Lecture 11

Exception Handling and Text IO

Motivation

- When a program runs into a runtime error, the program terminates abnormally.

- How can you handle the runtime error so that the program can continue to run or terminate gracefully?

Exception-Handling Example

```
public class Quotient {
  public static void main(String[] args) {
    Scanner input = new Scanner(System.in);

    // Prompt the user to enter two integers
    System.out.print("Enter two integers: ");
    int number1 = input.nextInt(); //1;
    int number2 = input.nextInt(); //0;

    System.out.println(number1 + " / " +
      number2 + " is " + (number1 / number2));
  }
}
```

Exception-Handling Example

```
public class Quotient {
  public static void main(String[] args) {
    Scanner input = new Scanner(System.in);

    // Prompt the user to enter two integers
```

```
Exception in thread "main"
java.lang.ArithmeticException: / by zero
    at Quotient.main(Quotient.java:12)
```

```
    System.out.println(number1 + " / " +
      number2 + " is " + (number1 / number2));
  }
}
```

Exception-Handling Example

```
public class QuotientWithIf {
  public static void main(String[] args) {
    Scanner input = new Scanner(System.in);

    // Prompt the user to enter two integers
    System.out.print("Enter two integers: ");
    int number1 = input.nextInt(); //1;
    int number2 = input.nextInt(); //0;
    if (number2 != 0)
      System.out.println(number1 + " / " + number2 + " is
" +
        (number1 / number2));
    else
      System.out.println("Divisor cannot be zero ");
  }
}
```

Exception-Handling Example

```
public class QuotientWithException {
  public static void main(String[] args) {
    Scanner input = new Scanner(System.in);

    // Prompt the user to enter two integers
    System.out.print("Enter two integers: ");
    int number1 = input.nextInt(); //1
    int number2 = input.nextInt(); //0

    try {
      int result = number1 / number2;
      System.out.println(number1 + " / " + number2 + " is "
        + result);
    }
    catch (ArithmeticException ex) {
      System.out.println("Exception: an integer " +
        "cannot be divided by zero ");
    }

    System.out.println("Execution continues ...");
  }
}
```

Exception Advantages

- It enables a method to throw an exception to its caller.

- Without this capability, a method must handle the exception or terminate the program.

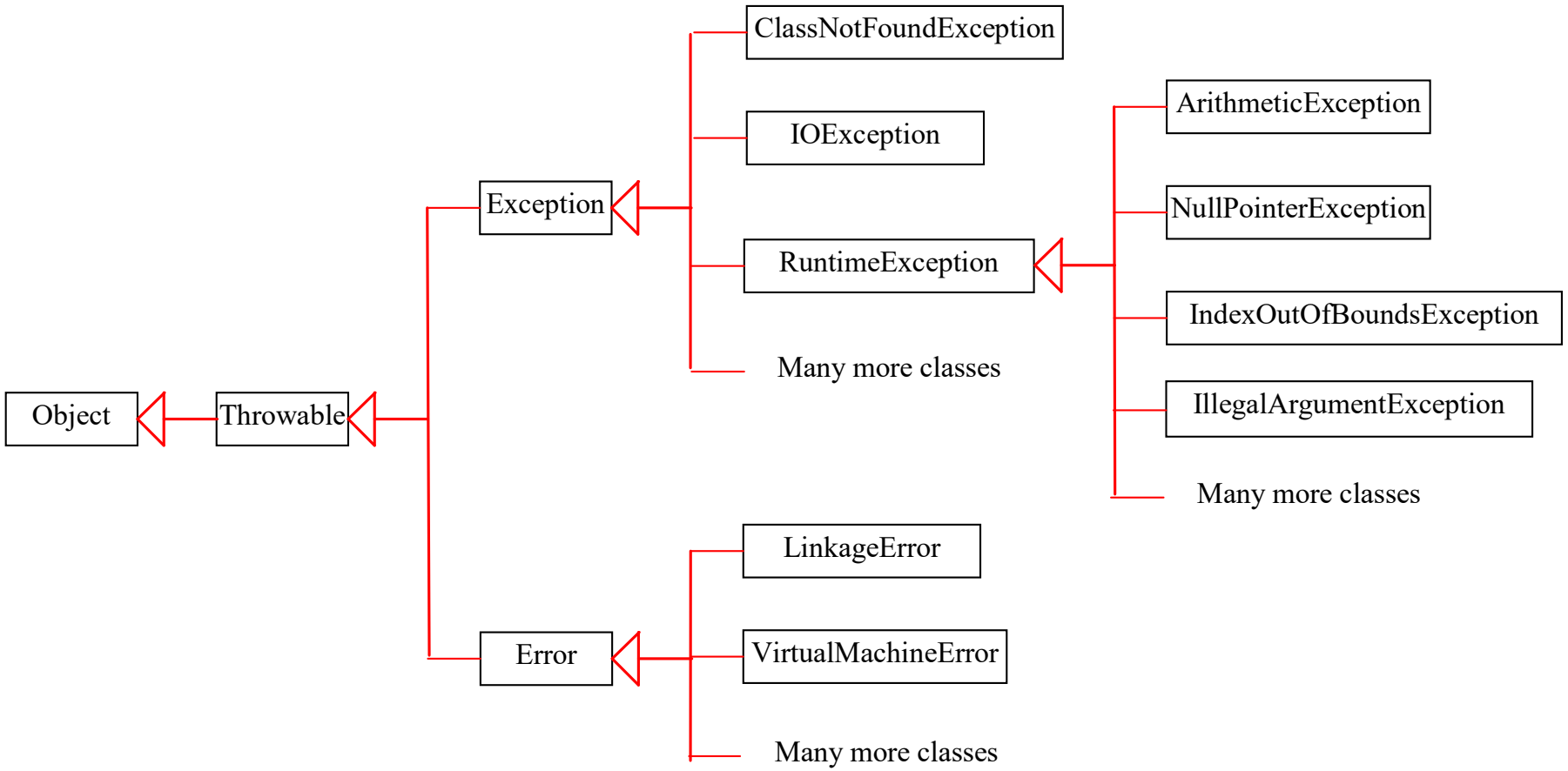
Handling InputMismatchException

```
public class InputMismatchExceptionDemo {
  public static void main(String[] args) {
    Scanner input = new Scanner(System.in);
    boolean continueInput = true;

    do {
      try {
        System.out.print("Enter an integer: ");
        int number = input.nextInt();

        // Display the result
        System.out.println(
          "The number entered is " + number);

        continueInput = false;
      }
      catch (InputMismatchException ex) {
        System.out.println("Try again. (" +
          "Incorrect input: an integer is required)");
        input.nextLine(); // discard input
      }
    } while (continueInput);
  }
}
```

