INHERITANCE, POLYMORPHISM, AND INTERFACES

CODE EXAMPLES FROM JAVA: AN INTRODUCTION TO PROGRAMMING AND PROBLEM SOLVING (6TH EDITION), BY WALTER SAVITCH

IQS2: Spring 2013

Objectives

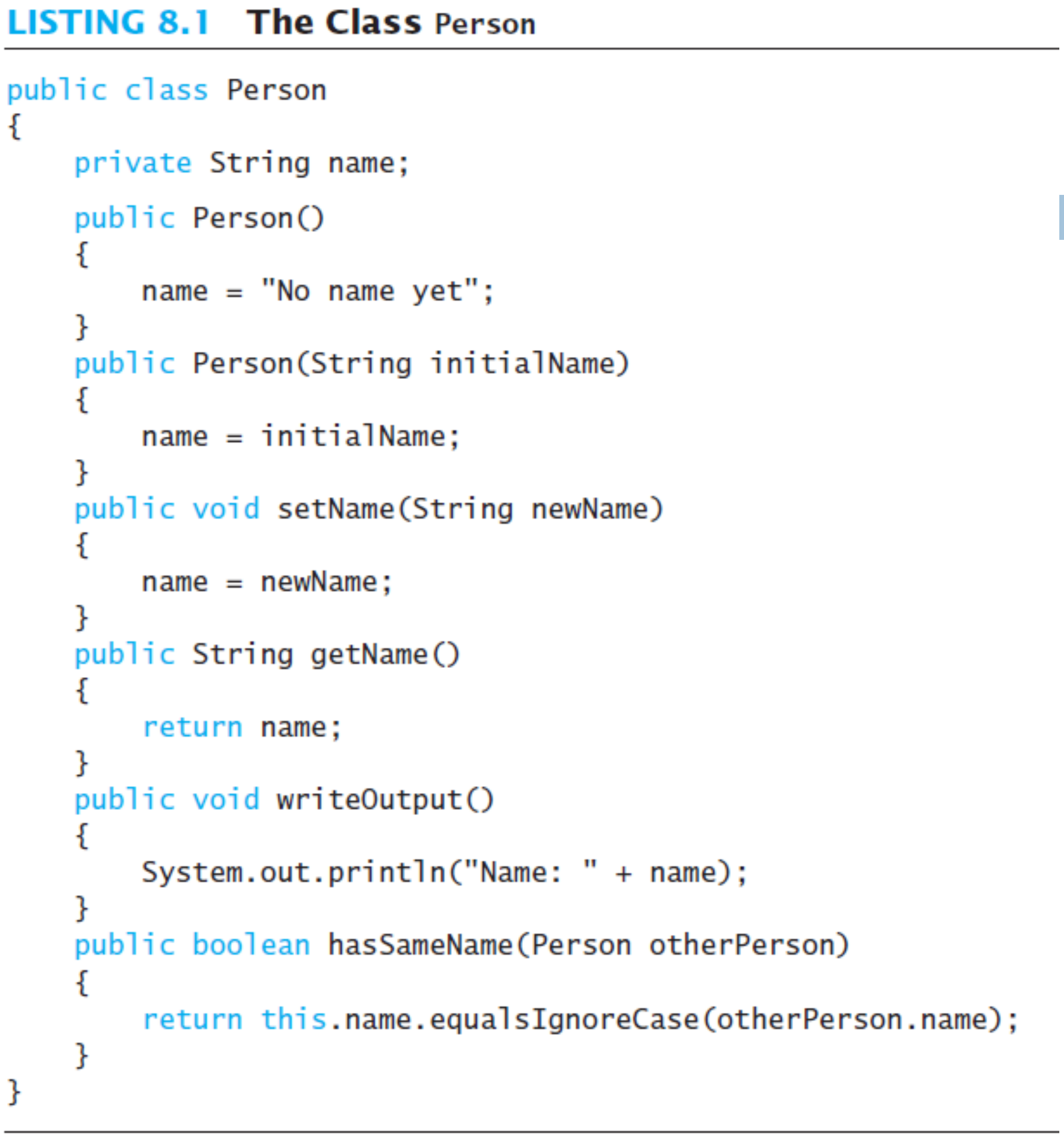
- Describe polymorphism and inheritance in general
- Define interfaces to specify methods
- Describe dynamic binding
- Define and use derived classes in Java
- Understand how inheritance is used in the `JFrame` class

Inheritance Basics: Outline

- Derived Classes
- Overriding Method Definitions
- Overriding Versus Overloading
- The `final` Modifier
- Private Instance Variables and Private Methods of a Base Class
- UML Inheritance Diagrams

Inheritance Basics

- Inheritance allows programmer to define a general class
- Later you define a more specific class
  - Adds new details to general definition
- New class inherits all properties of initial, general class
- Example: the `Person` class



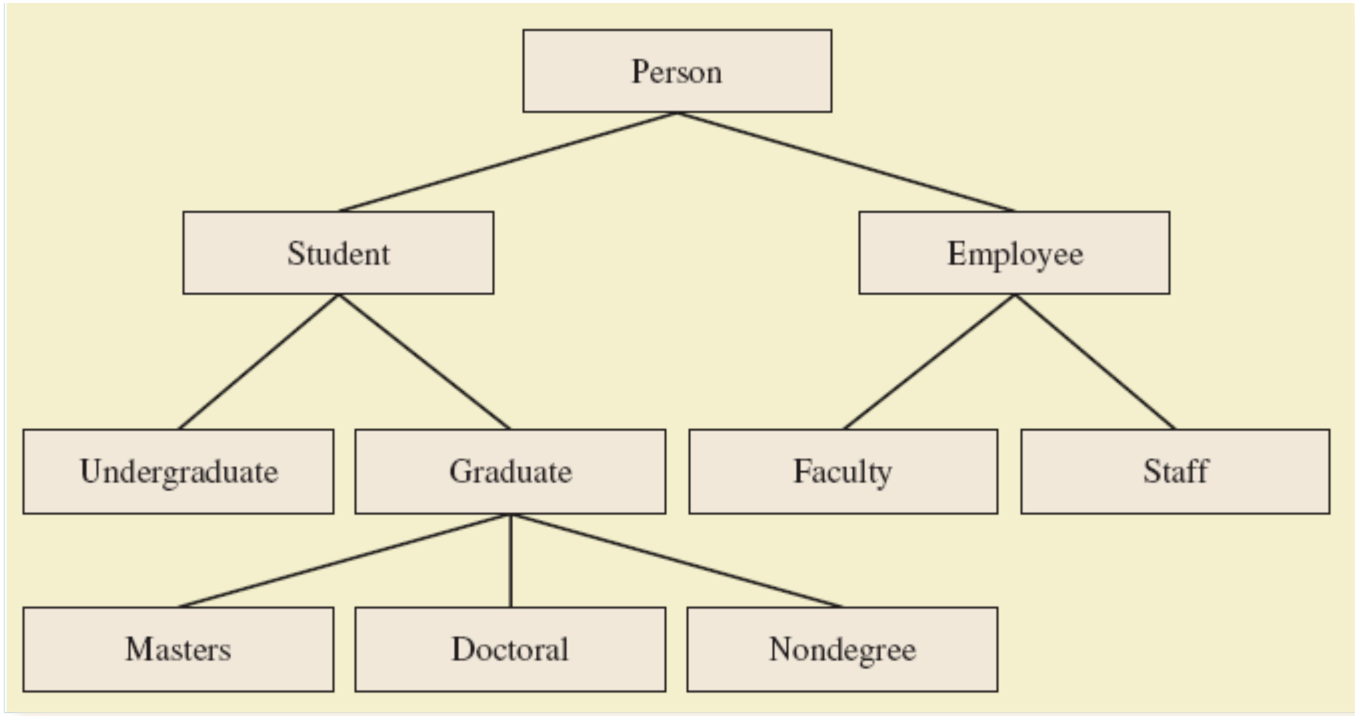
LISTING 8.1 The Class Person

```
public class Person
{
    private String name;

    public Person()
    {
        name = "No name yet";
    }
    public Person(String initialName)
    {
        name = initialName;
    }
    public void setName(String newName)
    {
        name = newName;
    }
    public String getName()
    {
        return name;
    }
    public void writeOutput()
    {
        System.out.println("Name: " + name);
    }
    public boolean hasSameName(Person otherPerson)
    {
        return this.name.equalsIgnoreCase(otherPerson.name);
    }
}
```

