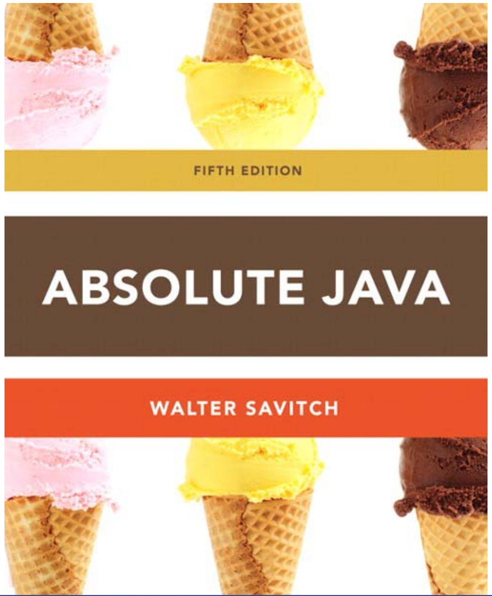

Chapter 7

Inheritance

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Introduction to Inheritance

- *Inheritance* is one of the main techniques of object-oriented programming (OOP)
- Using this technique, a very general form of a class is first defined and compiled, and then more specialized versions of the class are defined by adding instance variables and methods
  - The specialized classes are said to *inherit* the methods and instance variables of the general class

Introduction to Inheritance

- Inheritance is the process by which a new class is created from another class
  - The new class is called a *derived class*
  - The original class is called the *base class*
- A derived class automatically has all the instance variables and methods that the base class has, and it can have additional methods and/or instance variables as well
- Inheritance is especially advantageous because it allows code to be *reused*, without having to copy it into the definitions of the derived classes

Derived Classes

- When designing certain classes, there is often a natural hierarchy for grouping them
  - In a record-keeping program for the employees of a company, there are hourly employees and salaried employees
  - Hourly employees can be divided into full time and part time workers
  - Salaried employees can be divided into those on technical staff, and those on the executive staff

Derived Classes

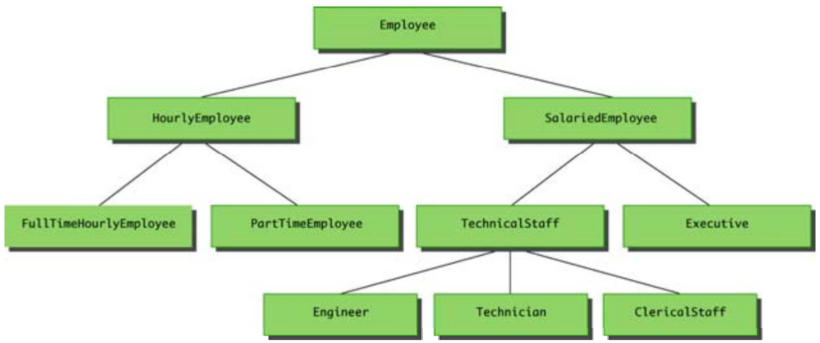
- All employees share certain characteristics in common
  - All employees have a name and a hire date
  - The methods for setting and changing names and hire dates would be the same for all employees
- Some employees have specialized characteristics
  - Hourly employees are paid an hourly wage, while salaried employees are paid a fixed wage
  - The methods for calculating wages for these two different groups would be different

Derived Classes

- Within Java, a class called `Employee` can be defined that includes all employees
- This class can then be used to define classes for hourly employees and salaried employees
  - In turn, the `HourlyEmployee` class can be used to define a `PartTimeHourlyEmployee` class, and so forth

A Class Hierarchy

Display 7.1 **A Class Hierarchy**



Derived Classes

- Since an hourly employee is an employee, it is defined as a *derived* class of the class `Employee`
  - A *derived class* is defined by adding instance variables and methods to an existing class
  - The existing class that the derived class is built upon is called the *base class*
  - The phrase `extends BaseClass` must be added to the derived class definition:

```
public class HourlyEmployee extends Employee
```

