Chapter 5

Polymorphism & Interface

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Objectives

- After you have read and studied this chapter, you should be able to
  - Write programs that are easily extensible and modifiable by applying polymorphism in program design.
  - Define reusable classes based on inheritance and abstract classes and abstract methods.
  - Explain the difference between dynamic (run-time) binding and static (compile-time) binding.
  - Differentiate the abstract classes and Java interfaces.
  - To declare and implement interfaces

OUTLINE

1. Introduction to Polymorphism
2. Static and Dynamic Binding
3. The instanceof Operator
4. Abstract Class & Abstract Method
5. Interfaces
6. Implementation of an Interface
7. Abstract Classes Implementing Interfaces
8. Derived Interfaces (Extending an Interface)
9. Defined Constants in Interfaces

1. Introduction to Polymorphism

- There are three main programming mechanisms that constitute object-oriented programming (OOP)
  - Encapsulation
  - Inheritance
  - Polymorphism

- Polymorphism is the ability to associate many meanings to one method name
  - It does this through a special mechanism known as *late binding* or *dynamic binding*

- A polymorphic method is one that has the same name for different classes of the same family, but has different implementations, or behavior, for the various classes.

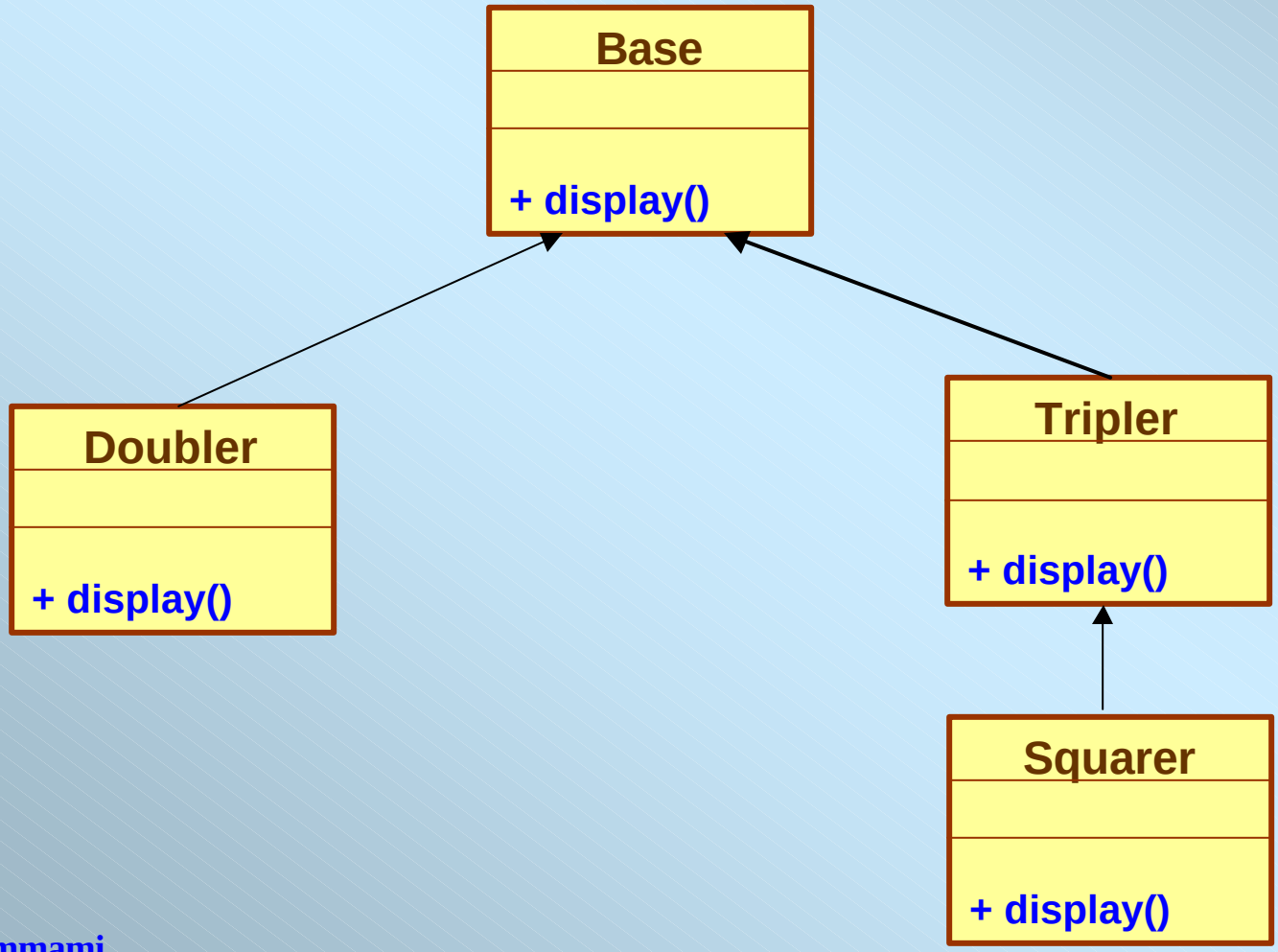
1. Introduction to Polymorphism

- **Polymorphism**
  - When a program invokes a method through a superclass variable, the correct subclass version of the method is called, based on the type of the reference stored in the superclass variable
  - The same method name and signature can cause different actions to occur, depending on the type of object on which the method is invoked
  - Facilitates adding new classes to a system with minimal modifications to the system's code

Example: Demonstrating Polymorphic Behavior

A polymorphic method (ex: display())

- **A method that has multiple meanings**
- **Created when a subclass overrides a method of the superclass**



Example: Demonstrating Polymorphic Behavior

```
public class Base {
   protected int i = 100;

   ...
   public void display() {    System.out.println( i );
   } }
```

```
public class Doubler extends Base {
   ...
   public void display() {System.out.println( i*2 );
   } }
```

```
public class Tripler extends Base {
   ...
   public void display() {
      System.out.println(i*3 );
   }  }
```

```
public class Squarer extends Tripler {
    ...
    public void display() {System.out.println( i*i );
    }  }
```

2. Static and Dynamic Binding

Case: Static binding

Some main program

output

```
Base  B = new Base();
B. display();
```
→ 100

```
Doubler D = new Doubler();
D. display();
```
→ 200

```
Tripler T = new Tripler();
T. display();
```
→ 300

```
Squarer S = new Squarer();
S. display();
```
→ 10000

Static binding occurs when a method is defined with the same name but with different headers and implementations. The actual code for the method is attached, or bound, at compile time. Static binding is used to support overloaded methods in Java.

2. Static and Dynamic Binding

Case: Dynamic binding

- A superclass reference can be aimed at a subclass object
  - This is possible because a subclass object *is a* superclass object as well
  - When invoking a method from that reference, the type of the actual referenced object, not the type of the reference, determines which method is called

Some main program

```
Base  B = new Base();
B. display();

Base D;
D = new Doubler();
D. display();

Base T;
T = new Tripler();
T. display();

Base S;
S = new Squarer();
S. display();
```