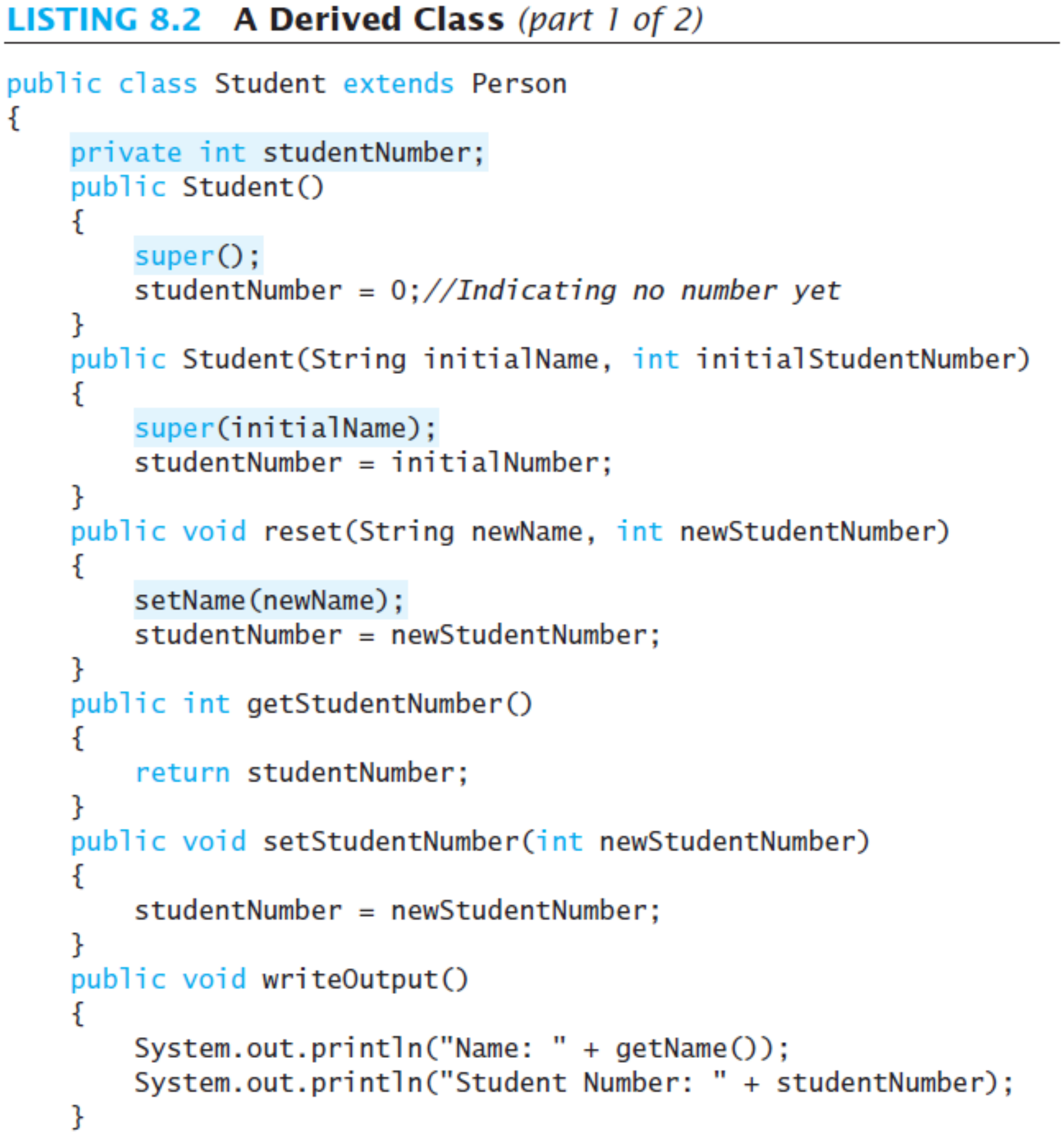
Derived Classes

- An example class hierarchy



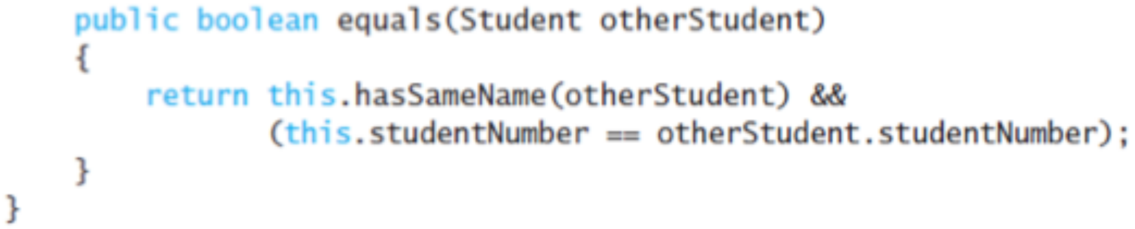
Derived Classes

- `Person` class used as a *base* class
  - Also called *superclass*
- `Student` is a *derived* class
  - Also called *subclass*
  - Inherits methods and members from the superclass

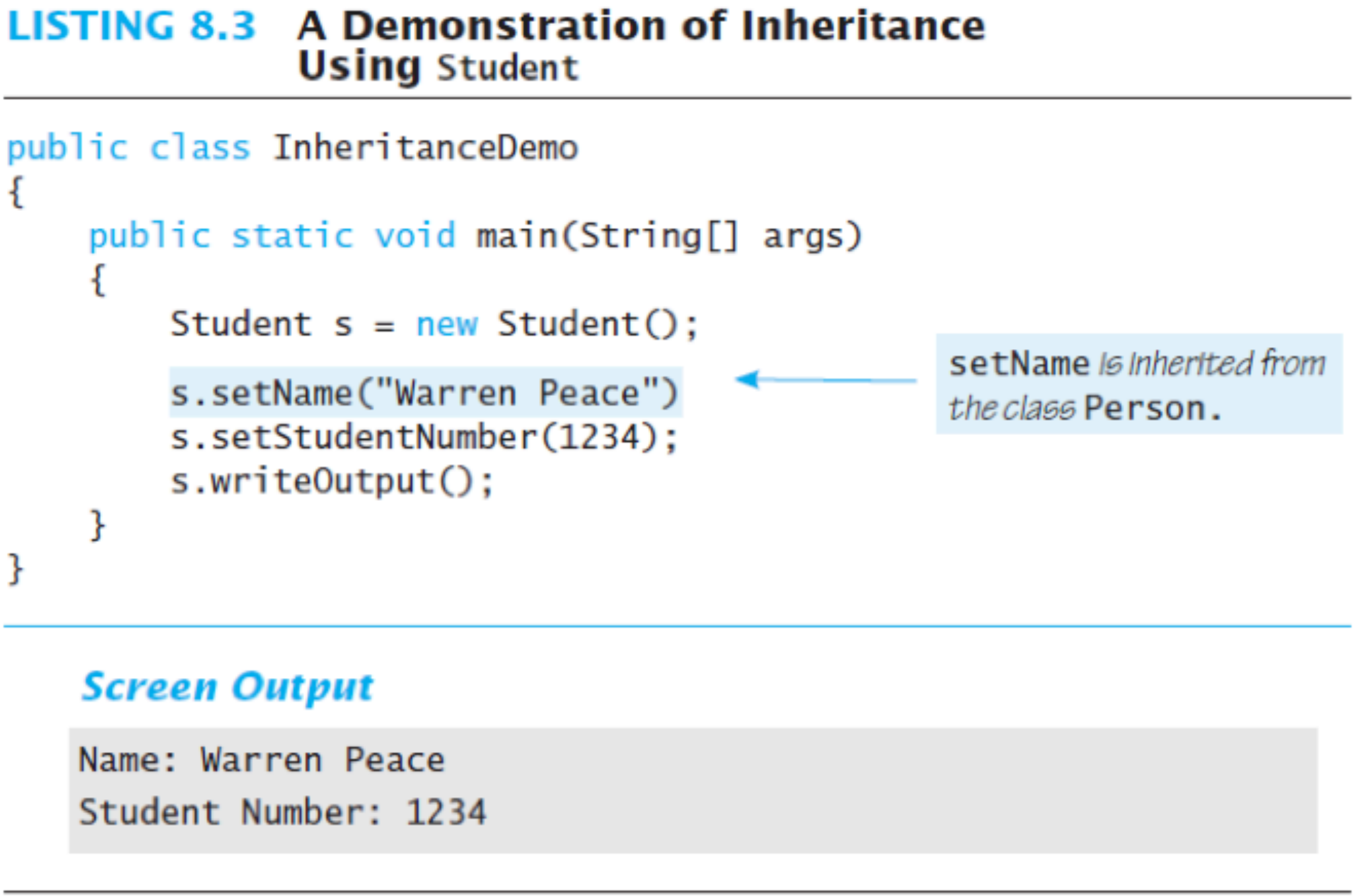


LISTING 8.2 A Derived Class *(part 1 of 2)*

```java
public class Student extends Person
{
    private int studentNumber;
    public Student()
    {
        super();
        studentNumber = 0;//Indicating no number yet
    }
    public Student(String initialName, int initialStudentNumber)
    {
        super(initialName);
        studentNumber = initialNumber;
    }
    public void reset(String newName, int newStudentNumber)
    {
        setName(newName);
        studentNumber = newStudentNumber;
    }
    public int getStudentNumber()
    {
        return studentNumber;
    }
    public void setStudentNumber(int newStudentNumber)
    {
        studentNumber = newStudentNumber;
    }
    public void writeOutput()
    {
        System.out.println("Name: " + getName());
        System.out.println("Student Number: " + studentNumber);
    }
```



```
    public boolean equals(Student otherStudent)
    {
        return this.hasSameName(otherStudent) &&
               (this.studentNumber == otherStudent.studentNumber);
    }
}
```



LISTING 8.3 A Demonstration of Inheritance Using Student

```
public class InheritanceDemo
{
    public static void main(String[] args)
    {
        Student s = new Student();
        s.setName("Warren Peace")
        s.setStudentNumber(1234);
        s.writeOutput();
    }
}
```

setName *is inherited from the class* Person.

Screen Output

```
Name: Warren Peace
Student Number: 1234
```

Don’t Recode What Is Already Coded!

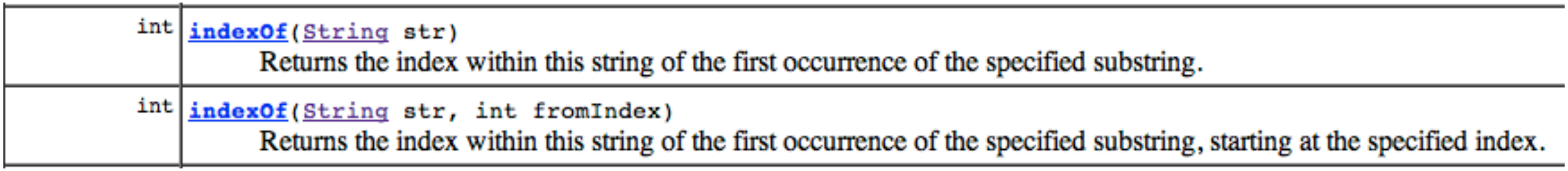
- When you implement a subclass, you get:
  - All of the data members of the base class…
    - …though you may not be able to access them the way you’d like. More on that later.
  - All of the methods of the base class…
    - …with same caveat as above
- So don’t add or recode them in the subclass!
- BUT, it may be that you don’t like the way some methods are coded/used in the base class. In that case…

Overriding Method Definitions

- Note method **`writeOutput`** in class **`Student`**
  - Class **`Person`** also has method with that name
- Method in subclass with **same signature** *overrides* method from base class
  - When an instance of the **`Student`** class calls the **`writeOutput()`** method, the version of the method that is run is the one shown in the **`Student`** class
- Overriding method must return same type of value

Overriding Versus Overloading

- Do not confuse overriding with overloading
  - Overriding takes place in subclass – new method with same signature
- Overloading
  - New method in same class with different signature
    - Example: In `String` class:



int	`indexOf(String str)` Returns the index within this string of the first occurrence of the specified substring.
int	`indexOf(String str, int fromIndex)` Returns the index within this string of the first occurrence of the specified substring, starting at the specified index.

The `final` Modifier

- Possible to specify that a method cannot be overridden in subclass
- Add modifier final to the heading
  `public final void specialMethod()`
- An entire class may be declared `final`
  - Thus cannot be used as a base class to derive any other class
- Included here for completeness: I’ve never used the `final` modifier for an entire class.

Private Instance Variables, Methods

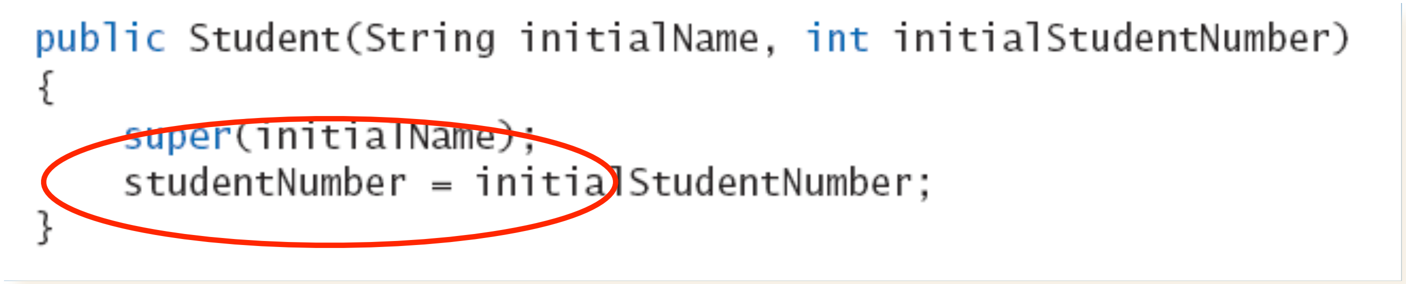
- **private** instance variable in a base class
  - Are inherited in subclass (despite what your text may say), but can't be directly manipulated by you)
  - Can only be manipulated by public accessor, modifier methods
- Similarly, **private** methods in a superclass cannot be called in your subclass code
  - Which at times, is not pleasant. But it's almost always OK. Why?