Derived Classes

- When a derived class is defined, it is said to inherit the instance variables and methods of the base class that it extends
  – Class **`Employee`** defines the instance variables **`name`** and **`hireDate`** in its class definition
  – Class **`HourlyEmployee`** also has these instance variables, but they are not specified in its class definition
  – Class **`HourlyEmployee`** has additional instance variables **`wageRate`** and **`hours`** that are specified in its class definition

Derived Classes

- Just as it inherits the instance variables of the class **`Employee`**, the class **`HourlyEmployee`** inherits all of its methods as well
  – The class **`HourlyEmployee`** inherits the methods **`getName`**, **`getHireDate`**, **`setName`**, and **`setHireDate`** from the class **`Employee`**
  – Any object of the class **`HourlyEmployee`** can invoke one of these methods, just like any other method

Derived Class (Subclass)

- A derived class, also called a *subclass*, is defined by starting with another already defined class, called a *base class* or *superclass*, and adding (and/or changing) methods, instance variables, and static variables
  – The derived class inherits all the public methods, all the public and private instance variables, and all the public and private static variables from the base class
  – The derived class can add more instance variables, static variables, and/or methods

Inherited Members

- A derived class automatically has all the instance variables, all the static variables, and all the public methods of the base class
  – Members from the base class are said to be *inherited*
- Definitions for the inherited variables and methods do not appear in the derived class
  – The code is reused without having to explicitly copy it, unless the creator of the derived class redefines one or more of the base class methods

Parent and Child Classes

- A base class is often called the *parent class*
  - A derived class is then called a *child class*
- These relationships are often extended such that a class that is a parent of a parent . . . of another class is called an *ancestor class*
  - If class **A** is an ancestor of class **B**, then class **B** can be called a *descendent* of class **A**

Overriding a Method Definition

- Although a derived class inherits methods from the base class, it can change or *override* an inherited method if necessary
  - In order to override a method definition, a new definition of the method is simply placed in the class definition, just like any other method that is added to the derived class

Changing the Return Type of an Overridden Method

- Ordinarily, the type returned may not be changed when overriding a method
- However, if it is a class type, then the returned type may be changed to that of any descendent class of the returned type
- This is known as a *covariant return type*
  - *Covariant return types* are new in Java 5.0; they are not allowed in earlier versions of Java

Covariant Return Type

- Given the following base class:

```
public class BaseClass
{ . . .
  public Employee getSomeone(int someKey)
  . . .
```

- The following is allowed in Java 5.0:

```
public class DerivedClass extends BaseClass
{ . . .
  public HourlyEmployee getSomeone(int someKey)
  . . .
```

Changing the Access Permission of an Overridden Method

- The access permission of an overridden method can be changed from private in the base class to public (or some other more permissive access) in the derived class
- However, the access permission of an overridden method can not be changed from public in the base class to a more restricted access permission in the derived class

Changing the Access Permission of an Overridden Method

- Given the following method header in a base case:
  `private void doSomething()`
- The following method header is valid in a derived class:
  `public void doSomething()`
- However, the opposite is not valid
- Given the following method header in a base case:
  `public void doSomething()`
- The following method header is not valid in a derived class:
  `private void doSomething()`

Pitfall: Overriding Versus Overloading

- Do not confuse *overriding* a method in a derived class with *overloading* a method name
  - When a method is overridden, the new method definition given in the derived class has the exact same number and types of parameters as in the base class
  - When a method in a derived class has a different signature from the method in the base class, that is overloading
  - Note that when the derived class overloads the original method, it still inherits the original method from the base class as well

The `final` Modifier

- If the modifier **`final`** is placed before the definition of a *method*, then that method may not be redefined in a derived class
- It the modifier **`final`** is placed before the definition of a *class*, then that class may not be used as a base class to derive other classes

The **super** Constructor

- A derived class uses a constructor from the base class to initialize all the data inherited from the base class
  - In order to invoke a constructor from the base class, it uses a special syntax:

```
public derivedClass(int p1, int p2, double p3)
{
  super(p1, p2);
  instanceVariable = p3;
}
```

