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Object-Oriented Programming VI

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Lecture Topics

- Multidimensional Arrays
- Objects of Arrays
- Arrays and Methods
  - Arrays as Method Arguments
  - Methods that return Arrays
  - Variable-Length Arguments
- Copying Objects
- Testing Equality of Objects
- Static Fields and Methods

Multidimensional Arrays

- When an array contains arrays, it is called ***multidimensional***.
  - A one-dimensional array:

```
int[] my1DArray = {2, 4, 6};
```

  - A two-dimensional array:

```
int[][] my2DArray = {{8, 3, 7}, {1, 9, 9}, {5, 6, 9}};
```

Multidimensional Arrays

- It’s often better to write two dimensional arrays like this:

```
int[][] my2DArray = {{8, 3, 7},
                     {1, 9, 9},
                     {5, 6, 9}};
```

- This way, it’s easier to see each “row” (first dimension) and “column” (second dimension).

Multidimensional Arrays

- Empty two dimensional arrays are initialized by specifying the number of rows (first) and columns (second):

```
int[][] my2DArray = new int[3][4];
```

Multidimensional Arrays

- Elements in a two dimensional array are referenced by row and column:
  - Row and column numbers start at zero.

```
int[][] my2DArray = {{8, 3, 7},
                     {1, 9, 9},
                     {5, 6, 9}};

my2DArray[1][2] = 2; //Assignment
System.out.println(my2DArray[0][1]); //Retrieval/Prints 3
```

Multidimensional Arrays

```
int[][] my2DArray = {{2, 4, 6},
                     {1, 3, 5},
                     {3, 6, 9},
                     {1, 2, 3}};
```

What element is at **`my2DArray[0][2]`**?

What element is at **`my2DArray[3][1]`**?

What element is at **`my2DArray[1][0]`**?

Multidimensional Arrays

- Rows in a multidimensional array do not have to be the same length.
  - This is called a ***Ragged Array***.

```
int[][] my2DArray = {{2, 4, 6},
                     {1, 3},
                     {9},
                     {1, 2, 3, 4}};
```

- Be careful with ragged arrays as not all rows have the same number of columns.

`my2DArray[2][1]` does not exist, even though every other row has a column 1.

Multidimensional Arrays

- Two for loops are required to iterate through a two-dimensional array.

```
int[][] my2DArray = {{8, 3},
                     {1, 9}};

for(int i = 0; i < my2DArray.length; i++) {
   for(int j = 0; j < my2DArray[i].length; j++) {
       System.out.println(my2DArray[i][j]);
   }
}
```

Rows

Columns

Multidimensional Arrays

- Iteration through a two-dimensional array using enhanced for loops.

```
int[][] my2DArray = {{8, 3},
                     {1, 9}};

for(int[] row : my2DArray) {
   for(int col : row) {
       System.out.println(col);
   }
}
```

Rows

Columns

Multidimensional Arrays

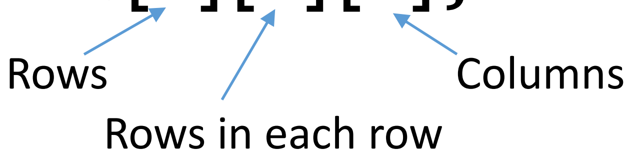
- There is no limit to the number of dimensions an array can have.

- A three-dimensional array:

```
int[][][] my3DArray = {{{4,8},{15,16,23,42}},{{11,33},{22,44}}};
```

- In the case of a three-dimensional array, the rows themselves have rows.

```
int[][][] my3DArray = new int[2][2][3];
```



