18. Introduction to Classes

Topics:

- Class Definitions
- Constructors
- Example: The class **`Point`**
- Functions that work with **`Point`** Objects
- Defining methods

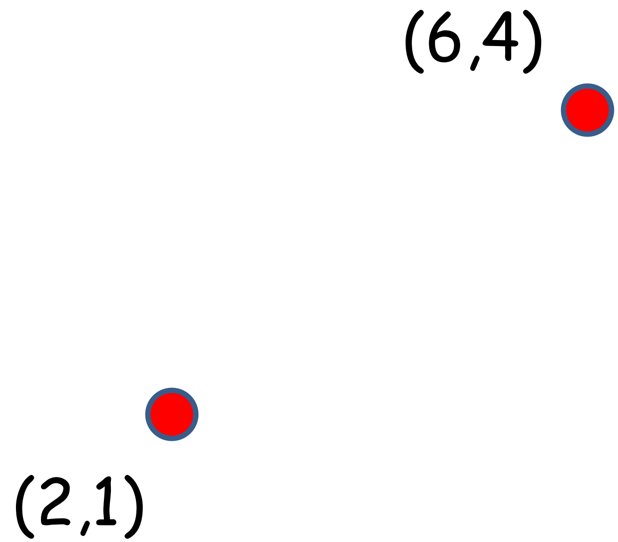
What a Simple Class Definition Looks Like

```
class Point(object):
    """
    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

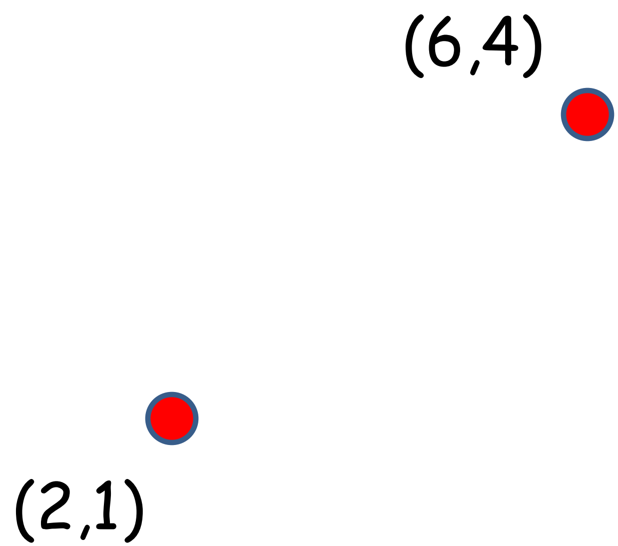
```
>>> P = Point(2,1)
>>> Q = Point(6,4)
>>> d = P.Dist(Q)
>>> print d
5
```



Here, **`Dist`** is a method and **`P.Dist(Q)`** says "compute and return the distance from point P to point Q.

One Reason for classes: They Elevate the Level Thinking

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



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(object):
    """
    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 provides a "blue print" for packaging data.
The data is stored in the attributes.

A Point Class

```
class Point(object):
    """
    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(object):
    """
    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 method defined in a class.