  - In the above example, `super(p1, p2);` is a call to the base class constructor

The **super** Constructor

- A call to the base class constructor can never use the name of the base class, but uses the keyword `super` instead
- A call to `super` must always be the first action taken in a constructor definition
- An instance variable cannot be used as an argument to `super`

The **super** Constructor

- If a derived class constructor does not include an invocation of `super`, then the no-argument constructor of the base class will automatically be invoked
  - This can result in an error if the base class has not defined a no-argument constructor
- Since the inherited instance variables should be initialized, and the base class constructor is designed to do that, then an explicit call to `super` should always be used

The **this** Constructor

- Within the definition of a constructor for a class, `this` can be used as a name for invoking another constructor in the same class
  - The same restrictions on how to use a call to `super` apply to the `this` constructor
- If it is necessary to include a call to both `super` and `this`, the call using `this` must be made first, and then the constructor that is called must call `super` as its first action

The **this** Constructor

- Often, a no-argument constructor uses `this` to invoke an explicit-value constructor
  - No-argument constructor (invokes explicit-value constructor using `this` and default arguments):

```
public ClassName()
{
  this(argument1, argument2);
}
```

  - Explicit-value constructor (receives default values):

```
public ClassName(type1 param1, type2 param2)
{
  . . .
}
```


The **this** Constructor

```
public HourlyEmployee()
{
  this("No name", new Date(), 0, 0);
}
```

- The above constructor will cause the constructor with the following heading to be invoked:

```
public HourlyEmployee(String theName,
  Date theDate, double theWageRate, double
  theHours)
```


Tip: An Object of a Derived Class Has More than One Type

- An object of a derived class has the type of the derived class, and it also has the type of the base class
- More generally, an object of a derived class has the type of every one of its ancestor classes
  - Therefore, an object of a derived class can be assigned to a variable of any ancestor type

Tip: An Object of a Derived Class Has More than One Type

- An object of a derived class can be plugged in as a parameter in place of any of its ancestor classes
- In fact, a derived class object can be used anyplace that an object of any of its ancestor types can be used
- Note, however, that this relationship does not go the other way
  - An ancestor type can never be used in place of one of its derived types

Pitfall: The Terms "Subclass" and "Superclass"

- The terms *subclass* and *superclass* are sometimes mistakenly reversed
  - A superclass or base class is more general and inclusive, but less complex
  - A subclass or derived class is more specialized, less inclusive, and more complex
    - As more instance variables and methods are added, the number of objects that can satisfy the class definition becomes more restricted

An Enhanced **`StringTokenizer`** Class

- Thanks to inheritance, most of the standard Java library classes can be enhanced by defining a derived class with additional methods
- For example, the **`StringTokenizer`** class enables all the tokens in a string to be generated one time
  - However, sometimes it would be nice to be able to cycle through the tokens a second or third time

An Enhanced **`StringTokenizer`** Class

- This can be made possible by creating a derived class:
  - For example, **`EnhancedStringTokenizer`** can inherit the useful behavior of **`StringTokenizer`**
  - It inherits the **`countTokens`** method unchanged
- The new behavior can be modeled by adding new methods, and/or overriding existing methods
  - A new method, **`tokensSoFar`**, is added
  - While an existing method, **`nextToken`**, is overriden

An Enhanced **`StringTokenizer`** Class (Part 1 of 4)

Display 7.7 **EnhancedStringTokenizer**

```
import java.util.StringTokenizer;

public class EnhancedStringTokenizer extends StringTokenizer
{
    private String[] a;
    private int count;

    public EnhancedStringTokenizer(String theString)
    {
        super(theString);
        a = new String[countTokens()];
        count = 0;
    }

    public EnhancedStringTokenizer(String theString, String delimiters)
    {
        super(theString, delimiters);
        a = new String[countTokens()];
        count = 0;
    }
```

The method countTokens *is inherited and is not overridden.*

(continued)

An Enhanced `StringTokenizer` Class (Part 2 of 4)

Display 7.7 **EnhancedStringTokenizer**

```
    /**
     Returns the same value as the same method in the StringTokenizer class,
     but it also stores data for the method tokensSoFar to use.
    */
    public String nextToken()
    {
        String token = super.nextToken();
        a[count] = token;
        count++;
        return token;
    }
```

