Classes: Defining New Types of Objects

Computer Science 111
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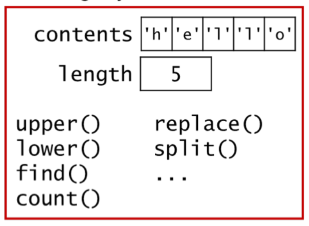
Objects, Objects, Everywhere!

- *Recall:* Strings are objects with:
  - *attributes* – data values inside the object
  - *methods* – functions inside the object

string object for `'hello'`



- In fact, *everything* in Python is an object!
  - integers
  - floats
  - lists
  - booleans
  - file handles
  - ...

Classes

- A *class* is a blueprint – a definition of a data type.
  - specifies the attributes and methods of that type
- Objects are built according to the blueprint provided by their class.
  - they are "values" / *instances* of that type
  - use the `type` function to determine the class:

```
>>> type(111)
<class 'int'>

>>> type(3.14159)
<class 'float'>

>>> type('hello!')
<class 'str'>

>>> type([1, 2, 3])
<class 'list'>
```

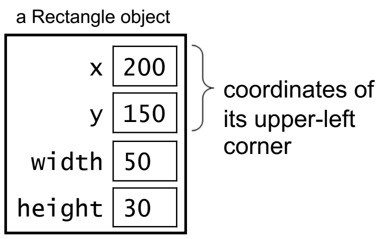
Another Analogy

- A class is like a cookie cutter.
  - specifies the "shape" that all objects of that type should have

- Objects are like the cookies.
  - created with the "shape" specified by their class

Creating Your Own Classes

- In an *object-oriented* programming language, you can define your own classes.
  - your own types of objects
  - your own data types!
- Example: let's say that we want objects that represent rectangles.

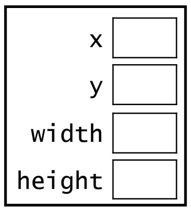


- A `Rectangle` object could have methods for:
  - computing its area, perimeter, etc.
  - growing it (changing its dimensions), moving it, etc.

An Initial `Rectangle` Class

```
class Rectangle:
    """ a blueprint for objects that represent
        a rectangular shape
    """

    def __init__(self, init_width, init_height):
        """ the Rectangle constructor """
        self.x = 0
        self.y = 0
        self.width = init_width
        self.height = init_height
```



- `__init__` is the ***constructor.***
  - it's used to create new objects
  - it specifies the attributes
- Inside its methods, an object refers to itself as `self`!

Constructing and Using an Object

```
class Rectangle:
    """ the Rectangle constructor """
    def __init__(self, init_width, init_height):
        self.x = 0
        self.y = 0
        self.width = init_width
        self.height = init_height
```

```
>>> r1 = Rectangle(100, 50)     # calls __init__!
```

Constructing and Using an Object

```
class Rectangle:
    """ the Rectangle constructor """
    def __init__(self, init_width, init_height):
        self.x = 0
        self.y = 0
        self.width = init_width
        self.height = init_height
```

```
>>> r1 = Rectangle(100, 50)     # calls __init__!
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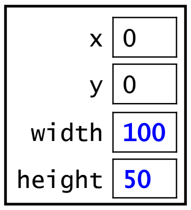
Constructing and Using an Object

```
class Rectangle:
    """ the Rectangle constructor """
    def __init__(self, init_width, init_height):
        self.x = 0
        self.y = 0
        self.width = init_width
        self.height = init_height
```

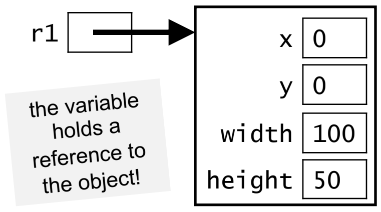
```
>>> r1 = Rectangle(100, 50)     # calls __init__!
```



Constructing and Using an Object

