y):
        self.x = x
        self.y = y
```

A “blue print” for packaging data.
The data will be stored in the attributes.

A Point Class

```
class Point:
    """
    Attributes:
        x: float, the x-coordinate of a point
        y: float, the y-coordinate of a point
    """
    def __init__(self,x,y):
        self.x = x
        self.y = y
```

This special function, called a constructor, does the packaging.

A Point Class

```
class Point:
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    Attributes:
        x: float, the x-coordinate of a point
        y: float, the y-coordinate of a point
    """
    def __init__(self,x,y):
        self.x = x
        self.y = y
```

The name of this class is “Point“

The "__init__" Function

```
def __init__(self,x,y):
    """ Creates a Point object

    PreC: x and y are floats
    """
    self.x = x
    self.y = y
```

That's a double underscore: __init__

The "__init__" Function

```
def __init__(self,x,y):
    """ Creates a Point object

    PreC: x and y are floats
    """
    self.x = x
    self.y = y
```

"self" is always the first argument for any function defined in a class.

The " __init__ " Function

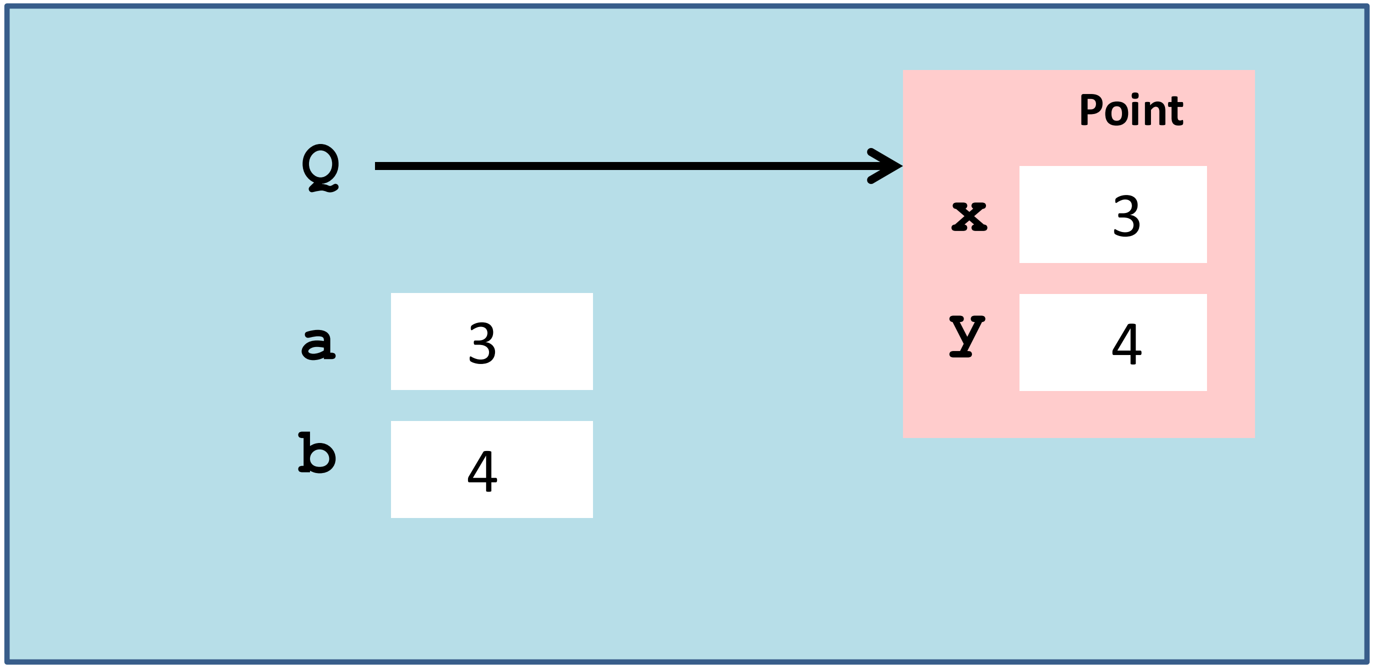
```
def __init__(self,x,y):
    """ Creates a Point object

