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Object Oriented Programming

Abstraction and Encapsulation

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Lecture Topics

- Basics of Object Oriented Design
  - Objects
  - Classes
- Instance Variables/Fields
- Constructors
- Access Modifiers
- Methods
  - Mutator Methods
  - Accessor Methods
  - Utility Methods
- Class Diagrams
- Overloaded Methods
- String Representation
- Copying Objects
- Object Equality
- Static Fields and Methods

Colors/Fonts

- Local Variable Names – Brown
- Primitive data types – Fuchsia
- Literals – Blue
- Keywords – Orange
- Object names – Green
- Operators/Punctuation – Black
- Field Names – Lt Blue
- Method Names – Purple
- Parameter Names – Gold
- Comments – Gray
- Package Names – Pink

Source Code – **Consolas**
Output – Courier New

What is Object Oriented Programming?

- A programming paradigm where software is written so that a program functions as a system of objects.
  - A different way of designing software.

- The objects interact with each other to complete the program's tasks.

- Software objects are coded to contain information about themselves and allow interaction with other objects.

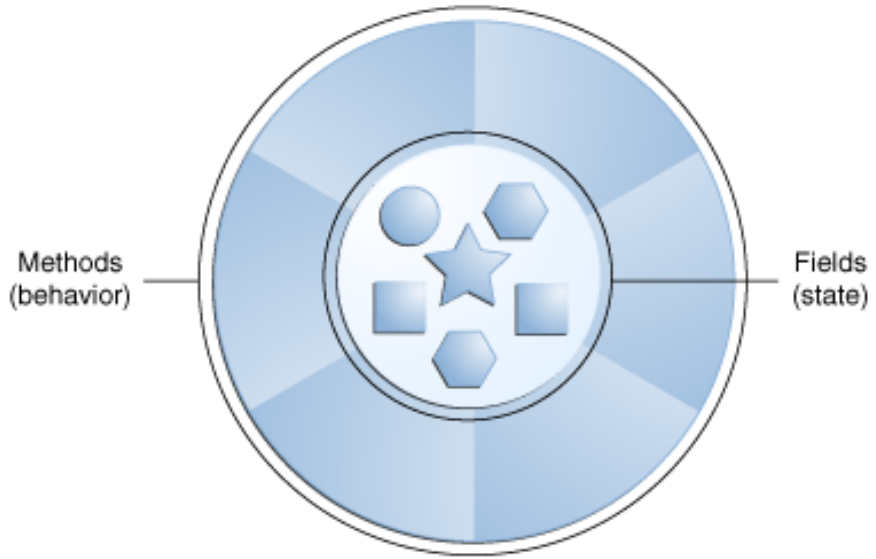
What are Objects?

- A software object is *conceptually* similar to real world objects.
- Real world objects all have two characteristics:
  - They have ***attributes***- properties that make something unique.
    - A bicycle's attributes could be its speed, color, tire size, etc.
  - They have ***behaviors***- actions that it can do.
    - A bicycle's behaviors could be pedaling, braking, changing gear, etc.

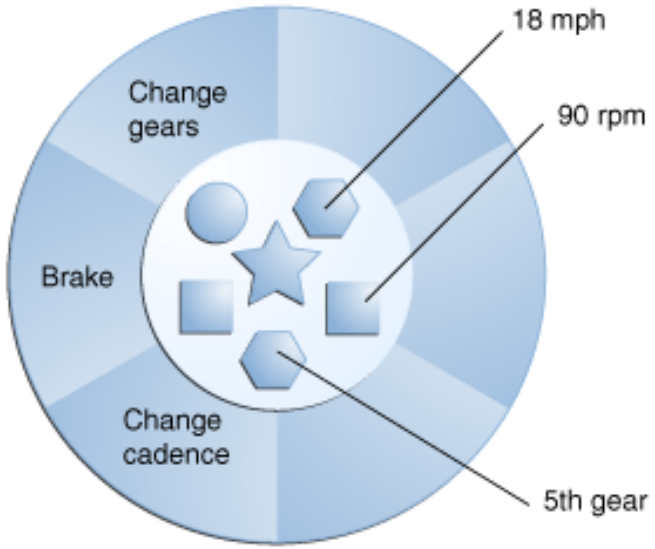
- When we model a software object, it too has attributes and behaviors.
  - Objects store their attributes in variables referred to as ***fields.***
  - Objects expose their behaviors as ***functions.***

A Bicycle Object

Software Object



Bicycle Object



Why apply Object Oriented Programming?

- Modularity (Abstraction)
  - The code for an object is written and maintained separately from the code of other objects.
- Information Hiding (Encapsulation)
  - By interacting with the object's methods, the details of its internal implementation is hidden.
- Reusability
  - You can create multiple instances of an object.

Abstraction

- ***Abstraction*** is an OOD principle that software objects are able to function as individual entities.

- Using fields, the object can hold information about itself.

- Using methods, the object can perform various actions and operations and communicate with other objects.

Encapsulation

- ***Encapsulation*** is an OOD principle that suggests we design objects so that all relevant data (attributes) and behaviors (methods) are together.
  - The object also controls how its information is seen or changed.

- Only attributes and behaviors relevant to the object should be in the object.
  - Other data or functions not related to the object's use should be placed in other objects.
  - For example, it wouldn't make sense for a Bicycle object to have a fuel level attribute (but would, perhaps, make sense in a Moped object.)

What are Classes?

- A ***class*** is the blueprint from which objects are created.

- It is the *source code* of the object.
  - The object is the idea, the code in the class is the implementation of the idea.