Handling InputMismatchException

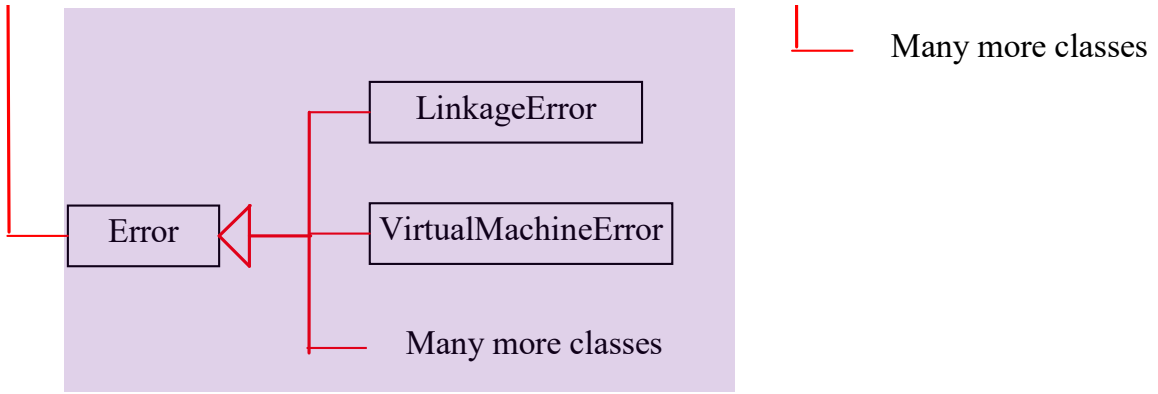
- By handling `InputMismatchException`, your program will continuously read an input until it is correct.

