10.5 Case Study: Payroll System Using Polymorphism

This section reexamines the `CommissionEmployee-BasePlusCommissionEmployee` hierarchy that we explored throughout Section 9.4. Now we use an abstract method and polymorphism to perform payroll calculations based on an enhanced employee inheritance hierarchy that meets the following 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 base-salaried commission employees by adding 10% to their base salaries. The company wants you to write an application that performs its payroll calculations polymorphically.

We use `abstract` class `Employee` to represent the general

concept of an employee. The classes that extend `Employee` are `SalariedEmployee`, `CommissionEmployee` and `Hourly-Employee`. Class `BasePlusCommissionEmployee`—which extends `CommissionEmployee`—represents the last employee type. The UML class diagram in Fig. 10.2 shows the inheritance hierarchy for our polymorphic employee-payroll application. Abstract class name `Employee` is *italicized*—a convention of the UML.

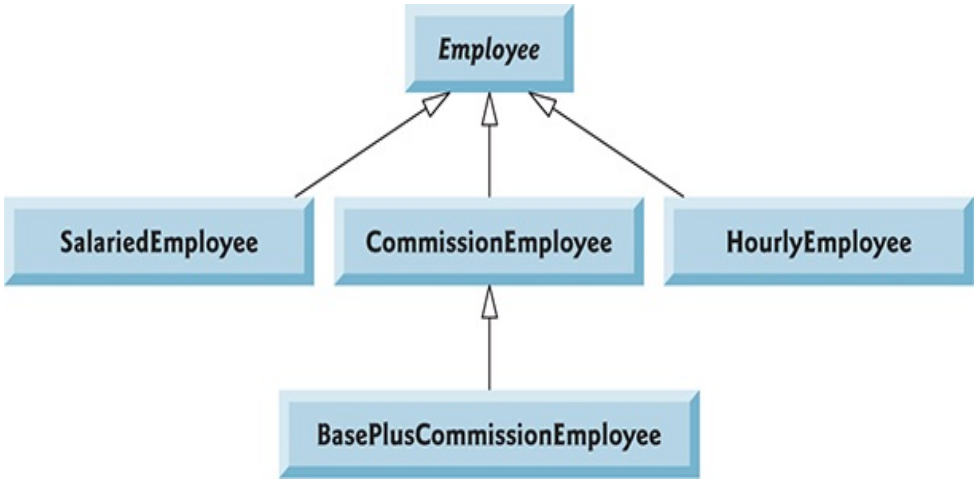


Fig. 10.2

`Employee` hierarchy UML class diagram.

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. Be

careful not to confuse the general notion of an “interface” with the formal notion of a Java interface, the subject of Section 10.9. Each employee, regardless of the way his or her earnings are calculated, has a first name, a last name and a social security number, so `private` instance variables `firstName`, `lastName` and `socialSecurityNumber` appear in abstract superclass `Employee`.

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. We do not list superclass `Employee`’s *get* methods because they’re *not* overridden in any of the subclasses—each of these methods is inherited and used “as is” by each subclass.

	earnings	toString
Employee	abstract	*firstName lastName* social security number: *S*
Salaried-Employee	weeklySalary	salaried employee: *firstName l* social security number: *S* weekly salary: *weeklySala*

Hourly-Employee	if (hours <= 40) {
	wage * hours
	}
	else if (hours > 40) {
	40 * wage +
	(hours - 40) *
		hourly employee: *firstName la*
		social security number: *S*
		hourly wage: *wage*; hours worke

	wage * 1.5 }	
Commission-Employee	commissionRate * grossSales	commission employee: *firstName* social security number: *S* gross sales: *grossSales* commission rate: *commission*
BasePlus-Commission-Employee	(commissionRate * grossSales) + baseSalary	base salaried commission empl *firstName lastName* social security number: *S* gross sales: *grossSales* commission rate: *commissionR* base salary: *baseSalary*

Fig. 10.3

Polymorphic interface for the `Employee` hierarchy classes.

The following sections implement the `Employee` class hierarchy of Fig. 10.2. The first section implements *abstract superclass* `Employee`. The next four sections each implement one of the *concrete* classes. The last section implements a test program that builds objects of all these classes and processes those objects polymorphically.

