

Lesson 8

Object-Oriented Programming: Polymorphism

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OBJECTIVES

In this Chapter you'll learn:

- The concept of polymorphism.
- To use overridden methods to effect polymorphism.
- To distinguish between abstract and concrete classes.
- To declare abstract methods to create abstract classes.
- How polymorphism makes systems extensible and maintainable.
- To determine an object's type at execution time.
- To declare and implement interfaces.

10.1 Introduction

10.2 Polymorphism Examples

10.3 Demonstrating Polymorphic Behavior

10.4 Abstract Classes and Methods

10.5 Case Study: Payroll System Using Polymorphism

10.5.1 Abstract Superclass **Employee**

10.5.2 Concrete Subclass **SalariedEmployee**

10.5.3 Concrete Subclass **HourlyEmployee**

10.5.4 Concrete Subclass **CommissionEmployee**

10.5.5 Indirect Concrete Subclass **BasePlusCommissionEmployee**

10.5.6 Polymorphic Processing, Operator **instanceof** and Downcasting

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10.7 Case Study: Creating and Using Interfaces

10.7.1 Developing a **Payable** Hierarchy

10.7.2 Interface **Payable**

10.7.3 Class **Invoice**

10.7.4 Modifying Class **Employee** to Implement Interface **Payable**

10.7.5 Modifying Class **SalariedEmployee** for Use in the **Payable** Hierarchy

10.7.6 Using Interface **Payable** to Process **Invoices** and **Employees** Polymorphically

10.7.7 Common Interfaces of the Java API

10.8 (Optional) GUI and Graphics Case Study: Drawing with Polymorphism

10.9 Wrap-Up

10.1 Introduction

▶ Polymorphism

- 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.

10.1 Introduction (Cont.)

- ▶ 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`.

10.1 Introduction (Cont.)

- ▶ Each specific type of `Animal` responds to a `move` message in a **unique way**:
 - a `Fish` might swim three feet
 - a `Frog` might jump five feet
 - a `Bird` might fly ten feet.
- ▶ 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**.

10.1 Introduction (Cont.)

- ▶ 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 that the program processes generically.
 - The only parts of a program that must be altered to accommodate new classes are those that **require direct knowledge** of the new classes that we add to the hierarchy.

10.1 Introduction (Cont.)

- ▶ Once a class implements an **interface**, all objects of that class have an *is-a relationship* with the interface type, and all objects of the class are guaranteed to provide the functionality described by the interface.
- ▶ This is true of all subclasses of that class as well.
- ▶ Interfaces are particularly useful for **assigning common functionality to possibly unrelated classes**.
 - Allows objects of unrelated classes to be **processed polymorphically** — objects of classes that implement the same interface can respond to all of the interface method calls.

10.1 Introduction (Cont.)

- ▶ An **interface** describes a set of methods that can be called on an object, but **does not provide** concrete implementations for all the methods.
- ▶ You can declare classes that **implement** (i.e., provide concrete implementations for the methods of) one or more interfaces.
- ▶ Each interface method must be declared in all the classes that **explicitly implement** the interface.

10.2 Polymorphism Examples

- ▶ Example: Quadrilaterals
 - If `Rectangle` is derived from `Quadrilateral`, then a `Rectangle` object is a **more specific version** of a `Quadrilateral`.
 - Any operation that can be performed on a `Quadrilateral` can also be performed on a `Rectangle`.
 - These operations can also be performed on other `Quadrilaterals`, such as `Squares`, `Parallelograms` and `Trapezoids`.
 - **Polymorphism occurs** when a program invokes a method through a superclass `Quadrilateral` variable — at execution time, the correct subclass version of the method is called, **based on the type of the reference stored in the superclass variable**.

10.2 Polymorphism Examples (Cont.)

- ▶ Example: Space Objects in a Video Game
 - A video game manipulates objects of classes `Martian`, `Venusian`, `Plutonian`, `SpaceShip` and `LaserBeam`. Each inherits from `SpaceObject` and overrides its `draw` method.
 - A screen manager maintains a collection of references to objects of the various classes and periodically sends each object the same message — namely, `draw`.
 - Each object responds in a unique way.
 - A `Martian` object might draw itself in red with green eyes and the appropriate number of antennae.
 - A `SpaceShip` object might draw itself as a bright silver flying saucer.
 - A `LaserBeam` object might draw itself as a bright red beam across the screen.
 - The same message (in this case, `draw`) sent to a variety of objects has “many forms” of results.

10.2 Polymorphism Examples (Cont.)

- ▶ A screen manager might use polymorphism to facilitate adding new classes to a system with minimal modifications to the system's code.
- ▶ To add new objects to our video game:
 - Build a class that extends `SpaceObject` and provides its own `draw` method implementation.
 - When objects of that class appear in the `SpaceObject` collection, the screen manager code invokes method `draw`, exactly as it does for every other object in the collection, regardless of its type.
 - So the new objects simply “plug right in” without any modification of the screen manager code by the programmer.