```
class Rectangle:
    """ the Rectangle constructor """
    def __init__(self, init_width, init_height):
        self.x = 0
        self.y = 0
        self.width = init_width
        self.height = init_height
```

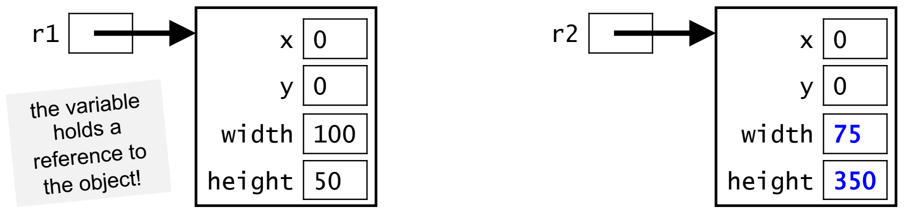
```
>>> r1 = Rectangle(100, 50)     # calls __init__!
```



Constructing and Using an Object

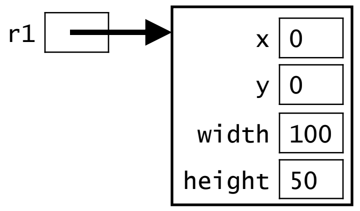
```
class Rectangle:
    """ the Rectangle constructor """
    def __init__(self, init_width, init_height):
        self.x = 0
        self.y = 0
        self.width = init_width
        self.height = init_height
```

```
>>> r1 = Rectangle(100, 50)     # calls __init__!
>>> r2 = Rectangle(75, 350)     # construct another one!
```



Accessing and Modifying an Object's Attributes

```
>>> r1 = Rectangle(100, 50)
```

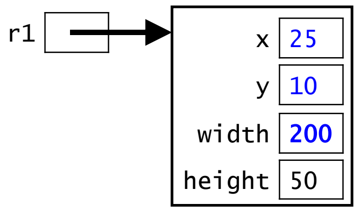


- Access the attributes using *dot notation:*

```
>>> r1.width
100
>>> r1.height
50
```

- Modify them as you would any other variable:

```
>>> r1.x = 25
>>> r1.y = 10
>>> r1.width *= 2
```



Client Programs

- Our `Rectangle` class is *not* a program.
- Instead, it will be used by code defined elsewhere.
  - referred to as *client programs* or *client code*
- More generally, when we define a new type of object, we create a building block that can be used in other code.
  - just like the objects from the built-in classes: `str`, `list`, `int`, etc.
  - our programs have been clients of those classes!

The Need to Import

- When client code is in a separate file, it needs to import the contents of the file with the class definition:

```
# assume this is in a file named rectangle.py
class Rectangle:
    """ a blueprint for objects that represent
        a rectangular shape
    """
    def __init__(self, init_width, init_height):
            self.x = 0
            self.y = 0
            self.width = init_width
            self.height = init_height
```

```
# client code in a different file
from rectangle import *

r1 = Rectangle(100, 50)
r2 = Rectangle(75, 350)
...
```

Initial Client Program

```
from rectangle import *

# construct two Rectangle objects
r1 = Rectangle(100, 50)
r2 = Rectangle(75, 350)

# print dimensions and area of each
print('r1:', r1.width, 'x', r1.height)
area1 = r1.width * r1.height
print('area =', area1)

print('r2:', r2.width, 'x', r2.height)
area2 = r2.width * r2.height
print('area =', area2)

# grow both Rectangles
r1.width += 50
r1.height += 10
r2.width += 5
r2.height += 30

# print new dimensions
print('r1:', r1.width, 'x', r1.height)
print('r2:', r2.width, 'x', r2.height)
```

Using Methods to Capture an Object's Behavior

- Rather than having the client grow the `Rectangle` objects, we'd like to give each `Rectangle` object the ability to grow itself.
- We do so by adding a method to the class:

```
class Rectangle:
    """ the Rectangle constructor """
    def __init__(self, init_width, init_height):
        self.x = 0
        self.y = 0
        self.width = init_width
        self.height = init_height

    def grow(self, dwidth, dheight):
        self.width += dwidth
        self.height += dheight
```

Calling a Method

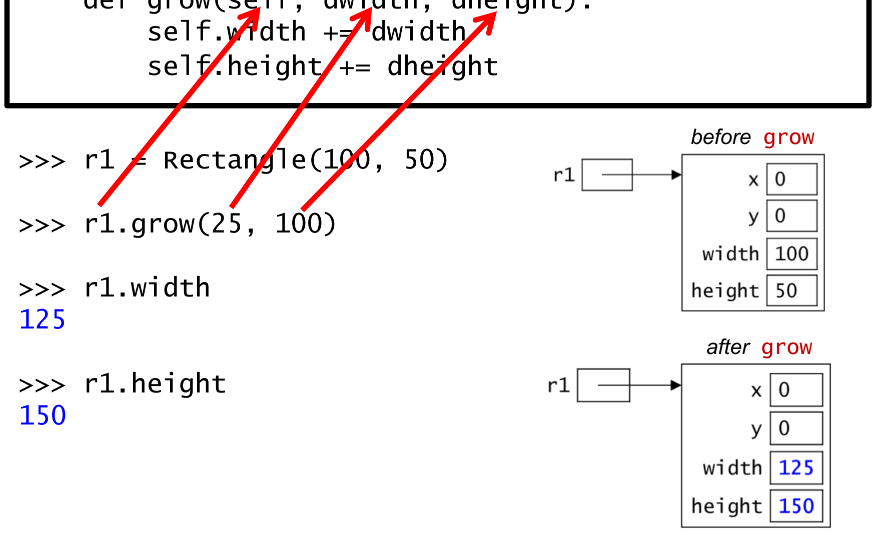
```
class Rectangle:
    ...
    def grow(self, dwidth, dheight):
        self.width += dwidth
        self.height += dheight
```

```
>>> r1 = Rectangle(100, 50)

>>> r1.grow(25, 100)

>>> r1.width
125

>>> r1.height
150
```



Another Example of a Method

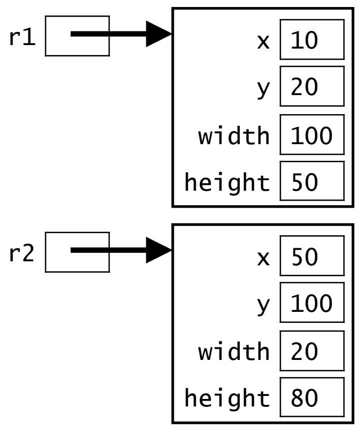
- Here's a method for getting the area of a `Rectangle`:

```
def area(self):
    return self.width * self.height
```

- Sample method calls:

```
>>> r1.area()
5000
>>> r2.area()
1600
```

  - we're asking r1 and r2 to give us their areas
  - nothing in the parentheses because the necessary info. is in the objects' attributes!



Second Version of our `Rectangle` Class

```
# assume this is in rectangle.py

class Rectangle:
    """ a blueprint for objects that represent
        a rectangular shape
    """
    def __init__(self, init_width, init_height):
        """ the Rectangle constructor """
        self.x = 0
        self.y = 0
        self.width = init_width
        self.height = init_height

    def grow(self, dwidth, dheight):
        self.width += dwidth
        self.height += dheight


    def area(self):
        return self.width * self.height
```

Simplified Client Program

```
from rectangle import *

# construct two Rectangle objects
r1 = Rectangle(100, 50)
r2 = Rectangle(75, 350)

# print dimensions and area of each
print('r1:', r1.width, 'x', r1.height)
print('area =', r1.area())

print('r2:', r2.width, 'x', r2.height)
print('area =', r2.area())

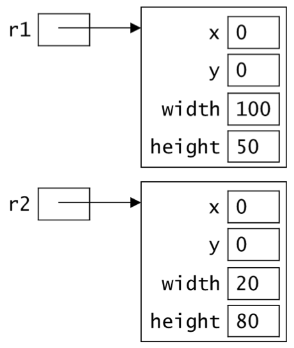
# grow both Rectangles
r1.grow(50, 10)
r2.grow(5, 30)

# print new dimensions
print('r1:', r1.width, 'x', r1.height)
print('r2:', r2.width, 'x', r2.height)
```

Be Objective!

```
class Rectangle:
    ...
    def grow(self, dwidth, dheight):
        ...
    def area(self):
        ...
```