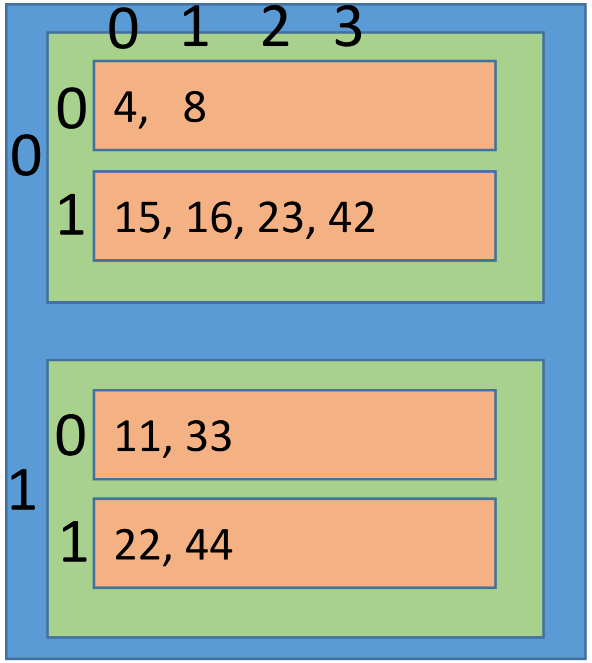
Rows

Rows in each row

Columns

Multidimensional Arrays

```
                         0   1   2   3
int[][][] my3DArray = {{{4, 8},              0
                        {15,16,23,42}},      1    0
                       {{11,33},             0
                        {22,44}}};           1    1
```



What element is at **`my3DArray[0][1][2]`**?

What element is at **`my3DArray[1][0][0]`**?

Multidimensional Arrays

- Three for loops are required to iterate through a three-dimensional array.

```
int[][][] my3DArray = {{{4, 8},
                        {15,16,23,42}},
                       {{11,33},
                        {22,44}}};
```

```
for(int i = 0; i < my3DArray.length; i++) {
   for(int j = 0; j < my3DArray[i].length; j++) {
       for(int k = 0; k < my3DArray[i][j].length; k++) {
          System.out.println(my3DArray[i][j][k]);
       }
   }
}
```

Columns

Inner Rows

Outer Rows

Multidimensional Arrays

- Iteration through a three-dimensional array using enhanced for loops.

```
int[][][] my3DArray = {{{4, 8},
                        {15,16,23,42}},
                       {{11,33},
                        {22,44}}};

for(int[][] outerRow : my3DArray) {
   for(int[] innerRow : outerRow) {
       for(int column : innerRow) {
          System.out.println(column);
       }
   }
}
```

Columns

Inner Rows

Outer Rows

Object of Arrays

- An object can have a field that is an array.
    - If private, the object will have complete control over what data is added to or retrieved from the array.

```
public class ParkingLot {

    private Car[] carLot;

    public ParkingLot(int sizeIn) {
        carLot = new Car[sizeIn];
    }

}
```

Object of Arrays

- This method would control adding Car objects to the ParkingLot object’s carLot field.
    - Checks that a Car object isn’t already parked in the desired space.

```
public void addCar(Car carIn, int spaceIn) {
    if(carLot[spaceIn] == null) {
        carLot[spaceIn] = carIn;
    }
}
```

Object of Arrays

- This method would control removing Car objects to the ParkingLot object's carLot field.
  - Checks that a Car object is parked in that space.

```
public Car removeCar(int spaceIn) {
    if(carLot[spaceIn] == null) {
        return null;
    }
    else {
        Car temp = carLot[spaceIn];
        carLot[spaceIn] = null;
        return temp;
    }
}
```

Object of Arrays

- This method would get the String version of a Car object in the ParkingLot object’s carLot field.
  - Wouldn’t remove the Car object.

```
public String getCarInfo(int spaceIn) {
    if(carLot[spaceIn] != null) {
        return carLot[spaceIn].toString();
    }
    else {
        return "No car parked in this space.";
    }
}
```

Arrays as Method Arguments

- An array can be passed to a method as an argument.

- Must match the array type specified as the parameter.

```
public int sum(int[] numbers)
```

Arrays as Method Arguments

```
public int sum(int[] numbers) {
    int sum = 0;
    for(int number : numbers) {
        sum += number;
    }
    return sum;
}
```

```
int[] threeNums = {4, 5, 6};
sum(threeNums);
```

Would return 15.

Arrays as Method Arguments

- Arrays are always passed to a method **by reference**.

- **Pass by reference**- The reference to data is passed to the method.
  - Arrays and Objects are always passed by reference in Java.

- **Pass by value**- The data is passed to the method.
  - Primitive data are always passed by value in Java.

Passing by Value

```
public void demoMethod(int number) {
    number = 0;
}
```

Changes the number parameter, not x.

```
int x = 5;
demoMethod(x);
```

Passes x’s value as the argument.

Passing by Reference

```
public void demoMethod(int[] array) {
    array[1]= 0;
}
```

Changes the threeNums array.

```
int[] threeNums = {4, 5, 6};
demoMethod(threeNums);
```

Passes threeNums’s reference as the argument.

