

# CHAPTER 12

## EXCEPTION HANDLING AND TEXT I/O

### Objectives

- To get an overview of exceptions and exception handling (§12.2).
- To explore the advantages of using exception handling (§12.2).
- To distinguish exception types: **Error** (fatal) vs. **Exception** (nonfatal) and checked vs. unchecked (§12.3).
- To declare exceptions in a method header (§12.4.1).
- To throw exceptions in a method (§12.4.2).
- To write a **try-catch** block to handle exceptions (§12.4.3).
- To explain how an exception is propagated (§12.4.3).
- To obtain information from an exception object (§12.4.4).
- To develop applications with exception handling (§12.4.5).
- To use the **finally** clause in a **try-catch** block (§12.5).
- To use exceptions only for unexpected errors (§12.6).
- To rethrow exceptions in a **catch** block (§12.7).
- To create chained exceptions (§12.8).
- To define custom exception classes (§12.9).
- To discover file/directory properties, to delete and rename files/directories, and to create directories using the **File** class (§12.10).
- To write data to a file using the **PrintWriter** class (§12.11.1).
- To use try-with-resources to ensure that the resources are closed automatically (§12.11.2).
- To read data from a file using the **Scanner** class (§12.11.3).
- To understand how data is read using a **Scanner** (§12.11.4).
- To develop a program that replaces text in a file (§12.11.5).
- To read data from the Web (§12.12).
- To develop a Web crawler (§12.13).



12.1
Introduction



*Exceptions are runtime errors. Exception handling enables a program to deal with runtime errors and continue its normal execution.*

Runtime errors occur while a program is running if the JVM detects an operation that is impossible to carry out. For example, if you access an array using an index that is out of bounds, you will get a runtime error with an `ArrayIndexOutOfBoundsException`. If you enter a `double` value when your program expects an integer, you will get a runtime error with an `InputMismatchException`.

In Java, runtime errors are thrown as exceptions. An *exception* is an object that represents an error or a condition that prevents execution from proceeding normally. If the exception is not handled, the program will terminate abnormally. How can you handle the exception so the program can continue to run or else terminate gracefully? This chapter introduces this subject, and text input and output.

exception

12.2
Exception-Handling Overview



*Exceptions are thrown from a method. The caller of the method can catch and handle the exception.*

To demonstrate exception handling, including how an exception object is created and thrown, let's begin with the example in Listing 12.1, which reads in two integers and displays their quotient.



VideoNote  
Exception-handling advantages

read two integers

integer division

LISTING 12.1
Quotient.java

```

1  import java.util.Scanner;
2
3  public class Quotient {
4      public static void main(String[] args) {
5          Scanner input = new Scanner(System.in);
6
7          // Prompt the user to enter two integers
8          System.out.print("Enter two integers: ");
9          int number1 = input.nextInt();
10         int number2 = input.nextInt();
11
12         System.out.println(number1 + " / " + number2 + " is " +
13             (number1 / number2));
14     }
15 }
```



Enter two integers: 5 2   
5 / 2 is 2



Enter two integers: 3 0   
Exception in thread "main" java.lang.ArithmeticException: / by zero  
at Quotient.main(Quotient.java:13)

If you entered `0` for the second number, a runtime error would occur, because you cannot divide an integer by `0`. (Note a floating-point number divided by `0` does not raise an exception.) A simple way to fix this error is to add an `if` statement to test the second number, as shown in Listing 12.2.

**LISTING 12.2** QuotientWithIf.java

```

1  import java.util.Scanner;
2
3  public class QuotientWithIf {
4      public static void main(String[] args) {
5          Scanner input = new Scanner(System.in);
6
7          // Prompt the user to enter two integers
8          System.out.print("Enter two integers: ");
9          int number1 = input.nextInt();           read two integers
10         int number2 = input.nextInt();
11
12         if (number2 != 0)                         test number2
13             System.out.println(number1 + " / " + number2
14                 + " is " + (number1 / number2));
15         else
16             System.out.println("Divisor cannot be zero ");
17     }
18 }

```

Enter two integers: 5 0   
 Divisor cannot be zero



Before introducing exception handling, let us rewrite Listing 12.2 to compute a quotient using a method, as shown in Listing 12.3.

**LISTING 12.3** QuotientWithMethod.java

```

1  import java.util.Scanner;
2
3  public class QuotientWithMethod {
4      public static int quotient(int number1, int number2) {           quotient method
5          if (number2 == 0) {
6              System.out.println("Divisor cannot be zero");
7              System.exit(1);                                           terminate the program
8          }
9
10         return number1 / number2;
11     }
12
13     public static void main(String[] args) {
14         Scanner input = new Scanner(System.in);
15
16         // Prompt the user to enter two integers
17         System.out.print("Enter two integers: ");
18         int number1 = input.nextInt();           read two integers
19         int number2 = input.nextInt();
20
21         int result = quotient(number1, number2);           invoke method
22         System.out.println(number1 + " / " + number2 + " is "
23             + result);
24     }
25 }

```



```

Enter two integers: 5 3
5 / 3 is 1

```



```

Enter two integers: 5 0
Divisor cannot be zero

```

The method `quotient` (lines 4–11) returns the quotient of two integers. If `number2` is `0`, it cannot return a value, so the program is terminated in line 7. This is clearly a problem. You should not let the method terminate the program—the *caller* should decide whether to terminate the program.

How can a method notify its caller when an exception has occurred? Java enables a method to throw an exception that can be caught and handled by the caller. Listing 12.3 can be rewritten, as shown in Listing 12.4.

**LISTING 12.4**   `QuotientWithException.java`

quotient method

throw exception

read two integers

try block  
invoke method

catch block

```

1  import java.util.Scanner;
2
3  public class QuotientWithException {
4      public static int quotient(int number1, int number2) {
5          if (number2 == 0)
6              throw new ArithmeticException("Divisor cannot be zero");
7
8          return number1 / number2;
9      }
10
11     public static void main(String[] args) {
12         Scanner input = new Scanner(System.in);
13
14         // Prompt the user to enter two integers
15         System.out.print("Enter two integers: ");
16         int number1 = input.nextInt();
17         int number2 = input.nextInt();
18
19         try {
20             int result = quotient(number1, number2);
21             System.out.println(number1 + " / " + number2 + " is "
22                               + result);
23         }
24         catch (ArithmeticException ex) {
25             System.out.println("Exception: an integer " +
26                               "cannot be divided by zero ");
27         }
28
29         System.out.println("Execution continues ...");
30     }
31 }

```



```

Enter two integers: 5 3
5 / 3 is 1
Execution continues ...

```

```
Enter two integers: 5 0 
Exception: an integer cannot be divided by zero
Execution continues ...
```



If **number2** is 0, the method throws an exception (line 6) by executing

```
throw new ArithmeticException("Divisor cannot be zero");
```

throw statement

The value thrown, in this case **new ArithmeticException("Divisor cannot be zero")**, is called an *exception*. The execution of a **throw** statement is called *throwing an exception*. The exception is an object created from an exception class. In this case, the exception class is **java.lang.ArithmeticException**. The constructor **ArithmeticException(str)** is invoked to construct an exception object, where **str** is a message that describes the exception.

exception  
throw exception

When an exception is thrown, the normal execution flow is interrupted. As the name suggests, to “throw an exception” is to pass the exception from one place to another. The statement for invoking the method is contained in a **try** block. The **try** block (lines 19–23) contains the code that is executed in normal circumstances. The exception is caught by the **catch** block. The code in the **catch** block is executed to *handle the exception*. Afterward, the statement (line 29) after the **catch** block is executed.

handle exception

The **throw** statement is analogous to a method call, but instead of calling a method, it calls a **catch** block. In this sense, a **catch** block is like a method definition with a parameter that matches the type of the value being thrown. Unlike a method, however, after the **catch** block is executed, the program control does not return to the **throw** statement; instead, it executes the next statement after the **catch** block.

The identifier **ex** in the **catch**-block header

```
catch (ArithmeticException ex)
```

acts very much like a parameter in a method. Thus, this parameter is referred to as a **catch**-block parameter. The type (e.g., **ArithmeticException**) preceding **ex** specifies what kind of exception the **catch** block can catch. Once the exception is caught, you can access the thrown value from this parameter in the body of a **catch** block.

catch-block parameter

In summary, a template for a **try-throw-catch** block may look as follows:

```
try {
    Code to run;
    A statement or a method that may throw an exception;
    More code to run;
}
catch (type ex) {
    Code to process the exception;
}
```

An exception may be thrown directly by using a **throw** statement in a **try** block, or by invoking a method that may throw an exception.

The main method invokes **quotient** (line 20). If the **quotient** method executes normally, it returns a value to the caller. If the **quotient** method encounters an exception, it throws the exception back to its caller. The caller’s **catch** block handles the exception.

Now you can see the *advantage* of using exception handling: It enables a method to throw an exception to its caller, enabling the caller to handle the exception. Without this capability, the called method itself must handle the exception or terminate the program. Often the called method does not know what to do in case of error. This is typically the case for the library methods. The library method can detect the error, but only the caller

advantage

knows what needs to be done when an error occurs. The key benefit of exception handling is separating the detection of an error (done in a called method) from the handling of an error (done in the calling method).

Many library methods throw exceptions. Listing 12.5 gives an example that handles an `InputMismatchException` when reading an input.

### LISTING 12.5 `InputMismatchExceptionDemo.java`

```

1  import java.util.*;
2
3  public class InputMismatchExceptionDemo {
4      public static void main(String[] args) {
5          Scanner input = new Scanner(System.in);
6          boolean continueInput = true;
7
8          do {
9              try {
10                 System.out.print("Enter an integer: ");
11                 int number = input.nextInt();
12             }
13             // If an InputMismatchException occurs
14             // Display the result
15             System.out.println(
16                 "The number entered is " + number);
17             continueInput = false;
18         }
19         catch (InputMismatchException ex) {
20             System.out.println("Try again. (" +
21                 "Incorrect input: an integer is required)");
22             input.nextLine(); // Discard input
23         }
24     } while (continueInput);
25 }
26 }
```

create a Scanner

try block

If an `InputMismatchException` occurs

catch block



```

Enter an integer: 3.5 Enter
Try again. (Incorrect input: an integer is required)
Enter an integer: 4 Enter
The number entered is 4
```

When executing `input.nextInt()` (line 11), an `InputMismatchException` occurs if the input entered is not an integer. Suppose `3.5` is entered. An `InputMismatchException` occurs and the control is transferred to the `catch` block. The statements in the `catch` block are now executed. The statement `input.nextLine()` in line 22 discards the current input line so the user can enter a new line of input. The variable `continueInput` controls the loop. Its initial value is `true` (line 6) and it is changed to `false` (line 17) when a valid input is received. Once a valid input is received, there is no need to continue the input.



**12.2.1** What is the advantage of using exception handling?

**12.2.2** Which of the following statements will throw an exception?

```

System.out.println(1 / 0);
System.out.println(1.0 / 0);
```

**12.2.3** Point out the problem in the following code. Does the code throw any exceptions?

```
long value = Long.MAX_VALUE + 1;
System.out.println(value);
```

**12.2.4** What does the JVM do when an exception occurs? How do you catch an exception?

**12.2.5** What is the output of the following code?

```
public class Test {
    public static void main(String[] args) {
        try {
            int value = 30;
            if (value < 40)
                throw new Exception("value is too small");
        }
        catch (Exception ex) {
            System.out.println(ex.getMessage());
        }
        System.out.println("Continue after the catch block");
    }
}
```

What would be the output if the line

```
int value = 30;
```

were changed to

```
int value = 50;
```

**12.2.6** Show the output of the following code:

```
public class Test {
    public static void main(String[] args) {
        for (int i = 0; i < 2; i++) {
            System.out.print(i + " ");
            try {
                System.out.println(1 / 0);
            }
            catch (Exception ex) {
            }
        }
    }
}
```

(a)

```
public class Test {
    public static void main(String[] args) {
        try {
            for (int i = 0; i < 2; i++) {
                System.out.print(i + " ");
                System.out.println(1 / 0);
            }
        }
        catch (Exception ex) {
        }
    }
}
```

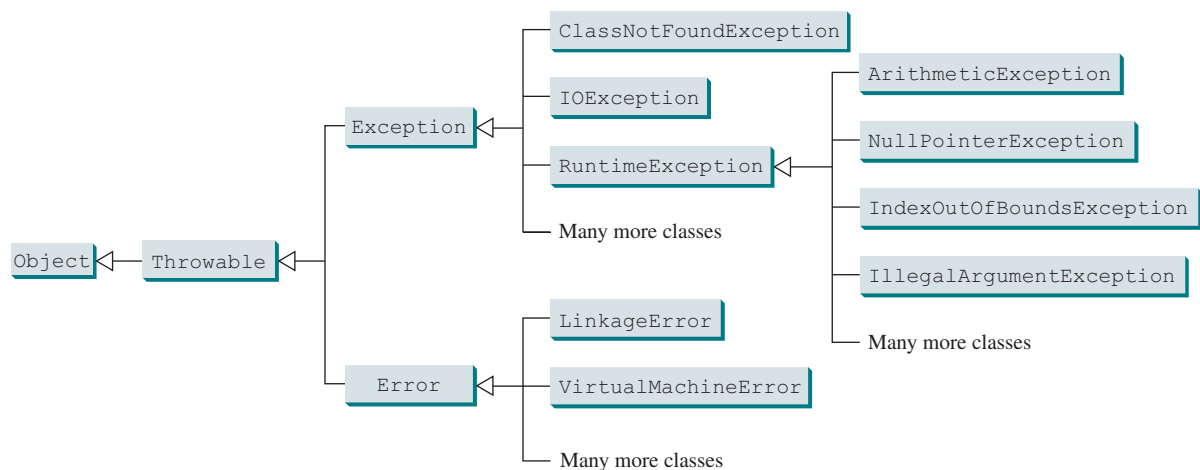
(b)

## 12.3 Exception Types

*Exceptions are objects, and objects are defined using classes. The root class for exceptions is `java.lang.Throwable`.*



The preceding section used the classes `ArithmeticException` and `InputMismatchException`. Are there any other types of exceptions you can use? Can you define your own exception classes? Yes. There are many predefined exception classes in the Java API. Figure 12.1 shows some of them, and in Section 12.9, you will learn how to define your own exception classes.