```
r1 = Rectangle(100, 50)
r2 = Rectangle(20, 80)
```



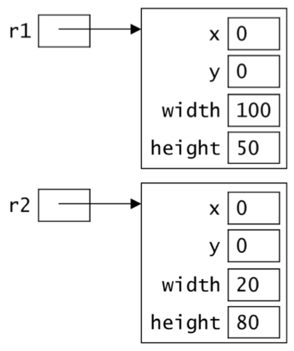
- Give an expression for:
  - the width of `r1`:
  - the height of `r2`:
- Write an assignment that changes `r1`'s x-coordinate to 50:
- Write a method call that:
  - increases `r2`'s width by 5 and height by 10:
  - gets `r1`'s area:

Be Objective!

```
class Rectangle:
    ...
    def grow(self, dwidth, dheight):
        ...

    def area(self):
        ...
```

```
r1 = Rectangle(100, 50)
r2 = Rectangle(20, 80)
```



- Give an expression for:
  - the width of `r1`: `r1.width`
  - the height of `r2`: `r2.height`
- Write an assignment that changes `r1`'s x-coordinate to 50:
  `r1.x = 50`
- Write a method call that:
  - increases `r2`'s width by 5 and height by 10: `r2.grow(5, 10)`
  - gets `r1`'s area: `r1.area()`

Method vs. Function

- Our `area` ***method*** is part of the `Rectangle` class:

```
class Rectangle:
    ...
    def area(self):         # methods have a self
        return self.width * self.height
```

  - thus, it is inside `Rectangle` objects
  - sample call:

```
r.area()
```

- Here's a ***function*** that takes two `Rectangle` objects as inputs:

```
def total_area(r1, r2):    # functions don't
    return r1.area() + r2.area()
```

  - it is *not* part of the class and is *not* inside `Rectangle` objects
  - sample call:

```
total_area(r, other_r)
```

  - it is a client of the `Rectangle` class!

Methods That Modify an Object

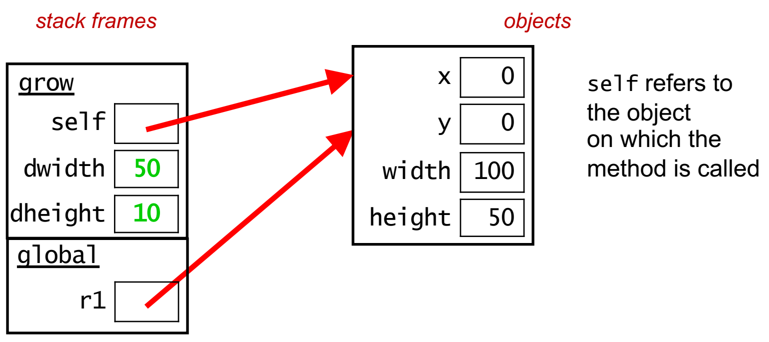
```
class Rectangle:
    """ a blueprint for objects that represent
        a rectangular shape
    """
    def __init__(self, init_width, init_height):
        """ the Rectangle constructor """
        self.x = 0
        self.y = 0
        self.width = init_width
        self.height = init_height

    def grow(self, dwidth, dheight):
        self.width += dwidth
        self.height += dheight
        # why don't we need a return?

    def area(self):
       return self.width * self.height
```

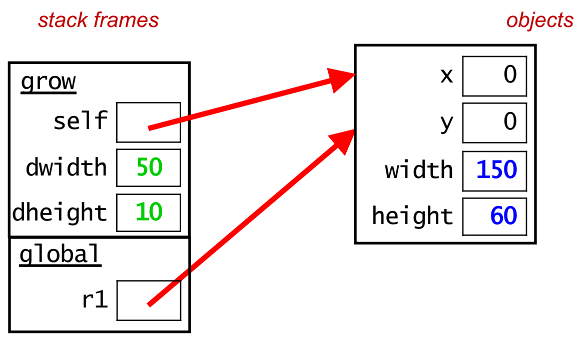
Methods That Modify an Object

