BBM 102 – Introduction to Programming II

Polymorphism
Abstract Classes and Interfaces

Polymorphism

Polymorphism means *many* (poly) *shapes* (morph) : "having many forms"

Enables you to “program in the general” rather than “program in the specific.”

Polymorphism enables you to write programs that process objects that share the same superclass as if they’re all objects of the superclass; this can simplify programming.

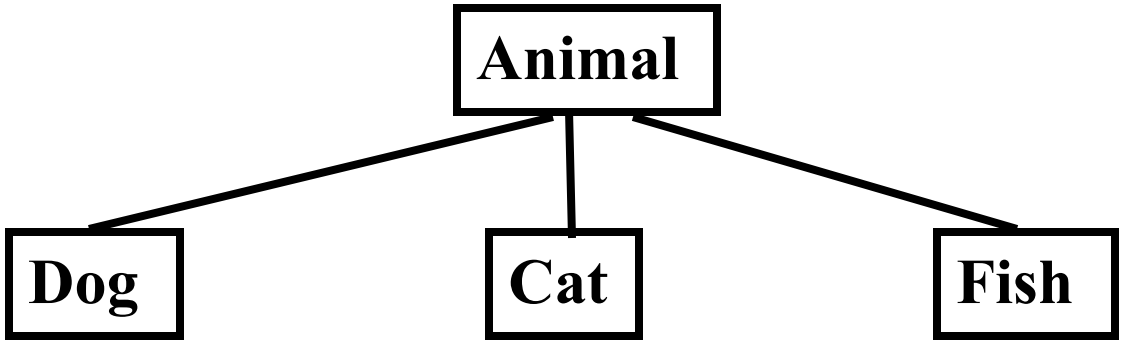
Polymorphism

A *polymorphic reference* is a variable that can refer to different types of objects at different points in time

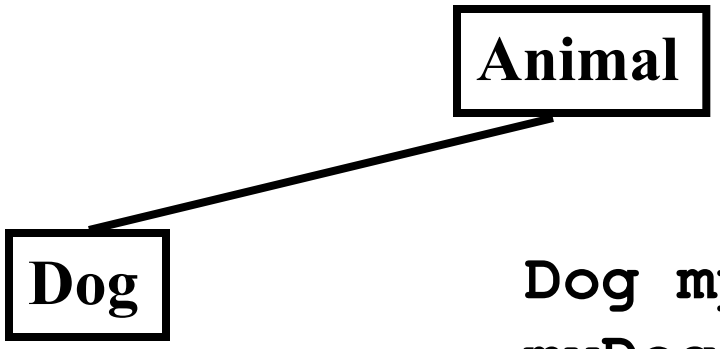
All object references in Java are potentially polymorphic and can refer to an object of any type compatible with its defined type

Compatibility of class types can be based on either Inheritance or Interfaces (which we will see later)

An Example Class Hierarchy



A Polymorphic Example




```
Dog myDog;
myDog = new Dog();

Animal myAnimal;

myAnimal = myDog;
```

Everything is an Object!

When we say:

myDog = new Dog();

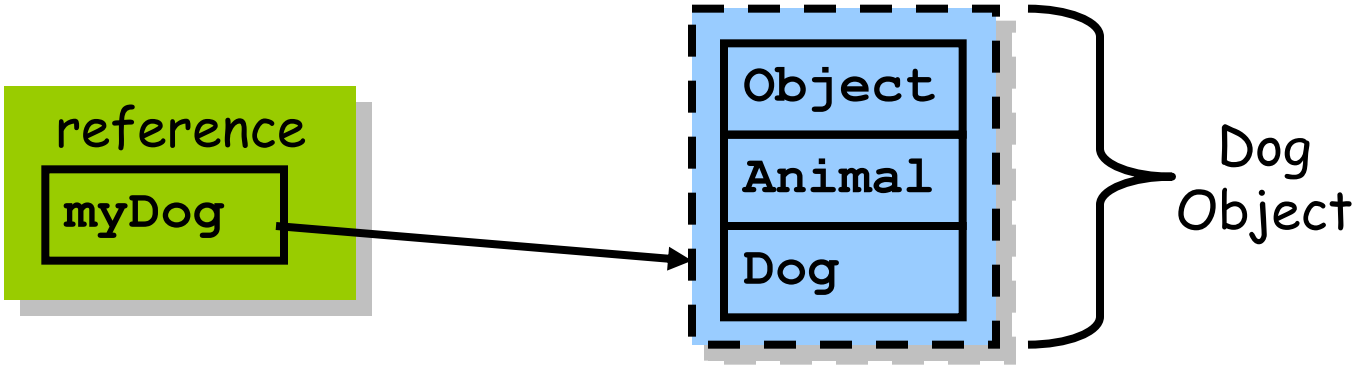
the Dog constructor gets called.

It, in turn, must call the Animal constructor

When you don't extend anything by default you extend Object

Thus the Animal constructor calls the Object constructor

Looking at an object in memory it would look something like this



Polymorphism Explained

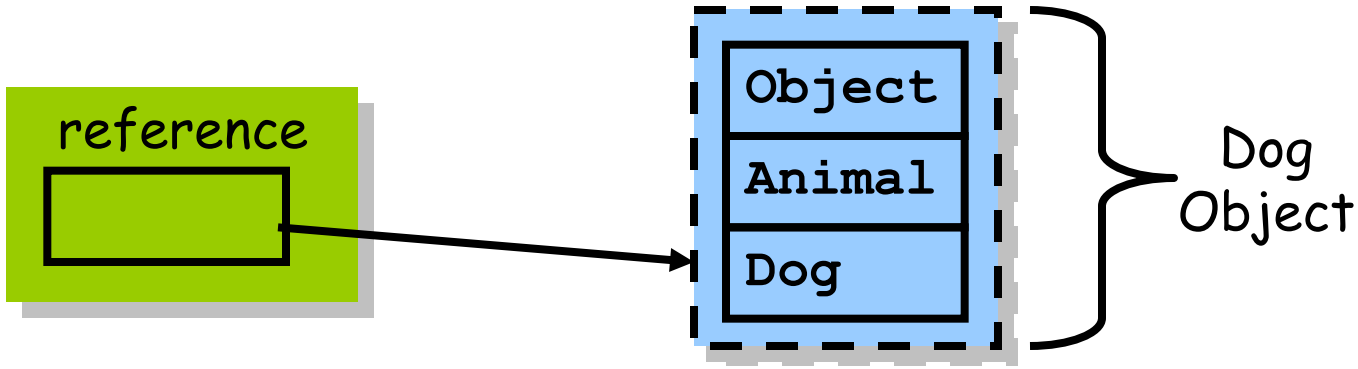
The rule is very simple

A reference can refer to an object which is either

- The same type as the reference
- Has a superclass of the same type as the reference

So all of the following are legal

- Dog d = new Dog();
- Animal a = new Animal();
- Object o = new Object;



An Illegal Example

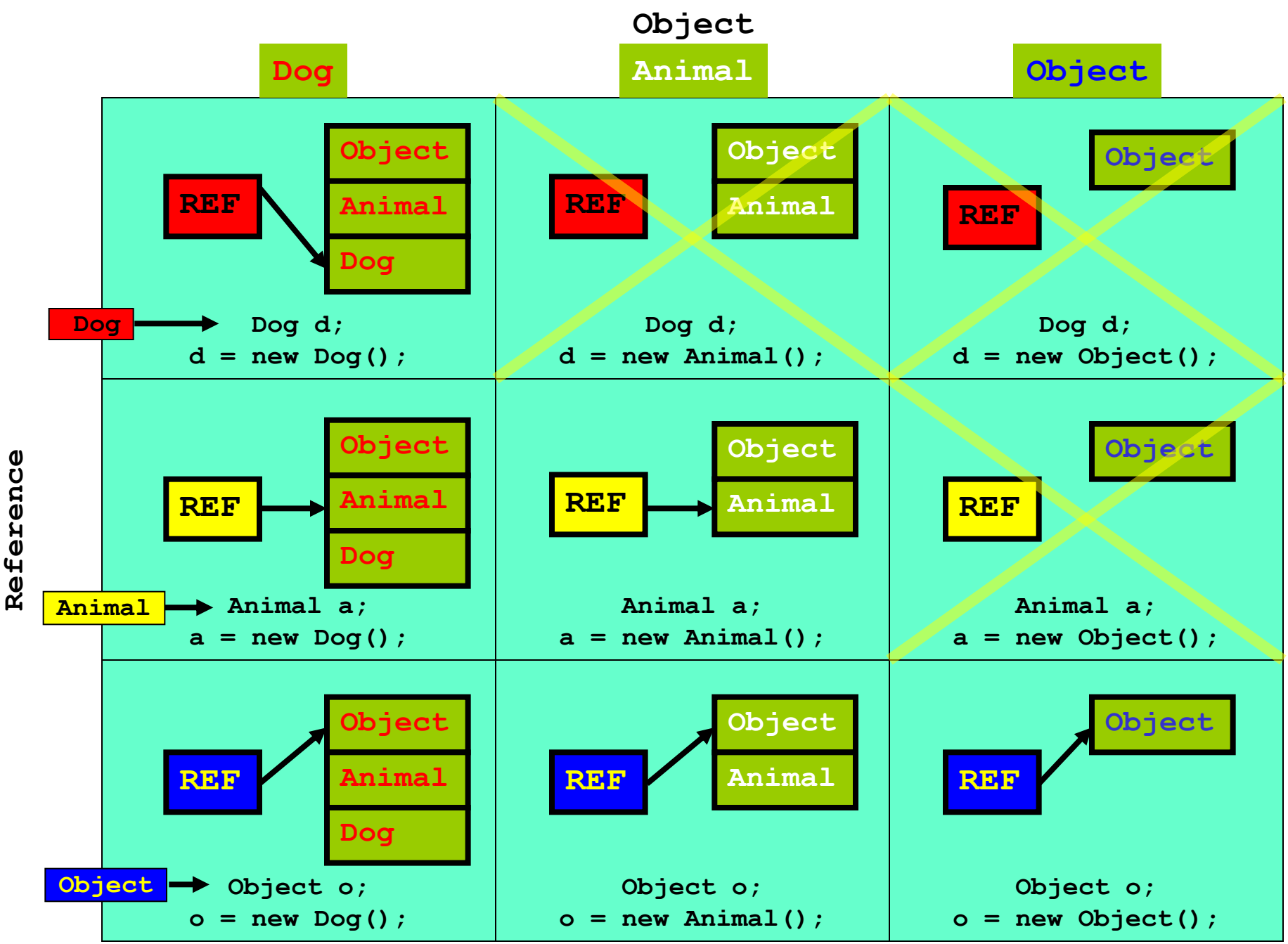
We are able to assign an object of a sub-class into an object of a super-class as in:

```
Animal MyAnimal = new Dog();
```