10.5.1 Abstract Superclass `Employee`

Class `Employee` (Fig. 10.4) provides methods `earnings` and `toString`, in addition to the *get* methods that return the values of `Employee`'s instance variables. An `earnings` method certainly applies *generically* to all employees. But each earnings calculation depends on the employee's particular class. So we declare `earnings` as `abstract` in superclass `Employee` because a *specific* default implementation does not make sense for that method—there isn't enough information to determine what amount `earnings` should return.

Each subclass overrides `earnings` with an appropriate implementation. To calculate an employee's earnings, the program assigns to a superclass `Employee` variable a reference to the employee's object, then invokes the `earnings` method on that variable. We maintain an array of `Employee` variables, each holding a reference to an `Employee` object. You *cannot* use class `Employee` directly to create `Employee` *objects*, because `Employee` is an *abstract* class. Due to inheritance, however, all objects of all `Employee` subclasses may be thought of as `Employee` objects. The program will iterate through the array and call method `earnings` for each `Employee` object. Java processes these method calls *polymorphically*. Declaring `earnings` as an `abstract` method in `Employee` enables the calls to `earnings` through `Employee` variables to

compile and forces every direct *concrete* subclass of `Employee` to *override* `earnings`.

Method `toString` in class `Employee` returns a `String` containing the first name, last name and social security number of the employee. As we'll see, each subclass of `Employee` *overrides* method `toString` to create a `String` representation of an object of that class that contains the employee's type (e.g., `"salaried employee:"`) followed by the rest of the employee's information.

Let's consider class `Employee`'s declaration (Fig. 10.4). The class includes a constructor that receives the first name, last name and social security number (lines 10–15); *get* methods that return the first name, last name and social security number (lines 18, 21 and 24, respectively); method `toString` (lines 27–31), which returns the `String` representation of an `Employee`; and `abstract` method `earnings` (line 34), which will be implemented by each of the *concrete* subclasses. The `Employee` constructor does *not* validate its parameters in this example; normally, such validation should be provided.

```
   1  // Fig. 10.4: Employee.java
 2  // Employee abstract superclass.
                    3
 4  public abstract class Employee {
5     private final String firstName;
 6     private final String lastName;
 7     private final String socialSecurityNumber;
                    8
          9     // constructor
10     public Employee(String firstName, String lastN
```

```
11        String socialSecurityNumber) {
12          this.firstName = firstName;
13           this.lastName = lastName;
14        this.socialSecurityNumber = socialSecurityN
15     }
16
17     // return first name
18     public String getFirstName() {return firstName
19
20     // return last name
21     public String getLastName() {return lastName;}
22
23     // return social security number
24     public String getSocialSecurityNumber() {retur
25
26     // return String representation of Employee ob
27     @Override
28     public String toString() {
29        return String.format("%s %s%nsocial securit
30           getFirstName(), getLastName(), getSocial
31     }
32
33     // abstract method must be overridden by concr
34     public abstract double earnings(); // no imple
35  }
```

Fig. 10.4

`Employee` abstract superclass.

Why did we decide to declare `earnings` as an `abstract` method? It simply does not make sense to provide a *specific* implementation of this method in class `Employee`. We cannot calculate the earnings for a *general* `Employee`—we

first must know the *specific* type of `Employee` to determine the appropriate earnings calculation. By declaring this method `abstract`, we indicate 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`.

10.5.2 Concrete Subclass `SalariedEmployee`

Class `SalariedEmployee` (Fig. 10.5) extends class `Employee` (line 4) and overrides *abstract* method `earnings` (lines 34–35), which makes `SalariedEmployee` a *concrete* class. The class includes a constructor (lines 8–18) that receives a first name, a last name, a social security number and a weekly salary; a *set* method to assign a new *nonnegative* value to instance variable `weeklySalary` (lines 21–28); a *get* method to return `weeklySalary`'s value (line 31); a method `earnings` (lines 34–35) to calculate a `SalariedEmployee`'s earnings; and a method `toString` (lines 38–42), which returns a `String` including `"salaried employee: "` followed by employee-specific information produced by superclass `Employee`'s `toString` method and `SalariedEmployee`'s `getWeeklySalary` method. Class `SalariedEmployee`'s constructor passes the first name, last name and social security number to the `Employee`

constructor (line 10) to initialize the `private` instance variables of the superclass. Once again, we've duplicated the `weeklySalary` validation code in the constructor and the `setWeeklySalary` method. Recall that more complex validation could be placed in a `static` class method that's called from the constructor and the *set* method.