output

100

200

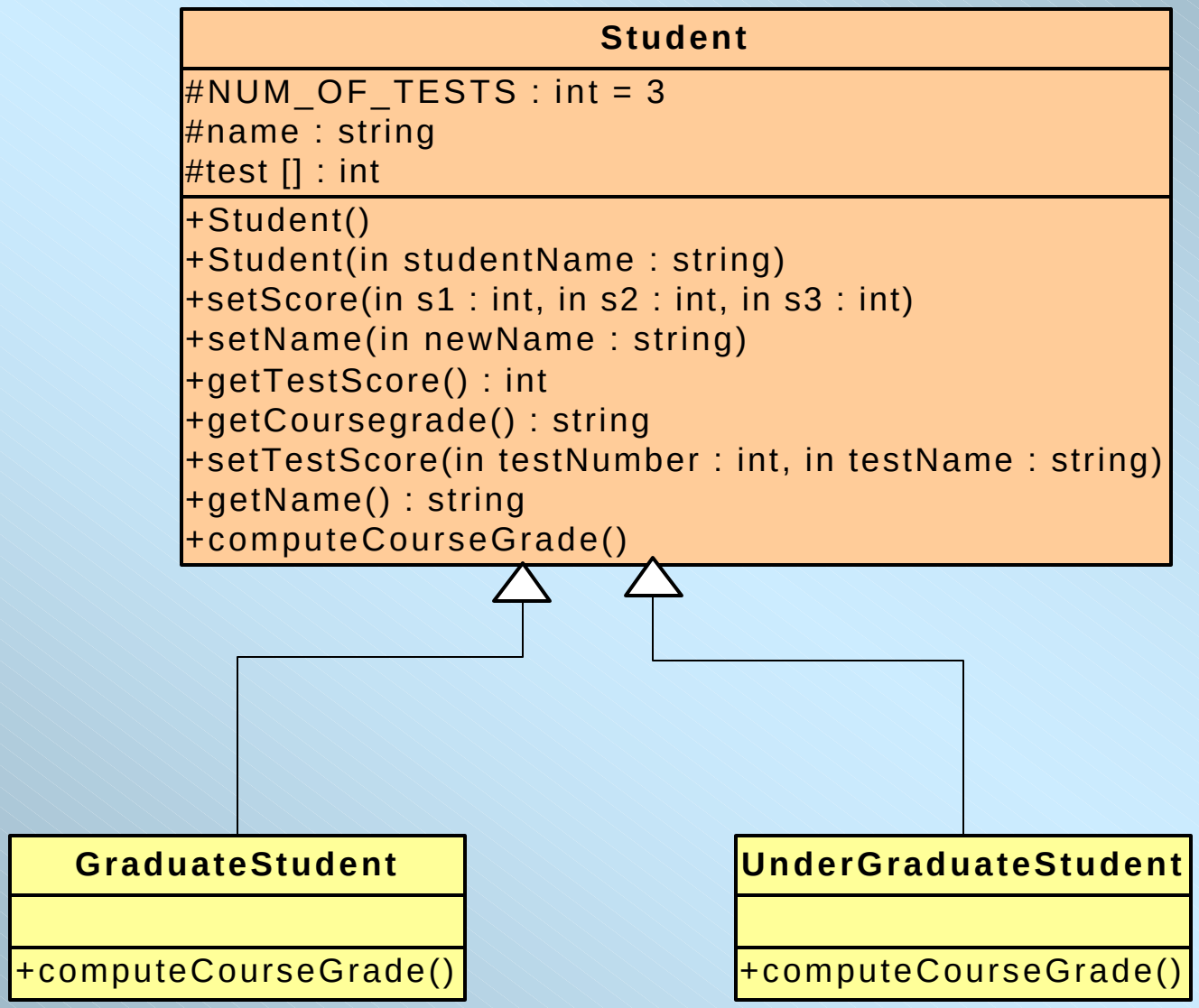
300

10000

Late binding or dynamic binding :

The appropriate version of a polymorphic method is decided at execution time

Example: Inheritance Hierarchy of Class Student : Polymorphism case



Example: Inheritance Hierarchy of Class Student : Polymorphism case

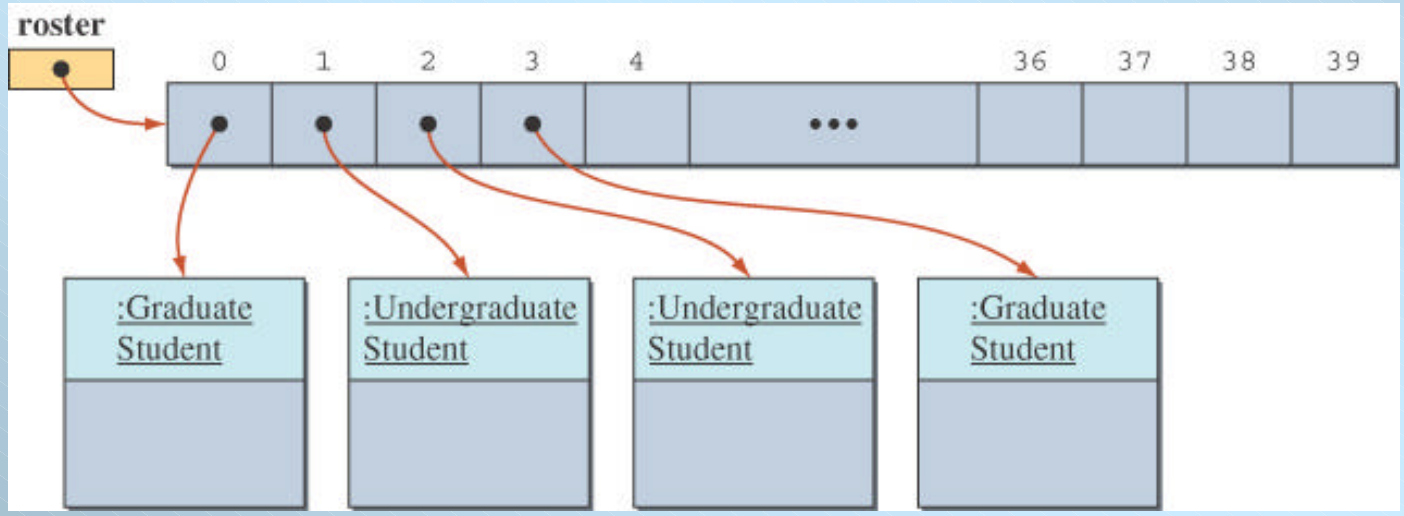
Creating the roster Array

- We mentioned in array definition that an array must contain elements of the same data type. For example, we can't store integers and real numbers in the same array.
- To follow this rule, it seems necessary for us to declare two separate arrays, one for graduate and another for undergraduate students. This rule, however, does not apply when the array elements are objects using the polymorphism. We only need to declare a single array.
- We can create the roster array combining objects from the **Student**, **UndergraduateStudent**, and **GraduateStudent** classes.

```
Student roster = new Student[40];
. . .
roster[0] = new GraduateStudent();
roster[1] = new UndergraduateStudent();
roster[2] = new UndergraduateStudent();
. . .
```

State of the roster Array

- The roster array with elements referring to instances of **GraduateStudent** or **UndergraduateStudent** classes.



Sample Polymorphic Message

- To compute the course grade using the roster array, we execute

```
for (int i = 0; i < numberOfStudents; i++) {
    roster[i].computeCourseGrade();
}
```

- If roster[i] refers to a GraduateStudent, then the computeCourseGrade method of the GraduateStudent class is executed.

- If roster[i] refers to an UndergraduateStudent, then the computeCourseGrade method of the UndergraduateStudent class is executed.

3. The instanceof Operator

- The instanceof operator can help us learn the class of an object.
- The following code counts the number of undergraduate students.

```
int undergradCount = 0;
for (int i = 0; i < numberOfStudents; i++) {
    if ( roster[i] instanceof UndergraduateStudent ) {
        undergradCount++;
    }
}
```

Implementation Student in Java

Case Study :

```
class Student {
   protected  final static int NUM_OF_TESTS = 3;
   protected  String         name;
   protected  int[]          test;
   protected  String         courseGrade;
   public Student( ) { this ("No Name"); }
   public Student(String studentName) {
      name = studentName;
      test = new int[NUM_OF_TESTS];
      courseGrade = "****";
   }
  public void setScore(int s1, int s2, int s3) {
      test[0] = s1; test[1] = s2; test[2] = s3;
   }
  public void computeCourseGrade() { courseGrade="";}

  public String getCourseGrade( ) {
    return courseGrade;    }
  public String getName( ) { return name; }
  public int getTestScore(int testNumber) {
    return test[testNumber-1];  }
  public void setName(String newName) {
    name = newName;  }
 public void setTestScore(int testNumber, int testScore)
  {              test[testNumber-1]=testScore;  }
 }
```

```
class GraduateStudent extends Student
{
  /**
    * students. Pass if total >= 80; otherwise, No Pass.
  */
   public void computeCourseGrade() {
      int total = 0;
      for (int i = 0; i < NUM_OF_TESTS; i++) {
        total += test[i]; }
      if (total >= 80) {
        courseGrade = "Pass";
      } else { courseGrade = "No Pass";  }
   }
}
```

```
class UnderGraduateStudent extends Student {

   public void computeCourseGrade() {
     int total = 0;
     for (int i = 0; i < NUM_OF_TESTS; i++) {
       total += test[i]; }
     if (total >= 70) {
       courseGrade = "Pass";
     } else {   courseGrade = "No Pass";  }
   }
}
```

Implementation StudentTest in Java

Case Study :

```
public class StudentTest  {
  public static void main(String[] args)
  {
     Student roster[]= new Student[2];
      roster[0] = new  GraduateStudent();
      roster[1] = new  UnderGraduateStudent();

      roster[0].setScore (20, 30, 50);
       roster[1].setScore (10, 17, 13);

      for (int i=0; i<roster.length; i++)
      {
       System.out.println("The name of the class is : " +  roster[i].getClass().getName());
       roster[i].computeCourseGrade();
        System.out.println(" Pass or Not  : " + roster[i].getCourseGrade());
      }
   }
 }
```

```
------ execution----------
The name of the class is : GraduateStudent
 Pass or Not  : Pass
The name of the class is : UnderGraduateStudent
 Pass or Not  : No Pass
```

If roster[i] refers to a GraduateStudent, then the computeCourseGrade method of the GraduateStudent class is executed.