    PreC: x and y are floats
    """
    self.x = x
    self.y = y
```

The attributes are assigned values.

Call the Constructor to Create an Object

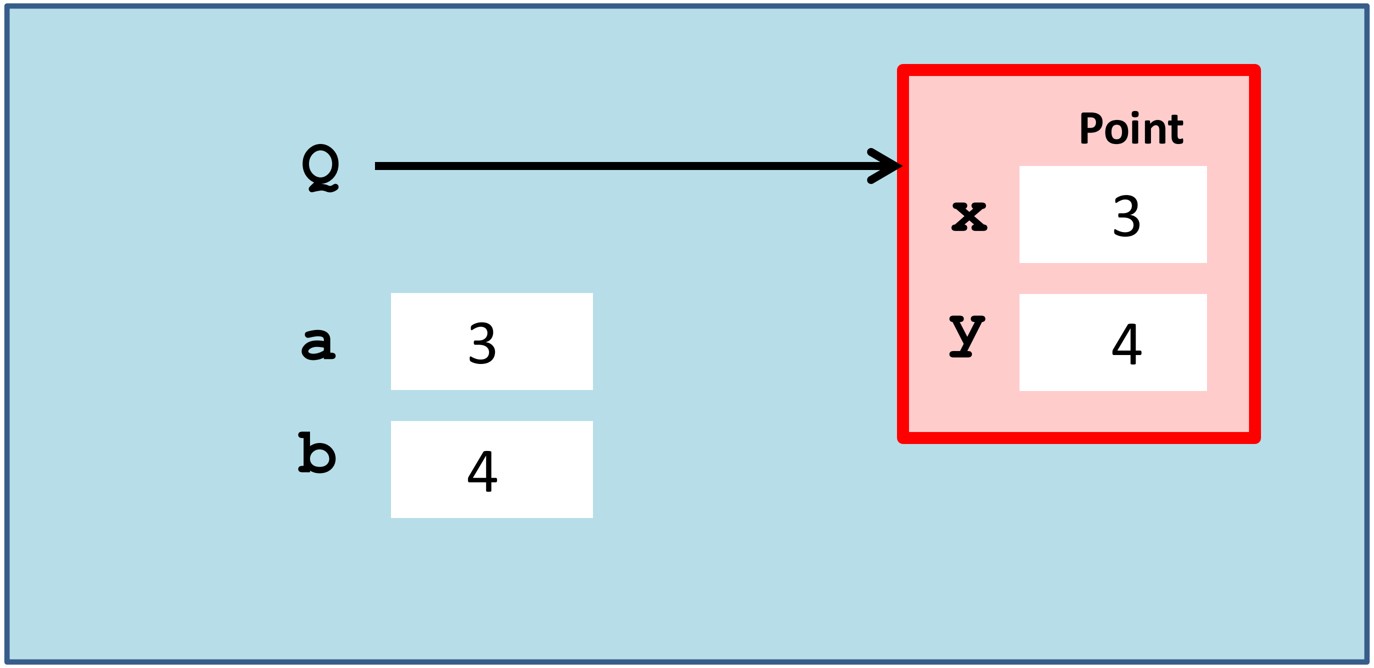
Calling the Constructor



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

The constructor's name is the name of the class

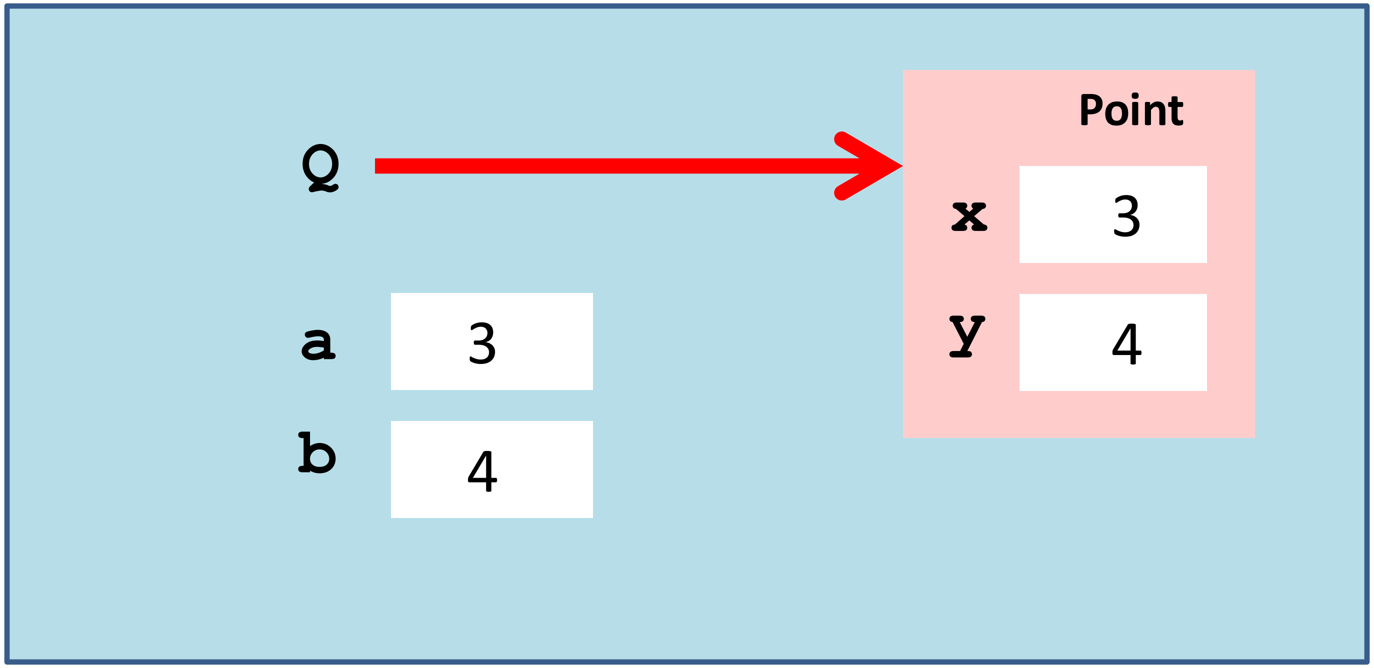
Calling the Constructor



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

This creates a Point object

Calling the Constructor



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

The constructor returns a reference

Objects: The Folder Metaphor

Manila folders organize data.

Objects organize data.

A point object houses float variables x and y, called the attributes, where (x,y) is the point.

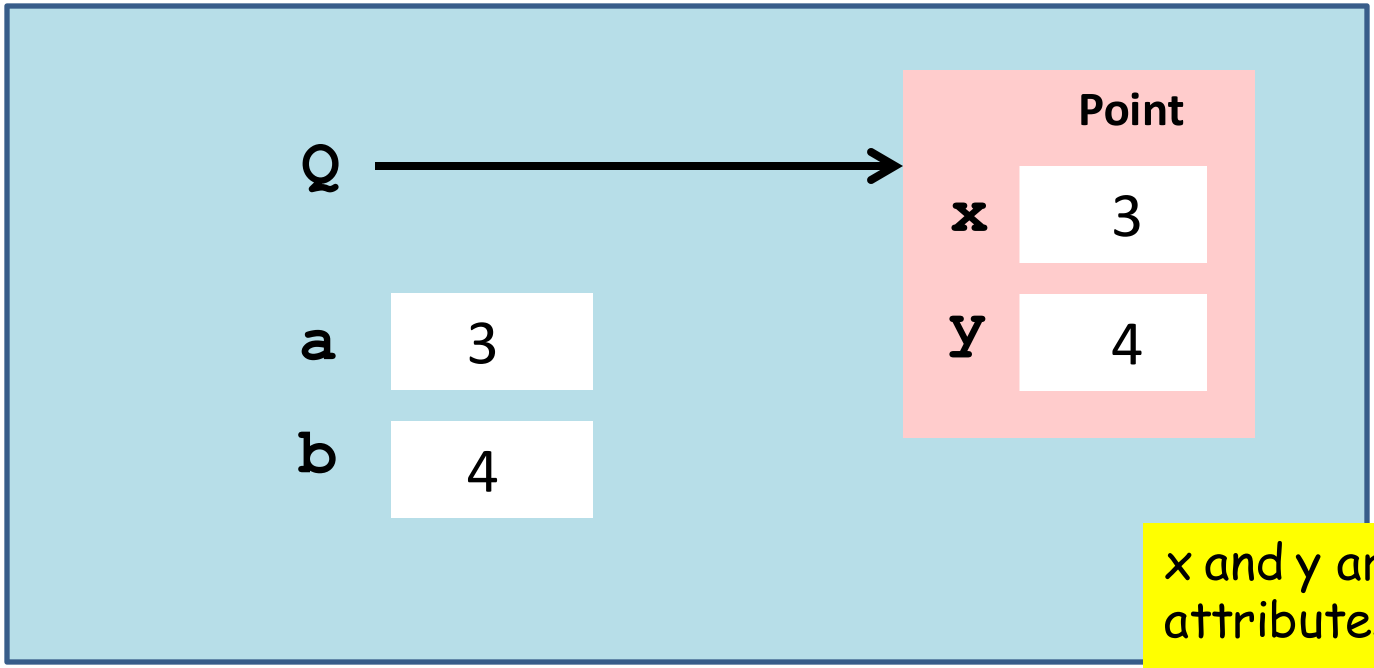
Objects: The Folder Metaphor

Manila folders organize data.

Objects organize data.

A color object might house an rgb triple [1,0,1] and a name 'magenta'

Visualizing a Point Object



x and y are attributes

Attributes are variables that live inside objects

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

Accessing an Attribute

The “Dot Notation” Again

Not a coincidence: modules are objects

Accessing Attributes

```
>>> Q = Point(3,4)
>>> print Q
( 3.000, 4.000)
>>> Q.x = Q.x + 5
>>> print Q
( 8.000, 4.000)
```

Q.x is a variable and can “show up” in all the usual places, i.e., in an assignment statement.

Accessing Attributes

```
>>> Q = Point(3,4)
>>> print Q
( 3.000, 4.000)
>>> Q.x = Q.x + 5
>>> print Q
( 8.000, 4.000)
```

Seems that we can print an object!

The “ __str__ “ function