10.3 Demonstrating Polymorphic Behavior

- ▶ In the next example, we aim a superclass reference at a subclass object.
 - Invoking a method of a subclass object via a superclass reference invokes the subclass functionality
 - The type of the referenced object, not the type of the variable, determines which method is called
- ▶ This example demonstrates that an object of a subclass can be treated as an object of its superclass, enabling various interesting manipulations.
- ▶ A program can create an array of superclass variables that refer to objects of many subclass types.
 - Allowed because each subclass object *is an* object of its superclass.

10.3 Demonstrating Polymorphic Behavior (Cont.)

- ▶ 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.

```
1 // Fig. 10.1: PolymorphismTest.java
2 // Assigning superclass and subclass references to superclass and
3 // subclass variables.
4
5 public class PolymorphismTest
6 {
7     public static void main( String[] args )
8     {
9         // assign superclass reference to superclass variable
10        CommissionEmployee commissionEmployee = new CommissionEmployee(
11            "Sue", "Jones", "222-22-2222", 10000, .06 );
12
13        // assign subclass reference to subclass variable
14        BasePlusCommissionEmployee basePlusCommissionEmployee =
15            new BasePlusCommissionEmployee(
16                "Bob", "Lewis", "333-33-3333", 5000, .04, 300 );
17
18        // invoke toString on superclass object using superclass variable
19        System.out.printf( "%s %s:\n\n%s\n\n",
20            "Call CommissionEmployee's toString with superclass reference ",
21            "to superclass object", commissionEmployee.toString() );
22
```

Variable refers to a CommissionEmployee object, so that class's toString method is called

Fig. 10.1 | Assigning superclass and subclass references to superclass and subclass variables. (Part 1 of 3.)

```

23 // invoke toString on subclass object using subclass variable
24 System.out.printf( "%s %s:\n\n%s\n\n",
25 "Call BasePlusCommissionEmployee's toString with subclass",
26 "reference to subclass object",
27 basePlusCommissionEmployee.toString() );
28
29 // invoke toString on subclass object using superclass variable
30 CommissionEmployee commissionEmployee2 =
31 basePlusCommissionEmployee;
32 System.out.printf( "%s %s:\n\n%s\n",
33 "Call BasePlusCommissionEmployee's toString with superclass",
34 "reference to subclass object", commissionEmployee2.toString() );
35 } // end main
36 } // end class PolymorphismTest

```

Variable refers to a BasePlus-CommissionEmployee object, so that class's toString method is called

Variable refers to a BasePlus-CommissionEmployee object, so that class's toString method is called

Call CommissionEmployee's toString with superclass reference to superclass object:

```

commission employee: Sue Jones
social security number: 222-22-2222
gross sales: 10000.00
commission rate: 0.06

```

Fig. 10.1 | Assigning superclass and subclass references to superclass and subclass variables. (Part 2 of 3.)


```
Call BasePlusCommissionEmployee's toString with subclass reference to subclass object:
```

```
base-salaried commission employee: Bob Lewis  
social security number: 333-33-3333  
gross sales: 5000.00  
commission rate: 0.04  
base salary: 300.00
```

```
Call BasePlusCommissionEmployee's toString with superclass reference to subclass object:
```

```
base-salaried commission employee: Bob Lewis  
social security number: 333-33-3333  
gross sales: 5000.00  
commission rate: 0.04  
base salary: 300.00
```

Fig. 10.1 | Assigning superclass and subclass references to superclass and subclass variables. (Part 3 of 3.)

10.3 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)*.
- ▶ 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**.

10.4 Abstract Classes and Methods

▶ Abstract classes

- Sometimes it's useful to declare classes for which you never intend to create objects.
 - Used only as **superclasses in inheritance hierarchies**, so they are sometimes called **abstract superclasses**.
 - **Cannot** be used to instantiate objects — abstract classes are incomplete.
 - Subclasses must declare the “**missing pieces**” to become “**concrete**” classes, from which you can instantiate objects; otherwise, these subclasses, too, will be abstract.
- ▶ An abstract class provides a superclass from which other classes can inherit and thus share a common design.

10.4 Abstract Classes and Methods (Cont.)

- ▶ Classes that can be used to instantiate objects are called **concrete classes**.
- ▶ Such classes provide implementations of every method they declare (some of the implementations can be inherited).
- ▶ Abstract superclasses are **too general** to create real objects — they specify only what is common among subclasses.
- ▶ Concrete classes **provide the specifics** that make it reasonable to instantiate objects.
- ▶ **Not all** hierarchies contain abstract classes.

10.4 Abstract Classes and Methods (Cont.)

- ▶ You make a class abstract by declaring it with keyword `abstract`.
- ▶ An abstract class normally contains one or more **abstract methods**.
 - An abstract method is one with keyword `abstract` in its declaration, as in

```
public abstract void draw(); // abstract method
```
- ▶ Abstract methods **do not** provide implementations.
- ▶ A class that contains abstract methods must be an abstract class **even if that class contains some concrete (nonabstract) methods**.
- ▶ Each concrete subclass of an abstract superclass also **must provide concrete implementations** of each of the superclass's abstract methods.
- ▶ **Constructors and static methods cannot be declared abstract.**

10.4 Abstract Classes and Methods (Cont.)

- ▶ Cannot **instantiate** objects of abstract superclasses, but you can use abstract superclasses to **declare variables**
 - These can hold **references to objects** of any concrete class derived from those abstract superclasses.
 - Programs typically use such variables **to manipulate subclass objects polymorphically**.
- ▶ Can use abstract superclass names to **invoke static methods declared in those abstract superclasses**.