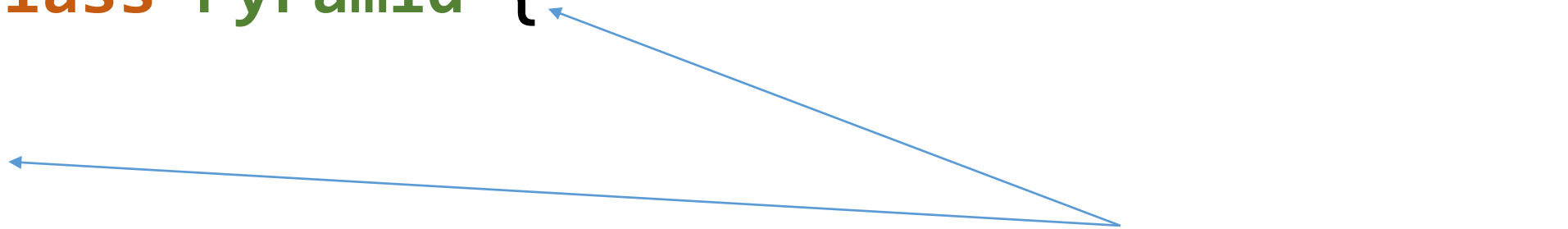
- When a new software object is created from a class, this is referred to as instantiation.
  - *Creating a new instance of an object.*
  - *Instantiating an object.*

Classes

- ***Class Declaration*** (or ***Class Header***) for an object named “Pyramid” is shown below.

```
class Pyramid {

}
```



Classes

- We will create a Pyramid class throughout the rest of this lecture.
- After completing our Pyramid class, we will instantiate a Pyramid object in a separate program.
- We have been using classes already.
  - We have only seen the use of a *main* method, which is not required in every class.
  - A main method allows the JVM to know where to start executing a Java program.

Instance Variables

- An ***instance variable*** is a field that is accessible by the methods of the class.
  - It is declared inside the class, but outside of any method.

- The data stored in an instance variable is unique to each instance of an object.

Declaring Instance Variables

```
class Pyramid {

   int width;
   int length;
   int height;
   String color;

}
```

- Declared just as we have seen before, but not within any particular method.
- Can be initialized at declaration or in a method.

Creating an Instance of an Object

- In a second class (and in a separate source code file) named PyramidTest, we will ***instantiate*** a Pyramid object in its main method (shown below).
  - ***Instantiation*** is the term used when you create an ***instance*** of an object.

```
class PyramidTest {

    public static void main(String[] args) {
        Pyramid example = new Pyramid();

    }
}
```

The Default Constructor

- Objects are instantiated using a special method called a ***constructor***.
- Constructors are used to “set up” or *construct* an instance of an object.
- When there are no constructors present in a class, the compiler automatically adds a ***default constructor***.
  - This guarantees every object has a constructor.

```
class Pyramid {

    public static void main(String[] args) {
        Pyramid example = new Pyramid();

    }
}
```

Accessing an Instance's Fields

- We can access an instance's fields using dot notation.

```
class PyramidTest {

    public static void main(String[] args) {
        Pyramid example = new Pyramid();

        //Sets the object's width attribute to 3
        example.width = 3;

    }
}
```

Accessing an Instance's Fields

- We can access an instance's fields using dot notation.

```
class PyramidTest {

    public static void main(String[] args) {
        Pyramid example = new Pyramid();

        //Sets the object's width attribute to 3
        example.width = 3;
        System.out.println("The pyramid's width is " + example.width);

    }
}
```

```
The pyramid's width is 3
```

Constructors

- Constructors are a special type of method/behavior that prepares the instance of the object.

- Constructors almost always have the same name as the class file.
  - Not always the case as a single source code file can contain multiple classes.

- Classes may have multiple constructors.
  - This is referred to as ***overloading*** or having ***overloaded constructors***.

The No Argument (No-Arg) Constructor

```
class Pyramid {

    int width;
    int length;
    int height;
    String color;

    Pyramid() {
        width = 1;
        length = 1;
        height = 5;
        color = "White";
    }


}
```

- Replaces the default constructor added by the compiler.
  - A class only has a default constructor when the class has no constructors defined.
- The code in the no-arg constructor's body will be executed when the no-arg constructor is called.
- The names of any constructors must always match the class name.

Without the No-Arg Constructor

```
class PyramidTest {

    public static void main(String[] args) {
        Pyramid example = new Pyramid();

        System.out.println("The pyramid's width is " + example.width);
        System.out.println("The pyramid's length is " + example.length);
        System.out.println("The pyramid's height is " + example.height);
        System.out.println("The pyramid's color is " + example.color);
    }
}
```

```
The pyramid's width is 0
The pyramid's length is 0
The pyramid's height is 0
The pyramid's color is null
```

With the No-Arg Constructor defined

```
class PyramidTest {

    public static void main(String[] args) {
        Pyramid example = new Pyramid();

        System.out.println("The pyramid's width is " + example.width);
        System.out.println("The pyramid's length is " + example.length);
        System.out.println("The pyramid's height is " + example.height);
        System.out.println("The pyramid's color is " + example.color);
    }
}
```

```
The pyramid's width is 1
The pyramid's length is 1
The pyramid's height is 5
The pyramid's color is white
```

Passing Values into a Constructor

- In many cases, you will want to pass data into a constructor to set the values of the fields.

- ***Parameters*** are variables that represent data that is given (or *passed*) to a constructor.
  - Data given to the constructor are called ***arguments***.

- If a constructor declares a parameter list, a value for each parameter must be present.
  - The list must include the data type for each parameter.

Constructors

```
Pyramid() {
    width = 1;
    length = 1;
    height = 5;
    color = "White";
}
```

No-Arg Constructor

Parameter

```
Pyramid(int widthIn) {
    width = widthIn;
    length = 1;
    height = 5;
    color = "White";
}
```

A Constructor with 1 Parameter

Constructors

- Now, we have a second way to instantiate an instance of a Pyramid object.

```
class PyramidTest {

    public static void main(String[] args) {
        Pyramid example1 = new Pyramid();
        Pyramid example2 = new Pyramid(5);

        System.out.println("The first pyramid's width is " + example1.width);
        System.out.println("The second pyramid's width is " + example2.width);
    }
}
```

Argument

```
The first pyramid's width is 1
The second pyramid's width is 5
```

Constructors

```
Pyramid() {
    width = 1;
    length = 1;
    height = 5;
    color = "White";
}

Pyramid(int widthIn) {
    width = widthIn;
    length = 1;
    height = 5;
    color = "White";
}

Pyramid(int widthIn, int lengthIn) {
    width = widthIn;
    length = lengthIn;
    height = 5;
    color = "White";
}
```