Error-Prevention Tip 10.1

We've said that you should not call a class's instance methods from its constructors—you can call `static` *class methods and make the required call to one of the superclass's constructors. If you follow this advice, you'll avoid the problem of calling the class's overridable methods either directly or indirectly, which can lead to runtime errors. See Section 10.8 for additional details.*

```
 1  // Fig. 10.5: SalariedEmployee.java
 2  // SalariedEmployee concrete class extends abstra
 3
 4  public class SalariedEmployee extends Employee {
 5     private double weeklySalary;
 6
 7     // constructor
 8     public SalariedEmployee(String firstName, Stri
 9        String socialSecurityNumber, double weeklyS
10        super(firstName, lastName, socialSecurityNu
11
12        if (weeklySalary < 0.0) {
```

```
13            throw new IllegalArgumentException(
14                "Weekly salary must be >= 0.0");
                  15        }
                            16
   17         this.weeklySalary = weeklySalary;
                    18      }
                            19
               20      // set salary
21      public void setWeeklySalary(double weeklySalar
        22         if (weeklySalary < 0.0) {
23            throw new IllegalArgumentException(
24                "Weekly salary must be >= 0.0");
                  25        }
                            26
   27         this.weeklySalary = weeklySalary;
                    28      }
                            29
              30      // return salary
31      public double getWeeklySalary() {return weekly
                            32
33      // calculate earnings; override abstract metho
                  34      @Override
35      public double earnings() {return getWeeklySala
                            36
37      // return String representation of SalariedEmp
                  38      @Override
          39      public String toString() {
40          return String.format("salaried employee: %s
41            super.toString(), "weekly salary", getWee
                    42      }
                      43  }
```

Fig. 10.5

`SalariedEmployee` concrete class extends `abstract`

class `Employee`.

Method `earnings` overrides `Employee`'s *abstract* method `earnings` to provide a *concrete* implementation that returns the `SalariedEmployee`'s weekly salary. If we do not implement `earnings`, class `SalariedEmployee` must be declared `abstract`—otherwise, class `SalariedEmployee` will not compile. Of course, we want `SalariedEmployee` to be a *concrete* class in this example.

Method `toString` (lines 38–42) overrides `Employee`'s `toString`. If class `SalariedEmployee` did *not* override `toString`, it would have inherited `Employee`'s version. In that case, `SalariedEmployee`'s `toString` method would simply return the employee's full name and social security number, which does *not* adequately represent a `SalariedEmployee`. To produce a complete `String` representation of a `SalariedEmployee`, the subclass's `toString` method returns `"salaried employee: "` followed by the superclass `Employee`-specific information (i.e., first name, last name and social security number) obtained by invoking the *superclass's* `toString` method (line 41)—this is a nice example of *code reuse*. The `String` representation of a `SalariedEmployee` also contains the employee's weekly salary obtained by invoking the class's `getWeeklySalary` method.