But the reverse is not true. We can't assign a superclass object into a sub-class object.

```
Dog MyDog = new Animal(); // illegal
```

All dogs are animals but not all animals are dogs


Object
Dog
Animal
Object
Reference
REF
Object
Animal
Dog
Dog
Dog d;
d = new Dog();
Dog d;
d = new Animal();
Dog d;
d = new Object();
Animal
Animal a;
a = new Dog();
Animal a;
a = new Animal();
Animal a;
a = new Object();
Object
Object o;
o = new Dog();
Object o;
o = new Animal();
Object o;
o = new Object();

Polymorphism Examples

- **Example:** Suppose we create a program that simulates the movement of several types of animals for a biological study. Classes Fish, Frog and Bird represent the three types of animals under investigation.

- Each class extends superclass Animal, which contains a method move and maintains an animal's current location as x-y coordinates. Each subclass implements method move.

- A program maintains an Animal array containing references to objects of the various Animal subclasses. To simulate the animals' movements, the program sends each object the same message once per second—namely, move.

Polymorphism Examples

Each specific type of Animal responds to a move message in a unique way:

- a Fish might swim three meters
- a Frog might jump five meters
- a Bird might fly ten meters.

The program issues the same message (i.e., move) to each animal object, but each object knows how to modify its x-y coordinates appropriately for its specific type of movement.

Relying on each object to know how to "do the right thing" in response to the same method call is the key concept of polymorphism.

The same message sent to a variety of objects has "many forms" of results—hence the term polymorphism.

```
Animal a = new Animal();

Fish f =  new Fish();

Frog r = new Frog();

Bird b = new Bird();

Animal aa = new Animal();

Animal af = new Fish();

Animal ar =  new Frog();

Animal ab = new Bird();
```

Demonstrating Polymorphic Behavior

- A superclass object cannot be treated as a subclass object, because a superclass object is *not* an object of any of its subclasses.
- The *is-a* relationship applies only up the hierarchy from a subclass to its direct (and indirect) superclasses, and not down the hierarchy.
- The Java compiler *does* allow the assignment of a superclass reference to a subclass variable if you explicitly cast the superclass reference to the subclass type
  - A technique known as downcasting that enables a program to invoke subclass methods that are not in the superclass.

Demonstrating Polymorphic Behavior (Cont.)

When a superclass variable contains a reference to a subclass object, and that reference is used to call a method, the subclass version of the method is called.

- The Java compiler allows this "crossover" because an object of a subclass *is an object of its superclass (but not vice versa).*

When the compiler encounters a method call made through a variable, the compiler determines if the method can be called by checking the variable's class type.

- If that class contains the proper method declaration (or inherits one), the call is compiled.

At execution time, the type of the object to which the variable refers determines the actual method to use.

- This process is called dynamic binding.

Method Calls and Polymorphism

Assume the Dog class extends the Animal class, redefining the "makeNoise" method.

Consider the following:

```
Animal myAnimal = new Dog();
myAnimal.makeNoise();
```

Note: The Animal reference is referring to a Dog object. And it is the Dog's makeNoise method that gets invoked!

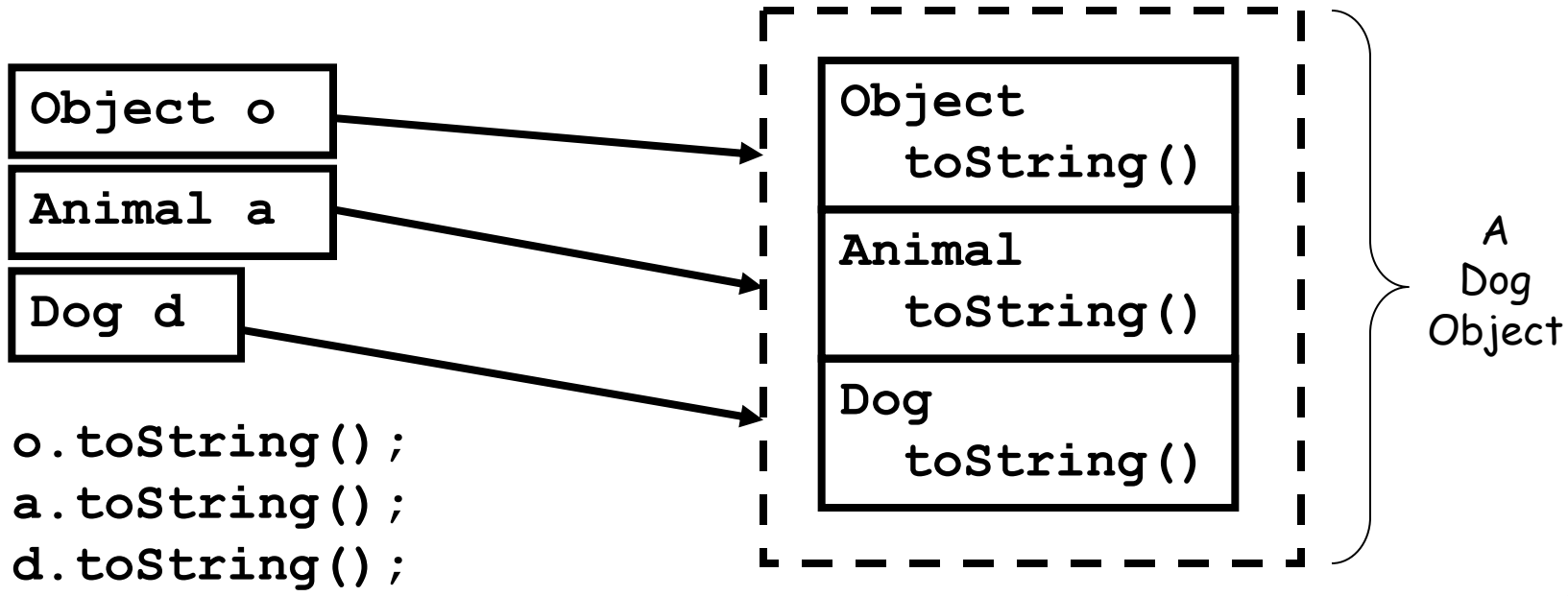
Dynamic Binding

Very simple rule.

- No matter what the reference type is, Java will search the object and **execute the lowest occurrence of a method it finds**.

class Object has a toString method.

Assume that both Animal and Dog have overridden the toString method.



Polymorphism

With polymorphism, we can design and implement systems that are easily extensible.

New classes can be added with little or no modification to the general portions of the program, as long as the new classes are part of the inheritance hierarchy.

The only parts of a program that must be altered for new classes are those that require direct knowledge of the new classes.

Polymorphism

A variable of a type T can legally refer to an object of any subclass of T.

```
Employee person = new Lawyer();
System.out.println(person.getSalary());         // 50000.0
System.out.println(person.getVacationForm());   // pink
```

You can call any methods from `Employee` on the variable `person`, but not any methods specific to `Lawyer` (such as `sue`).

Once a method is called on the object, it behaves in its normal way (as a `Lawyer`, not as a normal `Employee`).

