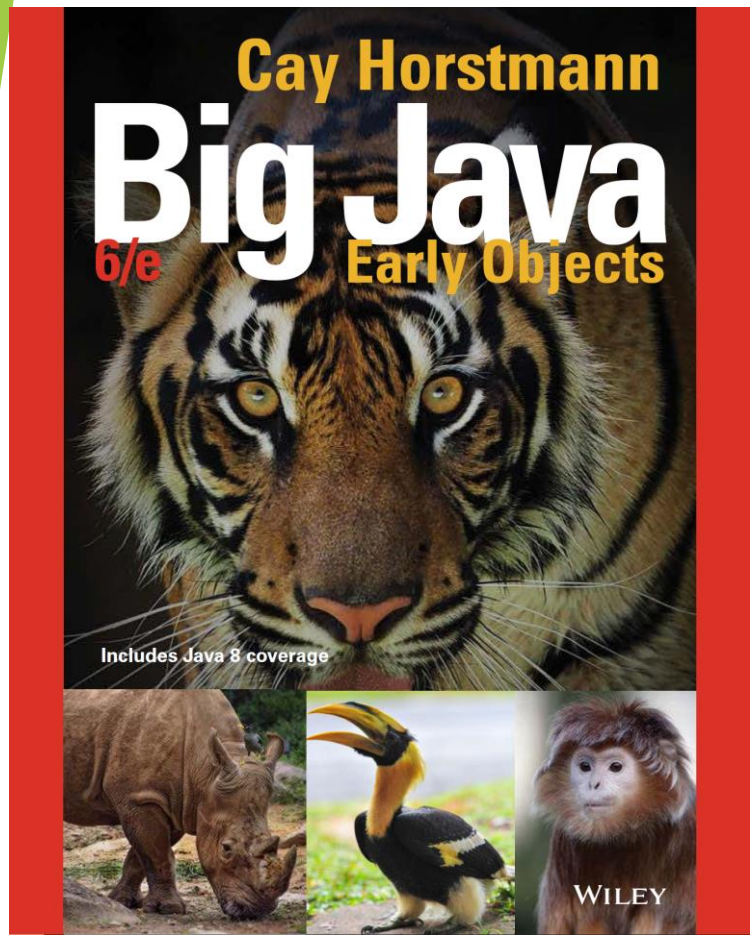


Chapter 9 : Inheritance

Part I

Chapter Goals

- To learn about inheritance
- To understand how to inherit and override superclass methods
- To be able to invoke superclass constructors
- To learn about `protected` and package access control
- To understand the common superclass `Object` and to override its `toString` and `equals` methods
- To use inheritance for customizing user interfaces

An Introduction to Inheritance

- Inheritance: extend classes by adding methods and fields
- Example: Savings account = bank account with interest

```
class SavingsAccount extends BankAccount
{
   new methods
   new instance fields
}
```

- `SavingsAccount` automatically inherits all methods and instance fields of `BankAccount`

```
SavingsAccount collegeFund = new SavingsAccount(10);
// Savings account with 10% interest
collegeFund.deposit(500);
// OK to use BankAccount method with SavingsAccount
   object
```

Continued

An Introduction to Inheritance (cont.)

- Extended class = *superclass* (`BankAccount`), extending class = *subclass* (`Savings`)
- Inheriting from class ≠ implementing interface: subclass inherits behavior and state
- One advantage of inheritance is code reuse

An Inheritance Diagram

Every class extends the `Object` class either directly or indirectly

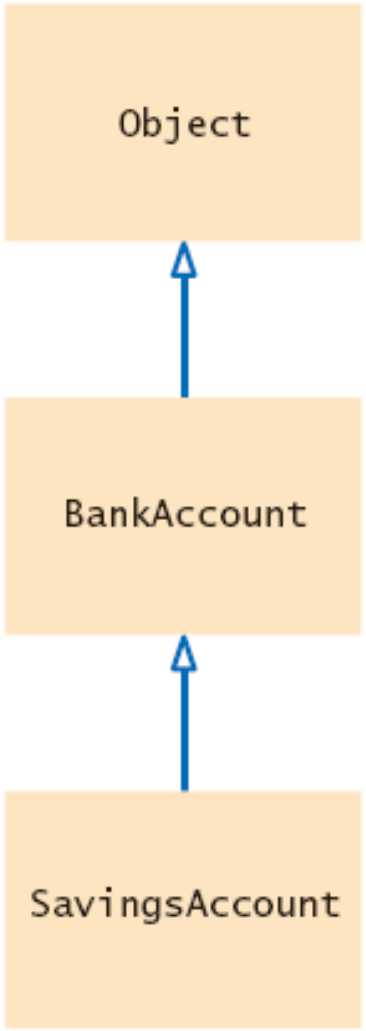


Figure 1
An Inheritance Diagram

An Introduction to Inheritance

- In `subclass`, specify added instance fields, added methods, and changed or overridden methods

```
public class SavingsAccount extends BankAccount
{
   public SavingsAccount(double rate)
   {
      interestRate = rate;
   }

   public void addInterest()
   {
      double interest = getBalance() * interestRate /
         100;
      deposit(interest);
   }
```

Continued

```
    private double interestRate;
}
```

- Encapsulation: `addInterest` calls `getBalance` rather than updating the `balance` field of the superclass (field is `private`)
- Note that `addInterest` calls `getBalance` without specifying an implicit parameter (the calls apply to the same object)

Layout of a Subclass Object

`SavingsAccount` object inherits the `balance` instance field from `BankAccount`, and gains one additional instance field: `interestRate`:

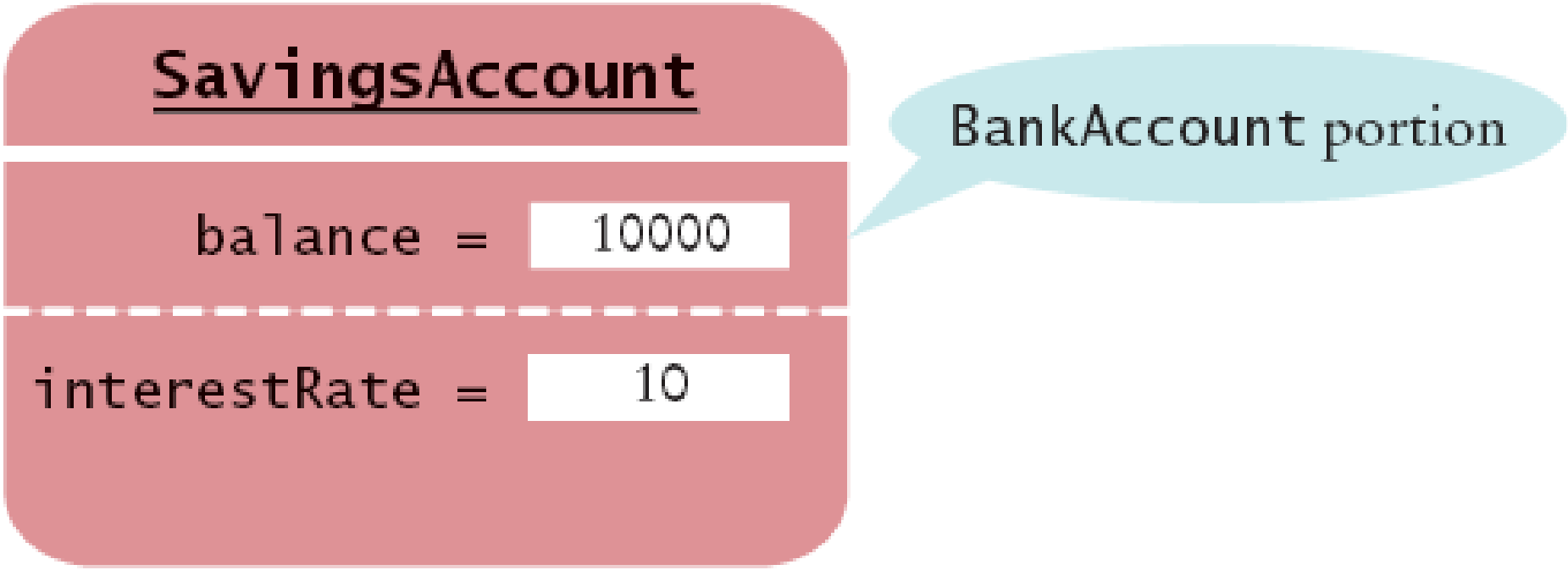


Figure 2 Layout of a Subclass Object

Syntax 10.1 Inheritance

```
class SubclassName extends SuperclassName
{
   methods
   instance fields
}
```