**FIGURE 12.1** Exceptions thrown are instances of the classes shown in this diagram, or of subclasses of one of these classes.



**Note**

The class names **Error**, **Exception**, and **RuntimeException** are somewhat confusing. All three of these classes are exceptions and all of the errors occur at runtime.

The **Throwable** class is the root of exception classes. All Java exception classes inherit directly or indirectly from **Throwable**. You can create your own exception classes by extending **Exception** or a subclass of **Exception**.

The exception classes can be classified into three major types: system errors, exceptions, and runtime exceptions.

system error

- *System errors* are thrown by the JVM and are represented in the **Error** class. The **Error** class describes internal system errors, though such errors rarely occur. If one does, there is little you can do beyond notifying the user and trying to terminate the program gracefully. Examples of subclasses of **Error** are listed in Table 12.1.

**TABLE 12.1** Examples of Subclasses of **Error**

Class	Reasons for Exception
<b>LinkageError</b>	A class has some dependency on another class, but the latter class has changed incompatibly after the compilation of the former class.
<b>VirtualMachineError</b>	The JVM is broken or has run out of the resources it needs in order to continue operating.

exception

- *Exceptions* are represented in the **Exception** class, which describes errors caused by your program and by external circumstances. These errors can be caught and handled by your program. Examples of subclasses of **Exception** are listed in Table 12.2.

**TABLE 12.2** Examples of Subclasses of **Exception**

Class	Reasons for Exception
<b>ClassNotFoundException</b>	Attempt to use a class that does not exist. This exception would occur, for example, if you tried to run a nonexistent class using the <b>java</b> command or if your program were composed of, say, three class files, only two of which could be found.
<b>IOException</b>	Related to input/output operations, such as invalid input, reading past the end of a file, and opening a nonexistent file. Examples of subclasses of <b>IOException</b> are <b>InterruptedIOException</b> , <b>EOFException</b> (EOF is short for End of File), and <b>FileNotFoundException</b> .



- *Runtime exceptions* are represented in the `RuntimeException` class, which describes programming errors, such as bad casting, accessing an out-of-bounds array, and numeric errors. Runtime exceptions normally indicate programming errors. Examples of subclasses are listed in Table 12.3.
- runtime exception

TABLE 12.3 Examples of Subclasses of `RuntimeException`

Class	Reasons for Exception
<code>ArithmeticException</code>	Dividing an integer by zero. Note floating-point arithmetic does not throw exceptions (see Appendix E, Special Floating-Point Values).
<code>NullPointerException</code>	Attempt to access an object through a <code>null</code> reference variable.
<code>IndexOutOfBoundsException</code>	Index to an array is out of range.
<code>IllegalArgumentException</code>	A method has passed an argument that is illegal or inappropriate.

`RuntimeException`, `Error`, and their subclasses are known as *unchecked exceptions*. All other exceptions are known as *checked exceptions*, meaning the compiler forces the programmer to check and deal with them in a `try-catch` block or declare it in the method header. Declaring an exception in the method header will be covered in Section 12.4.

In most cases, unchecked exceptions reflect programming logic errors that are unrecoverable. For example, a `NullPointerException` is thrown if you access an object through a reference variable before an object is assigned to it; an `IndexOutOfBoundsException` is thrown if you access an element in an array outside the bounds of the array. These are logic errors that should be corrected in the program. Unchecked exceptions can occur anywhere in a program. To avoid cumbersome overuse of `try-catch` blocks, Java does not mandate that you write code to catch or declare unchecked exceptions.

- 12.3.1

Describe the Java `Throwable` class, its subclasses, and the types of exceptions.
- 12.3.2

What `RuntimeException` will the following programs throw, if any?



```
public class Test {
    public static void main(String[] args) {
        System.out.println(1 / 0);
    }
}
```

(a)

```
public class Test {
    public static void main(String[] args) {
        int[] list = new int[5];
        System.out.println(list[5]);
    }
}
```

(b)

```
public class Test {
    public static void main(String[] args) {
        String s = "abc";
        System.out.println(s.charAt(3));
    }
}
```

(c)

```
public class Test {
    public static void main(String[] args) {
        Object o = new Object();
        String d = (String)o;
    }
}
```

(d)

```
public class Test {
    public static void main(String[] args) {
        Object o = null;
        System.out.println(o.toString());
    }
}
```

(e)

```
public class Test {
    public static void main(String[] args) {
        System.out.println(1.0 / 0);
    }
}
```

(f)

- 12.3.3

What is a checked exception and what is an unchecked exception?

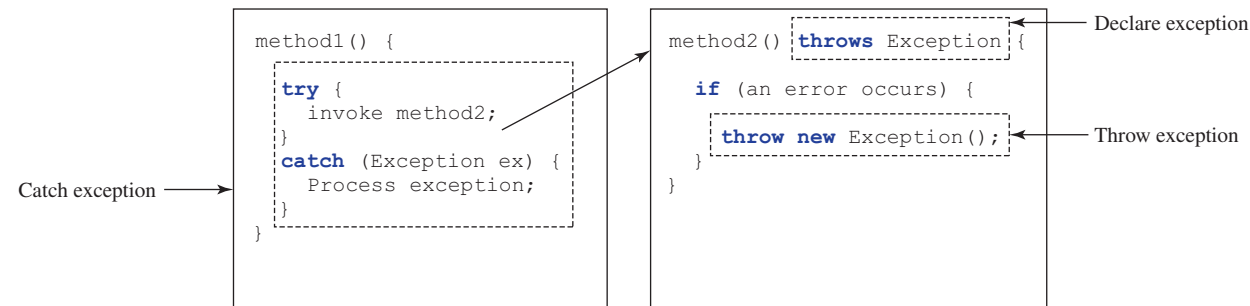


## 12.4 Declaring, Throwing, and Catching Exceptions

*A handler for an exception is found by propagating the exception backward through a chain of method calls, starting from the current method.*

The preceding sections gave you an overview of exception handling and introduced several predefined exception types. This section provides an in-depth discussion of exception handling.

Java’s exception-handling model is based on three operations: *declaring an exception*, *throwing an exception*, and *catching an exception*, as shown in Figure 12.2.



**FIGURE 12.2** Exception handling in Java consists of declaring exceptions, throwing exceptions, and catching and processing exceptions.

### 12.4.1 Declaring Exceptions

In Java, the statement currently being executed belongs to a method. The Java interpreter invokes the `main` method to start executing a program. Every method must state the types of checked exceptions it might throw. This is known as *declaring exceptions*. Because system errors and runtime errors can happen to any code, Java does not require that you declare `Error` and `RuntimeException` (unchecked exceptions) explicitly in the method. However, all other exceptions thrown by the method must be explicitly declared in the method header so the caller of the method is informed of the exception.

To declare an exception in a method, use the `throws` keyword in the method header, as in this example:

```
public void myMethod() throws IOException
```

The `throws` keyword indicates `myMethod` might throw an `IOException`. If the method might throw multiple exceptions, add a list of the exceptions, separated by commas, after `throws`:

```
public void myMethod()  
    throws Exception1, Exception2, ..., ExceptionN
```



#### Note

If a method does not declare exceptions in the superclass, you cannot override it to declare exceptions in the subclass.

### 12.4.2 Throwing Exceptions

A program that detects an error can create an instance of an appropriate exception type and throw it. This is known as *throwing an exception*. Here is an example: Suppose the program detects that an argument passed to the method violates the method contract (e.g., the argument

must be nonnegative, but a negative argument is passed); the program can create an instance of `IllegalArgumentException` and throw it, as follows:

```
IllegalArgumentException ex =
    new IllegalArgumentException("Wrong Argument");
throw ex;
```

Or, if you prefer, you can use the following:

```
throw new IllegalArgumentException("Wrong Argument");
```



#### Note

`IllegalArgumentException` is an exception class in the Java API. In general, each exception class in the Java API has at least two constructors: a no-arg constructor and a constructor with a `String` argument that describes the exception. This argument is called the *exception message*, which can be obtained by invoking `getMessage()` from an exception object.

exception message



#### Tip

The keyword to declare an exception is `throws`, and the keyword to throw an exception is `throw`.

throws vs. throw

### 12.4.3 Catching Exceptions

You now know how to declare an exception and how to throw an exception. When an exception is thrown, it can be caught and handled in a `try-catch` block, as follows:

catch exception

```
try {
    statements; // Statements that may throw exceptions
}
catch (Exception1 exVar1) {
    handler for exception1;
}
catch (Exception2 exVar2) {
    handler for exception2;
}
...
catch (ExceptionN exVarN) {
    handler for exceptionN;
}
```

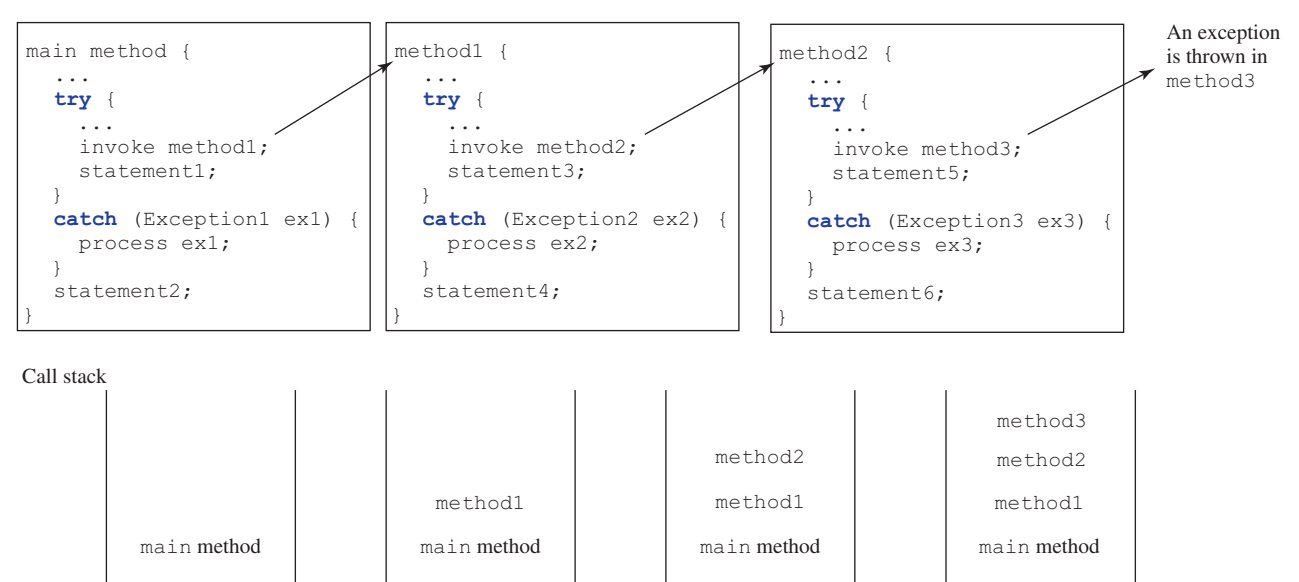
If no exceptions arise during the execution of the `try` block, the `catch` blocks are skipped.

If one of the statements inside the `try` block throws an exception, Java skips the remaining statements in the `try` block and starts the process of finding the code to handle the exception. The code that handles the exception is called the *exception handler*; it is found by *propagating the exception* backward through a chain of method calls, starting from the current method. Each `catch` block is examined in turn, from first to last, to see whether the type of the exception object is an instance of the exception class in the `catch` block. If so, the exception object is assigned to the variable declared and the code in the `catch` block is executed. If no handler is found, Java exits this method, passes the exception to the method's caller, and continues the same process to find a handler. If no handler is found in the chain of methods being invoked, the program terminates and prints an error message on the console. The process of finding a handler is called *catching an exception*.

exception handler  
exception propagation


Suppose the `main` method invokes `method1`, `method1` invokes `method2`, `method2` invokes `method3`, and `method3` throws an exception, as shown in Figure 12.3. Consider the following scenario:

- If the exception type is `Exception3`, it is caught by the `catch` block for handling exception `ex3` in `method2`. `statement5` is skipped and `statement6` is executed.
- If the exception type is `Exception2`, `method2` is aborted, the control is returned to `method1`, and the exception is caught by the `catch` block for handling exception `ex2` in `method1`. `statement3` is skipped and `statement4` is executed.
- If the exception type is `Exception1`, `method1` is aborted, the control is returned to the `main` method, and the exception is caught by the `catch` block for handling exception `ex1` in the `main` method. `statement1` is skipped and `statement2` is executed.
- If the exception type is not caught in `method2`, `method1`, or `main`, the program terminates and `statement1` and `statement2` are not executed.