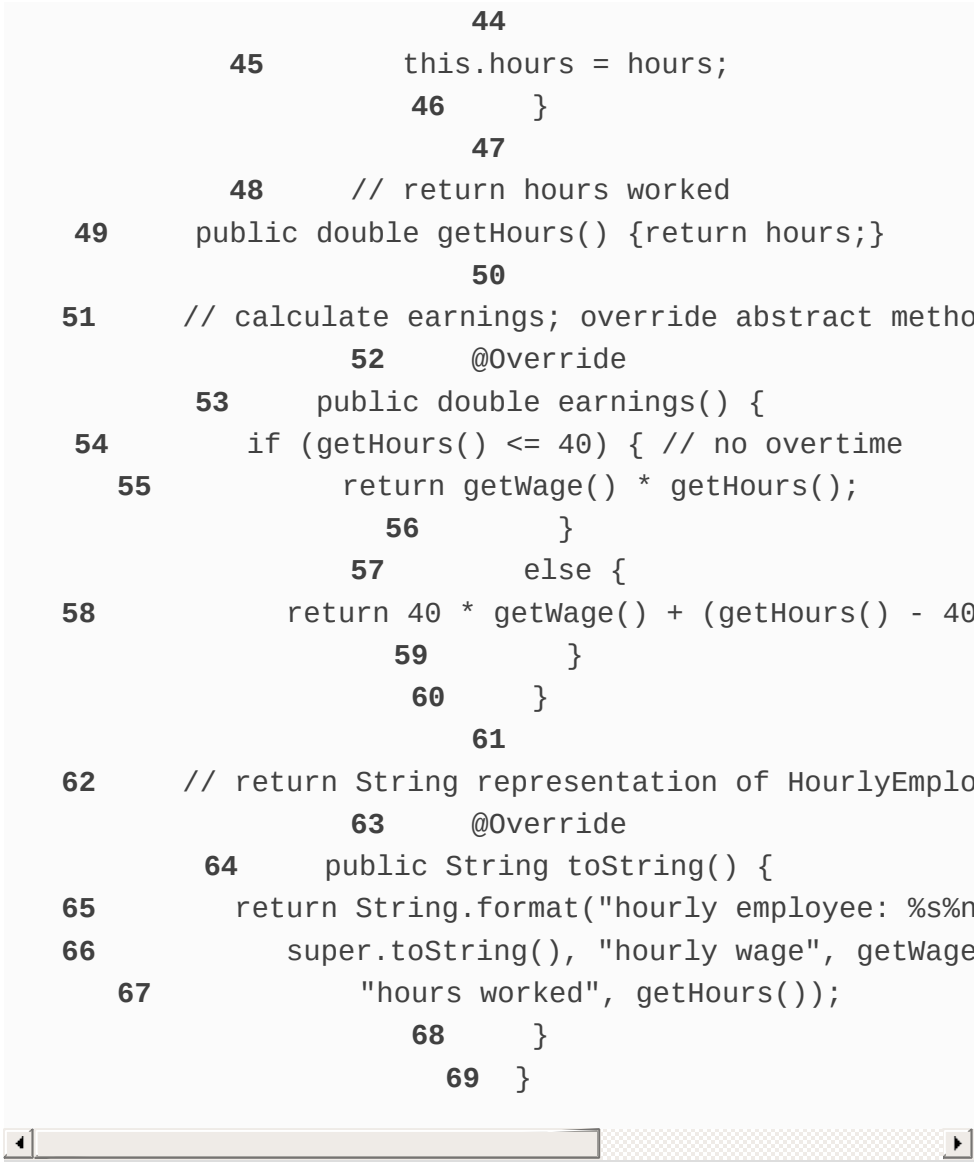
10.5.3 Concrete Subclass

HourlyEmployee

Class `HourlyEmployee` (Fig. 10.6) also extends `Employee` (line 4). The class includes a constructor (lines 9–24) that receives a first name, a last name, a social security number, an hourly wage and the number of hours worked. Lines 27–33 and 39–46 declare *set* methods that assign new values to instance variables `wage` and `hours`, respectively. Method `setWage` ensures that `wage` is *nonnegative*, and method `setHours` ensures that the value of `hours` is between 0 and 168 (the total number of hours in a week) inclusive. Class `HourlyEmployee` also includes *get* methods (lines 36 and 49) to return the values of `wage` and `hours`, respectively; a method `earnings` (lines 52–60) to calculate an `HourlyEmployee`'s earnings; and a method `toString` (lines 63–68), which returns a `String` containing the employee's type (`"hourly employee: "`) and the employee-specific information. The `HourlyEmployee` constructor, like the `SalariedEmployee` constructor, passes the first name, last name and social security number to the superclass `Employee` constructor (line 11) to initialize the `private` instance variables. In addition, method `toString` calls *superclass* method `to-String` (line 66) to obtain the `Employee`-specific information (i.e., first name, last name and social security number)—this is another nice example of *code reuse*.

