

CHAPTER

9

INHERITANCE AND INTERFACES





Chapter Goals

- ❑ To learn about inheritance
- ❑ To implement subclasses that inherit and override superclass methods
- ❑ To understand the concept of polymorphism
- ❑ To understand the common superclass `Object` and its methods
- ❑ To work with interface types

In this chapter, you will learn how the notion of inheritance expresses the relationship between specialized and general classes.



Contents

- ❑ Inheritance Hierarchies
- ❑ Implementing Subclasses
- ❑ Overriding Methods
- ❑ Polymorphism
- ❑ Object: The Cosmic Superclass
- ❑ Interface Types





9.1 Inheritance Hierarchies

- ❑ In object-oriented programming, inheritance is a relationship between:
 - A *superclass*: a more generalized class
 - A *subclass*: a more specialized class
- ❑ The subclass 'inherits' data (variables) and behavior (methods) from the superclass



Vehicle



Car

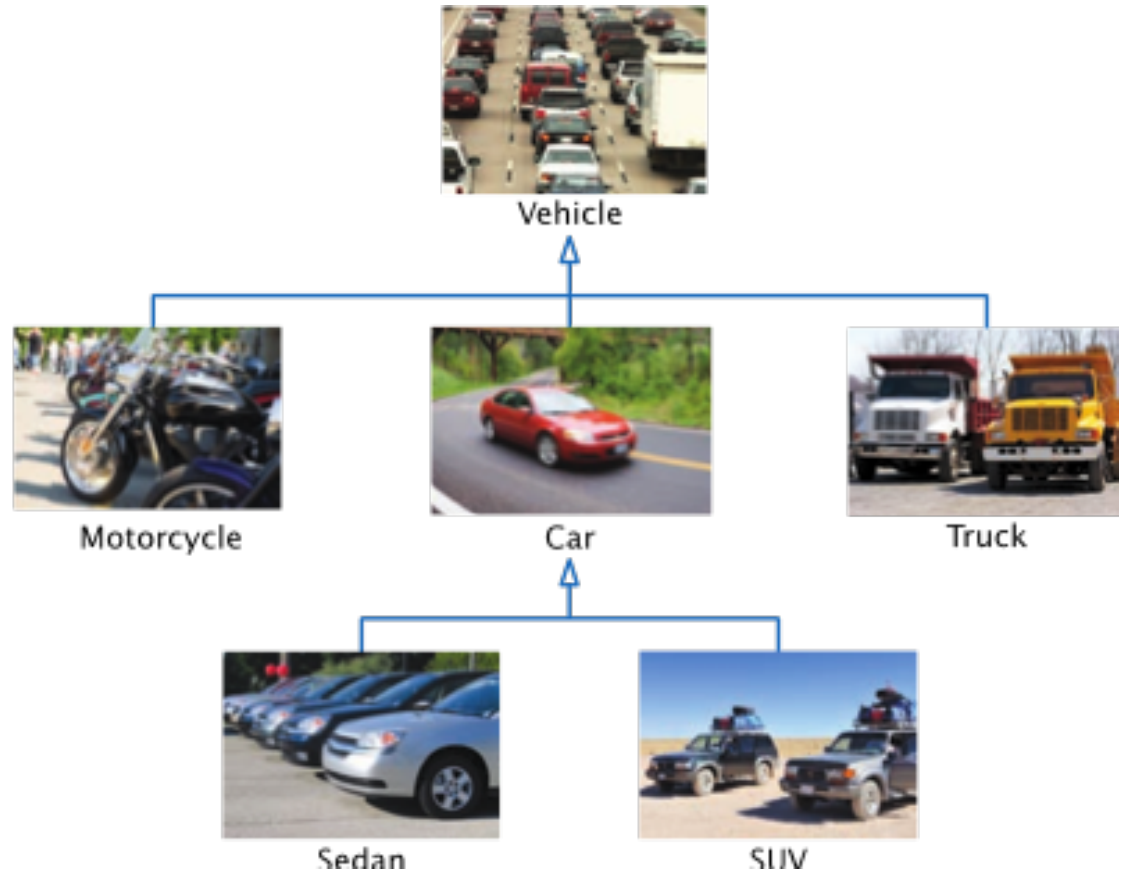


A Vehicle Class Hierarchy

□ General

□ Specialized

□ More Specific

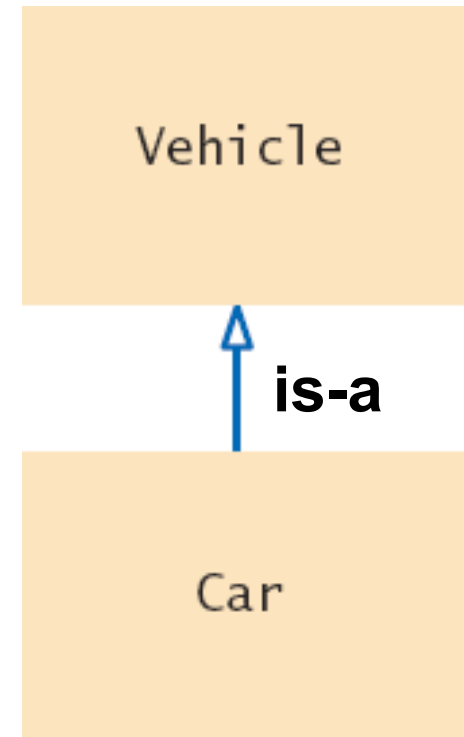




The Substitution Principle

- ❑ Since the subclass Car “**is-a**” Vehicle
 - Car shares common traits with Vehicle
 - You can substitute a Car object in an algorithm that expects a Vehicle object

```
Car myCar = new Car(. . .);  
processVehicle(myCar);
```



The ‘is-a’ relationship is represented by an arrow in a class diagram and means that the subclass can behave as an object of the superclass.



Quiz Question Hierarchy

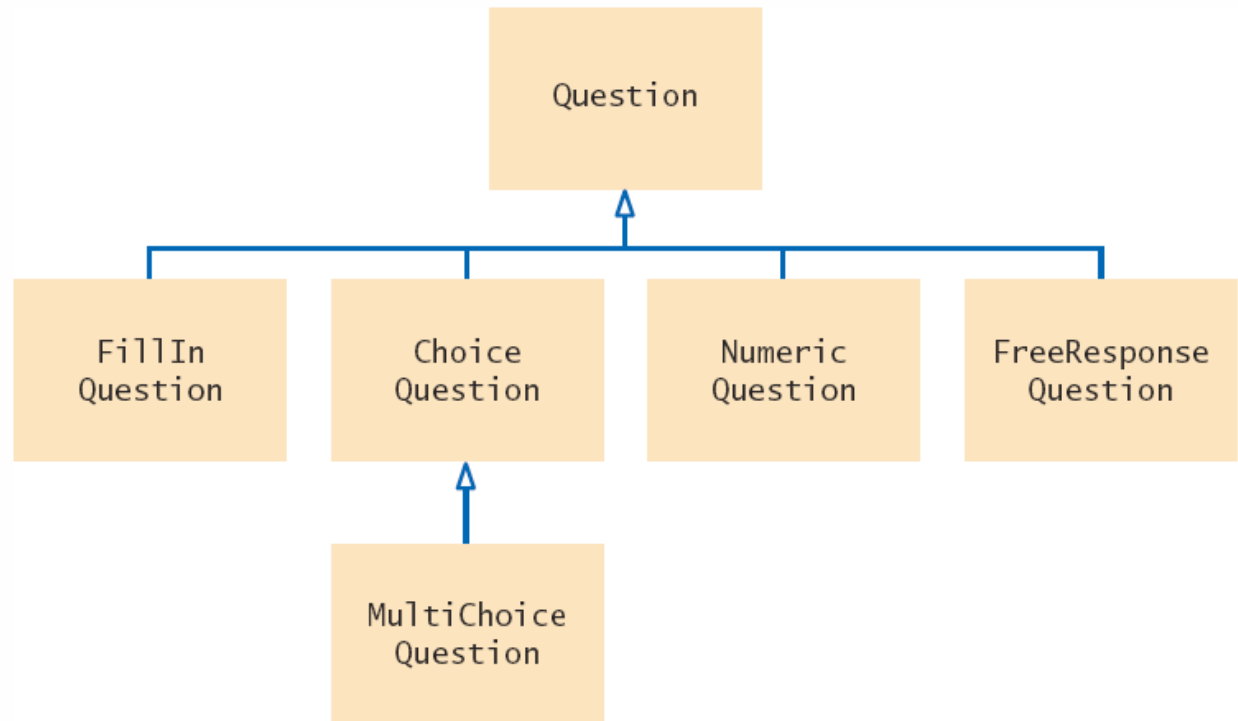
- There are different types of quiz questions:

- 1) Fill-in-the-blank
- 2) Single answer choice
- 3) Multiple answer choice
- 4) Numeric answer
- 5) Free Response

The 'root' of the hierarchy is shown at the top.

- A question can:

- Display it's text
- Check for correct answer





Question.java (1)

```
1  /**
2   * A question with a text and an answer.
3   */
4  public class Question
5  {
6      private String text;
7      private String answer;
8
9      /**
10     * Constructs a question with empty question and answer.
11     */
12     public Question()
13     {
14         text = "";
15         answer = "";
16     }
17
18     /**
19     * Sets the question text.
20     * @param questionText the text of this question
21     */
22     public void setText(String questionText)
23     {
24         text = questionText;
25     }
```

The class `Question` is the 'root' of the hierarchy, also known as the superclass

- ❑ Only handles Strings
- ❑ No support for:
 - Approximate values
 - Multiple answer choice



Question.java (2)

```
27  /**
28     Sets the answer for this question.
29     @param correctResponse the answer
30  */
31  public void setAnswer(String correctResponse)
32  {
33      answer = correctResponse;
34  }
35
36  /**
37     Checks a given response for correctness.
38     @param response the response to check
39     @return true if the response was correct, false otherwise
40  */
41  public boolean checkAnswer(String response)
42  {
43      return response.equals(answer);
44  }
45
46  /**
47     Displays this question.
48  */
49  public void display()
50  {
51      System.out.println(text);
52  }
53 }
```



QuestionDemo1.java

Program Run

```
1 import java.util.ArrayList;
2 import java.util.Scanner;
3
4 /**
5  This program shows a simple quiz with one question.
6  */
7 public class QuestionDemo1
8 {
9     public static void main(String[] args)
10    {
11        Scanner in = new Scanner(System.in);
12
13        Question q = new Question();
14        q.setText("Who was the inventor of Java?");
15        q.setAnswer("James Gosling");
16
17        q.display();
18        System.out.print("Your answer: ");
19        String response = in.nextLine();
20        System.out.println(q.checkAnswer(response));
21    }
22 }
```

Who was the inventor of Java?
Your answer: James Gosling
true

Creates an object of the
Question class and
uses methods.



Programming Tip 9.1



- ❑ Use a Single Class for Variation in Values, Inheritance for Variation in Behavior
 - If two vehicles only vary by fuel efficiency, use an instance variable for the variation, not inheritance

```
// Car instance variable  
double milesPerGallon;
```

- If two vehicles behave differently, use inheritance

Be careful not to over-use inheritance





9.2 Implementing Subclasses

- Consider implementing `ChoiceQuestion` to handle:

In which country was the inventor of Java born?

1. Australia
2. Canada
3. Denmark
4. United States

In this section you will see how to form a subclass and how a subclass automatically inherits from its superclass

- How does `ChoiceQuestion` differ from `Question`?
 - It stores choices (1,2,3 and 4) in addition to the question
 - There must be a method for adding multiple choices
 - The display method will show these choices below the question, numbered appropriately



Inheriting from the Superclass

- ❑ Subclasses inherit from the superclass:
 - All public methods that it does not override
 - All instance variables
- ❑ The Subclass can
 - Add new instance variables
 - Add new methods
 - Change the implementation of inherited methods

Form a subclass by specifying what is different from the superclass.





Overriding Superclass Methods

- ❑ Can you re-use any methods of the `Question` class?
 - Inherited methods perform exactly the same
 - If you need to change how a method works:
 - Write a new more specialized method in the subclass
 - Use the same method name as the superclass method you want to replace
 - It must take all of the same parameters
 - This will **override** the superclass method
- ❑ The new method will be invoked with the same method name when it is called on a subclass object

A subclass can override a method of the superclass by providing a new implementation.

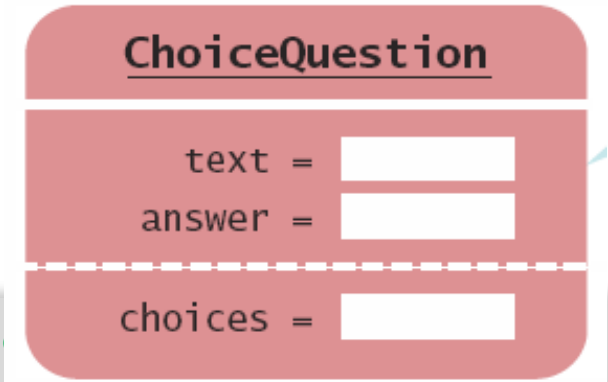


Planning the subclass

- ❑ Use the reserved word **extends** to inherit from

Question

- Inherits text and answer variables
- Add new instance variable choices



```
public class ChoiceQuestion extends Question
{
    // This instance variable is added to the subclass
    private ArrayList<String> choices;

    // This method is added to the subclass
    public void addChoice(String choice, boolean correct)
    { . . . }

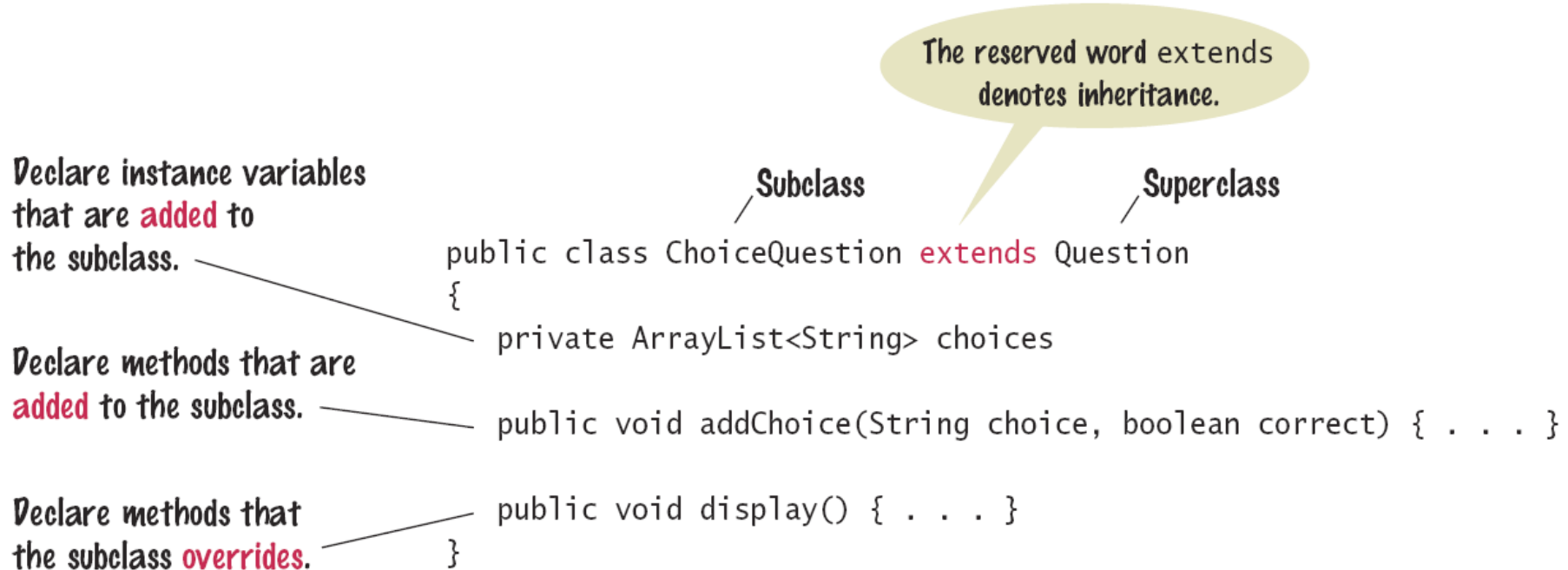
    // This method overrides a method from the superclass
    public void display() { . . . }
}
```