The "__init__" Function

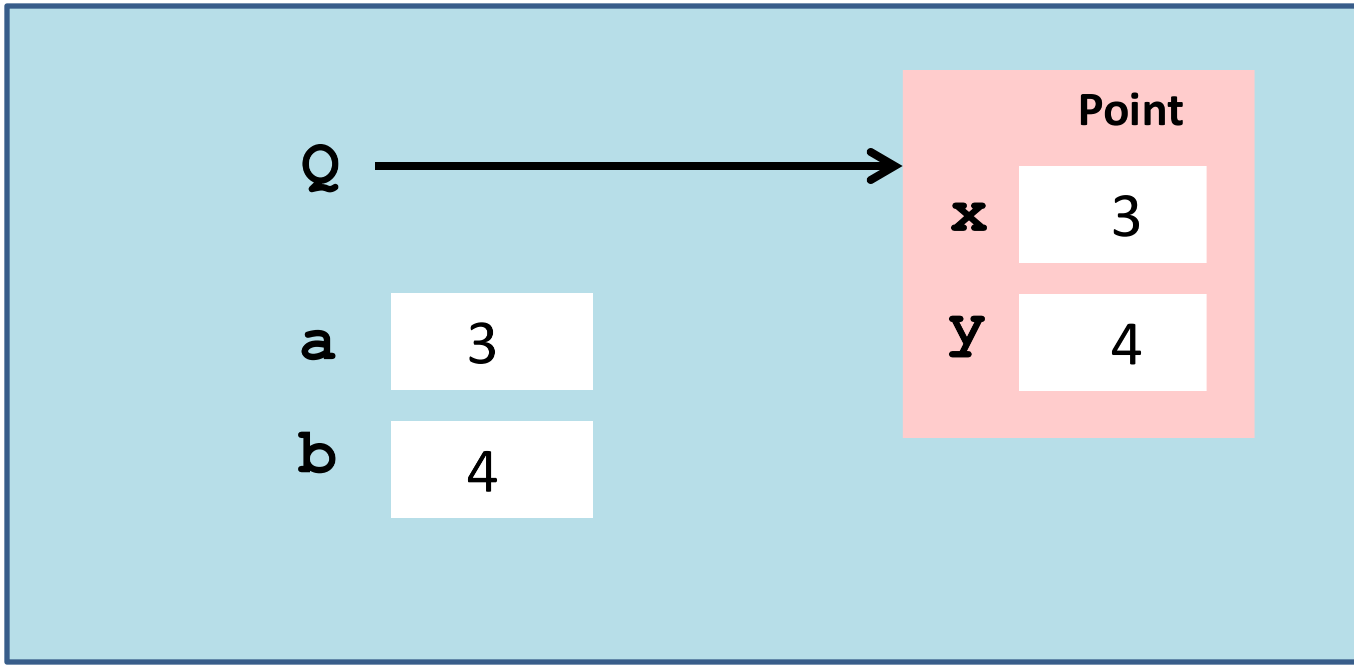
```
def __init__(self,x,y):
    """ Creates a Point object

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

The attributes are assigned values.

Calling the Constructor Creates an Object

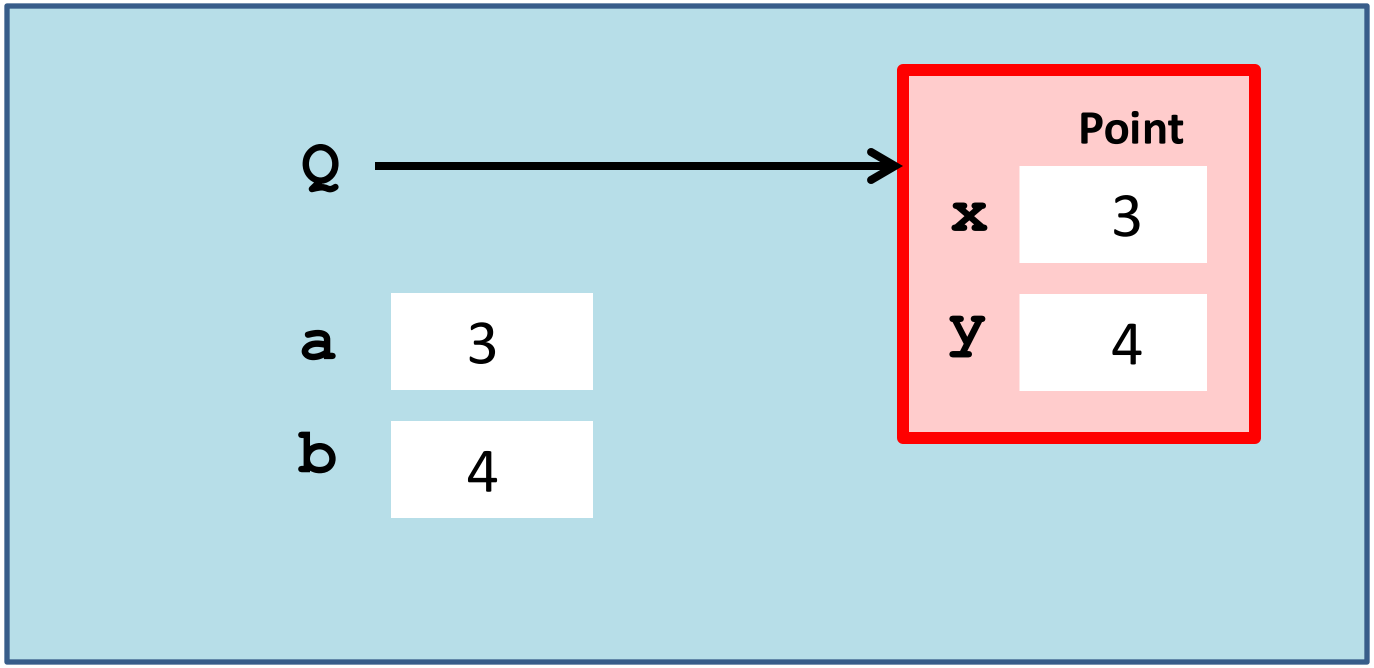
Calling the Constructor




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

The constructor's name is the name of the class

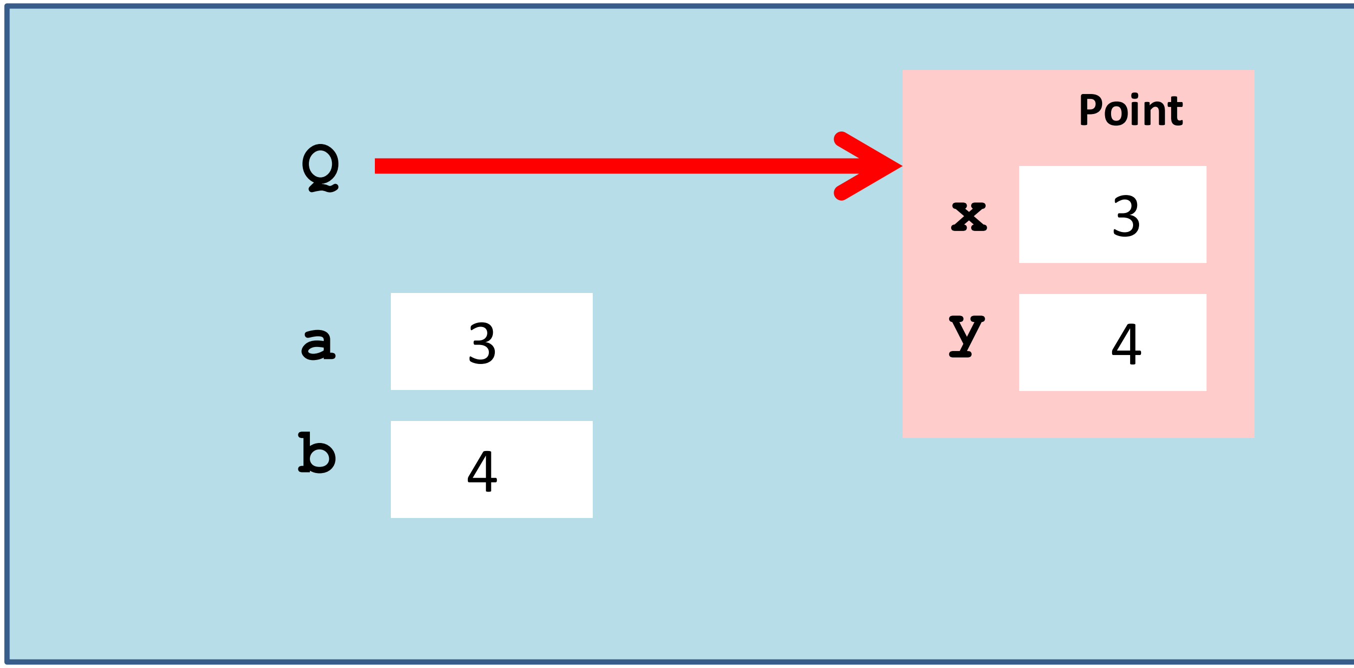
Calling the Constructor




```
>>> 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, in effect, the red arrow.

Objects: The Folder Metaphor

In the office, 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.

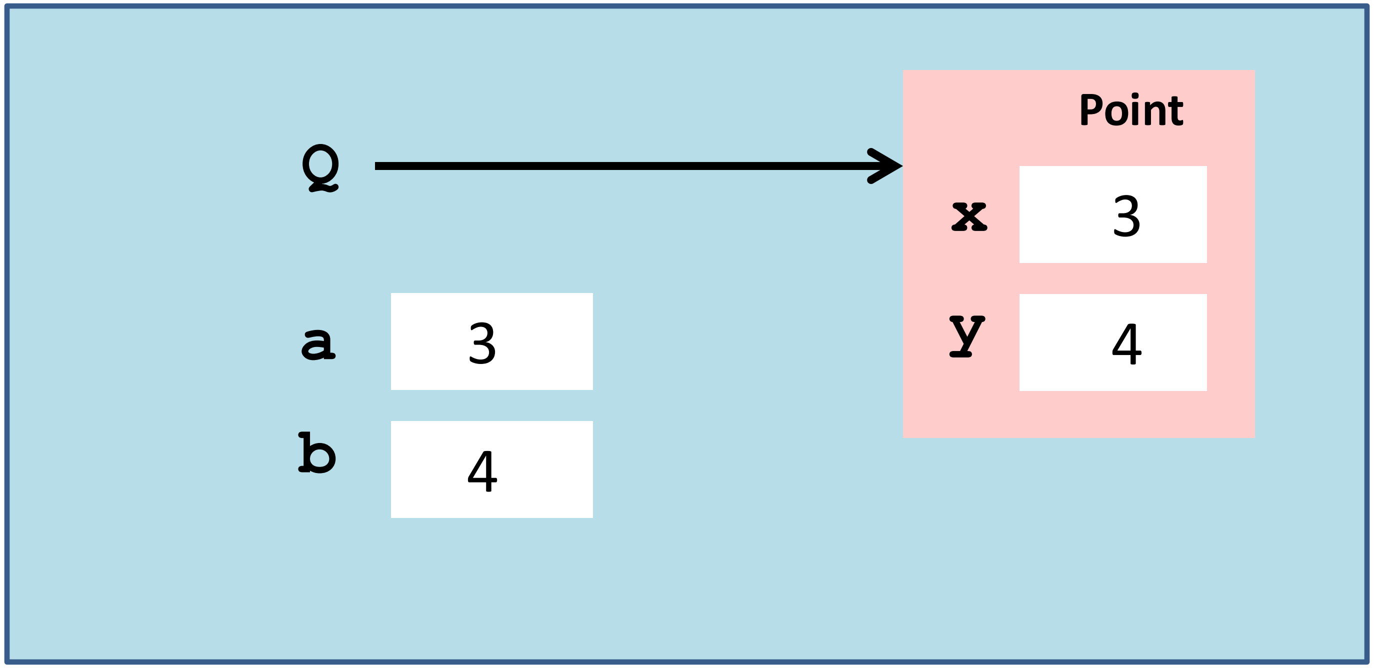
Objects: The Folder Metaphor

In the office manila folders organize data.