Example:

```
public class SavingsAccount extends
BankAccount
{
   public SavingsAccount(double rate)
   {
      interestRate = rate;
   }
```

Continued

Syntax 10.1 Inheritance

```
   public void addInterest()
   {
      double interest = getBalance() *
interestRate / 100;
      deposit(interest);
   }

   private double interestRate;
}
```

Purpose:

To define a new class that inherits from an existing class, and define the methods and instance fields that are added in the new class.

Self Check 10.1

Which instance fields does an object of class `SavingsAccount` have?

Answer: Two instance fields: `balance` and `interestRate`.

Self Check 10.2

Name four methods that you can apply to `SavingsAccount` objects.

Answer: `deposit`, `withdraw`, `getBalance`, and `addInterest`.

Self Check 10.3

If the class `Manager` extends the class `Employee`, which class is the `superclass` and which is the `subclass`?

Answer: `Manager` is the `subclass`; Employee is the `superclass`.

Inheritance Hierarchies

- Sets of classes can form complex inheritance hierarchies
- Example:

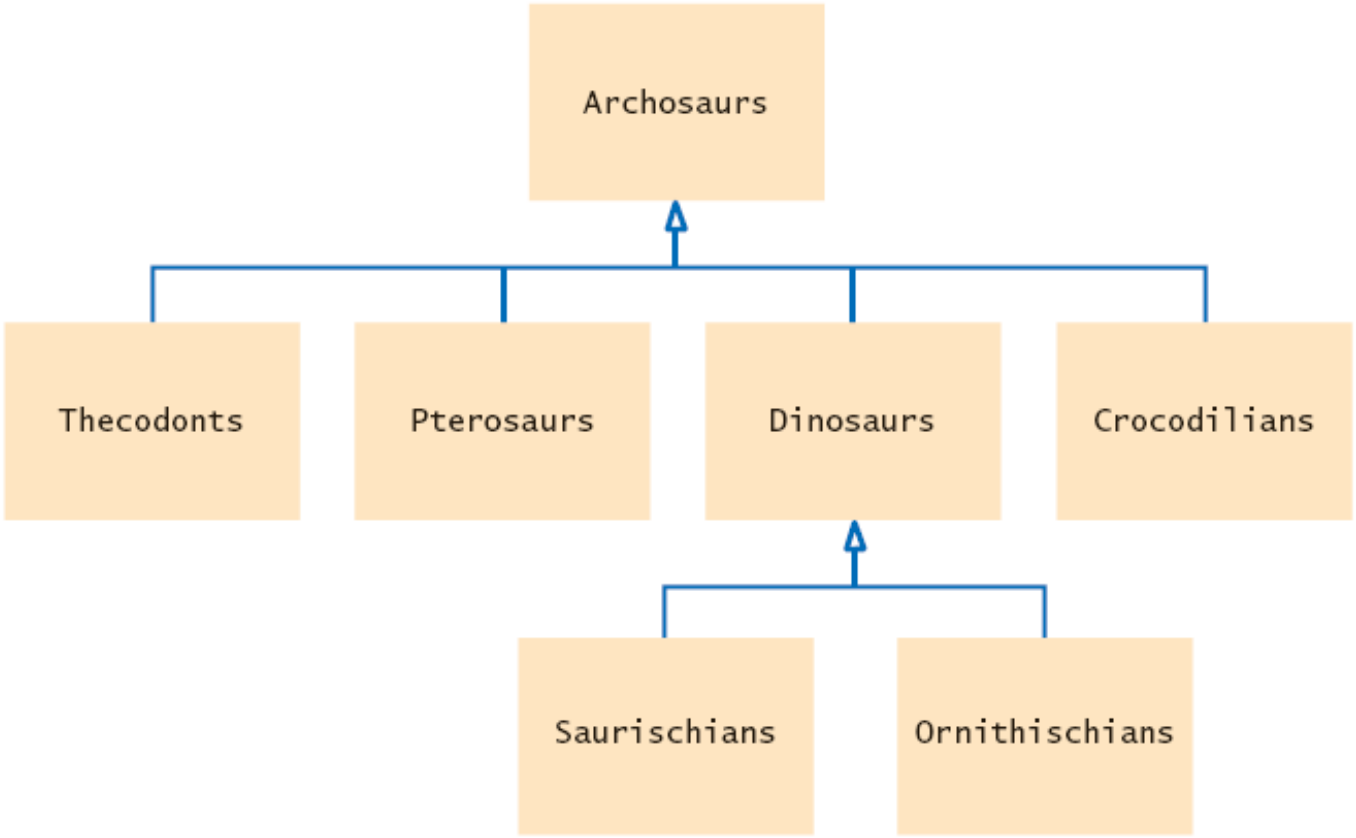


Figure 3 A Part of the Hierarchy of Ancient Reptiles

Inheritance Hierarchies Example: Swing Hierarchy

- Superclass `JComponent` has methods `getWidth, getHeight`
- `AbstractButton` class
  has methods to set/get
  button text and icon