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Syntax 9.1: Subclass Declaration

- ❑ The subclass inherits from the superclass and **'extends'** the functionality of the superclass





Implementing addChoice

- ❑ The method will receive two parameters
 - The text for the choice
 - A boolean denoting if it is the correct choice or not
- ❑ It adds text as a choice, adds choice number to the text and calls the inherited `setAnswer` method

```
public void addChoice(String choice, boolean correct)
{
    choices.add(choice);
    if (correct)
    {
        // Convert choices.size() to string
        String choiceString = "" + choices.size();
        setAnswer(choiceString);
    }
}
```

`setAnswer()` is the same as
calling `this.setAnswer()`



Common Error 9.1



- ❑ Replicating Instance Variables from the Superclass
 - A subclass cannot directly access private instance variables of the superclass

```
public class Question
{
    private String text;
    private String
    answer;
```

```
public class ChoiceQuestion extends
    Question
{
    . . .
    text = questionText;    // Compiler
    Error!
```



Common Error 9.1 (2)

- Do not try to fix the compiler error with a new instance variable of the same name

```
public class ChoiceQuestion extends  
    Question  
{  
    private String text; // Second copy
```

- The constructor sets one `text` variable
- The display method outputs the other

<u>ChoiceQuestion</u>	
text =	<input type="text"/>
answer =	<input type="text"/>
<hr/>	
choices =	<input type="text"/>
text =	<input type="text"/>



9.3 Overriding Methods

- ❑ The `ChoiceQuestion` class needs a `display` method that overrides the `display` method of the `Question` class
- ❑ They are two different method implementations
- ❑ The two methods named `display` are:
 - `Question display`
 - Displays the instance variable text String
 - `ChoiceQuestion display`
 - Overrides `Question display` method
 - Displays the instance variable text String
 - Displays the local list of choices



Calling Superclass Methods

In which country was the inventor of Java born?

1. Australia
2. Canada
3. Denmark
4. United States

- ❑ Consider the `display` method of the `ChoiceQuestion` class

- It needs to display the question AND the list of choices

- ❑ `text` is a private instance variable of the superclass

- ❑ How do you get access to it to print the question?

- ❑ Call the `display` method of the superclass `Question`!

- ❑ From a subclass, preface the method name with:

- ❑ `super.`

```
public void display()
{
    // Display the question text
    super.display(); // OK
    // Display the answer choices
    . . .
}
```



QuestionDemo2.java (1)

```
1  import java.util.Scanner;
2
3  /**
4   * This program shows a simple quiz with two choice questions.
5   */
6  public class QuestionDemo2
7  {
8      public static void main(String[] args)
9      {
10         ChoiceQuestion first = new ChoiceQuestion();
11         first.setText("What was the original name of the Java language?");
12         first.addChoice("*7", false);
13         first.addChoice("Duke", false);
14         first.addChoice("Oak", true);
15         first.addChoice("Gosling", false);
16
17         ChoiceQuestion second = new ChoiceQuestion();
18         second.setText("In which country was the inventor of Java born? ");
19         second.addChoice("Australia", false);
20         second.addChoice("Canada", true);
21         second.addChoice("Denmark", false);
22         second.addChoice("United States", false);
23
24         presentQuestion(first);
25         presentQuestion(second);
26     }
```

Creates two objects of the ChoiceQuestion class, uses new addChoice method.

Calls presentQuestion (next page)



QuestionDemo2.java (2)

```
28  /**
29   * Presents a question to the user and checks the response.
30   * @param q the question
31   */
32  public static void presentQuestion(ChoiceQuestion q)
33  {
34      q.display();
35      System.out.print("Your answer: ");
36      Scanner in = new Scanner(System.in);
37      String response = in.nextLine();
38      System.out.println(q.checkAnswer(response));
39  }
40 }
```

Uses ChoiceQuestion
(subclass) display
method.



ChoiceQuestion.java (1)

```
1 import java.util.ArrayList;
2
3 /**
4  * A question with multiple choices.
5  */
6 public class ChoiceQuestion extends Question
7 {
8     private ArrayList<String> choices;
9
10    /**
11     * Construct:
12     */
13    public ChoiceQuestion()
14    {
15        choices = new ArrayList<String>();
16    }
```

Inherits from Question class.

```
17
18    /**
19     * Adds an answer choice to this question.
20     * @param choice the choice to add
21     * @param correct true if this is the correct choice, false otherwise
22     */
23    public void addChoice(String choice, boolean correct)
24    {
25        choices.add(choice);
26        if (correct)
27        {
28            // Convert choices.size() to string
29            String choiceString = "" + choices.size();
30            setAnswer(choiceString);
31        }
32    }
```

New addChoice method.



ChoiceQuestion.java (2)

```
33
34 public void display()
35 {
36     // Display the question text
37     super.display();
38     // Display the answer choices
39     for (int i = 0; i < choices.size(); i++)
40     {
41         int choiceNumber = i + 1;
42         System.out.println(choiceNumber + ": " + choices.get(i));
43     }
44 }
45 }
```

Overridden display method.

Program Run

```
Who was the inventor of Java?
Your answer: Bjarne Stroustrup
false
In which country was the inventor of Java born?
1: Australia
2: Canada
3: Denmark
4: United States
Your answer: 2
true
```



Common Error 9.3



❑ Accidental Overloading

```
println(int x);  
println(String s); //
```

- Remember that **overloading** is when two methods share the same name but have different parameters
- **Overriding** is where a subclass defines a method with the same name and exactly the same parameters as the superclass method
 - Question display() method
 - ChoiceQuestion display() method
- If you intend to **override**, but change parameters, you will be **overloading** the inherited method, not **overriding** it
 - ChoiceQuestion display(printStream out) method



Common Error 9.4



- ❑ Forgetting to use **super** when invoking a Superclass method
 - Assume that Manager inherits from Employee
 - `getSalary` is an overridden method of Employee
 - `Manager.getSalary` includes an additional bonus

```
public class Manager extends Employee
{
    . . .
    public double getSalary()
    {
        double baseSalary = getSalary();    //
Manager.getSalary
        // should be super.getSalary();    //
Employee.getSalary
        return baseSalary + bonus;
    }
}
```



Special Topic 9.1



- ❑ Calling the Superclass Constructor
 - When a subclass is instantiated, it will call the superclass constructor with no arguments
 - If you prefer to call a more specific constructor, you can invoke it by using replacing the superclass name with the reserved word `super` followed by `()`:

```
public ChoiceQuestion(String  
    questionText)  
{  
    super(questionText);  
    choices = new ArrayList<String>();  
}
```

■ It must



Constructor with Superclass



- ❑ To initialize private instance variables in the superclass, invoke a specific constructor

The superclass constructor is called first.