Exception Types

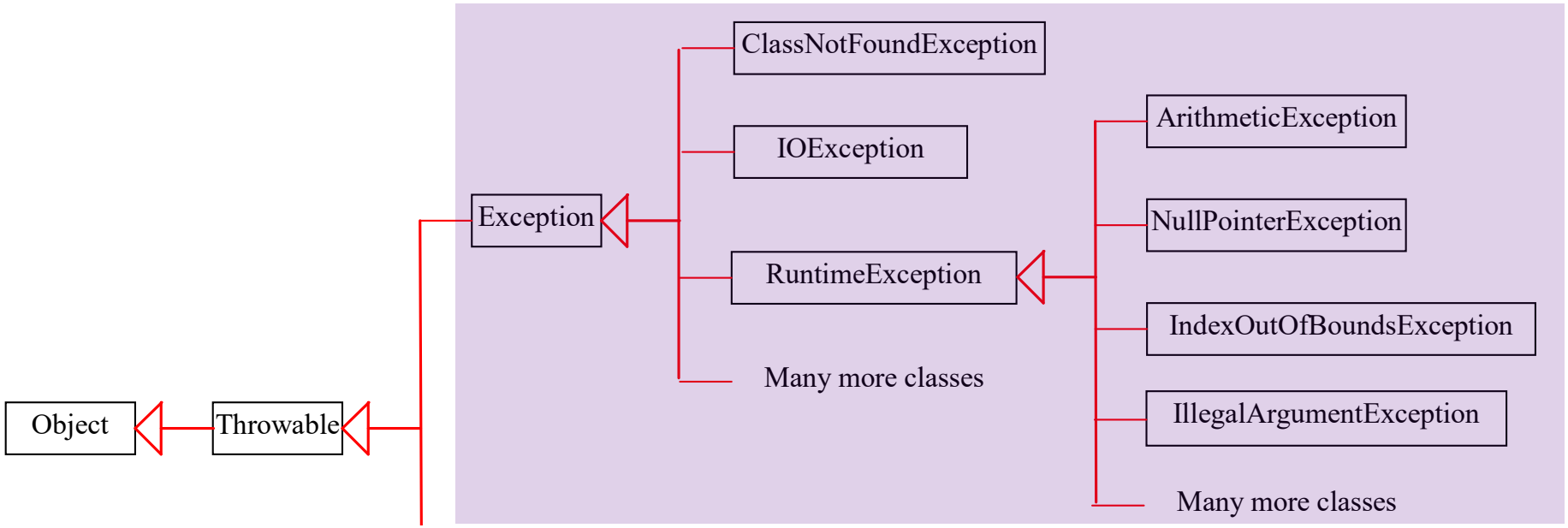


System Errors

- System errors are thrown by JVM and represented in the Error class.
- The Error class describes internal system errors.
- Such errors rarely occur.
- If one does, there is little you can do beyond notifying the user and trying to terminate the program gracefully.

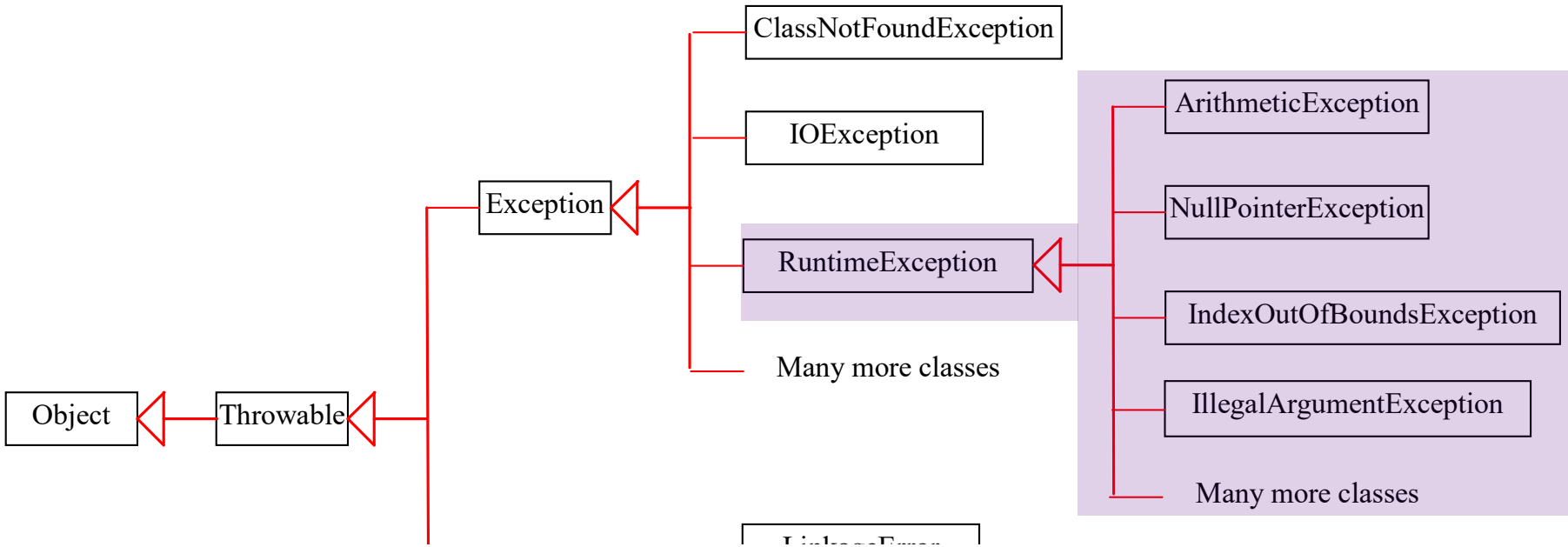


Exceptions



- `Exception` describes errors caused by your program and external circumstances.
- These errors can be caught and handled by your program.

Runtime Exceptions



- `RuntimeException` is caused by programming errors, such as bad casting, accessing an out-of-bounds array, and numeric errors.