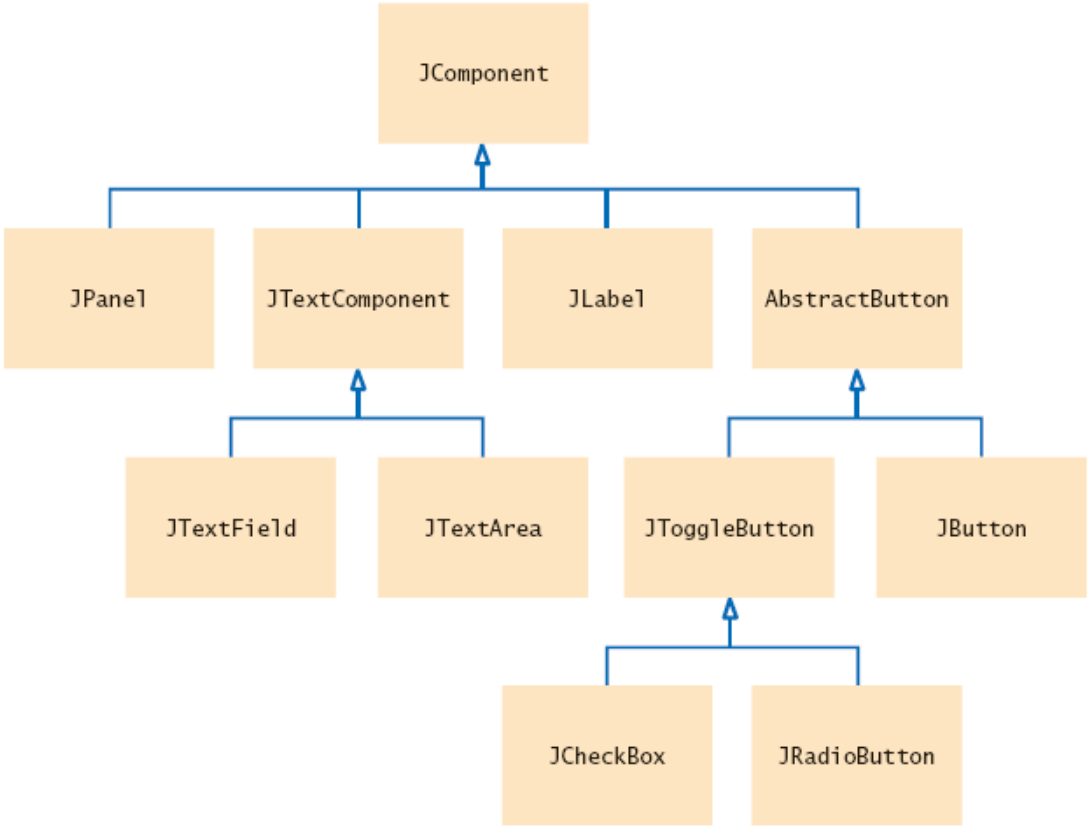


Figure 4 A Part of the Hierarchy of Swing User Interface Components

A Simpler Example: Hierarchy of Bank Accounts

- Consider a bank that offers its customers the following account types:
  1. *Checking account: no interest; small number of free transactions per month, additional transactions are charged a small fee*
  2. *Savings account: earns interest that compounds monthly*
- Inheritance hierarchy:
- All bank accounts support the `getBalance` method
- All bank accounts support the `deposit` and `withdraw` methods, but the implementations differ
- Checking account needs a method `deductFees`; savings account needs a method `addInterest`

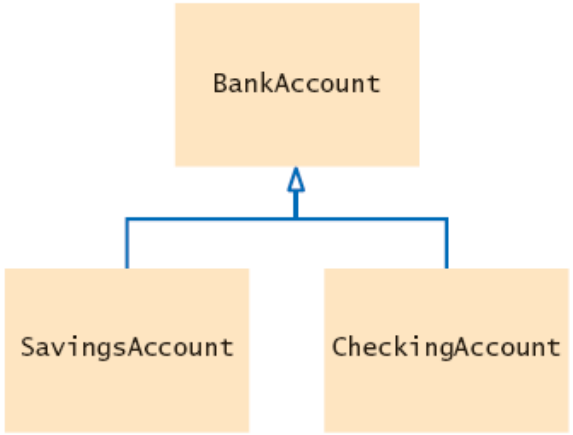


Figure 5 Inheritance Hierarchy for Bank Account Classes

Self Check 10.4

What is the purpose of the `JTextComponent` class in Figure 4?

Answer: To express the common behavior of text fields and text components.

Self Check 10.5

Which instance field will we need to add to the `CheckingAccount` class?

Answer: We need a counter that counts the number of withdrawals and deposits.

Inheriting Methods

- Override method:
  - *Supply a different implementation of a method that exists in the* `superclass`
  - *Must have same signature (same name and same parameter types)*
  - *If method is applied to an object of the* `subclass` *type, the overriding method is executed*
- Inherit method:
  - *Don't supply a new implementation of a method that exists in* `superclass`
  - `Superclass` *method can be applied to the subclass objects*
- Add method:
  - *Supply a new method that doesn't exist in the* `superclass`
  - *New method can be applied only to* `subclass` *objects*

Inheriting Instance Fields

- Can't override fields
- Inherit field: All fields from the superclass are automatically inherited
- Add field: Supply a new field that doesn't exist in the superclass
- What if you define a new field with the same name as a superclass field?
  - *Each object would have two instance fields of the same name*
  - *Fields can hold different values*
  - *Legal but extremely undesirable*

Implementing the `CheckingAccount` Class

- Overrides `deposit` and `withdraw` to increment the transaction count:

```
public class CheckingAccount extends BankAccount
{
public void deposit(double amount) { . . . }
public void withdraw(double amount) { . . . }
public void deductFees() { . . . }
// new method private int transactionCount; // new
   instance field }
```

- Each `CheckingAccount` object has two instance fields:
  - *`balance`* *(inherited from* *`BankAccount`*`)`
  - *`transactionCount`* *(new to* *`CheckingAccount`*`)`

Continued

Implementing the `CheckingAccount` Class (cont.)

- You can apply four methods to `CheckingAccount` objects:
  - `getBalance()` *(inherited from* `BankAccount`*)*
  - `deposit(double amount)` *(overrides* `BankAccount` *method)*
  - `withdraw(double amount)` *(overrides* `BankAccount` *method)*
  - `deductFees()` *(new to* `CheckingAccount`*)*

Inherited Fields are Private

- Consider `deposit` method of `CheckingAccount`

```
public void deposit(double amount)
{
   transactionCount++;
   // now add amount to balance
   . . .
}
```

- Can't just add `amount` to `balance`
- `balance` is a *private* field of the superclass
- A subclass has no access to private fields of its superclass
- Subclass must use public interface

Invoking a Superclass Method

- Can't just call

  `deposit(amount)`

  `in` `deposit` method of `CheckingAccount`

- That is the same as `this.deposit(amount)`
- Calls the same method (infinite recursion)
- Instead, invoke *superclass method*

  `super.deposit(amount)`

- Now calls `deposit` method of `BankAccount` class

Continued

Invoking a Superclass Method (cont.)

- Complete method:

```
public void deposit(double amount)
{
    transactionCount++;
    // Now add amount to balance
    super.deposit(amount);
}
```

Syntax 10.2 Calling a Superclass Method

```
super.methodName(parameters)
```

Example:

```
public void deposit(double amount)
{
   transactionCount++;
   super.deposit(amount);
}
```

Purpose:

To call a method of the superclass instead of the method of the current class.

Implementing Remaining Methods

```
public class CheckingAccount extends BankAccount
{
   . . .
   public void withdraw(double amount)
   {
      transactionCount++;
      // Now subtract amount from balance
      super.withdraw(amount);
   }

   public void deductFees()
   {
      if (transactionCount > FREE_TRANSACTIONS)
      {
         double fees = TRANSACTION_FEE
            * (transactionCount - FREE_TRANSACTIONS);
         super.withdraw(fees);
      }
```

Continued

Implementing Remaining Methods (cont.)

```
        transactionCount = 0;
    }
    . . .
    private static final
    int FREE_TRANSACTIONS = 3;
    private static final double TRANSACTION_FEE = 2.0;
}
```

Self Check 10.6

Why does the `withdraw` method of the `CheckingAccount` class call `super.withdraw`?

Answer: It needs to reduce the balance, and it cannot access the balance field directly.

Self Check 10.7

Why does the `deductFees` method set the transaction count to zero?

Answer: So that the count can reflect the number of transactions for the following month.

Common Error: Shadowing Instance Fields

- A subclass has no access to the private instance fields of the superclass
- Beginner's error: "solve" this problem by adding another instance field with same name:

```
public class CheckingAccount extends BankAccount
{
   public void deposit(double amount)
   {
      transactionCount++;
      balance = balance + amount;
   }
   . . .
   private double balance; // Don't
}
```

Continued

Common Error: Shadowing Instance Fields (cont.)

- Now the deposit method compiles, but it doesn't update the correct balance!