The constructor body can contain additional statements.

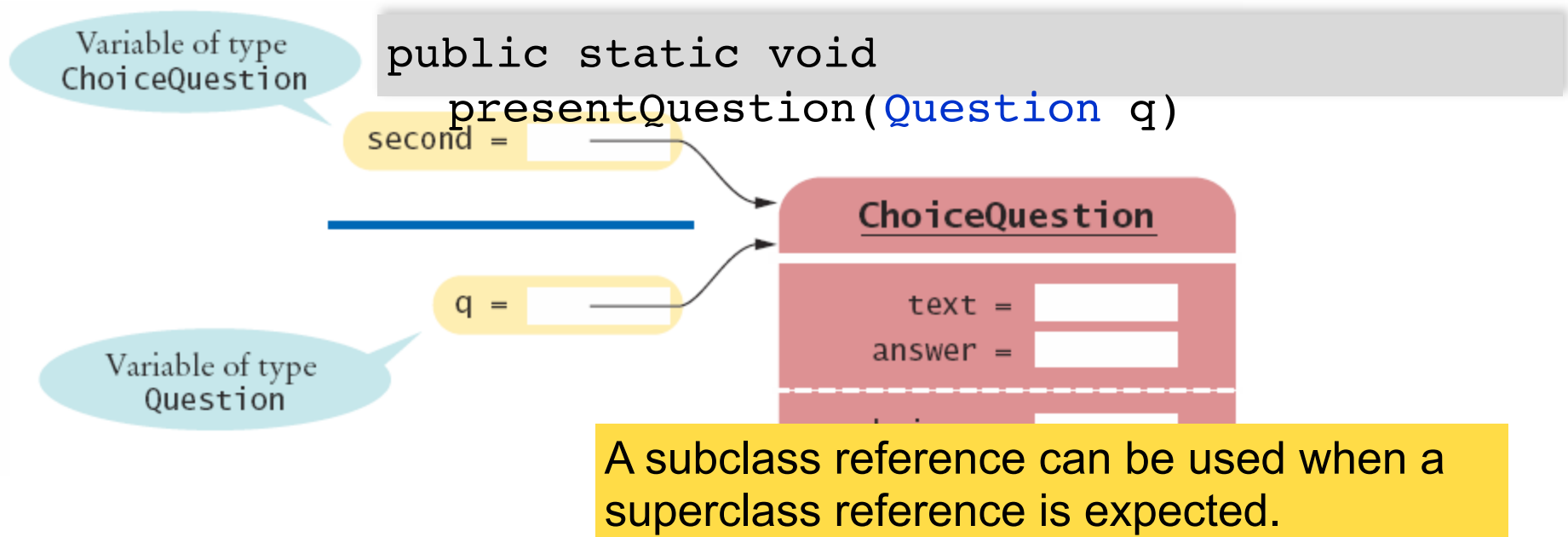
```
public ChoiceQuestion(String questionText)
{
    super(questionText);
    choices = new ArrayList<String>;
}
```

If you omit the superclass constructor call, the superclass constructor with no arguments is invoked.



9.4 Polymorphism

- ❑ QuestionDemo2 passed two **ChoiceQuestion** objects to the `presentQuestion` method
 - Can we write a `presentQuestion` method that displays both **Question** and **ChoiceQuestion** types?
 - **How would that work?**



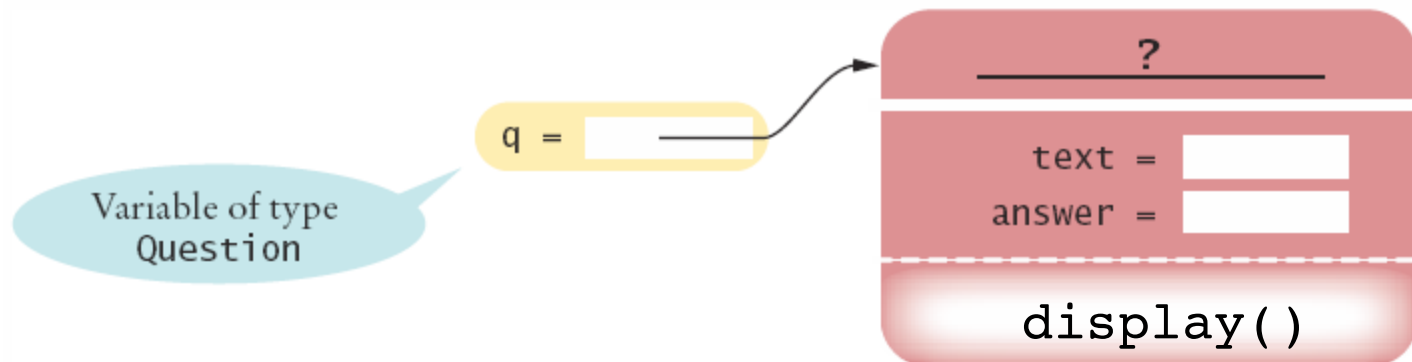


Which display method was called?

- presentQuestion simply calls the **display** method of whatever type is passed:

```
public static void presentQuestion(Question  
    q)  
{  
    q.display();
```

- The variable `q` does
 - If passed an object of the `Question` class:
 - `Question display`
 - If passed an object of the `ChoiceQuestion` class:
 - `ChoiceQuestion display`





Polymorphism Benefits

- ❑ In Java, method calls *are always determined by the type of the actual object*, **not** the type of the variable containing the object reference
 - This is called *dynamic method lookup*
 - Dynamic method lookup allows us to treat objects of different classes in a uniform way
- ❑ This feature is called **polymorphism**
- ❑ We ask multiple objects to carry out a task, and each object does so in its own way
- ❑ Polymorphism makes programs *easily extensible*



QuestionDemo3.java (1)

```
1  import java.util.Scanner;
2
3  /**
4   * This program shows a simple quiz with two question types.
5   */
6  public class QuestionDemo3
7  {
8      public static void main(String[] args)
9      {
10         Question first = new Question();
11         first.setText("Who was the inventor of Java?");
12         first.setAnswer("James Gosling");
13
14         ChoiceQuestion second = new ChoiceQuestion();
15         second.setText("In which country was the inventor of Java born?");
16         second.addChoice("Australia", false);
17         second.addChoice("Canada", true);
18         second.addChoice("Denmark", false);
19         second.addChoice("United States", false);
20
21         presentQuestion(first);
22         presentQuestion(second);
23     }
24 }
```

Creates an object of the
Question class

Creates an object of the
ChoiceQuestion class,
uses new addChoice
method

Calls presentQuestion (next page)
passing both types of objects.



QuestionDemo3.java (2)

```
24
25  /**
26   Presents a question to the user and checks the response.
27   @param q the question
28   */
29  public static void presentQuestion(Question q)
30  {
31      q.display();
32      System.out.print("Your answer: ");
33      Scanner in = new Scanner(System.in);
34      String response = in.nextLine();
35      System.out.println(q.checkAnswer(response));
36  }
37 }
```

Receives a parameter of the super-class type

Uses appropriate display method.

