Streams, File I/O, and Networking

Chapter 14

Objectives

- Describe the concept of an I/O stream
- Explain the difference between text and binary files
- Save data, including objects, in a file
- Read data, including objects, in a file

Overview: Outline

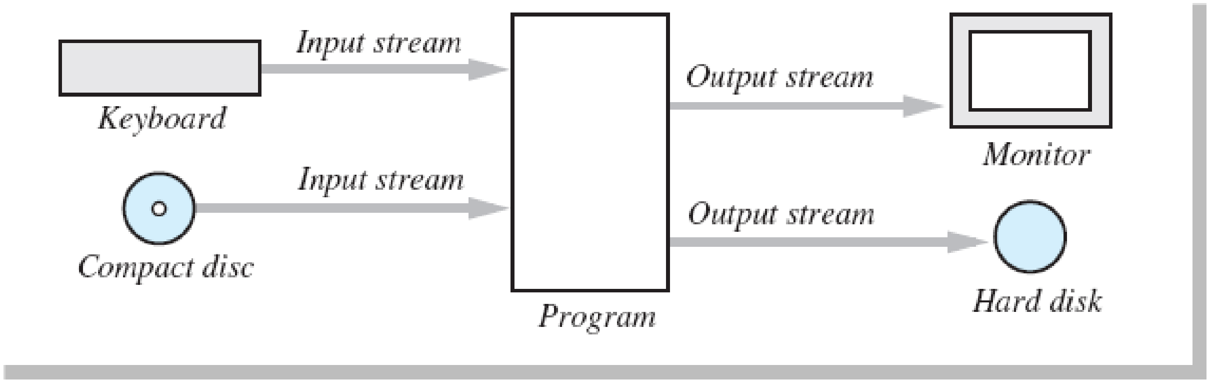
- The Concept of a Stream
- Why Use Files for I/O?
- Text Files and Binary Files

The Concept of a Stream

- Use of files
  - Store Java classes, programs
  - Store pictures, music, videos
  - Can also use files to store program I/O
- A *stream* is a flow of input or output data
  - Characters
  - Numbers
  - Bytes

The Concept of a Stream

- Streams are implemented as objects of special stream classes
  - Class `Scanner`
  - Object `System.out`
- Figure 14.1
  I/O Streams



Why Use Files for I/O

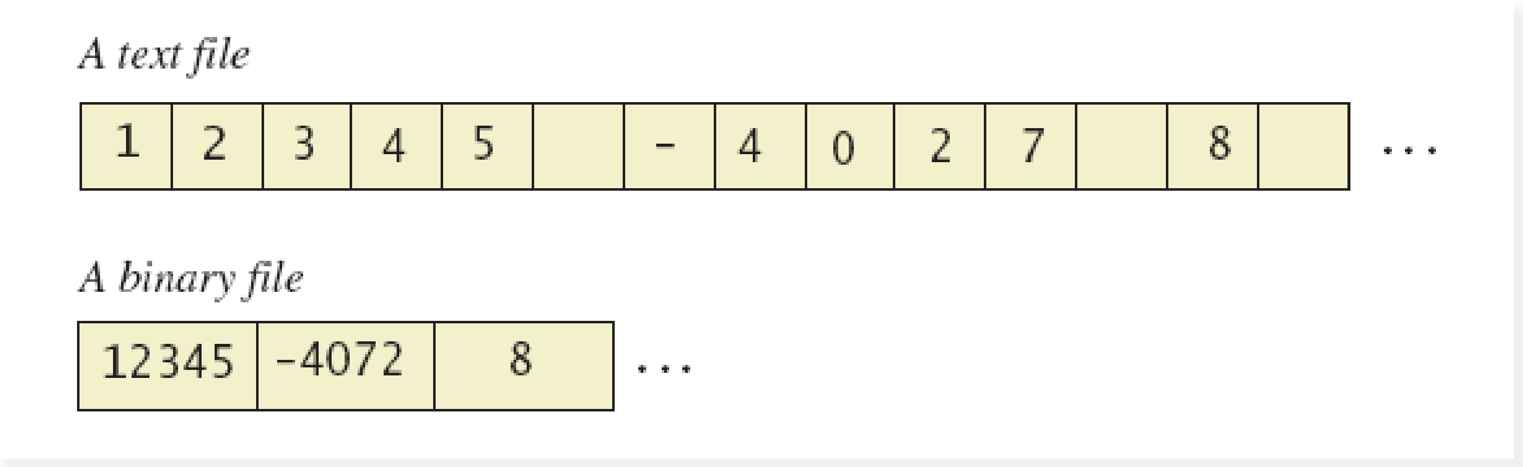
- Keyboard input, screen output deal with temporary data
  - When program ends, data is gone
- Data in a file remains after program ends
  - Can be used next time program runs
  - Can be used by another program