```
r1 = Rectangle(100, 50)
r1.grow(50, 10)
print('r1:', r1.width, 'x', r1.height)
```



Methods That Modify an Object

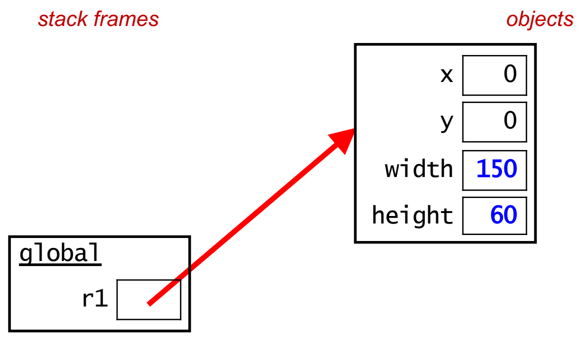
```
r1 = Rectangle(100, 50)
r1.grow(50, 10)
print('r1:', r1.width, 'x', r1.height)
```



the method changes the internals of the object

Methods That Modify an Object

```
r1 = Rectangle(100, 50)
r1.grow(50, 10)
print('r1:', r1.width, 'x', r1.height)
```

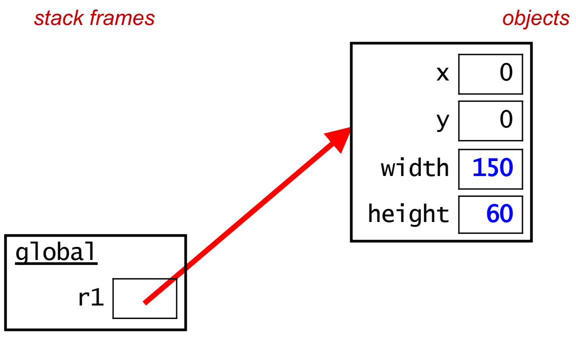


those changes are still there after the method returns

Methods That Modify an Object

```
r1 = Rectangle(100, 50)
r1.grow(50, 10)
print('r1:', r1.width, 'x', r1.height)
```

output: `r1: 150 x 60`



Which of these is a correct perimeter method?

A.
```
def perimeter(self, width, height):
    return 2*width + 2*height
```

B.
```
def perimeter():
    return 2*self.width + 2*self.height
```

C.
```
def perimeter(self):
    return 2*self.width + 2*self.height
```

D. more than one of these

E. none of these

Which of these is a correct perimeter method?

A.
```
def perimeter(self, width, height):
    return 2*width + 2*height
```

B.
```
def perimeter():
    return 2*self.width + 2*self.height
```

C.
```
def perimeter(self):
    return 2*self.width + 2*self.height
```

D. more than one of these

E. none of these

Fill in the blank to call the `perimeter` method.

```
class Rectangle:
    ...
    def perimeter(self):
        return 2*self.width + 2*self.height
```

```
r = Rectangle(35, 20)

perim = ____________________________
```

A. `perimeter(r)`

B. `perimeter(self, r)`

C. `perimeter(self, 35, 20)`

D. `r.perimeter(35, 20)`

E. `r.perimeter()`

Fill in the blank to call the `perimeter` method.

```
class Rectangle:
    ...
    def perimeter(self):
        return 2*self.width + 2*self.height
```

```
r = Rectangle(35, 20)

perim = r.perimeter()
```

A. `perimeter(r)`

B. `perimeter(self, r)`

C. `perimeter(self, 35, 20)`

D. `r.perimeter(35, 20)`

[✓ E. `r.perimeter()`]

`scale` Method

```
class Rectangle:
    ...
    def perimeter(self):
        return 2*self.width + 2*self.height

    def scale(______________________):
```

Write a method called `scale` that will scale the dimensions of a `Rectangle` by a specified factor.

sample call:
`r.scale(5)`

scale Method

```
class Rectangle:
    ...
    def perimeter(self):
        return 2*self.width + 2*self.height

    def scale(self, factor):
        self.width *= factor
        self.height *= factor
```

scale Method

