CHAPTER 5
Defining Classes

Shin-Jie Lee (李信杰)
Associate Professor
Computer and Network Center
Department of Computer Science and Information Engineering
National Cheng Kung University

Introduction

- Classes are the most important language feature that make *object-oriented programming* (*OOP*) possible
- Programming in Java consists of defining a number of classes
  - Every program is a class
  - All helping software consists of classes
  - All programmer-defined types are classes
- Classes are central to Java

Class Definitions

- You already know how to use classes and the objects created from them, and how to invoke their methods
  - For example, you have already been using the predefined **`String`** and **`Scanner`** classes
- Now you will learn how to define your own classes and their methods, and how to create your own objects from them

A Class Is a Type

- A class is a special kind of programmer-defined type, and variables can be declared of a class type
- A value of a class type is called an object or *an instance of the class*
  - If Cat is a class, then the phrases “cat is of type Cat," “cat is an object of the class Cat," and “cat is an instance of the class Cat" mean the same thing
- A class determines the types of data that an object can contain, as well as the actions it can perform

Primitive Type Values vs. Class Type Values

- A primitive type value is a **single piece of data**
- A class type value or object can have **multiple pieces of data**, as well as actions called ***methods***
  - All objects of a class have the same methods
  - All objects of a class have the same pieces of data (i.e., name, type, and number)
  - For a given object, each piece of data can hold a different value

The Contents of a Class Definition

- A class definition specifies the data items and methods that all of its objects will have
- These data items and methods are sometimes called ***members*** of the object
- **Data items are called *fields* or *instance variables***
- Instance variable declarations and method definitions can be placed in any order within the class definition

Lab

```
public class Duck {

  public boolean canfly = false;

  public void quack(){
    System.out.println("Quack!!");
  }

}
```

The `new` Operator

- An object of a class is named or declared by a variable of the class type:

```
ClassName  classVar;
```

- The **`new`** operator must then be used to create the object and associate it with its variable name:

```
classVar = new ClassName();
```

- These can be combined as follows:

```
ClassName classVar = new ClassName();
```

Lab

```
public class Farm {

  public static void main(String[] args) {
    Duck duck = new Duck();
  }

}
```

Instance Variables and Methods

- Instance variables can be defined as in the following two examples
  - Note the **`public`** modifier (for now):

```
public String  instanceVar1;
public int  instanceVar2;
```

- In order to refer to a particular instance variable, preface it with its object name as follows:

```
objectName.instanceVar1
objectName.instanceVar2
```

Instance Variables and Methods

- Method definitions are divided into two parts: a *heading* and a *method body:*

```
public void myMethod()
{
    code to perform some action
    and/or compute a value
}
```

Heading

Body

- Methods are invoked using the name of the calling object and the method name as follows:

```
classVar.myMethod();
```

- Invoking a method is equivalent to executing the method body

Lab

```
public class Farm {

public static void main(String[] args) {

  Duck duck = new Duck();

  boolean canTheDuckFly = duck.canfly;
  if(canTheDuckFly == true){
    System.out.println("The duck can fly");
  }

  duck.quack();
}
}
```

A Method Can Return a Value

- A method that returns a value must specify the type of that value in its heading:

```
public int getScore(){
        int score = 100;
        return score;
}
```

- A **void** method uses the keyword **void** in its heading to show that it does not return a value :

```
public void printScore(){
        int score = 100;
        System.out.println(score);
}
```

Receiving a Return Value

- An invocation of a method that returns a value can be used as an expression anyplace that a value of the can be used:

```
int result = getScore();
```

- An invocation of a **`void`** method is simply a statement:

```
printScore();
```