Protected Instance Variables, Methods

- protected instance variables and methods in a base class
  - Can be used any way you want in any descendent class of the base class
  - Can be used any way you want inside any method in any class in the same package
    - See Appendix 5 in your text

Constructors in Derived Classes

- A derived class does not inherit constructors from base class
  - Constructor in a subclass must invoke constructor from base class
- Use the reserve word `super`

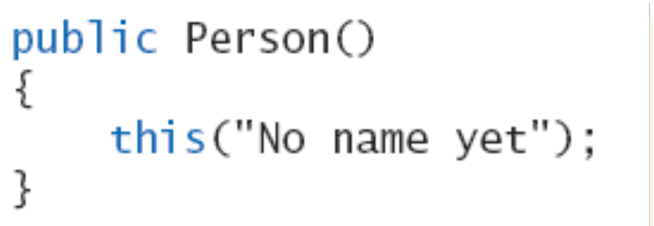


```
public Student(String initialName, int initialStudentNumber)
{
    super(initialName);
    studentNumber = initialStudentNumber;
}
```

  - **Must be first action in the constructor**

The **this** Method – Again

- Also possible to use the **this** keyword
  - Use to call any constructor in the class

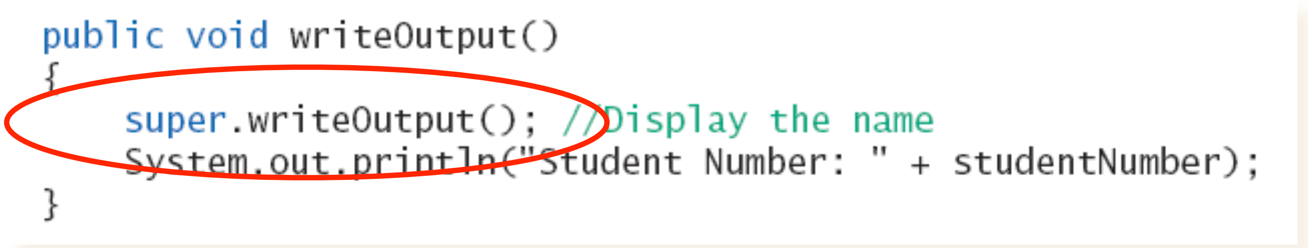


```
public Person()
{
    this("No name yet");
}
```

- When used in a constructor, this calls constructor in same class
  - Contrast use of **super** which invokes constructor of base class
- Again, here for completeness

Calling an Overridden Method

- Reserved word **super** can also be used to call method in overridden method

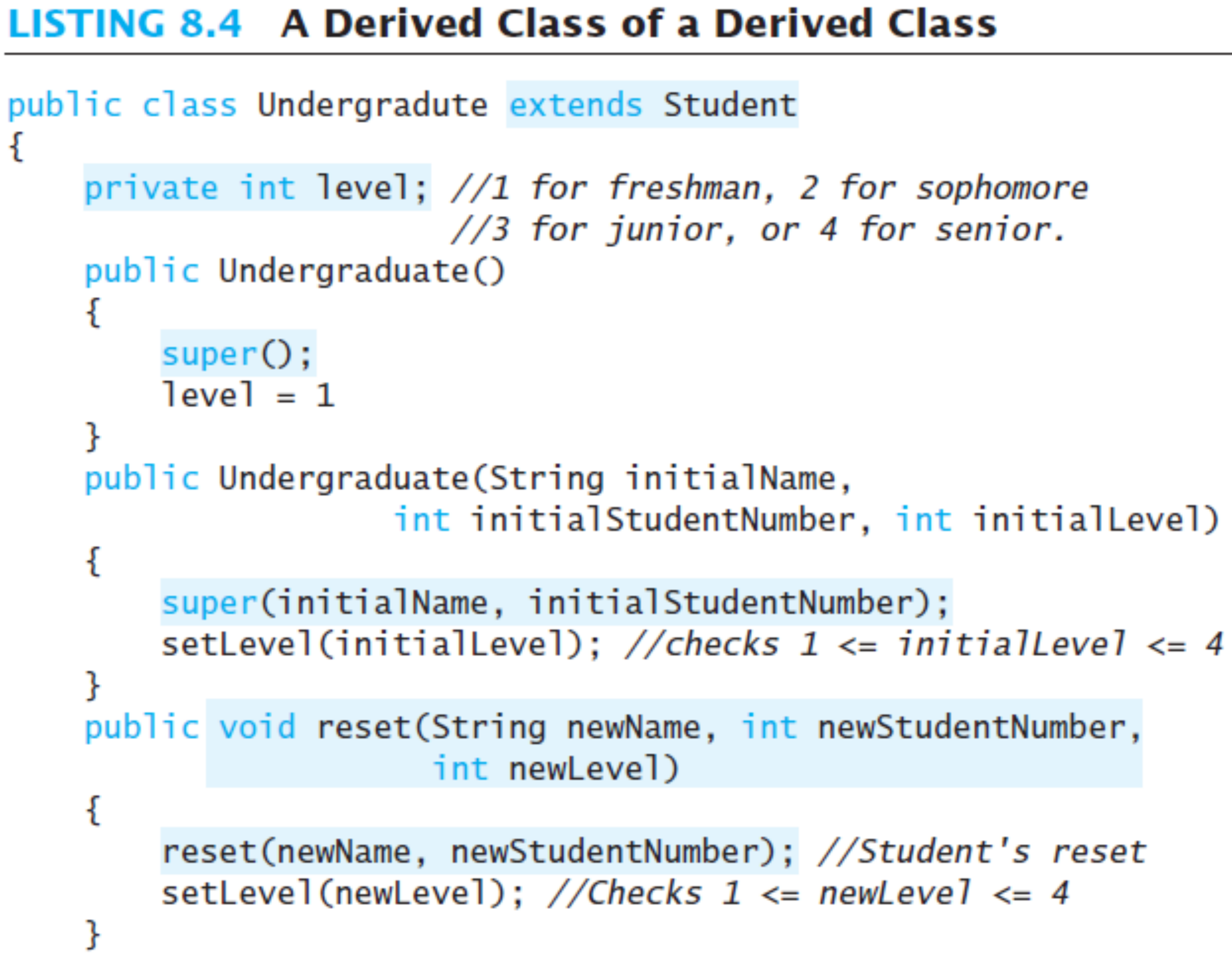


```
public void writeOutput()
{
    super.writeOutput(); //Display the name
    System.out.println("Student Number: " + studentNumber);
}
```

- Calls method by same name in base class

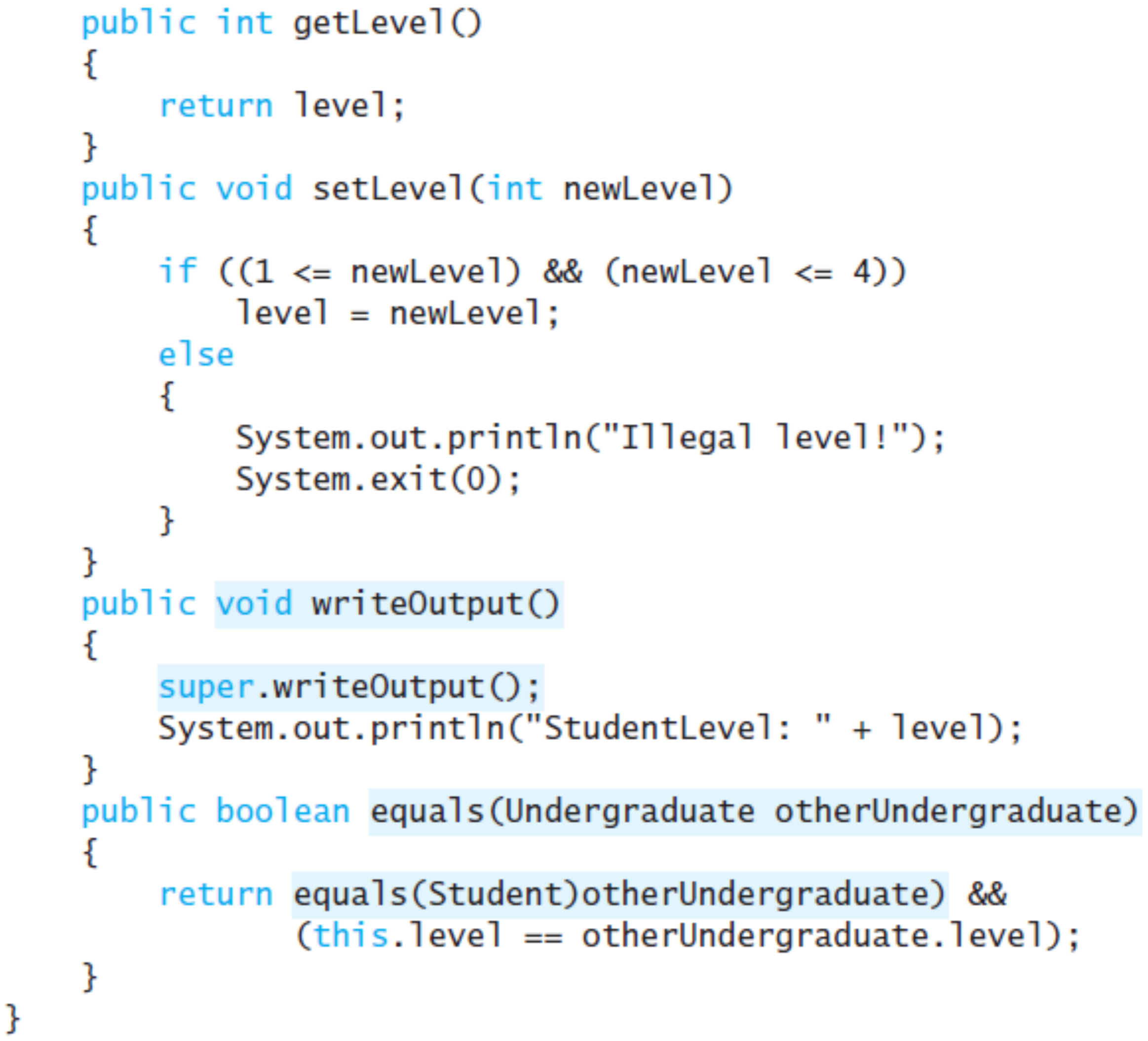
Programming Example

- A derived class of a derived class: `Undergraduate` class
- Has all public members of both
  - `Person`
  - `Student`
- This reuses the code in superclasses