If roster[i] refers to a UnderGraduateStudent, then the computeCourseGrade method of the UnderGraduateStudent class is executed.

We call the message computeCourseGrade *polymorphic*

Implementation StudentTest2 in Java

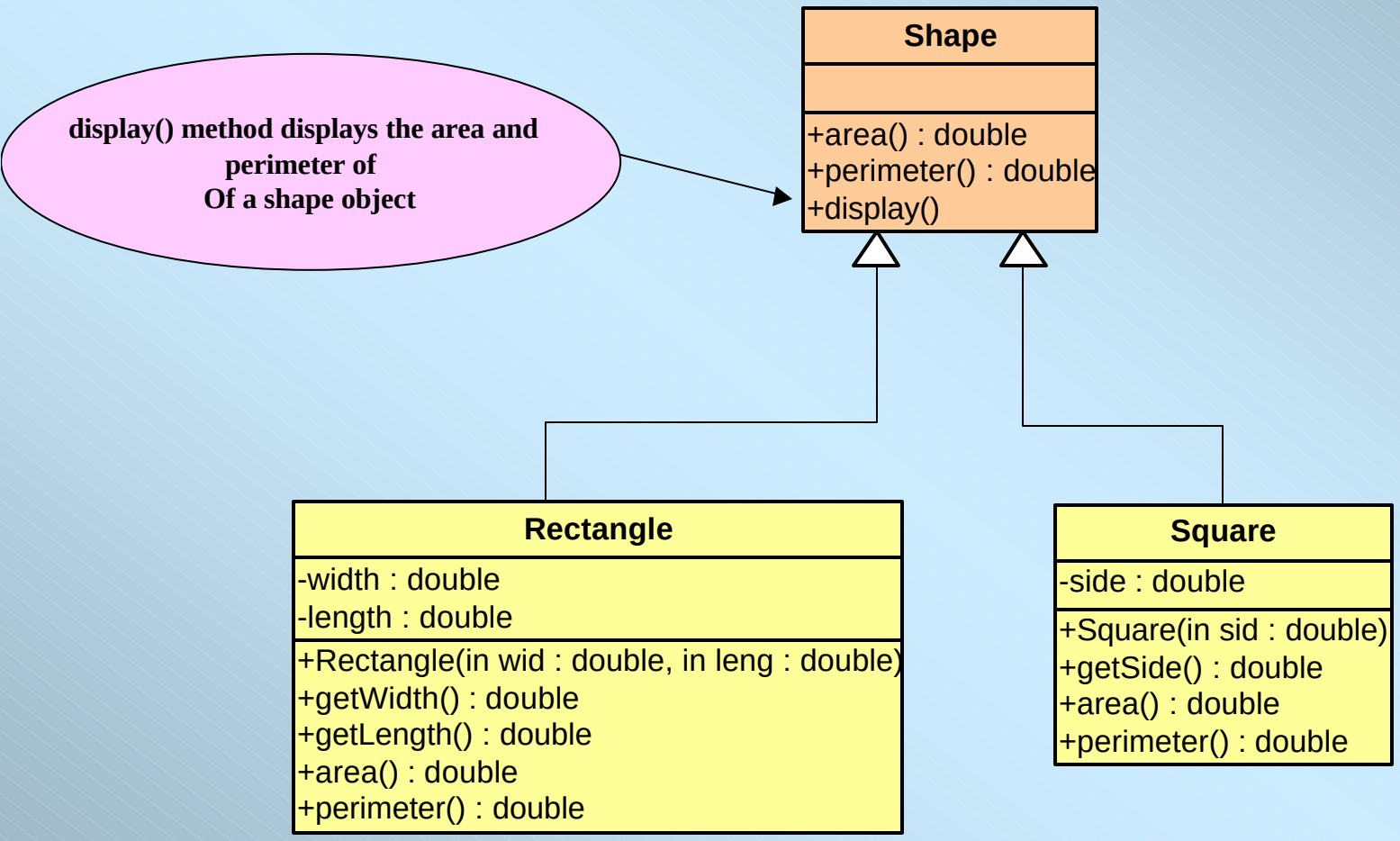
Case Study : **Question: Count the number of under graduate students**

```
public class StudentTest2  {
  public static void main(String[] args)
  {
     Student roster[]= new Student[2];
      roster[0] = new  GraduateStudent();
      roster[1] = new  UnderGraduateStudent();

      roster[0].setScore (20, 30, 50);
       roster[1].setScore (10, 17, 13);
      int nb=0;   //=== count the number of Under Graduate Students
      for (int i=0; i<roster.length; i++)
         if (roster[I] instanceof UnderGraduateStudent )
               nb++;

        System.out.println("The number of Under Graduate Students : " + nb);
      }       }  }
```

```
------ execution----------
The number of Under Graduate Students : 1
```

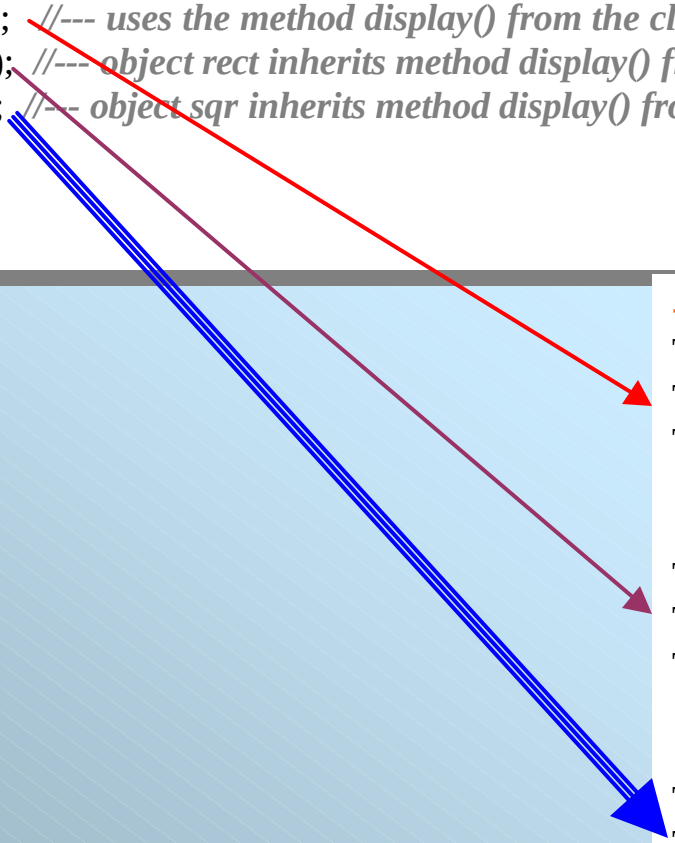
Rule: To Determine the class of an object , we use the *instanceof* operator.