10.5 Case Study: Payroll System Using Polymorphism

- ▶ Use an abstract method and polymorphism to perform payroll calculations based on the type of inheritance hierarchy headed by an employee.
- ▶ Enhanced employee inheritance hierarchy requirements:
 - A company pays its employees on a weekly basis. The employees are of four types: Salaried employees are paid a fixed weekly salary regardless of the number of hours worked, hourly employees are paid by the hour and receive overtime pay (i.e., 1.5 times their hourly salary rate) for all hours worked in excess of 40 hours, commission employees are paid a percentage of their sales and base-salaried commission employees receive a base salary plus a percentage of their sales. For the current pay period, the company has decided to reward salaried-commission employees by adding 10% to their base salaries. The company wants to write a Java application that performs its payroll calculations polymorphically.

10.5 Case Study: Payroll System Using Polymorphism (Cont.)

- ▶ abstract class `Employee` represents the general concept of an employee.
- ▶ Subclasses: `SalariedEmployee`, `CommissionEmployee`, `HourlyEmployee` and `BasePlusCommissionEmployee` (an indirect subclass)
- ▶ Fig. 10.2 shows the inheritance hierarchy for our polymorphic employee-payroll application.
- ▶ Abstract class names are italicized in the UML.

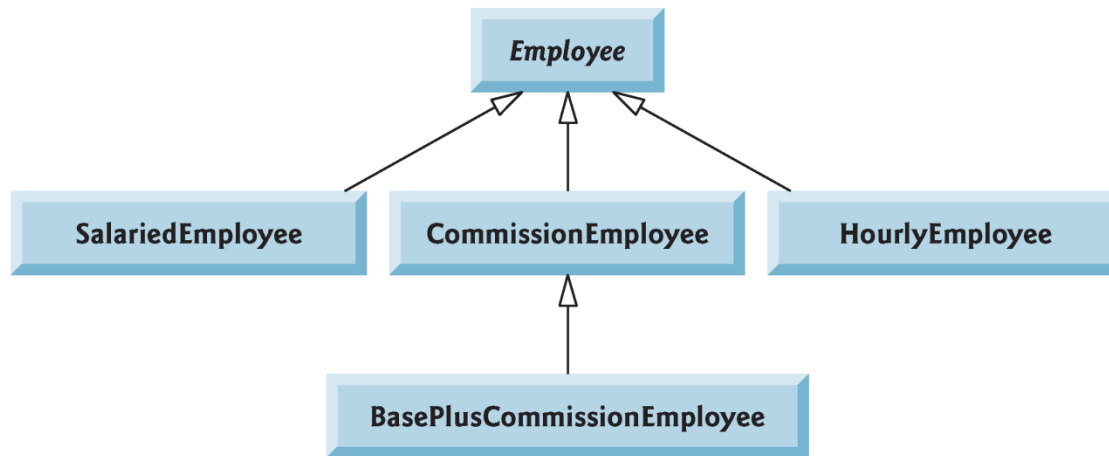


Fig. 10.2 | Employee hierarchy UML class diagram.

10.5 Case Study: Payroll System Using Polymorphism (Cont.)

- ▶ Abstract superclass `Employee` declares the “`interface`” to the hierarchy—that is, the set of methods that a program can invoke on all `Employee` objects.
 - We use the term “interface” here in a general sense to refer to the various ways programs can communicate with objects of any `Employee` subclass.
- ▶ Each employee has a first name, a last name and a social security number defined in abstract superclass `Employee`.

10.5.1 Abstract Superclass Employee

- ▶ Class `Employee` (Fig. 10.4) provides methods `earnings` and `toString`, in addition to the *get* and *set* methods that manipulate `Employee`'s instance variables.
- ▶ An `earnings` method **applies to all employees**, but each earnings calculation **depends** on the employee's class.
 - An **abstract** method—there is not enough information to determine what amount `earnings` should return.
 - Each subclass **overrides** `earnings` with an appropriate implementation.
- ▶ Iterate through the array of `Employees` and call method `earnings` for each `Employee` subclass object.
 - **Method calls processed polymorphically.**

10.5.1 Abstract Superclass Employee (Cont.)

- ▶ The diagram in Fig. 10.3 shows each of the five classes in the hierarchy down the left side and methods `earnings` and `toString` across the top.
- ▶ For each class, the diagram shows the desired results of each method.
- ▶ Declaring the `earnings` method abstract indicates that each concrete subclass **must provide an appropriate `earnings` implementation** and that a program will be able to use superclass `Employee` variables to invoke method `earnings` polymorphically for any type of `Employee`.

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

Fig. 10.3 | Polymorphic interface for the Employee hierarchy classes.

```
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; // should validate
22    } // end method setFirstName
23
```

Fig. 10.4 | Employee abstract superclass. (Part 1 of 3.)

```
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; // should validate
34 } // end method setLastName
35
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
```

Fig. 10.4 | Employee abstract superclass. (Part 2 of 3.)

```
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 @Override
56 public String toString()
57 {
58     return String.format( "%s %s\nsocial security number: %s",
59         getFirstName(), getLastName(), getSocialSecurityNumber() );
60 } // end method toString
61
62 // abstract method overridden by concrete subclasses
63 public abstract double earnings(); // no implementation here
64 } // end abstract class Employee
```

This method must be overridden in subclasses to make them concrete

Fig. 10.4 | Employee abstract superclass. (Part 3 of 3.)