Polymorphism + parameters

You can declare methods to accept superclass types as parameters, then pass a parameter of any subtype.

```
public class EmployeeMain {
    public static void main(String[] args) {
        Lawyer lisa = new Lawyer();
        Secretary steve = new Secretary();
        printInfo(lisa);
        printInfo(steve);
    }

    public static void printInfo(Employee empl) {
        System.out.println("salary = " + empl.getSalary());
        System.out.println("days = " + empl.getVacationDays());
        System.out.println("form = " + empl.getVacationForm());
        System.out.println();
    }
}
```

OUTPUT:

```
salary = 50000.0
vacation days = 21
vacation form = pink

salary = 50000.0
vacation days = 10
vacation form = yellow
```

You can declare arrays of superclass types, and store objects of any subtype as elements.

```
public class EmployeeMain2 {
    public static void main(String[] args) {
        Employee[] employees = {new Lawyer(), new Secretary(),
                new Marketer(), new LegalSecretary()};

        for (int i = 0; i < employees.length; i++) {
            System.out.println("salary = " +
                               employees[i].getSalary());
            System.out.println("vacation days = " +
                               employees[i].getVacationDays());
            System.out.println();
        }
    }
}
```

OUTPUT:

```
salary = 50000.0
vacation days = 15

salary = 50000.0
vacation days = 10

salary = 60000.0
vacation days = 10

salary = 55000.0
vacation days = 10
```

Polymorphism vs. Inheritance

Inheritance is required in order to achieve polymorphism (we must have class hierarchies).

- Re-using class definitions via extension and redefinition

Polymorphism is not required in order to achieve inheritance.

- An object of class A acts as an object of class B (an ancestor to A).

Polymorphism Example

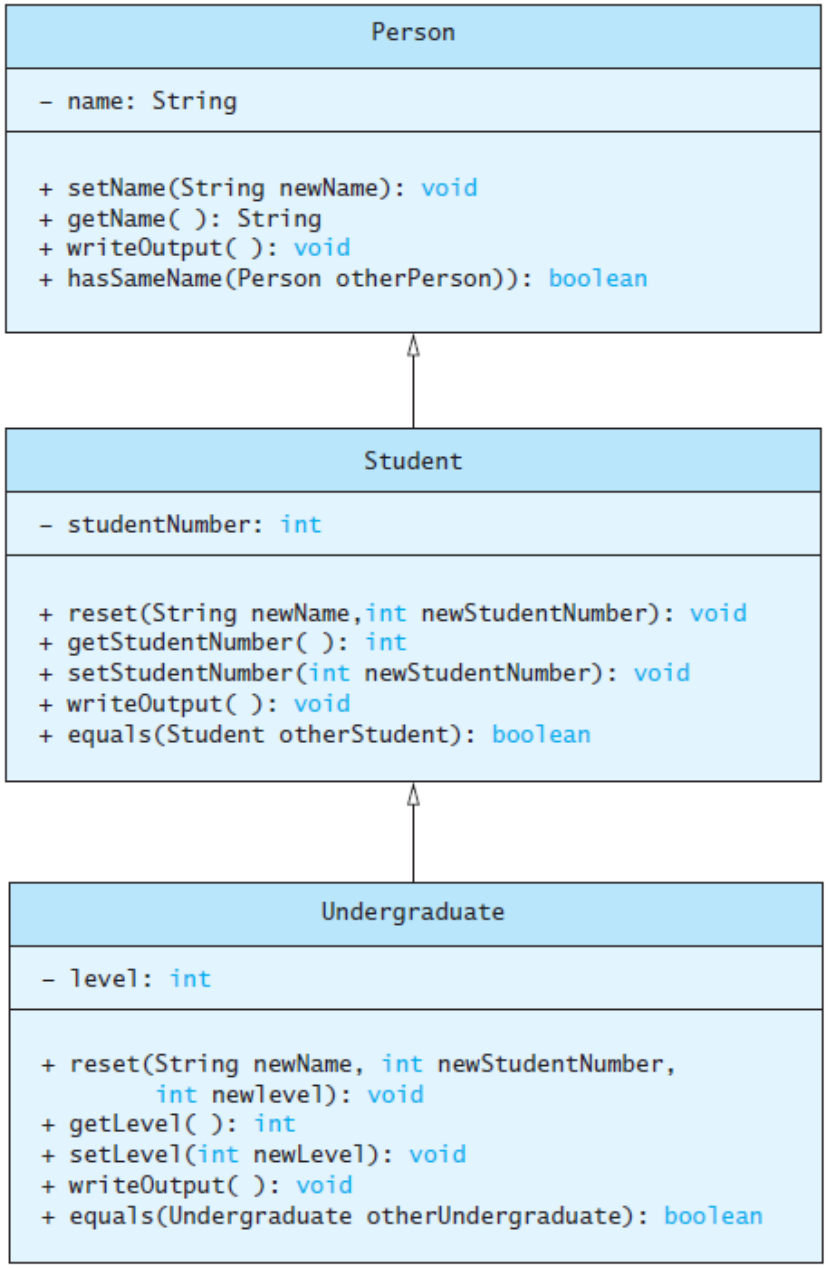
Consider an array of **Person**

```
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);
```



Example

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`

Example

```
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();
       }
    }
}
```

```
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
```

A polymorphism problem

Assume that the following four classes have been declared:

```
public class Foo {
    public void method1() {
        System.out.println("foo 1");
    }

    public void method2() {
        System.out.println("foo 2");
    }

    public String toString() {
        return "foo";
    }
}

public class Bar extends Foo {
    public void method2() {
        System.out.println("bar 2");
    }
}
```

(continued on next slide)

```
public class Baz extends Foo {
    public void method1() {
        System.out.println("baz 1");
    }

    public String toString() {
        return "baz";
    }
}

public class Mumble extends Baz {
    public void method2() {
        System.out.println("mumble 2");
    }
}
```

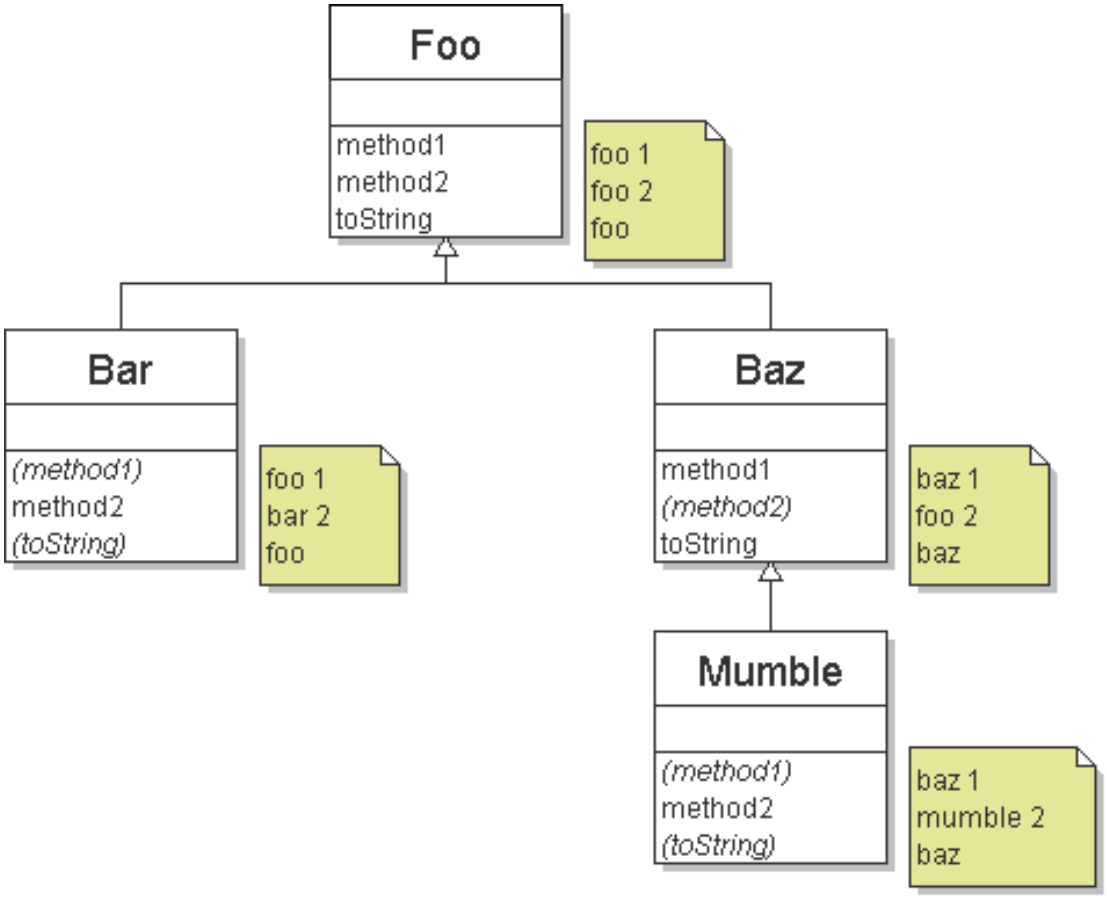
What would be the output of the following client code?

```
Foo[] pity = {new Baz(), new Bar(), new Mumble(), new Foo()};
for (int i = 0; i < pity.length; i++) {
    System.out.println(pity[i]);
    pity[i].method1();
    pity[i].method2();
    System.out.println();
}
```

Finding output with diagrams

One way to determine the output is to diagram each class and its methods, including their output:

- Add the classes from top (superclass) to bottom (subclass).
- Include any inherited methods and their output.



