STUDENT OUTLINE

Lesson 14 – Inheritance

INTRODUCTION: Inheritance, a major component of object-oriented-programming, is a technique that will allow you to define a very general class and then later define more specialized classes based on it. You will do this by adding some new capabilities to the existing more general class definitions or by changing the way the existing methods work to match the needs of the more specialized class. Inheritance saves work because the more specialized class inherits all the properties of the general class and you, the programmer, need only program the new features.

The key topics for this lesson are:

A. Single Inheritance
B. Class Hierarchies
C. Using Inheritance
D. Method Overriding
E. Interfaces

VOCABULARY:

PARENT CLASS	SUPERCLASS
BASE CLASS	SUBCLASS
CHILD CLASS	DERIVED CLASS
METHOD OVERRIDING	**`super`**
`extends`	**`interface`**
`implements`	

DISCUSSION:

A. Single Inheritance

1. *Inheritance* enables you to define a new class based on a class that already exists. The new class will inherit the characteristics of the existing class, but also provide some additional capabilities. This makes programming easier, because you can reuse and extend your previous work and avoid duplication of code.

2. The class that is used as a basis for defining a new class is called a *superclass* (or *parent class* or *base class*). The new class based on the superclass is called a *subclass* (or *child class* or *derived class*.)

3. The process by which a subclass inherits characteristics from just one parent class is called single inheritance. Some languages allow a derived class to inherit from more than one parent class in a process called multiple inheritance. Multiple inheritance, makes is difficult to determine which class will contribute what characteristics to the child class. Java avoids these issues by only providing support for single inheritance.

4. The figure shows a superclass and a subclass. The line between them shows the "is a kind of" relationship. The picture can be read as "a Student is a kind of Person." The clouds represent the classes. That is, the picture does not show any particular `Student` or any particular `Person`, but shows that the class `Student` is a subclass of the `Person` class.

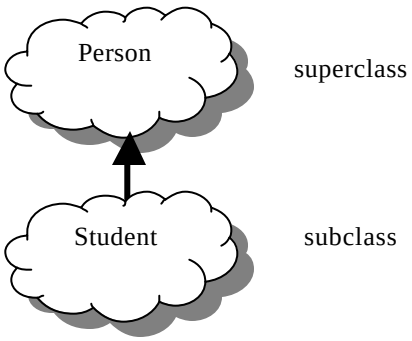


Figure 14.1 – Subclass and Superclass.

5. Inheritance is between classes, not between objects. A superclass is a blueprint that is followed when a new object is constructed. That newly constructed object is another blueprint that looks much like the original, but with added features. The subclass in turn can be used to construct objects that look like the superclass's objects, but with additional capabilities.

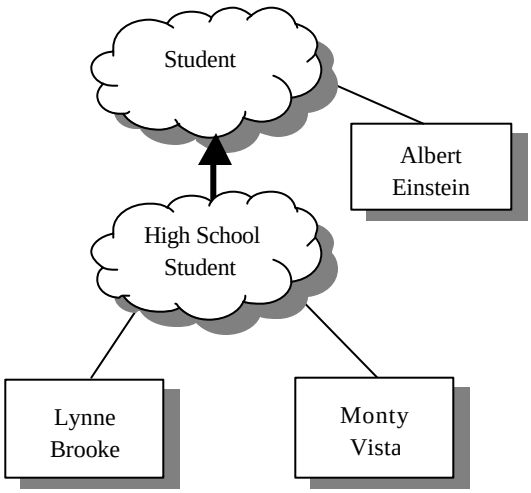


Figure 14.2 – Subclass and Superclass.

6. The figure shows a superclass and a subclass, and some objects that have been constructed from each. These objects that are shown as rectangles are actual instances of the class. In the picture, "Albert Einstein," "Lynne Brooke," and "Monty Vista" represent actual objects.

B. Hierarchies

1. In a hierarchy, each class has at most one superclass, but might have several subclasses. There is one class, at the "top" of the hierarchy that has no superclass. This is sometimes called the root of the hierarchy.