This method `nextToken` *has its definition overridden.*

`super.nextTokens` *is the version of* `nextToken` *defined in the base class* `StringTokenizer`. *This is explained more fully in Section 7.3.*

(continued)

An Enhanced `StringTokenizer` Class (Part 3 of 4)

Display 7.7 **EnhancedStringTokenizer**

```
    /**
     Returns the same value as the same method in the StringTokenizer class,
     changes the delimiter set in the same way as does the same method in the
     StringTokenizer class, but it also stores data for the method tokensSoFar to use.
    */
    public String nextToken(String delimiters)
    {
        String token = super.nextToken(delimiters);
        a[count] = token;
        count++;
        return token;
    }
```

This method `nextToken` *also has its definition overridden.*

`super.nextTokens` *is the version of* `nextToken` *defined in the base class* `StringTokenizer`.

(continued)

An Enhanced `StringTokenizer` Class (Part 4 of 4)

Display 7.7 **EnhancedStringTokenizer**

```
    /**
     Returns an array of all tokens produced so far.
     Array returned has length equal to the number of tokens produced so far.
    */
    public String[] tokensSoFar()
    {
        String[] arrayToReturn = new String[count];
        for (int i = 0; i < count; i++)
            arrayToReturn[i] = a[i];
        return arrayToReturn;
    }
}
```

`tokensSoFar` *is a new method.*

Encapsulation and Inheritance Pitfall: Use of Private Instance Variables from the Base Class

- An instance variable that is private in a base class is not accessible *by name* in the definition of a method in any other class, not even in a method definition of a derived class
  - For example, an object of the **`HourlyEmployee`** class cannot access the private instance variable **`hireDate`** by name, even though it is inherited from the **`Employee`** base class
- Instead, a private instance variable of the base class can only be accessed by the public accessor and mutator methods defined in that class
  - An object of the **`HourlyEmployee`** class can use the **`getHireDate`** or **`setHireDate`** methods to access **`hireDate`**

Encapsulation and Inheritance Pitfall: Use of Private Instance Variables from the Base Class

- If private instance variables of a class were accessible in method definitions of a derived class, then anytime someone wanted to access a private instance variable, they would only need to create a derived class, and access it in a method of that class
  - This would allow private instance variables to be changed by mistake or in inappropriate ways (for example, by not using the base type's accessor and mutator methods only)

Pitfall: Private Methods Are Effectively Not Inherited

- The private methods of the base class are like private variables in terms of not being directly available
- However, a private method is completely unavailable, unless invoked indirectly
  - This is possible only if an object of a derived class invokes a public method of the base class that happens to invoke the private method
- This should not be a problem because private methods should just be used as helping methods
  - If a method is not just a helping method, then it should be public, not private

`Protected` and `Package` Access

- If a method or instance variable is modified by `protected` (rather than `public` or `private`), then it can be accessed *by name*
  - Inside its own class definition
  - Inside any class derived from it
  - In the definition of any class in the same package
- The `protected` modifier provides very weak protection compared to the `private` modifier
  - It allows direct access to any programmer who defines a suitable derived class
  - Therefore, instance variables should normally not be marked `protected`

`Protected` and `Package` Access

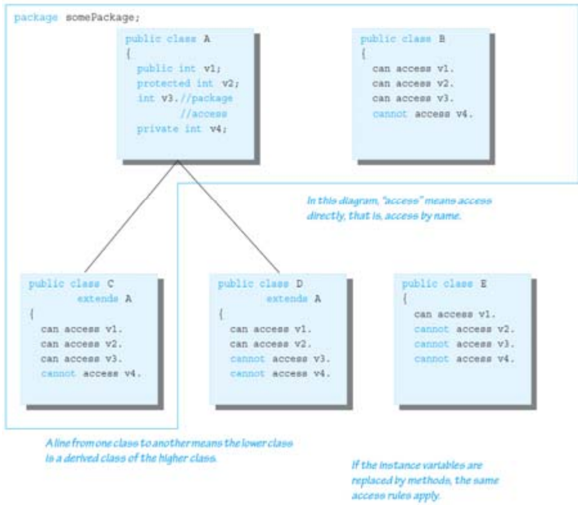
- An instance variable or method definition that is not preceded with a modifier has *package access*
  - Package access is also known as *default* or *friendly access*
- Instance variables or methods having package access can be accessed *by name* inside the definition of any class in the same package
  - However, neither can be accessed outside the package