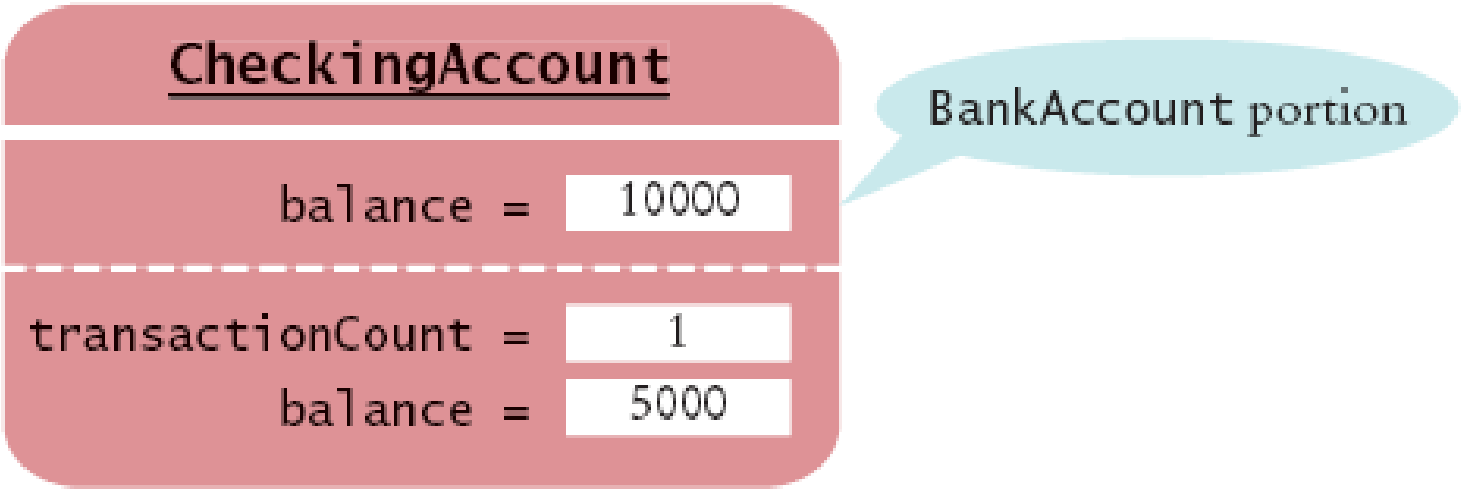


Figure 6 Shadowing Instance Fields

Subclass Construction

- `super` followed by a parenthesis indicates a call to the `superclass` constructor

```
public class CheckingAccount extends BankAccount
{
   public CheckingAccount(double initialBalance)
   {
      // Construct superclass
      super(initialBalance);
      // Initialize transaction count
      transactionCount = 0;
   }
   . . .
}
```

- Must be the *first* statement in subclass constructor

Continued

Subclass Construction (cont.)

- If subclass constructor doesn't call superclass constructor, default superclass constructor is used
  - *Default constructor: constructor with no parameters*
  - *If all constructors of the superclass require parameters, then the compiler reports an error*

Syntax 10.3 Calling a Superclass Constructor

```
ClassName(parameters)
{
   super(parameters);
   . . .
}
```

Example:

```
public CheckingAccount(double
initialBalance)
{
   super(initialBalance);
   transactionCount = 0;
}
```

Purpose:

To invoke a constructor of the superclass. Note that this statement must be the first statement of the subclass constructor.

Self Check 10.8

Why didn't the `SavingsAccount` constructor in Section 10.1 call its superclass constructor?

Answer: It was content to use the default constructor of the superclass, which sets the balance to zero.

Self Check 10.9

When you invoke a superclass method with the `super` keyword, does the call have to be the first statement of the `subclass` method?

Answer: No – this is a requirement only for constructors. For example, the `SavingsAccount.deposit` method first increments the transaction count, then calls the superclass method.

Converting Between Subclass and Superclass Types

- Ok to convert subclass reference to superclass reference

```
SavingsAccount collegeFund = new
SavingsAccount(10); BankAccount anAccount =
collegeFund;
Object anObject = collegeFund;
```

- The three object references stored in `collegeFund`, `anAccount`, and `anObject` all refer to the same object of type `SavingsAccount`

Continued

Converting Between Subclass and Superclass Types (cont.)

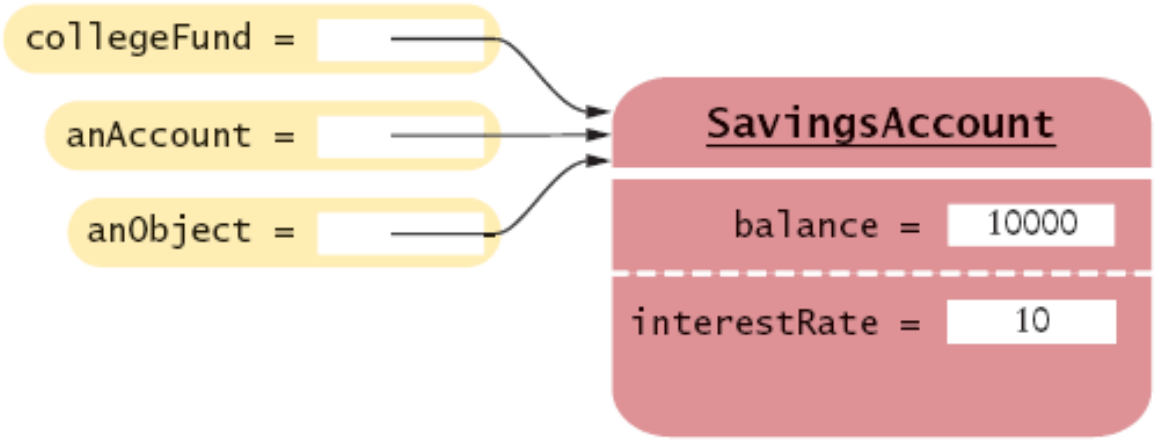


Figure 7 Variables of Different Types Refer to the Same Object

Converting Between Subclass and Superclass Types

- Superclass references don't know the full story: `anAccount.deposit(1000);`

```
// OK
anAccount.addInterest();
// No--not a method of the class to which anAccount
   belongs
```

- When you convert between a subclass object to its `superclass` type:
  - *The value of the reference stays the same – it is the memory location of the object*
  - *But, less information is known about the object*

Continued

Converting Between Subclass and Superclass Types (cont.)

- Why would anyone want to know *less* about an object?
  - *Reuse code that knows about the* `superclass` *but not the* `subclass`*:*

```
public void transfer(double amount, BankAccount other)
{
   withdraw(amount);
   other.deposit(amount);
}
```

Can be used to transfer money from any type of BankAccount

Converting Between Subclass and Superclass Types

- Occasionally you need to convert from a superclass reference to a subclass reference

```
BankAccount anAccount = (BankAccount) anObject;
```

- This cast is dangerous: if you are wrong, an exception is thrown
- Solution: use the `instanceof` operator
- `instanceof`: tests whether an object belongs to a particular type

```
if (anObject instanceof BankAccount)
{
   BankAccount anAccount = (BankAccount) anObject;
   . . .
}
```

Syntax 10.4 The instanceof Operator

object `instanceof` *TypeName*

Example:

```
if (anObject instanceof BankAccount)
{
   BankAccount anAccount = (BankAccount)
anObject;
   . . .
}
```

Purpose:

To return `true` if the *object* is an instance of *TypeName* (or one of its subtypes), and `false` otherwise.

Self Check 10.10

Why did the second parameter of the `transfer` method have to be of type `BankAccount` and not, for example, `SavingsAccount`?

Answer: We want to use the method for all kinds of bank accounts. Had we used a parameter of type `SavingsAccount`, we couldn't have called the method with a `CheckingAccount` object.