If Question => Question.display()

If ChoiceQuestion => ChoiceQuestion.display()



Special Topic 9.2



- ❑ Dynamic Method Lookup and the Implicit Parameter
 - Suppose we move the `presentQuestion` method to inside the `Question` class and call it as follows:

```
ChoiceQuestion cq = new ChoiceQuestion();  
cq.setText("In which country was the inventor of Java  
born?");
```

```
. . .  
cq.presentQuestion(); {  
    void presentQuestion()  
    {  
        display();  
        System.out.print("Your answer: ");  
        Scanner in = new Scanner(System.in);  
        String response = in.nextLine();  
  
        System.out.println(checkAnswer(response  
        ));  
    }  
}
```

- Which `display` a



Dynamic Method Lookup



- Add the Implicit Parameter to the code to find out
 - Because of dynamic method lookup, the `ChoiceQuestion` versions of the `display` and `checkAnswer` methods are called automatically.
 - This happens even though the `presentQuestion` method is declared in the `Question` class, which has no knowledge of the `ChoiceQuestion` class.

```
public class Question
{
    void presentQuestion()
    {
        this.display();
        System.out.print("Your answer: ");
        Scanner in = new Scanner(System.in);
        String response = in.nextLine();

        System.out.println(this.checkAnswer(response));
    }
}
```



Special Topic 9.3



❑ Abstract Classes

- If it is desirable to **force** subclasses to override a method of a base class, you can declare a method as **abstract**.
- You cannot instantiate an object that has **abstract** methods
 - Therefore the class is considered **abstract**

```
public abstract class Account
{
    public abstract void deductFees(); // no method
    // ...
}

// ...
public class SavingsAccount extends Account // Not
    abstract
    {
        public void deductFees() // Provides an
            implementation
            { // method implementation. . . }
    }
}
```

methods.



Abstract References

- ❑ A class that can be instantiated is called **concrete** class
- ❑ You cannot instantiate an object that has **abstract** methods
 - But you can declare an object reference whose type is an **abstract** class.
 - The actual object to which it refers must be an instance of a **concrete** subclass

```
Account anAccount;           // OK: Reference to abstract
                               object
anAccount = new Account();    // Error: Account is abstract
anAccount = new SavingsAccount(); // Concrete class is OK
anAccount = null;             // OK
```

- This allows for polymorphism based on even an **abstract** class!

One reason for using abstract classes is to force programmers to create subclasses.



Abstract Classes

- ❑ `abstract` classes typically have:
 - `abstract` methods with no definitions (like an interface)
 - probably also non-`abstract` methods with full definitions
- ❑ Does not have to contain `abstract` methods -- simply declaring it as `abstract` makes it so
- ❑ The child of an `abstract` class must override the `abstract` methods of the parent, or it too will be considered `abstract`



Abstract Classes

```
abstract class A1 {  
    abstract void m1();  
    abstract String m2();  
}
```

```
class C1 extends A1 {  
    void m1() { System.out.println("C1-m1"); }  
    String m2() { return "C1-m2"; }  
}
```

```
abstract C2 extends A1 {  
    void m1() { System.out.println("C2-m1"); }  
}
```

→ C2 must be abstract, because it does not implement the abstract method m2.



Abstract Classes

- ❑ Abstract methods cannot be defined as `final` or `static`
 - `final` cannot be overridden (contradiction!)
 - `static` could be invoked by just using the name of the class – can't invoke it with no implementation



Special Topic 9.4



Final Methods and Classes

- You can also **prevent** programmers from creating subclasses and override methods using **final**.
- The String class in the Java library is an example:

```
public final class String { . . . }
```

- Example of a method that cannot be overridden:

```
public class SecureAccount extends BankAccount
{
    . . .
    public final boolean checkPassword(String password)
    {
        . . .
    }
}
```



Special Topic 9.5



□ `protected` Access

- When trying to implement the `display` method of the `ChoiceQuestion` class, the `display` method wanted to access the instance variable `text` of the superclass, but it was `private`.
- We chose to use a method of the superclass to display the text.

□ Java provides a more elegant solution

- The superclass can declare an instance variable as `protected` instead of `private`
- `protected` data in an object can be accessed by the methods of the object's class and all its subclasses.
- But it can also be accessed by all other classes in the same package!

```
public class Question
{
    protected String text;
    . . .
}
```

If you want to grant access to the data to subclass methods only, consider making the accessor method `protected`.



Steps to Using Inheritance

- ❑ As an example, we will consider a bank that offers customers the following account types:
 - 1) A savings account that earns interest. The interest compounds monthly and is based on the minimum monthly balance.
 - 2) A checking account that has no interest, gives you three free withdrawals per month, and charges a \$1 transaction fee for each additional withdrawal.
- ❑ The program will manage a set of accounts of both types
 - It should be structured so that other account types can be added without affecting the main processing loop.
- ❑ The menu: `D)eposit W)ithdraw M)onth end Q)uit`
 - For deposits and withdrawals, query the account number and amount. Print the balance of the account after each transaction.
 - In the “Month end” command, accumulate interest or clear the transaction counter, depending on the type of the bank account. Then print the balance of all accounts.



Steps to Using Inheritance

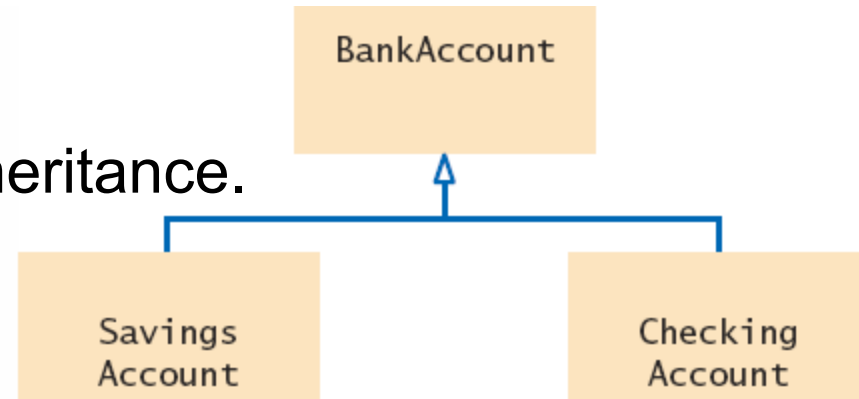
1) List the classes that are part of the hierarchy.

SavingsAccount

CheckingAccount

2) Organize the classes into an inheritance hierarchy

Base on superclass BankAccount



3) Determine the common responsibilities.

- Write *Pseudocode* for each task
- Find common tasks



Using Inheritance

For each user command

 If it is a deposit or withdrawal

 Deposit or withdraw the amount from the specified account.

 Print the balance.

 If it is month end processing

 For each account

 Call month end processing.

 Print the balance.

Deposit money.

Withdraw money.

Get the balance.

Carry out month end processing.