Finding output with tables

Another possible technique for solving these problems is to make a table of the classes and methods, writing the output in each square.

method	Foo	Bar	Baz	Mumble
`method1`	`foo 1`	*`foo 1`*	`baz 1`	*`baz 1`*
`method2`	`foo 2`	`bar 2`	*`foo 2`*	`mumble 2`
`toString`	`foo`	*`foo`*	`baz`	*`baz`*

```
Foo[] pity = {new Baz(), new Bar(), new Mumble(), new Foo()};
for (int i = 0; i < pity.length; i++) {
    System.out.println(pity[i]);
    pity[i].method1();
    pity[i].method2();
    System.out.println();
}
```

The code produces the following output:

```
baz
baz 1
foo 2

foo
foo 1
bar 2

baz
baz 1
mumble 2

foo
foo 1
foo 2
```

Polymorphism answer

Polymorphism

- In order to polymorphism;
  - The **inheritance** relationship must be defined.
  - The object created from subclass type must be **reached** with the reference variable defined from the ancestor class type.
  - The subclass must **override** the method (s) in its ancestor.

- Polymorphism provides the extensibility of the code by separating **what to do** and **how to do it.**

Abstract Classes and Interfaces

Abstract Classes

- Abstract methods
- Polymorphism with abstract classes
- Example project: Payroll System

Interfaces

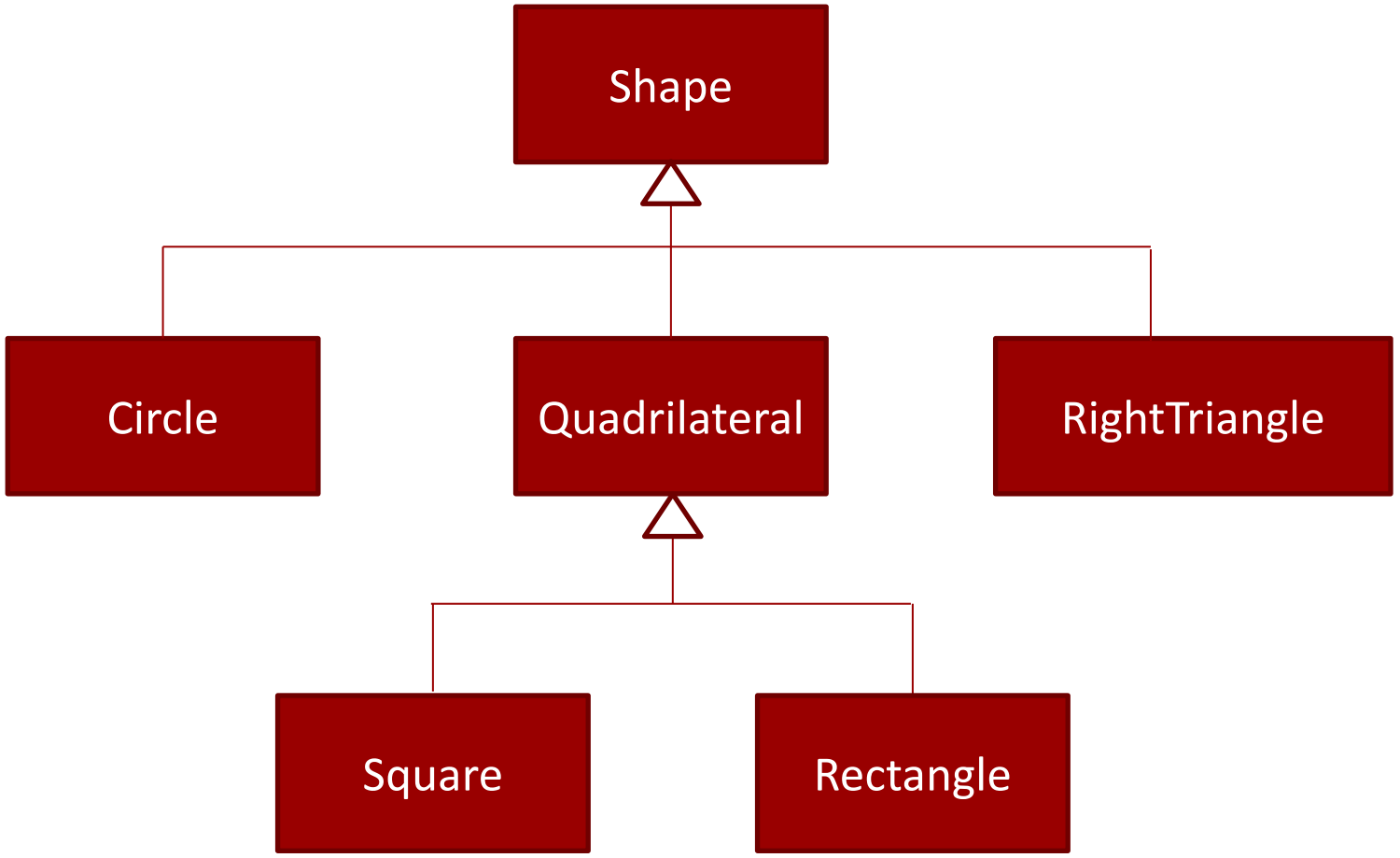
- What is an Interface?
- Defining an Interface
- Implementing an Interface
- Implementing Multiple Interfaces
- Extending a Class and Implementing Interface(s)
- Extending an Interface
- Interfaces as Types

Interfaces vs Abstract Classes

Abstract Classes

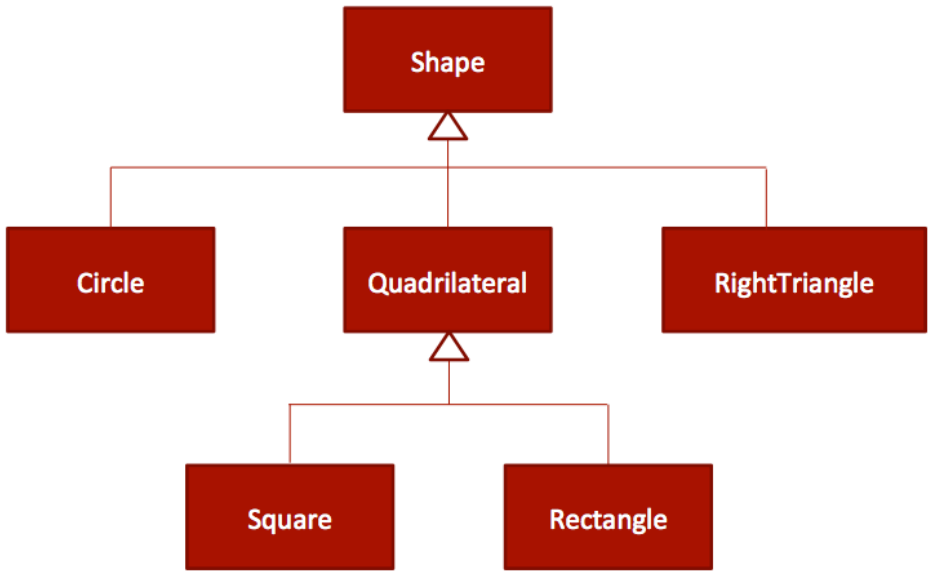
- An *abstract class* is a class that is declared **abstract**
- An *abstract class* **may** or **may not** include abstract methods.
- Abstract classes cannot be **instantiated**, but they can be **subclassed**.

Abstract Classes



Abstract Classes

- Shapes all have certain states (for example: position, orientation, line color, fill color) and behaviors (for example: moveTo, rotate, resize, draw) in common.
- Some of these states and behaviors are the same for all shapes (for example: position, fill color, and moveTo).
- Others require different implementations (for example, resize or draw).
- All Shapes must be able to draw or resize themselves; they just differ in how they do it.



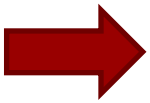
Abstract Classes

```
public class Shape {
        private String name;

        public Shape(String name)
{
                this.name = name;
        }

        public String getName() {
                return name;
        }

        public void draw() {
                // what is the shape?
                // Code...?! Nothing!
        }
}
```



```
public abstract class Shape {
        private String name;

        public Shape(String name)
{
                this.name = name;
        }

        public String getName() {
                return name;
        }

        public abstract void
draw();
}
```

Abstract Methods

- An *abstract method* is a method that is declared without an implementation
  - without braces, and followed by a semicolon, like this:

```
public abstract void draw();
```

- When an abstract class is subclassed, the subclass usually provides implementations for all of the abstract methods in its parent class.
  - However, if it does not, then the subclass must also be declared abstract.