Lab

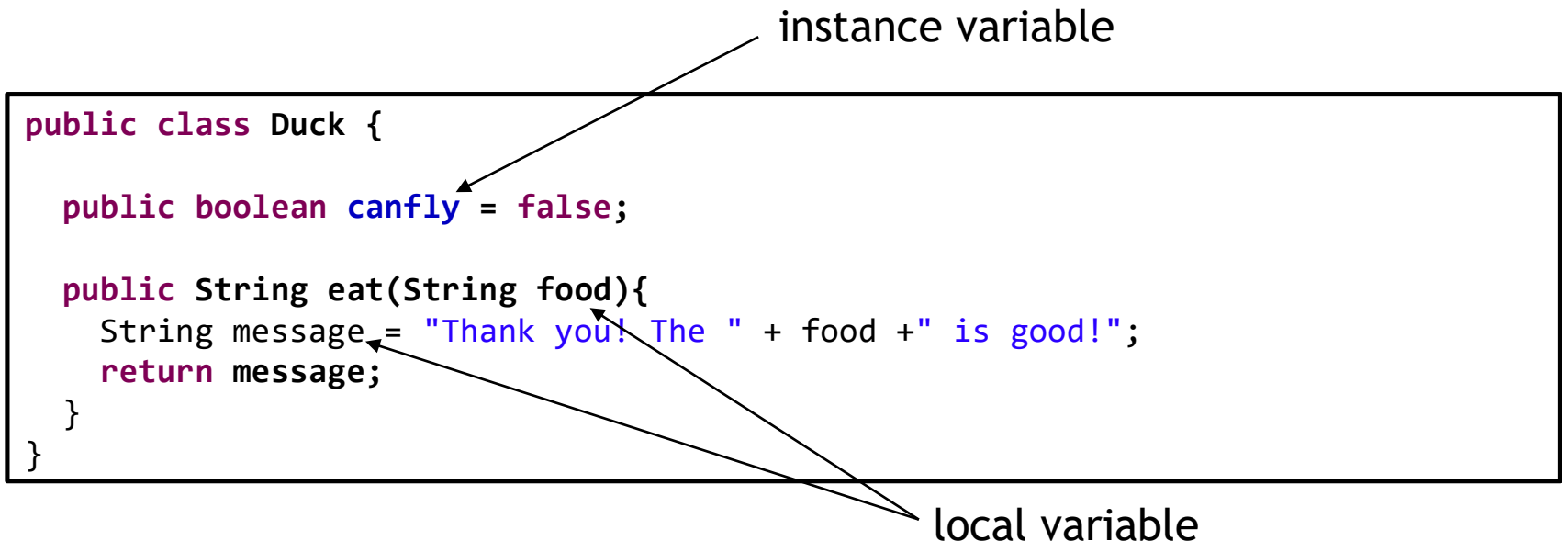
```
public class Duck {

  public boolean canfly = false;

  public void quack(){
    System.out.println("Quack!!");
  }

  public String eat(String food){
    String message = "Thank you! The " + food +" is good!";
    return message;
  }
}
```

Lab

```
public class Farm {

public static void main(String[] args) {
  Duck duck = new Duck();

  boolean canTheDuckFly = duck.canfly;
  if(canTheDuckFly == true){
    System.out.println("The duck can fly");
  }

  duck.quack();

  String food = "Hamburger";
  String message = duck.eat(food);
  System.out.println(message);
}
}
```

Local Variables

- A variable declared within a method definition is called a *local variable*
  - All variables declared in a method are local variables
  - All method parameters are local variables
- If two methods each have a local variable of the same name, they are still two entirely different variables



Blocks

- A *block* is another name for a compound statement, that is, a set of Java statements enclosed in braces, **{ }**
- A variable declared within a block is **local** to that block, and cannot be used outside the block
- Once a variable has been declared within a block, its name cannot be used for anything else within the same method definition

Declaring Variables in a `for` Statement

- You can declare one or more variables within the initialization portion of a **`for`** statement
- **A variable so declared will be local to the `for` loop, and cannot be used outside of the loop**
- If you need to use such a variable outside of a loop, then declare it outside the loop

```
int sum = 0;
for(int i=1; i <= 50; i++)
{
        sum += i;
}
System.out.println("The total is: " + sum);
```

Parameters of a Method

- A parameter list provides a description of the data required by a method

```
public double myMethod(int p1, int p2, double p3){
      double sum = p1 + p2 +p3;
      return sum;
}
```

Arguments

- When a method is invoked, the type of each argument must be compatible with the type of the corresponding parameter

```
int    a=1;
int    b=2;
double c=3.0;
double result = myMethod(a,b,c);
```

Automatic Upper Casting

- A primitive argument can be automatically type cast from any of the following types, to any of the types that appear to its right:

For example:

```
int    a=1;
int    b=2;
int    c=3;
double result = myMethod(a,b,c);
```

Call-by-value (Primitive Type)

- The value of each argument (not the variable name) is plugged into the corresponding method parameter
  - known as the *call-by-value mechanism*