10.5.2 Concrete Subclass

SalariEdEmployee

```
1 // Fig. 10.5: SalariedEmployee.java
2 // SalariedEmployee concrete class extends abstract class Employee.
3
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
```

Fig. 10.5 | SalariedEmployee concrete class extends abstract class Employee.
(Part 1 of 2.)

```

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 @Override
30 public double earnings() ←
31 {
32     return getWeeklySalary();
33 } // end method earnings
34
35 // return String representation of SalariedEmployee object
36 @Override
37 public String toString() ←
38 {
39     return String.format( "salaried employee: %s\n%s: $%,.2f",
40         super.toString(), "weekly salary", getWeeklySalary() );
41 } // end method toString
42 } // end class SalariedEmployee

```

Overriding earnings makes this class concrete

Overriding toString provides customized String representation for this class

Fig. 10.5 | SalariedEmployee concrete class extends abstract class Employee.
(Part 2 of 2.)

10.5.3 Concrete Subclass HourlyEmployee

```
1 // Fig. 10.6: HourlyEmployee.java
2 // HourlyEmployee class extends Employee.
3
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
```

Fig. 10.6 | HourlyEmployee class derived from Employee. (Part 1 of 3.)

```
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
36
37 // return hours worked
38 public double getHours()
39 {
40     return hours;
41 } // end method getHours
42
```

Fig. 10.6 | HourlyEmployee class derived from Employee. (Part 2 of 3.)

```

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

```

Overriding earnings makes this class concrete

Overriding toString provides customized String representation for this class

Fig. 10.6 | HourlyEmployee class derived from Employee. (Part 3 of 3.)

10.5.4 Concrete Subclass CommissionEmployee

```
1 // Fig. 10.7: CommissionEmployee.java
2 // CommissionEmployee class extends Employee.
3
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
```

Fig. 10.7 | CommissionEmployee class derived from Employee. (Part I of 3.)

```
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
35
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 @Override
44 public double earnings() ←
45 {
46     return getCommissionRate() * getGrossSales();
47 } // end method earnings
```

Overriding earnings
makes this class
concrete

Fig. 10.7 | CommissionEmployee class derived from Employee. (Part 2 of 3.)

```
48
49 // return String representation of CommissionEmployee object
50 @Override
51 public String toString() ←
52 {
53     return String.format( "%s: %s\n%s: $%,.2f; %s: %.2f",
54         "commission employee", super.toString(),
55         "gross sales", getGrossSales(),
56         "commission rate", getCommissionRate() );
57 } // end method toString
58 } // end class CommissionEmployee
```

Overriding toString provides customized String representation for this class

Fig. 10.7 | CommissionEmployee class derived from Employee. (Part 3 of 3.)

10.5.5 Indirect Concrete Subclass BasePlusCommissionEmployee

```
1 // Fig. 10.8: BasePlusCommissionEmployee.java
2 // BasePlusCommissionEmployee class extends CommissionEmployee.
3
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
```

Fig. 10.8 | BasePlusCommissionEmployee class extends CommissionEmployee.
(Part 1 of 2.)

```

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 @Override
30 public double earnings() ←
31 {
32     return getBaseSalary() + super.earnings();
33 } // end method earnings
34
35 // return String representation of BasePlusCommissionEmployee object
36 @Override
37 public String toString() ←
38 {
39     return String.format( "%s %s; %s: $%,.2f",
40         "base-salaried", super.toString(),
41         "base salary", getBaseSalary() );
42 } // end method toString
43 } // end class BasePlusCommissionEmployee

```

If we do not override `earnings` in this class, we inherit the version in from superclass `CommissionEmployee` and this class is still a concrete class

Overriding `toString` provides customized String representation for this class

Fig. 10.8 | BasePlusCommissionEmployee class extends CommissionEmployee.
(Part 2 of 2.)

10.5.6 Polymorphic Processing, Operator instanceof and Downcasting

- ▶ Fig. 10.9 creates an object of each of the four concrete.
 - Manipulates these objects **nonpolymorphically, via variables of each object's own type**, then polymorphically, using an array of `Employee` variables.
- ▶ While processing the objects polymorphically, the program increases the base salary of each `BasePlusCommissionEmployee` by 10%.
 - **Requires determining the object's type at execution time.**
- ▶ Finally, the program **polymorphically determines** and outputs the type of each object in the `Employee` array.

```

1 // Fig. 10.9: PayrollSystemTest.java
2 // Employee hierarchy test program.
3
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() );

```

Fig. 10.9 | Employee hierarchy test program. (Part 1 of 6.)


```

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;
40
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 }

```

Does not create Employee objects—just variables that can refer to objects of Employee subclasses

Aim each Employee variable at an object of an Employee subclass

Polymorphically invokes toString

Fig. 10.9 | Employee hierarchy test program. (Part 2 of 6.)

```

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     employee.setBaseSalary( 1.10 * employee.getBaseSalary() );
57
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

```

Is currentEmployee a BasePlus-CommissionEmployee?