```
def __str__(self):
        return '(%6.3f,%6.3f)' %(self.x,self.y)
```

This function is part of the class definition.

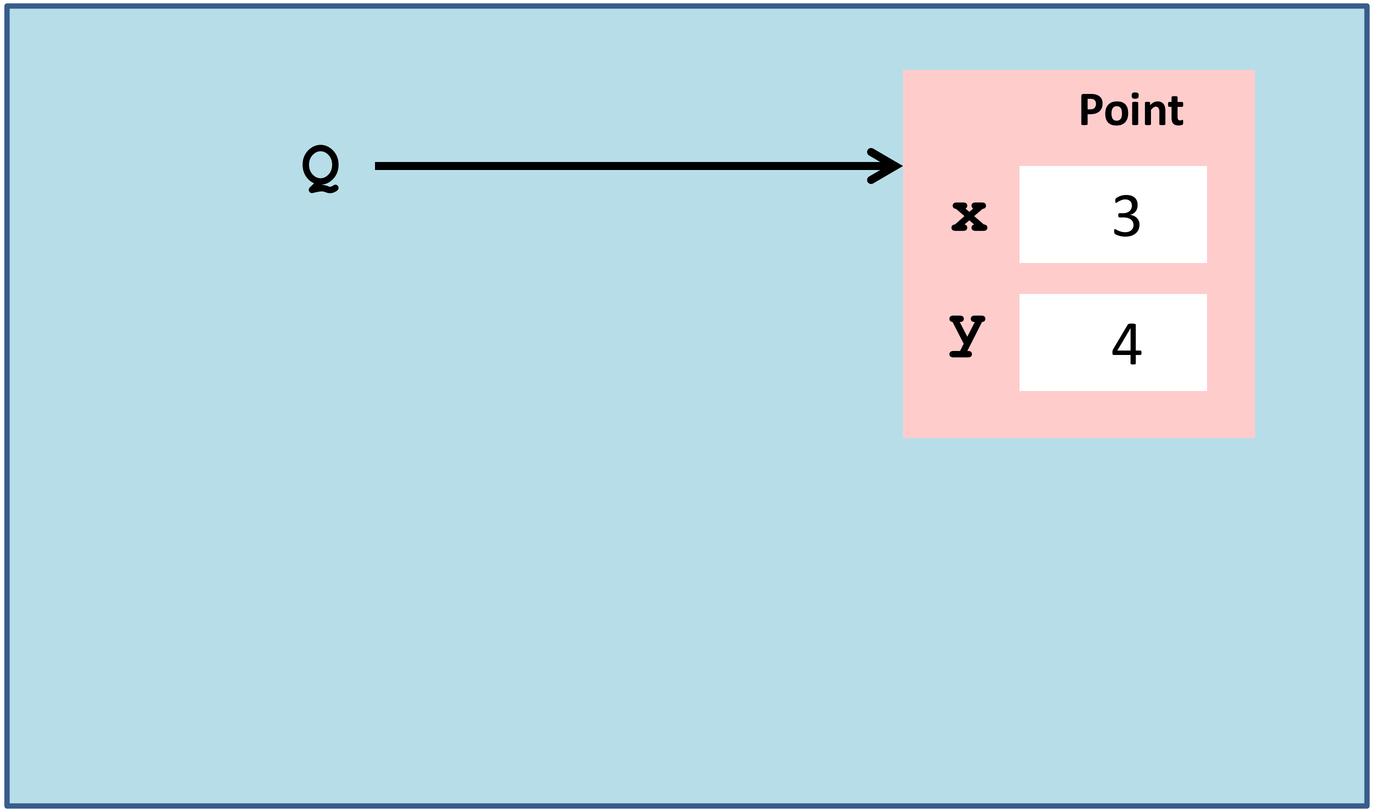
Whenever a statement like

```
print P
```

is encountered, then P is printed according to format rules.

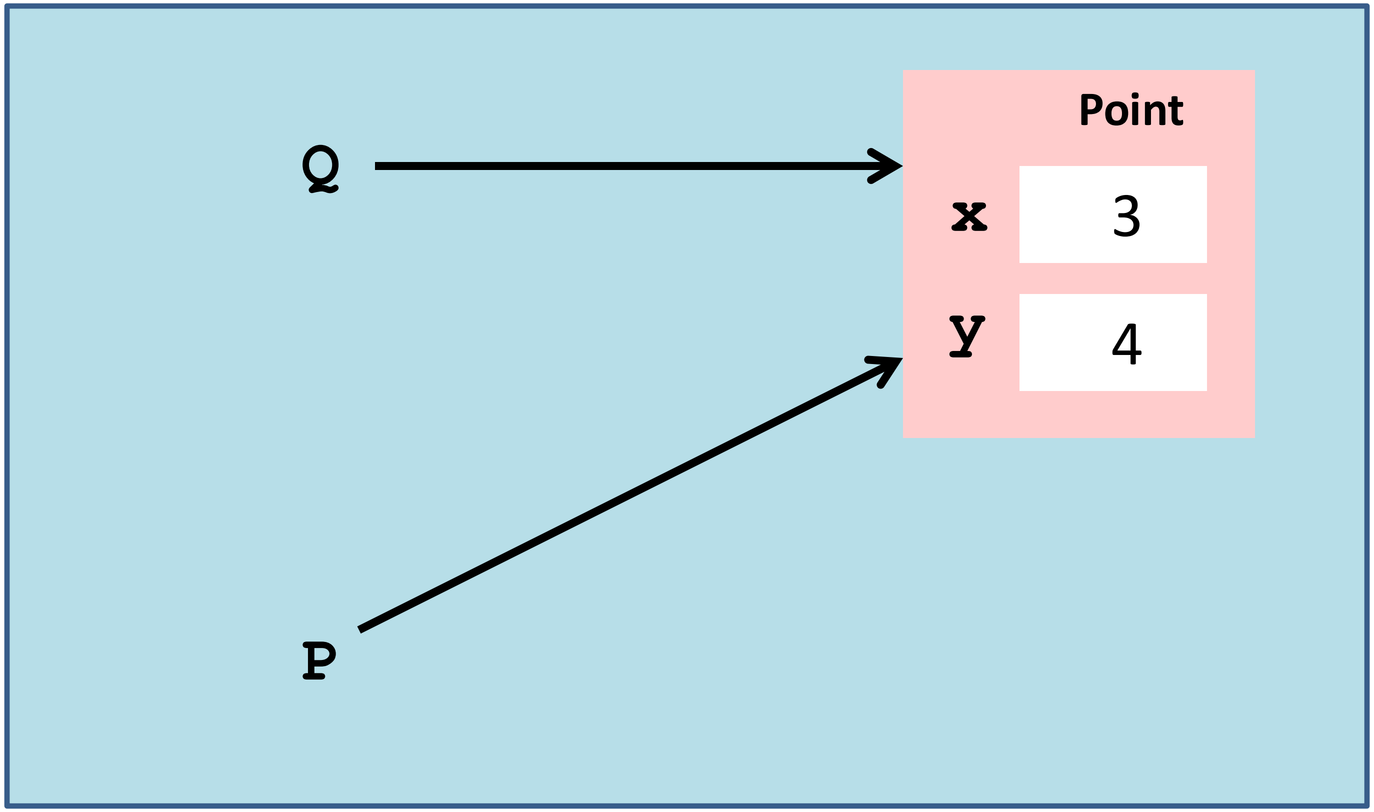
A Note on Copying an Object

Not Making a Copy of a Point



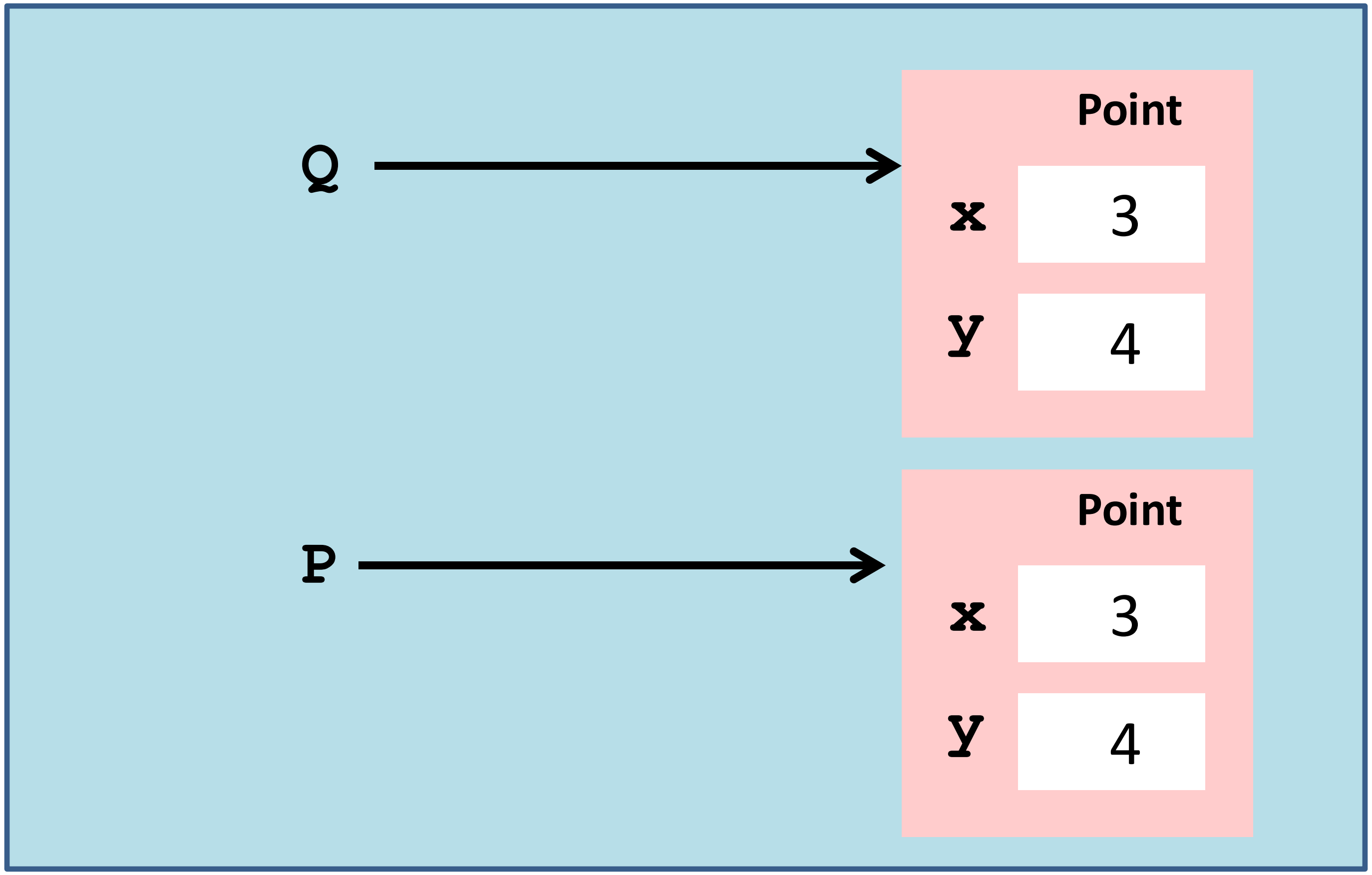
```
>>> Q = Point(3,4)
>>> P = Q
```

Not Making a Copy of a Point