Self Check 10.11

Why can't we change the second parameter of the `transfer` method to the type `Object`?

Answer: We cannot invoke the `deposit` method on a variable of type `Object`.

Polymorphism

- In Java, type of a variable doesn't completely determine type of object to which it refers

```
BankAccount aBankAccount = new SavingsAccount(1000); //
aBankAccount holds a reference to a SavingsAccount
```

- Method calls are determined by type of actual object, not type of object reference

```
BankAccount anAccount = new CheckingAccount();
anAccount.deposit(1000); // Calls "deposit" from
   CheckingAccount
```

- Compiler needs to check that only legal methods are invoked `Object anObject = new BankAccount(); anObject.deposit(1000); // Wrong!`

Polymorphism

- Polymorphism: ability to refer to objects of multiple types with varying behavior
- Polymorphism at work:

```
public void transfer(double amount, BankAccount other)
{
   withdraw(amount); // Shortcut for
      this.withdraw(amount)
   other.deposit(amount);
}
```

- Depending on types of `amount` and `other`, different versions of `withdraw` and `deposit` are called

ch10/accounts/AccountTester.java

```
01: /**
02:    This program tests the BankAccount class and
03:    its subclasses.
04: */
05: public class AccountTester
06: {
07:    public static void main(String[] args)
08:    {
09:       SavingsAccount momsSavings
10:             = new SavingsAccount(0.5);
11:
12:       CheckingAccount harrysChecking
13:             = new CheckingAccount(100);
14:
15:       momsSavings.deposit(10000);
16:
17:       momsSavings.transfer(2000, harrysChecking);
18:       harrysChecking.withdraw(1500);
19:       harrysChecking.withdraw(80);
20:
```

Continued

ch10/accounts/AccountTester.java (cont.)

```
21:         momsSavings.transfer(1000, harrysChecking);
22:         harrysChecking.withdraw(400);
23:
24:         // Simulate end of month
25:         momsSavings.addInterest();
26:         harrysChecking.deductFees();
27:
28:         System.out.println("Mom's savings balance: "
29:               + momsSavings.getBalance());
30:         System.out.println("Expected: 7035");
31:
32:         System.out.println("Harry's checking balance: "
33:               + harrysChecking.getBalance());
34:         System.out.println("Expected: 1116");
35:     }
36: }
```

ch10/accounts/CheckingAccount.java

```
01: /**
02:    A checking account that charges transaction fees.
03: */
04: public class CheckingAccount extends BankAccount
05: {
06:    /**
07:       Constructs a checking account with a given balance.
08:       @param initialBalance the initial balance
09:    */
10:    public CheckingAccount(double initialBalance)
11:    {
12:       // Construct superclass
13:       super(initialBalance);
14:
15:       // Initialize transaction count
16:       transactionCount = 0;
17:    }
18:
19:    public void deposit(double amount)
20:    {
21:       transactionCount++;
```

Continued

ch10/accounts/CheckingAccount.java (cont.)

```
22:          // Now add amount to balance
23:          super.deposit(amount);
24:       }
25:
26:       public void withdraw(double amount)
27:       {
28:          transactionCount++;
29:          // Now subtract amount from balance
30:          super.withdraw(amount);
31:       }
32:
33:       /**
34:          Deducts the accumulated fees and resets the
35:          transaction count.
36:       */
37:       public void deductFees()
38:       {
39:          if (transactionCount > FREE_TRANSACTIONS)
40:          {
41:             double fees = TRANSACTION_FEE *
42:                   (transactionCount - FREE_TRANSACTIONS);
43:             super.withdraw(fees);
44:          }
```

Continued

ch10/accounts/CheckingAccount.java (cont.)

```
45:          transactionCount = 0;
46:       }
47:
48:       private int transactionCount;
49:
50:       private static final int FREE_TRANSACTIONS = 3;
51:       private static final double TRANSACTION_FEE = 2.0;
52: }
```

ch10/accounts/BankAccount.java

```
01: /**
02:    A bank account has a balance that can be changed by
03:    deposits and withdrawals.
04: */
05: public class BankAccount
06: {
07:    /**
08:       Constructs a bank account with a zero balance.
09:    */
10:    public BankAccount()
11:    {
12:       balance = 0;
13:    }
14:
15:    /**
16:       Constructs a bank account with a given balance.
17:       @param initialBalance the initial balance
18:    */
19:    public BankAccount(double initialBalance)
20:    {
21:       balance = initialBalance;
22:    }
23:
```

Continued

ch10/accounts/BankAccount.java (cont.)

```
24:    /**
25:       Deposits money into the bank account.
26:       @param amount the amount to deposit
27:    */
28:    public void deposit(double amount)
29:    {
30:       balance = balance + amount;
31:    }
32:
33:    /**
34:       Withdraws money from the bank account.
35:       @param amount the amount to withdraw
36:    */
37:    public void withdraw(double amount)
38:    {
39:       balance = balance - amount;
40:    }
41:
42:    /**
43:       Gets the current balance of the bank account.
44:       @return the current balance
45:    */
```

Continued

ch10/accounts/BankAccount.java (cont.)

```
46:    public double getBalance()
47:    {
48:       return balance;
49:    }
50:
51:    /**
52:       Transfers money from the bank account to another account
53:       @param amount the amount to transfer
54:       @param other the other account
55:    */
56:    public void transfer(double amount, BankAccount other)
57:    {
58:       withdraw(amount);
59:       other.deposit(amount);
60:    }
61:
62:    private double balance;
63: }
```

ch10/accounts/SavingsAccount.java

```
01: /**
02:    An account that earns interest at a fixed rate.
03: */
04: public class SavingsAccount extends BankAccount
05: {
06:    /**
07:       Constructs a bank account with a given interest rate.
08:       @param rate the interest rate
09:    */
10:    public SavingsAccount(double rate)
11:    {
12:       interestRate = rate;
13:    }
14:
15:    /**
16:       Adds the earned interest to the account balance.
17:    */
```

Continued

ch10/accounts/SavingsAccount.java (cont.)

```
18:     public void addInterest()
19:     {
20:        double interest = getBalance() * interestRate / 100;
21:        deposit(interest);
22:     }
23:
24:     private double interestRate;
25: }
```

Output:

```
Mom's savings balance: 7035.0
Expected: 7035
Harry's checking balance: 1116.0
Expected: 1116
```

Self Check 10.12

If `a` is a variable of type `BankAccount` that holds a non-`null` reference, what do you know about the object to which a refers?

Answer: The object is an instance of `BankAccount` or one of its subclasses.

Self Check 10.13

If `a` refers to a checking account, what is the effect of calling `a.transfer(1000, a)`?

Answer: The balance of a is unchanged, and the transaction count is incremented twice.

Access Control

- Java has four levels of controlling access to fields, methods, and classes:
  - `public` *access*
    - *Can be accessed by methods of all classes*
  - `private` *access*
    - *Can be accessed only by the methods of their own class*
  - `protected` *access*
    - *See Advanced Topic 10.3*
  - *package access*
    - *The default, when no access modifier is given*
    - *Can be accessed by all classes in the same package*
    - *Good default for classes, but extremely unfortunate for fields*

Recommended Access Levels

- `Instance` and `static` fields: Always private. Exceptions:
  - *`public static final` constants are useful and safe*
  - *Some objects, such as `System.out`, need to be accessible to all programs (`public`)*
  - *Occasionally, classes in a package must collaborate very closely (give some fields package access); inner classes are usually better*
- Methods: `public` or `private`
- Classes and interfaces: `public` or package
  - Better alternative to package access: inner classes
    - In general, inner classes should not be `public` (some exceptions exist, e.g., `Ellipse2D.Double`)
- Beware of accidental package access (forgetting `public` or `private`)

Self Check 10.14

What is a common reason for defining package-visible instance fields?