**FIGURE 12.3** If an exception is not caught in the current method, it is passed to its caller. The process is repeated until the exception is caught or passed to the `main` method.

catch block


**Note**

Various exception classes can be derived from a common superclass. If a `catch` block catches exception objects of a superclass, it can catch all the exception objects of the subclasses of that superclass.

order of exception handlers


**Note**

The order in which exceptions are specified in `catch` blocks is important. A compile error will result if a catch block for a superclass type appears before a catch block for a subclass type. For example, the ordering in (a) below is erroneous, because `RuntimeException` is a subclass of `Exception`. The correct ordering should be as shown in (b).

```
try {
    ...
}
catch (Exception ex) {
    ...
}
catch (RuntimeException ex) {
    ...
}
```

(a) Wrong order

```
try {
    ...
}
catch (RuntimeException ex) {
    ...
}
catch (Exception ex) {
    ...
}
```

(b) Correct order

**Note**

Java forces you to deal with checked exceptions. If a method declares a checked exception (i.e., an exception other than **Error** or **RuntimeException**), you must invoke it in a **try-catch** block or declare to throw the exception in the calling method. For example, suppose method **p1** invokes method **p2** and **p2** may throw a checked exception (e.g., **IOException**); you have to write the code as shown in (a) or (b) below.

catch or declare checked exceptions

```
void p1() {
    try {
        p2();
    }
    catch (IOException ex) {
        ...
    }
}
```

(a) Catch exception

```
void p1() throws IOException {
    p2();
}
```

(b) Throw exception

**Note**

You can use the new JDK 7 multcatch feature to simplify coding for the exceptions with the same handling code. The syntax is:

JDK 7 multcatch

```
catch (Exception1 | Exception2 | ... | Exceptionk ex) {
    // Same code for handling these exceptions
}
```

Each exception type is separated from the next with a vertical bar (**|**). If one of the exceptions is caught, the handling code is executed.

### 12.4.4 Getting Information from Exceptions

An exception object contains valuable information about the exception. You may use the following instance methods in the **java.lang.Throwable** class to get information regarding the exception, as shown in Figure 12.4. The **printStackTrace()** method prints stack trace information on the console. The stack trace lists all the methods in the call stack, which provides

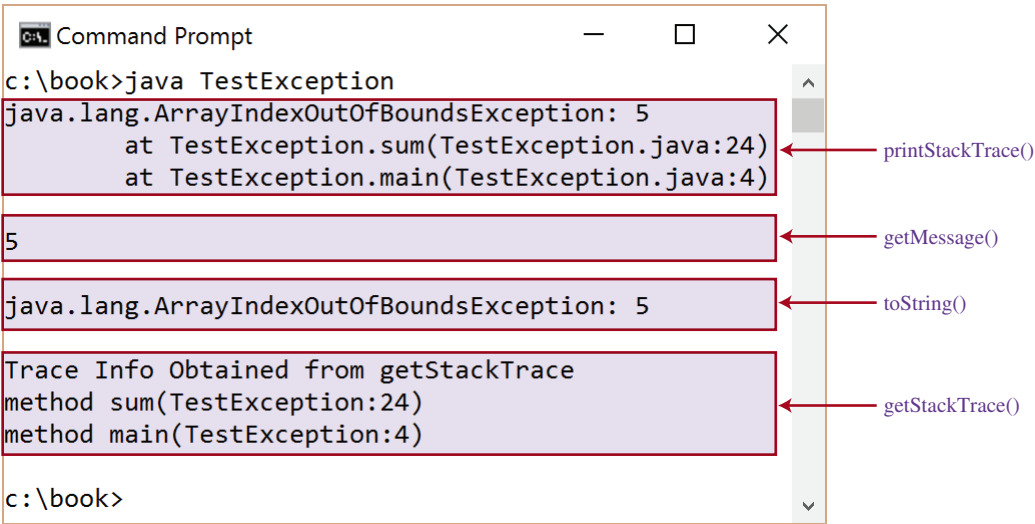
methods in Throwable

<b>java.lang.Throwable</b>	
<b>+getMessage(): String</b>	Returns the message that describes this exception object.
<b>+toString(): String</b>	Returns the concatenation of three strings: (1) the full name of the exception class; (2) " : " (a colon and a space); and (3) the <code>getMessage()</code> method.
<b>+printStackTrace(): void</b>	Prints the <code>Throwable</code> object and its call stack trace information on the console.
<b>+getStackTrace(): StackTraceElement[]</b>	Returns an array of stack trace elements representing the stack trace pertaining to this exception object.

**FIGURE 12.4** **Throwable** is the root class for all exception objects.

valuable information for debugging runtime errors. The `getStackTrace()` method provides programmatic access to the stack trace information printed by `printStackTrace()`.

Listing 12.6 gives an example that uses the methods in `Throwable` to display exception information. Line 4 invokes the `sum` method to return the sum of all the elements in the array. There is an error in line 23 that causes the `ArrayIndexOutOfBoundsException`, a subclass of `IndexOutOfBoundsException`. This exception is caught in the `try-catch` block. Lines 7, 8, and 9 display the stack trace, exception message, and exception object and message using the `printStackTrace()`, `getMessage()`, and `toString()` methods, as shown in Figure 12.5. Line 12 brings stack trace elements into an array. Each element represents a method call. You can obtain the method (line 14), class name (line 15), and exception line number (line 16) for each element.



**FIGURE 12.5** You can use the `printStackTrace()`, `getMessage()`, `toString()`, and `getStackTrace()` methods to obtain information from exception objects.

**LISTING 12.6**
TestException.java

invoke sum

printStackTrace()

getMessage()

toString()

getStackTrace()

cause an exception

```

1 public class TestException {
2     public static void main(String[] args) {
3         try {
4             System.out.println(sum(new int[] {1, 2, 3, 4, 5}));
5         }
6         catch (Exception ex) {
7             ex.printStackTrace();
8             System.out.println("\n" + ex.getMessage());
9             System.out.println("\n" + ex.toString());
10
11             System.out.println("\nTrace Info Obtained from getStackTrace");
12             StackTraceElement[] traceElements = ex.getStackTrace();
13             for (int i = 0; i < traceElements.length; i++) {
14                 System.out.print("method " + traceElements[i].getMethodName());
15                 System.out.print("(" + traceElements[i].getClassName() + ":");
16                 System.out.println(traceElements[i].getLineNumber() + ")");
17             }
18         }
19     }
20
21     private static int sum(int[] list) {
22         int result = 0;
23         for (int i = 0; i <= list.length; i++)

```

```

24         result += list[i];
25     return result;
26 }
27 }

```

### 12.4.5 Example: Declaring, Throwing, and Catching Exceptions

This example demonstrates declaring, throwing, and catching exceptions by modifying the `setRadius` method in the `Circle` class in Listing 9.8, `Circle.java` (`CircleWithPrivateDataField`). The new `setRadius` method throws an exception if the radius is negative.

Listing 12.7 defines a new circle class named `CircleWithException`, which is the same as `Circle` in Listing 9.8 except that the `setRadius(double newRadius)` method throws an `IllegalArgumentException` if the argument `newRadius` is negative.

#### LISTING 12.7 `CircleWithException.java`

```

1  public class CircleWithException {
2      /** The radius of the circle */
3      private double radius;
4
5      /** The number of the objects created */
6      private static int numberOfObjects = 0;
7
8      /** Construct a circle with radius 1 */
9      public CircleWithException() {
10         this(1.0);
11     }
12
13     /** Construct a circle with a specified radius */
14     public CircleWithException(double newRadius) {
15         setRadius(newRadius);
16         numberOfObjects++;
17     }
18
19     /** Return radius */
20     public double getRadius() {
21         return radius;
22     }
23
24     /** Set a new radius */
25     public void setRadius(double newRadius)
26         throws IllegalArgumentException {                declare exception
27         if (newRadius >= 0)
28             radius = newRadius;
29         else
30             throw new IllegalArgumentException(           throw exception
31                 "Radius cannot be negative");
32     }
33
34     /** Return numberOfObjects */
35     public static int getNumberOfObjects() {
36         return numberOfObjects;
37     }
38
39     /** Return the area of this circle */
40     public double findArea() {
41         return radius * radius * 3.14159;
42     }
43 }

```

A test program that uses the new `Circle` class is given in Listing 12.8.

### LISTING 12.8 `TestCircleWithException.java`

```

1  public class TestCircleWithException {
2      public static void main(String[] args) {
3          try {
4              CircleWithException c1 = new CircleWithException(5);
5              CircleWithException c2 = new CircleWithException(-5);
6              CircleWithException c3 = new CircleWithException(0);
7          }
8          catch (IllegalArgumentException ex) {
9              System.out.println(ex);
10         }
11
12         System.out.println("Number of objects created: " +
13             CircleWithException.getNumberOfObjects());
14     }
15 }

```



```

java.lang.IllegalArgumentException: Radius cannot be negative
Number of objects created: 1

```

The original `Circle` class remains intact except that the class name is changed to `CircleWithException`, a new constructor `CircleWithException(newRadius)` is added, and the `setRadius` method now declares an exception and throws it if the radius is negative.

The `setRadius` method declares to throw `IllegalArgumentException` in the method header (lines 25–32 in Listing 12.7 `CircleWithException.java`). The `CircleWithException` class would still compile if the `throws IllegalArgumentException` clause (line 26) were removed from the method declaration, since it is a subclass of `RuntimeException` and every method can throw `RuntimeException` (an unchecked exception) regardless of whether it is declared in the method header.

The test program creates three `CircleWithException` objects—`c1`, `c2`, and `c3`—to test how to handle exceptions. Invoking `new CircleWithException(-5)` (line 5 in Listing 12.8) causes the `setRadius` method to be invoked, which throws an `IllegalArgumentException`, because the radius is negative. In the `catch` block, the type of the object `ex` is `IllegalArgumentException`, which matches the exception object thrown by the `setRadius` method, so this exception is caught by the `catch` block.

The exception handler prints a short message, `ex.toString()` (line 9 in Listing 12.8), about the exception, using `System.out.println(ex)`.

Note that the execution continues in the event of the exception. If the handlers had not caught the exception, the program would have abruptly terminated.

The test program would still compile if the `try` statement were not used, because the method throws an instance of `IllegalArgumentException`, a subclass of `RuntimeException` (an unchecked exception).



**12.4.1** What is the purpose of declaring exceptions? How do you declare an exception and where? Can you declare multiple exceptions in a method header?

**12.4.2** How do you throw an exception? Can you throw multiple exceptions in one `throw` statement?

**12.4.3** What is the keyword `throw` used for? What is the keyword `throws` used for?

**12.4.4** Suppose `statement2` causes an exception in the following `try-catch` block:

```

try {
    statement1;
}

```



```

    statement2;
    statement3;
}
catch (Exception1 ex1) {
}
catch (Exception2 ex2) {
}

statement4;

```

Answer the following questions:

- Will **statement3** be executed?
- If the exception is not caught, will **statement4** be executed?
- If the exception is caught in the **catch** block, will **statement4** be executed?

**12.4.5** What is displayed when running the following program?

```

public class Test {
    public static void main(String[] args) {
        try {
            int[] list = new int[10];
            System.out.println("list[10] is " + list[10]);
        }
        catch (ArithmeticException ex) {
            System.out.println("ArithmeticException");
        }
        catch (RuntimeException ex) {
            System.out.println("RuntimeException");
        }
        catch (Exception ex) {
            System.out.println("Exception");
        }
    }
}

```

**12.4.6** What is displayed when running the following program?

```

public class Test {
    public static void main(String[] args) {
        try {
            method();
            System.out.println("After the method call");
        }
        catch (ArithmeticException ex) {
            System.out.println("ArithmeticException");
        }
        catch (RuntimeException ex) {
            System.out.println("RuntimeException");
        }
        catch (Exception e) {
            System.out.println("Exception");
        }
    }

    static void method() throws Exception {
        System.out.println(1 / 0);
    }
}

```

**12.4.7** What is displayed when running the following program?

```
public class Test {
    public static void main(String[] args) {
        try {
            method();
            System.out.println("After the method call");
        }
        catch (RuntimeException ex) {
            System.out.println("RuntimeException in main");
        }
        catch (Exception ex) {
            System.out.println("Exception in main");
        }
    }

    static void method() throws Exception {
        try {
            String s = "abc";
            System.out.println(s.charAt(3));
        }
        catch (RuntimeException ex) {
            System.out.println("RuntimeException in method()");
        }
        catch (Exception ex) {
            System.out.println("Exception in method()");
        }
    }
}
```

**12.4.8** What does the method `getMessage()` do?

**12.4.9** What does the method `printStackTrace()` do?

**12.4.10** Does the presence of a **try-catch** block impose overhead when no exception occurs?

**12.4.11** Correct a compile error in the following code:

```
public void m(int value) {
    if (value < 40)
        throw new Exception("value is too small");
}
```

## 12.5 The **finally** Clause

*The **finally** clause is always executed regardless of whether an exception occurred or not.*



Occasionally, you may want some code to be executed regardless of whether an exception occurs or is caught. Java has a **finally** clause that can be used to accomplish this objective. The syntax for the **finally** clause might look like this:

```
try {
    statements;
}
catch (TheException ex) {
    handling ex;
}
finally {
    finalStatements;
}
```

The code in the **finally** block is executed under all circumstances, regardless of whether an exception occurs in the **try** block or is caught. Consider three possible cases:

1. If no exception arises in the **try** block, **finalStatements** is executed and the next statement after the **try** statement is executed.
2. If a statement causes an exception in the **try** block that is caught in a **catch** block, the rest of the statements in the **try** block are skipped, the **catch** block is executed, and the **finally** clause is executed. The next statement after the **try** statement is executed.
3. If one of the statements causes an exception that is not caught in any **catch** block, the other statements in the **try** block are skipped, the **finally** clause is executed, and the exception is passed to the caller of this method.