No-Arg Constructor

A Constructor with 1 Parameter

A Constructor with 2 Parameters

Constructors

```
Pyramid(int widthIn, int lengthIn, int heightIn) {
    width = widthIn;
    length = lengthIn;
    height = heightIn;
    color = "White";
}

Pyramid(int widthIn, int lengthIn, int heightIn, String colorIn) {
    width = widthIn;
    length = lengthIn;
    height = heightIn;
    color = colorIn;
}
```

A Constructor with 3 Parameters

A Constructor with 4 Parameters

Constructors

- Now, there are 5 different ways to instantiate an instance of a Pyramid object.

```
class PyramidTest {

    public static void main(String[] args) {
        Pyramid example1 = new Pyramid();
        Pyramid example2 = new Pyramid(5);
        Pyramid example3 = new Pyramid(7, 7, 15, "Blue");

        System.out.println("The third pyramid's height is " + example3.height);
        System.out.println("The third pyramid’s color is " + example3.color);
    }
}
```

```
The third pyramid’s height is 15
The third pyramid’s color is Blue
```

Constructor Signatures

- There is no limit to the number of constructors in a class.
- However, each constructor must have a unique ***signature***.
  - A constructor signature consists of its name and parameter list data types.

```
Pyramid()
Pyramid(int widthIn)
Pyramid(int widthIn, int lengthIn)
Pyramid(int widthIn, int lengthIn, int heightIn)
Pyramid(int widthIn, int lengthIn, int heightIn, String colorIn)
```

Signatures:

Pyramid()
Pyramid(int)
Pyramid(int, int)
Pyramid(int, int, int)
Pyramid(int, int, int, String)

Constructor Signatures

- If our Pyramid class had the following constructors, it would not compile.
  - Their signatures are not unique.

```
Pyramid(int widthIn) {
    width = widthIn;
    length = 1;
    height = 5;
    color = "White";
}
```

→ Pyramid(int)

```
Pyramid(int lengthIn) {
    width = 1;
    length = lengthIn;
    height = 5;
    color = "White";
}
```

→ Pyramid(int)

```
Pyramid example = new Pyramid(5);
```

There's no way to know which constructor to use.

Access Modifiers

- Access Modifiers specify how classes, fields, and methods can be accessed by other objects.
  - This limits other objects from making changes to the data in the fields or using methods that pertain only to the object's internal implementation.

public

- Modifier that allows a field or method to be accessible to all other objects.

private

- Modifier that does not allow a field or method to be accessible to other objects.

Private Fields

```
public class Rectangle {

   private int length;
   private int width;

}
```

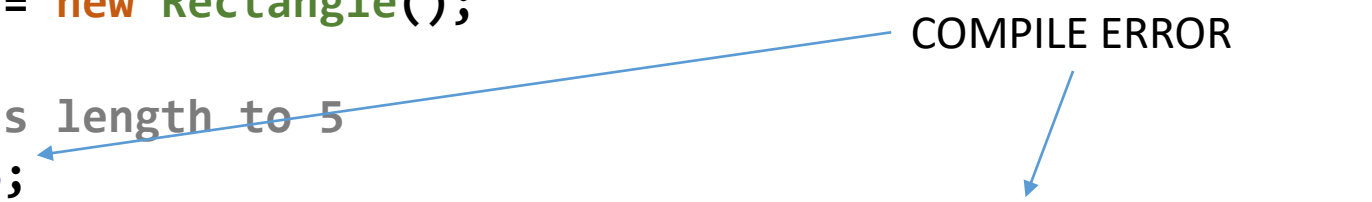
- This Rectangle class has two private fields.
- These fields cannot be accessed anywhere except from within the Rectangle class.

Private Fields

```
public class RectangleTest {

    public static void main(String[] args) {
        Rectangle example = new Rectangle();

        //Sets the object's length to 5
        example.length = 5;
        System.out.println("The third pyramid's height is " + example.length);
  }
}
```



- A private field is not accessible.
- The only way to change or retrieve the value of a field would be to use a *method*.

Methods

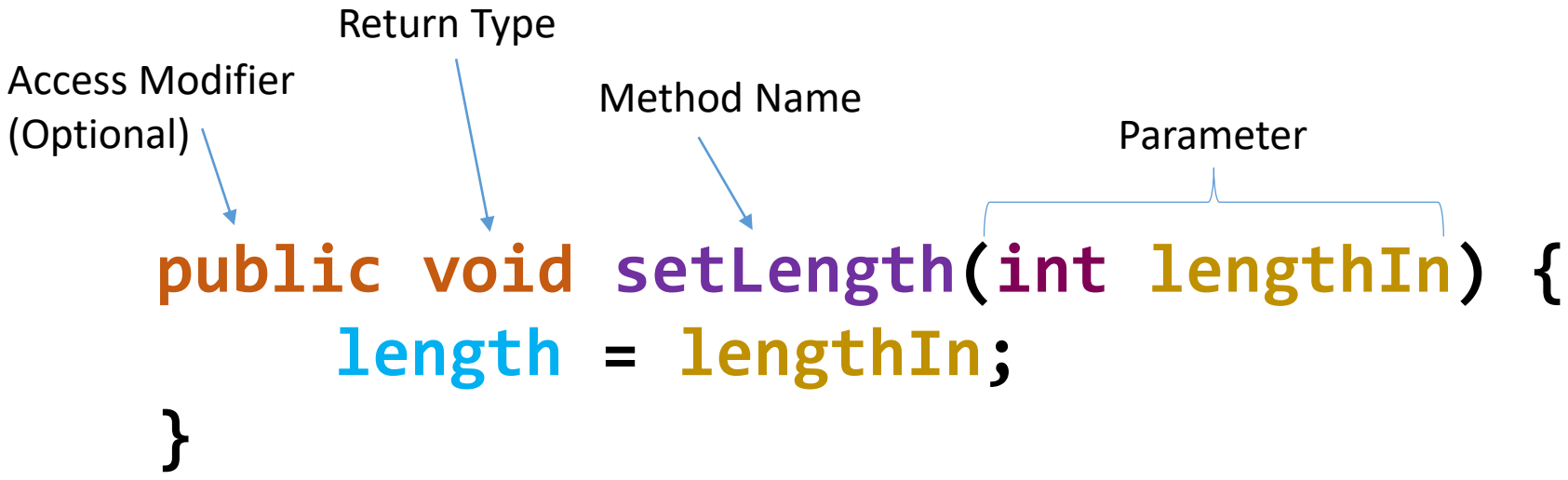
- A ***method*** is a collection of statements that operates on an object's internal data.
  - After the method finishes executing its code, it may or may not return data.