This downcast works because currentEmployee is a BasePlus-CommissionEmployee

Polymorphically invokes earnings

Every object in Java knows its own type

Fig. 10.9 | Employee hierarchy test program. (Part 3 of 6.)

Employees processed individually:

salariéd employé: John Smith
social security number: 111-11-1111
weekly salary: \$800.00
earned: \$800.00

hourly employé: Karen Price
social security number: 222-22-2222
hourly wage: \$16.75; hours worked: 40.00
earned: \$670.00

commission employé: Sue Jones
social security number: 333-33-3333
gross sales: \$10,000.00; commission rate: 0.06
earned: \$600.00

base-salariéd commission employé: Bob Lewis
social security number: 444-44-4444
gross sales: \$5,000.00; commission rate: 0.04; base salary: \$300.00
earned: \$500.00

Fig. 10.9 | Employee hierarchy test program. (Part 4 of 6.)

Employees processed polymorphically:

salari ed employee: John Smith
social security number: 111-11-1111
weekly salary: \$800.00
earned \$800.00

hourly employee: Karen Price
social security number: 222-22-2222
hourly wage: \$16.75; hours worked: 40.00
earned \$670.00

commission employee: Sue Jones
social security number: 333-33-3333
gross sales: \$10,000.00; commission rate: 0.06
earned \$600.00

base-salari ed commission employee: Bob Lewis
social security number: 444-44-4444
gross sales: \$5,000.00; commission rate: 0.04; base salary: \$300.00
new base salary with 10% increase is: \$330.00
earned \$530.00

Fig. 10.9 | Employee hierarchy test program. (Part 5 of 6.)

```
Employee 0 is a SalariedEmployee  
Employee 1 is a HourlyEmployee  
Employee 2 is a CommissionEmployee  
Employee 3 is a BasePlusCommissionEmployee
```

Fig. 10.9 | Employee hierarchy test program. (Part 6 of 6.)

10.5.6 Polymorphic Processing, Operator instanceof and Downcasting (Cont.)

- ▶ All calls to method `toString` and `earnings` are resolved at execution time, based on the type of the object to which `currentEmployee` refers.
 - Known as **dynamic binding** or **late binding**.
 - Java decides which class's `toString` method to call at **execution time rather than at compile time**
- ▶ A superclass reference can be used to invoke only methods of the superclass
 - The subclass method implementations are **invoked polymorphically**.
 - Attempting to invoke a subclass-only method directly on a superclass reference is a **compilation error**.



Common Programming Error 10.3

Assigning a superclass variable to a subclass variable (without an explicit cast) is a compilation error.

10.5.6 Polymorphic Processing, Operator instanceof and Downcasting (Cont.)

- ▶ Every object in Java knows its own class and can access this information through the `getClass` method, which all classes inherit from class `Object`.
 - The `getClass` method returns an object of type `Class` (from package `java.lang`), which contains information about the object's type, including its class name.
 - The result of the `getClass` call is used to invoke `getName` to get the object's class name.

10.5.7 Summary of the Allowed Assignments Between Superclass and Subclass Variables

- ▶ There are **four ways** to assign superclass and subclass references to variables of superclass and subclass types.
- ▶ **Assigning** a superclass reference to a superclass variable is straightforward.
- ▶ **Assigning** a subclass reference to a subclass variable is straightforward.
- ▶ **Assigning** a subclass reference to a superclass variable is safe, because the subclass object *is an object of its superclass*.
 - The superclass variable can be used to refer only to superclass members.
 - If this code refers to subclass-only members through the superclass variable, the compiler reports errors.

10.5.7 Summary of the Allowed Assignments Between Superclass and Subclass Variables (Cont.)

- ▶ Attempting to assign a superclass reference to a subclass variable is a compilation error.
 - To avoid this error, the superclass reference **must be cast** to a subclass type explicitly.
 - *At execution time, if the object to which the reference refers is not a subclass object, an exception will occur.*
 - Use the **instanceof** operator to ensure that such a cast is performed only if the object is a subclass object.

10.6 final Methods and Classes

- ▶ A `final` method in a superclass cannot be overridden in a subclass.
 - Methods that are declared `private` are `implicitly final`, because it's not possible to override them in a subclass.
 - Methods that are declared `static` are `implicitly final`.
 - A `final` method's declaration can `never change`, so all subclasses use the same method implementation, and calls to `final` methods are resolved at compile time—this is known as `static binding`.

10.6 final Methods and Classes (Cont.)

- ▶ A `final` class cannot be a superclass (i.e., a class cannot extend a `final` class).
 - All methods in a `final` class are implicitly `final`.
- ▶ Class `String` is an example of a `final` class.
 - If you were allowed to create a subclass of `String`, objects of that subclass could be used wherever `Strings` are expected.
 - Since class `String` cannot be extended, programs that use `Strings` can rely on the functionality of `String` objects as specified in the Java API.
 - Making the class `final` also prevents programmers from creating subclasses that might bypass security restrictions.