The code in the **finally** clause is often for closing files and for cleaning up resources. The **finally** block executes even if there is a **return** statement prior to reaching the **finally** block.



### Note

The **catch** block may be omitted when the **finally** clause is used, as shown in the following code:

omit catch block

```
try {
    code may throw a non-checked exception; regardless of whether an
    exception occurs, finalStatements are executed.
}
finally {
    finalStatements;
}
```

**12.5.1** Suppose you run the following code:

```
public static void main(String[] args) throws Exception2 {
    m();
    statement7;
}

public static void m() {
    try {
        statement1;
        statement2;
        statement3;
    }
    catch (Exception1 ex1) {
        statement4;
    }
    finally {
        statement5;
    }
    statement6;
}
```



Check  
Point

Answer the following questions:

- a. If no exception occurs, which statements are executed?
- b. If **statement2** throws an exception of type **Exception1**, which statements are executed?
- c. If **statement2** throws an exception of type **Exception2**, which statements are executed?
- d. If **statement2** throws an exception that is neither **Exception1** nor **Exception2**, which statements are executed?



## 12.6 When to Use Exceptions

*A method should throw an exception if the error needs to be handled by its caller.*

The **try** block contains the code that is executed in normal circumstances. The **catch** block contains the code that is executed in exceptional circumstances. Exception handling separates error-handling code from normal programming tasks, thus making programs easier to read and to modify. Be aware, however, that exception handling usually requires more time and resources, because it requires instantiating a new exception object, rolling back the call stack, and propagating the exception through the chain of method calls to search for the handler.

An exception occurs in a method. If you want the exception to be processed by its caller, you should create an exception object and throw it. If you can handle the exception in the method where it occurs, there is no need to throw or use exceptions.

In general, common exceptions that may occur in multiple classes in a project are candidates for exception classes. Simple errors that may occur in individual methods are best handled without throwing exceptions. This can be done by using **if** statements to check for errors.

When should you use a **try-catch** block in the code? Use it when you have to deal with unexpected error conditions. Do not use a **try-catch** block to deal with simple, expected situations. For example, the following code:

```
try {
    System.out.println(refVar.toString());
}
catch (NullPointerException ex) {
    System.out.println("refVar is null");
}
```

is better replaced by

```
if (refVar != null)
    System.out.println(refVar.toString());
else
    System.out.println("refVar is null");
```

Which situations are exceptional and which are expected is sometimes difficult to decide. The point is not to abuse exception handling as a way to deal with a simple logic test.



**12.6.1** The following method checks whether a string is a numeric string:

```
public static boolean isNumeric(String token) {
    try {
        Double.parseDouble(token);
        return true;
    }
    catch (java.lang.NumberFormatException ex) {
        return false;
    }
}
```

Is it correct? Rewrite it without using exceptions.



## 12.7 Rethrowing Exceptions

*Java allows an exception handler to rethrow the exception if the handler cannot process the exception, or simply wants to let its caller be notified of the exception.*

The syntax for rethrowing an exception may look like this:

```
try {
    statements;
```

```

}
catch (TheException ex) {
    perform operations before exits;
    throw ex;
}

```

The statement `throw ex` rethrows the exception to the caller so other handlers in the caller get a chance to process the exception `ex`.

**12.7.1** Suppose that `statement2` may cause an exception in the following code:



```

try {
    statement1;
    statement2;
    statement3;
}
catch (Exception1 ex1) {
}
catch (Exception2 ex2) {
    throw ex2;
}
finally {
    statement4;
}
statement5;

```

Answer the following questions:

- If no exception occurs, will `statement4` or `statement5` be executed?
- If the exception is of type `Exception1`, will `statement4` or `statement5` be executed?
- If the exception is of type `Exception2`, will `statement4` or `statement5` be executed?
- If the exception is not `Exception1` nor `Exception2`, will `statement4` or `statement5` be executed?

## 12.8 Chained Exceptions

*Throwing an exception along with another exception forms a chained exception.*



In the preceding section, the `catch` block rethrows the original exception. Sometimes, you may need to throw a new exception (with additional information) along with the original exception. This is called *chained exceptions*. Listing 12.9 illustrates how to create and throw chained exceptions.

chained exception

### LISTING 12.9 ChainedExceptionDemo.java

```

1 public class ChainedExceptionDemo {
2     public static void main(String[] args) {
3         try {
4             method1();
5         }
6         catch (Exception ex) {
7             ex.printStackTrace();
8         }
9     }
10
11     public static void method1() throws Exception {
12         try {
13             method2();

```

stack trace

```

14     }
15     catch (Exception ex) {
16         throw new Exception("New info from method1", ex);
17     }
18 }
19
20 public static void method2() throws Exception {
21     throw new Exception("New info from method2");
22 }
23 }

```

chained exception

throw exception



```

java.lang.Exception: New info from method1
    at ChainedExceptionDemo.method1(ChainedExceptionDemo.java:16)
    at ChainedExceptionDemo.main(ChainedExceptionDemo.java:4)
Caused by: java.lang.Exception: New info from method2
    at ChainedExceptionDemo.method2(ChainedExceptionDemo.java:21)
    at ChainedExceptionDemo.method1(ChainedExceptionDemo.java:13)
    ... 1 more

```

The **main** method invokes **method1** (line 4), **method1** invokes **method2** (line 13), and **method2** throws an exception (line 21). This exception is caught in the **catch** block in **method1** and is wrapped in a new exception in line 16. The new exception is thrown and caught in the catch block in the **main** method in line 6. The sample output shows the output from the **printStackTrace()** method in line 7. The new exception thrown from **method1** is displayed first, followed by the original exception thrown from **method2**.



**12.8.1** What would be the output if line 16 of Listing 12.9 is replaced by the following line?

```
throw new Exception("New info from method1");
```

## 12.9 Defining Custom Exception Classes

*You can define a custom exception class by extending the `java.lang.Exception` class.*



Java provides quite a few exception classes. Use them whenever possible instead of defining your own exception classes. However, if you run into a problem that cannot be adequately described by the predefined exception classes, you can create your own exception class, derived from **Exception** or from a subclass of **Exception**, such as **IOException**.

In Listing 12.7, `CircleWithException.java`, the **setRadius** method throws an exception if the radius is negative. Suppose you wish to pass the radius to the handler. In that case, you can define a custom exception class, as shown in Listing 12.10.



VideoNote

Create custom exception classes

### LISTING 12.10 InvalidRadiusException.java

```

1  public class InvalidRadiusException extends Exception {
2      private double radius;
3
4      /** Construct an exception */
5      public InvalidRadiusException(double radius) {
6          super("Invalid radius " + radius);
7          this.radius = radius;
8      }
9
10     /** Return the radius */
11     public double getRadius() {
12         return radius;
13     }
14 }

```

extends Exception

This custom exception class extends `java.lang.Exception` (line 1). The `Exception` class extends `java.lang.Throwable`. All the methods (e.g., `getMessage()`, `toString()`, and `printStackTrace()`) in `Exception` are inherited from `Throwable`. The `Exception` class contains four constructors. Among them, the following constructors are often used:

<code>java.lang.Exception</code>	
<code>+Exception()</code>	Constructs an exception with no message.
<code>+Exception(message: String)</code>	Constructs an exception with the specified message.
<code>+Exception(message: String, cause: Exception)</code>	Constructs an exception with the specified message and a cause. This forms a chained exception.

Line 6 invokes the superclass's constructor with a message. This message will be set in the exception object and can be obtained by invoking `getMessage()` on the object.



### Tip

Most exception classes in the Java API contain two constructors: a no-arg constructor and a constructor with a message parameter.

To create an `InvalidRadiusException`, you have to pass a radius. Therefore, the `setRadius` method in Listing 12.7 can be modified as shown in Listing 12.11.

## LISTING 12.11 TestCircleWithCustomException.java

```

1  public class TestCircleWithCustomException {
2      public static void main(String[] args) {
3          try {
4              new CircleWithCustomException(5);
5              new CircleWithCustomException(-5);
6              new CircleWithCustomException(0);
7          }
8          catch (InvalidRadiusException ex) {
9              System.out.println(ex);
10         }
11
12         System.out.println("Number of objects created: " +
13             CircleWithCustomException.getNumberOfObjects());
14     }
15 }
16
17 class CircleWithCustomException {
18     /** The radius of the circle */
19     private double radius;
20
21     /** The number of objects created */
22     private static int numberOfObjects = 0;
23
24     /** Construct a circle with radius 1 */
25     public CircleWithCustomException() throws InvalidRadiusException { declare exception
26         this(1.0);
27     }
28
29     /** Construct a circle with a specified radius */
30     public CircleWithCustomException(double newRadius)
31         throws InvalidRadiusException {
32         setRadius(newRadius);
33         numberOfObjects++;
34     }
35 }

```

throw exception

```

36  /** Return radius */
37  public double getRadius() {
38      return radius;
39  }
40
41  /** Set a new radius */
42  public void setRadius(double newRadius)
43      throws InvalidRadiusException {
44      if (newRadius >= 0)
45          radius = newRadius;
46      else
47          throw new InvalidRadiusException(newRadius);
48  }
49
50  /** Return numberOfObjects */
51  public static int getNumberOfObjects() {
52      return numberOfObjects;
53  }
54
55  /** Return the area of this circle */
56  public double findArea() {
57      return radius * radius * 3.14159;
58  }
59  }

```



```

InvalidRadiusException: Invalid radius -5.0
Number of objects created: 1

```

The `setRadius` method in `CircleWithCustomException` throws an `InvalidRadiusException` when radius is negative (line 47). Since `InvalidRadiusException` is a checked exception, the `setRadius` method must declare it in the method header (line 43). Since the constructors for `CircleWithCustomException` invoke the `setRadius` method to set a new radius, and it may throw an `InvalidRadiusException`, the constructors are declared to throw `InvalidRadiusException` (lines 25 and 31).

Invoking `new CircleWithCustomException(-5)` (line 5) throws an `InvalidRadiusException`, which is caught by the handler. The handler displays the radius in the exception object `ex`.

checked custom exception

**Tip**

Can you define a custom exception class by extending `RuntimeException`? Yes, but it is not a good way to go because it makes your custom exception unchecked. It is better to make a custom exception checked, so the compiler can force these exceptions to be caught in your program.

**Check Point****12.9.1** How do you define a custom exception class?**12.9.2** Suppose that the `setRadius` method throws the `InvalidRadiusException` defined in Listing 12.10. What is displayed when running the following program?

```

public class Test {
    public static void main(String[] args) {
        try {
            method();
            System.out.println("After the method call");
        }
        catch (RuntimeException ex) {
            System.out.println("RuntimeException in main");
        }
    }
}

```



```

        catch (Exception ex) {
            System.out.println("Exception in main");
        }
    }

    static void method() throws Exception {
        try {
            Circle c1 = new Circle(1);
            c1.setRadius(-1);
            System.out.println(c1.getRadius());
        }
        catch (RuntimeException ex) {
            System.out.println("RuntimeException in method()");
        }
        catch (Exception ex) {
            System.out.println("Exception in method()");
            throw ex;
        }
    }
}

```

## 12.10 The **File** Class

The **File** class contains the methods for obtaining the properties of a file/directory, and for renaming and deleting a file/directory.

Having learned exception handling, you are ready to step into file processing. Data stored in the program are temporary; they are lost when the program terminates. To permanently store the data created in a program, you need to save them in a file on a disk or other permanent storage device. The file can then be transported and read later by other programs. Since data are stored in files, this section introduces how to use the **File** class to obtain file/directory properties, to delete and rename files/directories, and to create directories. The next section introduces how to read/write data from/to text files.

Every file is placed in a directory in the file system. An *absolute file name* (or *full name*) contains a file name with its complete path and drive letter. For example, **c:\book\Welcome.java** is the absolute file name for the file **Welcome.java** on the Windows operating system. Here, **c:\book** is referred to as the *directory path* for the file. Absolute file names are machine dependent. On the UNIX platform, the absolute file name may be **/home/liang/book/Welcome.java**, where **/home/liang/book** is the directory path for the file **Welcome.java**.

A *relative file name* is in relation to the current working directory. The complete directory path for a relative file name is omitted. For example, **Welcome.java** is a relative file name. If the current working directory is **c:\book**, the absolute file name would be **c:\book\Welcome.java**.

The **File** class is intended to provide an abstraction that deals with most of the machine-dependent complexities of files and path names in a machine-independent fashion. The **File** class contains the methods for obtaining file and directory properties, and for renaming and deleting files and directories, as shown in Figure 12.6. However, the **File** class does not contain the methods for reading and writing file contents.