Checked vs. Unchecked Exceptions

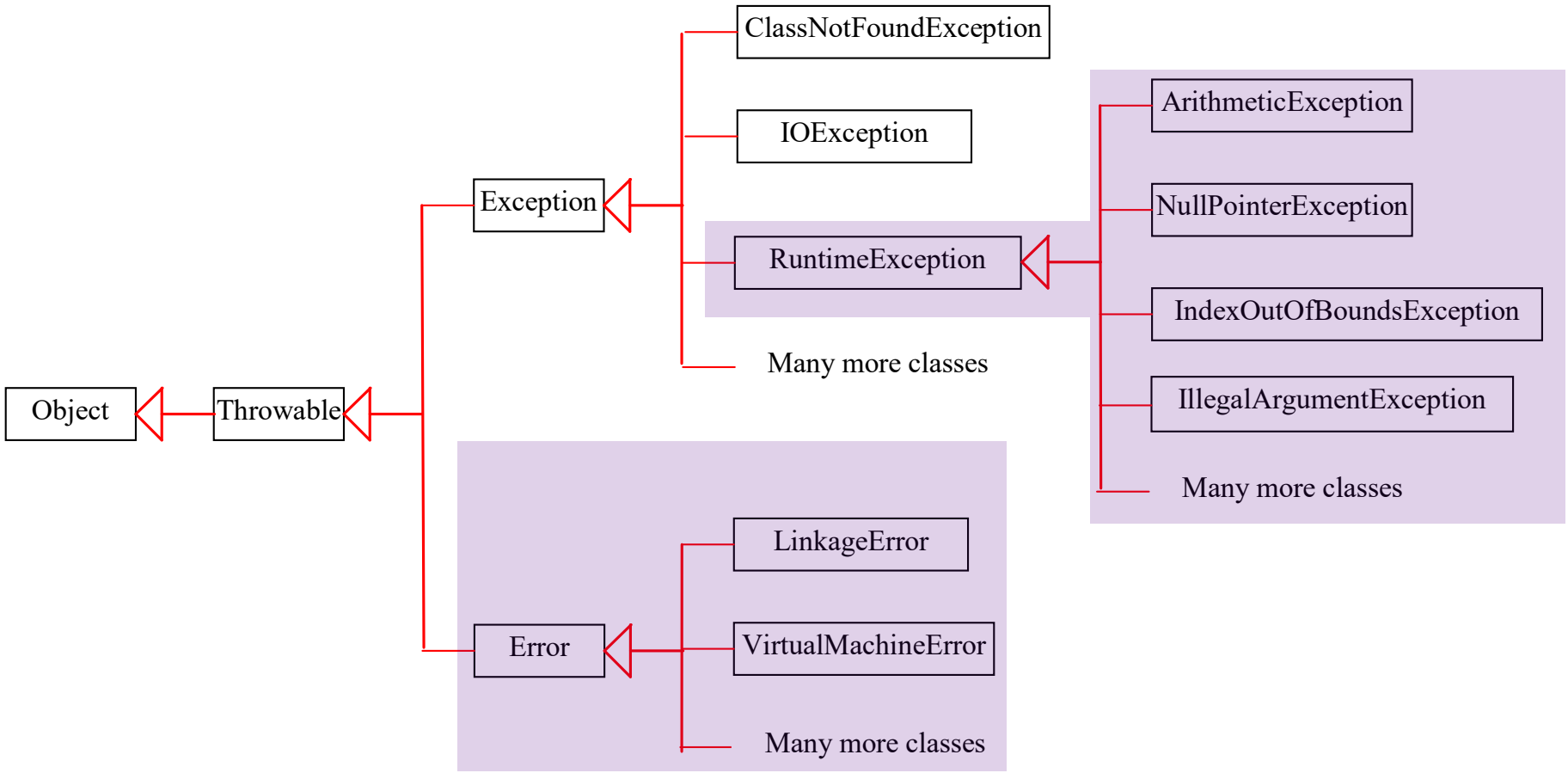
- `RuntimeException`, `Error` and their subclasses are known as **unchecked exceptions**.

- All other exceptions are known as **checked exceptions**, meaning that the compiler forces the programmer to check and deal with the exceptions.