Abstract Classes

```
public class RightTriangle extends Shape {
        private int a;

        public RightTriangle(String name, int a) {
                super(name);
                this.a = a;
        }

        public int getA() {
                return a;
        }
        // override abstract method
        public void draw() {
                for (int line = 1; line <= a; line++) {
                        for (int i = 0; i < line; i++) {
                                System.out.print("*");
                        }
                        System.out.println();
                }
        }
}
```

Abstract Classes

```
public abstract class Quadrilateral
                    extends Shape {

        public Quadrilateral(String
name) {
                super(name);
        }

        // still nothing to draw!
        public abstract void draw();
}
```

```
public class Square extends Quadrilateral {
        private int a;

        public Square(String name, int a) {
                super(name);
                this.a = a;
        }
        public int getA() {
                return a;
        }

        // override abstract method
        public void draw() {
                for (int line = 0; line < a; line++) {
                        for (int col = 0; col < a;
col++) {
                                System.out.print("*");
                        }
                        System.out.println();

                }
        }
}
```

Abstract Classes

```
public class Program {

	public static void main(String[] args) {
		// compilation error!: "Cannot instantiate the type Shape"
		Shape shape = new Shape("Shape");

		// compilation error!: "Cannot instantiate the type
Quadrilateral"
		Quadrilateral quadrilateral = new
Quadrilateral("Quadrilateral");

		Square s = new Square("Square", 4);
		s.draw();

		Rectangle r = new Rectangle("Rectangle", 3, 7);
		r.draw();

		RightTriangle t = new RightTriangle("RightTriangle", 5);
		t.draw();
	}
}
```

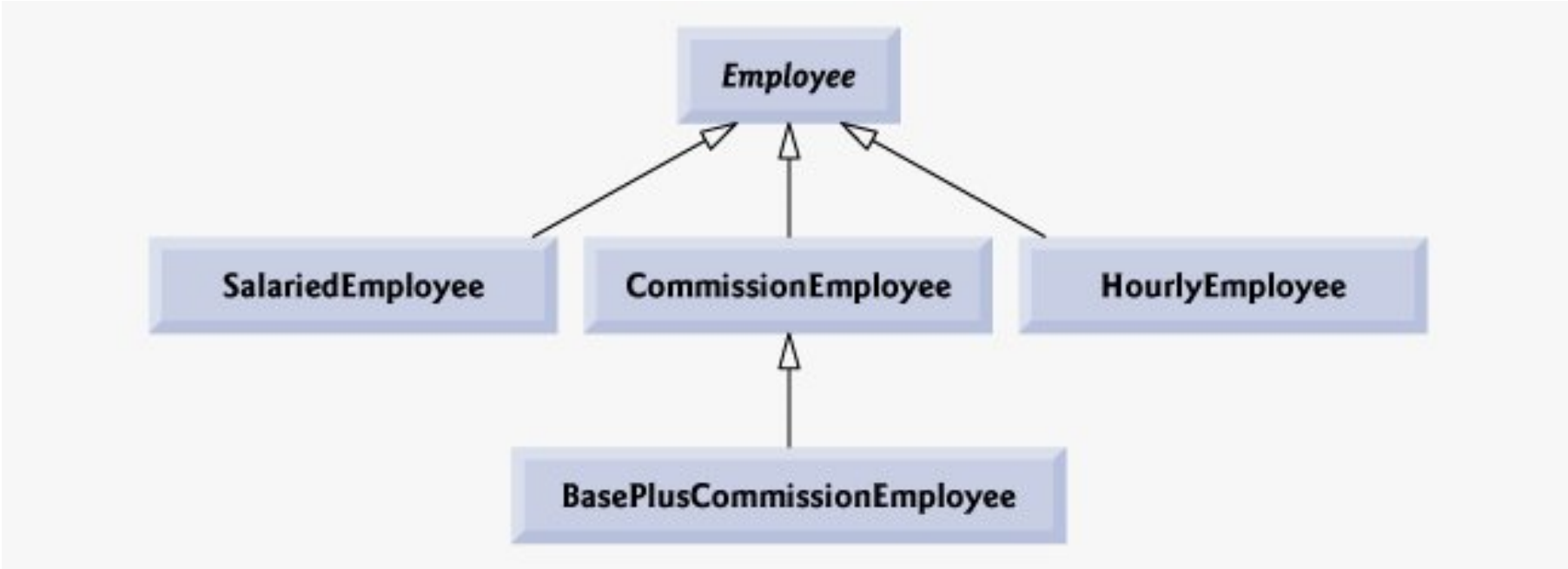
Abstract Classes

- Are part of the inheritance hierarchy
  - Circle extends Shape
  - Square extends Quadrilateral

- Can have constructor(s), but no objects of these classes can be created
  - Shape shape = new Shape("Shape");
  - // compilation error!: "Cannot instantiate the type Shape“

- Classes that can be used to instantiate objects are called **concrete classes**.

Example Project: Payroll System



Overview of the classes

	earnings	toString
Employee	abstract	*firstName lastName* social security number: *SSN*
Salaried-Employee	weeklySalary	salaried employee: *firstName lastName* social security number: *SSN* weekly salary: *weeklysalary*
Hourly-Employee	*If hours <= 40* wage * hours *If hours > 40* 40 * wage + (hours - 40) * wage * 1.5	hourly employee: *firstName lastName* social security number: *SSN* hourly wage: *wage*; hours worked: *hours*
Commission-Employee	commissionRate * grossSales	commission employee: *firstName lastName* social security number: *SSN* gross sales: *grossSales*; commission rate: *commissionRate*
BasePlus-Commission-Employee	(commissionRate * grossSales) + baseSalary	base salaried commission employee: *firstName lastName* social security number: *SSN* gross sales: *grossSales*; commission rate: *commissionRate*; base salary: *baseSalary*

Employee.java (1)

```
1  // Fig. 10.4: Employee.java
2  // Employee abstract superclass.
3
4  public abstract class Employee
5  {
6     private String firstName;
7     private String lastName;
8     private String socialSecurityNumber;
9
10    // three-argument constructor
11    public Employee( String first, String last, String ssn )
12    {
13       firstName = first;
14       lastName = last;
15       socialSecurityNumber = ssn;
16    } // end three-argument Employee constructor
17
18    // set first name
19    public void setFirstName( String first )
20    {
21       firstName = first;
22    } // end method setFirstName
23
24    // return first name
25    public String getFirstName()
26    {
27       return firstName;
28    } // end method getFirstName
29
30    // set last name
31    public void setLastName( String last )
32    {
33       lastName = last;
34    } // end method setLastName
35
```

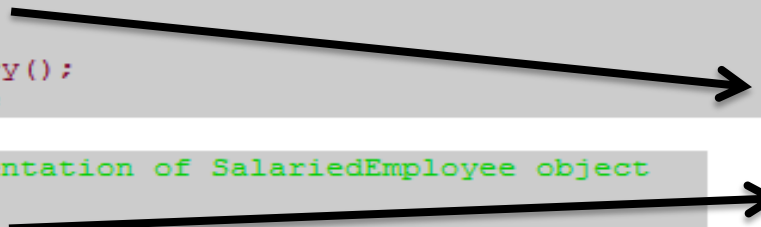
Employee.java (2)

```
36     // return last name
37     public String getLastName()
38     {
39        return lastName;
40     } // end method getLastName
41
42     // set social security number
43     public void setSocialSecurityNumber( String ssn )
44     {
45        socialSecurityNumber = ssn; // should validate
46     } // end method setSocialSecurityNumber
47
48     // return social security number
49     public String getSocialSecurityNumber()
50     {
51        return socialSecurityNumber;
52     } // end method getSocialSecurityNumber
53
54     // return String representation of Employee object
55     public String toString()
56     {
57        return String.format( "%s %s\nsocial security number: %s",
58           getFirstName(), getLastName(), getSocialSecurityNumber(
59     } // end method toString
60
61     // abstract method overridden by subclasses
62     public abstract double earnings(); // no implementation here
63  } // end abstract class Employee
```

Earnings will be calculated in subclasses

SalariedEmployee.java

```
 4  public class SalariedEmployee extends Employee
 5  {
 6     private double weeklySalary;
 7
 8     // four-argument constructor
 9     public SalariedEmployee( String first, String last, String ssn,
10        double salary )
11     {
12        super( first, last, ssn ); // pass to Employee constructor
13        setWeeklySalary( salary ); // validate and store salary
14     } // end four-argument SalariedEmployee constructor
15
16     // set salary
17     public void setWeeklySalary( double salary )
18     {
19        weeklySalary = salary < 0.0 ? 0.0 : salary;
20     } // end method setWeeklySalary
21
22     // return salary
23     public double getWeeklySalary()
24     {
25        return weeklySalary;
26     } // end method getWeeklySalary
27
28     // calculate earnings; override abstract method earnings in Employee
29     public double earnings()
30     {
31        return getWeeklySalary();
32     } // end method earnings
33
34     // return String representation of SalariedEmployee object
35     public String toString()
36     {
37        return String.format( "salaried employee: %s\n%s: $%,.2f",
38           super.toString(), "weekly salary", getWeeklySalary() );
39     } // end method toString
40  } // end class SalariedEmployee
```