The file name is a string. The **File** class is a wrapper class for the file name and its directory path. For example, **new File("c:\\book")** creates a **File** object for the directory **c:\book** and **new File("c:\\book\\test.dat")** creates a **File** object for the file **c:\book\test.dat**, both on Windows. You can use the **File** class's **isDirectory()** method to check whether the object represents a directory, and the **isFile()** method to check whether the object represents a file.



why file?

absolute file name

directory path

relative file name

java.io.File	
+File(pathname: String)	Creates a File object for the specified path name. The path name may be a directory or a file.
+File(parent: String, child: String)	Creates a File object for the child under the directory parent. The child may be a file name or a subdirectory.
+File(parent: File, child: String)	Creates a File object for the child under the directory parent. The parent is a File object. In the preceding constructor, the parent is a string.
+exists(): boolean	Returns true if the file or the directory represented by the File object exists.
+canRead(): boolean	Returns true if the file represented by the File object exists and can be read.
+canWrite(): boolean	Returns true if the file represented by the File object exists and can be written.
+isDirectory(): boolean	Returns true if the File object represents a directory.
+isFile(): boolean	Returns true if the File object represents a file.
+isAbsolute(): boolean	Returns true if the File object is created using an absolute path name.
+isHidden(): boolean	Returns true if the file represented in the File object is hidden. The exact definition of <i>hidden</i> is system dependent. On Windows, you can mark a file hidden in the File Properties dialog box. On Unix systems, a file is hidden if its name begins with a period (.) character.
+getAbsolutePath(): String	Returns the complete absolute file or directory name represented by the File object.
+getCanonicalPath(): String	Returns the same as getAbsolutePath() except that it removes redundant names, such as "." and "..", from the path name, resolves symbolic links (on Unix), and converts drive letters to standard uppercase (on Windows).
+getName(): String	Returns the last name of the complete directory and file name represented by the File object. For example, new File("c:\\book\\test.dat").getName() returns test.dat.
+getPath(): String	Returns the complete directory and file name represented by the File object. For example, new File("c:\\book\\test.dat").getPath() returns c:\\book\\test.dat.
+getParent(): String	Returns the complete parent directory of the current directory or the file represented by the File object. For example, new File("c:\\book\\test.dat").getParent() returns c:\\book.
+lastModified(): long	Returns the time that the file was last modified.
+length(): long	Returns the size of the file, or 0 if it does not exist or if it is a directory.
+listFile(): File[]	Returns the files under the directory for a directory File object.
+delete(): boolean	Deletes the file or directory represented by this File object. The method returns true if the deletion succeeds.
+renameTo(dest: File): boolean	Renames the file or directory represented by this File object to the specified name represented in dest. The method returns true if the operation succeeds.
+mkdir(): boolean	Creates a directory represented in this File object. Returns true if the the directory is created successfully.
+mkdirs(): boolean	Same as mkdir() except that it creates directory along with its parent directories if the parent directories do not exist.

**FIGURE 12.6** The **File** class can be used to obtain file and directory properties, to delete and rename files and directories, and to create directories.

\ in file names



**Caution**

The directory separator for Windows is a backslash (\). The backslash is a special character in Java and should be written as \\ in a string literal (see Table 4.5).



**Note**

Constructing a **File** instance does not create a file on the machine. You can create a **File** instance for any file name regardless of whether it exists or not. You can invoke the **exists()** method on a **File** instance to check whether the file exists.

relative file name

Java directory separator (/)

Do not use absolute file names in your program. If you use a file name such as **c:\\book\\Welcome.java**, it will work on Windows but not on other platforms. You should use a file name relative to the current directory. For example, you may create a **File** object using **new File("Welcome.java")** for the file **Welcome.java** in the current directory. You may create a **File** object using **new File("image/us.gif")** for the file **us.gif** under the **image** directory in the current directory. The forward slash (/) is the Java directory separator, which

is the same as on UNIX. The statement `new File("image/us.gif")` works on Windows, UNIX, and any other platform.

Listing 12.12 demonstrates how to create a **File** object and use the methods in the **File** class to obtain its properties. The program creates a **File** object for the file **us.gif**. This file is stored under the **image** directory in the current directory.

### LISTING 12.12 TestFileClass.java

```

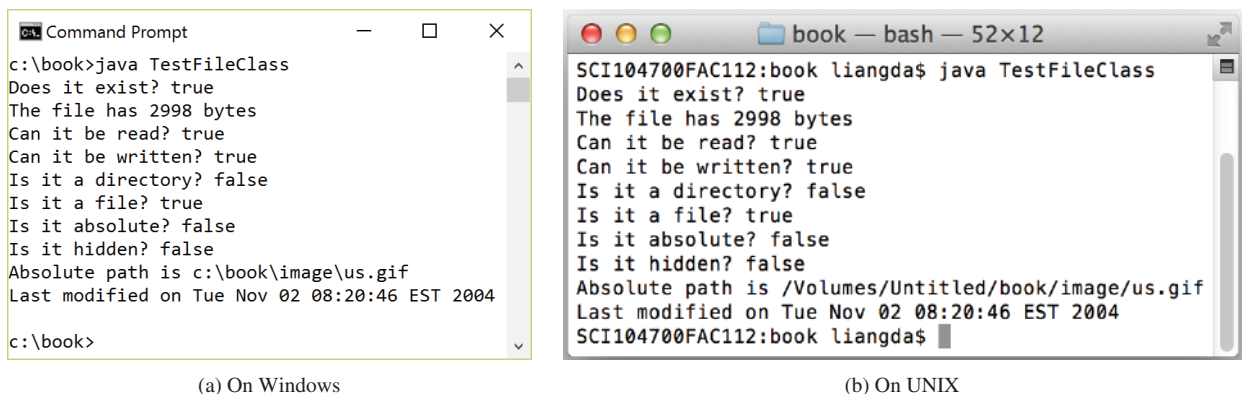
1 public class TestFileClass {
2     public static void main(String[] args) {
3         java.io.File file = new java.io.File("image/us.gif");
4         System.out.println("Does it exist? " + file.exists());
5         System.out.println("The file has " + file.length() + " bytes");
6         System.out.println("Can it be read? " + file.canRead());
7         System.out.println("Can it be written? " + file.canWrite());
8         System.out.println("Is it a directory? " + file.isDirectory());
9         System.out.println("Is it a file? " + file.isFile());
10        System.out.println("Is it absolute? " + file.isAbsolute());
11        System.out.println("Is it hidden? " + file.isHidden());
12        System.out.println("Absolute path is " +
13            file.getAbsolutePath());
14        System.out.println("Last modified on " +
15            new java.util.Date(file.lastModified()));
16    }
17 }

```

create a File  
exists()  
length()  
canRead()  
canWrite()  
isDirectory()  
isFile()  
isAbsolute()  
isHidden()  
getAbsolutePath()  
lastModified()

The `lastModified()` method returns the date and time when the file was last modified, measured in milliseconds since the beginning of UNIX time (00:00:00 GMT, January 1, 1970). The **Date** class is used to display it in a readable format in lines 14 and 15.

Figure 12.7a shows a sample run of the program on Windows and Figure 12.7b, a sample run on UNIX. As shown in the figures, the path-naming conventions on Windows are different from those on UNIX.



**FIGURE 12.7** The program creates a **File** object and displays file properties.

- 12.10.1** What is wrong about creating a **File** object using the following statement?  
`new File("c:\book\test.dat");`
- 12.10.2** How do you check whether a file already exists? How do you delete a file? How do you rename a file? Can you find the file size (the number of bytes) using the **File** class? How do you create a directory?
- 12.10.3** Can you use the **File** class for I/O? Does creating a **File** object create a file on the disk?



## 12.11 File Input and Output



Use the **Scanner** class for reading text data from a file, and the **PrintWriter** class for writing text data to a file.



VideoNote

Write and read data

A **File** object encapsulates the properties of a file or a path, but it does not contain the methods for writing/reading data to/from a file (referred to as data *input* and *output*, or *I/O* for short). In order to perform I/O, you need to create objects using appropriate Java I/O classes. The objects contain the methods for reading/writing data from/to a file. There are two types of files: text and binary. Text files are essentially characters on disk. This section introduces how to read/write strings and numeric values from/to a text file using the **Scanner** and **PrintWriter** classes. Binary files will be introduced in Chapter 17.

### 12.11.1 Writing Data Using **PrintWriter**

The **java.io.PrintWriter** class can be used to create a file and write data to a text file. First, you have to create a **PrintWriter** object for a text file as follows:

```
PrintWriter output = new PrintWriter(filename);
```

Then, you can invoke the **print**, **println**, and **printf** methods on the **PrintWriter** object to write data to a file. Figure 12.8 summarizes frequently used methods in **PrintWriter**.

java.io.PrintWriter	
+PrintWriter(file: File) +PrintWriter(filename: String) +print(s: String): void +print(c: char): void +print(cArray: char[]): void +print(i: int): void +print(l: long): void +print(f: float): void +print(d: double): void +print(b: boolean): void  Also contains the overloaded println methods.  Also contains the overloaded printf methods.	Creates a <b>PrintWriter</b> object for the specified file object. Creates a <b>PrintWriter</b> object for the specified file name string. Writes a string to the file. Writes a character to the file. Writes an array of characters to the file. Writes an <b>int</b> value to the file. Writes a <b>long</b> value to the file. Writes a <b>float</b> value to the file. Writes a <b>double</b> value to the file. Writes a <b>boolean</b> value to the file.  A <b>println</b> method acts like a <b>print</b> method; additionally, it prints a line separator. The line-separator string is defined by the system. It is <code>\r\n</code> on Windows and <code>\n</code> on Unix.  The <b>printf</b> method was introduced in §4.6, “Formatting Console Output.”

FIGURE 12.8 The **PrintWriter** class contains the methods for writing data to a text file.

Listing 12.13 gives an example that creates an instance of **PrintWriter** and writes two lines to the file **scores.txt**. Each line consists of a first name (a string), a middle-name initial (a character), a last name (a string), and a score (an integer).

### LISTING 12.13 WriteData.java

```
1 public class WriteData {  
2     public static void main(String[] args) throws java.io.IOException {  
3         java.io.File file = new java.io.File("scores.txt");  
4         if (file.exists()) {  
5             System.out.println("File already exists");  
6             System.exit(1);  
7         }  
8     }
```

throws an exception  
create File object  
file exist?

```

9      // Create a file
10     java.io.PrintWriter output = new java.io.PrintWriter(file);
11
12     // Write formatted output to the file
13     output.print("John T Smith ");
14     output.println(90);
15     output.print("Eric K Jones ");
16     output.println(85);
17
18     // Close the file
19     output.close();
20 }
21 }

```

create PrintWriter

print data

scores.txt

close file

Lines 4–7 check whether the file **scores.txt** exists. If so, exit the program (line 6).

Invoking the constructor of **PrintWriter** will create a new file if the file does not exist. If the file already exists, the current content in the file will be discarded without verifying with the user.

Invoking the constructor of **PrintWriter** may throw an I/O exception. Java forces you to write the code to deal with this type of exception. For simplicity, we declare **throws IOException** in the main method header (line 2).

You have used the **System.out.print**, **System.out.println**, and **System.out.printf** methods to write text to the console output. **System.out** is a standard Java object for the console. You can create **PrintWriter** objects for writing text to any file using **print**, **println**, and **printf** (lines 13–16).

The **close()** method must be used to close the file (line 19). If this method is not invoked, the data may not be saved properly in the file.



### Note

You can append data to an existing file using `new PrintWriter(new FileOutputStream(file, true))` to create a **PrintWriter** object. **FileOutputStream** will be introduced in Chapter 17.



### Tip

When the program writes data to a file, it first stores the data temporarily in a buffer in the memory. When the buffer is full, the data are automatically saved to the file on the disk. Once you close the file, all the data left in the buffer are saved to the file on the disk. Therefore, you must close the file to ensure that all data are saved to the file.

## 12.11.2 Closing Resources Automatically Using try-with-resources

Programmers often forget to close the file. JDK 7 provides the following try-with-resources syntax that automatically closes the files.

```

try (declare and create resources) {
    Use the resource to process the file;
}

```

Using the try-with-resources syntax, we rewrite the code in Listing 12.13 as shown in Listing 12.14.

### LISTING 12.14 WriteDataWithAutoClose.java

```

1 public class WriteDataWithAutoClose {
2     public static void main(String[] args) throws Exception {
3         java.io.File file = new java.io.File("scores.txt");
4         if (file.exists()) {
5             System.out.println("File already exists");
6             System.exit(0);

```

```

7      }
8
9      try (
10         // Create a file
11         java.io.PrintWriter output = new java.io.PrintWriter(file);
12     ) {
13         // Write formatted output to the file
14         output.print("John T Smith ");
15         output.println(90);
16         output.print("Eric K Jones ");
17         output.println(85);
18     }
19 }
20 }

```

declare/create resource

use the resource

A resource is declared and created in the parentheses following the keyword **try**. The resources must be a subtype of **AutoCloseable** such as a **PrintWriter** that has the **close()** method. A resource must be declared and created in the same statement, and multiple resources can be declared and created inside the parentheses. The statements in the block (lines 12–18) immediately following the resource declaration use the resource. After the block is finished, the resource's **close()** method is automatically invoked to close the resource. Using try-with-resources can not only avoid errors, but also make the code simpler. Note the catch clause may be omitted in a try-with-resources statement.