Objects organize data.

A color object might house an rgb list like [1,0,1] and a string that names it, i.e., 'magenta'

Visualizing a Point Object




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

x and y are attributes

Attributes are variables that live inside objects

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 "double underscore" function is part of the class definition.

Whenever a statement like

```
print P
```

is encountered, then P is "pretty printed" according to the format rules.

Two Examples

A function that returns a **`Point`** Object:

`RandomPoint(Lx,Rx,Ly,Ry)`

A function that has input parameters that are **`Point`** objects:

`Midpoint(P,Q)`

Computing a Random Point

```
def RandomPoint(Lx,Rx,Ly,Ry):
    """ Returns a point that is randomly chosen
    from the square Lx<=x<=Rx, Ly<=y<=Ry.

    PreC: Lx and Rx are floats with Lx<Rx
    Ly and Ry are floats with Ly<Ry
    """
    x = randu(Lx,Rx)
    y = randu(Ly,Ry)
    P = Point(x,y)
    return P
```

calling the constructor

Computing a 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 point objects.
    """
    xm = (P1.x + P2.x)/2.0
    ym = (P1.y + P2.y)/2.0
    Q = Point(xm,ym)
    return Q
```

Computing a Midpoint

```
def Midpoint(P1,P2):
    """ Returns a point that is the midpoint of
    the 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

Methods

Methods are functions that are defined inside a class definition.

We have experience using them with strings

```
s.upper(),s.find(s1),s.count(s2),
s.append(s2), s.split(c), etc
```

and lists

```
L.append(x),L.extend(x),L.sort(),etc
```

Methods

Now we show how to implement them.

We will design a method for the **`Point`** class that can be used to compute the distance between two points.

It will be used like this:

```
delta = P.Dist(Q)
```

Note the dot notation syntax for method Calls.

A Point Class Method: `Dist`

```
class Point(object):
    def __init__(self,x,y):
        self.x = x
        self.y = y

    def Dist(self,other):
       """ Returns distance from self to other.
       PreC: other is a point
       """
       dx = self.x - other.x
       dy = self.y - other.y
       d = sqrt(dx**2+dy**2)
       return d
```

Assume proper importing from math class

Using the `Dist` Method

Let's create two point objects and compute the distance between them. This can be done two ways…

```
>>> P = Point(3,4)
>>> Q = Point(6,8)
>>> deltaPQ = P.Dist(Q)
>>> deltaQP = Q.Dist(P)
>>> print deltaPQ,deltaQP
5.0 5.0
```

The usual "dot" notation for invoking a method

Method Implementation: Syntax Concerns

```
class Point(object)
             :
   def Dist(self,other):
      """ Returns distance from self to other.
        PreC: P is a point
        """
        dx = self.x - other.x
        dy = self.y - other.y
        d = sqrt(dx**2+dy**2)
        return d
```

Note the use of "self".
It is always the first argument of a method.

How to Think "Method"

```
class Point(object):
            :
   def Dist(self,other):
      """ Returns distance from self to other.
      PreC: P is a point
      """
      dx = self.x - other.x
      dy = self.y - other.y
      d = sqrt(dx**2+dy**2)
      return d
```

Think like this: "We are going to apply the method `dist` to a pair of `Point` objects, `self` and `other`."

Method Implementation: Syntax Concerns

```
class Point(object):
          :
   def Dist(self,other):
     """ Returns distance from self to other
     PreC: other is a point
     """
     dx = self.x - other.x
     dy = self.y - other.y
     d = sqrt(dx**2+dy**2
     return d
```

Two Facts:

Indentation is important.

A class method is part of the class definition.

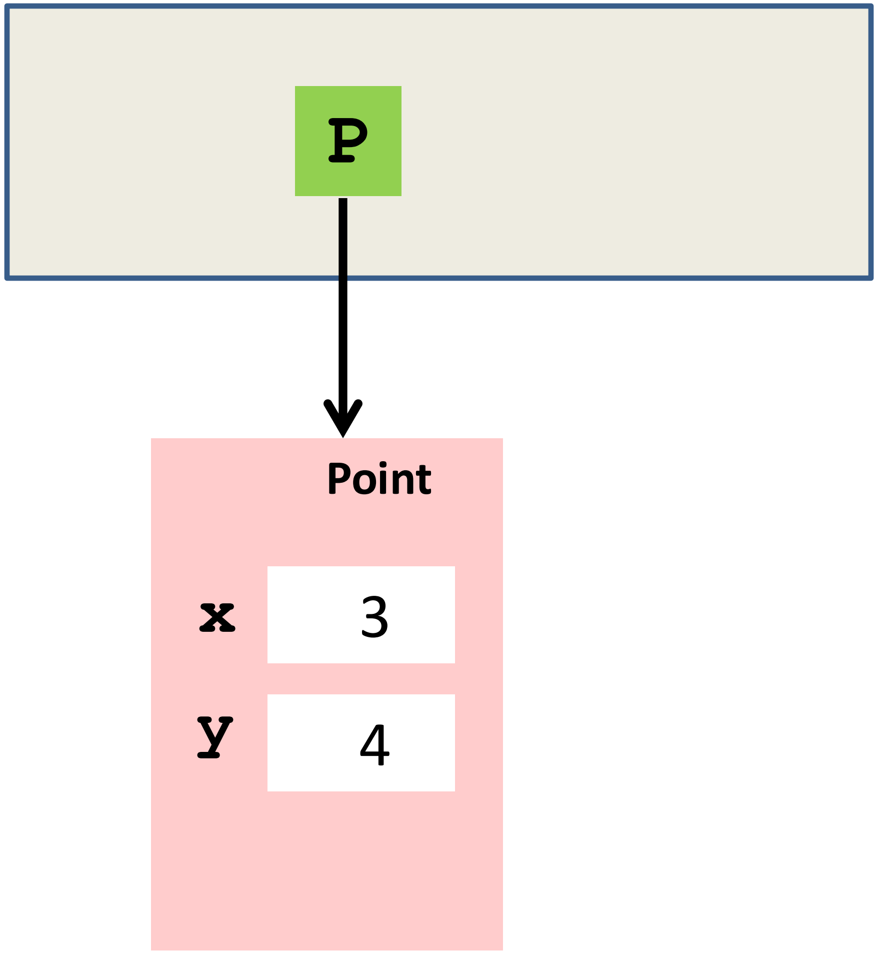
Visualizing a Method Call Using State Diagrams

Let's see what happens when we execute the following:

```
P = Point(3,4)
Q = Point(6,8)
D = P.Dist(Q)
```