Answer: Accidentally forgetting the `private` modifier.

Self Check 10.15

If a class with a public constructor has package access, who can construct objects of it?

Answer: Any methods of classes in the same package.

Object: The Cosmic Superclass

- All classes defined without an explicit `extends` clause automatically extend `Object`

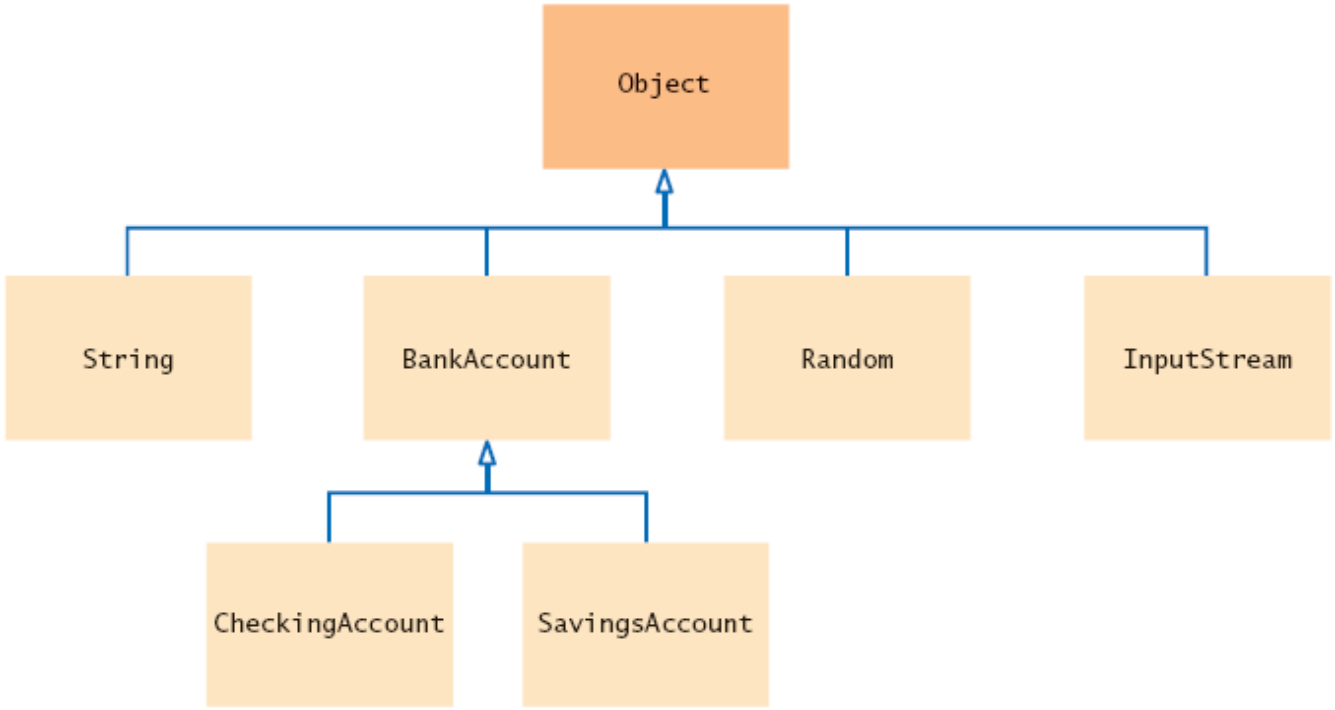


Figure 8 The `Object` Class Is the Superclass of Every Java Class

Object: The Cosmic Superclass

- All classes defined without an explicit `extends` clause automatically extend `Object`
- Most useful methods:
  - *`String toString()`*
  - *`boolean equals(Object otherObject)`*
  - *`Object clone()`*
- Good idea to override these methods in your classes

Overriding the `toString` Method

- Returns a string representation of the object
- Useful for debugging:

```
Rectangle box = new Rectangle(5, 10, 20, 30);
String s = box.toString();
// Sets s to java.awt.Rectangle[x=5,y=10,width=20,
   height=30]"
```

- `toString` is called whenever you concatenate a string with an object:

```
"box=" + box;
// Result: "box=java.awt.Rectangle[x=5,y=10,width=20,
   height=30]"
```

Continued

Overriding the `toString` Method (cont.)

- `Object.toString` prints class name and the *hash code* of the object

```
BankAccount momsSavings = new BankAccount(5000);
String s = momsSavings.toString();
// Sets s to something like "BankAccount@d24606bf"
```

Overriding the `toString` Method

- To provide a nicer representation of an object, override `toString`:

```
public String toString()
{
   return "BankAccount[balance=" + balance + "]";
}
```

- This works better:

```
BankAccount momsSavings = new BankAccount(5000);
String s = momsSavings.toString();
// Sets s to "BankAccount[balance=5000]"
```

Overriding the `equals` Method

- `Equals` tests for equal *contents*

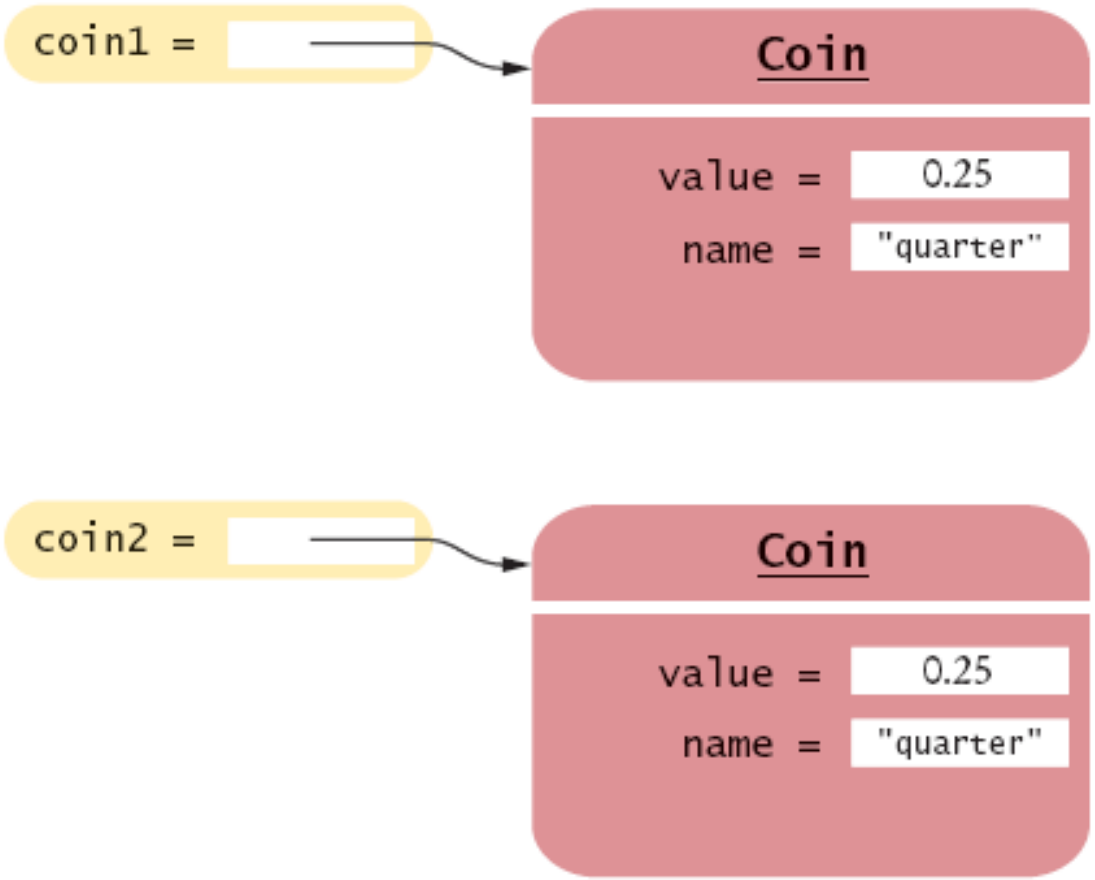


Figure 9 Two References to Equal Objects

Continued

Overriding the `equals` Method (cont.)