Note that (1) you have to declare the resource reference variable and create the resource altogether in the **try(...)** clause; (2) the semicolon (;) in last statement in the **try(...)** clause may be omitted; (3) You may create multiple **AutoCloseable** resources in the the **try(...)** clause; (4) The **try(...)** clause can contain only the statements for creating resources. Here is an example.

```

          Declare reference      Create resource
          to resource            objects
          ↓                      ↓
try (
    Scanner input = new Scanner(System.in);
    PrintWriter output =
        new PrintWriter("c:\\temp\\temp.txt");
) {
    System.out.println(input.nextLine());
}
          ↑
          The ; for the
          last statement
          may be omitted

```

### 12.11.3 Reading Data Using Scanner

The **java.util.Scanner** class was used to read strings and primitive values from the console in Section 2.3, Reading Input from the Console. A **Scanner** breaks its input into tokens delimited by whitespace characters. To read from the keyboard, you create a **Scanner** for **System.in**, as follows:

```
Scanner input = new Scanner(System.in);
```

To read from a file, create a **Scanner** for a file, as follows:

```
Scanner input = new Scanner(new File(filename));
```

Figure 12.9 summarizes frequently used methods in **Scanner**.

java.util.Scanner	
<pre> +Scanner(source: File) +Scanner(source: String) +close() +hasNext(): boolean +next(): String +nextLine(): String +nextByte(): byte +nextShort(): short +nextInt(): int +nextLong(): long +nextFloat(): float +nextDouble(): double +useDelimiter(pattern: String):   Scanner </pre>	<p>Creates a <b>Scanner</b> that produces values scanned from the specified file.</p> <p>Creates a <b>Scanner</b> that produces values scanned from the specified string.</p> <p>Closes this scanner.</p> <p>Returns true if this scanner has more data to be read.</p> <p>Returns next token as a string from this scanner.</p> <p>Returns a line ending with the line separator from this scanner.</p> <p>Returns next token as a byte from this scanner.</p> <p>Returns next token as a <b>short</b> from this scanner.</p> <p>Returns next token as an <b>int</b> from this scanner.</p> <p>Returns next token as a <b>long</b> from this scanner.</p> <p>Returns next token as a <b>float</b> from this scanner.</p> <p>Returns next token as a <b>double</b> from this scanner.</p> <p>Sets this scanner's delimiting pattern and returns this scanner.</p>

**FIGURE 12.9** The **Scanner** class contains the methods for scanning data.

Listing 12.15 gives an example that creates an instance of **Scanner** and reads data from the file **scores.txt**.

### LISTING 12.15 ReadData.java

```

1  import java.util.Scanner;
2
3  public class ReadData {
4      public static void main(String[] args) throws Exception {
5          // Create a File instance
6          java.io.File file = new java.io.File("scores.txt");
7
8          // Create a Scanner for the file
9          Scanner input = new Scanner(file);
10
11         // Read data from a file
12         while (input.hasNext()) {
13             String firstName = input.next();
14             String mi = input.next();
15             String lastName = input.next();
16             int score = input.nextInt();
17             System.out.println(
18                 firstName + " " + mi + " " + lastName + " " + score);
19         }
20
21         // Close the file
22         input.close();
23     }
24 }

```

create a File

create a Scanner

has next?  
read items

close file

Note **new Scanner(String)** creates a **Scanner** for a given string. To create a **Scanner** to read data from a file, you have to use the **java.io.File** class to create an instance of the **File** using the constructor **new File(filename)** (line 6) and use **new Scanner(File)** to create a **Scanner** for the file (line 9).

File class

Invoking the constructor **new Scanner(File)** may throw an I/O exception, so the **main** method declares **throws Exception** in line 4.

throws Exception

Each iteration in the **while** loop reads the first name, middle initial, last name, and score from the text file (lines 12–19). The file is closed in line 22.



close file

It is not necessary to close the input file (line 22), but it is a good practice to do so to release the resources occupied by the file. You can rewrite this program using the try-with-resources syntax. See [liveexample.pearsoncmg.com/html/ReadDataWithAutoClose.html](http://liveexample.pearsoncmg.com/html/ReadDataWithAutoClose.html).

12.11.4 How Does Scanner Work?

change delimiter

Section 4.5.5 introduced token-based and line-based input. The token-based input methods `nextByte()`, `nextShort()`, `nextInt()`, `nextLong()`, `nextFloat()`, `nextDouble()`, and `next()` read input separated by delimiters. By default, the delimiters are whitespace characters. You can use the `useDelimiter(String regex)` method to set a new pattern for delimiters.

InputMismatchException  
next() vs. nextLine()

How does an input method work? A token-based input first skips any delimiters (whitespace characters by default) then reads a token ending at a delimiter. The token is then automatically converted into a value of the `byte`, `short`, `int`, `long`, `float`, or `double` type for `nextByte()`, `nextShort()`, `nextInt()`, `nextLong()`, `nextFloat()`, and `nextDouble()`, respectively. For the `next()` method, no conversion is performed. If the token does not match the expected type, a runtime exception `java.util.InputMismatchException` will be thrown.

Both methods `next()` and `nextLine()` read a string. The `next()` method reads a string separated by delimiters and `nextLine()` reads a line ending with a line separator.



**Note**  
The line-separator string is defined by the system. It is `\r\n` on Windows and `\n` on UNIX. To get the line separator on a particular platform, use

```
String lineSeparator = System.getProperty("line.separator");
```

If you enter input from a keyboard, a line ends with the *Enter* key, which corresponds to the `\n` character.

behavior of nextLine()

The token-based input method does not read the delimiter after the token. If the `nextLine()` method is invoked after a token-based input method, this method reads characters that start from this delimiter and end with the line separator. The line separator is read, but it is not part of the string returned by `nextLine()`.

input from file

Suppose a text file named `test.txt` contains a line

34 567

After the following code is executed,

```
Scanner input = new Scanner(new File("test.txt"));
int intValue = input.nextInt();
String line = input.nextLine();
```

`intValue` contains 34 and `line` contains the characters ' ', 5, 6, and 7.

What happens if the input is *entered from the keyboard*? Suppose you enter 34, press the *Enter* key, then enter 567 and press the *Enter* key for the following code:

```
Scanner input = new Scanner(System.in);
int intValue = input.nextInt();
String line = input.nextLine();
```

You will get 34 in `intValue` and an empty string in `line`. Why? Here is the reason. The token-based input method `nextInt()` reads in 34 and stops at the delimiter, which in this case is a line separator (the *Enter* key). The `nextLine()` method ends after reading the line separator and returns the string read before the line separator. Since there are no characters before the line separator, `line` is empty. For this reason, *you should not use a line-based input after a token-based input*.

scan a string

You can read data from a file or from the keyboard using the `Scanner` class. You can also scan data from a string using the `Scanner` class. For example, the following code:



```
Scanner input = new Scanner("13 14");
int sum = input.nextInt() + input.nextInt();
System.out.println("Sum is " + sum);
```

displays

```
Sum is 27
```

### 12.11.5 Case Study: Replacing Text

Suppose you are to write a program named **ReplaceText** that replaces all occurrences of a string in a text file with a new string. The file name and strings are passed as command-line arguments as follows:

```
java ReplaceText sourceFile targetFile oldString newString
```

For example, invoking

```
java ReplaceText FormatString.java t.txt StringBuilder StringBuffer
```

replaces all the occurrences of **StringBuilder** by **StringBuffer** in the file **FormatString.java** and saves the new file in **t.txt**.

Listing 12.16 gives the program. The program checks the number of arguments passed to the **main** method (lines 7–11), checks whether the source and target files exist (lines 14–25), creates a **Scanner** for the source file (line 29), creates a **PrintWriter** for the target file (line 30), and repeatedly reads a line from the source file (line 33), replaces the text (line 34), and writes a new line to the target file (line 35).

#### LISTING 12.16 ReplaceText.java

```
1 import java.io.*;
2 import java.util.*;
3
4 public class ReplaceText {
5     public static void main(String[] args) throws Exception {
6         // Check command line parameter usage
7         if (args.length != 4) {
8             System.out.println(
9                 "Usage: java ReplaceText sourceFile targetFile oldStr newStr");
10            System.exit(1);
11        }
12
13        // Check if source file exists
14        File sourceFile = new File(args[0]);
15        if (!sourceFile.exists()) {
16            System.out.println("Source file " + args[0] + " does not exist");
17            System.exit(2);
18        }
19
20        // Check if target file exists
21        File targetFile = new File(args[1]);
22        if (targetFile.exists()) {
23            System.out.println("Target file " + args[1] + " already exists");
24            System.exit(3);
25        }
26
27        try (
28            // Create input and output files
29            Scanner input = new Scanner(sourceFile);
30            PrintWriter output = new PrintWriter(targetFile);
```

check command usage

source file exists?

target file exists?

try-with-resources

create a Scanner

create a PrintWriter

```

31     ) {
32         while (input.hasNext()) {
33             String s1 = input.nextLine();
34             String s2 = s1.replaceAll(args[2], args[3]);
35             output.println(s2);
36         }
37     }
38 }
39 }

```

has next?  
read a line

In a normal situation, the program is terminated after a file is copied. The program is terminated abnormally if the command-line arguments are not used properly (lines 7–11), if the source file does not exist (lines 14–18), or if the target file already exists (lines 22–25). The exit status codes 1, 2, and 3 are used to indicate these abnormal terminations (lines 10, 17, and 24).



**12.11.1** How do you create a **PrintWriter** to write data to a file? What is the reason to declare **throws Exception** in the main method in Listing 12.13, WriteData.java? What would happen if the **close()** method were not invoked in Listing 12.13?

**12.11.2** Show the contents of the file **temp.txt** after the following program is executed:

```

public class Test {
    public static void main(String[] args) throws Exception {
        java.io.PrintWriter output = new
            java.io.PrintWriter("temp.txt");
        output.printf("amount is %f %e\r\n", 32.32, 32.32);
        output.printf("amount is %5.4f %5.4e\r\n", 32.32, 32.32);
        output.printf("%6b\r\n", (1 > 2));
        output.printf("%6s\r\n", "Java");
        output.close();
    }
}

```

**12.11.3** Rewrite the code in the preceding question using a try-with-resources syntax.

**12.11.4** How do you create a **Scanner** to read data from a file? What is the reason to define **throws Exception** in the main method in Listing 12.15, ReadData.java? What would happen if the **close()** method were not invoked in Listing 12.15?

**12.11.5** What will happen if you attempt to create a **Scanner** for a nonexistent file? What will happen if you attempt to create a **PrintWriter** for an existing file?

**12.11.6** Is the line separator the same on all platforms? What is the line separator on Windows?

**12.11.7** Suppose you enter **45 57.8 789**, then press the *Enter* key. Show the contents of the variables after the following code is executed:

```

Scanner input = new Scanner(System.in);
int intValue = input.nextInt();
double doubleValue = input.nextDouble();
String line = input.nextLine();

```

**12.11.8** Suppose you enter **45**, press the *Enter* key, enter **57.8**, press the *Enter* key, and enter **789**, press the *Enter* key. Show the contents of the variables after the following code is executed:

```

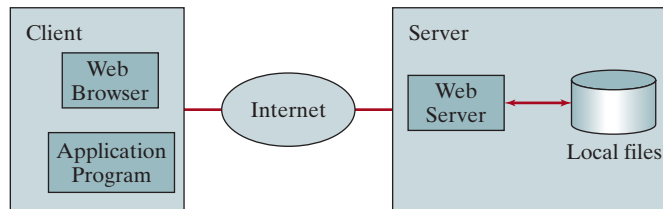
Scanner input = new Scanner(System.in);
int intValue = input.nextInt();
double doubleValue = input.nextDouble();
String line = input.nextLine();

```

## 12.12 Reading Data from the Web

*Just like you can read data from a file on your computer, you can read data from a file on the Web.*

In addition to reading data from a local file on a computer or file server, you can also access data from a file that is on the Web if you know the file's URL (Uniform Resource Locator—the unique address for a file on the Web). For example, `www.google.com/index.html` is the URL for the file **index.html** located on the Google web server. When you enter the URL in a Web browser, the Web server sends the data to your browser, which renders the data graphically. Figure 12.10 illustrates how this process works.



**FIGURE 12.10** The client retrieves files from a Web server.

For an application program to read data from a URL, you first need to create a **URL** object using the `java.net.URL` class with this constructor:

```
public URL(String spec) throws MalformedURLException
```

For example, the following statement creates a URL object for `http://www.google.com/index.html`.

```
1 try {
2     URL url = new URL("http://www.google.com/index.html");
3 }
4 catch (MalformedURLException ex) {
5     ex.printStackTrace();
6 }
```

A **MalformedURLException** is thrown if the URL string has a syntax error. For example, the URL string `http:www.google.com/index.html` would cause a **MalformedURLException** runtime error because two slashes (`//`) are required after the colon (`:`). Note the `http://` prefix is required for the **URL** class to recognize a valid URL. It would be wrong if you replace line 2 with the following code:

```
URL url = new URL("www.google.com/index.html");
```

After a **URL** object is created, you can use the `openStream()` method defined in the **URL** class to open an input stream and use this stream to create a **Scanner** object as follows:

```
Scanner input = new Scanner(url.openStream());
```

Now you can read the data from the input stream just like from a local file. The example in Listing 12.17 prompts the user to enter a URL and displays the size of the file.