Variable Length Arguments

- ***Variable Length Arguments*** (or ***varargs***) allow a method to accept an undetermined number of parameters/arguments.

```
        public int sum(int... numbers)
```

- The varargs must all be of the correct type.

- The varargs will be treated as an array inside the method.
  - Varargs *are* arrays, just not declared as such.

Variable Length Arguments

```
public int sum(int... numbers) {
    int sum = 0;
    for(int number : numbers) {
        sum += number;
    }
    return sum;
}
```

`sum(4, 5, 6);`	Valid. Would return 15.
`sum(2, 3);`	Valid. Would return 5.
`sum(7, 8.5);`	Not valid.

Variable Length Arguments

```
public int sum(int... numbers) {
    int sum = 0;
    for(int number : numbers) {
        sum += number;
    }
    return sum;
}
```

```
int[] myOriginalArray = {3, 5, 7, 9};

sum(myOriginalArray);
```

You can pass an array to a vararg. The sum method would return 24 in this example.

Variable Length Arguments

- No additional parameters can follow a vararg.

```
public int doMath(int... numbers, String operationType) {   INVALID
```

- Although, there can be any number of normal parameters preceding it.

```
public int doMath(String operationType, int... numbers) {  VALID
```

Variable Length Arguments

```
public int doMath(String operationType, int... numbers) {
    int answer = 0;
    if(operationType.equals("+")) {
        for(int number : numbers) {
            answer += number;
        }
    } else if(operationType.equals("*")) {
        answer = 1;
        for(int number : numbers) {
            answer *= number;
        }
    }
    return answer;
}
```

```
doMath("+", 4, 5, 6);
doMath("*", 7, 3);
```

Valid. Would return 15.
Valid. Would return 21.

Variable Length Arguments

```
public int doMath(String operationType, int... numbers) {
    int answer = 0;
    if(operationType.equals("+")) {
        for(int number : numbers) {
            answer += number;
        }
    } else if(operationType.equals("*")) {
        answer = 1;
        for(int number : numbers) {
            answer *= number;
        }
    }
    return answer;
}
```

```
int[] threeNums = {4, 5, 6};
doMath("+", threeNums);
```

Valid. Would return 15.

Returning an Array from a Method

- An array can be returned by a method.
  - Be sure the method’s return type is an array.

```
public int[] getNumbers() {
   int[] threeNums = {4, 5, 6};
   return threeNums;
}
```

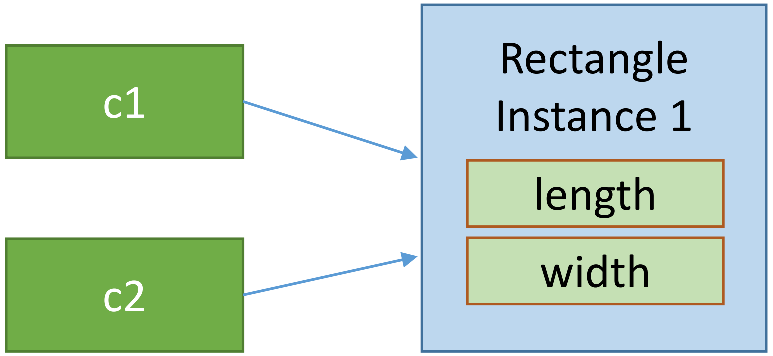
Shallow Copy vs Deep Copy

- There are two ways to create a copy of an instance.