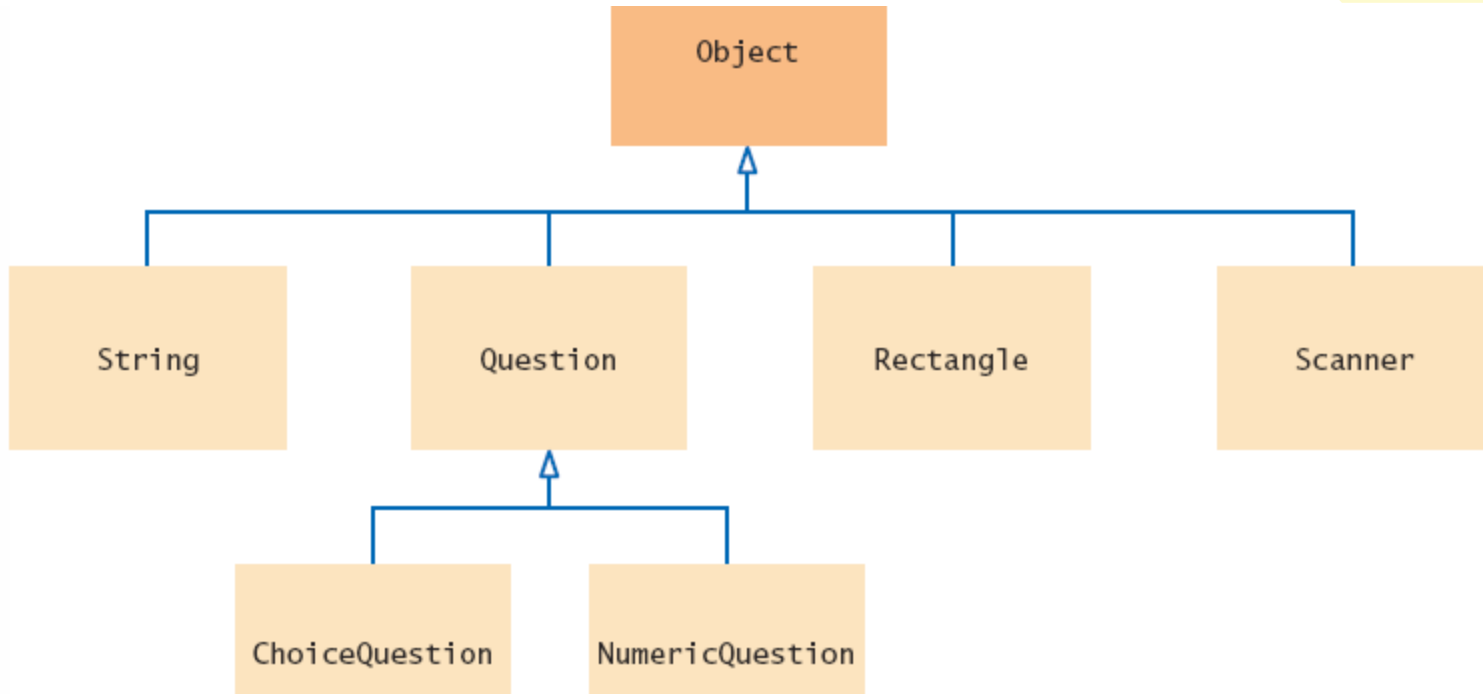
Steps to Using Inheritance

- 4) Decide which methods are overridden in subclasses.
 - For each subclass and each of the common responsibilities, decide whether the behavior can be inherited or whether it needs to be overridden
- 5) Declare the public interface of each subclass.
 - Typically, subclasses have responsibilities other than those of the superclass. List those, as well as the methods that need to be overridden.
 - You also need to specify how the objects of the subclasses should be constructed.
- 6) Identify instance variables.
 - List the instance variables for each class. Place instance variables that are common to all classes in the base of the hierarchy.
- 7) Implement constructors and methods.
- 8) Construct objects of different subclasses and process them.



9.5 Object: The Cosmic Superclass

- In Java, every class that is declared without an explicit extends clause automatically extends the class Object.



The methods of the `Object` class are very general. You will learn to override the `toString` method.



Writing a `toString` method

- ❑ The `toString` method returns a `String` representation for each object.
- ❑ The `Rectangle` class (`java.awt`) has a `toString` method
 - You can invoke the `toString` method directly

```
Rectangle box = new Rectangle(5, 10, 20, 30);  
String s = box.toString();           // Call toString  
directly  
// Sets s to "java.awt.Rectangle[x=5,y=10,width=20,height=30]"  
concatenate a String with an object:
```

- ❑ `System.out.println("box=" + box);` // Call `toString`
implicitly

knows that every *object* has a `toString` method:

- Every class extends the `Object` class, and can override `toString`



Overriding the `toString` method

- ❑ Example: Override the `toString` method for the `BankAccount` class

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

- All that is printed is the name of the class, followed by the hash code which can be used to tell objects (Chapter 10)

- ❑ We want to know what is inside the object

```
public class BankAccount  
{  
    public String toString()  
    {  
        // returns "BankAccount[balance=5000]"  
        return "BankAccount[balance=" + balance + "];"  
    }  
}
```

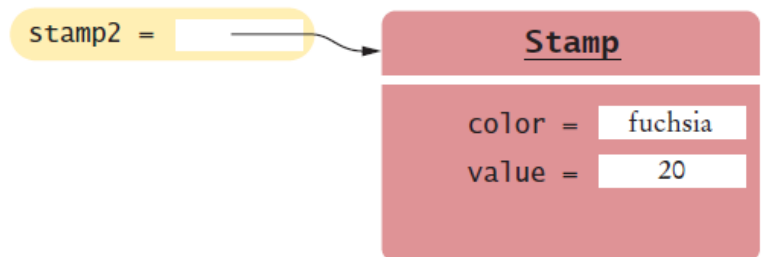
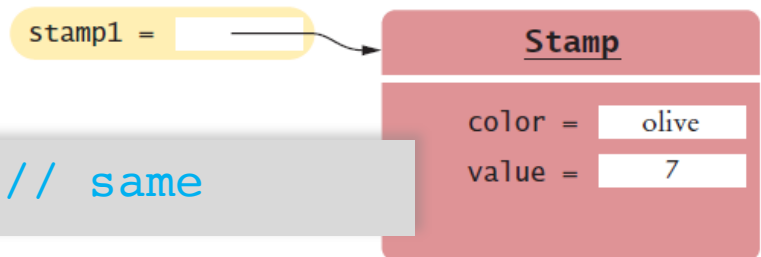
Override the `toString` method to yield a string that describes the object's state.



Overriding the `equals` method

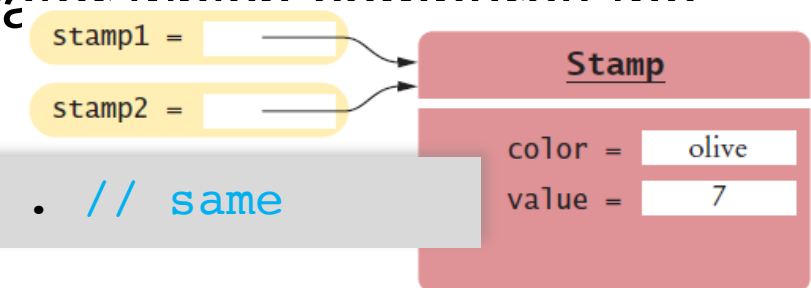
- In addition to the `toString` method, the `Object` class `equals` method checks whether two objects have the same contents:

```
if (stamp1.equals(stamp2)) . . . // same  
Contents?
```



- This is different from the `==` operator, which compares the two references:

```
if (stamp1 == stamp2) . . . // same  
Objects?
```





Overriding the `equals` method

- ❑ The `Object` class specifies the type of parameter as `Object`

```
public class Stamp
{
    private String color;
    private int value;
    . . .
    public boolean equals(Object
        otherObject)
    {
        . . .
    }
    public boolean equals(Object otherObject)
    . . {
    }
        Stamp other = (Stamp) otherObject;
        return color.equals(other.color)
            && value == other.value;
    }
```

The `Stamp` `equals` method must declare the same type of parameter as the `Object` `equals` method to override it.

Cast the parameter variable to the class `Stamp`



The `instanceof` operator

- ❑ It is legal to store a subclass reference in a variable declared as superclass reference type
- ❑ The opposite conversion is also possible:
 - From a superclass reference to a subclass reference
 - If you have a variable of type `Object`, and you know that it actually holds a `Question` reference, you can cast it:

```
Question q = (Question) obj;
```
- ❑ To make sure it is an object of the `Question` type, you can test it with the `instanceof` operator:

```
if (obj instanceof Question)
{
    Question q = (Question)
    obj;
```

`instanceof` returns a boolean



Syntax 9.3: Using instanceof

- ❑ Using the `instanceof` operator also involves casting
 - Returns true if you can safely cast one object to another
- ❑ Casting allows the use of methods of the new object
 - Most often used to make a reference more specific
 - Cast from an `Object` reference to a more specific class type

If `anObject` is null,
`instanceof` returns false.