Lab

```
public class Duck {

public boolean canfly = false;

  public void quack(){
    System.out.println("Quack!!");
  }

  public String eat(String food){
    String message = "Thank you! The " + food +" is good!";
    return message;
  }

  public void swim(int distance){
    distance = distance - 1;
    System.out.println("The distance of my swimming is " +    distance);
  }
}
```

Lab

```
public class Farm {

public static void main(String[] args) {
  Duck duck = new Duck();

  boolean canTheDuckFly = duck.canfly;
  if(canTheDuckFly == true){
    System.out.println("The duck can fly");
  }

  duck.quack();

  String food = "Hamburger";
  String message = duck.eat(food);
  System.out.println(message);

  int expectedDistance = 10;
  duck.swim(expectedDistance);
  System.out.println("The expected distance is " + expectedDistance);
}

}
```

The `this` Parameter

- `this` ***must*** be used if a parameter or other local variable with the same name is used in the method
  - Otherwise, all instances of the variable name will be interpreted as local

```
class A{
    int someVariable = 10;
    public void method1(int newVariable){
        this.someVariable = newVariable
    }
}
```

instance

local

Lab

```
public class Duck {

public boolean canfly = false;

public Duck(boolean canfly){
  this.canfly = canfly;
}

public void quack(){
  System.out.println("Quack!!");
}

public String eat(String food){
  String message = "Thank you! The " + food +" is good!";
  return message;
}

public void swim(int distance){
  distance = distance - 1;
  System.out.println("The distance of my swimming is " + distance);
}
}
```

Lab

```
public class Farm {

public static void main(String[] args) {
  Duck duck = new Duck(true);

  boolean canTheDuckFly = duck.canfly;
  if(canTheDuckFly == true){
    System.out.println("The duck can fly");
  }

  duck.quack();

  String food = "Hamburger";
  String message = duck.eat(food);
  System.out.println(message);

  int expectedDistance = 10;
  duck.swim(expectedDistance);
  System.out.println("The expected distance is " + expectedDistance);
}
}
```

Encapsulation

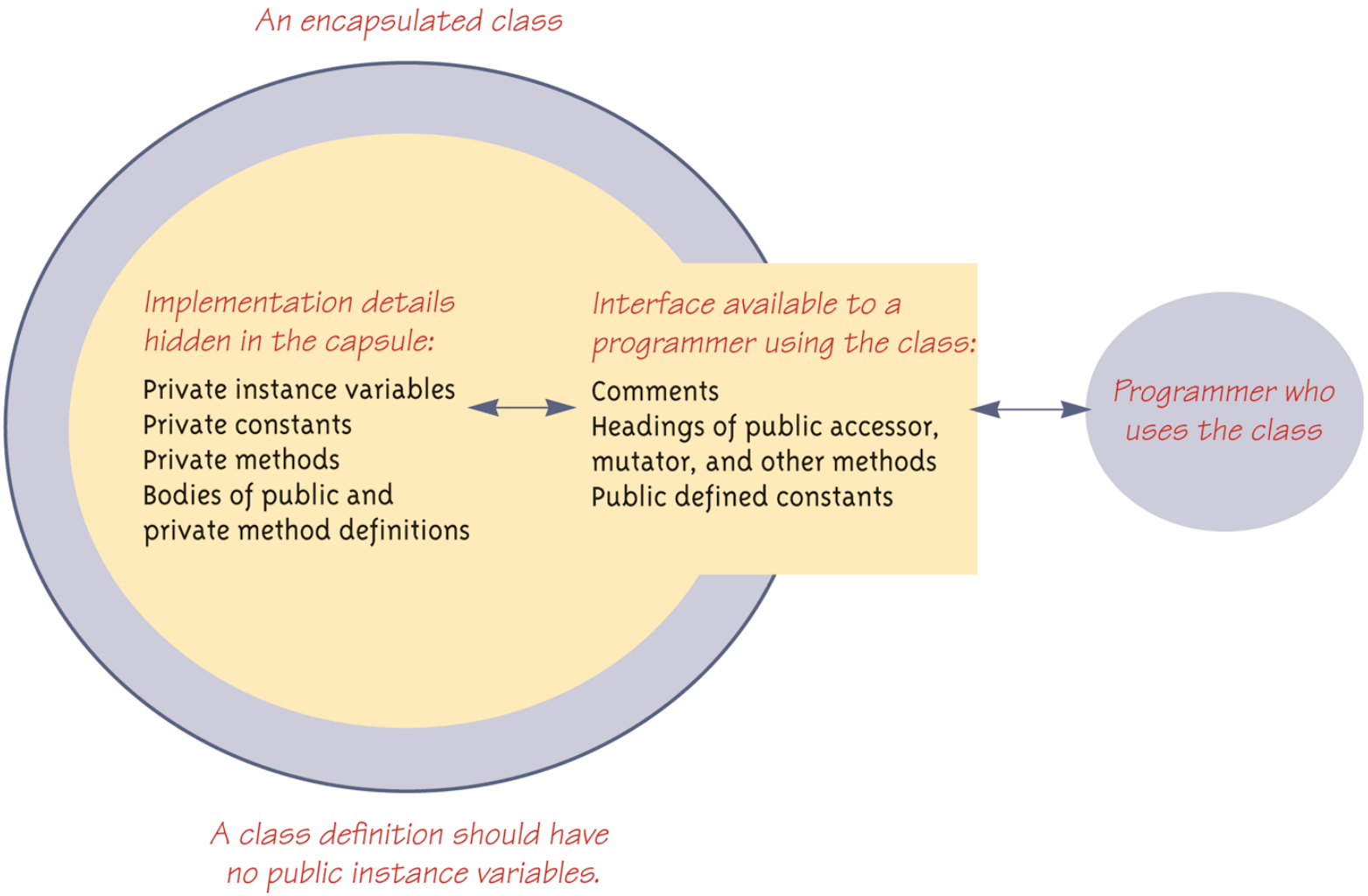
- *Encapsulation* means that the data and methods of a class are combined into a single unit (i.e., a class object), which hides the implementation details
  - Knowing the details is unnecessary because interaction with the object occurs via a well-defined and simple interface
  - In Java, hiding details is done by marking them **`private`**