```
>>> Q = Point(3,4)
>>> P = Q
```

Making a Copy of a Point



```
>>> Q = Point(3,4)
>>> P = copy(Q)
```

The Module copy

```
from copy import copy
```

Import this function and use it to make copies of objects

deepcopy is another useful function from this module—more later.

Using copy

```
>>> Q = Point(3,4)
>>> P1 = copy(Q)
>>> P1.x = 5
>>> print Q
( 3.000, 4.000)
>>> print P1
( 5.000, 4.000)
```

We are modifying P1, but Q remains the same

Example:
A Function that Returns a Point Object

Computing a Random Point

```
def RandomPoint(L,R):
    """ Returns a point that is randomly chosen
    from the square L<=x<=R, L<=y<=R.

    PreC: L and R are floats with L<R
    """
    x = randu(L,R)
    y = randu(L,R)
    P = Point(x,y)
    return P
```

calling the constructor

Another Example: Computing the Midpoint

```
def MidPoint(P1,P2):
    """ Returns a point that is the midpoint of
    a line segment that connects P1 and P2.

    PreC: P1 and P2 are points.
    """
    xm = (P1.x + P2.x)/2.0
    ym = (P1.y + P2.y)/2.0
    Q = Point(xm,ym)
    return Q
```

Computing the Midpoint

```
def MidPoint(P1,P2):
    """ Returns a point that is the midpoint of
    a line segment that connects P1 and P2.

    PreC: P1 and P2 are points.
    """
    xm = (P1.x + P2.x)/2.0
    ym = (P1.y + P2.y)/2.0
    Q = Point(xm,ym)
    return Q
```

referencing a point's attributes

calling the constructor

Distance Between Two Points

```
def Dist(P1,P2):
    """ Returns a float that is the distance
    from P1 to P2.

    PreC: P1 and P2 are points
    """
    d = sqrt((P1.x-P2.x)**2+(P1.y-P2.y)**2)
    return d
```

Affirmation of Midpoint

```
>>> P1 = RandomPoint(-10,10)
>>> P2 = RandomPoint(-10,10)
>>> M = MidPoint(P1,P2)
>>> print Dist(M,P1)
4.29339610681
>>> print Dist(M,P2)
4.29339610681
```

A List of Objects

We would like to assemble a list whose elements are not numbers or strings, but references to objects.

For example, we have a hundred points in the plane and a length-100 list of points called `ListOfPoints`.

Let's compute the centroid.

A List of Objects

```
sx = 0
sy = 0
for P in ListOfPoints:
   sx += P.x
   sy += P.y
N = len(ListOfPoints)
TheCentroid = Point(sx/N,sy/N)
```

A lot of familiar stuff. Running sums. A for-loop.
The len function, Etc

A List of Random Points

```
def RandomCloud(L,R,n):
    """ Returns a length-n list of points,
    each chosen randomly from the square
    L<=x<=R, L<=y<=R.

    PreC: L and R are floats with L<R,
    n is a positive int.
    """
    A = []
    for k in range(n):
        P = RandomPoint(L,R)
        A.append(P)
    return A
```

A List of Random Points

```
def RandomCloud(L,R,n):
    """ Returns a length-n list of points,
    each chosen randomly from the square
    L<=x<=R, L<=y<=R.