LISTING 8.4 A Derived Class of a Derived Class

```
public class Undergradute extends Student
{
    private int level; //1 for freshman, 2 for sophomore
                       //3 for junior, or 4 for senior.
    public Undergraduate()
    {
        super();
        level = 1
    }
    public Undergraduate(String initialName,
                int initialStudentNumber, int initialLevel)
    {
        super(initialName, initialStudentNumber);
        setLevel(initialLevel); //checks 1 <= initialLevel <= 4
    }
    public void reset(String newName, int newStudentNumber,
                  int newLevel)
    {
        reset(newName, newStudentNumber); //Student's reset
        setLevel(newLevel); //Checks 1 <= newLevel <= 4
    }
```



```
    public int getLevel()
    {
        return level;
    }
    public void setLevel(int newLevel)
    {
        if ((1 <= newLevel) && (newLevel <= 4))
            level = newLevel;
        else
        {
            System.out.println("Illegal level!");
            System.exit(0);
        }
    }
    public void writeOutput()
    {
        super.writeOutput();
        System.out.println("StudentLevel: " + level);
    }
    public boolean equals(Undergraduate otherUndergraduate)
    {
        return equals(Student)otherUndergraduate) &&
               (this.level == otherUndergraduate.level);
    }
}
```

Type Compatibility

- In the class hierarchy
  - Each `Undergraduate` is also a `Student`
  - Each `Student` is also a `Person`
- An object of a derived class can serve as an object of the base class (that is, used wherever the base class is required)
  - Ex: as input parameters to methods
  - Note this is <u>not</u> typecasting
- An object of a class can be referenced by a variable of an ancestor type
  - So, for example, a `Person` variable can point to (reference) an `Undergraduate` object (but not vice versa)

Type Compatibility

- Be aware of the "is-a" relationship
  - An `Undergraduate` *is a* `Person`
  - But a `Person` is not necessarily an `Undergraduate`
- Another relationship is the "has-a"
  - A class can contain (as an instance variable) an object of another type
  - If we specify a date of birth variable for `Person` – it "has-a" `Date` object

The Class `Object`

- Java has a class that is the ultimate ancestor of every class
  - The class `Object`
- Thus possible to write a method with parameter of type `Object`
  - Actual parameter in the call can be object of <u>any</u> type
- Example: method `println(Object theObject)`

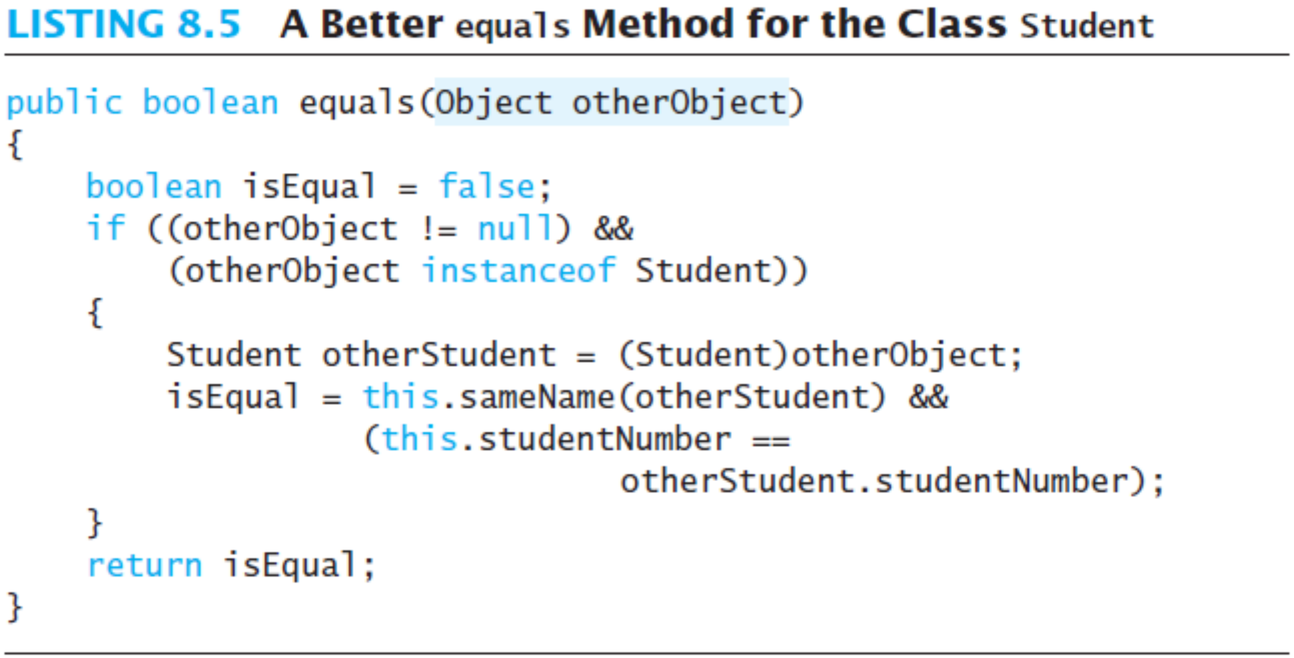
The Class `Object`

- Class Object has some methods that every Java class inherits
- Examples
  - Method `equals`
  - Method `toString`
- Method `toString` called when `println (theObject)` invoked
  - Best to define your own `toString` to handle this

A Better **equals** Method

- Programmer of a class should override method equals from `Object`
- View code of a better `equals` method

```
public boolean equals
          (Object theObject)
```



LISTING 8.5 A Better `equals` Method for the Class `Student`

```
public boolean equals(Object otherObject)
{
    boolean isEqual = false;
    if ((otherObject != null) &&
        (otherObject instanceof Student))
    {
        Student otherStudent = (Student)otherObject;
        isEqual = this.sameName(otherStudent) &&
                  (this.studentNumber ==
                               otherStudent.studentNumber);
    }
    return isEqual;
}
```

Polymorphism

- Inheritance allows you to define a base class and derive classes from the base class
- Polymorphism allows you to make changes in the method definition for the derived classes and have those changes apply to methods written in the base class

Polymorphism

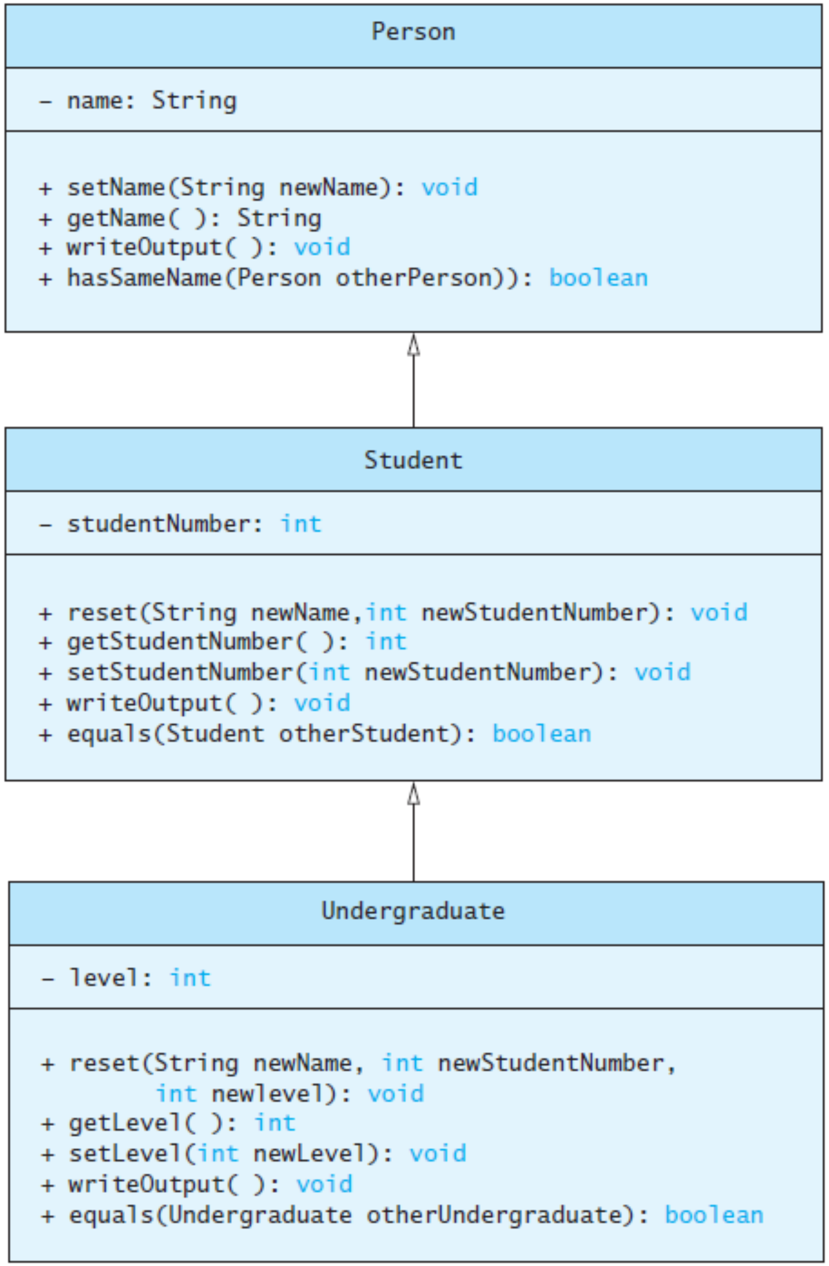
- □ Consider an array of **Person**

```
Person[] people = new Person[4];
```

- □ Since **Student** and **Undergraduate** are types of **Person**, we can assign them to **Person** variables

```
people[0] = new Student
("DeBanque, Robin", 8812);

people[1] = new Undergraduate
("Cotty, Manny", 8812, 1);
```



```
Person
- name: String
+ setName(String newName): void
+ getName( ): String
+ writeOutput( ): void
+ hasSameName(Person otherPerson)): boolean

Student
- studentNumber: int
+ reset(String newName,int newStudentNumber): void
+ getStudentNumber( ): int
+ setStudentNumber(int newStudentNumber): void
+ writeOutput( ): void
+ equals(Student otherStudent): boolean

Undergraduate
- level: int
+ reset(String newName, int newStudentNumber,
        int newLevel): void
+ getLevel( ): int
+ setLevel(int newLevel): void
+ writeOutput( ): void
+ equals(Undergraduate otherUndergraduate): boolean
```

Polymorphism

□ Given:

```
Person[] people = new Person[4];
people[0] = new Student("DeBanque, Robin",
8812);
```

□ When invoking:

```
people[0].writeOutput();
```

□ Which `writeOutput()` is invoked, the one defined for `Student` or the one defined for `Person`?