10.7 Case Study: Creating and Using Interfaces

- ▶ Our next example reexamines the payroll system of Section 10.5.
- ▶ Suppose that the company involved wishes to perform several accounting operations in a single accounts payable application
 - Calculating the earnings that must be paid to each employee
 - Calculate the payment due on each of several invoices (i.e., bills for goods purchased)
- ▶ Both operations have to do with obtaining some kind of payment amount.
 - For an employee, the payment refers to the employee's earnings.
 - For an invoice, the payment refers to the total cost of the goods listed on the invoice.

10.7 Case Study: Creating and Using Interfaces (Cont.)

- ▶ Interfaces offer a capability requiring that **unrelated classes** implement a set of common methods.
- ▶ Interfaces define and standardize the ways in which things such as people and systems can interact with one another.
 - Example: The controls on a radio serve as an interface between radio users and a radio's internal components.
 - Can perform only a limited set of operations (e.g., change the station, adjust the volume, choose between AM and FM)
 - **Different radios may implement the controls in different ways** (e.g., using push buttons, dials, voice commands).

10.7 Case Study: Creating and Using Interfaces (Cont.)

- ▶ The interface *specifies what* operations a radio must permit users to perform but *does not specify how* the operations are performed.
- ▶ A Java interface describes a set of methods that can be called on an object.

10.7 Case Study: Creating and Using Interfaces (Cont.)

- ▶ An **interface declaration** begins with the keyword `interface` and contains only constants and **abstract** methods.
 - All interface members must be **public**.
 - Interfaces **may not specify** any implementation details, such as concrete method declarations and instance variables.
 - All methods declared in an interface are **implicitly public abstract** methods.
 - All fields are implicitly **public, static** and **final**.

10.7 Case Study: Creating and Using Interfaces (Cont.)

- ▶ To use an interface, a concrete class must specify that it `implements` the interface and must declare each method in the interface with specified signature.
 - Add the `implements` keyword and the name of the interface to the end of your class declaration's first line.
- ▶ A class that `does not implement all the methods` of the interface is an abstract class and must be declared `abstract`.
- ▶ Implementing an interface is like signing a contract with the compiler that states, "I will declare all the methods specified by the interface or I will declare my class `abstract`."



Common Programming Error 10.6

Failing to implement any method of an interface in a concrete class that implements the interface results in a compilation error indicating that the class must be declared abstract.

10.7 Case Study: Creating and Using Interfaces (Cont.)

- ▶ An interface is often used in place of an `abstract` class when there is **no default implementation to inherit** — that is, no fields and no default method implementations.
- ▶ Like `public abstract` classes, interfaces are typically `public` types.
- ▶ A `public` interface must be declared in a file with the same name as the interface and the `.java` file-name extension.

10.7.1 Developing a Payable Hierarchy

- ▶ Next example builds an application that can determine payments for employees and invoices alike.
 - Classes `Invoice` and `Employee` both represent things for which the company must be able to calculate a payment amount.
 - Both classes implement the `Payable` interface, so a program can invoke method `getPaymentAmount` on `Invoice` objects and `Employee` objects alike.
 - Enables the polymorphic processing of `Invoices` and `Employees`.

10.7.1 Developing a Payable Hierarchy (Cont.)

- ▶ Fig. 10.10 shows the accounts payable hierarchy.
- ▶ The UML distinguishes an interface from other classes by placing «interface» above the interface name.
- ▶ The UML expresses the relationship between a class and an interface through a **realization**.
 - A class is said to “**realize**,” or implement, the methods of an interface.
 - A class diagram **models a realization** as a dashed arrow with a hollow arrowhead pointing from the implementing class to the interface.
- ▶ A subclass inherits its superclass’s realization relationships.

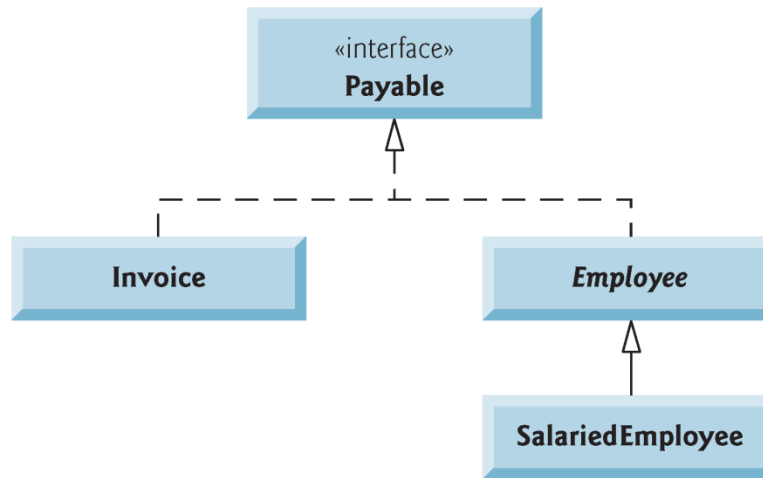


Fig. 10.10 | Payable interface hierarchy UML class diagram.

10.7.2 Interface Payable

- ▶ Fig. 10.11 shows the declaration of interface `Payable`.
- ▶ Interface methods are always `public` and `abstract`, so they do not need to be declared as such.
- ▶ Interfaces can have any number of methods.
- ▶ Interfaces may also contain fields that are implicitly `final` and `static`.

```
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
```

Fig. 10.11 | Payable interface declaration.