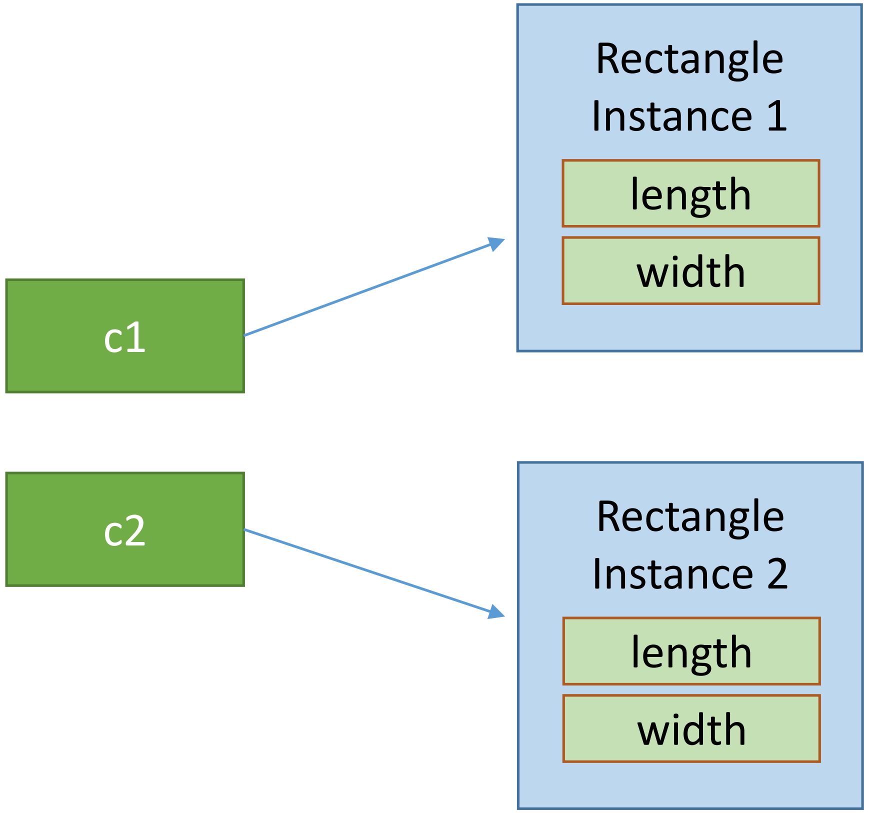
- Deep Copy: The ***data*** referenced by one variable is copied to a new location in memory, and is then referenced by a different variable.

- Shallow Copy: The ***reference*** to data at a location in memory is copied from one variable to a different variable. In essence, both variables reference the same data/object in memory, NOT their own.

Copying Instances



Shallow Copy

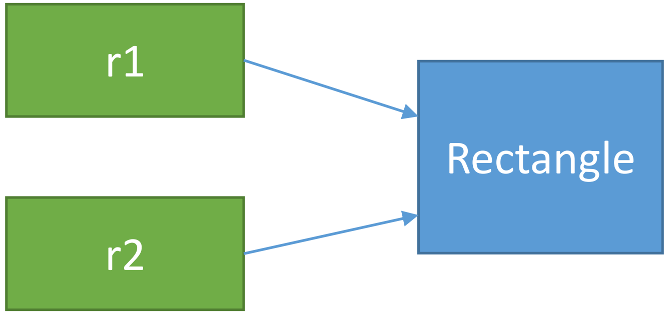


Deep Copy

Shallow Copying Instances

- To shallow copy an instance, simply use the assignment operator =
- Remember, the shallow copy is not a new instance.
  - The new variable will point to the same instance in memory.

```
public static void main(String[] args) {
  Rectangle r1 = new Rectangle(8, 9);
  Rectangle r2 = r1;
  r2.setLength(10);
  System.out.print("r1's length is ");
  System.out.println(r1.getLength());
}
```



```
r1's length is 10
```

Deep Copying Instances

- A deep copy gives us an entirely new instance with the current state of the instance we wish to copy.
  - All fields of the new instance should have the same values as the original instance.

- There are a number of techniques to deep copy instances, but we will look at two:
  - A method that returns a new instance with all of the new instance's fields set to the same values as the original instance.
  - A copy constructor.

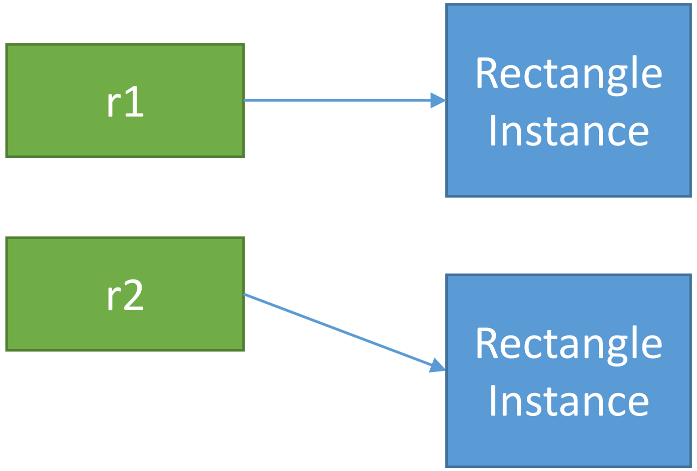
A simple clone method

- This method in the Rectangle class would return a new instance of a Rectangle object, using this instance’s data/fields.

```
public Rectangle clone() {
   return new Rectangle(length, width);
}
```