□ Answer: The one defined for `Student`

An Inheritance as a Type

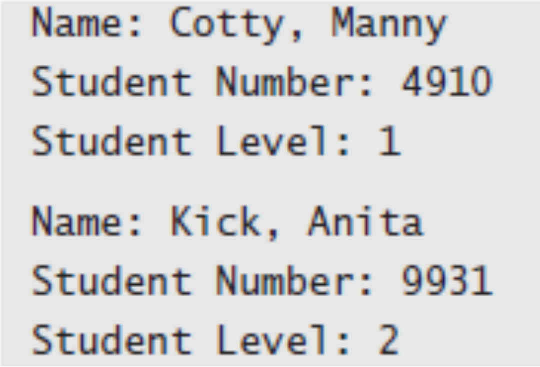
- The method can substitute one object for another
  - Called *polymorphism*
- This is made possible by mechanism
  - *Dynamic binding*
  - Also known as *late binding*

Dynamic Binding and Inheritance

- When an overridden method invoked
  - Action matches method defined in class used to create object using **`new`**
  - Not determined by type of variable naming the object
- Variable of any ancestor class can reference object of descendant class
  - Object always remembers which method actions to use for each method name

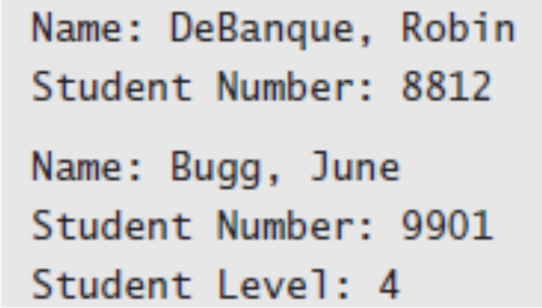
Polymorphism Example

- View sample class, listing 8.6
  class PolymorphismDemo
- Output



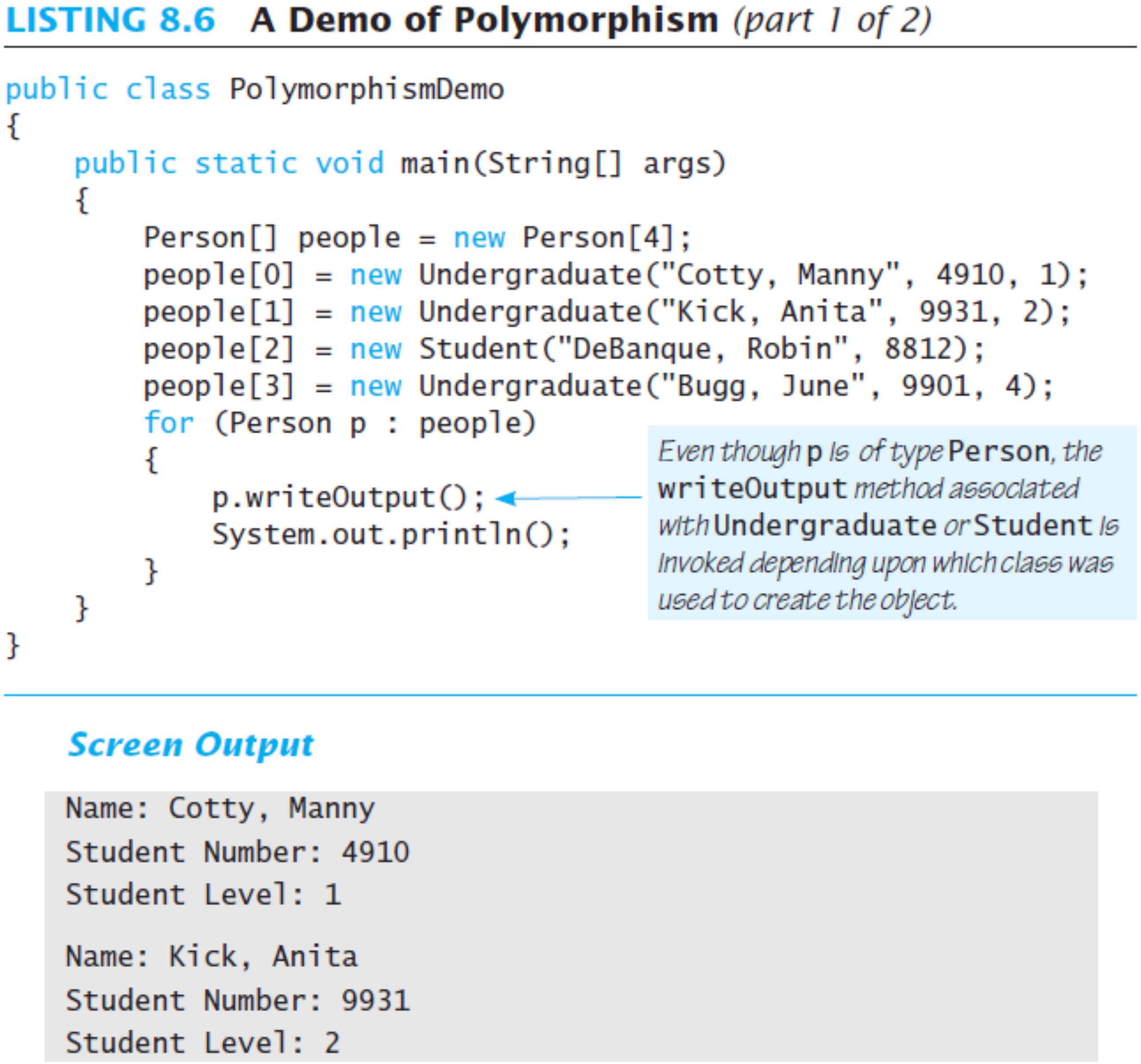
```
Name: Cotty, Manny
Student Number: 4910
Student Level: 1

Name: Kick, Anita
Student Number: 9931
Student Level: 2
```



```
Name: DeBanque, Robin
Student Number: 8812

Name: Bugg, June
Student Number: 9901
Student Level: 4
```



LISTING 8.6 A Demo of Polymorphism *(part 1 of 2)*

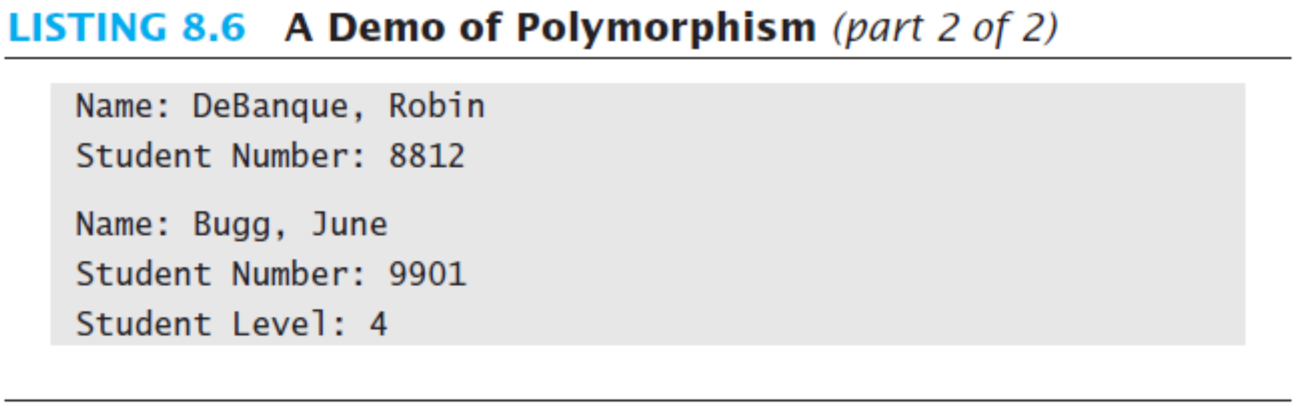
```
public class PolymorphismDemo
{
    public static void main(String[] args)
    {
        Person[] people = new Person[4];
        people[0] = new Undergraduate("Cotty, Manny", 4910, 1);
        people[1] = new Undergraduate("Kick, Anita", 9931, 2);
        people[2] = new Student("DeBanque, Robin", 8812);
        people[3] = new Undergraduate("Bugg, June", 9901, 4);
        for (Person p : people)
        {
            p.writeOutput();
            System.out.println();
        }
    }
}
```

Even though **p** *is of type* **Person**, *the* **writeOutput** *method associated with* **Undergraduate** *or* **Student** *is invoked depending upon which class was used to create the object.*

Screen Output

```
Name: Cotty, Manny
Student Number: 4910
Student Level: 1

Name: Kick, Anita
Student Number: 9931
Student Level: 2
```



LISTING 8.6 **A Demo of Polymorphism** *(part 2 of 2)*

```
Name: DeBanque, Robin
Student Number: 8812

Name: Bugg, June
Student Number: 9901
Student Level: 4
```

An Aside: Types and Security

- Java is a "strongly typed" language
  - This means that it is very careful about making sure appropriate typed objects are passed to methods and assigned as references
- All other factors being equal, strong typing makes a language much more secure.
  - Can anyone guess why this is?
- But, it turns out that the Java type system can be fooled via careful (mis)use of the dynamic binding system!
  - And if you manage to fool it even once, you have rendered the type system completely ineffective!
  - The method researchers discovered for doing this is considered so dangerous that it has never been published!

Class Interfaces

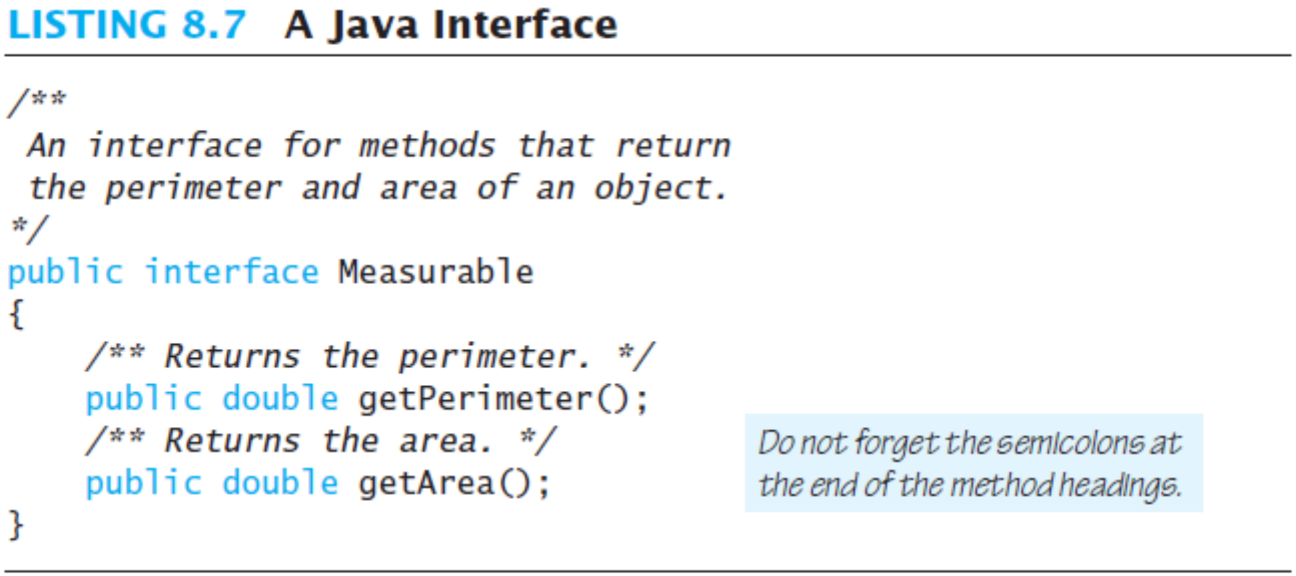
- Consider a set of behaviors for pets
  - Be named
  - Eat
  - Respond to a command
- We could specify method headings for these behaviors
- These method headings can form a class interface