Protected and **Package** Access

- Note that package access is more restricted than **protected**
  - Package access gives more control to the programmer defining the classes
  - Whoever controls the package directory (or folder) controls the package access

Access Modifiers

Display 7.9 Access Modifiers



Pitfall: Forgetting About the Default Package

- When considering package access, do not forget the default package
  - All classes in the current directory (not belonging to some other package) belong to an unnamed package called the *default package*
- If a class in the current directory is not in any other package, then it is in the default package
  - If an instance variable or method has package access, it can be accessed by name in the definition of any other class in the default package

Pitfall: A Restriction on Protected Access

- If a class **B** is derived from class **A**, and class **A** has a protected instance variable **n**, but the classes **A** and **B** are in *different packages*, then the following is true:
  - A method in class **B** can access **n** by name (**n** is inherited from class **A**)
  - A method in class **B** can create a local object of itself, which can access **n** by name (again, **n** is inherited from class **A**)

Pitfall: A Restriction on Protected Access

- However, if a method in class **B** creates an object of class **A**, it can not access **n** by name
  - A class knows about its own inherited variables and methods
  - However, it cannot directly access any instance variable or method of an ancestor class *unless they are public*
  - Therefore, **B** can access **n** whenever it is used as an instance variable of **B**, but **B** cannot access **n** when it is used as an instance variable of **A**
- This is true if **A** and **B** are *not* in the same package
  - If they were in the same package there would be no problem, because **protected** access implies package access

Tip: "Is a" Versus "Has a"

- A derived class demonstrates an *"is a"* relationship between it and its base class
  - Forming an "is a" relationship is one way to make a more complex class out of a simpler class
  - For example, an **HourlyEmployee** ***"is an"*** **Employee**
  - **HourlyEmployee** is a more complex class compared to the more general **Employee** class

Tip: "Is a" Versus "Has a"

- Another way to make a more complex class out of a simpler class is through a *"has a"* relationship
  - This type of relationship, called *composition*, occurs when a class contains an instance variable of a class type
  - The **Employee** class contains an instance variable, **hireDate**, of the class **Date**, so therefore, an **Employee** ***"has a"*** **Date**

Tip: "Is a" Versus "Has a"

- Both kinds of relationships are commonly used to create complex classes, often within the same class
  - Since **HourlyEmployee** is a derived class of **Employee**, and contains an instance variable of class **Date**, then **HourlyEmployee** ***"is an"*** **Employee** and ***"has a"*** **Date**

Tip: Static Variables Are Inherited

- Static variables in a base class are inherited by any of its derived classes
- The modifiers **public**, **private**, and **protected**, and package access have the same meaning for static variables as they do for instance variables

Access to a Redefined Base Method

- Within the definition of a method of a derived class, the base class version of an overridden method of the base class can still be invoked
  - Simply preface the method name with super and a dot

```
public String toString()
{
  return (super.toString() + "$" + wageRate);
}
```

- However, using an object of the derived class outside of its class definition, there is no way to invoke the base class version of an overridden method

You Cannot Use Multiple supers

- It is only valid to use **super** to invoke a method from a direct parent
  - Repeating **super** will not invoke a method from some other ancestor class
- For example, if the **Employee** class were derived from the class **Person**, and the **HourlyEmployee** class were derived form the class **Employee** , it would not be possible to invoke the **toString** method of the **Person** class within a method of the **HourlyEmployee** class

```
super.super.toString() // ILLEGAL!
```