`public` and `private` Modifiers

- The modifier **`public`** means that there are no restrictions on where an instance variable or method can be used
- The modifier **`private`** means that an instance variable or method cannot be accessed by name outside of the class
  - It is considered good programming practice to make **all** instance variables **`private`**
  - Most methods are **`public`**, and thus provide controlled access to the object
  - Usually, methods are **`private`** only if used as helping methods for other methods in the class

Encapsulation

Display 4.10 Encapsulation



Lab

```
public class Duck {

  private boolean canfly = false;

  public boolean getCanfly(){
    return canfly;
  }

  …

}
```

Lab

```
public class Farm {

public static void main(String[] args) {
  Duck duck = new Duck(true);

  boolean canTheDuckFly = duck.getCanfly();
  if(canTheDuckFly == true){
    System.out.println("The duck can fly");
  }

  …

}

}
```

Overloading

- *Overloading* is when two or more methods *in the same class* have the same method name
- To be valid, any two definitions of the method name must have different *signatures*
  - A signature consists of the name of a method together with its parameter list
  - Differing signatures must have different numbers and/or types of parameters

Lab

```
public class Duck {
  …
  public void quack(){
    System.out.println("Quack!!");
  }
  public void quack(String sound){
    System.out.println(sound);
  }
  …
}
```

```
public class Farm {

public static void main(String[] args) {
  Duck duck = new Duck(true);
  …
  duck.quack();
  duck.quack("Ga Ga Ga");
}
}
```

Constructors

- A *constructor* is a special kind of method that is designed to initialize the instance variables for an object:

```
public ClassName(anyParameters){code}
```

  - A constructor must have the same name as the class
  - A constructor has no type returned, not even **`void`**
  - Constructors are typically overloaded

Constructors

- A constructor is called when an object of the class is created using **`new`**

```
ClassName objectName = new ClassName(anyArgs);
```

- If a constructor is invoked again (using **`new`**), the first object is discarded and an entirely new object is created

No-Argument Constructor

- If you do not include any constructors in your class, Java will automatically create a *default* or *no-argument* constructor that takes no arguments, performs no initializations, but allows the object to be created

- If you include even one constructor in your class, Java will not provide this default constructor

```
Duck duck = new Duck();
```

```
public class Duck {

  private boolean canfly =
false;

  public boolean getCanfly(){
    return canfly;
  }
}
```