Text Files and Binary Files

- All data in files stored as binary digits
  - Long series of zeros and ones
- Files treated as sequence of characters called *text files*
  - Java program source code
  - Can be viewed, edited with text editor
- All other files are called *binary files*
  - Movie, music files
  - Access requires specialized program

Text Files and Binary Files

- Figure 14.2 A text file and a binary file containing the same values



Text-File I/O: Outlline

- Creating a Text File
- Appending to a text File
- Reading from a Text File

Creating a Text File

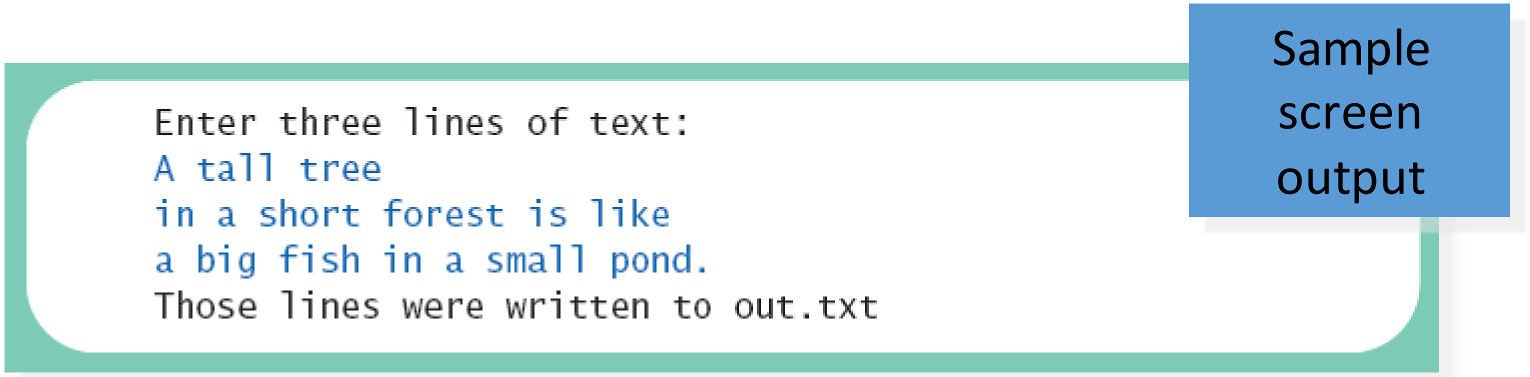
- Class `PrintWriter` defines methods needed to create and write to a text file
  - Must import package `java.io`
- To open the file
  - Declare *stream variable* for referencing the stream
  - Invoke `PrintWriter` constructor, pass file name as argument
  - Requires `try` and `catch` blocks

Creating a Text File

- File is empty initially
  - May now be written to with method `println`
- Data goes initially to memory buffer
  - When buffer full, goes to file
- Closing file empties buffer, disconnects from stream

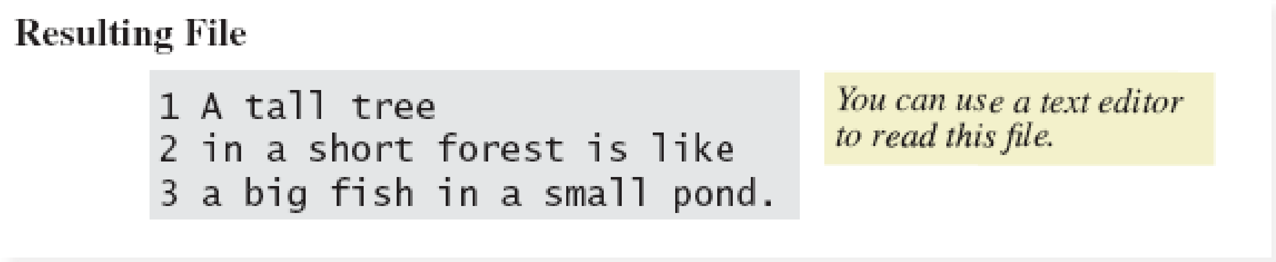
Creating a Text File

- View sample program, listing 14.1
  `class TextFileOutput`



Sample screen output

```
Enter three lines of text:
A tall tree
in a short forest is like
a big fish in a small pond.
Those lines were written to out.txt
```



Resulting File

```
1 A tall tree
2 in a short forest is like
3 a big fish in a small pond.
```

You can use a text editor to read this file.