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

```
public class HourlyEmployee extends Employee {
   private double wage; // wage per hour
   private double hours; // hours worked for week

   // constructor
   public HourlyEmployee(String firstName, String
      String socialSecurityNumber, double wage, d
      super(firstName, lastName, socialSecurityNu

      if (wage < 0.0) { // validate wage
         throw new IllegalArgumentException("Hour
      }

      if ((hours < 0.0) || (hours > 168.0)) { //
         throw new IllegalArgumentException(
            "Hours worked must be >= 0.0 and <=
      }

      this.wage = wage;
      this.hours = hours;
   }

   // set wage
   public void setWage(double wage) {
      if (wage < 0.0) { // validate wage
         throw new IllegalArgumentException("Hour
      }

      this.wage = wage;
   }

   // return wage
   public double getWage() {return wage;}

   // set hours worked
   public void setHours(double hours) {
      if ((hours < 0.0) || (hours > 168.0)) { //
         throw new IllegalArgumentException(
            "Hours worked must be >= 0.0 and <= 1
      }
```



```
                    44
          45        this.hours = hours;
                    46     }
                    47
          48     // return hours worked
 49     public double getHours() {return hours;}
                    50
 51     // calculate earnings; override abstract metho
                    52     @Override
          53     public double earnings() {
 54        if (getHours() <= 40) { // no overtime
    55           return getWage() * getHours();
                    56        }
                    57        else {
 58           return 40 * getWage() + (getHours() - 40
                    59        }
                    60     }
                    61
 62     // return String representation of HourlyEmplo
                    63     @Override
          64     public String toString() {
 65        return String.format("hourly employee: %s%n
 66           super.toString(), "hourly wage", getWage
    67           "hours worked", getHours());
                    68     }
                    69  }
```

Fig. 10.6

`HourlyEmployee` class extends `Employee`.

10.5.4 Concrete Subclass

CommissionEmployee

Class `CommissionEmployee` (Fig. 10.7) extends class `Employee` (line 4). The class includes a constructor (lines 9–25) that takes a first name, a last name, a social security number, a sales amount and a commission rate; *set* methods (lines 28–34 and 40–47) to assign valid new values to instance variables `grossSales` and `commissionRate`, respectively; *get* methods (lines 37 and 50) that retrieve the values of these instance variables; method `earnings` (lines 53–56) to calculate a `CommissionEmployee`'s earnings; and method `toString` (lines 59–65), which returns `"commission employee: "` followed by the employee's specific information. The constructor also passes the first name, last name and social security number to *superclass* `Employee`'s constructor (line 12) to initialize `Employee`'s `private` instance variables. Method `toString` calls *superclass* method `toString` (line 62) to obtain the `Employee`-specific information (i.e., first name, last name and social security number).

```
    1  // Fig. 10.7: CommissionEmployee.java
 2  // CommissionEmployee class extends Employee.
                       3
 4  public class CommissionEmployee extends Employee
 5     private double grossSales; // gross weekly sal
 6     private double commissionRate; // commission p
                       7
              8     // constructor
 9     public CommissionEmployee(String firstName, St
10        String socialSecurityNumber, double grossSa
      11        double commissionRate) {
```

```
12        super(firstName, lastName, socialSecurityNu
                    13
14        if (commissionRate <= 0.0 || commissionRate
15           throw new IllegalArgumentException(
16              "Commission rate must be > 0.0 and <
                 17        }
                    18
 19        if (grossSales < 0.0) { // validate
20           throw new IllegalArgumentException("Gros
                    21        }
                    22
    23         this.grossSales = grossSales;
24         this.commissionRate = commissionRate;
                   25      }
                    26
       27      // set gross sales amount
28      public void setGrossSales(double grossSales)
 29         if (grossSales < 0.0) { // validate
30            throw new IllegalArgumentException("Gro
                  31         }
                    32
    33         this.grossSales = grossSales;
                   34      }
                    35
      36      // return gross sales amount
37      public double getGrossSales() {return grossSa
                    38
        39      // set commission rate
40      public void setCommissionRate(double commissi
41         if (commissionRate <= 0.0 || commissionRat
42            throw new IllegalArgumentException(
43               "Commission rate must be > 0.0 and <
                  44         }
                    45
46         this.commissionRate = commissionRate;
                   47      }
                    48
       49      // return commission rate
50      public double getCommissionRate() {return com
                    51
```

```
52      // calculate earnings; override abstract meth
53      @Override
54      public double earnings() {
55         return getCommissionRate() * getGrossSales
56      }
57
58      // return String representation of Commission
59      @Override
60      public String toString() {
61         return String.format("%s: %s%n%s: $%,.2f;
62            "commission employee", super.toString()
63            "gross sales", getGrossSales(),
64            "commission rate", getCommissionRate())
65      }
66   }
```

Fig. 10.7

`CommissionEmployee` class extends `Employee`.