Class Interfaces

- Now consider different classes that implement this interface
  - They will each have the same behaviors
  - Nature of the behaviors will be different
- Each of the classes implements the behaviors/ methods differently

Java Interfaces

- A program component that contains headings for a number of public methods
  - Will include comments that describe the methods
- Interface can also define public named constants



LISTING 8.7 A Java Interface

```
/**
 An interface for methods that return
 the perimeter and area of an object.
*/
public interface Measurable
{
    /** Returns the perimeter. */
    public double getPerimeter();
    /** Returns the area. */
    public double getArea();
}
```

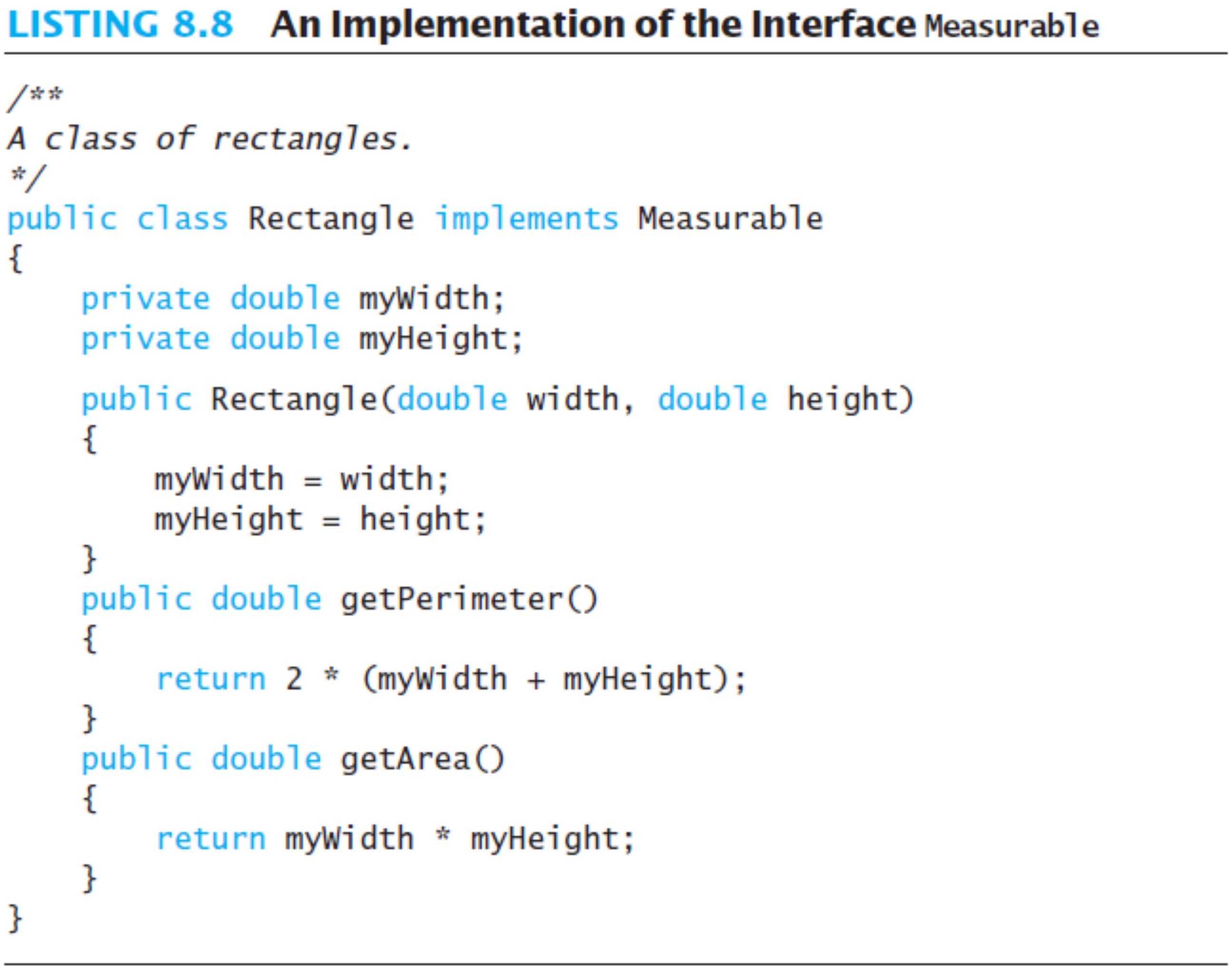
Do not forget the semicolons at the end of the method headings.

Java Interfaces

- Interface name begins with uppercase letter
- Stored in a file with suffix `.java`
- Interface does not include
  - Declarations of constructors
  - Instance variables
  - Method bodies

Implementing an Interface

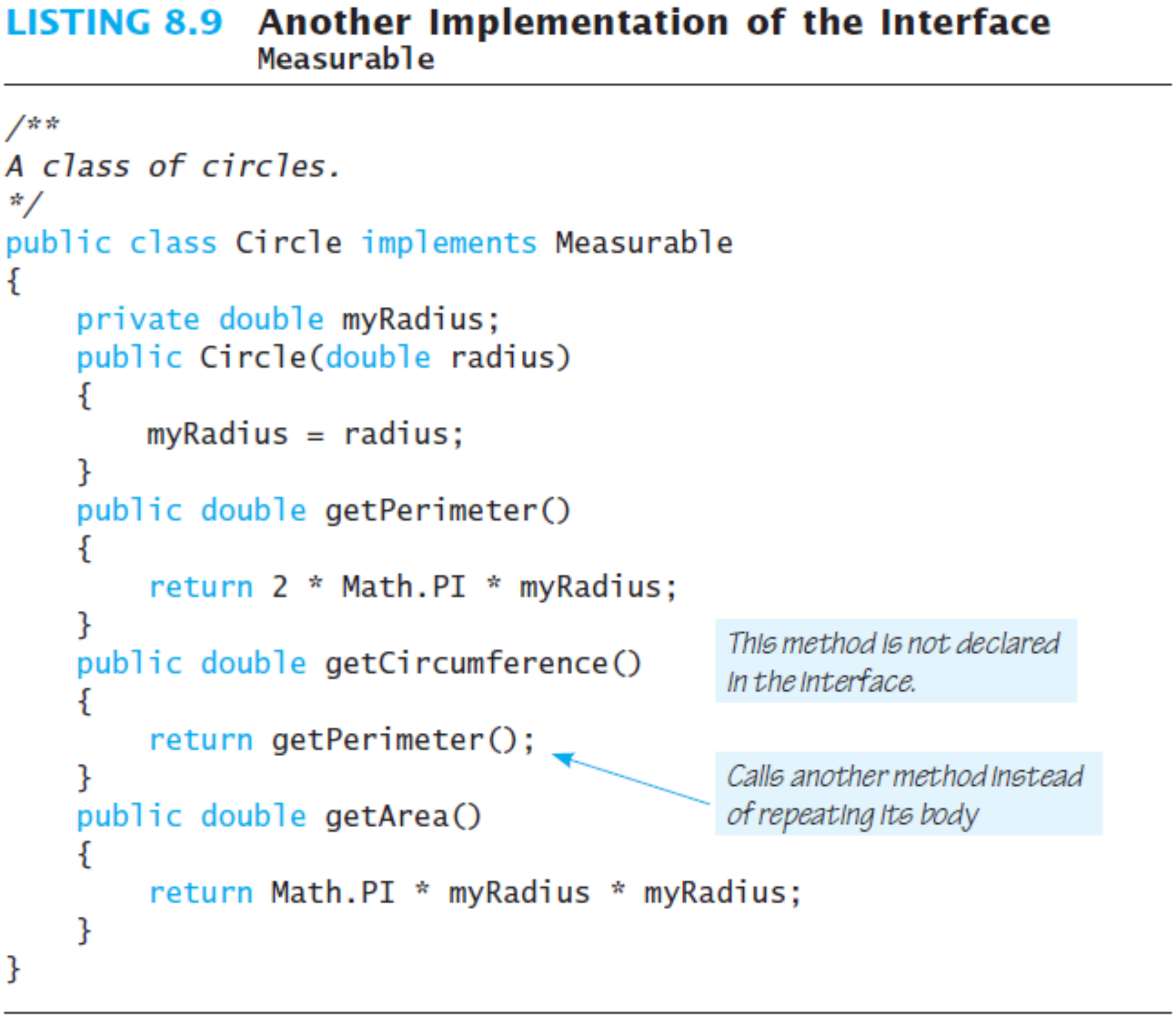
- To implement a method, a class must
  - Include the phrase
    ```
    implements Interface_name
    ```
  - Define each specified method



LISTING 8.8 An Implementation of the Interface `Measurable`

```
/**
A class of rectangles.
*/
public class Rectangle implements Measurable
{
    private double myWidth;
    private double myHeight;

    public Rectangle(double width, double height)
    {
        myWidth = width;
        myHeight = height;
    }
    public double getPerimeter()
    {
        return 2 * (myWidth + myHeight);
    }
    public double getArea()
    {
        return myWidth * myHeight;
    }
}
```



LISTING 8.9 Another Implementation of the Interface Measurable

```
/**
A class of circles.
*/
public class Circle implements Measurable
{
    private double myRadius;
    public Circle(double radius)
    {
        myRadius = radius;
    }
    public double getPerimeter()
    {
        return 2 * Math.PI * myRadius;
    }
    public double getCircumference()
    {
        return getPerimeter();
    }
    public double getArea()
    {
        return Math.PI * myRadius * myRadius;
    }
}
```

This method is not declared in the interface.