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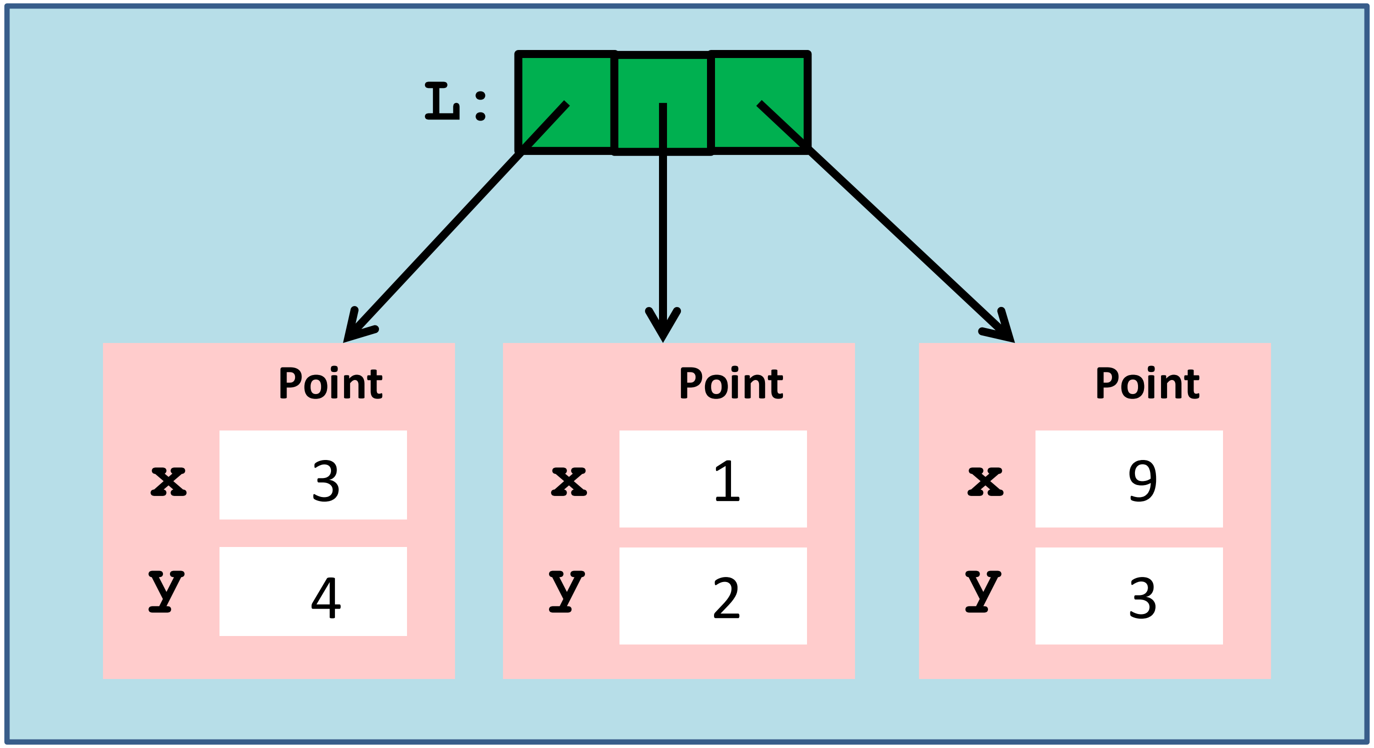
    n is a positive int.
    """
    A = []
    for k in range(n):
        P = RandomPoint(L,R)
        A.append(P)
    return A
```

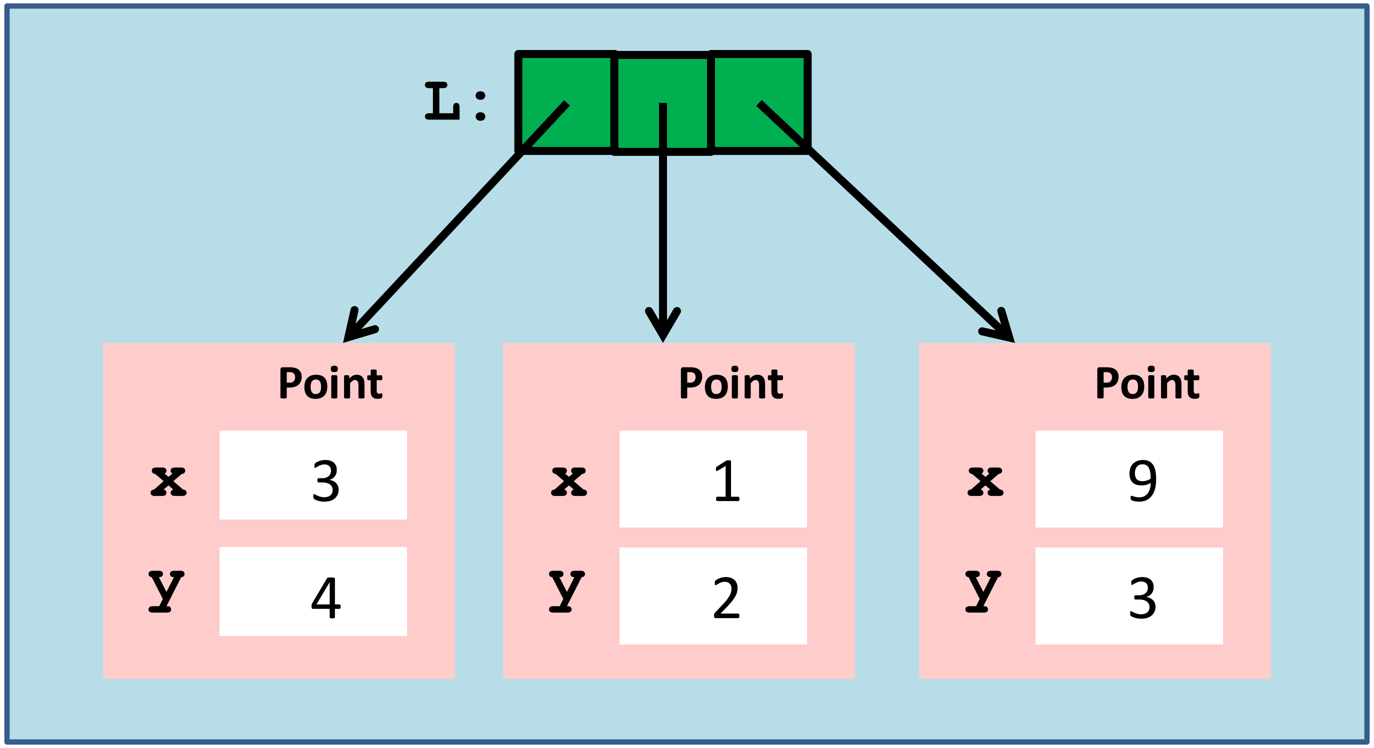
The append method for lists works for lists of objects

Visualizing a List of Points



```
>>> P = Point(3,4);Q = Point(1,2);R = Point(9,3)
>>> L = [P,Q,R]
```

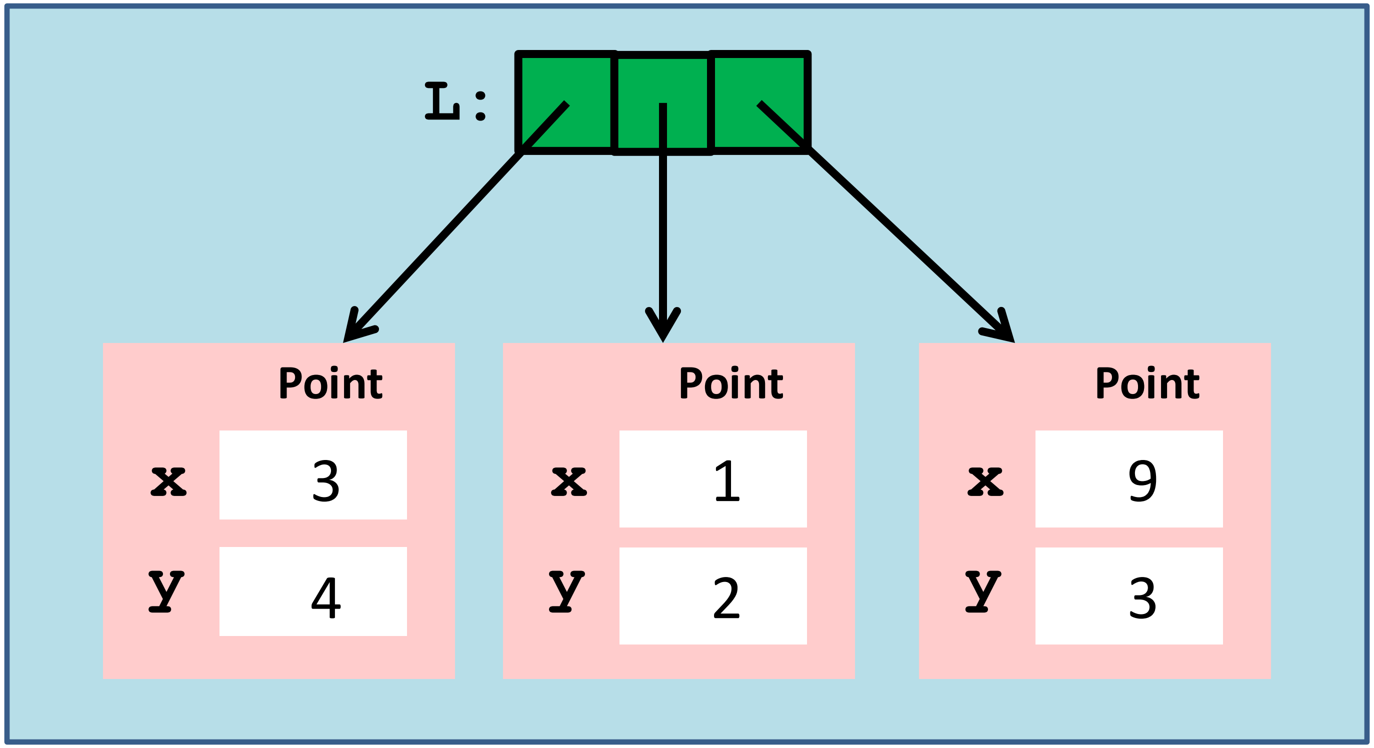
Visualizing a List of Points