```
class Rectangle:
    ...
    def perimeter(self):
        return 2*self.width + 2*self.height

    def scale(self, factor):
        self.width *= factor
        self.height *= factor
```

```
r = Rectangle(35, 20)
perim = r.perimeter()

# How would we triple the dimensions of r?
```

scale Method

```
class Rectangle:
    ...
    def perimeter(self):
        return 2*self.width + 2*self.height

    def scale(self, factor):
        self.width *= factor
        self.height *= factor
```

```
r = Rectangle(35, 20)
perim = r.perimeter()

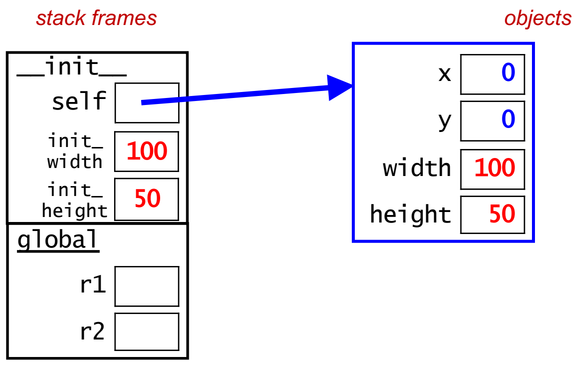
# How would we triple the dimensions of r?
r.scale(3)
```

Why doesn't `scale` *need to return anything?*

Memory Diagrams for Method Calls

```
# Rectangle client code
r1 = Rectangle(100, 50)
r2 = Rectangle(20, 80)

r1.scale(5)
r2.scale(3)
print(r1.width, r1.height, r2.width, r2.height)
```



Memory Diagrams for Method Calls

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r1 = Rectangle(100, 50)
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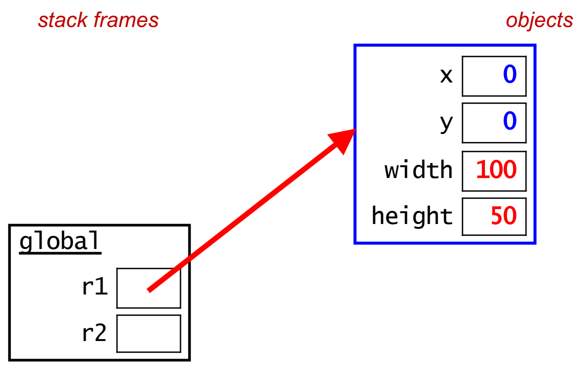
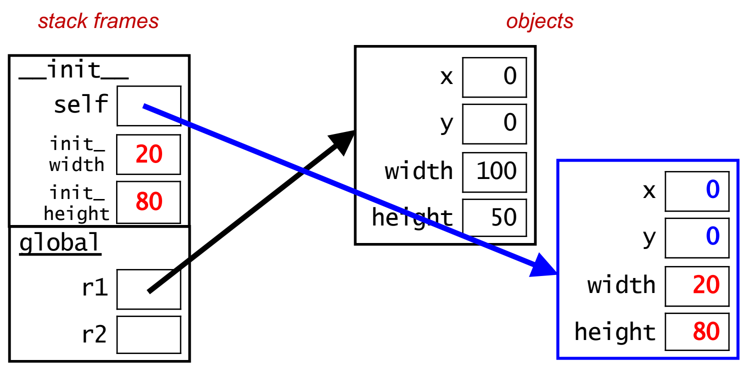
r1.scale(5)
r2.scale(3)
print(r1.width, r1.height, r2.width, r2.height)
```



Memory Diagrams for Method Calls

```
# Rectangle client code
r1 = Rectangle(100, 50)
r2 = Rectangle(20, 80)

r1.scale(5)
r2.scale(3)
print(r1.width, r1.height, r2.width, r2.height)
```