Calls another method instead of repeating its body

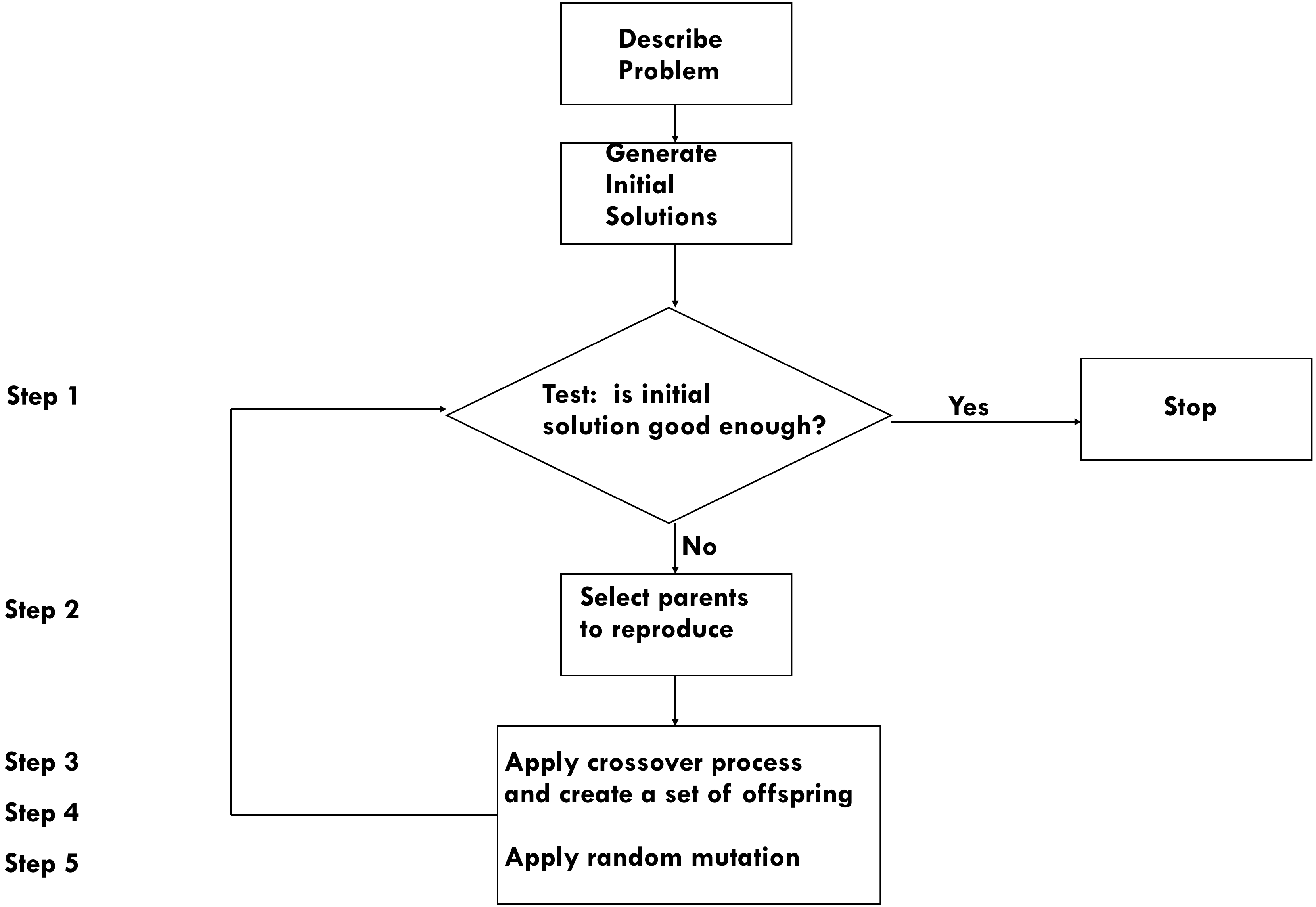
An Inheritance as a Type

- Possible to write a method that has an Interface type as a parameter
  - An interface is a reference type
- Program invokes the method, passing it an object of any class which implements that interface

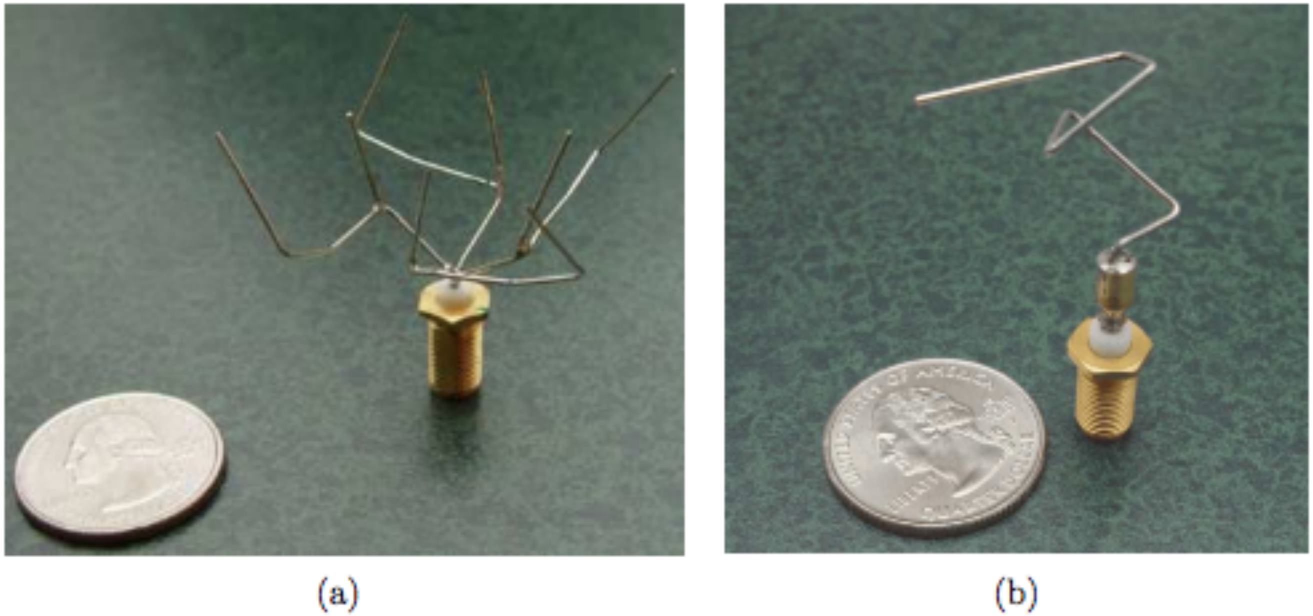
Example: Genetic Algorithm

- A Population described by chromosomes
- Crossover
- Mutation
- Survival of the fittest
  - Fitness function

Flow Diagram of the Genetic Algorithm Process



Describe Problem
Generate Initial Solutions
Step 1
Test: is initial solution good enough?
Yes
Stop
No
Step 2
Select parents to reproduce
Step 3
Step 4
Step 5
Apply crossover process and create a set of offspring
Apply random mutation



(a)

(b)

Figure 2. Photographs of prototype evolved antennas: (a) the best evolved antenna for the initial gain pattern requirement, ST5-3-10; (b) the best evolved antenna for the revised specifications, ST5-33-142-7.

The `Comparator` Interface

- Required for use in Java `Arrays` class
  - `Arrays.sort()`

Extending an Interface

- Possible to define a new interface which builds on an existing interface
  - It is said to extend the existing interface
- A class that implements the new interface must implement all the methods of both interfaces

(Another) Case Study

- Java has many predefined interfaces
- One of them, the `Comparable` interface, is used to impose an ordering upon the objects that implement it
- Requires that the method `compareTo` be written

```
public int compareTo(Object other);
```

Sorting an Array of Fruit Objects

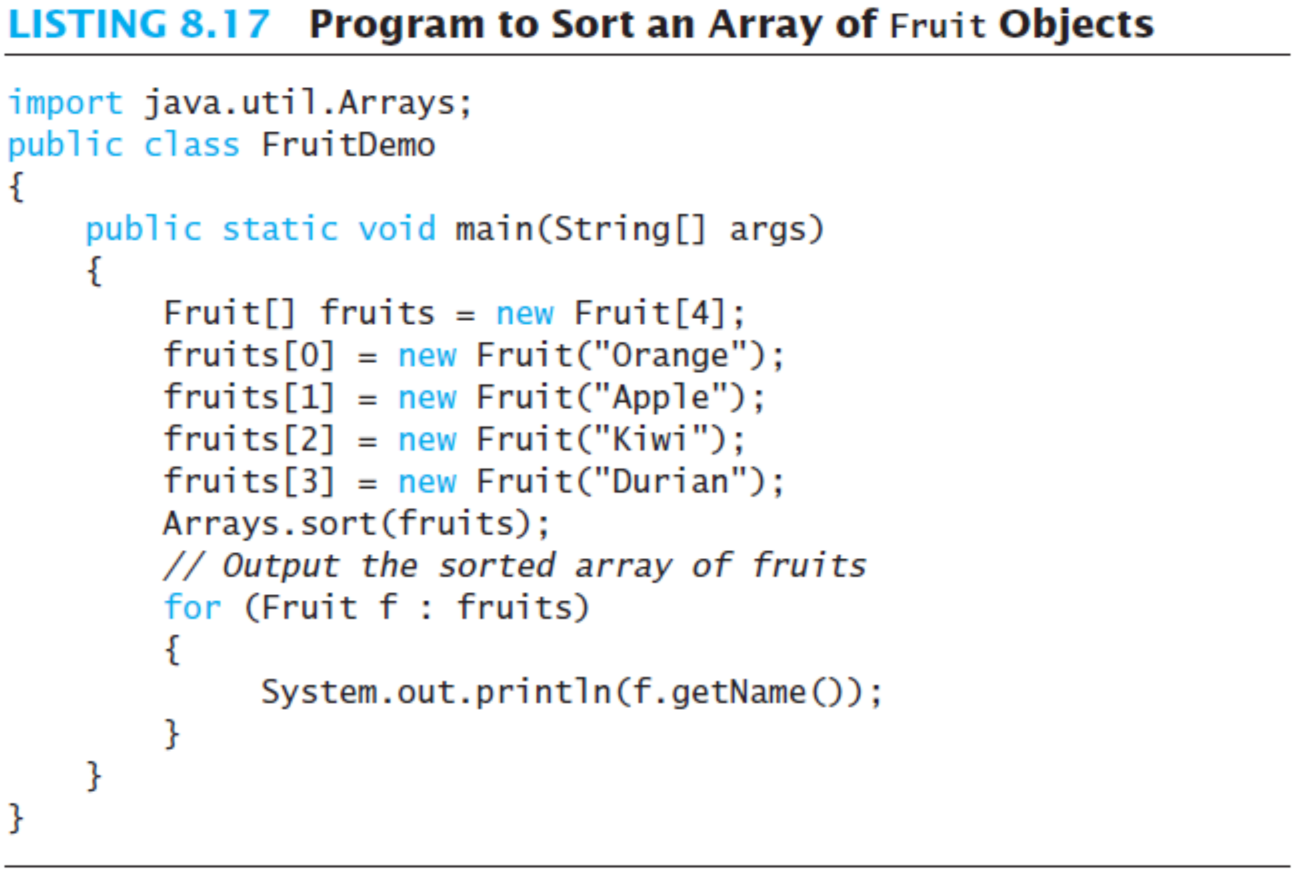
- Initial (non-working) attempt to sort an array of `Fruit` objects
- View class definition, listing 8.16
  `class Fruit`
- View test class, listing 8.17
  `class FruitDemo`
- Result: Exception in thread “main”
  - Sort tries to invoke `compareTo` method but it doesn’t exist