Visualizing a Method Call

```
P = Point(3,4)
Q = Point(6,8)
D = P.Dist(Q)
```



Visualizing a Method Call

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P = Point(3,4)
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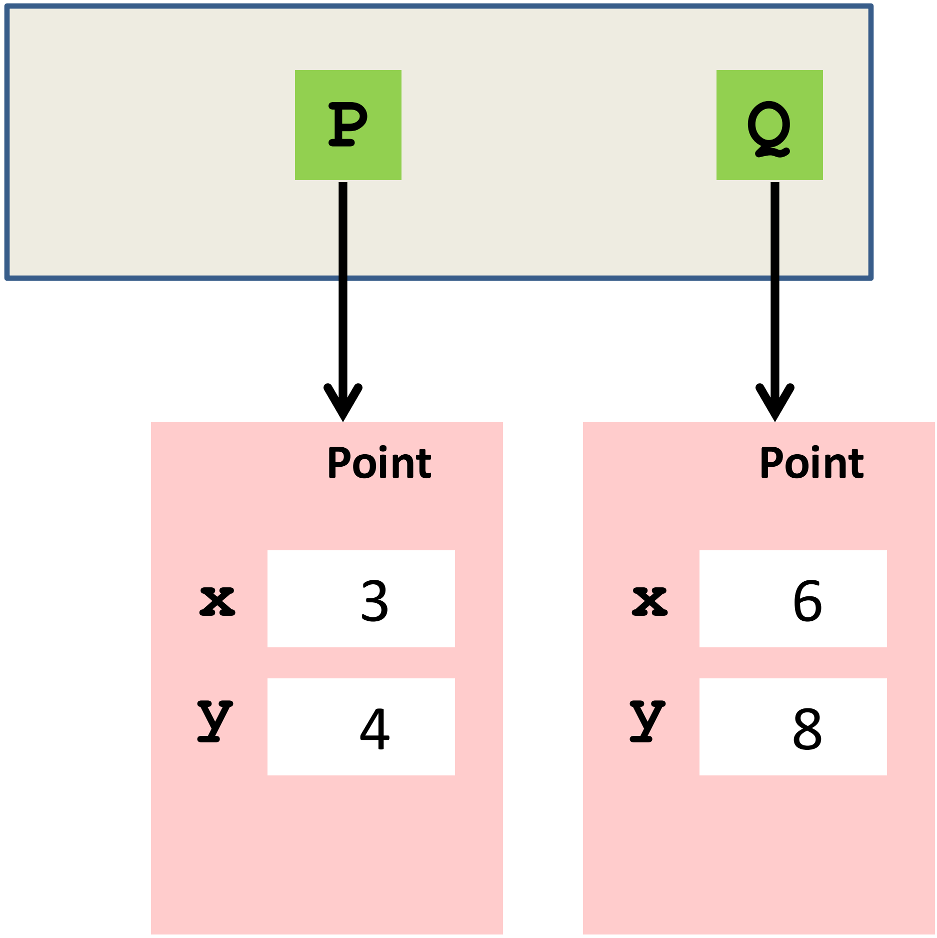
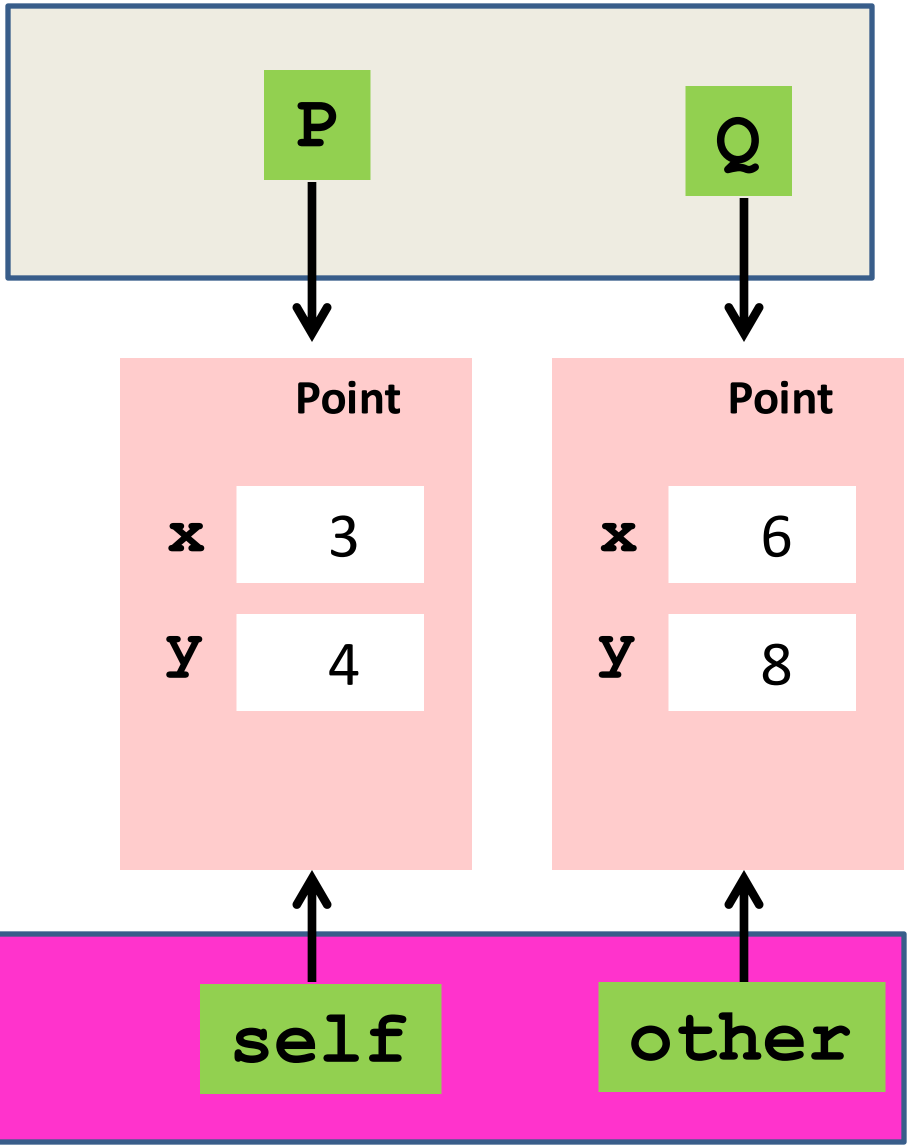


Visualizing a Method Call

```
 P = Point(3,4)
Q = Point(6,8)
D = P.Dist(Q)
```

Dist

```
dx = self.x-other.x
dy = self.y-other.y
d = sqrt(dx**2+dy**2)
return d
```



Method: Dist

```
class Point(object):
         :
    def Dist(self,other):
      """ Returns distance from self to other.
      PreC: other is a point
      """
      dx = self.x - other.x
      dy = self.y - other.y
      d = sqrt(dx**2+dy**2)
      return d
```

Think of **self** and **other** as input parameters.