10.7.3 Class Invoice

- ▶ Java does not allow subclasses to inherit from more than one superclass, but it allows a class to inherit from one superclass and implement as many interfaces as it needs.
- ▶ To implement more than one interface, use a comma-separated list of interface names after keyword `implements` in the class declaration, as in:

```
public class ClassName extends  
    SuperclassName  
    implements FirstInterface,  
    SecondInterface, ...
```

```
1 // Fig. 10.12: Invoice.java
2 // Invoice class implements Payable.
3
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
```

Class extends Object (implicitly) and implements interface Payable

Fig. 10.12 | Invoice class that implements Payable. (Part I of 4.)

```
21 // set part number
22 public void setPartNumber( String part )
23 {
24     partNumber = part; // should validate
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; // should validate
37 } // end method setPartDescription
38
39 // get description
40 public String getPartDescription()
41 {
42     return partDescription;
43 } // end method getPartDescription
44
```

Fig. 10.12 | Invoice class that implements Payable. (Part 2 of 4.)

```
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
```

Fig. 10.12 | Invoice class that implements Payable. (Part 3 of 4.)

```
69 // return String representation of Invoice object
70 @Override
71 public String toString()
72 {
73     return String.format( "%s: \n%s: %s (%s) \n%s: %d \n%s: $%,.2f",
74         "invoice", "part number", getPartNumber(), getPartDescription(),
75         "quantity", getQuantity(), "price per item", getPricePerItem() );
76 } // end method toString
77
78 // method required to carry out contract with interface Payable
79 @Override
80 public double getPaymentAmount() ←
81 {
82     return getQuantity() * getPricePerItem(); // calculate total cost
83 } // end method getPaymentAmount
84 } // end class Invoice
```

Providing an implementation of the interface's method(s) makes this class concrete

Fig. 10.12 | Invoice class that implements Payable. (Part 4 of 4.)

10.7.4 Modifying Class Employee to Implement Interface Payable

- ▶ When a class implements an interface, it makes a contract with the compiler
 - The class will implement each of the methods in the interface or that the class will be declared **abstract**.
 - If the latter, we do not need to declare the interface methods as **abstract** in the **abstract** class—they are already implicitly declared as such in the interface.
 - Any concrete subclass of the **abstract** class must implement the interface methods to fulfill the contract.
 - If the subclass does not do so, it too must be declared **abstract**.
- ▶ Each direct **Employee** subclass inherits the superclass's contract to implement method **getPaymentAmount** and thus must implement this method to become a concrete class for which objects can be instantiated.

```
1 // Fig. 10.13: Employee.java
2 // Employee abstract superclass implements Payable.
3
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    // set first name
19    public void setFirstName( String first )
20    {
21        firstName = first; // should validate
22    } // end method setFirstName
23
```

Abstract class extends Object
(implicitly) and implements interface
Payable

Fig. 10.13 | Employee class that implements Payable. (Part 1 of 3.)

```
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; // should validate
34 } // end method setLastName
35
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
```

Fig. 10.13 | Employee class that implements Payable. (Part 2 of 3.)


```
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 @Override
56 public String toString()
57 {
58     return String.format( "%s %s\nsocial security number: %s",
59         getFirstName(), getLastName(), getSocialSecurityNumber() );
60 } // end method toString
61
62 // Note: We do not implement Payable method getPaymentAmount here so
63 // this class must be declared abstract to avoid a compilation error.
64 } // end abstract class Employee
```

← We don't implement the interface's method, so this class must be declared abstract

Fig. 10.13 | Employee class that implements Payable. (Part 3 of 3.)

10.7.5 Modifying Class `SalariedEmployee` for Use in the `Payable` Hierarchy

- ▶ Figure 10.14 contains a modified `SalariedEmployee` class that extends `Employee` and fulfills superclass `Employee`'s contract to implement `Payable` method `getPaymentAmount`.

```
1 // Fig. 10.14: SalariedEmployee.java
2 // SalariedEmployee class extends Employee, which implements Payable.
3
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
```

Fig. 10.14 | SalariedEmployee class that implements interface Payable method
getPaymentAmount. (Part 1 of 2.)

```
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 @Override
31 public double getPaymentAmount() ←
32 {
33     return getWeeklySalary();
34 } // end method getPaymentAmount
35
36 // return String representation of SalariedEmployee object
37 @Override
38 public String toString()
39 {
40     return String.format( "salaried employee: %s\n%s: $%,.2f",
41         super.toString(), "weekly salary", getWeeklySalary() );
42 } // end method toString
43 } // end class SalariedEmployee
```

Providing an implementation of the interface's method(s) makes this class concrete

Fig. 10.14 | SalariedEmployee class that implements interface Payable method getPaymentAmount. (Part 2 of 2.)