Sorting an Array of Fruit Objects

- Working attempt to sort an array of `Fruit` objects – implement `Comparable`, write `compareTo` method
- Following slides show `Fruit` class
- Result: Exception in thread "main"
  - Sort tries to invoke method but it doesn't exist

LISTING 8.16 First Attempt to Define a `Fruit` Class

```java
public class Fruit
{
    private String fruitName;
    public Fruit()
    {
        fruitName = "";
    }
    public Fruit(String name)
    {
        fruitName = name;
    }
    Public void setName(String name)
    {
        fruitName = name;
    }
    public String getName()
    {
        return fruitName;
    }
}
```



LISTING 8.17 Program to Sort an Array of `Fruit` Objects

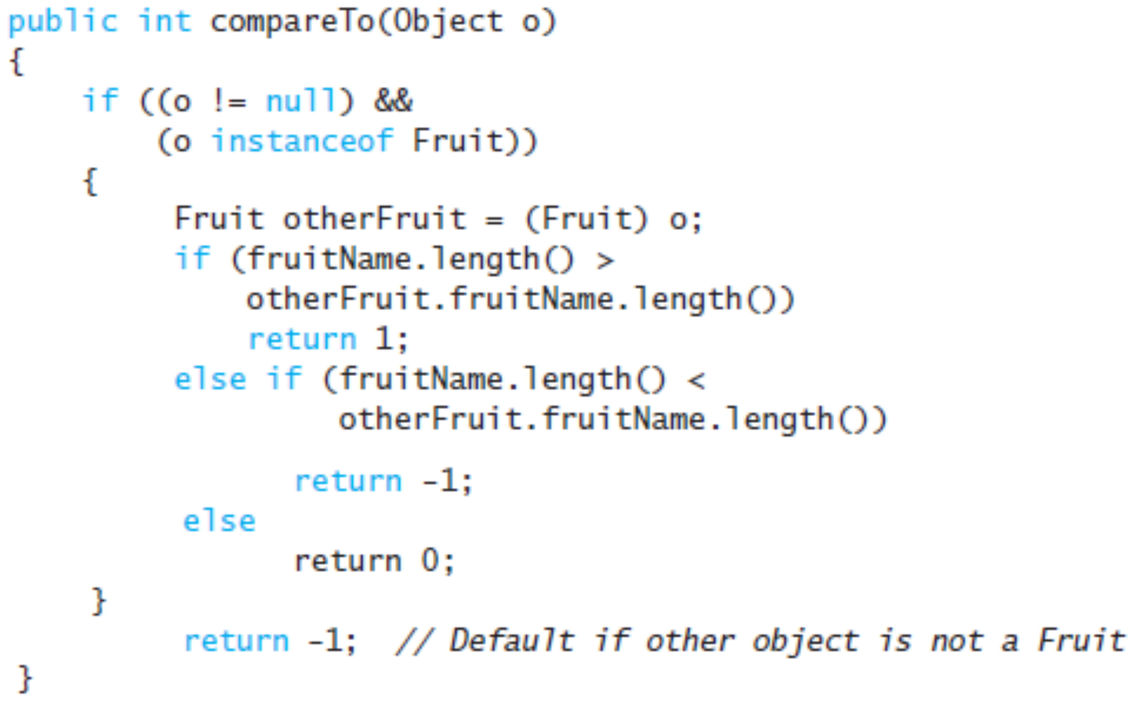
```
import java.util.Arrays;
public class FruitDemo
{
    public static void main(String[] args)
    {
        Fruit[] fruits = new Fruit[4];
        fruits[0] = new Fruit("Orange");
        fruits[1] = new Fruit("Apple");
        fruits[2] = new Fruit("Kiwi");
        fruits[3] = new Fruit("Durian");
        Arrays.sort(fruits);
        // Output the sorted array of fruits
        for (Fruit f : fruits)
        {
             System.out.println(f.getName());
        }
    }
}
```

LISTING 8.18 A Fruit Class implementing Comparable *(part 1 of 2)*

```
public class Fruit implements Comparable
{
    private String fruitName;
    public Fruit()
    {
        fruitName = "";
    }
    public Fruit(String name)
    {
        fruitName = name;
    }
    public void setName(String name)
    {
        fruitName = name;
    }
    public String getName()
    {
        return fruitName;
    }
    public int compareTo(Object o)
    {
        if ((o != null) &&
            (o instanceof Fruit))
        {
            Fruit otherFruit = (Fruit) o;
            return (fruitName.compareTo(otherFruit.fruitName));
        }
        return -1;   // Default if other object is not a Fruit
    }
}
```

compareTo Method

□ An alternate definition that will sort by length of the fruit name



```
public int compareTo(Object o)
{
    if ((o != null) &&
        (o instanceof Fruit))
    {
         Fruit otherFruit = (Fruit) o;
         if (fruitName.length() >
             otherFruit.fruitName.length())
             return 1;
         else if (fruitName.length() <
                  otherFruit.fruitName.length())

               return -1;
         else
               return 0;
    }
         return -1;  // Default if other object is not a Fruit
}
```

Abstract Classes

- Class `ShapeBasics` is designed to be a base class for other classes
  - Method `drawHere` will be redefined for each subclass
  - It should be declared *abstract* – a method that has no body
- This makes the class abstract
- You cannot create an object of an abstract class – thus its role as base class

Abstract Classes

- Not all methods of an abstract class are abstract methods
- Abstract class makes it easier to define a base class
  - Specifies the obligation of designer to override the abstract methods for each subclass

Abstract Classes

- Cannot have an instance of an abstract class
  - But OK to have a parameter of that type

Dynamic Binding and Inheritance

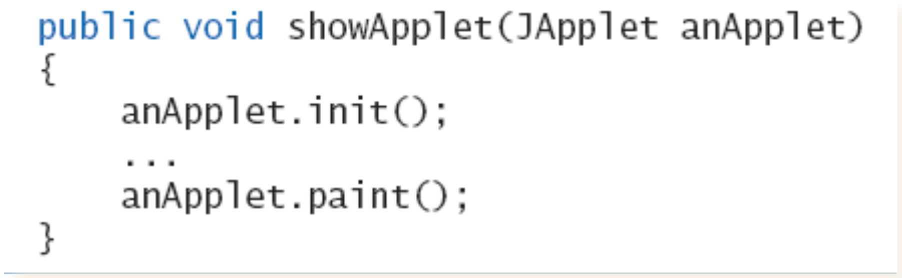
- How does Java know which version of a method is to be run?
- Happens with dynamic or late binding
  - Address of correct code to be executed determined at run time

Graphics Supplement: Outline

- □ The Class `JApplet`
- □ The Class `JFrame`
- □ Window Events and Window Listeners
- □ The `ActionListener` Interface

The Class **JApplet**

- Class **JApplet** is base class for all applets
  - Has methods **init** and **paint**
- When you extend **JApplet** you override (redefine) these methods
- Parameter shown will use your versions due to polymorphism



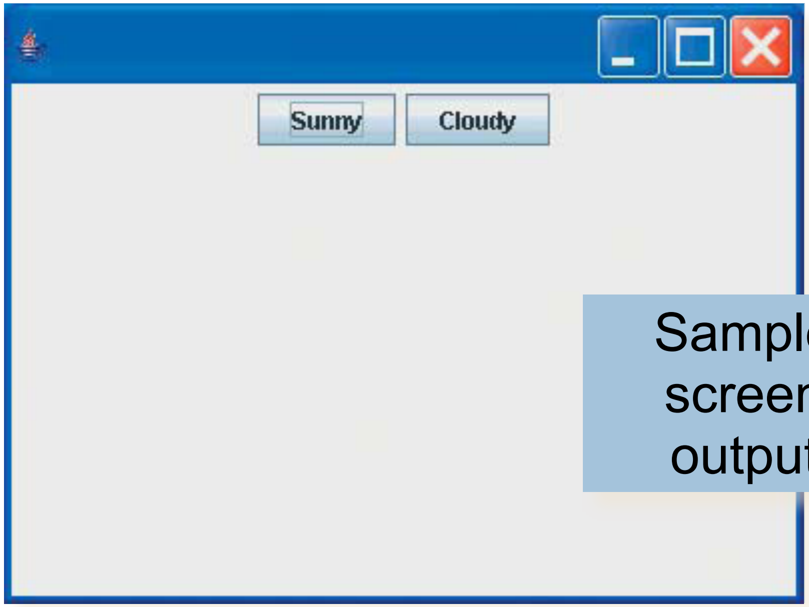
```
public void showApplet(JApplet anApplet)
{
      anApplet.init();
      . . .
      anApplet.paint();
}
```

The Class JFrame

- For GUIs to run as applications (instead of from a web page)
  - Use class JFrame as the base class
- View example program, listing 8.20
  class ButtonDemo
- Note method setSize
  - Width and height given in number of pixels
  - Sets size of window

The Class **JFrame**

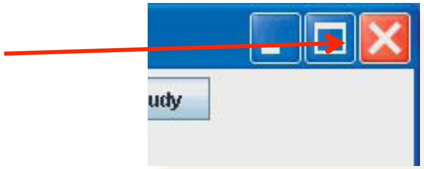
- View demo program, listing 8.21
  class **ShowButtonDemo**



Sample screen output

Window Events and Window Listeners

- Close-window button fires an event



  - Generates a *window event* handled by a *window listener*
- View class for window events, listing 8.22, `class WindowDestroyer`
- Be careful not to confuse `JButtons` and the close-window button

The **ActionListener** Interface

- Use of interface ActionListener requires only one method

```
public void actionPerformed
        (ActionEvent e)
```

- Listener that responds to button clicks
  - Must be an action listener
  - Thus must **`implement ActionListener`** interface

Summary

- An interface contains
  - Headings of public methods
  - Definitions of named constants
  - No constructors, no private instance variables
- Class which implements an interface must
  - Define a body for every interface method specified
- Interface enables designer to specify methods for another programmer

Summary

- Interface is a reference type
  - Can be used as variable or parameter type
- Interface can be extended to create another interface
- Dynamic (late) binding enables objects of different classes to substitute for one another
  - Must have identical interfaces
  - Called polymorphism

Summary

- Derived class obtained from base class by adding instance variables and methods
  - Derived class inherits all public elements of base class
- Constructor of derived class must first call a constructor of base class
  - If not explicitly called, Java automatically calls default constructor

Summary

- Within constructor
  - `this` calls constructor of same class
  - `super` invokes constructor of base class
- Method from base class can be overridden
  - Must have same signature
- If signature is different, method is overloaded

Summary

- Overridden method can be called with preface of `super`
- Private elements of base class cannot be accessed directly by name in derived class
- Object of derived class has type of both base and derived classes
- Legal to assign object of derived class to variable of any ancestor type

Summary

- Every class is descendant of class `Object`
- Class derived from `JFrame` produces applet like window in application program
- Method `setSize` resizes `JFrame` window
- Class derived from `WindowAdapter` defined to be able to respond to `closeWindow` button