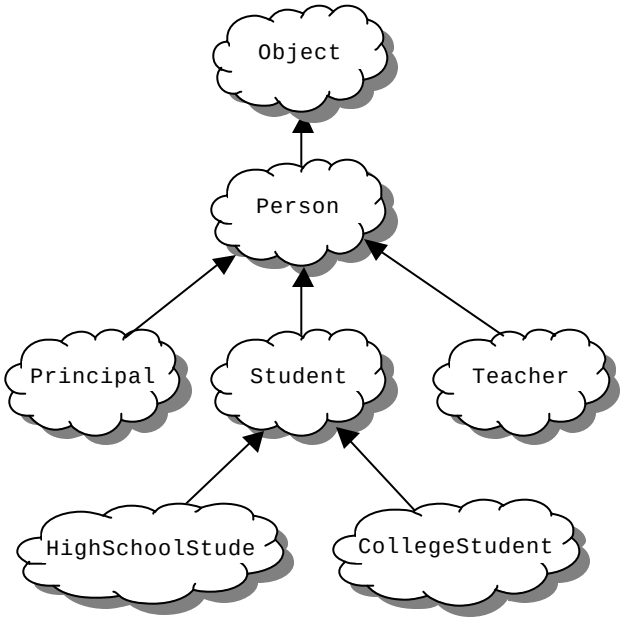


Figure 14.3 – `Person` Inheritance Hierarchy.

The figure shows a hierarchy of classes. It shows that "`Principal` is a kind of `Person`," "`Student` is a kind of `Person`," and that "`Teacher` is a kind of `Person`." It also shows that "`HighSchoolStudent` is a kind of `Student`" and "`CollegeStudent` is a kind of `Student`."

2. In our example, the class `Person` is the base class and the classes `Principal`, `Student`, `Teacher`, `HighSchoolStudent`, and `CollegeStudent` are derived classes.

3. In Java, the syntax for deriving a child class from a parent class is:

```
class subclass extends superclass
{
  // new characteristics of the subclass go here
}
```

4. Several classes are often subclasses of the same class. A subclass may in turn become a parent class for a new subclass. This means that inheritance can extend over several "generations" of classes. This is shown in the diagram, where class `HighSchoolStudent` is a subclass of class `Student`, which is itself a subclass of the `Person` class. In this case, class `HighSchoolStudent` is considered to be a subclass of the `Person` class, even though it is not a direct subclass.

5. In Java, every class that does not specifically extend another class is a subclass of the class `Object`. For example, in Figure 14.3, the `Person` class extends the `Object` class. The `Object` class has a small number of methods that make sense for all objects, such as the `toString` method, but these methods are not very useful and usually get redefined in classes lower in the hierarchy.

C. Using Inheritance

1. Here is a program that uses a class `Person` to represent people you might find at a school. The `Person` class has basic information in it, such as name, age and gender. An additional class, `Student`, is created that is similar to `Person`, but has the id and grade point average of the student.

```
class Person
{
  protected String myName ;   // name of the person
  protected int myAge;        // person's age
  protected String myGender;  // "M" for male, "F" for female

  // constructor
  public Person(String name, int age, String gender)
  {
    myName = name; myAge = age ; myGender = gender;
  }

  public String toString()
  {
    return myName + ", age: " + myAge + ", gender: " +myGender;
  }
}

class Student extends Person
{
  protected String myIdNum;    // Student Id Number
  protected double myGPA;      // grade point average

  // constructor
  public Student(String name, int age, String gender,
                 String idNum, double gpa)
  {
    // use the super class's constructor
    super(name, age, gender);

    // initialize what's new to Student
    myIdNum = idNum;
    myGPA = gpa;
  }
}

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

```
  {
    Person bob = new Person("Coach Bob", 27, "M");
    Student lynne = new Student("Lynne Brooke", 16, "F",
                                "HS95129", 3.5);
    System.out.println(bob);
    System.out.println(lynne);
  }
}
```

2. The `Student` class is a derived class (subclass) of `Person`. An object of type `Student` contains the following members:

Member	
`myName`	inherited from `Person`
`myAge`	inherited from `Person`
`myGender`	inherited from `Person`
`toString()`	inherited from `Person`
`myIdNum`	defined in `Student`
`myGPA`	defined in `Student`

3. The constructor for the `Student` class initializes the instance data of `Student` objects and uses the `Person` class's constructor to initialize the data of the `Person` superclass. The constructor for the `Student` class looks like this:

```
// constructor
public Student(String name, int age, String gender,
               String idNum, double gpa)
{
  // use the super class's constructor
  super(name, age, gender);

  // initialize what's new to Student
  myIdNum = idNum;
  myGPA = gpa;
}
```

The statement **`super`**`(name, age, gender)` invokes the `Person` class's constructor to initialize the inherited data in the superclass. The next two statements initialize the members that only `Student` has. Note that when **`super`** is used in a constructor, it must be the *first* statement.

4. It is not necessary to use **`super`**; the following would also work as a constructor for `Student`:

```
// constructor
public Student(String name, int age, String gender,
               String idNum, double gpa)
{
  // initialize the inherited members
  myName = name;
  myAge = age ;
  myGender = gender;
```

```
  // initialize what's new to Student
  myIdNum = idNum;
  myGPA = gpa;
}
```

In this constructor, each variable of the newly created `Student` object is set to an initial value.

5. So far, we have only seen the **`public`** (class members that are inaccessible from outside of the class**)** and **`private`** (class members that can be accessed outside of class**)** access modifiers. There is a third access modifier that can be applied to an instance variable or method. If it is declared to be **`protected`**, then it can be used in the class in which it is defined and in any subclass of that class. This declaration is less restrictive than **`private`** and more restrictive than **`public`**. Classes that are written specifically to be used as a basis for making subclasses often have protected members. The protected members are there to provide a foundation for the subclasses to build on. But they are still invisible to the public at large.

D. Method Overriding

1. A derived class can *override* a method from its base class by defining a replacement method with the same signature. For example in our `Student` subclass, the `toString()` method contained in the `Person` superclass does not reference the new variables that have been added to objects of type `Student`, so nothing new is printed out. We need a new `toString()` method in the class `Student`:

```
// overrides the toString method in the parent class
public String toString()
{
  return myName + ", age: " + myAge + ", gender: " + myGender +
         ", student id: " + myIdNum + ", gpa: " + myGPA;
}
```

2. Even though the base class has a `toString()` method, the new definition of `toString()` in the derived class will override the base class's version . The base class has its method, and the derived class has its own method with the same name. With the change in the `Student` class the following program will print out the full information for both items.

```
class School
{
  public static void main (String args[])
  {
    Person bob = new Person("Coach Bob", 27, "M");
    Student lynne = new Student("Lynne Brooke", 16, "F",
                                "HS95129", 3.5);

    System.out.println(bob.toString());
    System.out.println(lynne.toString());
  }
}
```

Run Output:

```
Coach Bob, age: 27, gender: M
Lynne Brooke, age: 16, gender: F, student id: HS95129, gpa: 3.5
```

The line `bob.toString()` calls the `toString()` method defined in `Person`, and the line `lynne.toString()` calls the `toString()` method defined in `Student`.

3. Sometimes (as in the example) you want a derived class to have its own method, but that method includes everything the derived class's method does. You can use the **`super`** reference in this situation to first invoke the original `toString()` method in the base class as follows:

```
public String toString()
{
  return super.toString() +
         ", student id: " + myIdNum + ", gpa: " + myGPA;
}
```

Inside a method, **`super`** does not have to be used in the first statement, unlike the case when **`super`** is used in a constructor.

E. Interfaces

1. In Java, an interface is a mechanism that unrelated objects use to interact with each other. Like a protocol, an interface specifies an agreed-on behavior (or behaviors).

2. The `Person` class and its class hierarchy defines the attributes and behaviors of a person. But a person can interact with the world in other ways. For example, an employment program could manage a person at a school. An employment program isn't concerned with the kinds of items it handles as long as each item provides certain information, such as salary and employee id. This interaction is enforced as a protocol of method definitions contained within an interface. The `Employable` interface would define, but not implement, methods that set and get the salary, assign an id number, and so on.

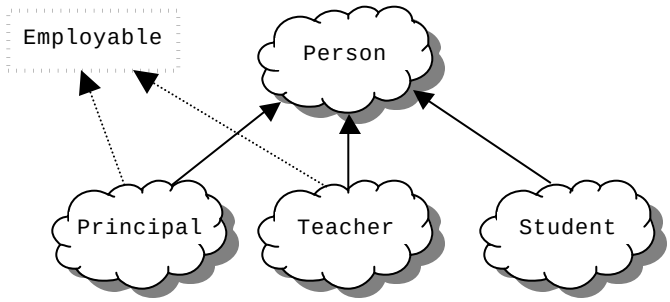


Figure 14.4 – `Employable` Interface.

3. To work in the employment program, the `Teacher` class must agree to this protocol by *implementing* the interface. To implement an interface, a class

must implement all of the methods defined in the interface. In our example, the shared methods of the `Employable` interface would be implemented in the `Teacher` class.

4. In Java, an **`interface`** consists of a set of methods, without any associated implementations. Here is an example of Java interface that defines the behaviors of "employability" described earlier:

```
public interface Employable
{
  public double getSalary();
  public String getEmployeeID();

  public void setSalary(double salary);
  public void setEmployeeID(String id);
}
```

A class *implements an interface* by supplying code for all the interface methods. **`implements`** is a reserved word. For example:

```
public class Teacher implements Employable
{
  ...
  public double getSalary() { return mySalary; }
  public int getEmployeeID() { return myEmployeeID; }

  public void setSalary(double salary) { mySalary = salary; }
  public void setEmployeeID(String id) { myEmployeeID = id; }
}
```

5. A class can implement any number of interfaces. In fact, a class can both extend another class and implement one or more interfaces. So, we can have things like

```
public class Teacher extends Person implements Employable
{
  ...
}
```

6. An interface defines a protocol that any class anywhere in the class hierarchy can implement. Interfaces are useful for the following:

   – Declaring a common set of methods that one or more classes are required to implement
   – Providing access to an object's programming interface without revealing the details of its class.
   – Providing a relationship between dissimilar classes without imposing an unnatural class relationship.

7. You are not likely to need to write your own interfaces until you get to the point of writing fairly complex programs. However, there are a few interfaces that are used in important ways in Java's standard packages. You'll learn about some of these standard interfaces in future lessons. In particular, the Marine Biology Simulation, which is supplied by the College Board™ for use in Advanced Placement Computer Science classes, makes frequent use of the interface concept.

SUMMARY/ REVIEW: Inheritance represents the “is a kind of” relationship between types of objects. In practice it may be used to add new features to an existing class. It is the primary tool for reusing your own and standard library classes. Inheritance allows a programmer to derive a new class (called a derived class or a subclass) from another class (called a base class or superclass). A derived class inherits all the data fields and methods (but not constructors) from the base class and can add its own methods or redefine some of the methods of the base class.

ASSIGNMENT: Lab Exercise, L.A.14.1, *BackToSchool*
Lab Exercise, L.A.14.2, *GraphicPolygon*

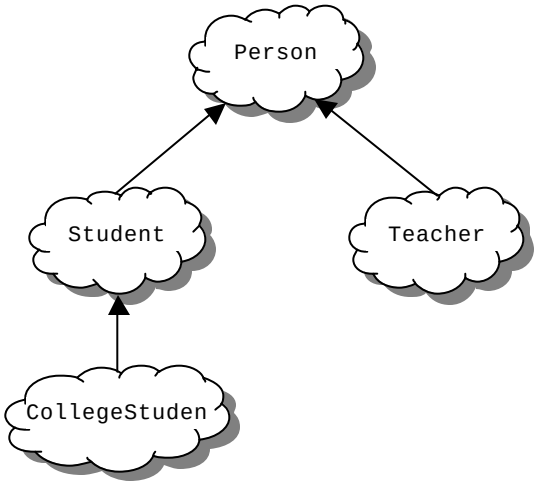
LAB EXERCISE

BackToSchool

Background:

The HighSchool application described in the lesson has two classes: the `Person` superclass and the `Student` subclass. Using inheritance, in this lab you will create two new classes, `Teacher` and `CollegeStudent`. A `Teacher` will be like `Person` but will have additional properties such as *salary* (the amount the teacher earns) and *subject* (e.g. “Computer Science”, "Chemistry", "English", "Other”). The `CollegeStudent` class will extend the `Student` class by adding a *year* (current level in college) and *major* (e.g. “Electrical Engineering”, “Communications”, “Undeclared”).

The inheritance hierarchy would appear as follows:



Here is the `Person` base class from the lesson to be used as a starting point for the `Teacher` class:

```
class Person
{
  protected String myName ;   // name of the person
  protected int myAge;        // person's age
  protected String myGender;  // "M" for male, "F" for female

  // constructor
  public Person(String name, int age, String gender)
  {
    myName = name; myAge = age ; myGender = gender;
  }

  public String toString()
  {
    return myName + ", age: " + myAge + ", gender: " +myGender;
```

```
  }
}
```

The `Student` class is derived from the `Person` class and used as a starting point for the `CollegeStudent` class:

```
class Student extends Person
{
  protected String myIdNum;    // Student Id Number
  protected double myGPA;      // grade point average

  // constructor
  public Student(String name, int age, String gender,
                 String idNum, double gpa)
  {
    // use the super class' constructor
    super(name, age, gender);

    // initialize what's new to Student
    myIdNum = idNum;
    myGPA = gpa;
  }
}
```

Assignment:

1. Add methods to "set" and "get" the instance variables in the `Person` class. These would consist of: `getName`, `getAge`, `getGender`, `setName`, `setAge`, and `setGender`.

2. Add methods to "set" and "get" the instance variables in the `Student` class. These would consist of: `getIdNum`, `getGPA`, `setIdNum`, and `setGPA`.

3. Write a `Teacher` class that extends the parent class `Person`.

   a. Add instance variables to the class for *subject* (e.g. "Computer Science", "Chemistry",, "English", "Other") and *salary* (the teachers annual salary). *Subject* should be of type `String` and *salary* of type **`double`**. Choose appropriate names for the instance variables.

   b. Write a constructor for the `Teacher` class. The constructor will use five parameters to initialize `myName`, `myAge`, `myGender`, *subject*, and *salary*. Use the **`super`** reference to use the constructor in the `Person` superclass to initialize the inherited values.

   c. Write "setter" and "getter" methods for all of the class variables. For the `Teacher` class they would be: `getSubject`, `getSalary`, `setSubject`, and `setSalary`.

   d. Write the `toString()` method for the `Teacher` class. Use a **`super`** reference to do the things already done by the superclass.

4. Write a `CollegeStudent` subclass that extends the `Student` class.

   a. Add instance variables to the class for *major* (e.g. "Electrical Engineering", "Communications", "Undeclared") and *year* (e.g. FROSH = 1, SOPH = 2, …). *Major* should be of type `String` and *year* of type **`int`**. Choose appropriate names for the instance variables.

   b. Write a constructor for the `CollegeStudent` class. The constructor will use seven parameters to initialize `myName`, `myAge`, `myGender`, `myIdNum`, `myGPA`, *year*, and *major*. Use the **`super`** reference to use the constructor in the `Student` superclass to initialize the inherited values.

   c. Write "setter" and "getter" methods for all of the class variables. For the `CollegeStudent` class they would be: `getYear`, `getMajor`, `setYear`, and `setMajor`.

   d. Write the `toString()` method for the `CollegeStudent` class. Use a **`super`** reference to do the things already done by the superclass.

5. Write a testing class with a `main()` that constructs all of the classes (`Person`, `Student`, `Teacher`, and `CollegeStudent`) and calls their `toString()` method. Sample usage would be:

```
Person bob = new Person("Coach Bob", 27, "M");
System.out.println(bob);

Student lynne = new Student("Lynne Brooke", 16, "F", "HS95129", 3.5);
System.out.println(lynne);

 Teacher mrJava = new Teacher("Duke Java", 34, "M", "Computer Science", 50000);
 System.out.println(mrJava);

CollegeStudent ima = new CollegeStudent("Ima Frosh", 18, "F", "UCB123",
                                        4.0, 1, "English");
System.out.println(ima);
```

   A sample run of the program would give:

```
Coach Bob, age: 27, gender: M
Lynne Brooke, age: 16, gender: F, student id: HS95129, gpa: 3.5
Duke Java, age: 34, gender: M, subject: Computer Science, salary: 50000.0
Ima Frosh, age: 18, gender: F, student id: UCB123, gpa: 4.0, year: 1, major: English
```

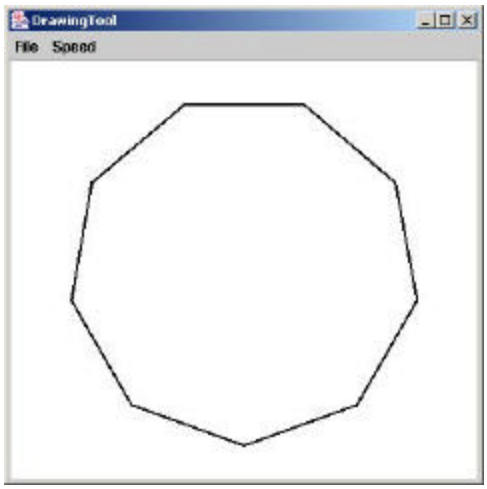
6. Turn in the source code with the run output attached. There should be one source file for each class: *Person.java* for the `Person` class, *Student.java* for the `Student` class, *Teacher.java* for the `Teacher` class, *CollegeStudent.java* for the `CollegeStudent` class, and *BackToSchool.java* for the `BackToSchool` testing class.

LAB EXERCISE

GraphicPolygon

Background:

In a previous lab exercise, we created a `RegularPolygon` class that maintained a large number of properties for any polygon of a given number and length of sides. By extending the `RegularPolygon` class to include the capabilities of the `DrawingTool` class, it is possible to display a graphic representation of any polygon. For example, a 9-sided regular polygon (nonagon) would be represented as follows:



Assignment:

1. Extend the `RegularPolygon` class created in lab L.A.7.1 to create a `GraphicPolygon` class. Use the following declarations as a starting point for your lab work.

```
class GraphicPolygon extends RegularPolygon
{
  private DrawingTool pen = new DrawingTool(new SketchPad(400, 400));
  private double xPosition, yPosition;

  // constructors

  // Initializes a polygon of numSides sides and sideLength
  //   length in the superclass. The polygon is centered at
  //   xPosition = yPosition = 0
  public GraphicPolygon(int numSides, double sideLength)
  {
  }

  // Initializes a polygon of numSides sides and sideLength
  //   length in the superclass. The polygon is centered at
  //   xPosition = x and yPosition = y
  public GraphicPolygon(int numSides, double sideLength, double x, double y)
  {
  }
```

```
  // public methods

  // Sets xPosition = x and yPosition = y to correspond to the new
  //   center of the polygon
  public void moveTo(double x, double y)
  {
  }

  // Draws the polygon about the center point (xPosition, yPosition).
  // Uses properties inherited from RegularPolygon to determine the
  //   number and length of the sides, the radius of the inscribed circle,
  //   and the vertex angle with which to draw the polygon
  public void draw()
  {
  }
}
```

2. Write two constructor methods. The first constructor initializes the number and length of the sides of a polygon centered about the point (0, 0). The Second constructor is used to initialize a polygon a specified number and length of sides with a center at a specified x and y location.

3. Write a method that draws the polygon onto the `Sketchpad` window using the movement and drawing methods available in the `DrawingTool` class.

4. Write a method that moves the center of the polygon to a specified `x` and `y` location.

5. Write a testing class with a `main()` method that constructs a `GraphicPolygon` and calls each method. Sample usage for a polygon with 9 sides of length 100 would give:

```
GraphicPolygon gPoly = new GraphicPolygon(9, 100);
gPoly.draw();
```

Instructions:

1. Use the following values to test your functions:

   Square: number of sides = 4, length of side = 150
   Octagon: number of sides = 8, length of side = 100
   Enneadecagon: number of sides = 19, length of side = 50
   Enneacontakaihenagon: number of sides = 91, length of side = 10