Deep Copying Instances

```
public static void main(String[] args) {

  Rectangle r1 = new Rectangle(11, 5);
  Rectangle r2 = r1.clone();
  r1.setLength(20);
  System.out.print("r1's length = ");
  System.out.println(r1.getLength());
  System.out.print("r2's length = ");
  System.out.println(r2.getLength());

}
```



```
r1's length = 11
r2's length = 20
```

The values are different because r1 and r2 are their own instances, not shallow copies.

```
public Rectangle clone() {
    return new Rectangle(length, width);
}
```

Copy Constructor

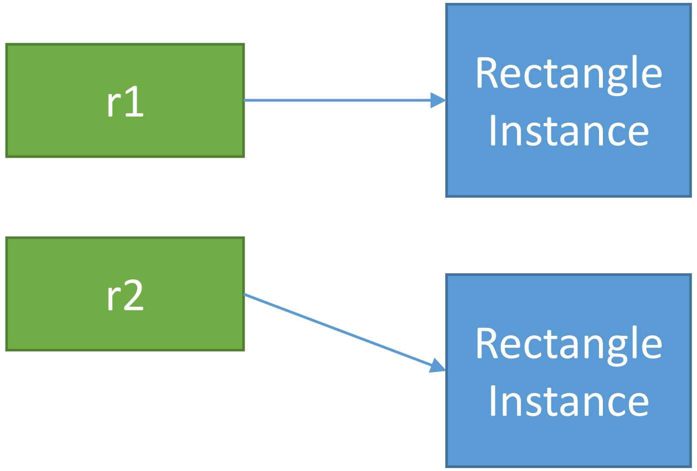
- A ***copy constructor*** is a constructor that takes an object of its own type as its argument.
    - It uses the data of that object to set its own fields.

```
public Rectangle(Rectangle rectangleIn) {
  length = rectangleIn.getLength();
  width = rectangleIn.getWidth();
}
```

Copy Constructor

```
public static void main(String[] args) {

  Rectangle r1 = new Rectangle(5, 4);
  Rectangle r2 = new Rectangle(r1);
  r2.setLength(20);
  System.out.print("r1's length = ");
  System.out.println(r1.getLength());
  System.out.print("r2's length = ");
  System.out.println(r2.getLength());

}
```

```
r1's length = 11
r2's length = 20
```



```
public Rectangle(Rectangle rectangleIn) {
  length = rectangleIn.getLength();
  width = rectangleIn.getWidth();
}
```

Equality of Instances

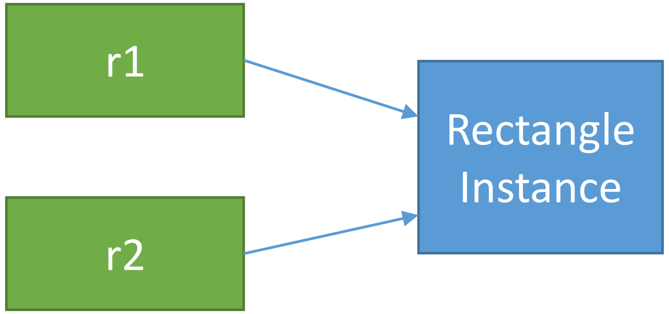
- What does it mean for two instances of an object to be "equal" to each other?
  - Do all of the fields in the two instances need to have the same values? Maybe only some fields?

- Two ways to test equality of instances:
  - If two different variables reference the same instance (ie. they are shallow copies)
  - If two different instances, referenced by two different variables, contain the same data (or however you define “equal”)

Testing the Equality of Instances

- Using the equality operator == will only tell us if the two variables being compared reference the same instance.

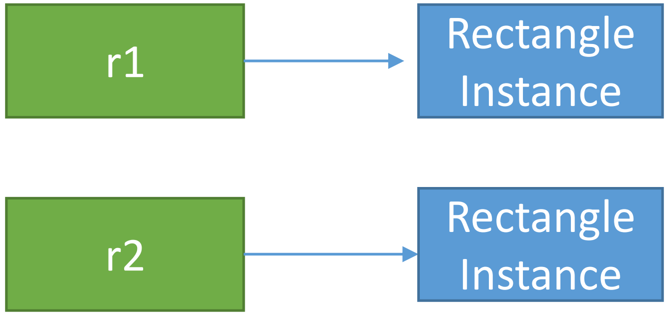
```
Rectangle r1 = new Rectangle(8, 9);
Rectangle r2 = r1;

if(r1 == r2) {
    System.out.println("r1 shares the same reference as r2");
}
```



Testing the Equality of Instances

- Even though r1 and r2’s instances have the same dimensions below, that is not what the equality operator checks for.
    - Since r1 and r2 have different references, the equality operator returns false.

```
Rectangle r1 = new Rectangle(8, 9);
Rectangle r2 = new Rectangle(8, 9);

if(r1 == r2) {
    System.out.println("r1 shares the same reference as r2");
}
```



Testing the Equality of Instances

- Every object is different, so there can be no one-size-fits-all solution.