10.5.5 Indirect Concrete Subclass `BasePlusCommissionEmployee`

Class `BasePlusCommissionEmployee` (Fig. 10.8) extends class `CommissionEmployee` (line 4) and therefore is an *indirect* subclass of class `Employee`. Class

`BasePlusCommission-Employee` has a constructor (lines 8–19) that receives a first name, a last name, a social security number, a sales amount, a commission rate and a base salary. It then passes all of these except the base salary to the `CommissionEmployee` constructor (lines 11–12) to initialize the superclass instance variables. `BasePlusCommissionEmployee` also contains a *set* method (lines 22–28) to assign a new value to instance variable `baseSalary` and a *get* method (line 31) to return `baseSalary`'s value. Method `earnings` (lines 34–35) calculates a `BasePlusCommissionEmployee`'s earnings. Line 35 in method `earnings` calls *superclass* `CommissionEmployee`'s `earnings` method to calculate the commission-based portion of the employee's earnings—this is another nice example of *code reuse*. `BasePlusCommissionEmployee`'s `toString` method (lines 38–43) creates a `String` representation of a `BasePlusCommissionEmployee` that contains `"base-salaried"`, followed by the `String` obtained by invoking *superclass* `CommissionEmployee`'s `toString` method (line 41), then the base salary. The result is a `String` beginning with `"base-salaried commission employee"` followed by the rest of the `BasePlusCommissionEmployee`'s information. Recall that `CommissionEmployee`'s `toString` obtains the employee's first name, last name and social security number by invoking the `toString` method of its *superclass* (i.e., `Employee`)—yet another example of *code reuse*. `BasePlusCommissionEmployee`'s `toString` method initiates a *chain of method calls* that span all three levels of the

`Employee` hierarchy.

```
// Fig. 10.8: BasePlusCommissionEmployee.java
// BasePlusCommissionEmployee class extends Commi
3
public class BasePlusCommissionEmployee extends C
   private double baseSalary; // base salary per
6
   // constructor
   public BasePlusCommissionEmployee(String first
      String socialSecurityNumber, double grossSa
      double commissionRate, double baseSalary) {
      super(firstName, lastName, socialSecurityNu
         grossSales, commissionRate);
13
      if (baseSalary < 0.0) { // validate baseSal
         throw new IllegalArgumentException("Base
16       }
17
       this.baseSalary = baseSalary;
19    }
20
    // set base salary
   public void setBaseSalary(double baseSalary) {
      if (baseSalary < 0.0) { // validate baseSal
         throw new IllegalArgumentException("Base
25       }
26
       this.baseSalary = baseSalary;
28    }
29
    // return base salary
   public double getBaseSalary() {return baseSala
32
   // calculate earnings; override method earning
34    @Override
   public double earnings() {return getBaseSalary
36
   // return String representation of BasePlusCom
```

```
    @Override
    public String toString() {
      return String.format("%s %s; %s: $%,.2f",
        "base-salaried", super.toString(),
        "base salary", getBaseSalary());
    }
}
```

Fig. 10.8

`BasePlusCommissionEmployee` class extends `CommissionEmployee`.