Example: Inheritance Hierarchy of Class Shape



Test: inheritance of Super-Class Shape

```
public class ShapeTest {
    public static void main(String[] args)
    {
            Shape shp =new Shape();  // shp is an object from class Shape
            Rectangle  rect =new Rectangle(4.0, 5.0);  // rect is an object from class Rectangle
            Square sqr = new Square(6.0);  // sqr is an object from class Square

            shp.display();  //--- uses the method display() from the class Shape
            rect.display();  //--- object rect inherits method display() from Superclass Shape
            sqr.display();  //--- object sqr inherits method display() from Superclass Shape
}
}
```

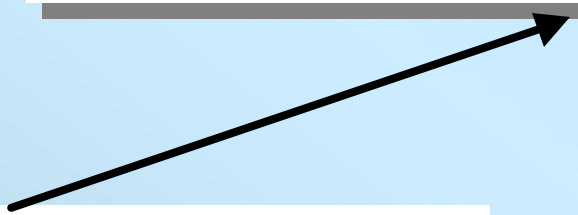


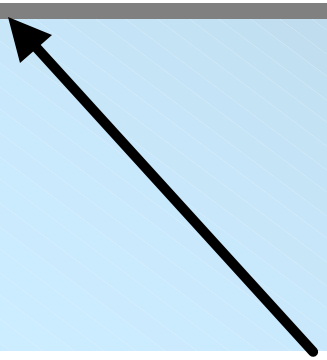
```
---- execution --------
The name of the class is : Shape
The area is :0.0
The perimeter is :0.0

The name of the class is : Rectangle
The area is :20.0
The perimeter is :13.0

The name of the class is : Square
The area is :36.0
The perimeter is :24.0
```

Implementation inheritance in Java

Case Study 3: Shape

```
public class Shape  {
    public double area()    {  return 0.0;  }
    public double perimeter() { return 0.0;};
    public void display()  {
     System.out.println("The name of the class is : " +  this.getClass().getName());
      //--- getClass() a method inherits from the super class Object.
      //--- getName() a method from the class String.
      System.out.println("The area is :"+ area());
      System.out.println("The perimeter is :"+ perimeter()+"\n\n");}
}
```

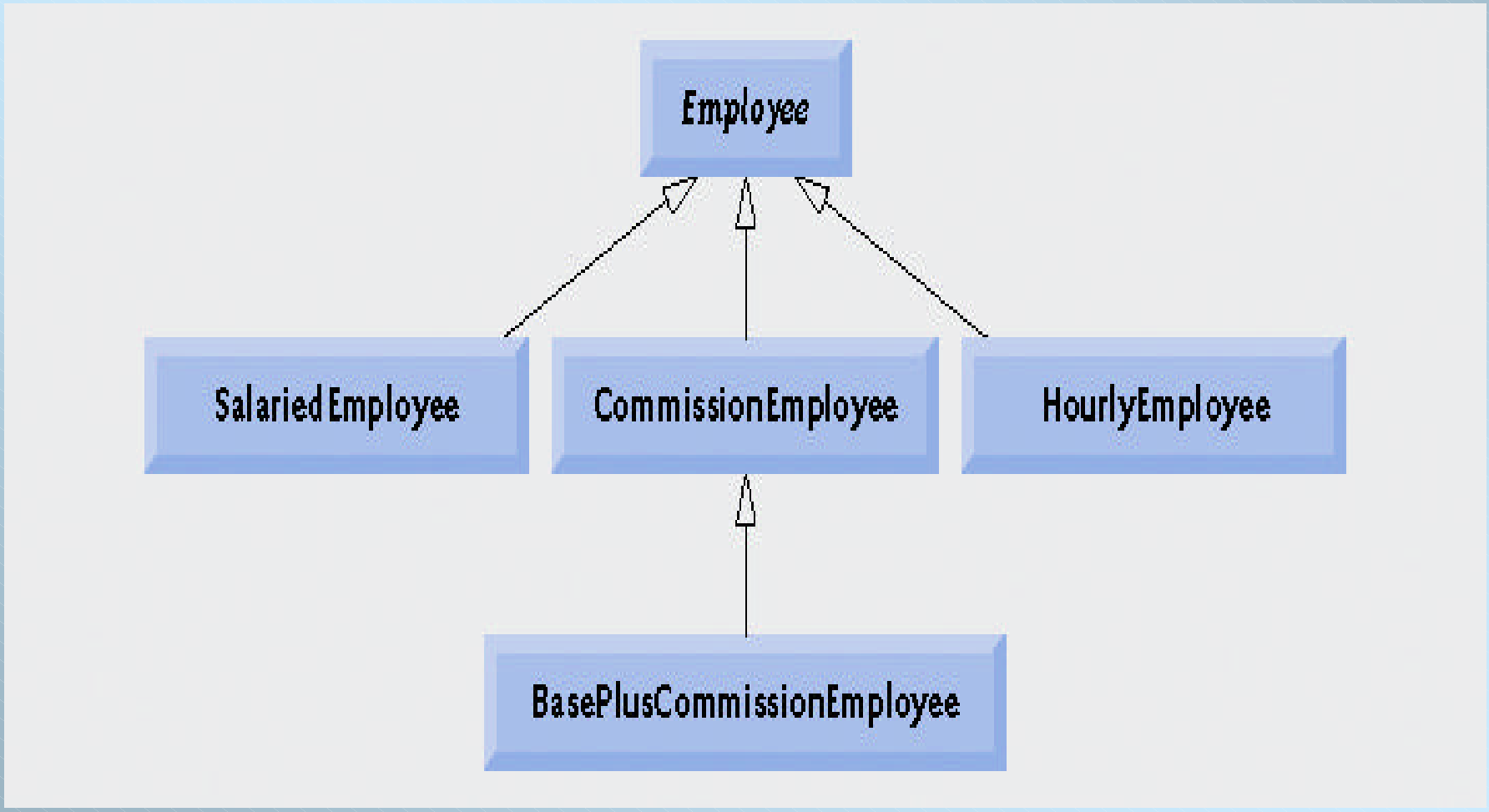




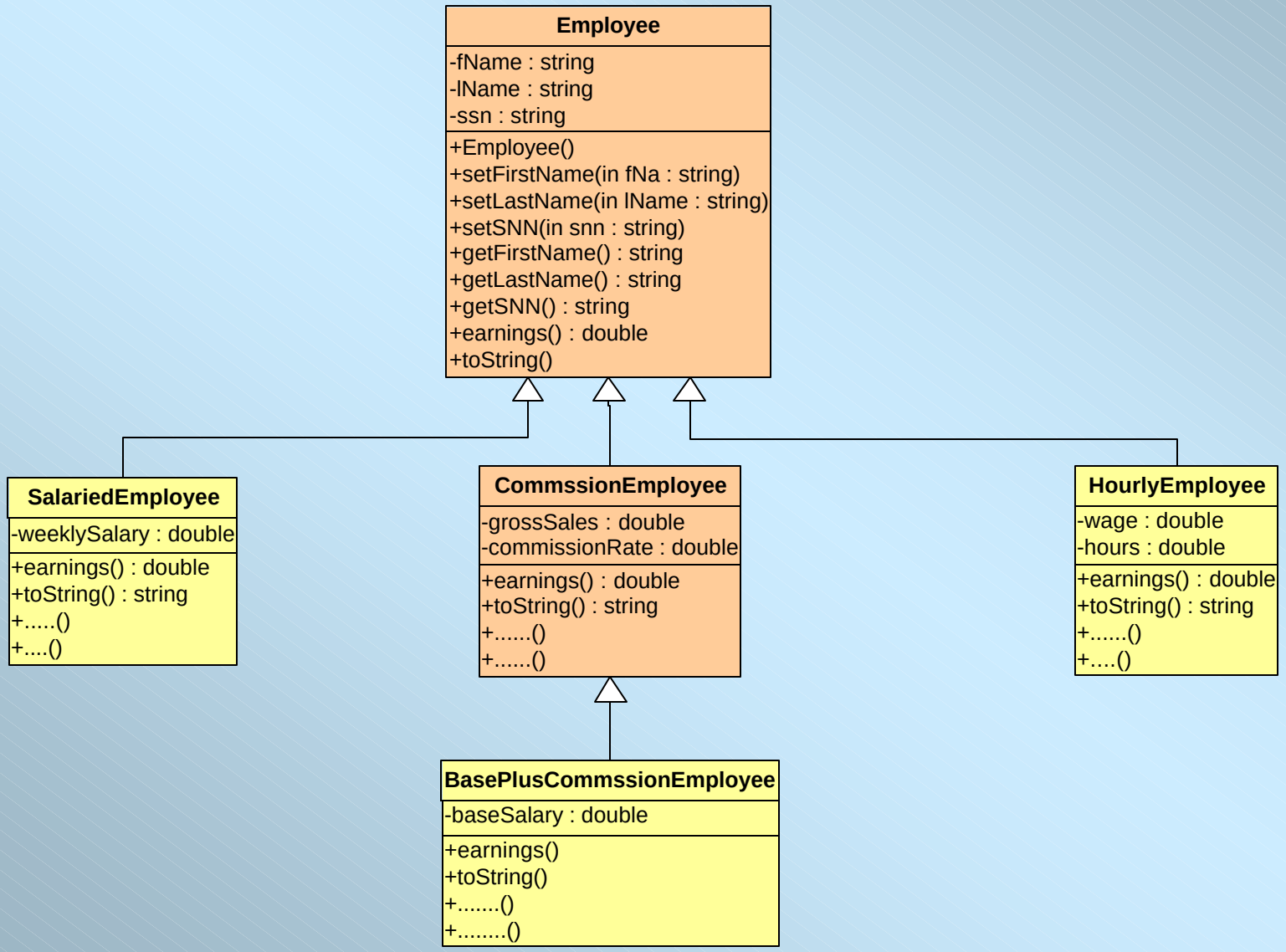
```
public class Rectangle extends Shape {
   private double width;
   private double length;
   public Rectangle(double length, double width)
   {   this.length = length;    this.width = width;
    }
public double getLength() {return length; }
public double getWidth()  {return width; }
 public double area(){
    return (this.getLength()*this.getWidth());
  }
 public double perimeter(){
    return (2*this.getLength()+this.getWidth()); }}
```

```
public class Square extends Shape  {
    private double side;
   public Square(double side) {  this.side = side; }
   public double getSide() {          return side;          }
   public double area() {
        return (this.getSide()*this.getSide());
    }
    public double perimeter() {
                return (4*this.getSide());

    }}
```