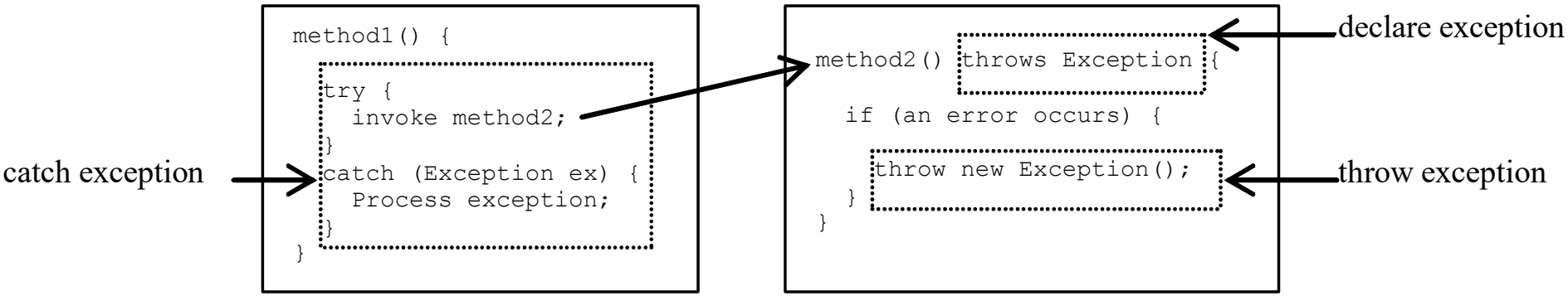
Unchecked Exceptions

- In most cases, unchecked exceptions reflect programming logic errors that are not recoverable.
- 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 the logic errors that should be corrected in the program.
- Unchecked exceptions can occur anywhere in the program.
- To avoid cumbersome overuse of try-catch blocks, Java does not mandate you to write code to catch unchecked exceptions.

Unchecked Exceptions



Declaring, Throwing, and Catching



Declaring Exceptions

- Every method must state the types of checked exceptions it might throw.
- This is known as declaring exceptions.

- Example:

```
public void myMethod() throws IOException

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

Throwing Exceptions

- When the program detects an error, the program can create an instance of an appropriate exception type and throw it.
- This is known as throwing an exception.

- Example:

```
throw new TheException();
```

```
TheException ex = new TheException();
throw ex;
```

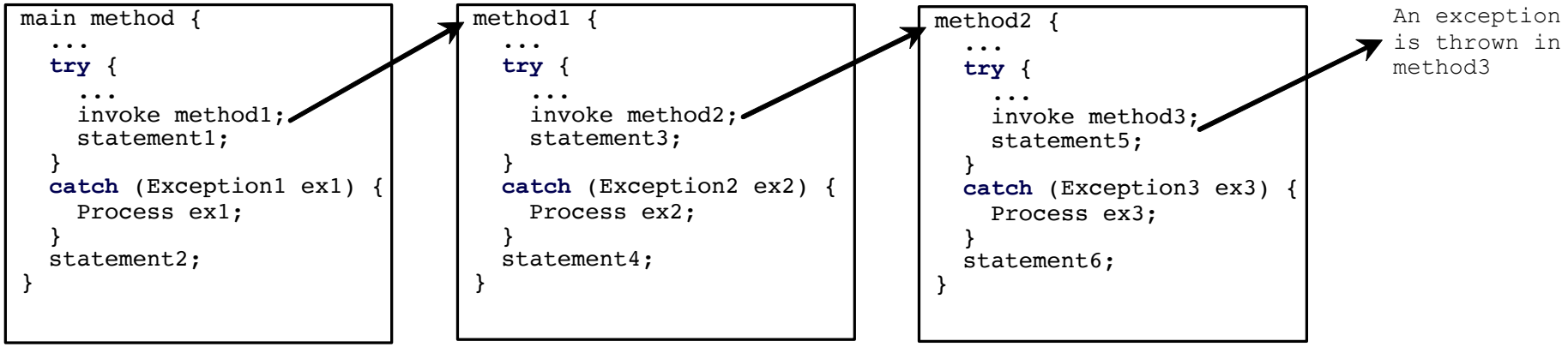
Throwing Exceptions Example

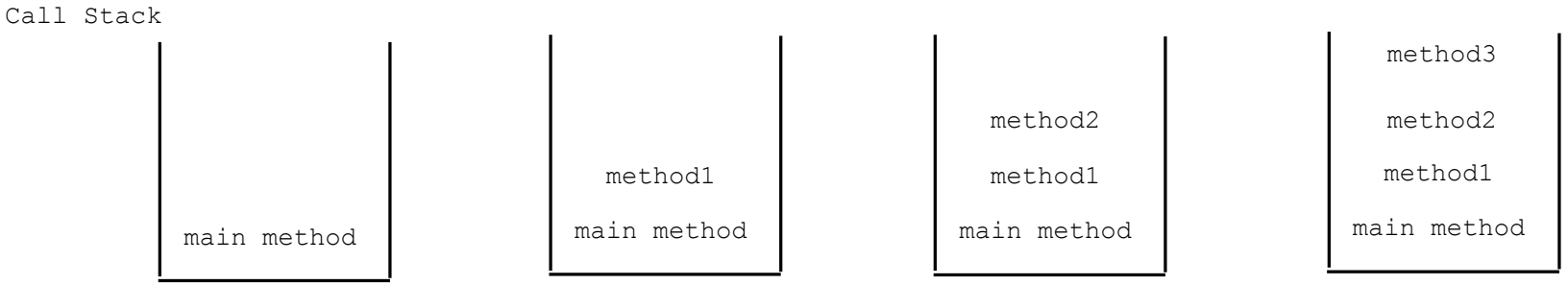
```
/** Set a new radius */
public void setRadius(double newRadius)
      throws IllegalArgumentException {
  if (newRadius >= 0)
    radius =  newRadius;
  else
    throw new IllegalArgumentException(
        "Radius cannot be negative");
}
```

Catching Exceptions