- The code in a method runs when the method is *called*.

Methods

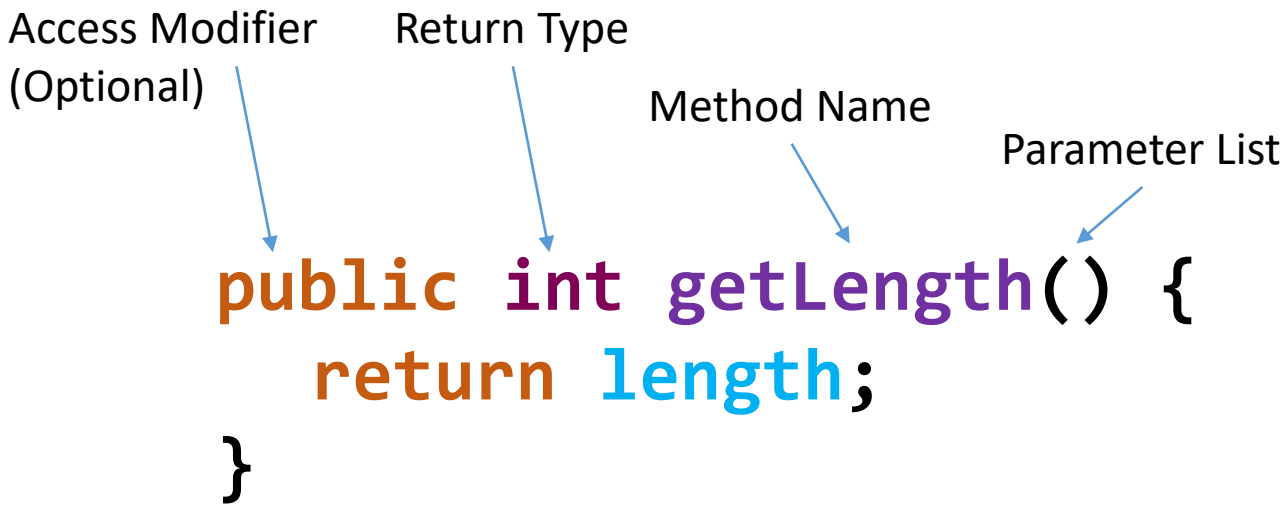
- Most methods in an object are either a mutator method or an accessor method.
- A **mutator method** changes (or “sets”) data in an object.
  - Colloquially called a “setter” method.
- An **accessor method** retrieves (or “gets”) data from an object.
  - Colloquially called a “getter” method.
- The use of mutators and accessors allows the object to specify how (and if) its private data is accessed or changed.

Mutator Method (Length)



- This method will change the current value of the object's length field.
- A method that does not return data must have a **void** return type.
  - Mutators typically do not return data. They "set" data- they don't "get" data.

Accessor Method (Length)



- This method will return the current value of our gear instance variable.
- A ***return statement*** indicates the value that is returned by the method.
- The type of data returned must match the method's return type.
  - Since this method's return type is int, the method can only return an int value when called.

Using Method Calls to set/get an Instance's Data

```
public class RectangleTest {

    public static void main(String[] args) {
        Rectangle example = new Rectangle();

        example.setLength(7);
        System.out.println("The rectangle's length is " + example.getLength());
    }

}
```

Argument

```
The rectangle's length is 7
```

Parameter

```
public void setLength(int lengthIn) {
     length = lengthIn;
}

public int getLength() {
     return length;
}
```

Accessor and Mutator Method (Width)

```
public void setWidth(int widthIn) {
   width = widthIn;
}

public int getWidth() {
   return width;
}
```

Using Method Calls to set/get an Instance's Data

```
public class RectangleTest {

    public static void main(String[] args) {
        Rectangle example = new Rectangle();

        example.setLength(5);
        example.setWidth(10);
        System.out.println("The rectangle's length is " + example.getLength());
        System.out.println("The rectangle's width is " + example.getWidth());
    }

}
```

```
The rectangle's length is 5
The rectangle's width is 10
```

Checking Data

- Using mutators to change the state of the object gives the object control of its state.

- For example, we can add checks to the length and width field mutators to check for negative distances or distances of zero.
  - The object (through its methods) can decide what happens.

Checking Data

- Additional code can be added to the mutator to check the argument passed to it.
  - Now, a zero or negative argument will cause the length field to be assigned 1.

```
public void setLength(int lengthIn) {
   if(lengthIn <= 0) {
      length = 1;
   }
    else {
      length = lengthIn;
   }
}
```

Checking Data

- A similar check can be added in the mutator for the width field.

```
public void setWidth(int widthIn) {
   if(widthIn <= 0) {
      width = 1;
   }
    else {
      width = widthIn;
   }
}
```

Using Method Calls to set/get an Instance's Data

```
public class RectangleTest {

    public static void main(String[] args) {
        Rectangle example = new Rectangle();

        example.setLength(-66);
        example.setWidth(0);
        System.out.println("The rectangle's length is " + example.getLength());
        System.out.println("The rectangle's width is " + example.getWidth());
    }

}
```

```
The rectangle's length is 1
The rectangle's width is 1
```

It's now impossible for a Rectangle object's length or width fields to be zero or negative.

Utility Methods

- Another type of method is a **utility method**.
  - These are methods that aren't wholly concerned with setting or getting data to/from an object, but perform some other operation or function.
  - A utility function may or may not return data.

- A Rectangle object might have a utility method to calculate the area or perimeter of the shape.