Returns true if `anObject`
can be cast to a `Question`.

The object may belong to a
subclass of `Question`.

```
if (anObject instanceof Question)
{
    Question q = (Question) anObject;
    . . .
}
```

You can invoke `Question`
methods on this variable.

Two references
to the same object.



Common Error 9.5



❑ Don't Use Type Tests

- ```
if (q instanceof ChoiceQuestion) // Don't do this
{
 // Do the task the ChoiceQuestion way
}
else if (q instanceof Question)
{
 // Do the task the Question way
}
```
- Th
  - Le
  - Override it in subclasses

revised.



# Special Topic 9.6



- ❑ Inheritance and the toString Method
  - Instead of writing the type of object in a toString method

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

- Then use inheritance, call the superclass toString first

```
public class SavingsAccount extends BankAccount
{
 . . .
 public String toString()
 {
 return super.toString() + "[interestRate=" + intRate +
 "]" ;
 }
 // returns SavingsAccount[balance= 10000][interestRate=
```

This allows the superclass to output private instance variables





# Special Topic 9.7



- ❑ Inheritance and the equals Method
  - What if someone called stamp1.equals(x) where x was not a Stamp object?
    - Using the instanceof operator, it would be possible for otherObject to belong to some subclass of Stamp.
  - Use the getClass method to compare your exact class to the passed object to make sure

Insures comparison of the same types

```
public boolean equals(Object otherObject)
{
 if (otherObject == null) { return false; }
 if (getClass() != otherObject.getClass()) { return
 false; }
 Stamp other = (Stamp) otherObject;
 return color.equals(other.color) && value == other.value;
}
```



## 9.6 Interface Types

- ❑ An **interface** is a special type of declaration that lists a set of methods and their signatures
  - A class that *implements* the **interface** must implement all of the methods of the **interface**
  - It is similar to a class, but there are differences:
    - All methods in an interface type are **abstract**:  
They have a name, parameters, and a return type, but they don't have an implementation
    - All methods in an interface type are automatically **public**
    - An interface type cannot have instance variables
    - An interface type cannot have static methods

```
public interface Measurable
{
 double getMeasure();
}
```

A Java **interface** type declares a set of methods and their signatures.



# Syntax 9.4: Interface Types

- An **interface** declaration and a class that **implements** the **interface**.

```
public interface Measurable
{
 double getMeasure();
}

public class BankAccount implements Measurable
{
 . . .
 public double getMeasure()
 {
 return balance;
 }
}
```

Interface methods are always public.

Interface methods have no implementation.

Other BankAccount methods.

A class can implement one or more interface types.

Implementation for the method that was declared in the interface type.



# Using Interface Types

- We can use the interface type `Measurable` to implement a “universal” static method for computing averages:

```
public interface Measurable
{
 double getMeasure();
}
```

```
public static double average(Measurable[]
 objs)
{
 if (objs.length == 0) return 0;
 double sum = 0;
 for (Measurable obj : objs)
 {
 sum = sum + obj.getMeasure();
 }
 return sum / objs.length;
}
```



# Implementing an Interface

- A class can be declared to **implement** an interface
  - The class must implement all methods of the interface

```
public class BankAccount implements Measurable
{
 public double getMeasure()
 {
 return balance;
 }
 . . .
}
```

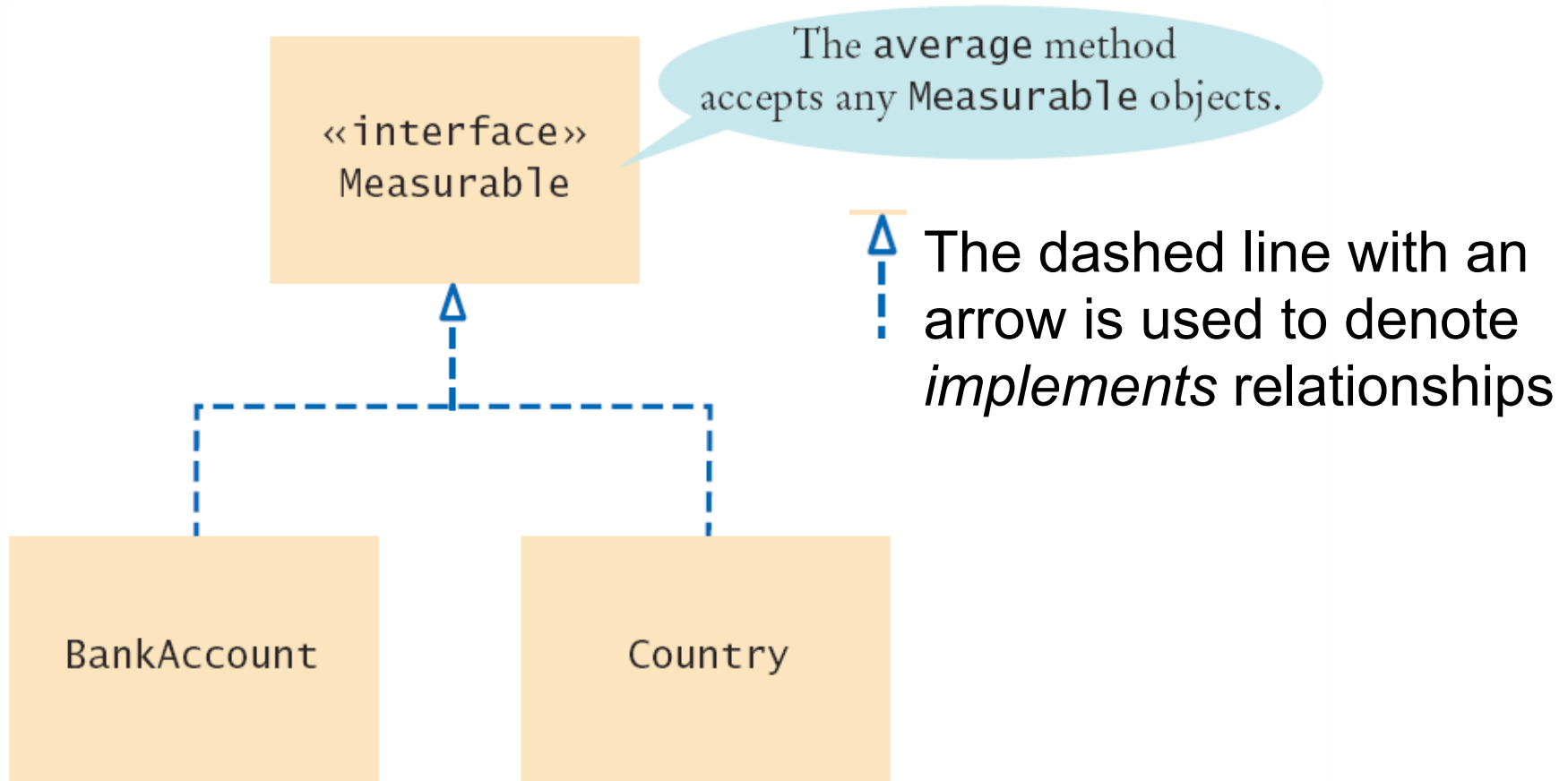
Use the **implements** reserved word in the class declaration.

```
public class Country implements Measurable
{
 public double getMeasure()
 {
 return area;
 }
 . . .
}
```