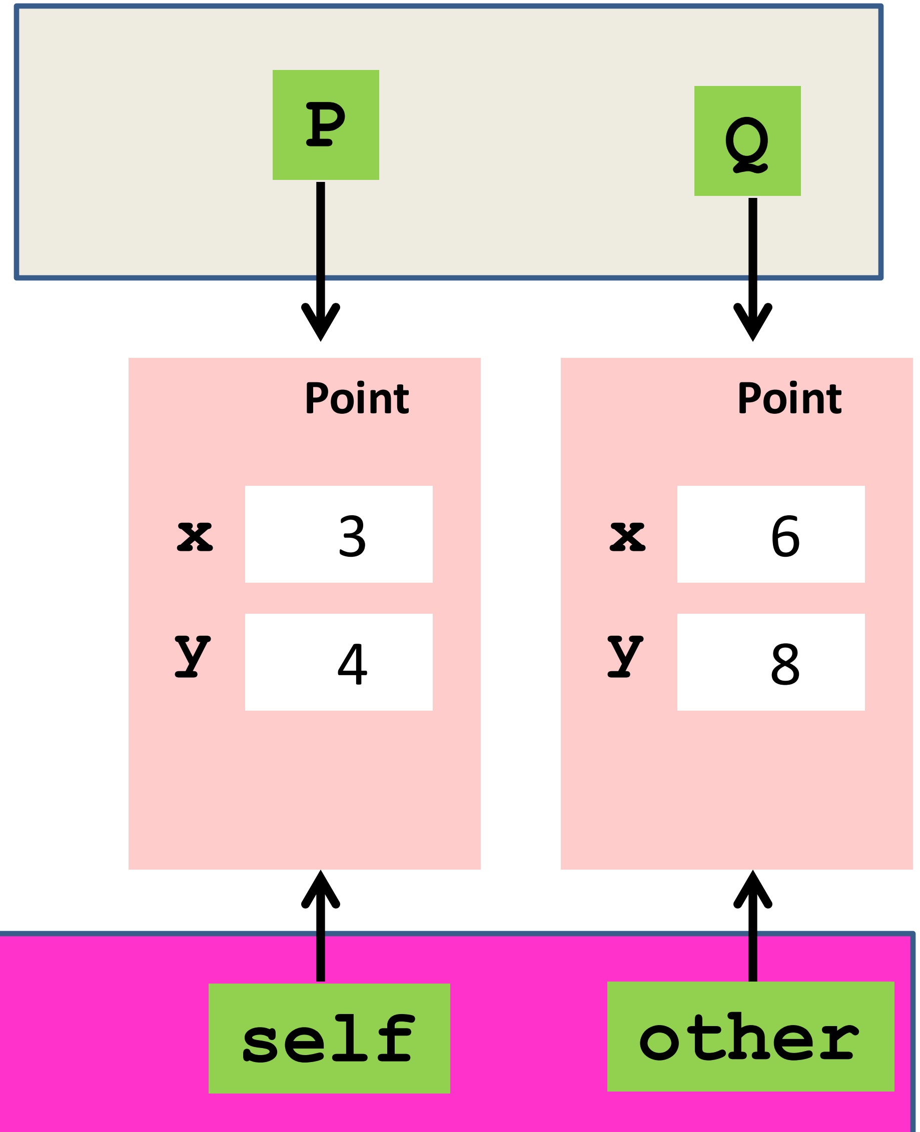
Visualizing a Method Call

```
 P = Point(3,4)
Q = Point(6,8)
D = P.Dist(Q)
```

Dist

```
dx = self.x-other.x
dy = self.y-other.y
d = sqrt(dx**2+dy**2)
return d
```

Control passes to
the method `Dist`



Visualizing a Method Call

```
P = Point(3,4)
Q = Point(6,8)
D = P.Dist(Q)
```

Dist

```
dx = self.x-other.x
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return d
```
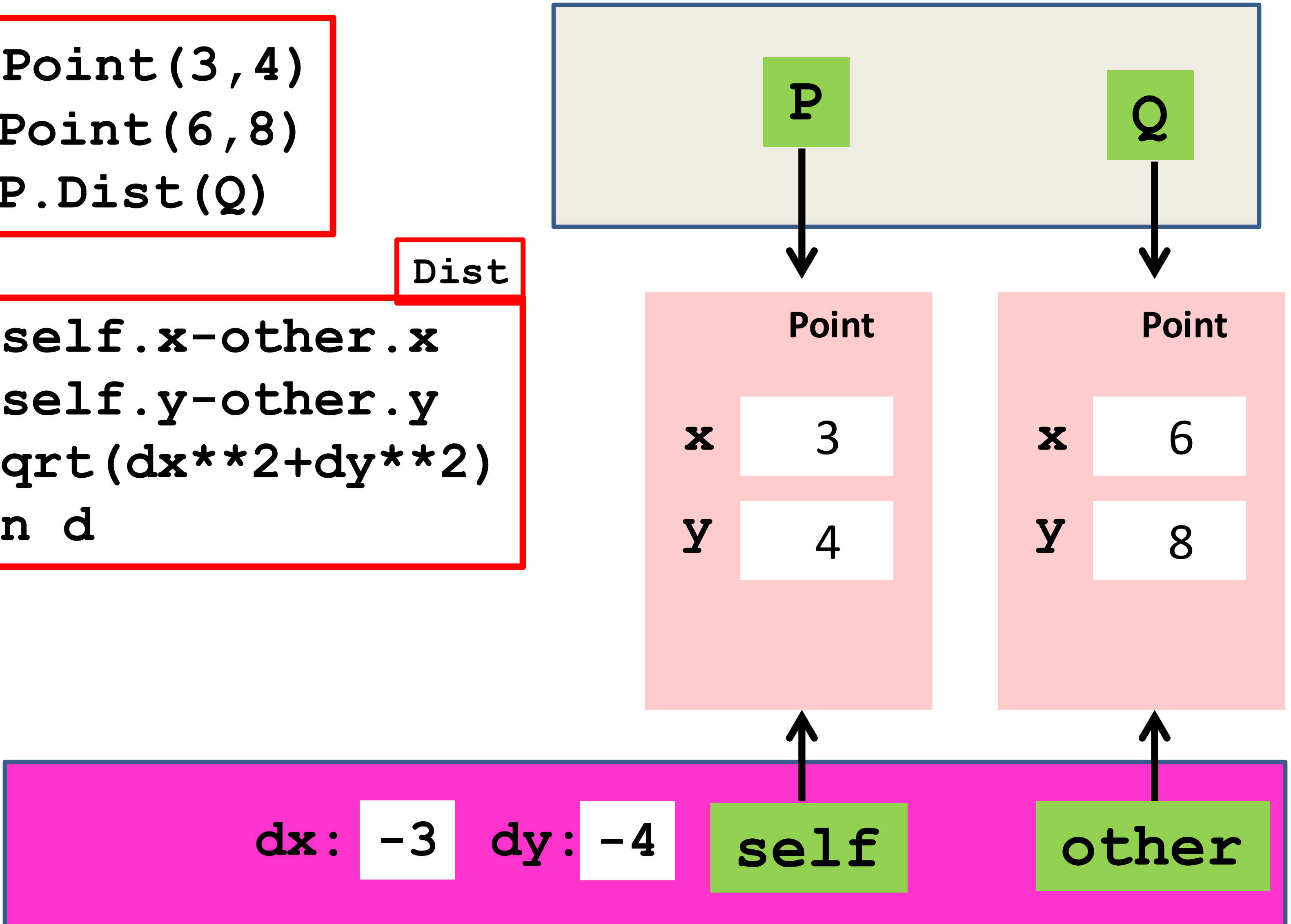
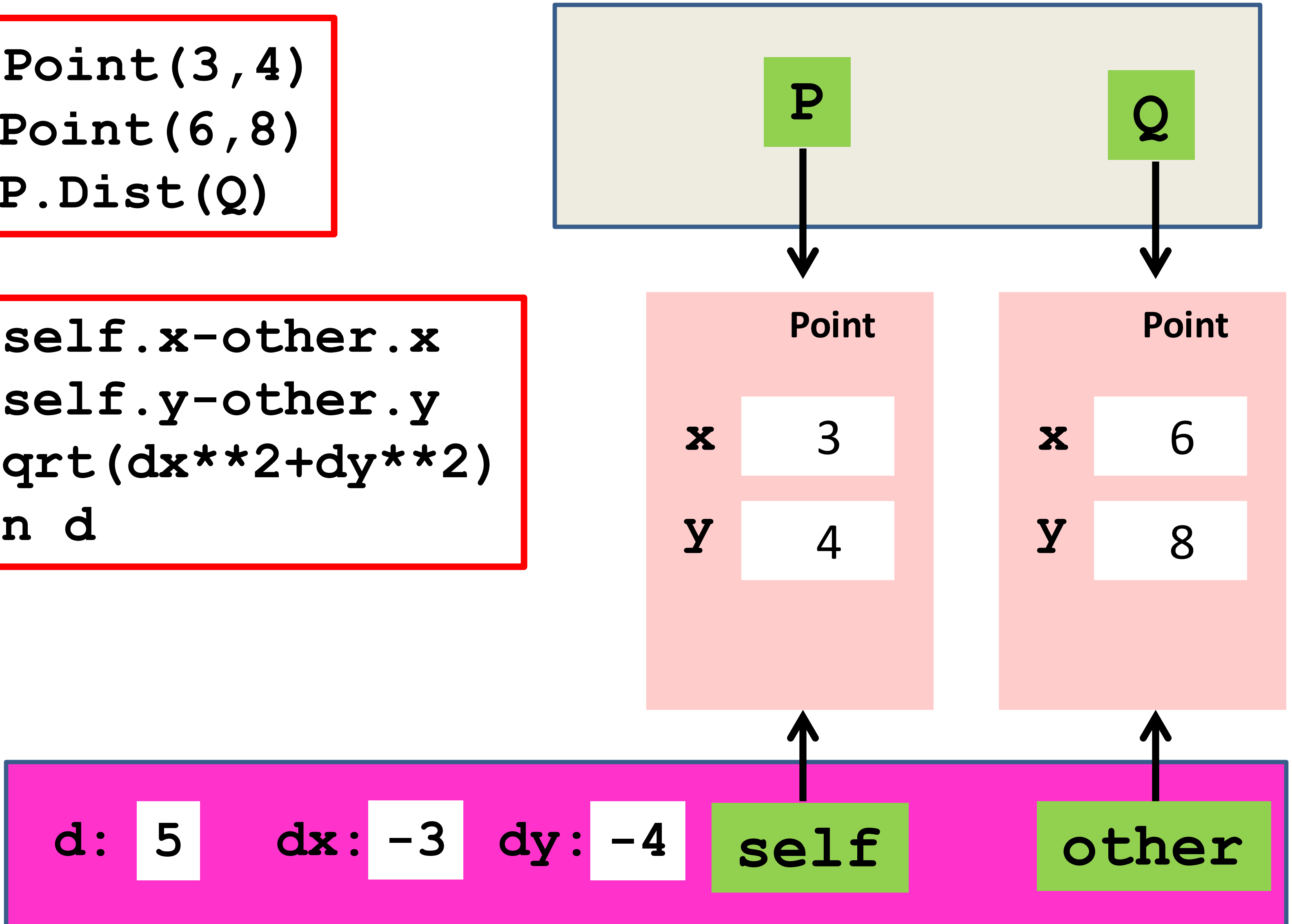