Utility Method (Area)

- This calculateArea method will calculate and return the area of the shape.

```
public int calculateArea() {
    int area = length * width;
    return area;
}
```

Utility Method (Perimeter)

- This calculatePerimeter method will calculate and return the perimeter of the shape.

```
public int calculatePerimeter() {
    int perimeter = 2 * (length + width);
    return perimeter;
}
```

Utility Methods

```
public class RectangleTest {

    public static void main(String[] args) {
        Rectangle example = new Rectangle();

        example.setLength(6);
        example.setWidth(5);
        int calc1 = example.calculateArea();
        int calc2 = example.calculatePerimeter();
        System.out.println("The rectangle's area is " + calc1);
        System.out.println("The rectangle's perimeter is " + calc2);
    }

}
```

```
The rectangle's area is 30
The rectangle's perimeter is 22
```

Method Naming

- By convention (in Java), method names are in camel-case.

- A method's name should always describe what it does.
  - Accessor methods normally start with "get".
    - For example: getValue, getName
  - Mutator methods normally start with "set".
    - For example: setValue, setName
  - Utility functions will vary in name.
    - For example: fixHeaders, validateData, updateValues, toSquareFeet
  - Methods that return a boolean normally start with "is" or "has".
    - For example: isFinished, isClosed, hasCorrectData

Method Access

- Accessor and mutator methods are normally public.
  - Other objects need to call these methods to interact with the object.

- Utility methods may or may not be public.
  - It depends on the object's design.
  - Make the method private if you don't want other objects to call it.

Method Signatures

- Like constructors, methods have signatures.
- A method signature consists of its name and parameter list data types.
- All methods in a class must have unique signatures.

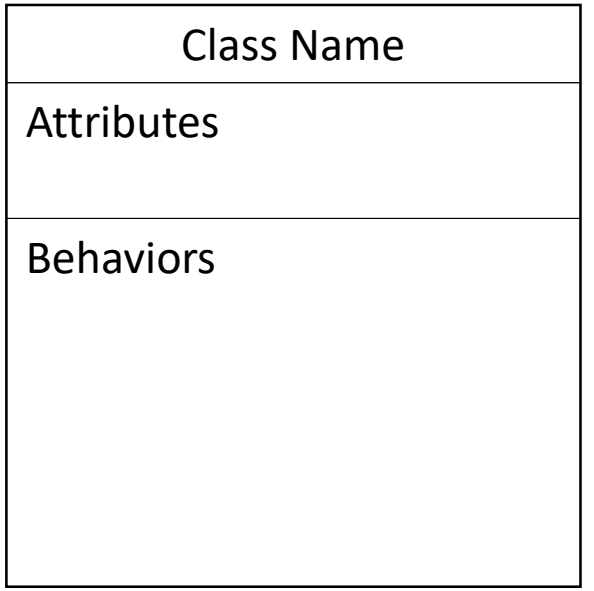
```
public void exampleMethod(int arg1, String arg2)
```
→ exampleMethod(int, String)

```
public int exampleMethod2()
```
→ exampleMethod2()

```
public String exampleMethod3(String[] arg1)
```
→ exampleMethod3(String[])

Class Diagrams

- Unified Modeling Language provides a set of standard diagrams for graphically depicting an object oriented system.
- In UML, each class is shown as a box, with three sections:
  - The Class Name
  - Class Attributes (Fields/Variables)
  - Class Behaviors (Constructors and Methods)



Class Diagrams

- When displaying fields (and parameter names in methods) in a class diagram, the format to use is:
  - name : type

- Access specifier symbols:
  - \+ public fields/methods
  - \- private fields/methods
  - None (or ~) No access specifier.

Class Diagram (Fields)

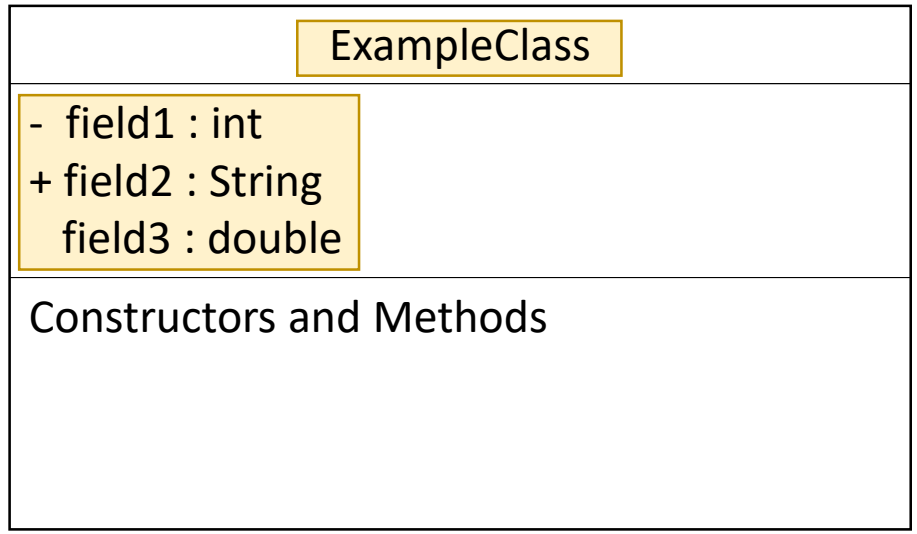
```
class ExampleClass {
    private int field1;
    public String field2;
    double field3;

    public ExampleClass(int argIn) {
         //Constructor code
    }

    int method1(double arg1In, int arg2In) {
        //method1 code
    }

    private void method2() {
        //method2 code
    }

}
```



Class Diagrams (Constructors and Methods)

- When displaying a constructor in a class diagram, the format to use is:
  - name(arg : type, …)

- When displaying a method in a class diagram, the format to use is:
  - name(arg : type, …) : returnType

- Access modifier symbols used are the same as for fields.