- To determine if two instances of the same type are "equal", you will need to decide what makes two objects equal and create a method to compare them.

Testing the Equality of Instances

- As an example, we could add the method below to the Rectangle class from earlier in the lecture.
  - We would also now need (at least) getter methods for the length and width fields.
- This equals method compares the fields of the parameter Rectangle object to this Rectangle object’s fields.

```
public boolean equals(Rectangle otherRectangle) {
  if(otherRectangle.getLength() == length &&
     otherRectangle.getWidth() == width) {
    return true;
  }
  return false;
}
```

Testing the Equality of Instances

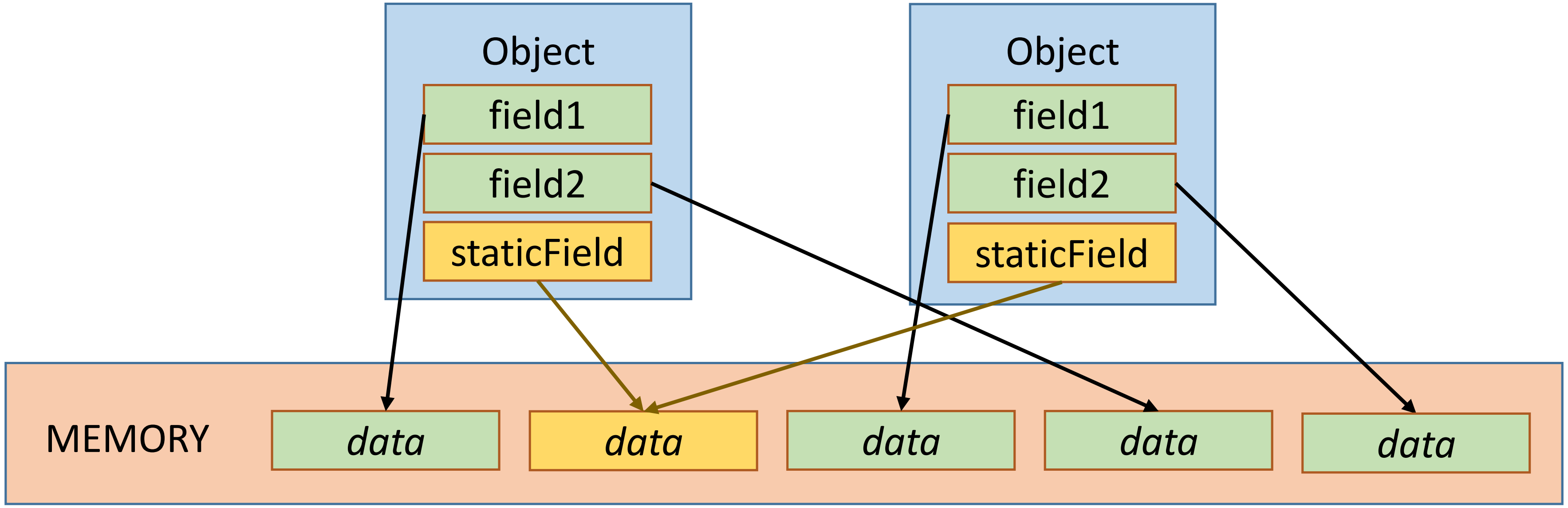
```
Rectangle r1 = new Rectangle(9, 12);
Rectangle r2 = new Rectangle(9, 12);

if(r1.equals(r2)) {
  System.out.println("r1 and r2 have the same dimensions");
}
else {
  System.out.println("r1 and r2 do not have the same dimensions");
}
```

```
r1 and r2 have the same dimensions
```

```
public boolean equals(Rectangle otherRectangle) {
  if(otherRectangle.getLength() == length &&
     otherRectangle.getWidth() == width) {
    return true;
  }
  return false;
}
```

Static Fields

- A ***static field*** (also called a ***class field***) is a field whose reference is shared across **<u>all</u>** instances of the object.
  - Unlike instance fields, which have unique references.