The Class Object

- In Java, every class is a descendent of the class ***Object***
  - Every class has **Object** as its ancestor
  - Every object of every class is of type **Object**, as well as being of the type of its own class
- If a class is defined that is not explicitly a derived class of another class, it is still automatically a derived class of the class **Object**

The Class **Object**

- The class **Object** is in the package **java.lang** which is always imported automatically
- Having an **Object** class enables methods to be written with a parameter of type **Object**
  - A parameter of type **Object** can be replaced by an object of any class whatsoever
  - For example, some library methods accept an argument of type **Object** so they can be used with an argument that is an object of any class

The Class **Object**

- The class **Object** has some methods that every Java class inherits
  - For example, the **equals** and **toString** methods
- Every object inherits these methods from some ancestor class
  - Either the class **Object** itself, or a class that itself inherited these methods (ultimately) from the class **Object**
- However, these inherited methods should be overridden with definitions more appropriate to a given class
  - Some Java library classes assume that every class has its own version of such methods

The Right Way to Define **equals**

- Since the **equals** method is always inherited from the class **Object**, methods like the following simply overload it:

```
public boolean equals(Employee otherEmployee)
{ . . . }
```

- However, this method should be overridden, not just overloaded:

```
public boolean equals(Object otherObject)
{ . . . }
```


The Right Way to Define **equals**

- The overridden version of **equals** must meet the following conditions
  - The parameter **otherObject** of type **Object** must be type cast to the given class (e.g., **Employee)**
  - However, the new method should only do this if **otherObject** really is an object of that class, and if **otherObject** is not equal to **null**
  - Finally, it should compare each of the instance variables of both objects

A Better **equals** Method for the Class **Employee**

```
public boolean equals(Object otherObject)
{
  if(otherObject == null)
    return false;
  else if(getClass( ) != otherObject.getClass( ))
    return false;
  else
  {
    Employee otherEmployee = (Employee)otherObject;
    return (name.equals(otherEmployee.name) &&
      hireDate.equals(otherEmployee.hireDate));
  }
}
```


Tip: **getClass** Versus **instanceof**

- Many authors suggest using the **instanceof** operator in the definition of **equals**
  - Instead of the **getClass()** method
- The **instanceof** operator will return **true** if the object being tested is a member of the class for which it is being tested
  - However, it will return **true** *if it is a descendent of that class* as well
- It is possible (and especially disturbing), for the **equals** method to behave inconsistently given this scenario

Tip: **getClass** Versus **instanceof**

- Here is an example using the class **Employee**

```
. . . //excerpt from bad equals method
else if(!(OtherObject instanceof Employee))
  return false; . . .
```

- Now consider the following:

```
Employee e = new Employee("Joe", new Date());
HourlyEmployee h = new
  HourlyEmployee("Joe", new Date(),8.5, 40);
boolean testH = e.equals(h);
boolean testE = h.equals(e);
```


Tip: **getClass** Versus **instanceof**

- **testH** will be **true**, because **h** is an **Employee** with the same name and hire date as **e**
- However, **testE** will be **false**, because **e** is not an **HourlyEmployee**, and cannot be compared to **h**
- Note that this problem would not occur if the **getClass()** method were used instead, as in the previous **equals** method example

instanceof and **getClass**

- Both the **instanceof** operator and the **getClass()** method can be used to check the class of an object
- However, the **getClass()** method is more exact
  - The **instanceof** operator simply tests the class of an object
  - The **getClass()** method used in a test with **==** or **!=** tests if two objects *were created with* the same class

The **instanceof** Operator

- The **instanceof** operator checks if an object is of the type given as its second argument

  Object instanceof ClassName

  - This will return **true** if **Object** is of type **ClassName**, and otherwise return **false**
  - Note that this means it will return **true** if **Object** is the type of *any descendent class* of **ClassName**

The **getClass()** Method

- Every object inherits the same **getClass()** method from the **Object** class
  - This method is marked **final**, so it cannot be overridden
- An invocation of **getClass()** on an object returns a representation *only* of the class that was used with **new** to create the object
  - The results of any two such invocations can be compared with **==** or **!=** to determine whether or not they represent the exact same class

```
(object1.getClass() == object2.getClass())
```