Class Diagram (Constructors and Methods)

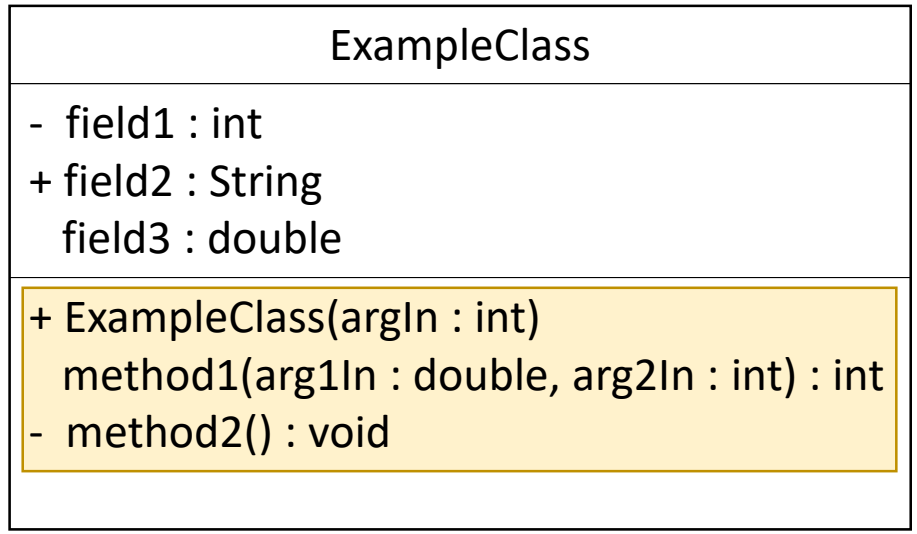
```
class ExampleClass {
    private int field1;
    public String field2;
    double field3;

    public ExampleClass(int argIn) {
        //Constructor code
    }

    int method1(double arg1In, int arg2In) {
        //method1 code
    }

    private void method2() {
        //method2 code
    }

}
```



Overloaded Methods

- A method is ***overloaded*** when two or more methods share the same name but have *different parameter types/lists*.

- No limit to the number of times a method can be overloaded.

```
public void setLength(int lengthIn) {
    if(lengthIn <= 0) {
        length = 1;
    }
   else {
        length = lengthIn;
    }
}

public void setLength(double lengthIn) {
    if(lengthIn <= 0) {
        length = 1;
    }
   else {
        length = (int)Math.round(lengthIn);
    }
}
```

Overloaded Methods

- Overloaded methods give the appearance of one method that handles multiple types of arguments.
  - Overloaded methods are also known as ***polymorphic methods*** for this reason.

```
class RectangleTest {

    public static void main(String[] args) {
        Rectangle example = new Rectangle();
        example.setLength(7);
        example.setLength(4.3); //Changes the length to 4.3 (rounded to 4)
    }
}
```

String Represenation

- An object's **toString()** method normally returns a String that describes the current state of an object.
  - It may include some or all of the current values of the object's fields.
  - Can be useful for debugging

- All objects have a toString() method, even if the method is not defined in the class.

An object **without** a toString() method defined

```
public class Circle {

    private int radius;
    private double area;
    private double circumference;

    public Circle(int radiusIn) {
        radius = radiusIn;
        area = Math.pow(Math.PI * radius, 2);
        circumference = 2 * Math.PI * radius;
    }

}
```

```
public class CircleTest {

  public static void main(String[] args) {
    Circle example = new Circle(10);
    String output = example.toString();
    System.out.println(output);
  }

}
```

```
package.Circle@659e0bfd
```

Name of the package

Name of the object

Memory address

An object **with** a toString() method defined

```
public class Circle {

    private int radius;
    private double area;
    private double circumference;

    public Circle(int radiusIn) {
        radius = radiusIn;
        area = Math.pow(Math.PI * radius, 2);
        circumference = 2 * Math.PI * radius;
    }

  public String toString() {
    return "Radius: " + radius +
           "\nArea: " + area +
           "\nCircumference: " + circumference;
  }

}
```

```
public class CircleTest {

  public static void main(String[] args) {
    Circle example = new Circle(10);
    String output = example.toString();
    System.out.println(output);
  }

}
```

```
Radius: 10
Area: 986.96…
Circumference: 62.83…
```

Creating a toString() method

- When an object has a toString() method, it is implicitly called when concatenating.

```
Circle example = new Circle(10);

String output = "Circle Information:\n" + example;

System.out.println(output);
```

```
Circle Information:
Radius: 10
Area: 986.96…
Circumference: 62.83…
```

Creating a toString() method

- It will also be implicitly called when passed to System.out.println (or print, or printf)

```
Circle example = new Circle(10);

System.out.println(example);
```

```
Radius: 10
Area: 986.96…
Circumference: 62.83…
```