HourlyEmployee.java (1)

```
 4  public class HourlyEmployee extends Employee
 5  {
 6     private double wage; // wage per hour
 7     private double hours; // hours worked for week
 8
 9     // five-argument constructor
10     public HourlyEmployee( String first, String last, String ssn,
11        double hourlyWage, double hoursWorked )
12     {
13        super( first, last, ssn );
14        setWage( hourlyWage ); // validate hourly wage
15        setHours( hoursWorked ); // validate hours worked
16     } // end five-argument HourlyEmployee constructor
17
18     // set wage
19     public void setWage( double hourlyWage )
20     {
21        wage = ( hourlyWage < 0.0 ) ? 0.0 : hourlyWage;
22     } // end method setWage
23
24     // return wage
25     public double getWage()
26     {
27        return wage;
28     } // end method getWage
29
30     // set hours worked
31     public void setHours( double hoursWorked )
32     {
33        hours = ( ( hoursWorked >= 0.0 ) && ( hoursWorked <= 168.0 ) ) ?
34           hoursWorked : 0.0;
35     } // end method setHours
```

HourlyEmployee.java (2)

```
36
37     // return hours worked
38     public double getHours()
39     {
40        return hours;
41     } // end method getHours
42
43     // calculate earnings; override abstract method earnings in Employee
44     public double earnings()
45     {
46        if ( getHours() <= 40 ) // no overtime
47           return getWage() * getHours();
48        else
49           return 40 * getWage() + ( gethours() - 40 ) * getWage() * 1.5;
50     } // end method earnings
51
52     // return String representation of HourlyEmployee object
53     public String toString()
54     {
55        return String.format( "hourly employee: %s\n%s: $%,.2f; %s: %,.2f",
56           super.toString(), "hourly wage", getWage(),
57           "hours worked", getHours() );
58     } // end method toString
59  } // end class HourlyEmployee
```

CommissionEmployee.java (1)

```
 4  public class CommissionEmployee extends Employee
 5  {
 6     private double grossSales; // gross weekly sales
 7     private double commissionRate; // commission percentage
 8
 9     // five-argument constructor
10     public CommissionEmployee( String first, String last, String ssn,
11        double sales, double rate )
12     {
13        super( first, last, ssn );
14        setGrossSales( sales );
15        setCommissionRate( rate );
16     } // end five-argument CommissionEmployee constructor
17
18     // set commission rate
19     public void setCommissionRate( double rate )
20     {
21        commissionRate = ( rate > 0.0 && rate < 1.0 ) ? rate : 0.0;
22     } // end method setCommissionRate
23
24     // return commission rate
25     public double getCommissionRate()
26     {
27        return commissionRate;
28     } // end method getCommissionRate
29
30     // set gross sales amount
31     public void setGrossSales( double sales )
32     {
33        grossSales = ( sales < 0.0 ) ? 0.0 : sales;
34     } // end method setGrossSales
```

CommissionEmployee.java (2)

```
36     // return gross sales amount
37     public double getGrossSales()
38     {
39        return grossSales;
40     } // end method getGrossSales
41
42     // calculate earnings; override abstract method earnings in Employee
43     public double earnings()
44     {
45        return getCommissionRate() * getGrossSales();
46     } // end method earnings
47
48     // return String representation of CommissionEmployee object
49     public String toString()
50     {
51        return String.format( "%s: %s\n%s: $%,.2f; %s: %.2f",
52           "commission employee", super.toString(),
53           "gross sales", getGrossSales(),
54           "commission rate", getCommissionRate() );
55     } // end method toString
56  } // end class CommissionEmployee
```

BasePlusCommissionEmployee.java

```
 4  public class BasePlusCommissionEmployee extends CommissionEmployee
 5  {
 6     private double baseSalary; // base salary per week
 7
 8     // six-argument constructor
 9     public BasePlusCommissionEmployee( String first, String last,
10        String ssn, double sales, double rate, double salary )
11     {
12        super( first, last, ssn, sales, rate );
13        setBaseSalary( salary ); // validate and store base salary
14     } // end six-argument BasePlusCommissionEmployee constructor
15
16     // set base salary
17     public void setBaseSalary( double salary )
18     {
19        baseSalary = ( salary < 0.0 ) ? 0.0 : salary; // non-negative
20     } // end method setBaseSalary
21
22     // return base salary
23     public double getBaseSalary()
24     {
25        return baseSalary;
26     } // end method getBaseSalary
27
28     // calculate earnings; override method earnings in CommissionEmployee
29     public double earnings()
30     {
31        return getBaseSalary() + super.earnings();
32     } // end method earnings
33
34     // return String representation of BasePlusCommissionEmployee object
35     public String toString()
36     {
37        return String.format( "%s %s; %s: $%,.2f",
38           "base-salaried", super.toString(),
39           "base salary", getBaseSalary() );
40     } // end method toString
41  } // end class BasePlusCommissionEmployee
```

PayrollSystemTest.java (1)

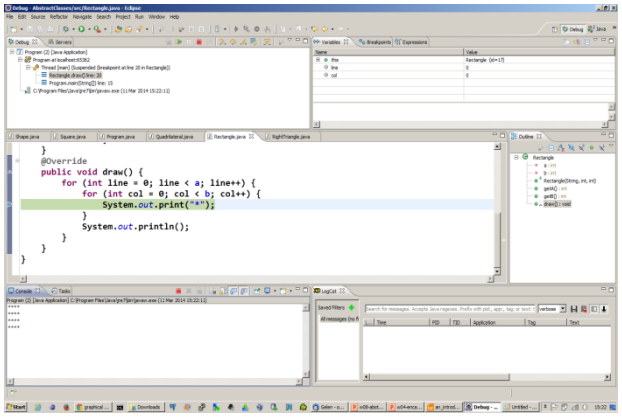
```
 4  public class PayrollSystemTest
 5  {
 6     public static void main( String args[] )
 7     {
 8        // create subclass objects
 9        SalariedEmployee salariedEmployee =
10           new SalariedEmployee( "John", "Smith", "111-11-1111", 800.00 );
11        HourlyEmployee hourlyEmployee =
12           new HourlyEmployee( "Karen", "Price", "222-22-2222", 16.75, 40 );
13        CommissionEmployee commissionEmployee =
14           new CommissionEmployee(
15           "Sue", "Jones", "333-33-3333", 10000, .06 );
16        BasePlusCommissionEmployee basePlusCommissionEmployee =
17           new BasePlusCommissionEmployee(
18           "Bob", "Lewis", "444-44-4444", 5000, .04, 300 );
19
20        System.out.println( "Employees processed individually:\n" );
21
22        System.out.printf( "%s\n%s: $%,.2f\n\n",
23           salariedEmployee, "earned", salariedEmployee.earnings() );
24        System.out.printf( "%s\n%s: $%,.2f\n\n",
25           hourlyEmployee, "earned", hourlyEmployee.earnings() );
26        System.out.printf( "%s\n%s: $%,.2f\n\n",
27           commissionEmployee, "earned", commissionEmployee.earnings() );
28        System.out.printf( "%s\n%s: $%,.2f\n\n",
29           basePlusCommissionEmployee,
30           "earned", basePlusCommissionEmployee.earnings() );
31
32        // create four-element Employee array
33        Employee employees[] = new Employee[ 4 ];
34
35        // initialize array with Employees
36        employees[ 0 ] = salariedEmployee;
37        employees[ 1 ] = hourlyEmployee;
38        employees[ 2 ] = commissionEmployee;
39        employees[ 3 ] = basePlusCommissionEmployee;
```

PayrollSystemTest.java (2)

```
41         System.out.println( "Employees processed polymorphically:\n" );
42
43         // generically process each element in array employees
44         for ( Employee currentEmployee : employees )
45         {
46            System.out.println( currentEmployee ); // invokes toString
47
48            // determine whether element is a BasePlusCommissionEmployee
49            if ( currentEmployee instanceof BasePlusCommissionEmployee )
50            {
51               // downcast Employee reference to
52               // BasePlusCommissionEmployee reference
53               BasePlusCommissionEmployee employee =
54                  ( BasePlusCommissionEmployee ) currentEmployee;
55
56               double oldBaseSalary = employee.getBaseSalary();
57               employee.setBaseSalary( 1.10 * oldBaseSalary );
58               System.out.printf(
59                  "new base salary with 10%% increase is: $%,.2f\n",
60                  employee.getBaseSalary() );
61            } // end if
62
63            System.out.printf(
64               "earned $%,.2f\n\n", currentEmployee.earnings() );
65         } // end for
66
67         // get type name of each object in employees array
68         for ( int j = 0; j < employees.length; j++ )
69            System.out.printf( "Employee %d is a %s\n", j,
70               employees[ j ].getClass().getName() );
71      } // end main
72   } // end class PayrollSystemTest
```