```
try {
  statements; // May throw exceptions
}
catch (Exception1 exVar1) {
  handler for exception1;
}
catch (Exception2 exVar2) {
  handler for exception2;
}
...
catch (ExceptionN exVar3) {
  handler for exceptionN;
}
```

Catching Exceptions





Catch or Declare?

- Java forces you to deal with checked exceptions.
- If a method declares a checked exception (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 that method `p1` invokes method `p2` that may throw a checked exception (e.g., `IOException`), you have 2 possibilities

Catch or Declare?

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

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

Example

```
public class Circle {
  private static int numberOfObjects = 0;

  public Circle(double newRadius) {
    setRadius(newRadius);
    numberOfObjects++;
  }

  public void setRadius(double newRadius)
      throws IllegalArgumentException {
    if (newRadius >= 0)
      radius = newRadius;
    else
      throw new IllegalArgumentException(
        "Radius cannot be negative");
  }
}
```

Example

```
public class TestCircle {
  public static void main(String[] args) {
    try {
      Circle c1 = new Circle(5);
      Circle c2 = new Circle(-5);
      Circle c3 = new Circle(0);
    }
    catch (IllegalArgumentException ex) {
      System.out.println(ex);
    }

    System.out.println("created: " +
      Circle.getNumberOfObjects());
  }
}
```

Rethrowing Exceptions

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

The finally Clause

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

Trace a Program Execution

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

nextStatement;
```

Suppose no exceptions in the statements

Trace a Program Execution

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

nextStatement;
```

The final block is always executed

Trace a Program Execution

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

nextStatement;
```

Next statement in the method is executed

Trace a Program Execution

```
try {
  statement1;
  statement2;
  statement3;
}
catch(Exception1 ex) {
  handling ex;
}
finally {
  finalStatements;
}

nextStatement;
```

Suppose an exception of type `Exception1` is thrown in `statement2`

Trace a Program Execution

```
try {
  statement1;
  statement2;
  statement3;
}
catch(Exception1 ex) {
  handling ex;
}
finally {
  finalStatements;
}

nextStatement;
```

The exception is handled.

Trace a Program Execution

```
try {
  statement1;
  statement2;
  statement3;
}
catch(Exception1 ex) {
  handling ex;
}
finally {
  finalStatements;
}

nextStatement;
```

The final block is always executed.

Trace a Program Execution

```
try {
  statement1;
  statement2;
  statement3;
}
catch(Exception1 ex) {
  handling ex;
}
finally {
  finalStatements;
}

nextStatement;
```

The next statement in the method is now executed.

Trace a Program Execution

```
try {
  statement1;
  statement2;
  statement3;
}
catch(Exception1 ex) {
  handling ex;
}
catch(Exception2 ex) {
  handling ex;
  throw ex;
}
finally {
  finalStatements;
}

nextStatement;
```

`statement2` throws an exception of type `Exception2`.

Trace a Program Execution

```
try {
  statement1;
  statement2;
  statement3;
}
catch(Exception1 ex) {
  handling ex;
}
catch(Exception2 ex) {
  handling ex;
  throw ex;
}
finally {
  finalStatements;
}

nextStatement;
```

Handling exception

Trace a Program Execution

```
try {
  statement1;
  statement2;
  statement3;
}
catch(Exception1 ex) {
  handling ex;
}
catch(Exception2 ex) {
  handling ex;
  throw ex;
}
finally {
  finalStatements;
}

nextStatement;
```

Execute the final block

Trace a Program Execution

```
try {
  statement1;
  statement2;
  statement3;
}
catch(Exception1 ex) {
  handling ex;
}
catch(Exception2 ex) {
  handling ex;
  throw ex;
}
finally {
  finalStatements;
}

nextStatement;
```

Rethrow the exception and control is transferred to the caller

Cautions When Using Exceptions

- 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 errors to the calling methods.

When to Throw Exceptions

- 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 it.

When to Use Exceptions

- When should you use the try-catch block in the code?
- You should use it to deal with unexpected error conditions.
- **Do not use it** to deal with simple, expected situations.

When to Use Exceptions

- Bad

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

- Better

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

Defining Custom Exception Classes

- Use the exception classes in the API whenever possible.
- Define custom exception classes if the predefined classes are not sufficient.
- Define custom exception classes by extending `Exception` or a subclass of `Exception`.

Assertions

- An **assertion** is a Java statement that enables you to assert an assumption about your program.
- An assertion contains a Boolean expression that should be true during program execution.
- Assertions can be used to assure program correctness and avoid logic errors.