10.5.6 Polymorphic Processing, Operator `instanceof` and Downcasting

To test our `Employee` hierarchy, the application in Fig. 10.9 creates an object of each of the four *concrete* classes `SalariedEmployee`, `HourlyEmployee`, `CommissionEmployee` and `BasePlusCommissionEmployee`. The program 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%—this 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. Lines 7–16 create objects of each of the four concrete `Employee` subclasses. Lines 20–28 output the `String` representation and earnings of each of these objects *nonpolymorphically*. Each object's `toString` method is called *implicitly* by `printf` when the object is output as a `String` with the `%s` format specifier.

```
 1  // Fig. 10.9: PayrollSystemTest.java
 2  // Employee hierarchy test program.
 3
 4  public class PayrollSystemTest {
 5     public static void main(String[] args) {
 6        // create subclass objects
 7        SalariedEmployee salariedEmployee =
 8           new SalariedEmployee("John", "Smith", "1
 9        HourlyEmployee hourlyEmployee =
10           new HourlyEmployee("Karen", "Price", "22
11        CommissionEmployee commissionEmployee =
12           new CommissionEmployee(
13           "Sue", "Jones", "333-33-3333", 10000, .0
14        BasePlusCommissionEmployee basePlusCommissi
15           new BasePlusCommissionEmployee(
16           "Bob", "Lewis", "444-44-4444", 5000, .04
17
18        System.out.println("Employees processed ind
19
20        System.out.printf("%n%s%n%s: $%,.2f%n%n",
21           salariedEmployee, "earned", salariedEmpl
22        System.out.printf("%s%n%s: $%,.2f%n%n",
23           hourlyEmployee, "earned", hourlyEmployee
24        System.out.printf("%s%n%s: $%,.2f%n%n",
25           commissionEmployee, "earned", commission
```

```
26          System.out.printf("%s%n%s: $%,.2f%n%n",
27             basePlusCommissionEmployee,
28             "earned", basePlusCommissionEmployee.ear
29
30          // create four-element Employee array
31          Employee[] employees = new Employee[4];
32
33          // initialize array with Employees
34          employees[0] = salariedEmployee;
35          employees[1] = hourlyEmployee;
36          employees[2] = commissionEmployee;
37          employees[3] = basePlusCommissionEmployee;
38
39          System.out.printf("Employees processed poly
40
41          // generically process each element in arra
42          for (Employee currentEmployee : employees)
43             System.out.println(currentEmployee); //
44
45             // determine whether element is a BasePl
46             if (currentEmployee instanceof BasePlusC
47                // downcast Employee reference to
48                // BasePlusCommissionEmployee referen
49                BasePlusCommissionEmployee employee =
50                   (BasePlusCommissionEmployee) curre
51
52                employee.setBaseSalary(1.10 * employe
53
54                System.out.printf(
55                   "new base salary with 10%% increas
56                   employee.getBaseSalary());
57             }
58
59             System.out.printf(
60                "earned $%,.2f%n%n", currentEmployee.
61          }
62
63          // get type name of each object in employee
64          for (int j = 0; j < employees.length; j++)
65             System.out.printf("Employee %d is a %s%n
```

```
66                employees[j].getClass().getName());
67             }
68          }
69       }
```

```
Employees processed individually:

salaried 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-salaried commission employee: Bob Lewis
social security number: 444-44-4444
gross sales: $5,000.00; commission rate: 0.04; base s
earned: $500.00

Employees processed polymorphically:

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

          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.

Creating the Array of `Employees`

Line 31 declares `employees` and assigns it an array of four `Employee` variables. Lines 34–37 assign to the elements a reference to a `SalariedEmployee`, an `HourlyEmployee`, a `CommissionEmployee` and a

`BasePlusCommissionEmployee`, respectively. These assignments are allowed, because a `SalariedEmployee` *is an* `Employee`, an `HourlyEmployee` *is an* `Employee`, a `CommissionEmployee` *is an* `Employee` and a `BasePlusCommissionEmployee` *is an* `Employee`. Therefore, we can assign the references of `SalariedEmployee`, `HourlyEmployee`, `CommissionEmployee` and `BasePlusCommissionEmployee` objects to *superclass* `Employee` variables, *even though* `Employee` *is an abstract class*.

Polymorphically Processing `Employees`

Lines 42–61 iterate through array `employees` and invoke methods `toString` and `earnings` with `Employee` variable `currentEmployee`, which is assigned the reference to a different `Employee` in the array on each iteration. The output illustrates that the specific methods for each class are indeed invoked. All calls to method `toString` and `earnings` are resolved at *execution* time, based on the *type* of the object to which `currentEmployee` refers. This process is known as **dynamic binding** or **late binding**. For example, line 43 *implicitly* invokes method `toString` of the object to which `currentEmployee` refers. As a result of *dynamic binding*, Java decides which class's `toString` method to call *at execution time rather than at compile time*.