Employee hierarchy UML class diagram.



Example: Inheritance Hierarchy of Class Employee



Implementation Employee in Java

Case Study :

```
public abstract class Employee
{
   private String firstName;
   private String lastName;
   private String socialSecurityNumber;

   // three-argument constructor
public Employee( String first, String last, String ssn
)
   {    firstName = first;    lastName = last;
     socialSecurityNumber = ssn;
   } // end three-argument Employee constructor

   // set first name
   public void setFirstName( String first )
   {      firstName = first;
   } // end method setFirstName

   // return first name
   public String getFirstName()
   { return firstName;
   } // end method getFirstName
   // set last name
   public void setLastName( String last )
   {lastName = last;
   } // end method setLastName
```

```
// return last name
   public String getLastName()
   {
     return lastName;
   } // end method getLastName
   // set social security number
   public void setSocialSecurityNumber( String ssn )
   {  socialSecurityNumber = ssn; // should validate
   } // end method setSocialSecurityNumber

   // return social security number
   public String getSocialSecurityNumber()
   {  return socialSecurityNumber;
   } // end method getSocialSecurityNumber

   // return String representation of Employee object
   public String toString()
   {return ("The name is :"+ getFirstName()+" "+
getLastName() + "\nThe Social Security Number: "+
getSocialSecurityNumber() );
   } // end method toString

   // abstract method overridden by subclasses
   public abstract double earnings(); // no
implementation here
} // end abstract class Employee
```

Implementation SalariedEmployee in Java

Case Study :

```
public class SalariedEmployee extends Employee
{
   private double weeklySalary;
   // four-argument constructor
   public SalariedEmployee( String first, String last, String
ssn,   double salary )
   {
      //super( first, last, ssn ) code reuse
     super( first, last, ssn ); // pass to Employee constructor
     setWeeklySalary( salary ); // validate and store salary
   } // end four-argument SalariedEmployee constructor

   // set salary
   public void setWeeklySalary( double salary )
   {
     weeklySalary = salary < 0.0 ? 0.0 : salary;
// this mean that, if salary is <0 then put it 0 else put it salary
   } // end method setWeeklySalary

   // return salary
   public double getWeeklySalary()
   {      return weeklySalary;
   } // end method getWeeklySalary
```

```
// calculate earnings; override abstract method earnings
in Employee
   public double earnings()
   { return getWeeklySalary();
   } // end method earnings

   // return String representation of SalariedEmployee
object
   //  this method override toString() of superclass method
   public String toString()
   {     //***** super.toString() : code reuse (good
example)
         return ( super.toString()+ "\nearnings = " +
getWeeklySalary());
          } // end method toString
} // end class SalariedEmployee
```

Implementation HourlyEmployee in Java

Case Study :

```
public class HourlyEmployee extends Employee
{
   private double wage; // wage per hour
   private double hours; // hours worked for week
   // five-argument constructor
   public HourlyEmployee( String first, String last, String
ssn,    double hourlyWage, double hoursWorked )
   {
      //  super( first, last, ssn ) code (constructor) reuse
     super( first, last, ssn );
  setWage( hourlyWage ); // validate and store hourly wage
setHours( hoursWorked ); // validate and store hours
worked
   } // end five-argument HourlyEmployee constructor
   public void setWage( double hourlyWage )
   {    wage = ( hourlyWage < 0.0 ) ? 0.0 : hourlyWage;
   } // end method setWage
   public double getWage()
   { return wage;
   } // end method getWage
   public void setHours( double hoursWorked )
   {hours = ( ( hoursWorked >= 0.0 ) && ( hoursWorked <=
168.0 ) ) ?   hoursWorked : 0.0;
   } // end method setHours
   public double getHours()
   {      return hours;
   } // end method getHours
```

```
   // calculate earnings; override abstract method earnings
in Employee
   public double earnings()
   {
      if ( getHours() <= 40 ) // no overtime
         return getWage() * getHours();
      else
         return 40 * getWage() + ( getHours() - 40 ) *
getWage() * 1.5;
   } // end method earnings

   // return String representation of HourlyEmployee
object
   public String toString()  /* here overriding the
toString() superclass method */
   {   /*code reuse using super.    */
      return (super.toString() + "\nHourly wage: " +
getWage() +
       "\nHours worked :"+ getHours()+ "\nSalary is :
"+earnings() );
   } // end method toString
} // end class HourlyEmployee
```

Implementation ComissionEmployee in Java

Case Studv :

```
public class CommissionEmployee extends Employee
{
   private double grossSales; // gross weekly sales
   private double commissionRate; // commission
percentage

   // five-argument constructor
   public CommissionEmployee( String first, String last,
String ssn,    double sales, double rate )
   {
      super( first, last, ssn );
      setGrossSales( sales );  setCommissionRate( rate );
   } // end five-argument CommissionEmployee constructor

   // set commission rate
   public void setCommissionRate( double rate )
   { commissionRate = ( rate > 0.0 && rate < 1.0 ) ? rate :
0.0;
   } // end method setCommissionRate

   // return commission rate
   public double getCommissionRate()
   {return commissionRate;
   } // end method getCommissionRate
```

```
// set gross sales amount
   public void setGrossSales( double sales )
   { grossSales = ( sales < 0.0 ) ? 0.0 : sales;
   } // end method setGrossSales

   // return gross sales amount
   public double getGrossSales()
   { return grossSales;
   } // end method getGrossSales

   // calculate earnings; override abstract method earnings
in Employee
   public double earnings()
   { return getCommissionRate() * getGrossSales();
   } // end method earnings

   // return String representation of
CommissionEmployee object
   public String toString()
   { return (super.toString() + "\nGross sales: " +
getGrossSales() +  "\nCommission rate: " +
getCommissionRate() + "\nearnings = " + earnings() );
   } // end method toString
} // end class CommissionEmployee
```

Implementation BasePlusComissionEmployee in Java

Case Study :

```
public class BasePlusCommissionEmployee extends
CommissionEmployee
{
   private double baseSalary; // base salary per week

   // six-argument constructor
   public BasePlusCommissionEmployee( String first,
String last,  String ssn, double sales, double rate, double
salary ) {
      super( first, last, ssn, sales, rate );
      setBaseSalary( salary ); // validate and store base salary
   } // end six-argument BasePlusCommissionEmployee
constructor

   // set base salary
   public void setBaseSalary( double salary )
   {
      baseSalary = ( salary < 0.0 ) ? 0.0 : salary; // non-
negative
   } // end method setBaseSalary

   // return base salary
   public double getBaseSalary()
   {
      return baseSalary;
   } // end method getBaseSalary
```