Declaring Assertions

- An assertion is declared using the new Java keyword assert in JDK 1.4
  - `assert assertion; or`
  - `assert assertion : detailMessage;`

- where `assertion` is a Boolean expression and
- `detailMessage` is a primitive-type or an Object value.

Executing Assertions

- When an assertion statement is executed, Java evaluates the assertion.
- If it is false, an AssertionError will be thrown.
- The AssertionError class has a
  - no-arg constructor and
  - seven overloaded single-argument constructors of type
    - int,
    - long,
    - float,
    - double,
    - boolean,
    - char, and
    - Object.

Executing Assertions

- `assert assertion;` (no detail message)
  - the no-arg constructor of `AssertionError` is used.
- `assert assertion : detailMessage;`
  - an appropriate `AssertionError` constructor is used to match the data type of the message.
- Since AssertionError is a subclass of Error, when an assertion becomes false, the program displays a message on the console and exits.

Executing Assertions Example

```
public class AssertionDemo {
  public static void main(String[] args) {
    int i; int sum = 0;
    for (i = 0; i < 10; i++) {
      sum += i;
    }
    assert i == 10;
    assert (sum > 10 && sum < 5 * 10) :
"sum is " + sum;
  }
}
```

Compiling Programs with Assertions

- Since assert is a new Java keyword introduced in JDK 1.4, you have to compile the program using a JDK 1.4 compiler.

- Furthermore, you need to include the switch `-source 1.4` in the compiler command as follows:
  - `javac -source 1.4 AssertionDemo.java`

- NOTE: If you use JDK 1.5, there is no need to use the `-source 1.4` option in the command.

Running Programs with Assertions

- By default, the assertions are disabled at runtime.
- To enable it, use the switch `-enableassertions`, or `-ea` for short, as follows:
  - `java -ea AssertionDemo`
- Assertions can be selectively enabled or disabled at class level or package level.
- The disable switch is `-disableassertions` or `-da` for short.
- Example
  - `java -ea:package1 -da:Class1 AssertionDemo`

Exception Handling vs Assertions

- Assertion should not be used to replace exception handling.
- Exception handling deals with unusual circumstances during program execution.
- Assertions are to assure the correctness of the program.

- Exception handling addresses robustness
- Assertion addresses correctness.

Exception Handling vs Assertions

- Like exception handling, assertions are not used for normal tests, but for internal consistency and validity checks.
- Assertions are checked at runtime and can be turned on or off at startup time.
- Do not use assertions for argument checking in public methods.

Exception Handling vs Assertions

- Valid arguments that may be passed to a public method are considered to be part of the method's contract.
- The contract must always be obeyed whether assertions are enabled or disabled.

- For example, the following code in the Circle class should be rewritten using exception handling.

```
public void setRadius(double newRadius) {
  assert newRadius >= 0;
  radius =  newRadius;
}
```

Exception Handling vs Assertions

- Use assertions to reaffirm assumptions.
- This gives you more confidence to assure correctness of the program.
- A common use of assertions is to replace assumptions with assertions in the code.

Exception Handling vs Assertions

- Another good use of assertions is place assertions in a switch statement without a default case.

- Example:

```
switch (month) {
  case 1: ... ; break;
  case 2: ... ; break;
  ...
  case 12: ... ; break;
  default: assert false : "Invalid month: " +
month
}
```

The File Class

- 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 filename is a string.
- The File class is a wrapper class for the file name and its directory path.

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 *hidden* 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.

Example

```
java.io.File file = ...

System.out.println("Does it exist? " + file.exists());
System.out.println("The file has " + file.length() + "
bytes");
System.out.println("Can it be read? " + file.canRead());
System.out.println("Can it be written? " +
file.canWrite());
System.out.println("Is it a directory? " +
file.isDirectory());
System.out.println("Is it a file? " + file.isFile());
System.out.println("Is it absolute? " +
file.isAbsolute());
System.out.println("Is it hidden? " + file.isHidden());
System.out.println("Absolute path is " +
file.getAbsolutePath());
System.out.println("Last modified on " + new
java.util.Date(file.lastModified()));
```

Text I/O

- A File object encapsulates the properties of a file or a path, but does not contain the methods for reading/writing data from/to a file.

- 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.

- How to read/write strings and numeric values from/to a text file using the `Scanner` and `PrintWriter` classes.

Writing Data Using PrintWriter

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

Writing Data Using PrintWriter

```
public class WriteData {
  public static void main(String[] args) throws
java.io.IOException {
    java.io.File file = new java.io.File("scores.txt");
    if (file.exists()) {
      System.out.println("File already exists");
      System.exit(0);
    }

    // Create a file
    java.io.PrintWriter output = new java.io.PrintWriter(file);

    // Write formatted output to the file
    output.print("John T Smith ");
    output.println(90);
    // Close the file
    output.close();
  }
}
```

Try-with-resources

- Programmers often forget to close the file.