```
>>> P = Point(3,4);Q = Point(1,2);R = Point(9,3)
>>> L = [P,Q,R]
```

More accurate: A List of references to Point objects

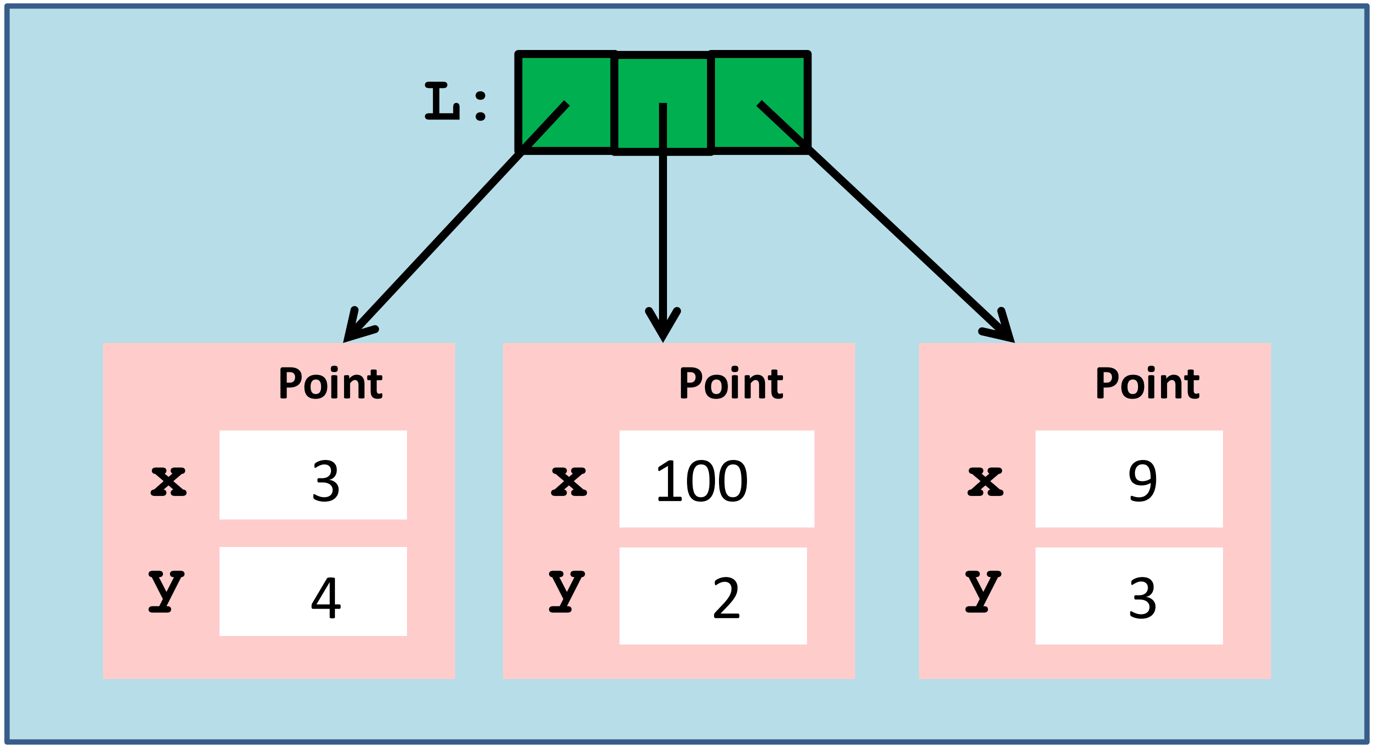
Operations on a List of Points



```
>>> L[1].x = 100
```

Before

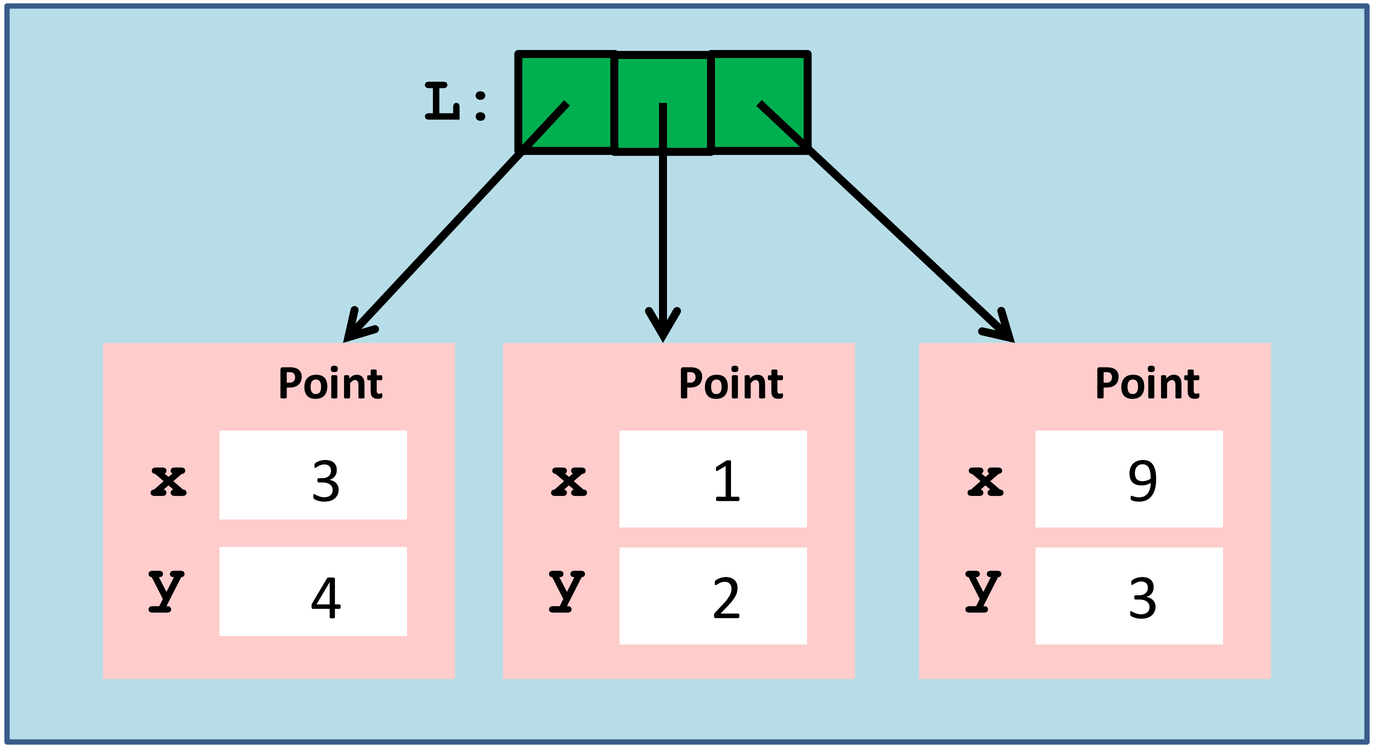
Operations on a List of Points