Creating a Text File

- When creating a file
  - Inform the user of ongoing I/O events, program should not be "silent"
- A file has two names in the program
  - File name used by the operating system
  - The stream name variable
- Opening, writing to file overwrites pre-existing file in directory

Appending to a Text File

- Opening a file new begins with an empty file
  - If already exists, will be overwritten
- Some situations require appending data to existing file
- Command could be

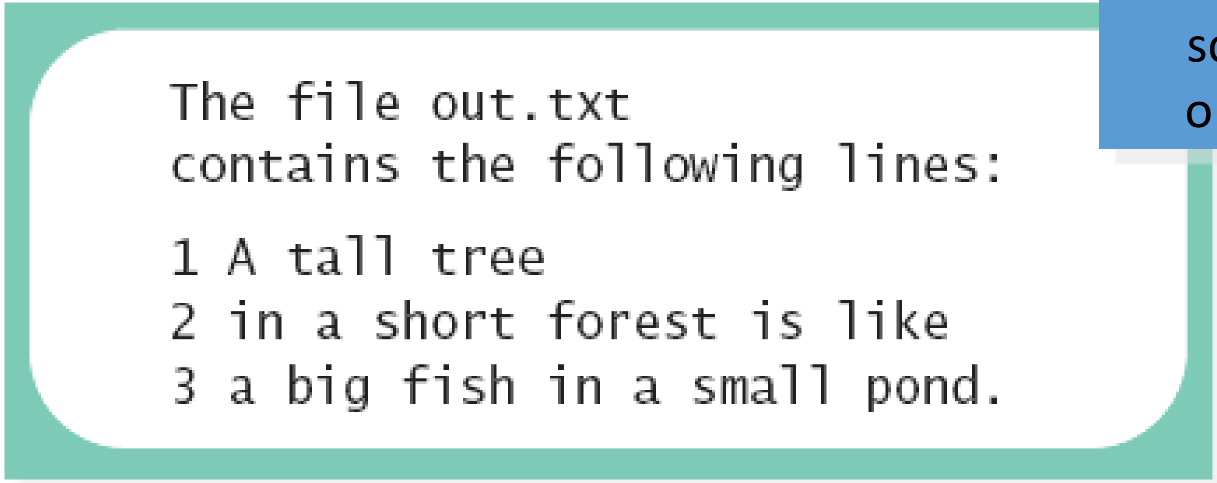
```
outputStream =
    new PrintWriter(
    new FileOutputstream(fileName, true));
```

- Method `println` would append data at end

Reading from a Text File

- Note text file reading program, listing 14.2
  `class TextFileInputDemo`
- Reads text from file, displays on screen
- Note
  - Statement which opens the file
  - Use of **`Scanner`** object
  - Boolean statement which reads the file and terminates reading loop