Interfaces

GUI



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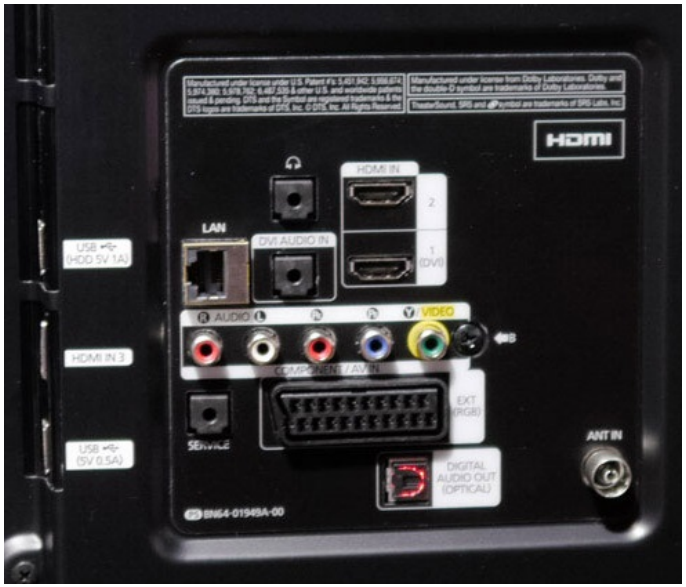


Laptop

Concept of Interface

- An interface is a contract. It guarantees that the system will have certain functionalities.
- An interface is an integration point between two systems.
- A system can have many interfaces, so it can be integrated to many other systems.

Defining an Interface

- Keyword `interface` is used to define an interface
- Methods in an interface must be `public` and `abstract`, these keywords are commonly omitted
- Interfaces can include `public static final` variables (constants), these keywords are commonly omitted

```
public interface Shape {
    public abstract void draw();

    public static final double PI = 3.14;
}
```

No need to write

Implementing an Interface

- An interface is implemented by the keyword `implements`
- Any class implementing an interface must either implement all methods of it, or be declared abstract

```
public class RightTriangle implements Shape {
        // .....
        public void draw() {
                for (int line = 1; line <= a; line++) {
                        for (int i = 0; i < line; i++) {
                                System.out.print("*");
                        }
                        System.out.println();
                }
        }
}
```

Extending a Class and Implementing Interface(s)

```
public class Car extends Vehicle
                        implements Shape {


        public void draw() {
            // ....
        }
}
```

Implementing Multiple Interfaces

- More than one interface can be implemented by a class.
- Names of interfaces are seperated by comma

```
public class LedTv implements Usb, Hdmi, Scart, Vga {

                    // .....

                    }
```

Question: What if at least two interfaces include the same method definition?

Extending an Interface

- It is possible for an interface to extend another interface

```
public interface I1 {
        void m1();
}
```

```
public interface I2 extends
I1 {
        void m2();
}
```

```
public class C1 implements
I1 {

        public void m1() {
            // ...
        }
}
```

```
public class C2 implements
I2 {
        public void m1() {
            // ...
        }
        public void m2() {
            // ...
        }
}
```

Interfaces as Types

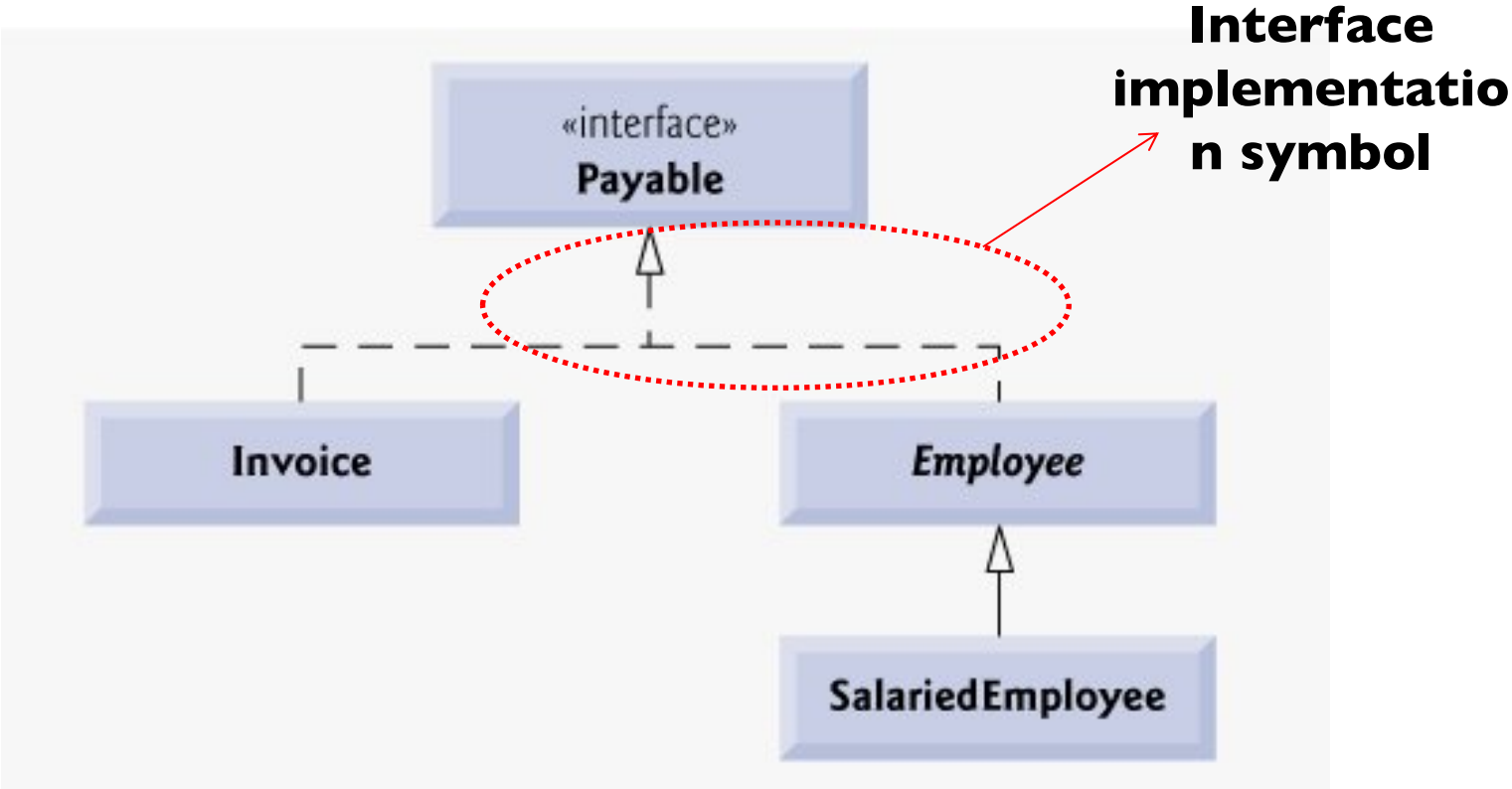
- When you define a new interface, you are defining a new reference data type.
- You can use interface names anywhere you can use any other data type name.
- If you define a reference variable whose type is an interface, any object you assign to it must be an instance of a class that implements the interface.

Interfaces as Types

```
public class Program {
    public static void main(String[] args) {
        Shape shape;

        shape = new Square(4);
        shape.draw();

        shape = new Rectangle(3, 7);
        shape.draw();

        shape = new RightTriangle(5);
        shape.draw();
    }
}
```

```
public class Program {
    public static void main(String[] args) {
        Shape[] shapes = new Shape[3];
        shapes[0] = new Square(5);
        shapes[1] = new Rectangle(2, 8);
        shapes[2] = new RightTriangle(3);
        for (Shape s : shapes) {
            drawIt(s);
        }
    }

    public static void drawIt(Shape s) {
        s.draw();
    }
}
```

Example Project: Payroll System Revisited



Payable.java

```
1  // Fig. 10.11: Payable.java
2  // Payable interface declaration.
3
4  public interface Payable
5  {
6     double getPaymentAmount(); // calculate payment; no implementation
7  } // end interface Payable
```

Invoice.java (1)