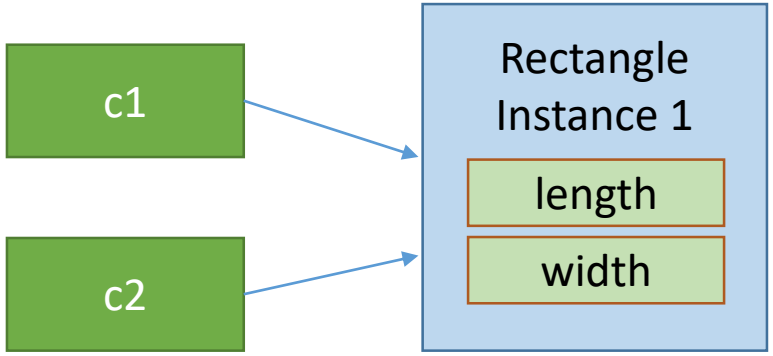
Shallow Copy vs Deep Copy

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

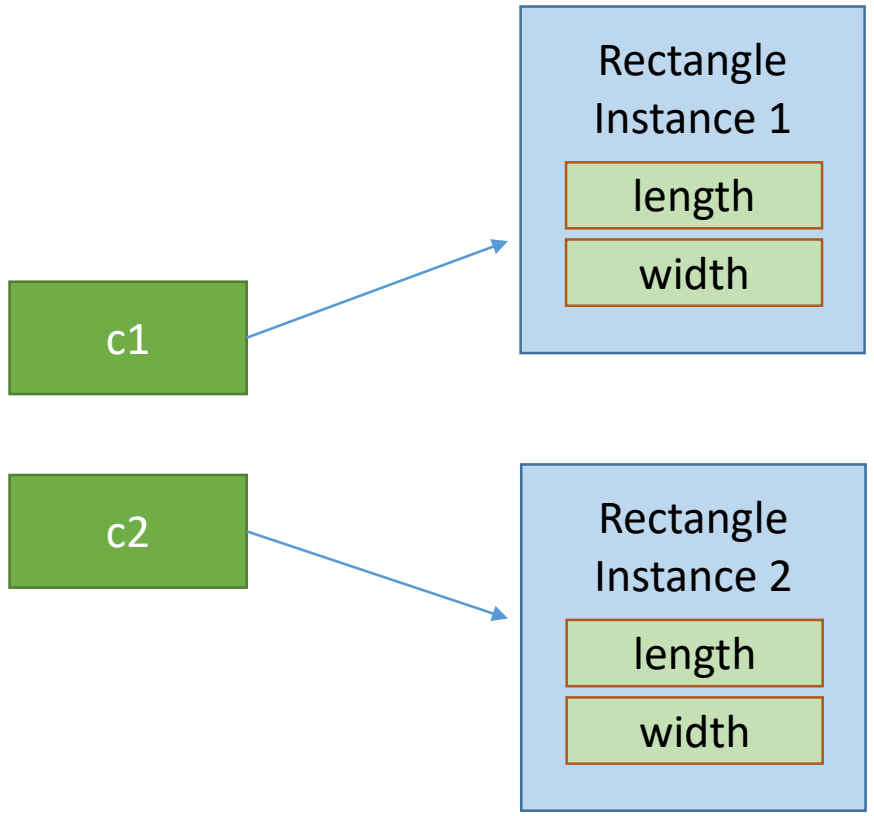
- Deep Copy: The ***data*** referenced by one variable is copied to a new location in memory, and is then referenced by a different variable.

- 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



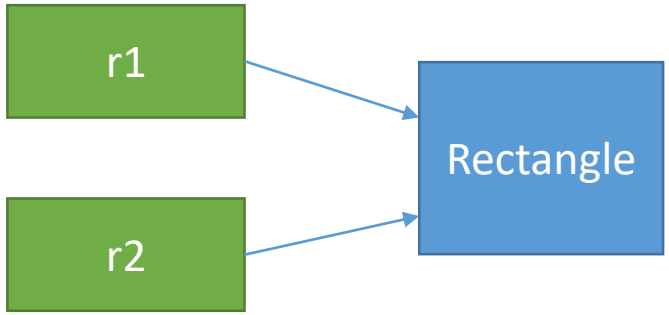
Deep Copy

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

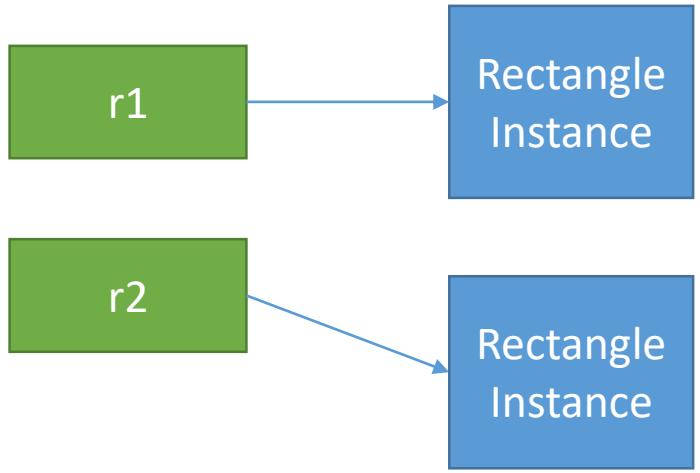
```
public static void main(String[] args) {

  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 = 20
r2's length = 11
```

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();
}
```

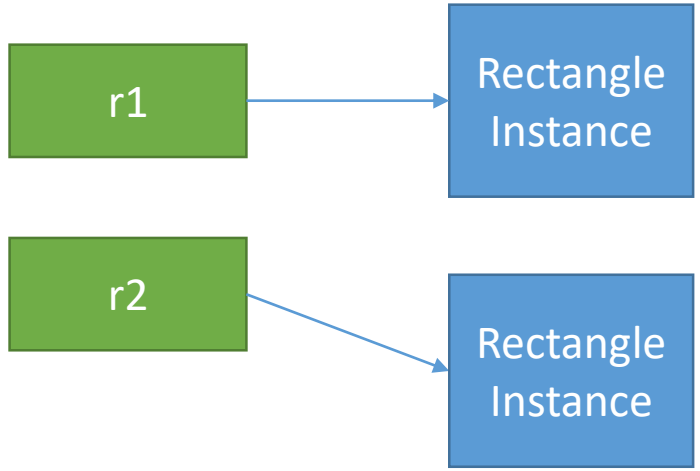
Copy Constructor

```
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 = 5
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”)

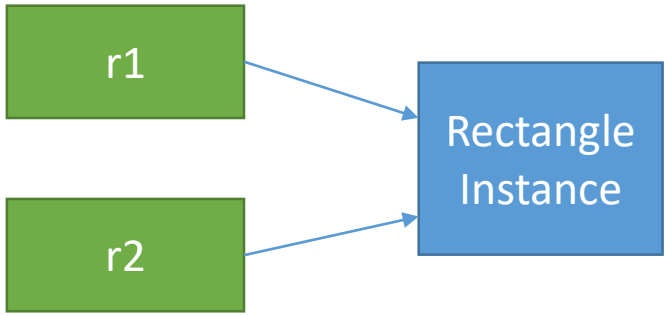
Testing the Equality of Instances

- 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;
```

true

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



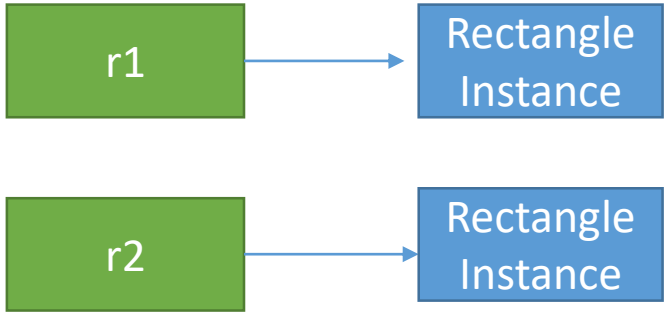
Testing the Equality of Instances

- 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);
```

false

```
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.

Writing an equals method

- 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;
}
```