Visualizing a Method Call

```
 P = Point(3,4)
Q = Point(6,8)
D = P.Dist(Q)
```

```
dx = self.x-other.x
dy = self.y-other.y
d = sqrt(dx**2+dy**2)
return d
```

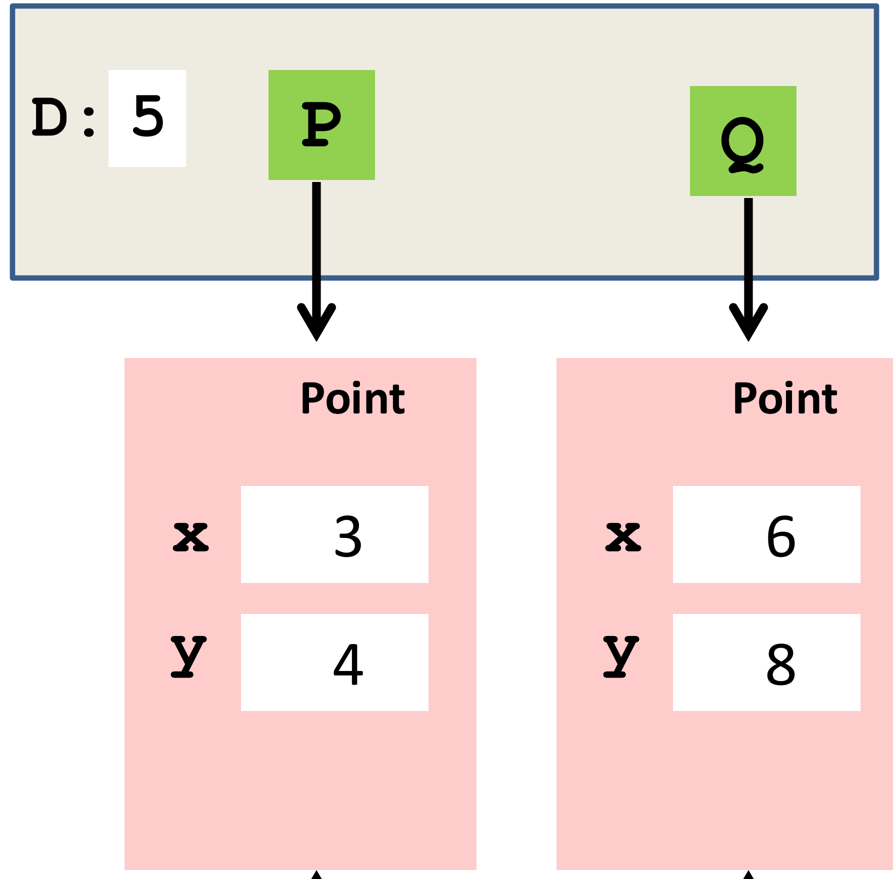


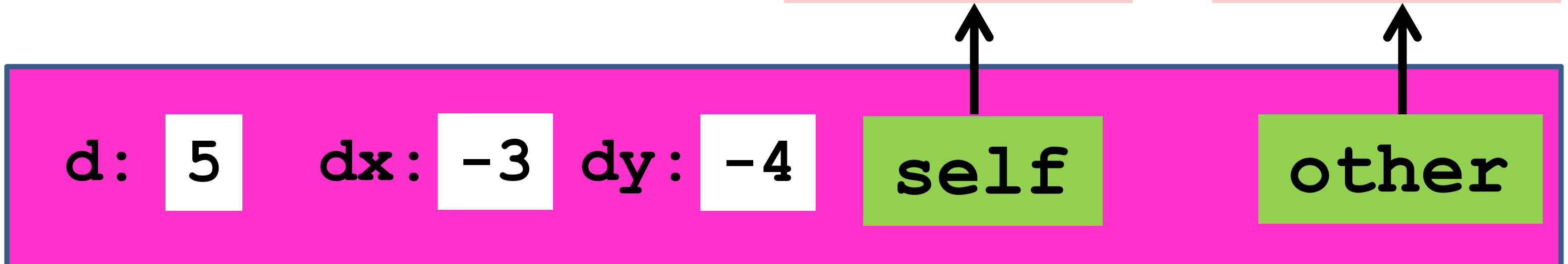
Visualizing a Method Call

```
P = Point(3,4)
Q = Point(6,8)
D = P.Dist(Q)
```