The `StringTokenizer` Class

- The **`StringTokenizer`** class is used to recover the words or *tokens* in a multi-word **`String`**
  - You can use whitespace characters to separate each token, or you can specify the characters you wish to use as separators
  - In order to use the **`StringTokenizer`** class, be sure to include the following at the start of the file:

```
import java.util.StringTokenizer;
```

Some Methods in the `StringTokenizer` Class (Part 1 of 2)

Display 4.17 Some Methods in the Class `StringTokenizer`

The class `StringTokenizer` is in the `java.util` package.

```
public StringTokenizer(String theString)
```

Constructor for a tokenizer that will use whitespace characters as separators when finding tokens in `theString`.

```
public StringTokenizer(String theString, String delimiters)
```

Constructor for a tokenizer that will use the characters in the string `delimiters` as separators when finding tokens in `theString`.

```
public boolean hasMoreTokens()
```

Tests whether there are more tokens available from this tokenizer's string. When used in conjunction with `nextToken`, it returns `true` as long as `nextToken` has not yet returned all the tokens in the string; returns `false` otherwise.

(continued)

Some Methods in the `StringTokenizer` Class (Part 2 of 2)

Display 4.17 Some Methods in the Class `StringTokenizer`

```
public String nextToken()
```

Returns the next token from this tokenizer's string. (Throws `NoSuchElementException` if there are no more tokens to return.)[5]

```
public String nextToken(String delimiters)
```

First changes the delimiter characters to those in the string `delimiters`. Then returns the next token from this tokenizer's string. After the invocation is completed, the delimiter characters are those in the string `delimiters`.
(Throws `NoSuchElementException` if there are no more tokens to return. Throws `NullPointerException` if `delimiters` is `null`.)[5]

```
public int countTokens()
```

Returns the number of tokens remaining to be returned by `nextToken`.

Lab

```
import java.util.StringTokenizer;

public class StringTokenizerTest {

  public static void main(String[] args) {
    String in = "Hello,World,Java";
    StringTokenizer st = new StringTokenizer(in, ",");
    while(st.hasMoreTokens()) {
      String token = st.nextToken();
      System.out.println(token);
    }
  }
}
```

Static Methods

- A *static method* is one that can be used without a calling object
- A static method still belongs to a class, and its definition is given inside the class definition
- When a static method is defined, the keyword **`static`** is placed in the method header

```
public static returnedType myMethod(parameters)
{ . . . }
```

- Static methods are invoked using the class name in place of a calling object

```
returnedValue = MyClass.myMethod(arguments);
```

Lab

```
public class StaticTest {

 public static void main(String[] args) {

          int sum = Tool.add(1,1);

          System.out.println(sum);
 }

}
```

```
public class Tool {

 public static int add(int a, int b){
          return a+b;
 }

}
```

Pitfall: Invoking a Non-static Method within a Static Method

- A static method cannot refer to an instance variable of the class, and it cannot invoke a nonstatic method of the class
  - A static method has no **`this`**, so it cannot use an instance variable or method that has an implicit or explicit **`this`** for a calling object
  - A static method can invoke another static method, however

Lab

```
public class StaticTest {

 public static void main(String[] args) {

         int sum = add(1,1);
         System.out.println(sum);

         StaticTest st = new StaticTest();
         sum = st.add2(2,2);          //Cannot be: sum = add2(2,2);
 }

 public static int add(int a, int b){
         return a+b;
 }


 public int add2(int a, int b){
         return a+b;
 }


}
```

Static Variables

- A *static variable* is a variable that belongs to the class as a whole, and not just to one object
- All objects of the class can read and change a static variable
- `private static int myStaticVariable=0;`

Static Variables as Constants

- In addition to **`static`**, the declaration for a static defined constant must include the modifier **`final`**, which indicates that its value cannot be changed

```
public class Circle{
    public static final double PI = 3.14159;
}
```

- Use the name of its class in place of a calling object

```
double pi = Circle.PI;
```

Lab

```
public class StaticTest {

public static int port = 80;

public static void main(String[] args) {
  StaticTest obj1 = new StaticTest();
  StaticTest obj2 = new StaticTest();

  System.out.println(StaticTest.port);
  System.out.println(obj1.port);
  System.out.println(obj2.port);

  StaticTest.port = 1234;
  System.out.println(obj1.port);

  obj2.port = 5678;
  System.out.println(obj1.port);
}
}
```