Only the methods of class `Employee` can be called via an `Employee` variable (and `Employee`, of course, includes the methods of class `Object`). A superclass reference can be used to invoke only methods of the *superclass*—the *subclass* method implementations are invoked *polymorphically*.

Performing Type-Specific Operations on `BasePlusCommissionEmployees`

We perform special processing on `BasePlusCommissionEmployee` objects—as we encounter these objects at execution time, we increase their base salary by 10%. When processing objects *polymorphically*, we typically do not need to worry about the *specifics*, but to adjust the base salary, we *do* have to determine the *specific* type of `Employee` object at *execution time*. Line 46 uses the `instanceof` operator to determine whether a particular `Employee` object's type is `BasePlusCommissionEmployee`. The condition in line 46 is *true* if the object referenced by `currentEmployee` *is a* `BasePlusCommissionEmployee`. This would also be *true* for any object of a `BasePlusCommissionEmployee` subclass because of the *is-a* relationship a subclass has with its superclass. Lines 49–50 *downcast* `currentEmployee` from type `Employee` to type

`BasePlusCommissionEmployee`—this cast is allowed only if the object has an *is-a* relationship with `BasePlusCommissionEmployee`. The condition at line 46 ensures that this is the case. This cast is required if we're to invoke subclass `BasePlusCommissionEmployee` methods `getBaseSalary` and `setBaseSalary` on the current `Employee` object—as you'll see momentarily, *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 is a compilation error.

Common Programming Error 10.4

When downcasting a reference, a `ClassCastException` *occurs if the referenced object at execution time does not have an* is-a *relationship with the type specified in the cast operator.*

If the `instanceof` expression in line 46 is `true`, lines 49–56 perform the special processing required for the

`BasePlusCommissionEmployee` object. Using `BasePlusCommissionEmployee` variable `employee`, line 52 invokes subclass-only methods `getBaseSalary` and `setBaseSalary` to retrieve and update the employee's base salary with the 10% raise.

Calling `earnings` Polymorphically

Lines 59–60 invoke method `earnings` on `currentEmployee`, which polymorphically calls the appropriate subclass object's `earnings` method. Obtaining the earnings of the `SalariedEmployee`, `HourlyEmployee` and `CommissionEmployee` polymorphically in lines 59–60 produces the same results as obtaining these employees' earnings individually in lines 20–25. The earnings amount obtained for the `BasePlusCommissionEmployee` in lines 59–60 is higher than that obtained in lines 26–28, due to the 10% increase in its base salary.

Getting Each `Employee`'s Class Name

Lines 64–67 display each employee's type as a `String`. Every object *knows its own class* and can access this

information through the `getClass` method, which all classes inherit from class `Object`. Method `getClass` returns an object of type `Class` (from package `java.lang`), which contains information about the object's type, including its class name. Line 66 invokes `getClass` on the current object to get its class. The result of the `getClass` call is used to invoke `getName` to get the object's class name.

Avoiding Compilation Errors with Downcasting

In the previous example, we avoided several compilation errors by *downcasting* an `Employee` variable to a `BasePlusCommissionEmployee` variable in lines 49–50. If you remove the cast operator `(BasePlusCommissionEmployee)` from line 50 and attempt to assign `Employee` variable `currentEmployee` directly to `BasePlusCommissionEmployee` variable `employee`, you'll receive an "`incompatible types`" compilation error. This error indicates that the attempt to assign the reference of superclass object `currentEmployee` to subclass variable `employee` is *not* allowed. The compiler prevents this assignment because a `CommissionEmployee` is *not* a `BasePlusCommissionEmployee`—*the* is-a *relationship applies only between the subclass and its superclasses, not vice versa.*

Similarly, if lines 52 and 56 used superclass variable `currentEmployee` to invoke subclass-only methods `getBaseSalary` and `setBaseSalary`, we'd receive "`cannot find symbol`" compilation errors at these lines. Attempting to invoke subclass-only methods via a superclass variable is *not* allowed—even though lines 52 and 56 execute only if `instanceof` in line 46 returns `true` to indicate that `currentEmployee` holds a reference to a `BasePlusCommissionEmployee` object. Using a superclass `Employee` variable, we can invoke only methods found in class `Employee`—`earnings`, `toString` and `Employee`'s *get* and *set* methods.

Software Engineering Observation 10.5

Although the actual method that's called depends on the runtime type of the object to which a variable refers, a variable can be used to invoke only those methods that are members of that variable's type, which the compiler verifies.