Memory Diagrams for Method Calls

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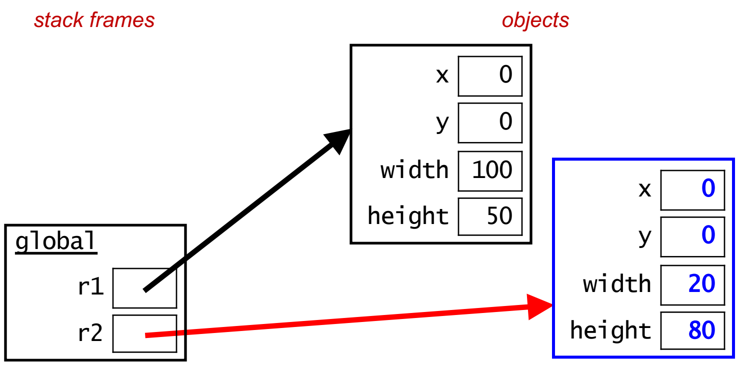
# Rectangle client code
r1 = Rectangle(100, 50)
r2 = Rectangle(20, 80)

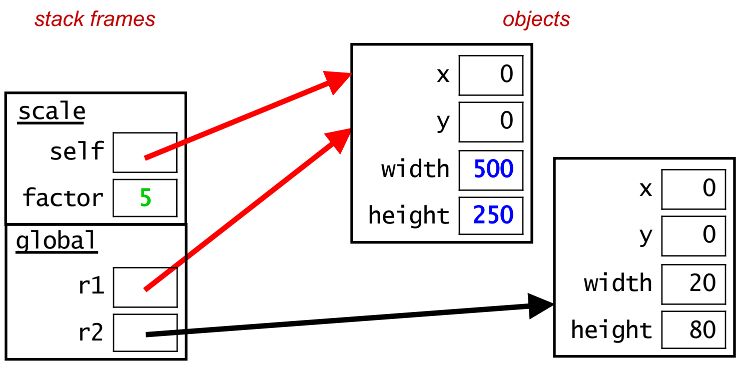
r1.scale(5)
r2.scale(3)
print(r1.width, r1.height, r2.width, r2.height)
```



Memory Diagrams for Method Calls

```
# Rectangle client code
r1 = Rectangle(100, 50)
r2 = Rectangle(20, 80)

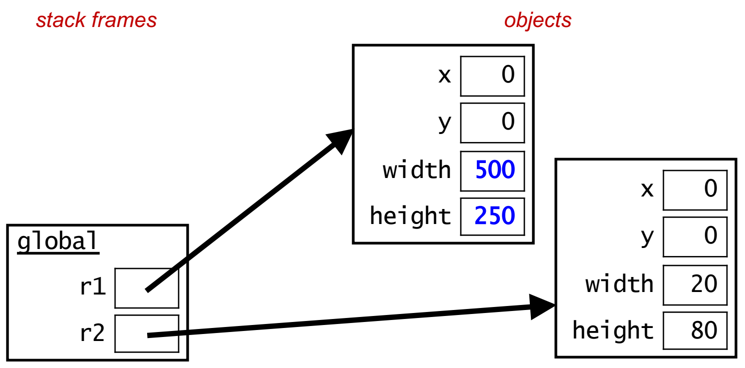
r1.scale(5)
r2.scale(3)
print(r1.width, r1.height, r2.width, r2.height)
```



Memory Diagrams for Method Calls

```
# Rectangle client code
r1 = Rectangle(100, 50)
r2 = Rectangle(20, 80)

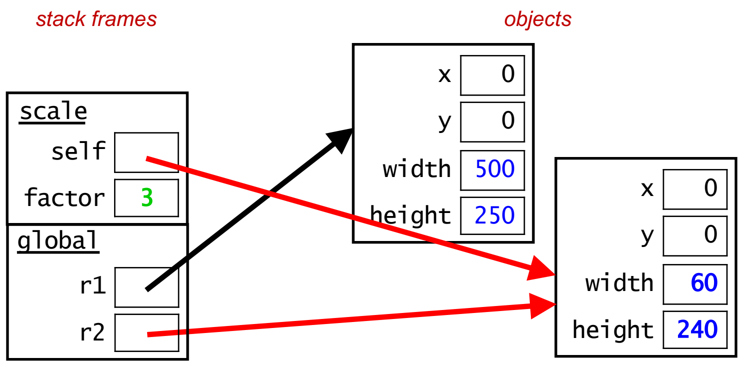
r1.scale(5)
r2.scale(3)
print(r1.width, r1.height, r2.width, r2.height)
```



Memory Diagrams for Method Calls