```
>>> L[1].x = 100
```

After

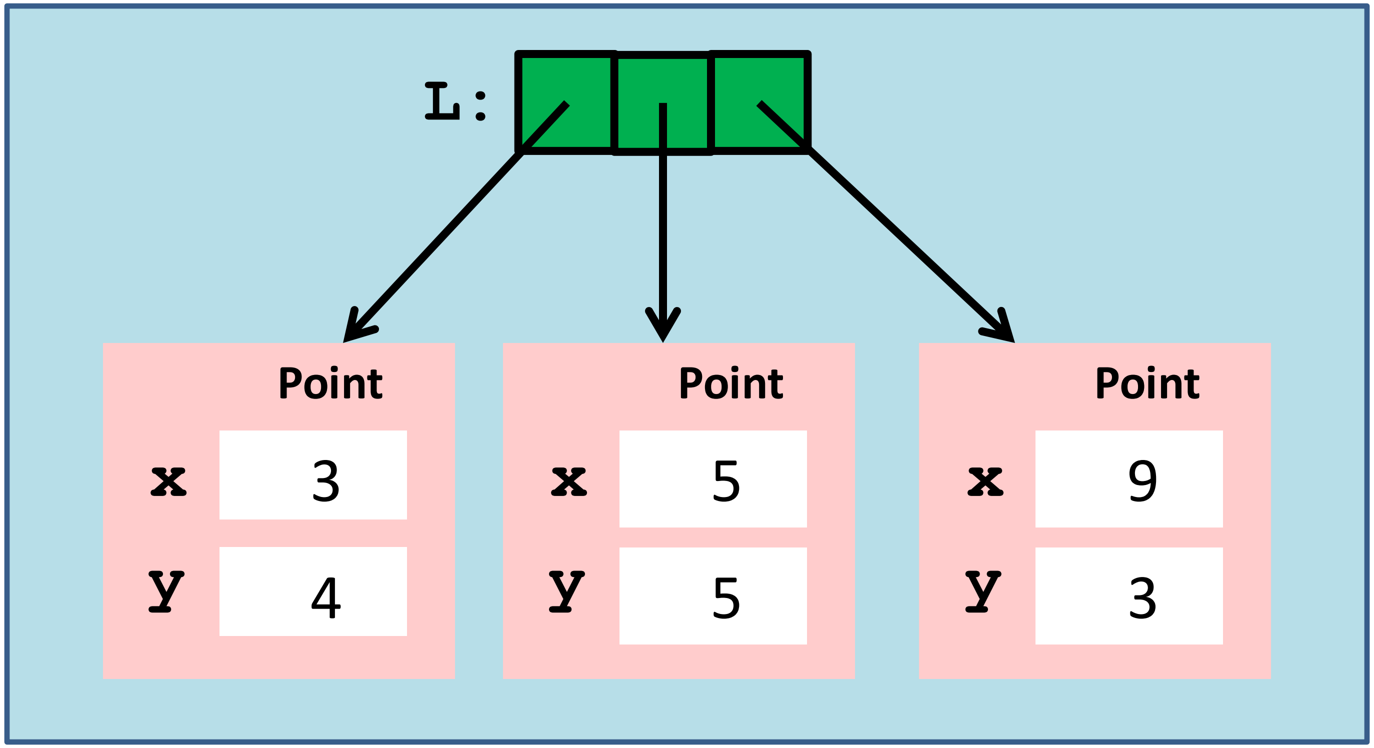
Operations on a List of Points



```
>>> L[1] = Point(5,5)
```

Before

Operations on a List of Points



```
>>> L[1] = Point(5,5)
```

After

Printing a List of Points

```
def printCloud(A):
    """ Prints the points in A

    PreC : A is a list of points.
    """
    for a in A:
        print a
```

Synonym for the loop:

```
for k in range(len(A)):
    print A[k]
```

An Odometer Function

```
def odometer(A):
    """ Returns a float that is the
    perimeter of the polygon whose vertices
    are the points in A.

    PreC: A is a list of points.
    """
    d = 0
    n = len(A)
    for k in range(n-1):
        d = d + Dist(A[k],A[k+1])
    d = d + Dist(A[n-1],A[0])
    return d
```

More on Copying Objects

A subtle issue is involved if you try to copy objects that have attributes that are objects themselves.

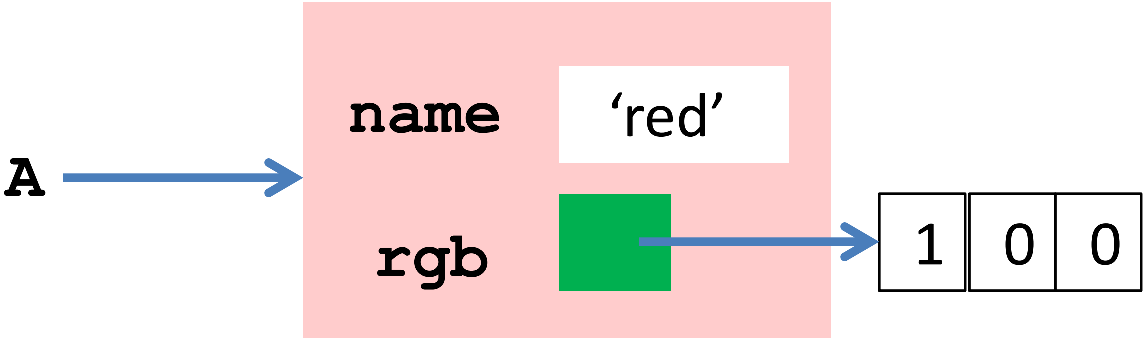
More on Copying Objects

To illustrate consider this class

```
class MyColor:
    """
    Attributes:
        rgb: length-3 float list
        name: str
    """
    def __init__(self,rgb,name):
        self.rgb = rgb
        self.name = name
```

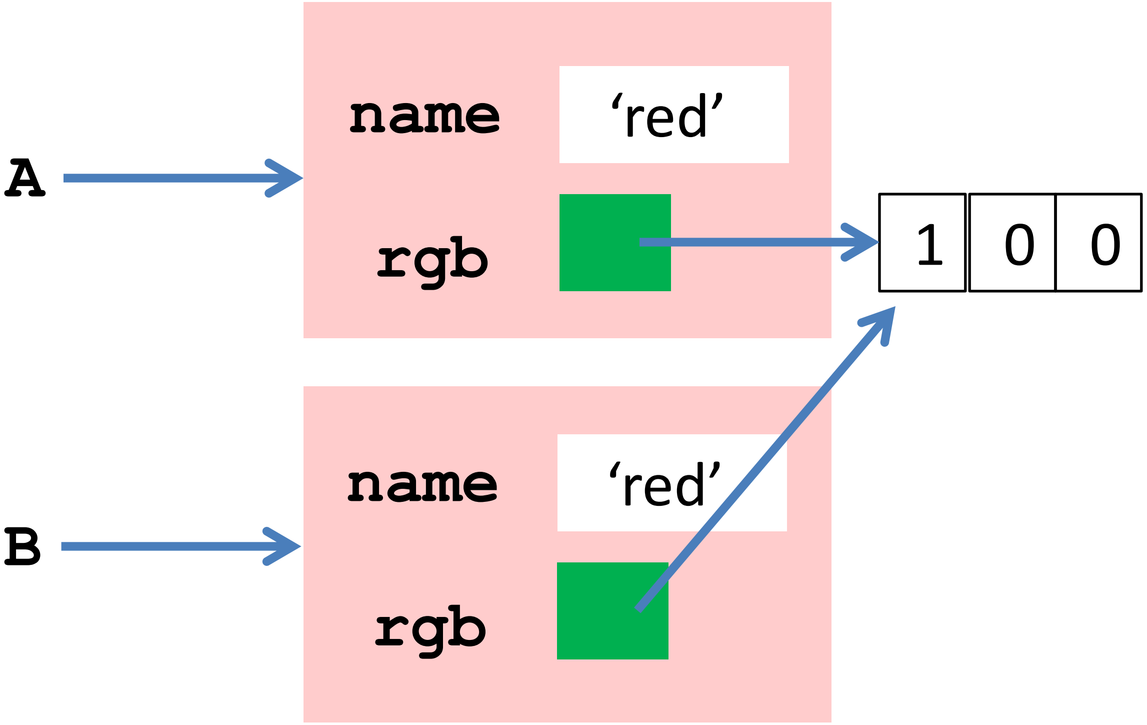
More on Copying Objects