- JDK 7 provides the followings new try-with-resources syntax that automatically closes the files.

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

Try-with-resources

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

    try (java.io.PrintWriter output =
                    new java.io.PrintWriter(file);
    ) {
      // Write formatted output to the file
      output.print("John T Smith ");
      output.println(90); }
  }
}
```

Reading Data Using Scanner

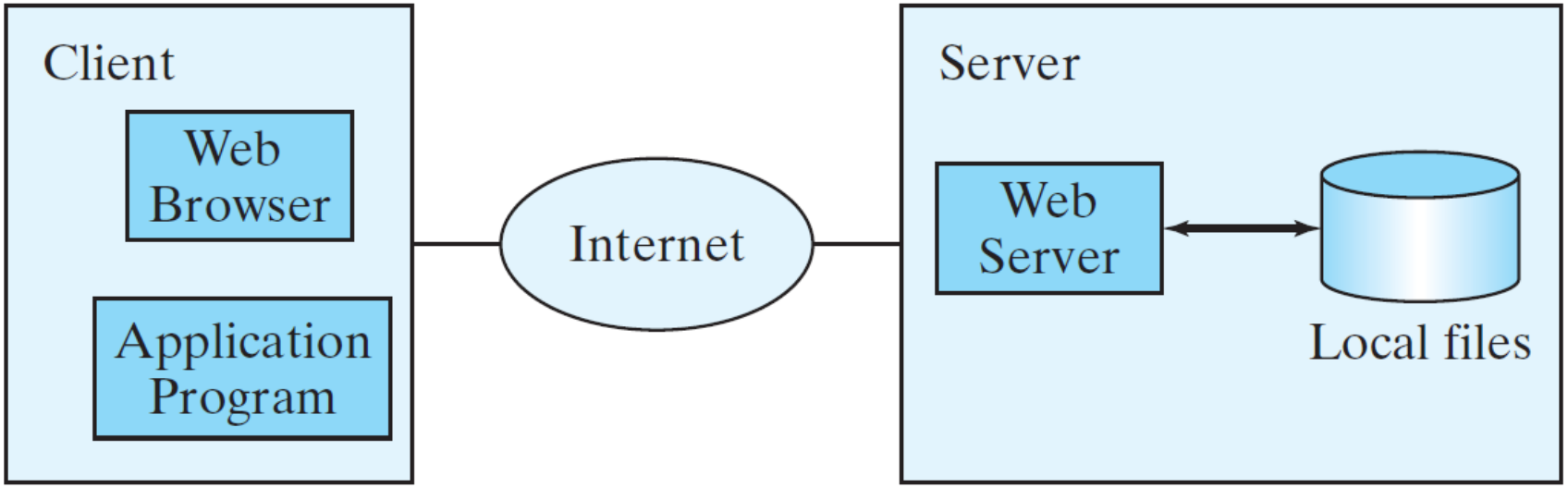
java.util.Scanner	
+Scanner(source: File)	Creates a Scanner object to read data from the specified file.
+Scanner(source: String)	Creates a Scanner object to read data from the specified string.
+close()	Closes this scanner.
+hasNext(): boolean	Returns true if this scanner has another token in its input.
+next(): String	Returns next token as a string.
+nextByte(): byte	Returns next token as a byte.
+nextShort(): short	Returns next token as a short.
+nextInt(): int	Returns next token as an int.
+nextLong(): long	Returns next token as a long.
+nextFloat(): float	Returns next token as a float.
+nextDouble(): double	Returns next token as a double.
+useDelimiter(pattern: String): Scanner	Sets this scanner's delimiting pattern.

Reading Data Using Scanner

```
public class ReadData {
  public static void main(String[] args) throws Exception {
    // Create a File instance
    java.io.File file = new java.io.File("scores.txt");

    // Create a Scanner for the file
    Scanner input = new Scanner(file);

    // Read data from a file
    while (input.hasNext()) {
      String firstName = input.next();
      int score = input.nextInt();
      System.out.println(firstName + " " + score);
    }

    // Close the file
    input.close();
  }
}
```

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.



Reading Data from the Web

- `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

- Use this stream to create a Scanner object as follows:
  - `Scanner input = new Scanner(url.openStream());`

Reading Data from the Web

```
public class ReadFileFromURL {
  public static void main(String[] args) {
    System.out.print("Enter a URL: ");
    String URLString = new Scanner(System.in).next();

    try {
      java.net.URL url = new java.net.URL(URLString);
      int count = 0;
      Scanner input = new Scanner(url.openStream());
      while (input.hasNext()) {
        String line = input.nextLine();
        count += line.length();
      }
      input.close();
      System.out.println("The file size is " + count + " characters");
    }
    catch (java.net.MalformedURLException ex) {
      System.out.println("Invalid URL");
    }
    catch (java.io.IOException ex) {
      System.out.println("IO Errors");
    }
  }
}
```