### LISTING 12.17 ReadFileFromURL.java

```
1 import java.util.Scanner;
2
3 public class ReadFileFromURL {
4     public static void main(String[] args) {
```



enter a URL

create a URL object

create a Scanner object  
more to read?  
read a line

MalformedURLException

IOException

```
5      System.out.print("Enter a URL: ");
6      String urlString = new Scanner(System.in).next();
7
8      try {
9          java.net.URL url = new java.net.URL(urlString);
10         int count = 0;
11         Scanner input = new Scanner(url.openStream());
12         while (input.hasNext()) {
13             String line = input.nextLine();
14             count += line.length();
15         }
16
17         System.out.println("The file size is " + count + " characters");
18     }
19     catch (java.net.MalformedURLException ex) {
20         System.out.println("Invalid URL");
21     }
22     catch (java.io.IOException ex) {
23         System.out.println("I/O Errors: no such file");
24     }
25 }
26 }
```



Enter a URL: `http://liveexample.pearsoncmg.com/data/Lincoln.txt`

The file size is 1469 characters



Enter a URL: `http://www.yahoo.com`

The file size is 190006 characters

MalformedURLException

The program prompts the user to enter a URL string (line 6) and creates a **URL** object (line 9). The constructor will throw a **java.net.MalformedURLException** (line 19) if the URL isn't formed correctly.

The program creates a **Scanner** object from the input stream for the URL (line 11). If the URL is formed correctly but does not exist, an **IOException** will be thrown (line 22). For example, <http://google.com/index1.html> uses the appropriate form, but the URL itself does not exist. An **IOException** would be thrown if this URL was used for this program.



**12.12.1** How do you create a **Scanner** object for reading text from a URL?

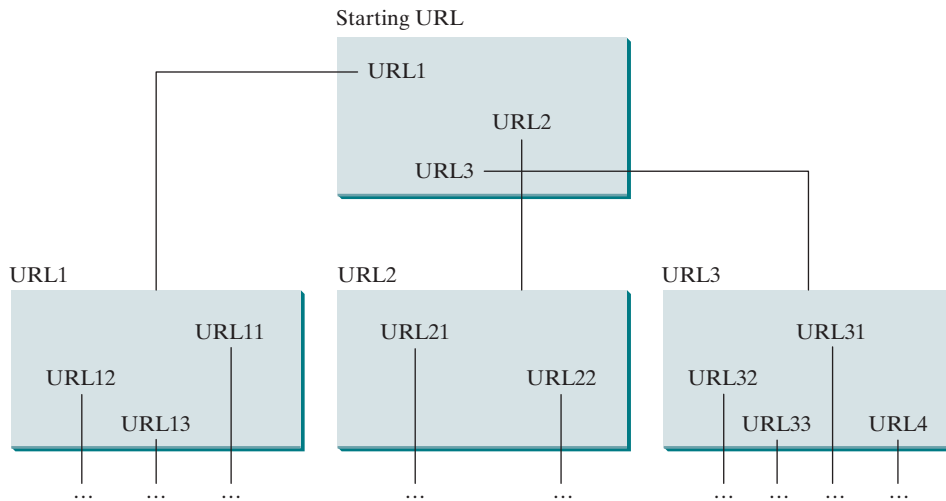


## 12.13 Case Study: Web Crawler

*This case study develops a program that travels the Web by following hyperlinks.*

web crawler

The World Wide web, abbreviated as WWW, W3, or Web, is a system of interlinked hyper-text documents on the Internet. With a web browser, you can view a document and follow the hyperlinks to view other documents. In this case study, we will develop a program that automatically traverses the documents on the Web by following the hyperlinks. This type of program is commonly known as a *web crawler*. For simplicity, our program follows the hyperlink that starts with **http://**. Figure 12.11 shows an example of traversing the Web. We start from a Webpage that contains three URLs named **URL1**, **URL2**, and **URL3**. Following **URL1** leads to the page that contains three URLs named **URL11**, **URL12**, and **URL13**. Following **URL2** leads to the page that contains two URLs named **URL21** and **URL22**. Following **URL3** leads to the page that contains four URLs named **URL31**, **URL32**, **URL33**, and **URL34**. Continue to traverse



**FIGURE 12.11** Web crawler explores the web through hyperlinks.

the Web following the new hyperlinks. As you see, this process may continue forever, but we will exit the program once we have traversed 100 pages.

The program follows the URLs to traverse the Web. To ensure that each URL is traversed only once, the program maintains two lists of URLs. One list stores the URLs pending for traversing, and the other stores the URLs that have already been traversed. The algorithm for this program can be described as follows:

```
Add the starting URL to a list named listOfPendingURLs;
while listOfPendingURLs is not empty and size of listOfTraversedURLs
<= 100 {
    Remove a URL from listOfPendingURLs;
    if this URL is not in listOfTraversedURLs {
        Add it to listOfTraversedURLs;
        Display this URL;
        Read the page from this URL and for each URL contained in the page {
            Add it to listOfPendingURLs if it is not in listOfTraversedURLs;
        }
    }
}
```

Listing 12.18 gives the program that implements this algorithm.

### LISTING 12.18 WebCrawler.java

```
1 import java.util.Scanner;
2 import java.util.ArrayList;
3
4 public class WebCrawler {
5     public static void main(String[] args) {
6         Scanner input = new Scanner(System.in);
7         System.out.print("Enter a URL: ");
8         String url = input.nextLine();
9         crawler(url); // Traverse the Web from the a starting url
10    }
11
12    public static void crawler(String startingURL) {
13        ArrayList<String> listOfPendingURLs = new ArrayList<>();
14        ArrayList<String> listOfTraversedURLs = new ArrayList<>();
```

enter a URL  
crawl from this URL

list of pending URLs  
list of traversed URLs

```

15
add starting URL    16    listOfPendingURLs.add(startingURL);
17    while (!listOfPendingURLs.isEmpty() &&
18            listOfTraversedURLs.size() <= 100) {
get the first URL  19        String urlString = listOfPendingURLs.remove(0);
20        if (!listOfTraversedURLs.contains(urlString)) {
URL traversed     21            listOfTraversedURLs.add(urlString);
22            System.out.println("Crawl " + urlString);
23
24            for (String s: getSubURLs(urlString)) {
25                if (!listOfTraversedURLs.contains(s))
add a new URL     26                    listOfPendingURLs.add(s);
27            }
28        }
29    }
30 }
31
32 public static ArrayList<String> getSubURLs(String urlString) {
33     ArrayList<String> list = new ArrayList<>();
34
35     try {
36         java.net.URL url = new java.net.URL(urlString);
37         Scanner input = new Scanner(url.openStream());
38         int current = 0;
39         while (input.hasNext()) {
40             String line = input.nextLine();
41             current = line.indexOf("http:", current);
42             while (current > 0) {
43                 int endIndex = line.indexOf("\\", current);
44                 if (endIndex > 0) { // Ensure that a correct URL is found
45                     list.add(line.substring(current, endIndex));
46                     current = line.indexOf("http:", endIndex);
47                 }
48                 else
49                     current = -1;
50             }
51         }
52     }
53     catch (Exception ex) {
54         System.out.println("Error: " + ex.getMessage());
55     }
56
57     return list;
58 }
59 }
return URLs

```



```

Enter a URL: http://cs.armstrong.edu/liang Enter
Crawl http://www.cs.armstrong.edu/liang
Crawl http://www.cs.armstrong.edu
Crawl http://www.armstrong.edu
Crawl http://www.pearsonhighered.com/liang
...

```

The program prompts the user to enter a starting URL (lines 7 and 8) and invokes the `crawler(url)` method to traverse the Web (line 9).

The `crawler(url)` method adds the starting url to `listOfPendingURLs` (line 16) and repeatedly process each URL in `listOfPendingURLs` in a while loop (lines 17–29). It removes the first URL in the list (line 19) and processes the URL if it has not been processed (lines 20–28).

To process each URL, the program first adds the URL to `listOfTraversedURLs` (line 21). This list stores all the URLs that have been processed. The `getSubURLs(ur1)` method returns a list of URLs in the webpage for the specified URL (line 24). The program uses a `foreach` loop to add each URL in the page into `listOfPendingURLs` if it is not in `listOfTraversedURLs` (lines 24–27).

The `getSubURLs(ur1)` method reads each line from the webpage (line 40) and searches for the URLs in the line (line 41). Note a correct URL cannot contain line break characters. Therefore, it is sufficient to limit the search for a URL in one line of the text in a webpage. For simplicity, we assume that a URL ends with a quotation mark `"` (line 43). The method obtains a URL and adds it to a list (line 45). A line may contain multiple URLs. The method continues to search for the next URL (line 46). If no URL is found in the line, `current` is set to `-1` (line 49). The URLs contained in the page are returned in the form of a list (line 57).

The program terminates when the number of traversed URLs reaches 100 (line 18).

This is a simple program to traverse the Web. Later, you will learn the techniques to make the program more efficient and robust.

**12.13.1** Before a URL is added to `listOfPendingURLs`, line 25 checks whether it has been traversed. Is it possible that `listOfPendingURLs` contains duplicate URLs? If so, give an example.

**12.13.2** Simplify the code in lines 20–28 as follows: 1. Delete lines 20 and 28; 2. Add an additional condition `!listOfPendingURLs.contains(s)` to the `if` statement in line 25. Write the complete new code for the `while` loop in lines 17–29. Does this revision work?



## KEY TERMS

---

absolute file name	477	exception	491
chained exception	473	exception propagation	463
checked exception	461	relative file name	477
declare exception	467	throw exception	457
directory path	477	unchecked exception	489

## CHAPTER SUMMARY

- 
1. Exception handling enables a method to throw an exception to its caller.
  2. A Java *exception* is an instance of a class derived from `java.lang.Throwable`. Java provides a number of predefined exception classes, such as `Error`, `Exception`, `RuntimeException`, `ClassNotFoundException`, `NullPointerException`, and `ArithmeticException`. You can also define your own exception class by extending `Exception`.
  3. Exceptions occur during the execution of a method. `RuntimeException` and `Error` are *unchecked exceptions*; all other exceptions are *checked*.
  4. When *declaring a method*, you have to declare a checked exception if the method might throw it, thus telling the compiler what can go wrong.
  5. The keyword for declaring an exception is `throws`, and the keyword for throwing an exception is `throw`.
  6. To invoke the method that declares checked exceptions, enclose it in a `try` statement. When an exception occurs during the execution of the method, the `catch` block catches and handles the exception.

7. If an exception is not caught in the current method, it is passed to its caller. The process is repeated until the exception is caught or passed to the `main` method.
8. Various exception classes can be derived from a common superclass. If a `catch` block catches the exception objects of a superclass, it can also catch all the exception objects of the subclasses of that superclass.
9. The order in which exceptions are specified in a `catch` block is important. A compile error will result if you specify an exception object of a class after an exception object of the superclass of that class.
10. When an exception occurs in a method, the method exits immediately if it does not catch the exception. If the method is required to perform some task before exiting, you can catch the exception in the method and then rethrow it to its caller.
11. The code in the `finally` block is executed under all circumstances, regardless of whether an exception occurs in the `try` block, or whether an exception is caught if it occurs.
12. Exception handling separates error-handling code from normal programming tasks, thus making programs easier to read and to modify.
13. Exception handling should not be used to replace simple tests. You should perform simple test using `if` statements whenever possible and reserve exception handling for dealing with situations that cannot be handled with `if` statements.
14. The `File` class is used to obtain file properties and manipulate files. It does not contain the methods for creating a file or for reading/writing data from/to a file.
15. You can use `Scanner` to read string and primitive data values from a text file and use `PrintWriter` to create a file and write data to a text file.
16. You can read from a file on the Web using the `URL` class.



## Quiz

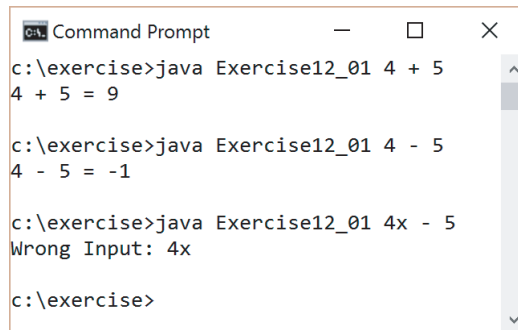
Answer the quiz for this chapter online at the Companion Website.