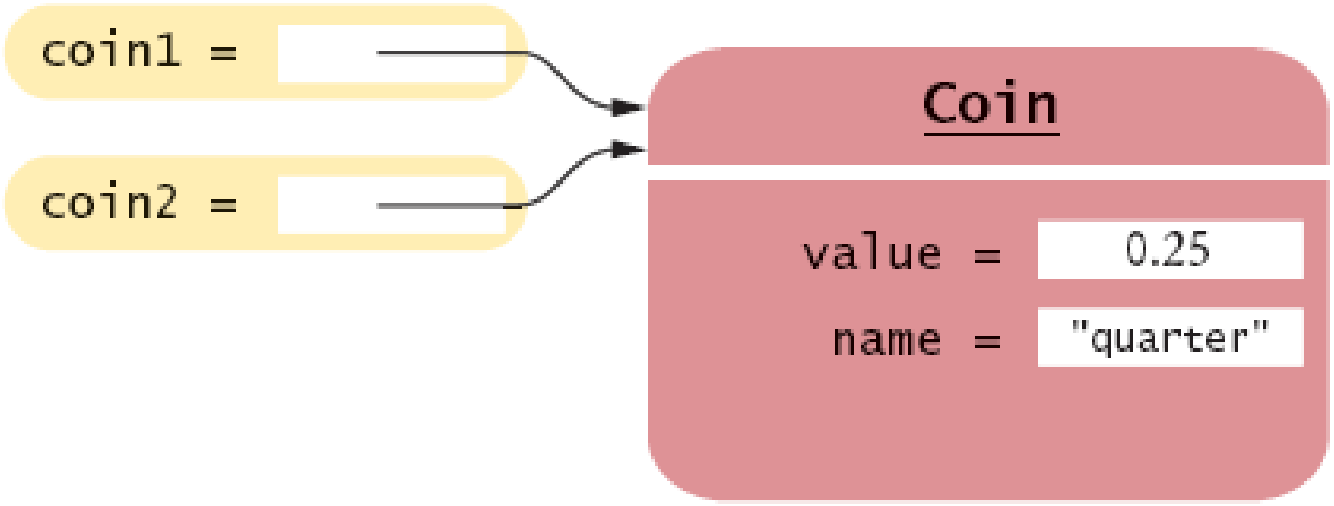


Figure 10 Two References to the Same Object

Overriding the `equals` Method

- Define the `equals` method to test whether two objects have equal state
- When redefining `equals` method, you cannot change object signature; use a *cast* instead:

```
public class Coin
{
   . . .
   public boolean equals(Object otherObject)
   {
      Coin other = (Coin) otherObject;
      return name.equals(other.name) && value ==
         other.value;
   }
   . . .
}
```

Continued

Overriding the `equals` Method (cont.)

- You should also override the `hashCode` method so that `equal` objects have the same hash code

Self Check 10.16

Should the call `x.equals(x)` always return `true`?

Answer: It certainly should – unless, of course, `x` is `null`.

Self Check 10.17

Can you implement `equals` in terms of `toString`? Should you?

Answer: If `toString` returns a string that describes all instance fields, you can simply call `toString` on the implicit and explicit parameters, and compare the results. However, comparing the fields is more efficient than converting them into strings.

Overriding the clone Method

- Copying an object reference gives two references to same object
  BankAccount account2 = account;
- Sometimes, need to make a copy of the object

Continued

Overriding the clone Method (cont.)

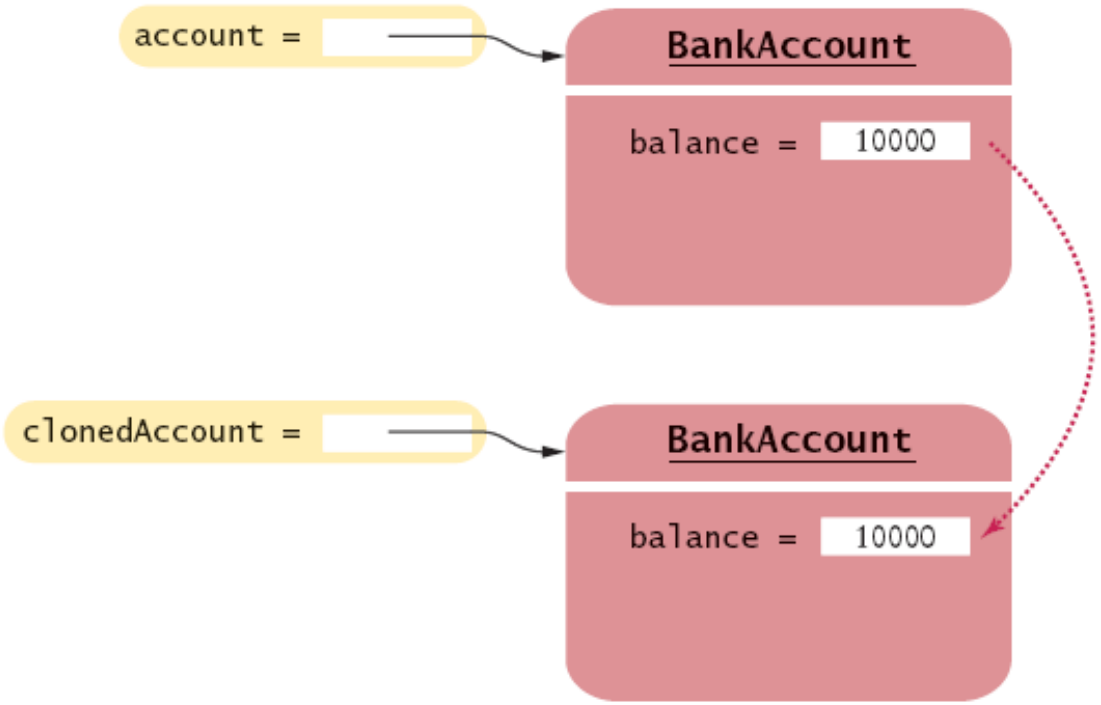


Figure 11
Cloning Objects

Continued

Overriding the clone Method (cont.)