Writing an equals method

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

true

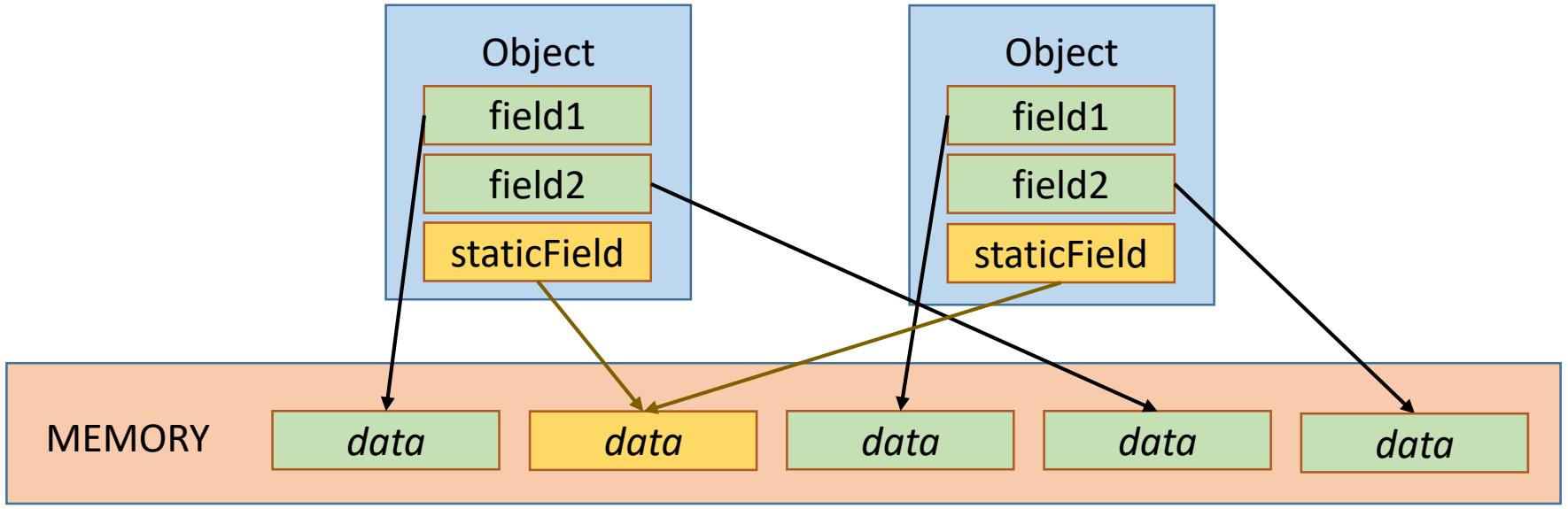
```
if(r1.equals(r2)) {
  System.out.println("r1 and r2 have the same dimensions");
}
else {
  System.out.println("r1 and r2 do not have the same dimensions");
}
```

```
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 **all** 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;`

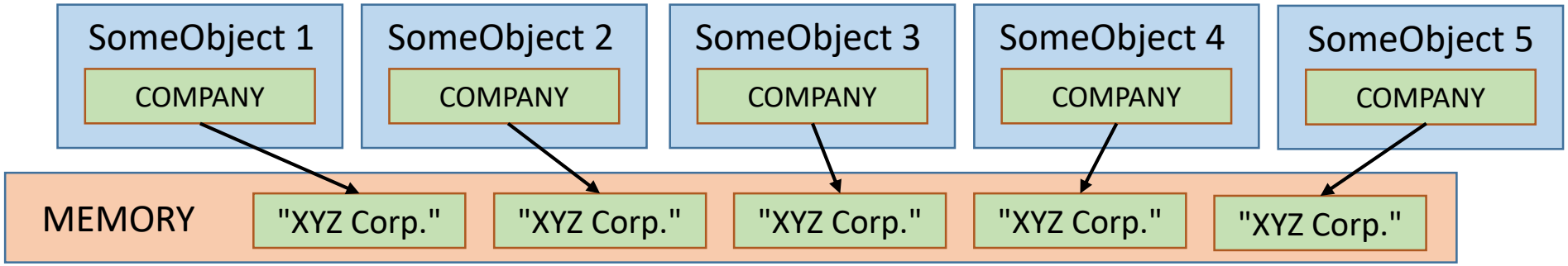
Static Fields

- 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.

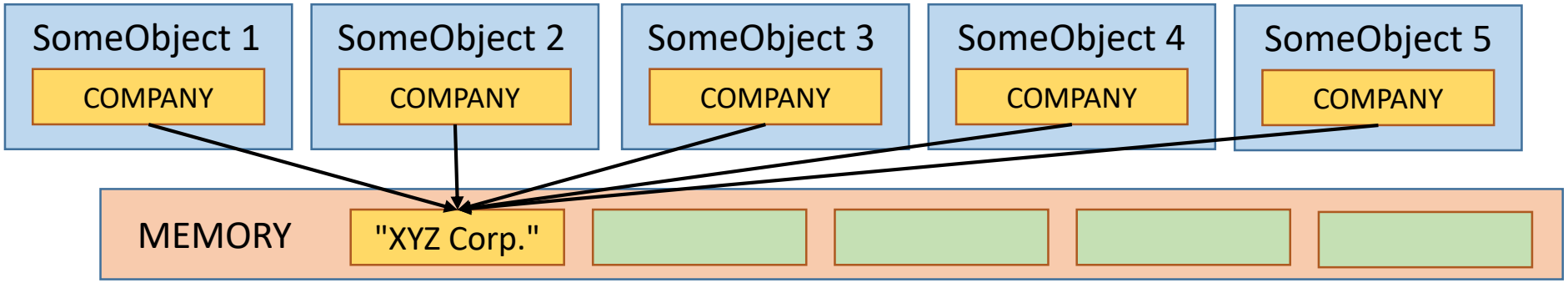


Static Fields

- 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 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;
  ...
}
```

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.

Static Members in UML

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