## PROGRAMMING EXERCISES

### Sections 12.2–12.9

- \*12.1 (*NumberFormatException*) Listing 7.9, `Calculator.java`, is a simple command-line calculator. Note the program terminates if any operand is nonnumeric. Write a program with an exception handler that deals with non-numeric operands; then write another program without using an exception handler to achieve the same objective. Your program should display a message that informs the user of the wrong operand type before exiting (see Figure 12.12).





```

c:\exercise>java Exercise12_01 4 + 5
4 + 5 = 9

c:\exercise>java Exercise12_01 4 - 5
4 - 5 = -1

c:\exercise>java Exercise12_01 4x - 5
Wrong Input: 4x

c:\exercise>

```

**FIGURE 12.12** The program performs arithmetic operations and detects input errors.

- \* **12.2** (***InputMismatchException***) Write a program that prompts the user to read two integers and displays their sum. Your program should prompt the user to read the number again if the input is incorrect.
- \* **12.3** (***ArrayIndexOutOfBoundsException***) Write a program that meets the following requirements:
  - Creates an array with **100** randomly chosen integers.
  - Prompts the user to enter the index of the array, then displays the corresponding element value. If the specified index is out of bounds, display the message "Out of Bounds".
- \* **12.4** (***IllegalArgumentException***) Modify the **Loan** class in Listing 10.2 to throw **IllegalArgumentException** if the loan amount, interest rate, or number of years is less than or equal to zero.
- \* **12.5** (***IllegalTriangleException***) Programming Exercise 11.1 defined the **Triangle** class with three sides. In a triangle, the sum of any two sides is greater than the other side. The **Triangle** class must adhere to this rule. Create the **IllegalTriangleException** class, and modify the constructor of the **Triangle** class to throw an **IllegalTriangleException** object if a triangle is created with sides that violate the rule, as follows:

```

/** Construct a triangle with the specified sides */
public Triangle(double side1, double side2, double side3)
    throws IllegalTriangleException {
    // Implement it
}

```

- \* **12.6** (***NumberFormatException***) Listing 6.8 implements the **hex2Dec(String hexString)** method, which converts a hex string into a decimal number. Implement the **hex2Dec** method to throw a **NumberFormatException** if the string is not a hex string. Write a test program that prompts the user to enter a hex number as a string and displays its decimal equivalent. If the method throws an exception, display "Not a hex number".
- \* **12.7** (***NumberFormatException***) Write the **bin2Dec(String binaryString)** method to convert a binary string into a decimal number. Implement the **bin2Dec** method to throw a **NumberFormatException** if the string is not a binary string. Write a test program that prompts the user to enter a binary number as a string and displays its decimal equivalent. If the method throws an exception, display "Not a binary number".
- \* **12.8** (***HexFormatException***) Programming Exercise 12.6 implements the **hex2Dec** method to throw a **NumberFormatException** if the string is not a hex string. Define a custom exception called **HexFormatException**.



VideoNote

HexFormatException

Implement the `hex2Dec` method to throw a `HexFormatException` if the string is not a hex string.

**\*12.9** (*BinaryFormatException*) Exercise 12.7 implements the `bin2Dec` method to throw a `BinaryFormatException` if the string is not a binary string. Define a custom exception called `BinaryFormatException`. Implement the `bin2Dec` method to throw a `BinaryFormatException` if the string is not a binary string.

**\*12.10** (*OutOfMemoryError*) Write a program that causes the JVM to throw an `OutOfMemoryError` and catches and handles this error.

### Sections 12.10–12.12

**\*\*12.11** (*Remove text*) Write a program that removes all the occurrences of a specified string from a text file. For example, invoking

```
java Exercise12_11 John filename
```

removes the string `John` from the specified file. Your program should get the arguments from the command line.

**\*\*12.12** (*Reformat Java source code*) Write a program that converts the Java source code from the next-line brace style to the end-of-line brace style. For example, the following Java source in (a) uses the next-line brace style. Your program converts it to the end-of-line brace style in (b).

```
public class Test
{
    public static void main(String[] args)
    {
        // Some statements
    }
}
```

(a) Next-line brace style

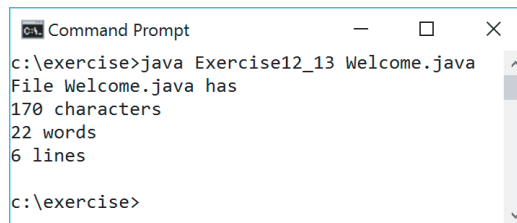
```
public class Test {
    public static void main(String[] args) {
        // Some statements
    }
}
```

(b) End-of-line brace style

Your program can be invoked from the command line with the Java source-code file as the argument. It converts the Java source code to a new format. For example, the following command converts the Java source-code file `Test.java` to the end-of-line brace style.

```
java Exercise12_12 Test.java
```

**\*12.13** (*Count characters, words, and lines in a file*) Write a program that will count the number of characters, words, and lines in a file. Words are separated by whitespace characters. The file name should be passed as a command-line argument, as shown in Figure 12.13.



```
Command Prompt
c:\exercise>java Exercise12_13 Welcome.java
File Welcome.java has
170 characters
22 words
6 lines
c:\exercise>
```

**FIGURE 12.13** The program displays the number of characters, words, and lines in the given file.

**\*12.14** (*Process scores in a text file*) Suppose a text file contains an unspecified number of scores separated by spaces. Write a program that prompts the user to enter the file, reads the scores from the file, and displays their total and average.

**\*12.15** (*Write/read data*) Write a program to create a file named **Exercise12\_15.txt** if it does not exist. Write **100** integers created randomly into the file using text I/O. Integers are separated by spaces in the file. Read the data back from the file and display the data in increasing order.

**\*\*12.16** (*Replace text*) Listing 12.16, **ReplaceText.java**, gives a program that replaces text in a source file and saves the change into a new file. Revise the program to save the change into the original file. For example, invoking

```
java Exercise12_16 file oldString newString
```

replaces **oldString** in the source file with **newString**.

**\*\*\*12.17** (*Game: hangman*) Rewrite Programming Exercise 7.35. The program reads the words stored in a text file named **hangman.txt**. Words are delimited by spaces.

**\*\*12.18** (*Add package statement*) Suppose you have Java source files under the directories **chapter1**, **chapter2**, . . . , **chapter34**. Write a program to insert the statement **package chapteri**; as the first line for each Java source file under the directory **chapteri**. Suppose **chapter1**, **chapter2**, . . . , **chapter34** are under the root directory **srcRootDirectory**. The root directory and **chapteri** directory may contain other folders and files. Use the following command to run the program:

```
java Exercise12_18 srcRootDirectory
```

**\*12.19** (*Count words*) Write a program that counts the number of words in President Abraham Lincoln's Gettysburg address from <https://liveexample.pearsoncmg.com/data/Lincoln.txt>.

**\*\*12.20** (*Remove package statement*) Suppose you have Java source files under the directories **chapter1**, **chapter2**, . . . , **chapter34**. Write a program to remove the statement **package chapteri**; in the first line for each Java source file under the directory **chapteri**. Suppose **chapter1**, **chapter2**, . . . , **chapter34** are under the root directory **srcRootDirectory**. The root directory and **chapteri** directory may contain other folders and files. Use the following command to run the program:

```
java Exercise12_20 srcRootDirectory
```

**\*12.21** (*Data sorted?*) Write a program that reads the strings from file **SortedStrings.txt** and reports whether the strings in the files are stored in increasing order. If the strings are not sorted in the file, it displays the first two strings that are out of the order.

**\*\*12.22** (*Replace text*) Revise Programming Exercise 12.16 to replace a string in a file with a new string for all files in the specified directory using the following command:

```
java Exercise12_22 dir oldString newString
```

**\*\*12.23** (*Process scores in a text file on the Web*) Suppose the text file on the Web <http://liveexample.pearsoncmg.com/data/Scores.txt> contains an unspecified number of scores separated by spaces. Write a program that reads the scores from the file and displays their total and average.

**\*12.24** (*Create large dataset*) Create a data file with 1,000 lines. Each line in the file consists of a faculty member's first name, last name, rank, and salary. The faculty member's first name and last name for the *i*th line are **FirstName<sub>i</sub>** and **LastName<sub>i</sub>**. The rank is randomly generated as assistant, associate, and full. The salary is randomly generated as a number with two digits after the decimal

point. The salary for an assistant professor should be in the range from 50,000 to 80,000, for associate professor from 60,000 to 110,000, and for full professor from 75,000 to 130,000. Save the file in **Salary.txt**. Here are some sample data:

FirstName1 LastName1 assistant 60055.95

FirstName2 LastName2 associate 81112.45

...

FirstName1000 LastName1000 full 92255.21

**\*12.25** (*Process large dataset*) A university posts its employees' salaries at <http://liveexample.pearsoncmg.com/data/Salary.txt>. Each line in the file consists of a faculty member's first name, last name, rank, and salary (see Programming Exercise 12.24). Write a program to display the total salary for assistant professors, associate professors, full professors, and faculty, respectively, and display the average salary for assistant professors, associate professors, full professors, and faculty, respectively.

**\*\*12.26** (*Create a directory*) Write a program that prompts the user to enter a directory name and creates a directory using the **File**'s **mkdirs** method. The program displays the message "Directory created successfully" if a directory is created or "Directory already exists" if the directory already exists.

**\*\*12.27** (*Replace words*) Suppose you have a lot of files in a directory that contain words **Exercise*i*\_j**, where *i* and *j* are digits. Write a program that pads a 0 before *i* if *i* is a single digit and 0 before *j* if *j* is a single digit. For example, the word **Exercise2\_1** in a file will be replaced by **Exercise02\_01**. In Java, when you pass the symbol **\*** from the command line, it refers to all files in the directory (see Supplement III.V). Use the following command to run your program:

```
java Exercise12_27 *
```

**\*\*12.28** (*Rename files*) Suppose you have a lot of files in a directory named **Exercise*i*\_j**, where *i* and *j* are digits. Write a program that pads a 0 before *i* if *i* is a single digit. For example, a file named **Exercise2\_1** in a directory will be renamed to **Exercise02\_1**. In Java, when you pass the symbol **\*** from the command line, it refers to all files in the directory (see Supplement III.V). Use the following command to run your program:

```
java Exercise12_28 *
```

**\*\*12.29** (*Rename files*) Suppose you have several files in a directory named **Exercise*i*\_j**, where *i* and *j* are digits. Write a program that pads a 0 before *j* if *j* is a single digit. For example, a file named **Exercise2\_1** in a directory will be renamed to **Exercise2\_01**. In Java, when you pass the symbol **\*** from the command line, it refers to all files in the directory (see Supplement III.V). Use the following command to run your program:

```
java Exercise12_29 *
```

**\*\*12.30** (*Occurrences of each letter*) Write a program that prompts the user to enter a file name and displays the occurrences of each letter in the file. Letters are case insensitive. Here is a sample run:



```
Enter a filename: Lincoln.txt 
Number of As: 56
Number of Bs: 134
...
Number of Zs: 9
```

- \*12.31** (*Baby name popularity ranking*) The popularity ranking of baby names from years 2001 to 2010 is downloaded from [www.ssa.gov/oact/babynames](http://www.ssa.gov/oact/babynames) and stored in files named **babynameranking2001.txt**, **babynameranking2002.txt**, . . . , **babynameranking2010.txt**. You can download these files using the URL such as <http://liveexample.pearsoncmg.com/data/babynamesranking2001.txt>. Each file contains 1,000 lines. Each line contains a ranking, a boy's name, number for the boy's name, a girl's name, and number for the girl's name. For example, the first two lines in the file **babynameranking2010.txt** are as follows:

1	Jacob	21,875	Isabella	22,731
2	Ethan	17,866	Sophia	20,477

Therefore, the boy's name Jacob and girl's name Isabella are ranked #1 and the boy's name Ethan and girl's name Sophia are ranked #2; 21,875 boys are named Jacob, and 22,731 girls are named Isabella. Write a program that prompts the user to enter the year, gender, followed by a name, and displays the ranking of the name for the year. Your program should read the data directly from the Web. Here are some sample runs:

```
Enter the year: 2010
Enter the gender: M
Enter the name: Javier
Javier is ranked #190 in year 2010
```



```
Enter the year: 2010
Enter the gender: F
Enter the name: ABC
The name ABC is not ranked in year 2010
```



- \*12.32** (*Ranking summary*) Write a program that uses the files described in Programming Exercise 12.31 and displays a ranking summary table for the first five girl's and boy's names as follows:

Year	Rank 1	Rank 2	Rank 3	Rank 4	Rank 5	Rank 1	Rank 2	Rank 3	Rank 4	Rank 5
2010	Isabella	Sophia	Emma	Olivia	Ava	Jacob	Ethan	Michael	Jayden	William
2009	Isabella	Emma	Olivia	Sophia	Ava	Jacob	Ethan	Michael	Alexander	William
2008	Emma	Isabella	Emily	Olivia	Ava	Jacob	Michael	Ethan	Joshua	Daniel
2007	Emily	Isabella	Emma	Ava	Madison	Jacob	Michael	Ethan	Joshua	Daniel
2006	Emily	Emma	Madison	Isabella	Ava	Jacob	Michael	Joshua	Ethan	Matthew
2005	Emily	Emma	Madison	Abigail	Olivia	Jacob	Michael	Joshua	Matthew	Ethan
2004	Emily	Emma	Madison	Olivia	Hannah	Jacob	Michael	Joshua	Matthew	Ethan
2003	Emily	Emma	Madison	Hannah	Olivia	Jacob	Michael	Joshua	Matthew	Andrew
2002	Emily	Madison	Hannah	Emma	Alexis	Jacob	Michael	Joshua	Matthew	Ethan
2001	Emily	Madison	Hannah	Ashley	Alexis	Jacob	Michael	Matthew	Joshua	Christopher

- \*\*12.33** (*Search Web*) Modify Listing 12.18 WebCrawler.java to search for the word (e.g., Computer Programming) starting from a URL (e.g., <http://cs.armstrong.edu/liang>). Your program prompts the user to enter the word and the starting URL and terminates once the word is found. Display the URL for the page that contains the word.