Dist

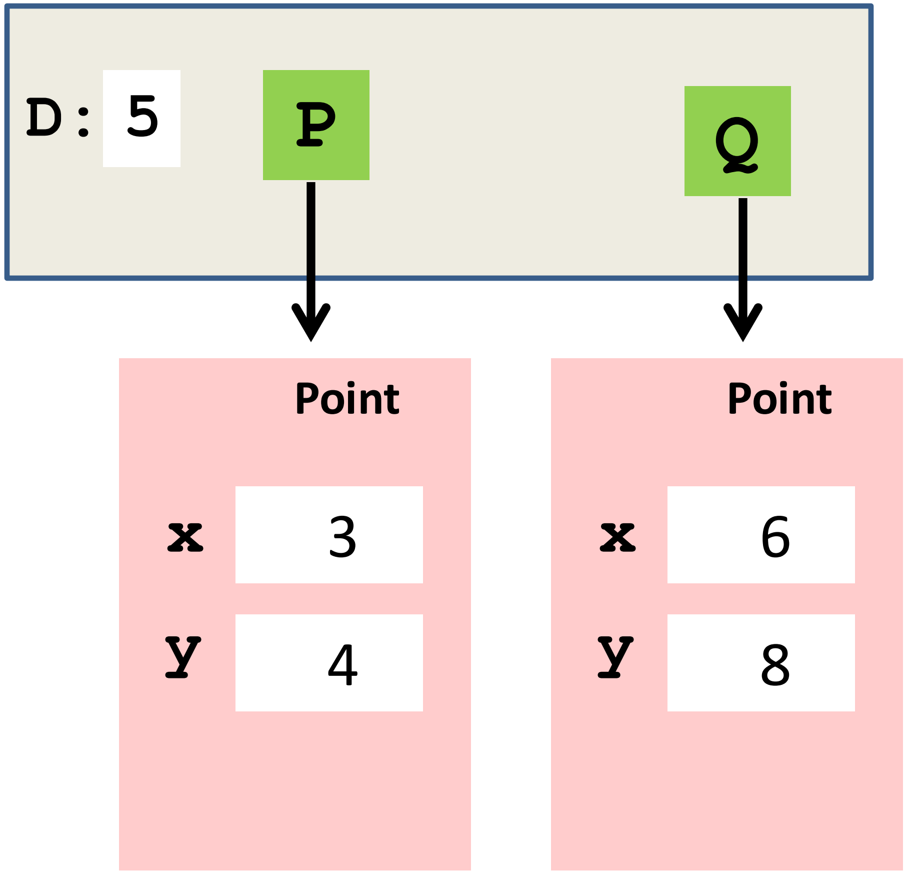
```
dx = self.x-other.x
dy = self.y-other.y
d = sqrt(dx**2+dy**2)
return d
```





Visualizing a Method Call

```
P = Point(3,4)
Q = Point(6,8)
D = P.Dist(Q)
```



Checking Things Out

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

Summary: Base Types vs Classes

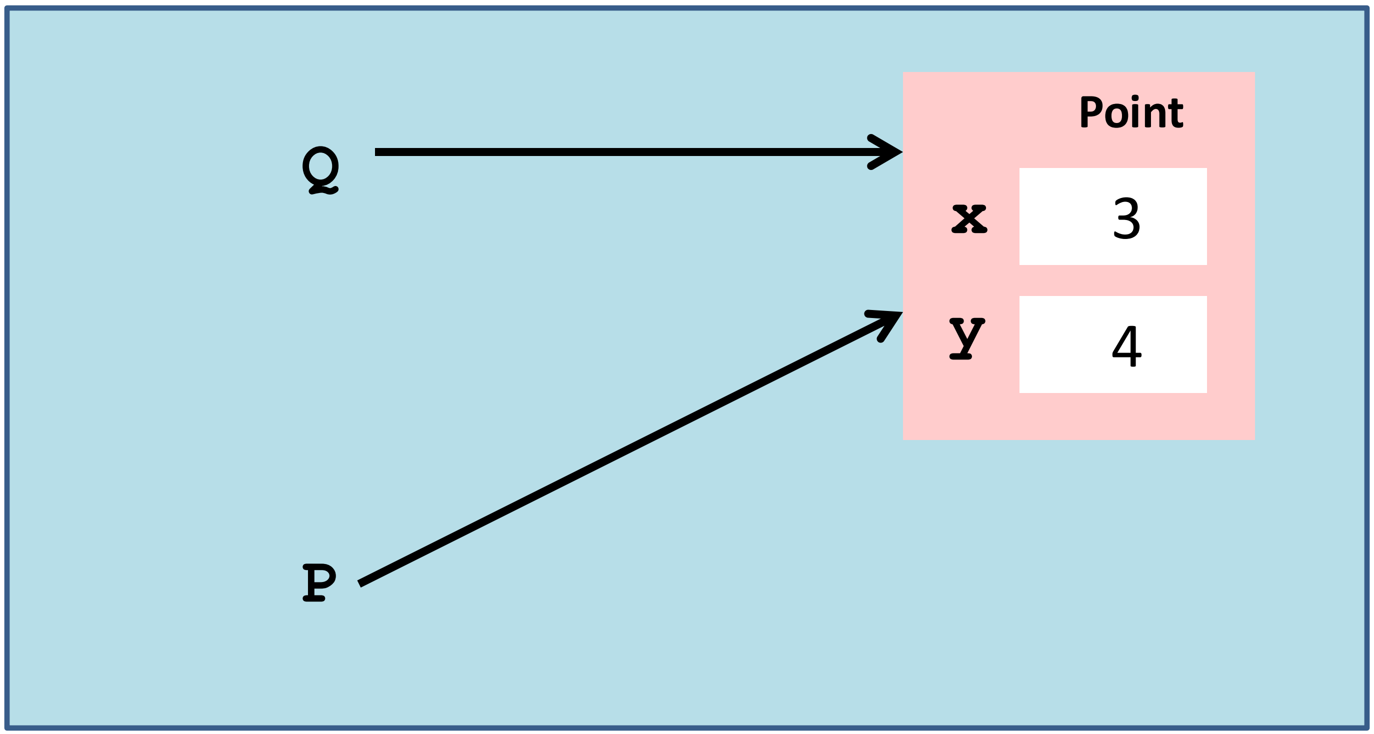
Base Types	Classes
Built into Python Instances are values Instantiate w/ Literals Immutable	Defined in Modules Instances are objects Instantiate w/ constructors Mutable

A Note on Copying an Object

There is a difference between creating an alias and creating a genuine second copy of an object.