The `Math` Class

- The **`Math`** class provides a number of standard mathematical methods
  - It is found in the **`java.lang`** package, so it does not require an **`import`** statement
  - All of its methods and data are static, therefore they are invoked with the class name **`Math`** instead of a calling object
  - The **`Math`** class has two predefined constants, **`E`** (*e*, the base of the natural logarithm system) and **`PI`** (π, 3.1415 . . .)

```
area = Math.PI * radius * radius;
```

Some Methods in the Class `Math` (Part 1 of 5)

Display 5.6 Some Methods in the Class `Math`

The `Math` class is in the `java.lang` package, so it requires no `import` statement.

```
public static double pow(double base, double exponent)
```

Returns `base` to the power `exponent`.

EXAMPLE

`Math.pow(2.0,3.0)` returns `8.0`.

(continued)

Some Methods in the Class `Math` (Part 2 of 5)

Display 5.6 Some Methods in the Class `Math`

```
public static double abs(double argument)
public static float abs(float argument)
public static long abs(long argument)
public static int abs(int argument)
```

Returns the absolute value of the `argument`. (The method name `abs` is overloaded to produce four similar methods.)

EXAMPLE

`Math.abs(-6)` and `Math.abs(6)` both return 6. `Math.abs(-5.5)` and `Math.abs(5.5)` both return `5.5`.

```
public static double min(double n1, double n2)
public static float min(float n1, float n2)
public static long min(long n1, long n2)
public static int min(int n1, int n2)
```

Returns the minimum of the arguments `n1` and `n2`. (The method name `min` is overloaded to produce four similar methods.)

EXAMPLE

`Math.min(3, 2)` returns 2.

(continued)

Some Methods in the Class `Math` (Part 3 of 5)

Display 5.6 Some Methods in the Class `Math`

```
public static double max(double n1, double n2)
public static float max(float n1, float n2)
public static long max(long n1, long n2)
public static int max(int n1, int n2)
```

Returns the maximum of the arguments n1 and n2. (The method name max is overloaded to produce four similar methods.)

EXAMPLE

`Math.max(3, 2)` returns 3.

```
public static long round(double argument)
public static int round(float argument)
```

Rounds its argument.

EXAMPLE

`Math.round(3.2)` returns 3; `Math.round(3.6)` returns 4.

(continued)

Some Methods in the Class `Math` (Part 4 of 5)

Display 5.6 Some Methods in the Class `Math`

```
public static double ceil(double argument)
```

Returns the smallest whole number greater than or equal to the `argument`.

EXAMPLE

`Math.ceil(3.2)` and `Math.ceil(3.9)` both return `4.0`.

(continued)

Some Methods in the Class `Math` (Part 5 of 5)

Display 5.6 Some Methods in the Class `Math`

```
public static double floor(double argument)
```

Returns the largest whole number less than or equal to the `argument`.

EXAMPLE

`Math.floor(3.2)` and `Math.floor(3.9)` both return `3.0`.

```
public static double sqrt(double argument)
```

Returns the square root of its `argument`.

EXAMPLE

`Math.sqrt(4)` returns `2.0`.

Lab

```
public class MathExample {

public static void main(String[] args){
    int i = 7;
    int j = -9;
    double x = 72.3;
    double y = 0.34;

    System.out.println("i is " + i);
    System.out.println("j is " + j);
    System.out.println("x is " + x);
    System.out.println("y is " + y);

    System.out.println("|" + i + "| is " + Math.abs(i));
    System.out.println("|" + j + "| is " + Math.abs(j));
    System.out.println("|" + x + "| is " + Math.abs(x));
    System.out.println("|" + y + "| is " + Math.abs(y));

    System.out.println(x + " is approximately " + Math.round(x));
    System.out.println(y + " is approximately " + Math.round(y));
```