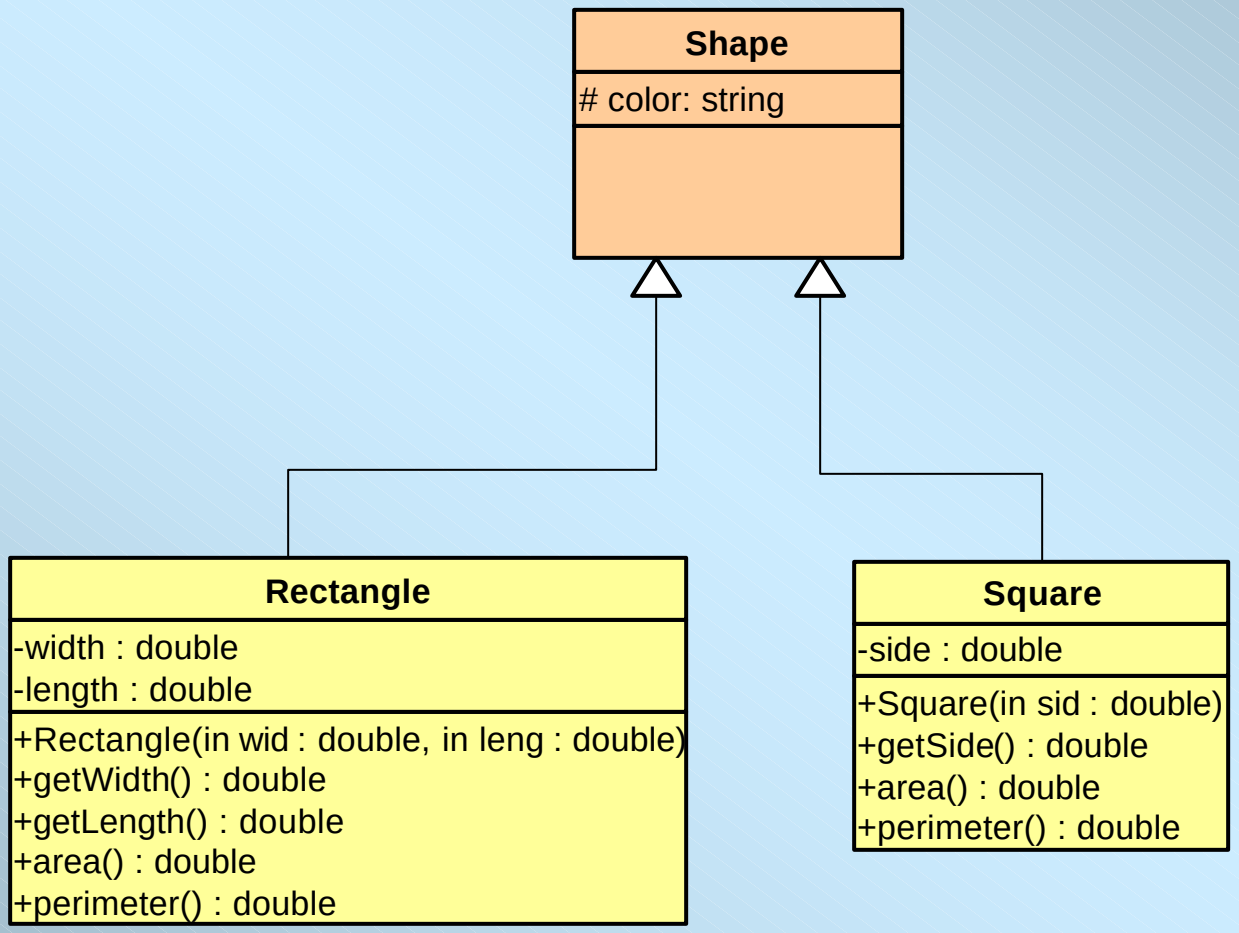
```
// calculate earnings; override method earnings in
CommissionEmployee
   public double earnings()
   {
      return getBaseSalary() + super.earnings(); //code
reuse form CommissionEmployee
   } // end method earnings

   // return String representation of
BasePlusCommissionEmployee object
   public String toString()
   {
      return ( "\nBase-salaried :" + super.toString() +
      "\nBase salary: " + getBaseSalary() + "\nearnings ="
+ earnings() );
   }// end method toString
} // end class BasePlusCommissionEmployee
```

Implementation PayrollSystemTest in Java

```
public class PayrollSystemTest
{
   public static void main( String args[] )
   {
      // create subclass objects
  SalariedEmployee SA=  new SalariedEmployee( “Ali", "Samer", "111-11-1111", 800.00 );
  HourlyEmployee HE =   new HourlyEmployee( “Ramzi", “Ibrahim", "222-22-2222", 16.75, 40 );
  CommissionEmployee CE =  new CommissionEmployee(  “Med", “Ahmed", "333-33-3333", 10000, .06 );
 BasePlusCommissionEmployee BP = new BasePlusCommissionEmployee(“Beji", “Lotfi", "444-44-4444", 5000, .04, 300 );

  System.out.println( "Employees processed individually:\n" );
     /*  salariedEmployee is the same as salariedEmployee.toString()  */
  System.out.println( SA.toString()+ "\nearned: " + SA.earnings()+"\n\n" );
  System.out.println( HE + "\n earned: " + HE.earnings()+"\n\n" );
  System.out.println(CE + "\n earned: " + CE.earnings()+"\n\n" );
  System.out.println(BP + "\n earned: "+ BP.earnings()+"\n\n" );
// create four-element Employee array
  Employee employees[] = new Employee[ 4 ];
  employees[ 0 ] = SA;   employees[ 1 ] = HE;  employees[ 2 ] = CE;   employees[ 3 ] = BP;
  System.out.println( "Employees processed polymorphically:\n" );
// generically process each element in array employees
  for (Employee currentEmployee : employees)        {
    System.out.println( currentEmployee );} // invokes toString  : here is polymorphysim : call toString() of class at the executiontime.
                                                 //  called dynamic binding or late binding
                                                 // Note :only methods of superclass  can be called via superclass variable
 // get type name of each object in employees array
  for ( int j = 0; j < employees.length; j++ )
    System.out.printf( "Employee %d is a %s\n", j,   employees[ j ].getClass().getName() );  // display the name of the class whos
                                                                                              //object is employee[j]
   } // end main      } // end class PayrollSystemTest
```

4. Abstract Class & Abstract Method

In the following example, we want to add to the Shape class a **display** method that prints the area and perimeter of a shape.



Abstract Classes

- The following method is added to the **Shape** class

```
public void display()
{
  System.out.println (this.area());
  System.out.println (this.perimeter());

}
```

Abstract Classes

- There are several problems with this method:
  - The **`area`** and **`perimeter`** methods are invoked in the **`display`** method
  - There are **`area`** and **`perimeter`** methods in each of the subclasses
  - There is no **`area`** and **`perimeter`** methods in the **`Shape`** class, nor is there any way to define it reasonably without knowing whether the shape is Rectangle or Square.