This Does Not Create a Copy…

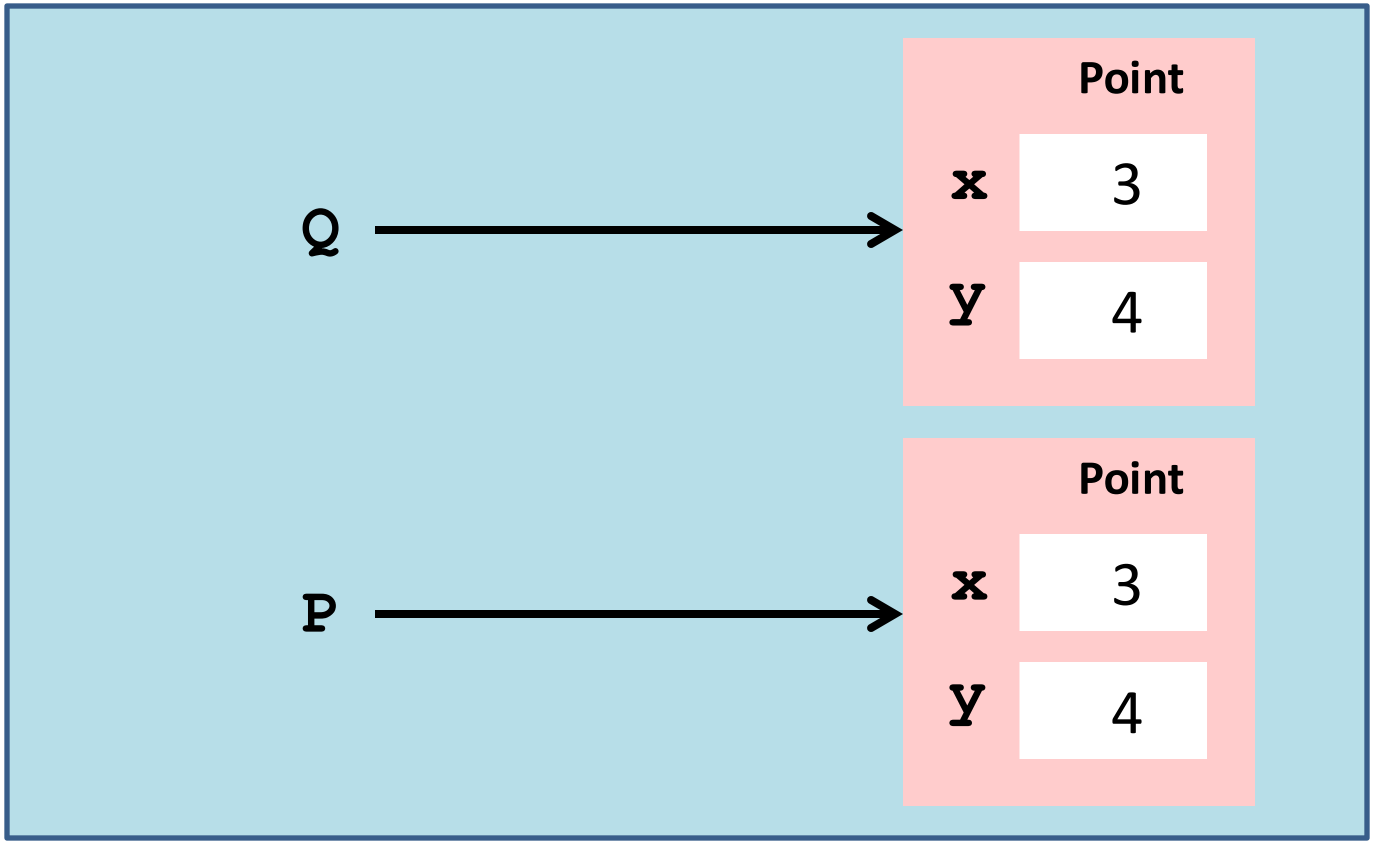
```
>>> Q = Point(3,4)
>>> P = Q
```



It creates an alias, not a copy.

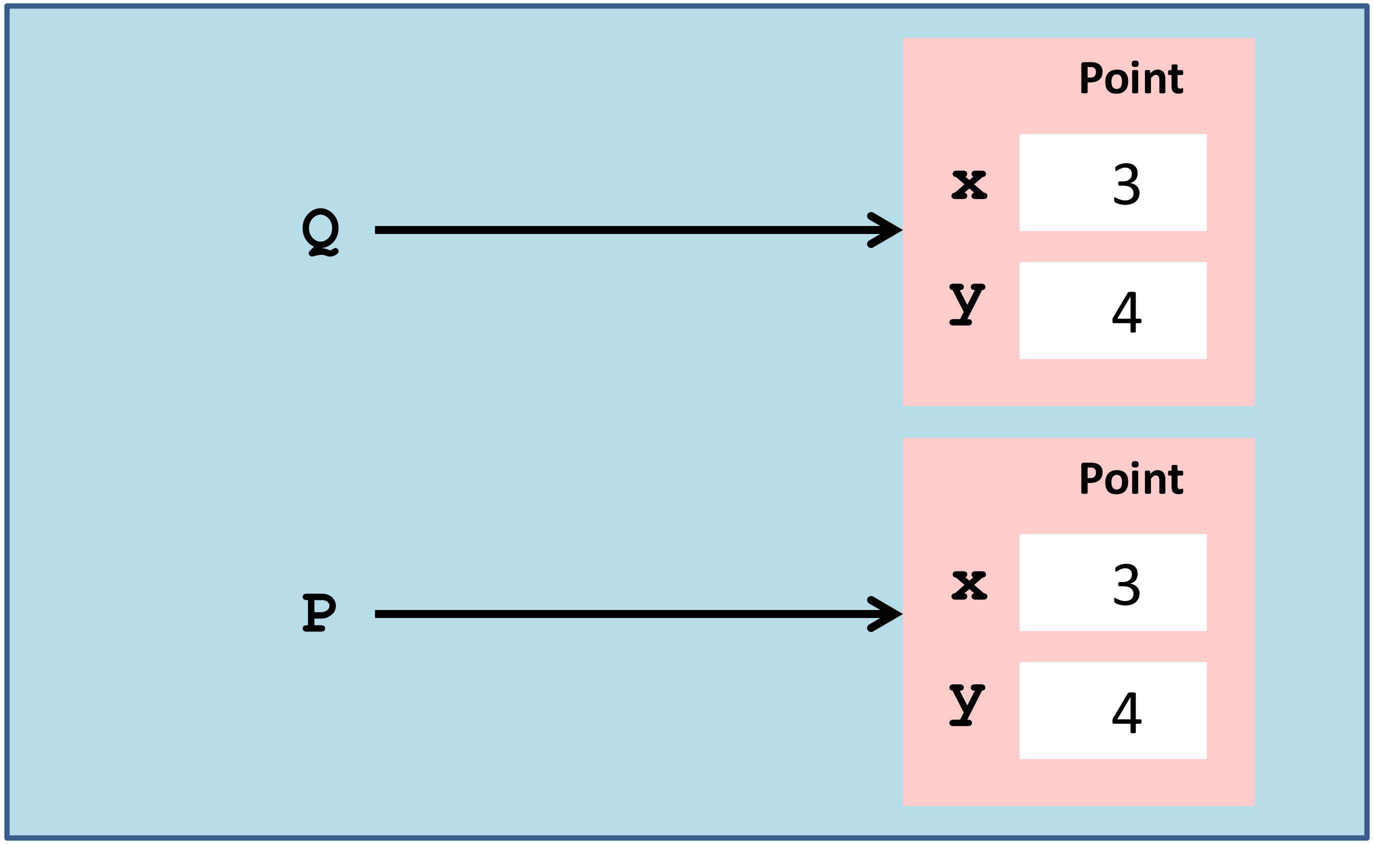
This Does Create a Copy…

```
>>> Q = Point(3,4)
>>> P = Point(Q.x,Q.y)
```



And This Also Creates a Copy…

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



The function copy must be imported.

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

Methods vs Functions

It is important to understand the differences between methods and functions, i.e., how they are defined and how they are invoked.

A >>Function<< that Returns the Distance Between Two Points

```
def Dist(P1,P2):
    """ Returns 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
```

Methods and (Regular) Functions

```
def Dist(self,other):
   dx = self.x - other.x
   dy = self.y - other.y
   D = sqrt(dx**2+dy**2)
   return D
```

```
>>> P = Point(3,4)
>>> Q = Point(6,8)
>>> P.Dist(Q)
5.0
```

```
def Dist(P,Q):
   dx = P.x - Q.x
   dy = P.y - Q.y
   D = sqrt(dx**2+dy**2)
   return D
```

```
>>> P = Point(3,4)
>>> Q = Point(6,8)
>>> Dist(Q,P)
5.0
```