```
>>> A = MyColor([1,0,0],'red')
```



More on Copying Objects

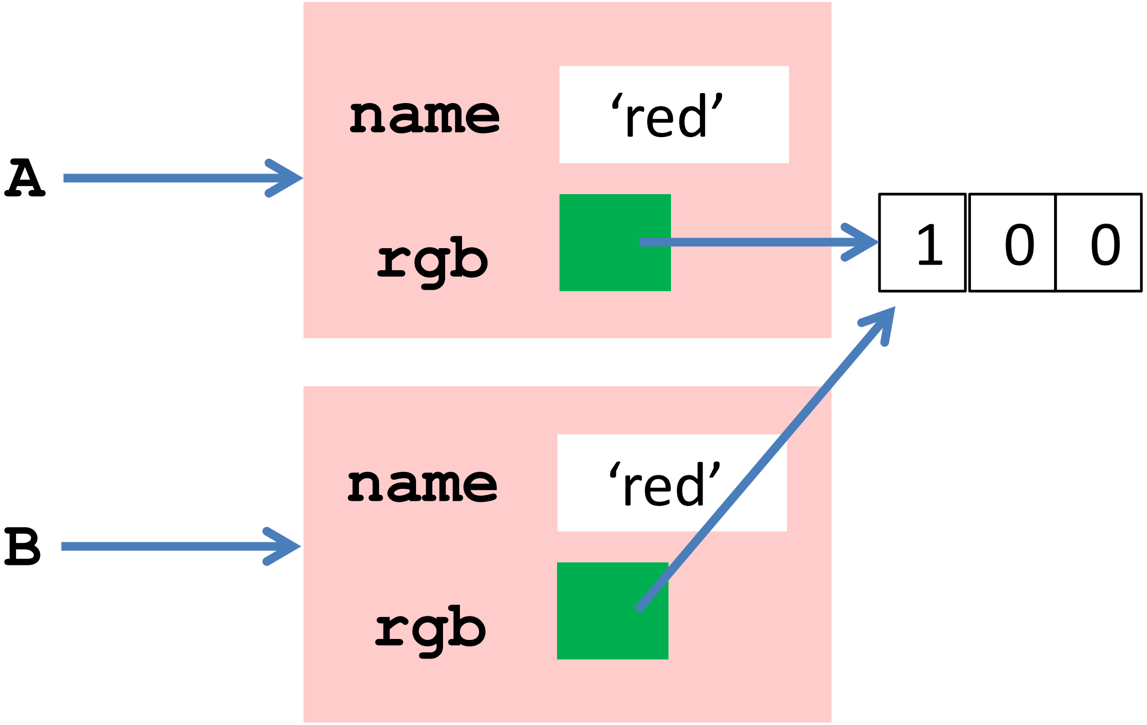
```
>>> B = copy(A)
```



More on Copying Objects

```
>>> B = copy(A)
```

Now let's make A yellow

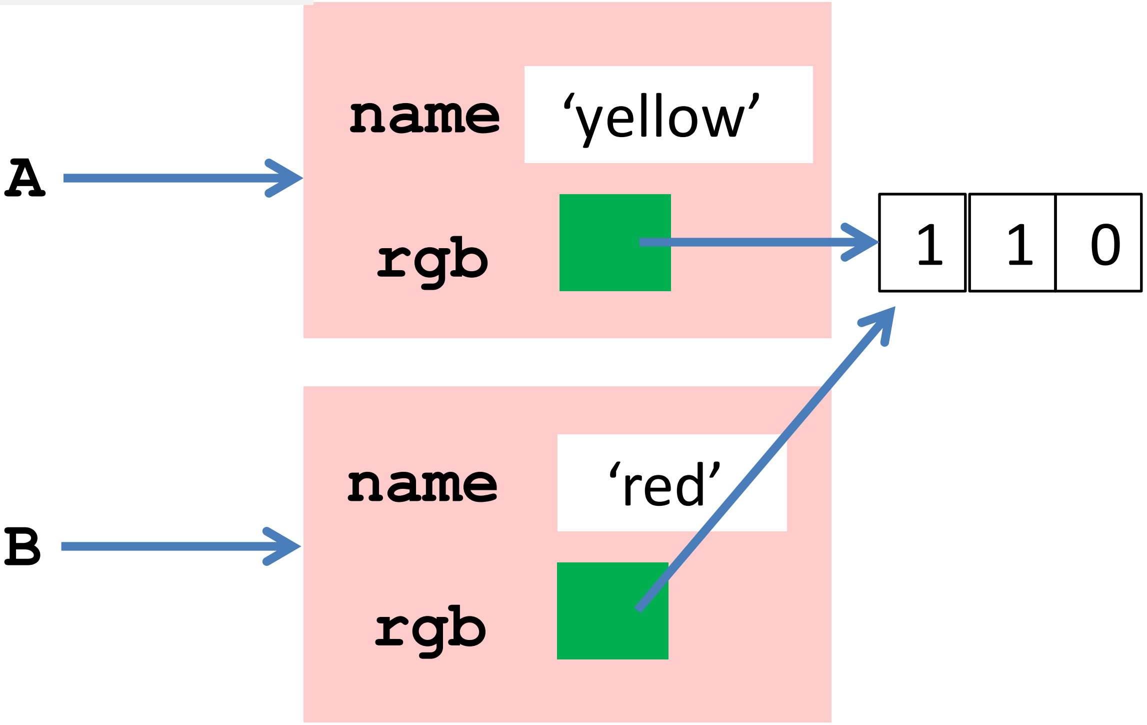


More on Copying Objects

```
>>> A.rgb[1]=1
>>> A.name = ‘yellow’
```

Unintended Effect

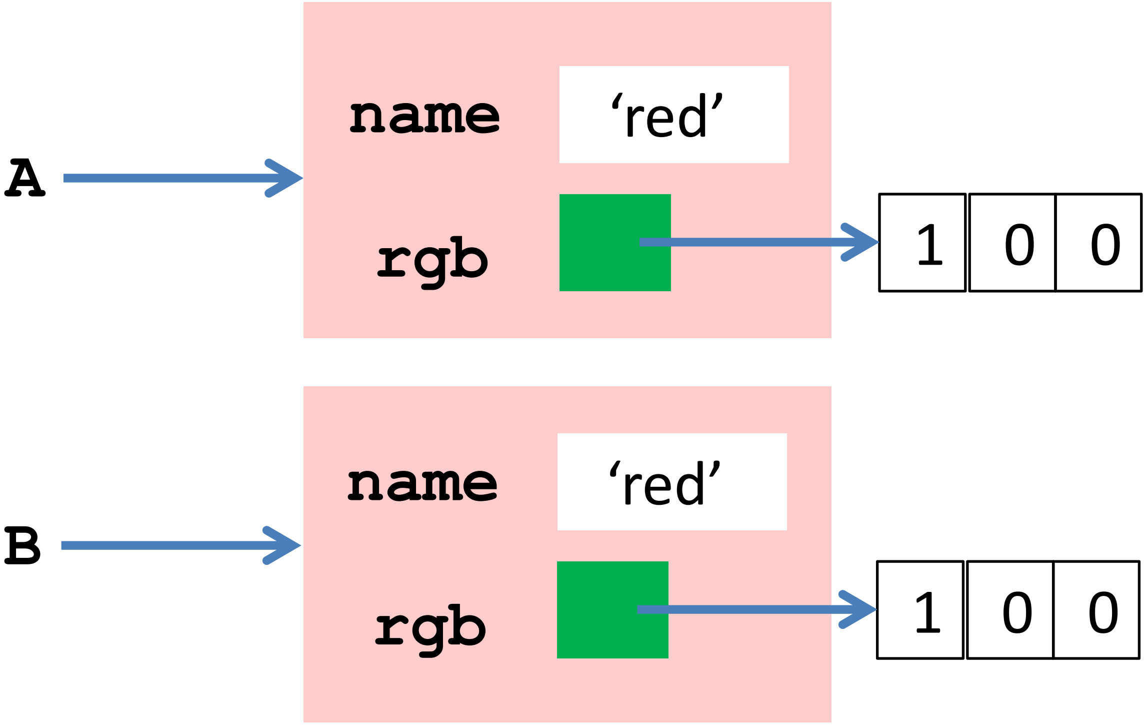
B.Rgb refers to a yellow triple



More on Copying Objects

```
>>> B = deepcopy(A)
```

deepcopy copies everything



Summary: Base Types vs Classes

Base Types	Classes
Built into Python	Defined in Modules
Instances are values	Instances are objects
Instantiate w/ Literals	Instantiate w/ constructors
Immutable	Mutable