The methods of the interface must be declared as **public**



# An Implementation Diagram





# MeasurableDemo.java (1)

```
1 /**
2 * This program demonstrates the measurable BankAccount and Country classes.
3 */
4 public class MeasurableDemo
5 {
6 public static void main(String[] args)
7 {
8 Measurable[] accounts = new Measurable[3];
9 accounts[0] = new BankAccount(0);
10 accounts[1] = new BankAccount(10000);
11 accounts[2] = new BankAccount(2000);
12
13 System.out.println("Average balance: "
14 + average(accounts));
15
16 Measurable[] countries = new Measurable[3];
17 countries[0] = new Country("Uruguay", 176220);
18 countries[1] = new Country("Thailand", 514000);
19 countries[2] = new Country("Belgium", 30510);
20
21 System.out.println("Average area: "
22 + average(countries));
23 }
```



# MeasurableDemo.java (2)

```
25 /**
26 * Computes the average of the measures of the given objects.
27 * @param objs an array of Measurable objects
28 * @return the average of the measures
29 */
30 public static double average(Measurable[] objs)
31 {
32 if (objs.length == 0) { return 0; }
33 double sum = 0;
34 for (Measurable obj : objs)
35 {
36 sum = sum + obj.getMeasure();
37 }
38 return sum / objs.length;
39 }
40 }
```

## Program Run

```
Average balance: 4000.0
Average area: 240243.33333333334
```





# The Comparable Interface

- ❑ The Java library includes a number of important interfaces including Comparable
  - It requires implementing one method: `compareTo()`
  - It is used to compare two objects
  - It is implemented by many objects in the Java API
  - If may want to implement it in your classes to use powerful Java API tools such as `sorting`
- ❑ It is called on one object, and is passed another
  - Called on object `a`, return values include:
    - Negative: `a` comes before `b`
    - Positive: `a` comes after `b`
    - 0: `a` is the same as `b`

```
a.compareTo(b);
```



# The Comparable Type parameter

- ❑ The Comparable interface uses a special type of parameter that allows it to work with any type:

```
public interface Comparable<T>
{
 int compareTo(T other);
}
```

- The type <T> is a placeholder for an actual type of object
- The class ArrayList class uses the same technique with the type surrounded by angle brackets < >

```
ArrayList<String> names = new
 ArrayList<String>();
```

Using the type inside angle braces will be covered further in the next chapter.



# A Comparable Example

- ❑ The BankAccount compareTo method compares bank accounts by their balance.
  - It takes one parameter of it's own class type (BankAccount)

```
public class BankAccount implements
 Comparable<BankAccount>
{
 . . .
 public int compareTo(BankAccount other)
 {
 if (balance < other.getBalance()) { return -1; }
 if (balance > other.getBalance()) { return 1; }
 return 0;
 }
 . . .
}
```

The methods of the interface  
must be declared as public



# Using compareTo to Sort

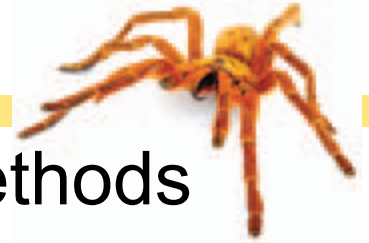
- The `Arrays.sort` method uses the `compareTo` method to sort the elements of the array
  - Once the `BankAccount` class implements the `Comparable` interface, you can sort an array of bank accounts with the `Arrays.sort` method:

```
BankAccount[] accounts = new
 BankAccount[3];
accounts[0] = new BankAccount(10000);
accounts[1] = new BankAccount(0);
accounts[2] = new BankAccount(2000);
The array is then sorted using
Arrays.sort(accounts);
```

Implementing Java Library interfaces allows you to use the power of the Java Library with your classes.



# Common Error 9.6



- ❑ Forgetting to Declare Implementing Methods as Public
  - The methods in an interface are not declared as public, because they are public by default.
  - However, the methods in a class are not public by default.
  - It is a common error to forget the public reserved word when declaring a method from an interface:

```
public class BankAccount implements Measurable
{
 double getMeasure() // Oops—should be public
 {
 return balance;
 }
 . . .
}
```



# Special Topic 9.8



## ❑ Interface Constants

- Interfaces cannot have instance variables, but it is legal to specify constants
- When declaring a constant in an interface, you can (and should) omit the reserved words `public static final`, because all variables in an interface are automatically `public static final`.

```
public interface SwingConstants
{
 int NORTH = 1;
 int NORTHEAST = 2;
 int EAST = 3;
 . . .
}
```



# Special Topic 9.9



## ❑ Function Objects

- Interfaces work well IF all objects that need the service are willing to implement the interface.
- The sole purpose of a function object is to execute a single method
  - This allows a non-implementing class to use the services of the interface by creating a function object and using it's method
- First, create a new interface
  - The measure method measures an object and returns its measurement. We use a parameter of type `Object`, the “lowest common denominator” of all classes in Java, because we do not want to restrict which classes can be measured.

```
public interface Measurer
{
 double measure(Object
anObject);
}
```



# Function Objects(2)



- Then declare a class that implements the new interface

```
public class StringMeasurer implements Measurer
{
 public double measure(Object obj)
 {
 String str = (String) obj; // Cast obj to String
 type
 return str.length();
 }
}

public interface Measurer
{
 double measure(Object
 anObject);
}
```





# Function Objects (3)



- ❑ Example of Function Object Use
  - Instantiate an object of the Function object class
  - Call your method that accepts an object of this type

```
String[] words = { "Mary", "had", "a", "little",
 "lamb" };
Measurer strMeas = new StringMeasurer();
double result = average(words, strMeas);
public static double average(Object[] objs, Measurer
 meas)
{
 if (objs.length == 0) { return 0; }
 double sum = 0;
 for (Object obj : objs)
 {
 sum = sum + meas.measure(obj);
 }
 return sum / objs.length;
}
```

See ch09/measure2 sample program.



# Summary: Inheritance

- ❑ A subclass inherits data and behavior from a superclass.
- ❑ You can always use a subclass object in place of a superclass object.
- ❑ A subclass inherits all methods that it does not override.
- ❑ A subclass can override a superclass method by providing a new implementation.



# Summary: Overriding Methods

- ❑ An overriding method can extend or replace the functionality of the superclass method.
- ❑ Use the reserved word `super` to call a superclass method.
- ❑ Unless specified otherwise, the subclass constructor calls the superclass constructor with no arguments.
- ❑ To call a superclass constructor, use the `super` reserved word in the first statement of the subclass constructor.
- ❑ The constructor of a subclass can pass arguments to a superclass constructor, using the reserved word `super`.



# Summary: Polymorphism

- ❑ A subclass reference can be used when a superclass reference is expected.
- ❑ Polymorphism (“having multiple shapes”) allows us to manipulate objects that share a set of tasks, even though the tasks are executed in different ways.
- ❑ An **abstract** method is a method whose implementation is not specified.
- ❑ An **abstract** class is a class that cannot be instantiated.



## Summary: `toString` and `instanceOf`

- ❑ Override the `toString` method to yield a `String` that describes the object's state.
- ❑ The `equals` method checks whether two objects have the same contents.
- ❑ If you know that an object belongs to a given class, use a cast to convert the type.
- ❑ The `instanceof` operator tests whether an object belongs to a particular type.



# Summary: Interfaces

- ❑ The Java `interface` type contains the return types, names, and parameter variables of
- ❑ Unlike a class, an `interface` type provides no implementation.
- ❑ By using an interface type for a parameter variable, a method can accept objects from many classes.
- ❑ The `implements` reserved word indicates which interfaces a class implements.
- ❑ Implement the `Comparable` interface so that objects of your class can be compared, for example, in a sort method.