Lab

```
        System.out.println("The ceiling of " + i + " is " + Math.ceil(i));
        System.out.println("The ceiling of " + j + " is " + Math.ceil(j));
        System.out.println("The ceiling of " + x + " is " + Math.ceil(x));
        System.out.println("The ceiling of " + y + " is " + Math.ceil(y));

        System.out.println("min(" + i + "," + j + ") is " + Math.min(i,j));
        System.out.println("min(" + x + "," + y + ") is " + Math.min(x,y));
        System.out.println("min(" + i + "," + x + ") is " + Math.min(i,x));
        System.out.println("min(" + y + "," + j + ") is " + Math.min(y,j));

        System.out.println("max(" + i + "," + j + ") is " + Math.max(i,j));
        System.out.println("max(" + x + "," + y + ") is " + Math.max(x,y));
        System.out.println("max(" + i + "," + x + ") is " + Math.max(i,x));
        System.out.println("max(" + y + "," + j + ") is " + Math.max(y,j));

        System.out.println("Pi is " + Math.PI);
        System.out.println("e is " + Math.E);

    System.out.println("pow(2.0, 2.0) is "  + Math.pow(2.0,2.0));
    System.out.println("pow(10.0, 3.5) is " + Math.pow(10.0,3.5));
    System.out.println("pow(8, -1) is "     + Math.pow(8,-1));

    System.out.println("Here's one random number: " + Math.random());
    System.out.println("Here's another random number: " + Math.random());
}
}
```

Wrapper Classes

- *Wrapper classes* provide a class type corresponding to each of the primitive types
  - **`Byte`**, **`Short`**, **`Long`**, **`Float`**, **`Double`**, and **`Character`**

- Wrapper classes also contain a number of useful predefined constants and static methods

Wrapper Classes

- *Boxing*: the process of going from a value of a primitive type to an object of its wrapper class
  - `Integer integerObject = new Integer(42);`

Wrapper Classes

- *Unboxing*: the process of going from an object of a wrapper class to the corresponding value of a primitive type
  - `int i = integerObject.intValue();`

Lab

```
public class WrapperClassTest {

  public static void main(String[] args) {
    int k = 100;
    Integer it1 = new Integer(k);
    int m = it1.intValue();

    System.out.println(m*k);
  }

}
```

Constants and Static Methods in Wrapper Classes

- Number to string

```
int i = Integer.parseInt("123");
```

- String to number

```
String s = Double.toString(123.99);
```

Lab

```
public class WrapperClassTest {

  public static void main(String[] args) {

    double pi = Double.parseDouble("3.14");
    System.out.println(pi);

    String str = Double.toString(1.5);
    System.out.println(str);
  }
}
```

Lab

```
import java.util.Scanner;
import java.util.StringTokenizer;

public class Parser {
  public static void main(String args[]) {
    Scanner keyboard = new Scanner(System.in);
    System.out.print("Enter a sentence and I'll display each
word you entered: ");
    String sentence = keyboard.nextLine();

    // Parse the string into tokens and echo back to the user
    StringTokenizer tk = new StringTokenizer(sentence, " ");
    System.out.println("Here are the tokens: ");
    while (tk.hasMoreTokens()) {
      System.out.println(tk.nextToken());
    }
  }
}
```

Lab

```
public class Student {
  private String name;
  private double gpa;

  /** Constructors */
  public Student() {
    name = null;
    gpa = 0.0;
  }
  public Student(String n, double g) {
    name = n;
    gpa = g;
  }
  /** Accessor methods */
  public String getName() {
    return name;
  }
  public double getGPA() {
    return gpa;
  }
  /** Mutator methods */
  public void setName(String n) {
    name = n;
  }
  public void setGPA(double g) {
    if ((g >= 0) && (g <= 4))
    gpa = g;
  }
```

Lab

```
/** Facilitator methods */
  public String toString() {
    return (name + ":"+ gpa);
  }
  public boolean equals(Student s) {
    return (name.equalsIgnoreCase(s.name));
  }
  public static void main(String[] args){
    Student student1 = new Student("Mike", 90);
    student1.setGPA(92);

    System.out.println(student1.getName());
    System.out.println(student1.getGPA());
    System.out.println(student1.toString());

    Student student2 = new Student("Mary", 90);
    if(student2.equals(student1)){
      System.out.println("student1 is student2!");
    }else{
      System.out.println("student1 is not student2!");
    }
  }
}
```

Reference

- "Absolute Java". Walter Savitch and Kenrick Mock. Addison-Wesley; 5 edition. 2012
- "Java How to Program". Paul Deitel and Harvey Deitel. Prentice Hall; 9 edition. 2011.
- "A Programmers Guide To Java SCJP Certification: A Comprehensive Primer 3rd Edition". Khalid Mughal, Rolf Rasmussen. Addison-Wesley Professional. 2008