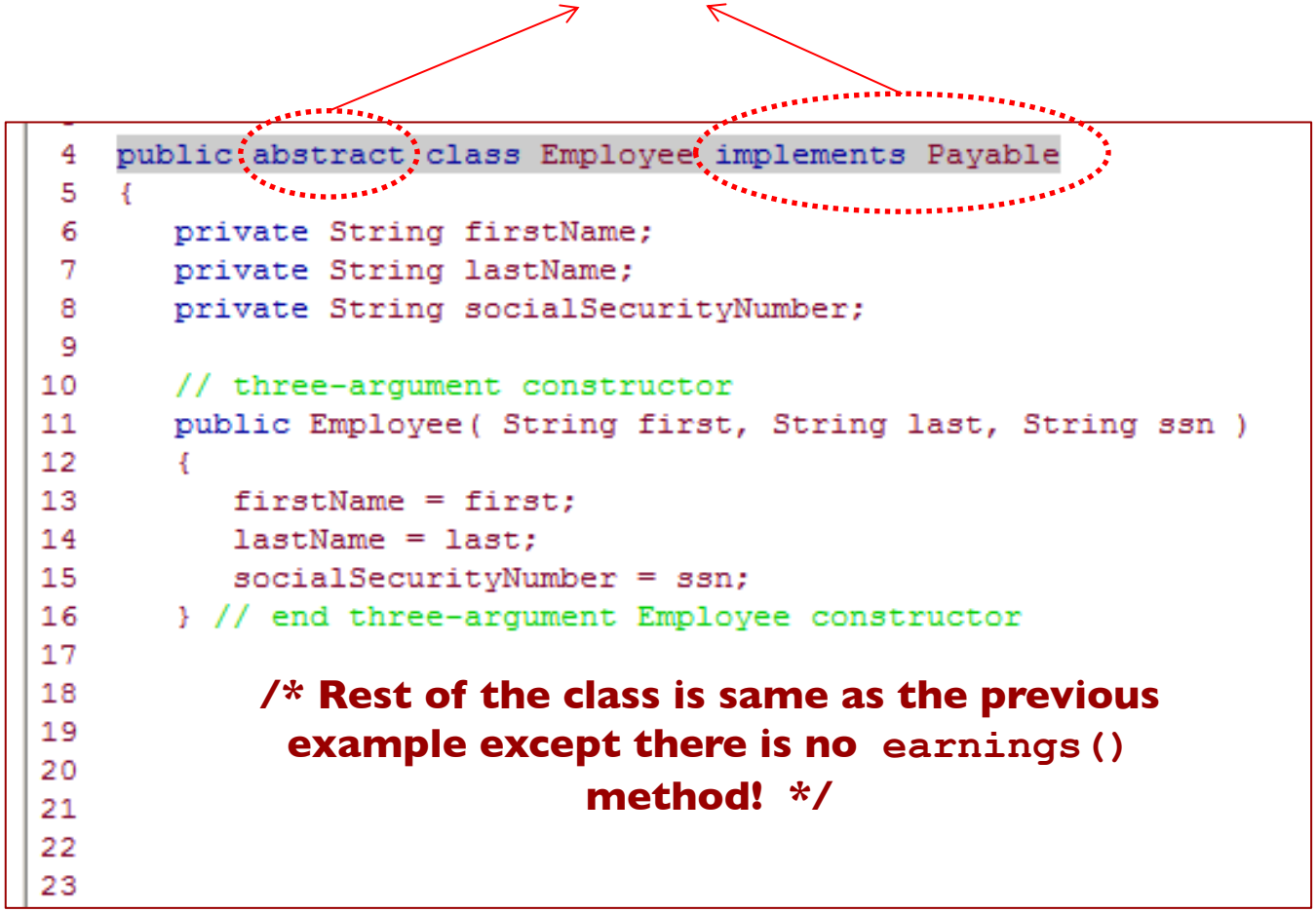
```
 4  public class Invoice implements Payable
 5  {
 6     private String partNumber;
 7     private String partDescription;
 8     private int quantity;
 9     private double pricePerItem;
10
11     // four-argument constructor
12     public Invoice( String part, String description, int count,
13        double price )
14     {
15        partNumber = part;
16        partDescription = description;
17        setQuantity( count ); // validate and store quantity
18        setPricePerItem( price ); // validate and store price per item
19     } // end four-argument Invoice constructor
20
21     // set part number
22     public void setPartNumber( String part )
23     {
24        partNumber = part;
25     } // end method setPartNumber
26
27     // get part number
28     public String getPartNumber()
29     {
30        return partNumber;
31     } // end method getPartNumber
32
33     // set description
34     public void setPartDescription( String description )
35     {
36        partDescription = description;
37     } // end method setPartDescription
38
39     // get description
40     public String getPartDescription()
41     {
42        return partDescription;
43     } // end method getPartDescription
```

Invoice.java (2)

```
45      // set quantity
46      public void setQuantity( int count )
47      {
48         quantity = ( count < 0 ) ? 0 : count; // quantity cannot be negative
49      } // end method setQuantity
50
51      // get quantity
52      public int getQuantity()
53      {
54         return quantity;
55      } // end method getQuantity
56
57      // set price per item
58      public void setPricePerItem( double price )
59      {
60         pricePerItem = ( price < 0.0 ) ? 0.0 : price; // validate price
61      } // end method setPricePerItem
62
63      // get price per item
64      public double getPricePerItem()
65      {
66         return pricePerItem;
67      } // end method getPricePerItem
68
69      // return String representation of Invoice object
70      public String toString()
71      {
72         return String.format( "%s: \n%s: %s (%s) \n%s: %d \n%s: $%,.2f",
73            "invoice", "part number", getPartNumber(), getPartDescription(),
74            "quantity", getQuantity(), "price per item", getPricePerItem() );
75      } // end method toString
76
77      // method required to carry out contract with interface Payable
78      public double getPaymentAmount()
79      {
80         return getQuantity() * getPricePerItem(); // calculate total cost
81      } // end method getPaymentAmount
82   } // end class Invoice
```

Employee.java

`Payable` interface includes `getPaymentAmount()` method, but `Employee` class does not implement it!



```
4  public abstract class Employee implements Payable
5  {
6     private String firstName;
7     private String lastName;
8     private String socialSecurityNumber;
9
10    // three-argument constructor
11    public Employee( String first, String last, String ssn )
12    {
13       firstName = first;
14       lastName = last;
15       socialSecurityNumber = ssn;
16    } // end three-argument Employee constructor
17
18       /* Rest of the class is same as the previous
19       example except there is no earnings()
20       method! */
21
22
23
```

SalariedEmployee.java

```
 4  public class SalariedEmployee extends Employee
 5  {
 6     private double weeklySalary;
 7
 8     // four-argument constructor
 9     public SalariedEmployee( String first, String last, String ssn,
10        double salary )
11     {
12        super( first, last, ssn ); // pass to Employee constructor
13        setWeeklySalary( salary ); // validate and store salary
14     } // end four-argument SalariedEmployee constructor
15
16     // set salary
17     public void setWeeklySalary( double salary )
18     {
19        weeklySalary = salary < 0.0 ? 0.0 : salary;
20     } // end method setWeeklySalary
21
22     // return salary
23     public double getWeeklySalary()
24     {
25        return weeklySalary;
26     } // end method getWeeklySalary
27
28     // calculate earnings; implement interface Payable method that was
29     // abstract in superclass Employee
30     public double getPaymentAmount()
31     {
32        return getWeeklySalary();
33     } // end method getPaymentAmount
34
35     // return String representation of SalariedEmployee object
36     public String toString()
37     {
38        return String.format( "salaried employee: %s\n%s: $%,.2f",
39           super.toString(), "weekly salary", getWeeklySalary() );
40     } // end method toString
41  } // end class SalariedEmployee
```

PayableInterfaceTest.java

```
 4  public class PayableInterfaceTest
 5  {
 6     public static void main( String args[] )
 7     {
 8        // create four-element Payable array
 9        Payable payableObjects[] = new Payable[ 4 ];
10
11        // populate array with objects that implement Payable
12        payableObjects[ 0 ] = new Invoice( "01234", "seat", 2, 375.00 );
13        payableObjects[ 1 ] = new Invoice( "56789", "tire", 4, 79.95 );
14        payableObjects[ 2 ] =
15           new SalariedEmployee( "John", "Smith", "111-11-1111", 800.00 );
16        payableObjects[ 3 ] =
17           new SalariedEmployee( "Lisa", "Barnes", "888-88-8888", 1200.00 );
18
19        System.out.println(
20           "Invoices and Employees processed polymorphically:\n" );
21
22        // generically process each element in array payableObjects
23        for ( Payable currentPayable : payableObjects )
24        {
25           // output currentPayable and its appropriate payment amount
26           System.out.printf( "%s \n%s: $%,.2f\n\n",
27              currentPayable.toString(),
28              "payment due", currentPayable.getPaymentAmount() );
29        } // end for
30     } // end main
31  } // end class PayableInterfaceTest
```

Interfaces vs Abstract Classes

- Interfaces are not necessarily a native part of the inheritance hierarchy
- Interfaces are used for extendable, flexible and loose coupling design
- A class can extend one class at most, but can implement as many interfaces as needed
- Abstract classes are commonly used as default implementations of interfaces
- Abstract classes can include instance variables, concrete methods and contructors

Summary

- Abstract class is defined with the keyword `abstract`
- If a class includes an abstract method, it must be declared as abstract
- Objects of abstract classes cannot be created
- Interface is defined with the keyword `interface`
- A class can *implement* an interface, an interface can *extend* an interface
- A class can implement many interfaces
- Objects of interfaces cannot be created