Abstract Classes

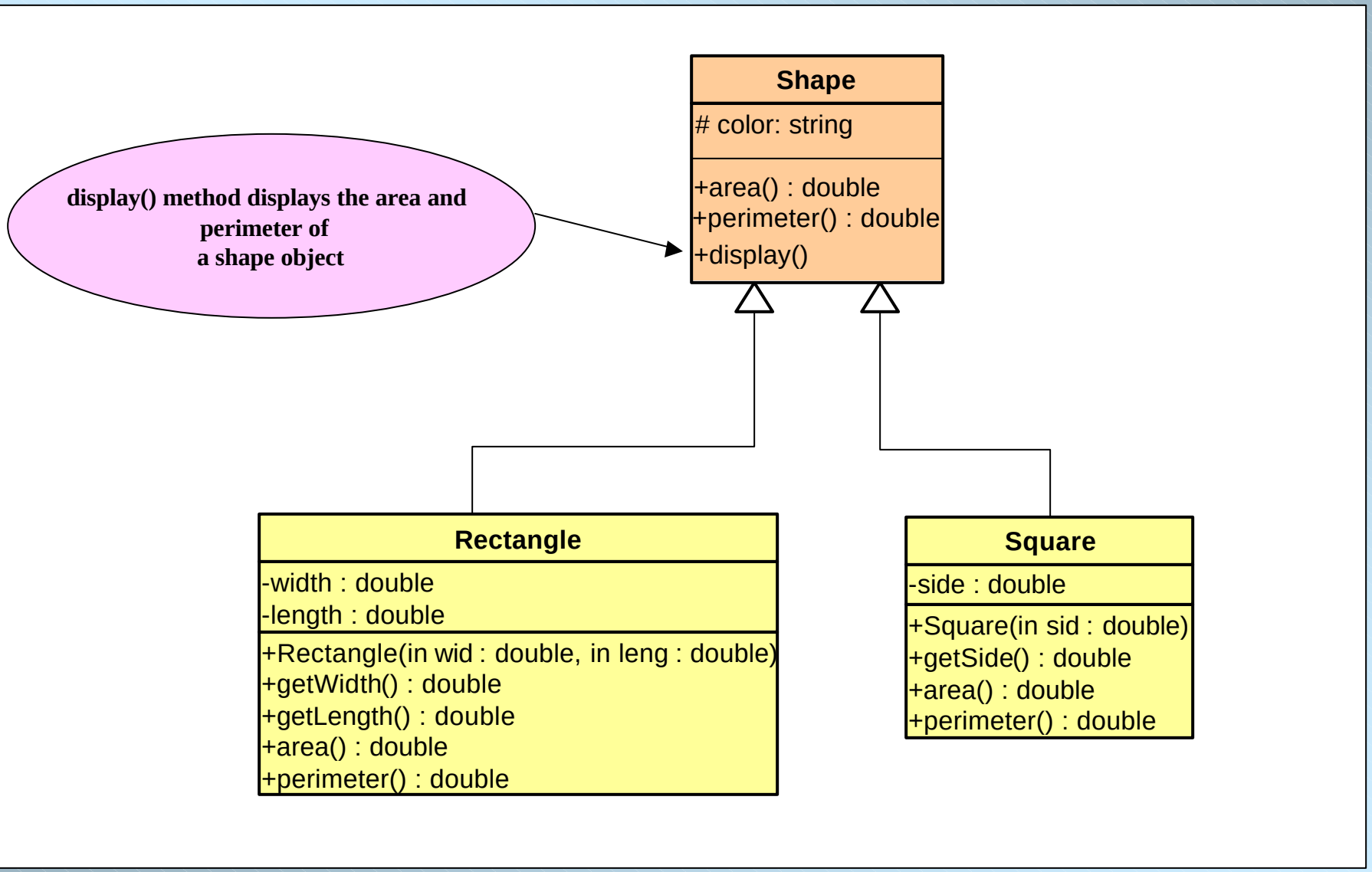
- In order to postpone the definition of a method, Java allows an *abstract method* to be declared
  - An abstract method has a heading, but no method body
  - The body of the method is defined in the subclasses
- **The class that contains an abstract method is called an *abstract class***

Abstract Method

- An abstract method is like a **placeholder** for a method that will be fully defined in a descendent class
- It has a complete method heading, to which has been added the modifier **abstract**
- **It cannot be private**
- It has **no method body**, and ends with a semicolon in place of its body

```
public abstract double area();
public abstract double perimeter();
```

UML representation after the definition of the display method



Abstract Class

- A class that has at least one abstract method is called an *abstract class*
  - An abstract class must have the modifier **`abstract`** included in its class heading:

```
public abstract class Shape
{
  protected String color;
  . . .
  public abstract double area();
  public abstract double perimeter();
  public void display()
  {
    System.out.println (this.area());
    System.out.println (this.perimeter());
  }
  . . .
}
```

Abstract Class

- An abstract class can have any number of abstract and/or fully defined methods

- If a derived class of an abstract class adds to or does not define all of the abstract methods, then it is abstract also, and must add **`abstract`** to its modifier

- A class that has no abstract methods is called a *concrete class*

Pitfall: You Cannot Create Instances of an Abstract Class

- An abstract class can only be used to derive more specialized classes
  - While it may be useful to discuss shape in general, in reality a shape must be a rectangle form or a square form
- An abstract class constructor cannot be used to create an object of the abstract class
  - However, a subclass constructor will include an invocation of the abstract class constructor in the form of **`super`**

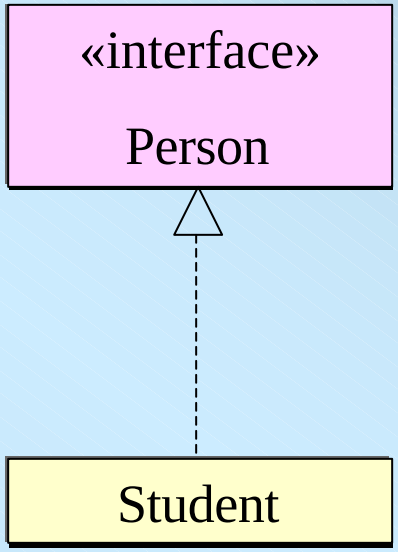
Dynamic Binding and Abstract Classes

- Controlling whether a subclass can override a superclass method
  - Field modifier `final`
    - Prevents a method from being overridden by a subclass
  - Field modifier `abstract`
    - Requires the subclass to override the method
- Early binding or static binding
  - The appropriate version of a method is decided at compilation time
  - Used by methods that are `final` or `static`

5. Interfaces

- An *interface* is something like an extreme case of an abstract class
  - However, *an interface is not a class*
  - *It is a type that can be satisfied by any class that implements the interface*
- The syntax for defining an interface is similar to that of defining a class
  - Except the word **`interface`** is used in place of **`class`**
  - **`public interface Person`**
- An interface specifies a set of methods that any class that implements the interface must have
  - It contains method headings and constant definitions only
  - It contains no instance variables nor any complete method definitions

Example: The Person Interface




```
public interface Person
{
   public double getSalary(); // calculate salary, no implementation
} // end interface Person
```

Interfaces

- An interface serves a function similar to a base class, though it is not a base class
  - Some languages allow one class to be derived from two or more different base classes
  - This *multiple inheritance* is not allowed in Java
  - Instead, Java's way of approximating multiple inheritance is through interfaces

Interfaces

- An interface and all of its method headings should be declared public
  - They cannot be given private, protected
  - When a class implements an interface, it must make all the methods in the interface public
- Because an interface is a type, a method may be written with a parameter of an interface type
  - That parameter will accept as an argument any class that implements the interface

Interfaces

- To *implement an interface*, a concrete class must do two things:

1. It must include the phrase

   `implements` ***`Interface_Name`***
   at the start of the class definition

   ```
   public class Student implements Person
   ```

   – If more than one interface is implemented, each is listed, separated by commas

2. The class must implement all the method headings listed in the definition(s) of the interface(s)

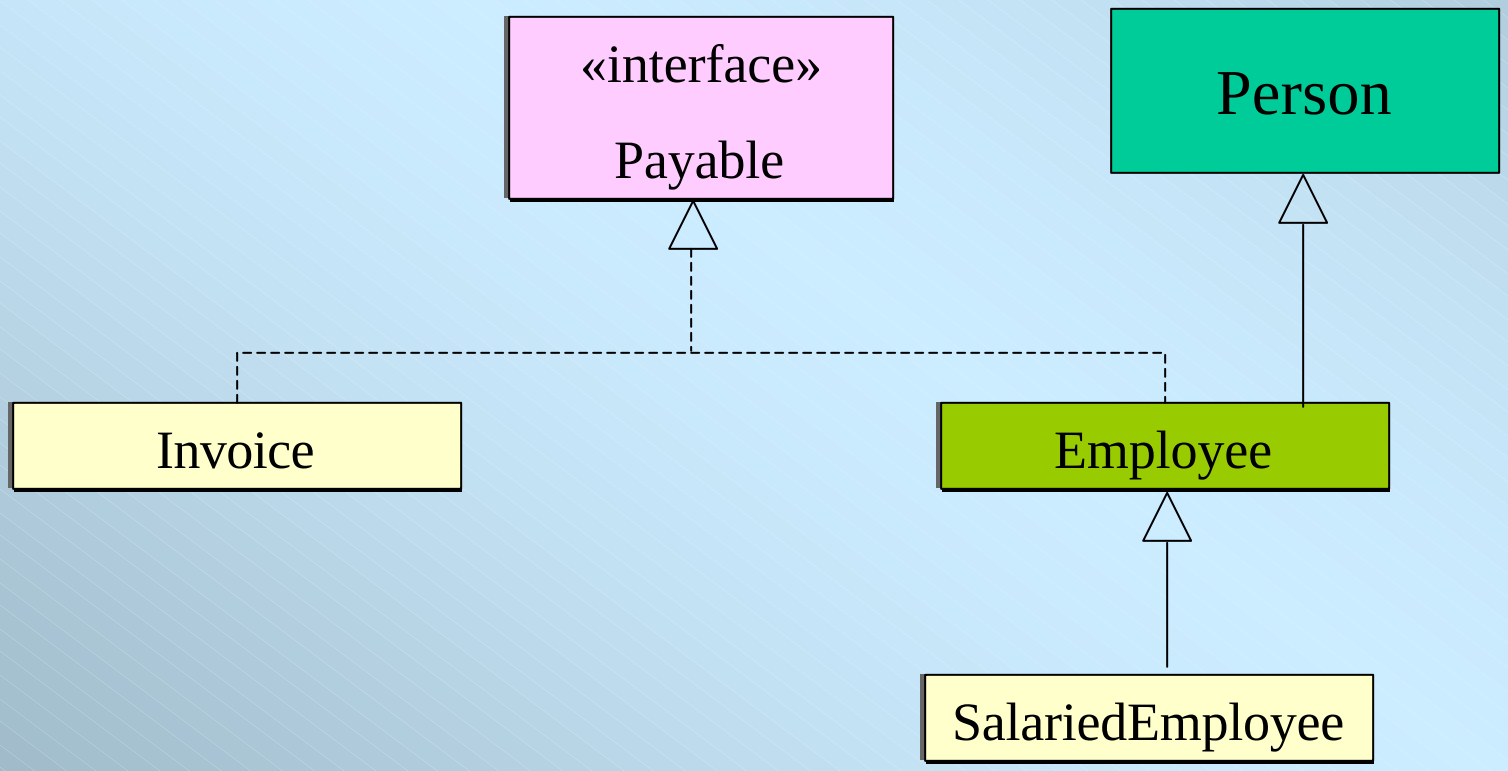
6. Implementation of an Interface

```
public class Student implements Person
{
   private int gpa;
   ……
   ……

   public double getSalary()
   {
      return (gpa * 200);
    }
}
```

7. Abstract Classes Implementing Interfaces

- Abstract classes may implement one or more interfaces
  - Any method headings given in the interface that are not given definitions are made into abstract methods
- A concrete class must give definitions for all the method headings given in the abstract class *and the interface*

Example


«interface»
Payable
Person
Invoice
Employee
SalariedEmployee

Payable & Person Class implementation

```
// Payable interface declaration.
public interface Payable
{  double getPaymentAmount(); // calculate payment; no implementation }
```

```
// Person class.
public class Person
{  protected String  address;
    public Person (String ad)
    {
        address = new String (ad);
      }
} // end Person class
```

Invoice class implementation

```
// Invoice class implements Payable.
public class Invoice implements Payable
{ private String partNumber,
  private String partDescription;
  private int quantity;
  private double pricePerItem;
  // constructor
  public Invoice( String part, String description,
                  int count, double price )
  { partNumber = part;
    partDescription = description;
    setQuantity( count );
    setPricePerItem( price );
  }
// set part number
  public void setPartNumber( String part )
  {  partNumber = part;
  }
// get part number
  public String getPartNumber()
  { return partNumber; }
// set description
  public void setPartDescription( String description )
  {  partDescription = description; }
// get description
  public String getPartDescription()
  { return partDescription; }
// set quantity
  public void setQuantity( int count )
  { quantity = ( count < 0 ) ? 0 : count; }
  // get quantity
  public int getQuantity()
  { return quantity; }
// set price per item
  public void setPricePerItem( double price )
  {  pricePerItem = ( price < 0.0 ) ? 0.0 : price; }
```

Invoice class implementation: Cont

```
// get price per item
   public double getPricePerItem()
   {  return pricePerItem; }
   // return String representation of Invoice object
   public String toString()
   {  return String.format( "%s: \n%s: %s (%s) \n%s: %d \n%s: $%,.2f",
         "invoice", "part number", getPartNumber(), getPartDescription(),
         "quantity", getQuantity(), "price per item", getPricePerItem() );
   }
   // method required to carry out contract with interface Payable
   public double getPaymentAmount()
   {  return getQuantity() * getPricePerItem();    }
} // end class Invoice
```

Employee Abstract class implementation

```
// Employee abstract superclass implements Payable.
public abstract class Employee extends Person implements Payable
{ private String firstName;
  private String lastName;
  private String socialSecurityNumber;
 // four-argument constructor
  public Employee( String first, String last, String ssn, String ad )
  { supper (ad);
    firstName = first;  lastName = last;
    socialSecurityNumber = ssn;
  } // end three-argument Employee constructor
  // set first name
  public void setFirstName( String first )
  { firstName = first; } // end method setFirstName
   // return first name
  public String getFirstName()
  { return firstName; } // end method getFirstName
```

Employee Abstract class implementation: Cont

```
public void setLastName( String last )
 { lastName = last; } // end method setLastName
public String getLastName()
 { return lastName; } // end method getLastName
 public void setSocialSecurityNumber( String ssn )
 { socialSecurityNumber = ssn;} // end method setSocialSecurityNumber
  // return social security number
 public String getSocialSecurityNumber()
 {return socialSecurityNumber; } // end method getSocialSecurityNumber
  // return String representation of Employee object
 public String toString()
 { return String.format( "%s %s\nsocial security number: %s",
    getFirstName(), getLastName(), getSocialSecurityNumber() );
 } // end method toString
 // Note: We do not implement Payable method getPaymentAmount here so
 // this class must be declared abstract to avoid a compilation error.
} // end abstract class Employee
```

SalariedEmployee Concrete class implementation

```
// SalariedEmployee class extends Employee, which implements Payable.
public class SalariedEmployee extends Employee
{    private double weeklySalary;
     public SalariedEmployee( String first, String last, String ssn, double salary )
     {  super( first, last, ssn ); // pass to Employee constructor
        setWeeklySalary( salary ); // validate and store salary
     } // end four-argument SalariedEmployee constructor
   public void setWeeklySalary( double salary )
    {weeklySalary = salary < 0.0 ? 0.0 : salary; } // end method setWeeklySalary
   public double getWeeklySalary()
   { return weeklySalary; } // end method getWeeklySalary
   // calculate earnings; implement interface Payable method that was abstract in superclass Employee
   public double getPaymentAmount()
   { return getWeeklySalary(); } // end method getPaymentAmount
   public String toString()
   { return String.format( "salaried employee: %s\n%s: $%,.2f",
      super.toString(), "weekly salary", getWeeklySalary() ); } // end method toString
} // end class SalariedEmployee
```

PayableInterfaceTest

```
// Tests interface Payable.
public class PayableInterfaceTest
{  public static void main( String args[] )
   { // create four-element Payable array
      Payable payableObjects[] = new Payable[ 4 ];
      // populate array with objects that implement Payable
      payableObjects[ 0 ] = new Invoice( "01234", "seat", 2, 375.00 );
      payableObjects[ 1 ] = new Invoice( "56789", "tire", 4, 79.95 );
      payableObjects[ 2 ] = new SalariedEmployee( “Ali", “Yassin", "111-11-1111", 800.00, “Malaz” );
      payableObjects[ 3 ] = new SalariedEmployee( “Med", “Ahmed", "888-88-8888", 1200.00, “Makka” );
      System.out.println( "Invoices and Employees processed polymorphically:\n" );
      // generically process each element in array payableObjects
      for ( Payable currentPayable : payableObjects )
      { System.out.printf( "%s \n%s: $%,.2f\n\n", currentPayable.toString(), "payment due",
                                 currentPayable.getPaymentAmount() );
      } // end for
   } // end main
} // end class PayableInterfaceTest
```

8. Derived Interfaces (Extending an Interface)

- Like classes, an interface may be derived from a base interface
  - This is called *extending* the interface
  - The derived interface must include the phrase
    `extends BaseInterfaceName`
- A concrete class that implements a derived interface must have definitions for any methods in the derived interface as well as any methods in the base interface

public interface X extends Y

9. Defined Constants in Interfaces

- An interface can contain defined constants in addition to or instead of method headings
  - Any variables defined in an interface must be public, static, and final
  - Because this is understood, Java allows these modifiers to be omitted
- Any class that implements the interface has access to these defined constants