Declaring a Static Field Variable

- Place the **`static`** keyword before the field's data type.

`MODIFIERS` **`static`** ***`TYPE VARIABLE`*****`;`**

Example:

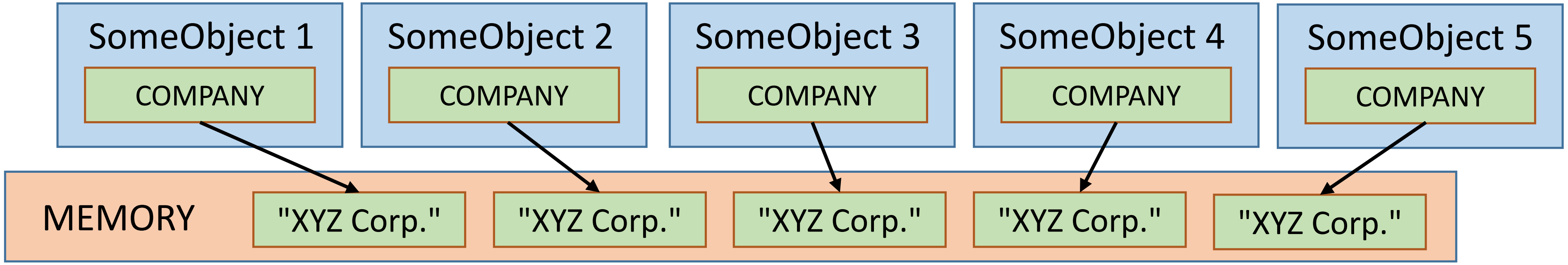
```
private static String myStaticField;
```

Static Fields

- The most common use of a static field is for any fields that are constant.
  - Imagine a class with a constant instance field:

```
public final String COMPANY = "XYZ Corp.";

public SomeObject() {
    ...
}
```

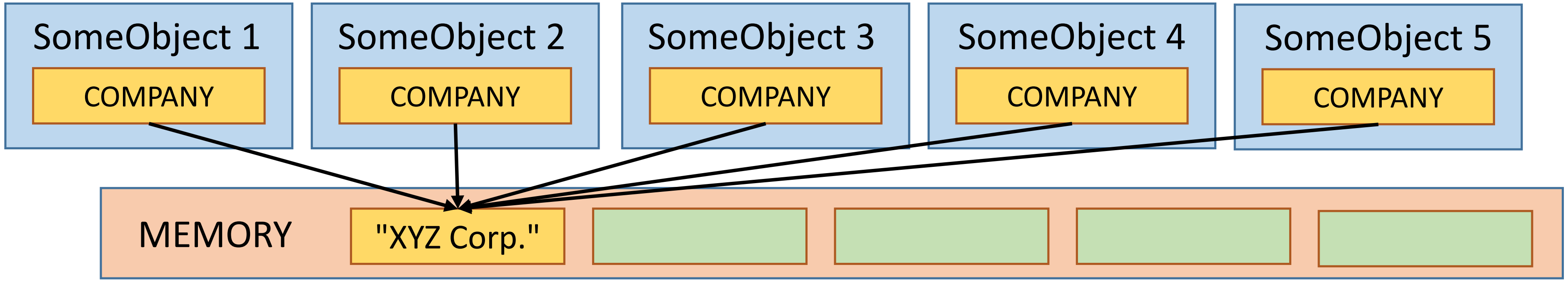
- Every time we instantiate this object, space is allotted for each object's COMPANY field.



Static Fields

- By making the constant a static field, we can save space:

```
public final static String COMPANY = "XYZ Corp.";

public SomeObject() {
    ...
}
```



Static Fields

- Another common use of static fields is to count how many instances of an object has been created:

```
private int length;
private int width;
private static int numInstances = 0;

public Rectangle(int lengthIn, int widthIn) {
    length = lengthIn;
    width = widthIn;
    numInstances += 1;
}
```

Every time a new Rectangle object is instantiated, the constructor increases the value of numInstances by 1.