10.7.5 Modifying Class SalariedEmployee for Use in the Payable Hierarchy (Cont.)

- ▶ Objects of any subclasses of a class that implements an interface can also be thought of as objects of the interface type.
- ▶ Thus, just as we can assign the reference of a SalariedEmployee object to a superclass Employee variable, we can assign the reference of a SalariedEmployee object to an interface Payable variable.
- ▶ Invoice implements Payable, so an Invoice object also is a *Payable* object, and we can assign the reference of an *Invoice* object to a *Payable* variable.

10.7.6 Using Interface Payable to Process Invoices and Employees Polymorphically

```

1 // Fig. 10.15: PayableInterfaceTest.java
2 // Tests interface Payable.
3
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

```

Creates an array of four Payable variables

Aim each Payable variable at an object of a class that implement the Payable interface

Fig. 10.15 | Payable interface test program processing Invoices and Employees polymorphically. (Part 1 of 3.)

```
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
```

Fig. 10.15 | Payable interface test program processing Invoices and Employees polymorphically. (Part 2 of 3.)

Invoices and Employees processed polymorphically:

invoice:

part number: 01234 (seat)

quantity: 2

price per item: \$375.00

payment due: \$750.00

invoice:

part number: 56789 (tire)

quantity: 4

price per item: \$79.95

payment due: \$319.80

salaries employee: John Smith

social security number: 111-11-1111

weekly salary: \$800.00

payment due: \$800.00

salaries employee: Lisa Barnes

social security number: 888-88-8888

weekly salary: \$1,200.00

payment due: \$1,200.00

Fig. 10.15 | Payable interface test program processing Invoices and Employees polymorphically. (Part 3 of 3.)

10.7.7 Common Interfaces of the Java API

- ▶ The Java API's interfaces enable you to use your own classes within the frameworks provided by Java, such as comparing objects of your own types and creating tasks that can execute concurrently with other tasks in the same program.
- ▶ Figure 10.16 presents a brief overview of a few of the more popular interfaces of the Java API used in *Java How to Program, Ninth Edition*.

Interface	Description
Comparable	Java contains several comparison operators (e.g., <, <=, >, >=, ==, !=) that allow you to compare primitive values. However, these operators cannot be used to compare objects. Interface Comparable is used to allow objects of a class that implements the interface to be compared to one another. Interface Comparable is commonly used for ordering objects in a collection such as an array. We use Comparable in Chapter 20, Generic Collections, and Chapter 21, Generic Classes and Methods.
Serializable	An interface used to identify classes whose objects can be written to (i.e., serialized) or read from (i.e., deserialized) some type of storage (e.g., file on disk, database field) or transmitted across a network. We use Serializable in Chapter 17, Files, Streams and Object Serialization, and Chapter 27, Networking.
Runnable	Implemented by any class for which objects of that class should be able to execute in parallel using a technique called multithreading (discussed in Chapter 26, Multithreading). The interface contains one method, run, which describes the behavior of an object when executed.

Fig. 10.16 | Common interfaces of the Java API. (Part 1 of 2.)

Interface	Description
GUI event-listener interfaces	You work with graphical user interfaces (GUIs) every day. In your web browser, you might type the address of a website to visit, or you might click a button to return to a previous site. The browser responds to your interaction and performs the desired task. Your interaction is known as an event, and the code that the browser uses to respond to an event is known as an event handler. In Chapter 14, GUI Components: Part 1, and Chapter 25, GUI Components: Part 2, you'll learn how to build GUIs and event handlers that respond to user interactions. Event handlers are declared in classes that implement an appropriate event-listener interface. Each event-listener interface specifies one or more methods that must be implemented to respond to user interactions.
SwingConstants	Contains a set of constants used in GUI programming to position GUI elements on the screen. We explore GUI programming in Chapters 14 and 25.

Fig. 10.16 | Common interfaces of the Java API. (Part 2 of 2.)



Lab session: Ex. 1

- ▶ ***(Payroll System Modification)*** Modify the payroll system of Figs. 10.4–10.9 to include private instance variable `birthDate` in class `Employee`.
- ▶ Use class `Date` of Fig. 8.7 to represent an employee's birthday. Add *get* methods to class `Date`. Assume that payroll is processed once per month.
- ▶ Create an array of `Employee` variables to store references to the various employee objects. In a loop, calculate the payroll for each `Employee` (polymorphically), and add a \$100.00 bonus to the person's payroll amount if the current month is the one in which the `Employee`'s birthday occurs.



Lab session: Ex. 2

- ▶ (Payroll System Modification) Modify the payroll system of Figs. 10.4–10.9 to include an additional Employee subclass PieceWorker that represents an employee whose pay is based on the number of pieces of merchandise produced.
- ▶ Class PieceWorker should contain private instance variables wage (to store the employee's wage per piece) and pieces (to store the number of pieces produced).
- ▶ Provide a concrete implementation of method earnings in class PieceWorker that calculates the employee's earnings by multiplying the number of pieces produced by the wage per piece.
- ▶ Create an array of Employee variables to store references to objects of each concrete class in the new Employee hierarchy. For each Employee, display its String representation and earnings.



Lab session: Ex. 3

- ▶ Extend the program with a class for invoices, Ex. Bill, with three attributes, amount, number and payment status.
- ▶ Introduce an interface so that bills and employees can be paid.
 - Introduce a method called pay for performing the payment
- ▶ Test the new feature by processing the unrelated classes polymorphically.

End of Class