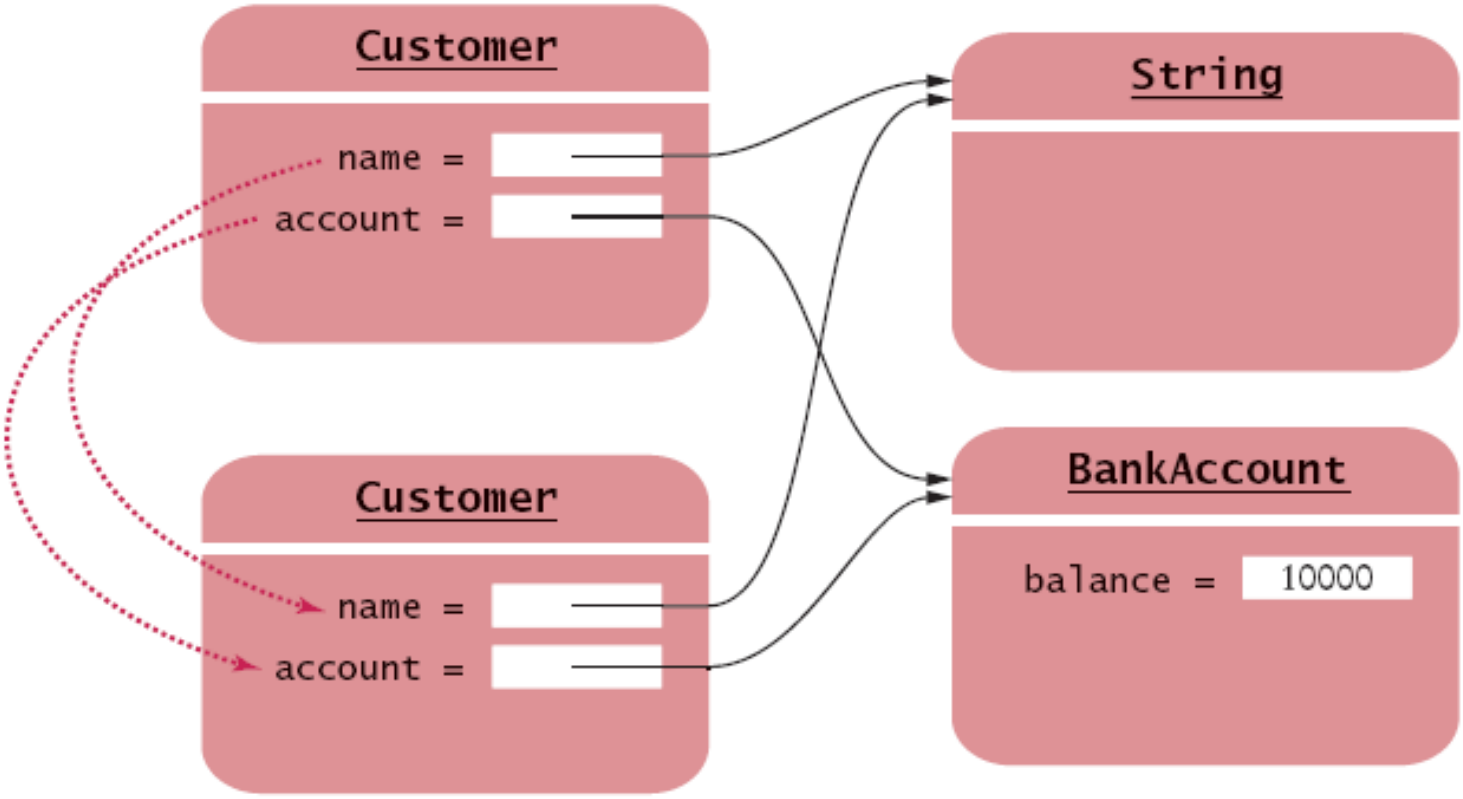
- Define `clone` method to make new object (see Advanced Topic 10.6)
- Use `clone`:

```
BankAccount clonedAccount =
    (BankAccount)account.clone();
```

- Must cast return value because return type is `Object`

The `Object.clone` method

- Creates *shallow copies*



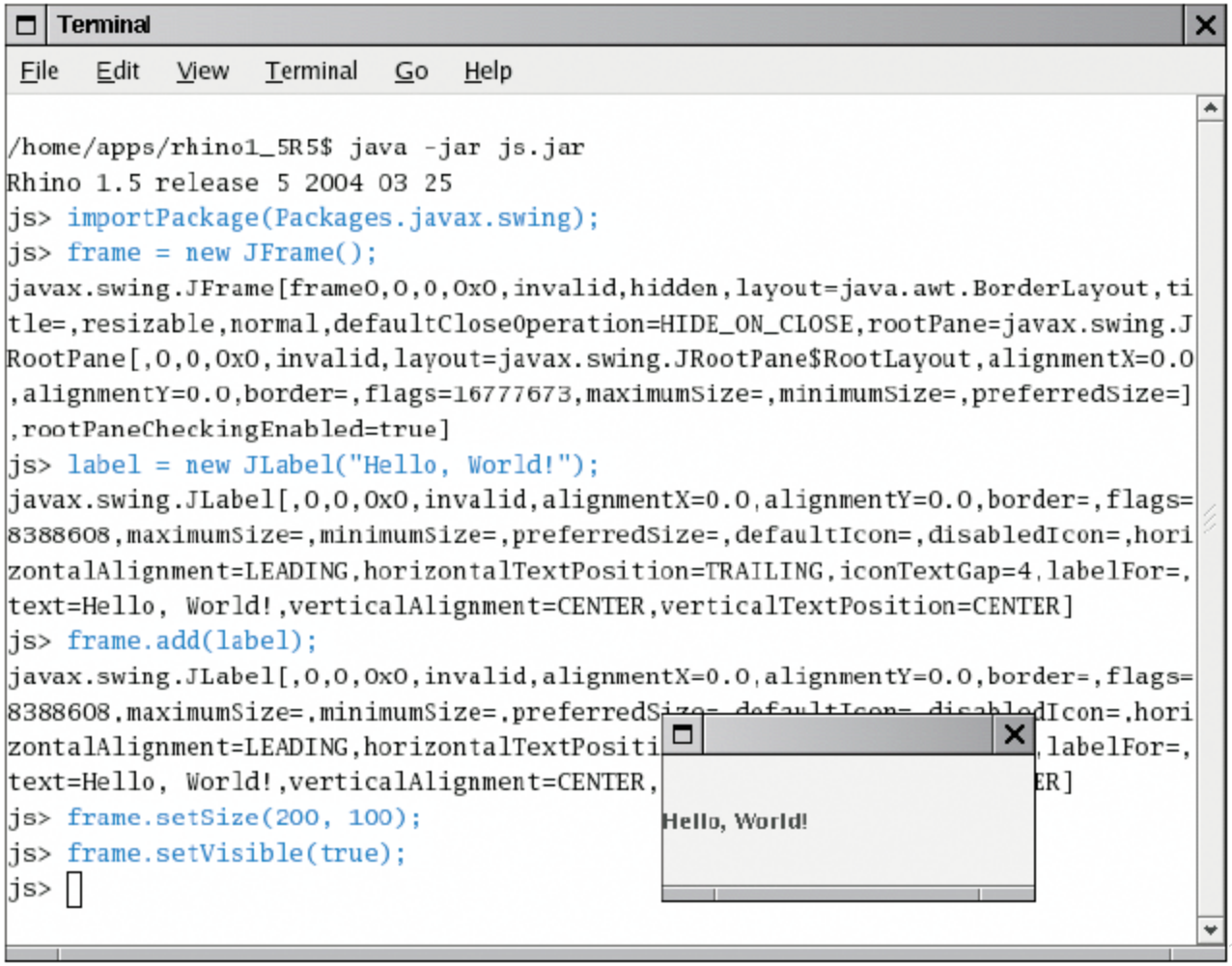
The `Object.clone` Method Makes a Shallow Copy

Continued

The `Object.clone` method (cont.)

- Does not systematically clone all subobjects
- Must be used with caution
- It is declared as `protected`; prevents from accidentally calling `x.clone()` if the class to which `x` belongs hasn't redefined `clone` to be `public`
- You should override the `clone` method with care (see Advanced Topic 10.6)

Scripting Languages



Writing a Rhino Script