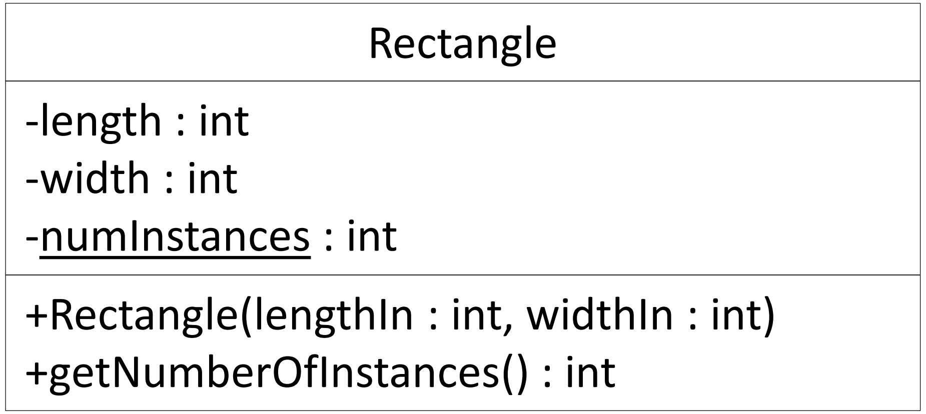
Static Fields

```
private int length;
private int width;
private static int numInstances = 0;

public Rectangle(int lengthIn, int widthIn) {
    length = lengthIn;
    width = widthIn;
    numInstances += 1;
}

public int getNumberOfInstances() {
    return numInstances;
}
```

Since the numInstances variable is static, the same value will be referenced for any instance of a Rectangle object.

Static Members in UML

- In UML Class Diagrams, static members are underlined.
  - Only the name; not type, return type, or parameters.



Rectangle

-length : int
-width : int
-numInstances : int

+Rectangle(lengthIn : int, widthIn : int)
+getNumberOfInstances() : int

Static Fields

```
public static void main(String[] args) {
    Rectangle r1 = new Rectangle(8, 9);
    System.out.println("Total instances = " + r1.getNumberOfInstances());
    Rectangle r2 = new Rectangle(10, 3);
    System.out.println("Total instances = " + r1.getNumberOfInstances());
}
```

```
Total instances = 1
Total instances = 2
```

- Every println statement uses "r1"
  - Notice we haven’t done anything to r1 besides call a getter method.
- Every constructor call incremented the value of the numInstances field, which shares the same reference across all instances.

Using Static Fields Within a Class

- Static variables have class scope.
  - They can be used by all methods and constructors in the class, just like any instance variable.

```
private double nonStaticExample;
private static int staticExample;

public SomeObject() {
    staticExample += 1;
    nonStaticExample += 2.5;
    ...
}

public double getSumOfValues() {
    return staticExample + nonStaticExample;
}
```

Using Static Fields Within a Class

- However, local variables cannot be static.

```
public void exampleMethod() {
  static int value;
  ...
}
```

Will not compile

Static Methods

- A ***static method*** is a method that can be called without having an instance of the object.
  - When you get the square root of a number using the Math class, notice how you don’t have to instantiate a Math object to do so. The sqrt method, like all methods in the Math class, are static.

```
Math.sqrt(16.0);
```

  - IMPORTANT: Since static methods can be called without an instance of the object, the body of a static method cannot use its object’s instance fields.

Declaring a Static Method

- Place the **`static`** keyword before the method's return type.

```
MODIFIERS static TYPE NAME(PARAMETERS) {
```

Example:

```
public static String myStaticMethod() {
```

Static Methods

- The add method in the Calculate class below can be called with or without an instance of the object.

```
public class Calculate {

  public static int add(int operand1, int operand2) {
    return operand1 + operand2;
  }

}
```

```
public static void main(String[] args) {
  Calculate calc = new Calculate();
  System.out.print("The sum of 5 and 6 is ");
  System.out.println(calc.add(5, 6));
}
```

```
public static void main(String[] args) {
  System.out.print("The sum of 5 and 6 is ");
  System.out.println(Calculate.add(5, 6));
}
```

Static Methods vs Non-Static Methods

- Static methods
  - Can contain local variables of any data or object type.
  - Can use the static fields of its class.
  - Cannot use the instance fields of its class.
  - Can call any static methods in the same class.
  - Cannot call any non-static methods in the same class.
    - As non-static methods may rely on using instance fields.
  - Can be called without an instance of the class.

- Non-static methods
  - Can contain local variables of any data or object type.
  - Can use any (static or non-static) fields of its class.
  - Can call any method (static or non-static) in the same class.
  - Cannot be called without an instance of the class.