```
# Rectangle client code
r1 = Rectangle(100, 50)
r2 = Rectangle(20, 80)

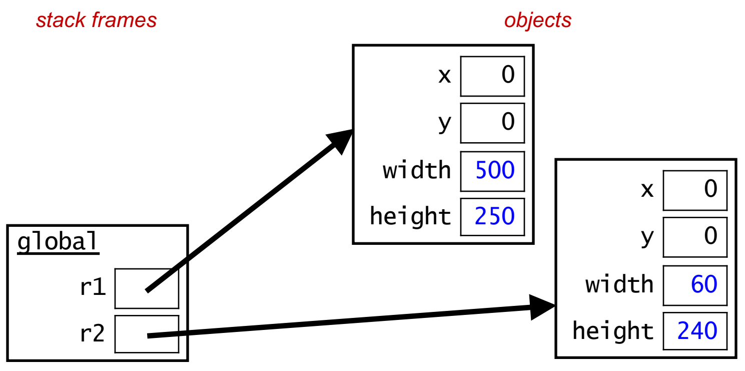
r1.scale(5)
r2.scale(3)
print(r1.width, r1.height, r2.width, r2.height)
```



Memory Diagrams for Method Calls

```
# Rectangle client code
r1 = Rectangle(100, 50)
r2 = Rectangle(20, 80)

r1.scale(5)
r2.scale(3)
print(r1.width, r1.height, r2.width, r2.height)
```

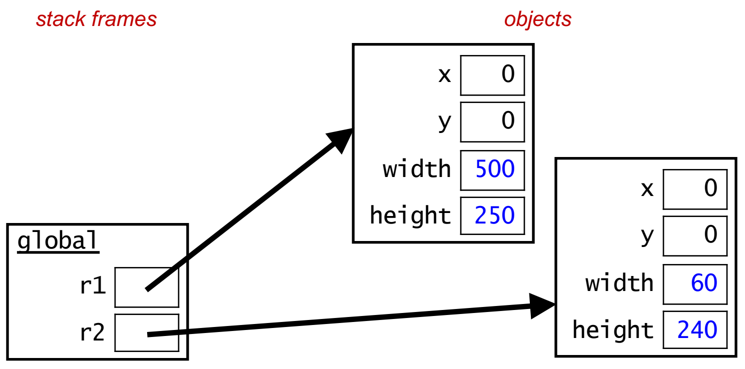


Memory Diagrams for Method Calls

```
# Rectangle client code
r1 = Rectangle(100, 50)
r2 = Rectangle(20, 80)

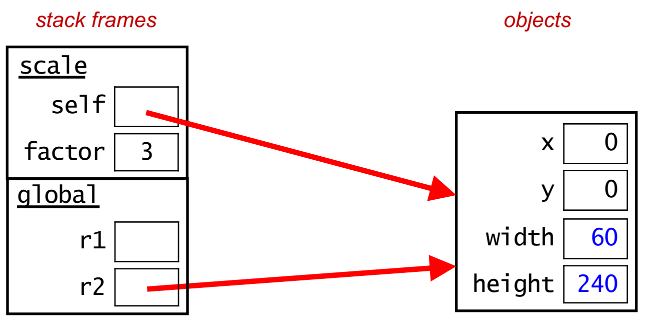
r1.scale(5)
r2.scale(3)
print(r1.width, r1.height, r2.width, r2.height)
```

output: 500 250 60 240



No Return Value Is Needed After a Change

- A method operates directly on the called object, so any changes it makes will be there after the method returns.
  - example: the call `r2.scale(3)` from the last slide



- `scale` gets a copy of the *reference* in `r2`
- thus, `scale's` changes to the *internals* of the object can be "seen" using `r2` after `scale` returns