Reading from a Text File



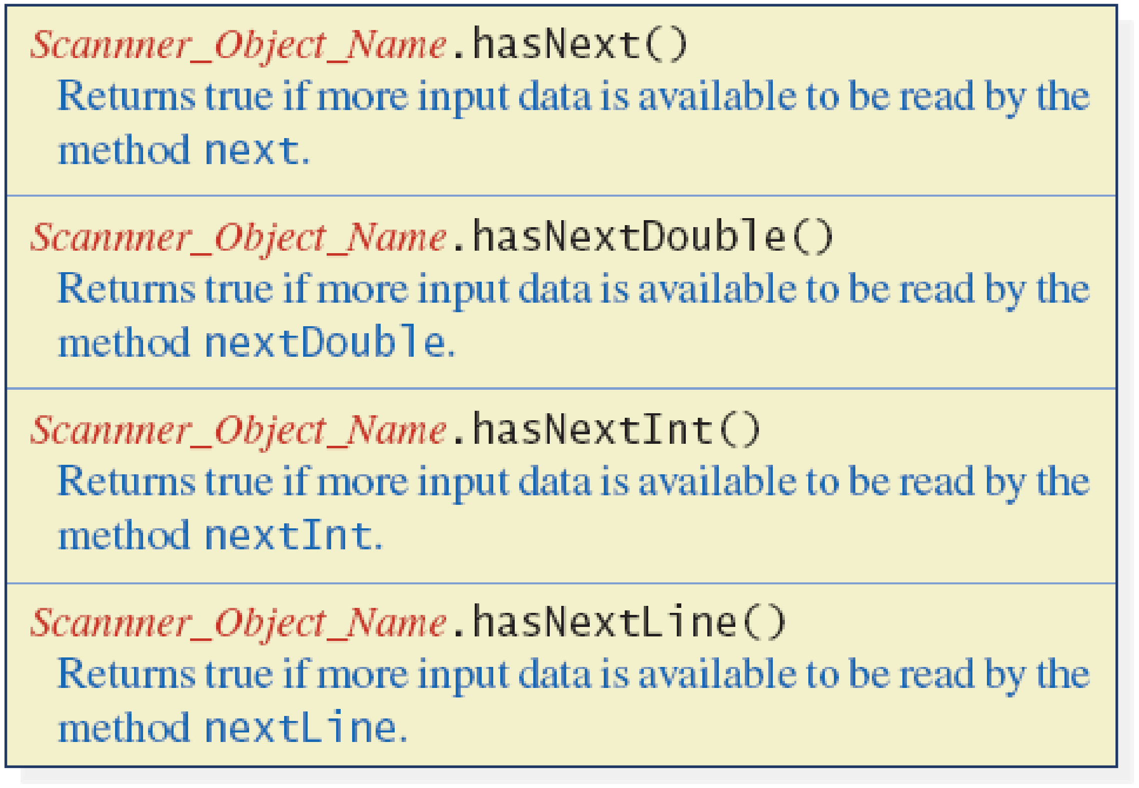
```
The file out.txt
contains the following lines:

1 A tall tree
2 in a short forest is like
3 a big fish in a small pond.
```

Sample screen output

Reading from a Text File

- Figure 14.3 Additional methods in class **`Scanner`**



Scannner_Object_Name`.hasNext()`
Returns true if more input data is available to be read by the method `next`.

Scannner_Object_Name`.hasNextDouble()`
Returns true if more input data is available to be read by the method `nextDouble`.

Scannner_Object_Name`.hasNextInt()`
Returns true if more input data is available to be read by the method `nextInt`.

Scannner_Object_Name`.hasNextLine()`
Returns true if more input data is available to be read by the method `nextLine`.

Techniques for Any File

- The Class `File`
- Programming Example: Reading a File Name from the Keyboard
- Using Path Names
- Methods of the Class `File`
- Defining a Method to Open a Stream

The Class `File`

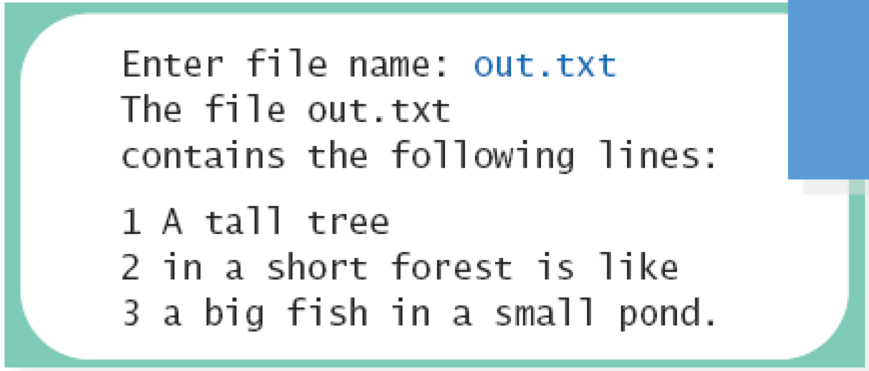
- Class provides a way to represent file names in a general way
  - A `File` object represents the name of a file
- The object

  ```
  new File ("treasure.txt")
  ```

  is not simply a string
  - It is an object that *knows* it is supposed to name a file

Programming Example

- Reading a file name from the keyboard
- View sample code, listing 14.4
  `class TextFileInputDemo2`



```
Enter file name: out.txt
The file out.txt
contains the following lines:

1 A tall tree
2 in a short forest is like
3 a big fish in a small pond.
```

Sample screen output

Using Path Names

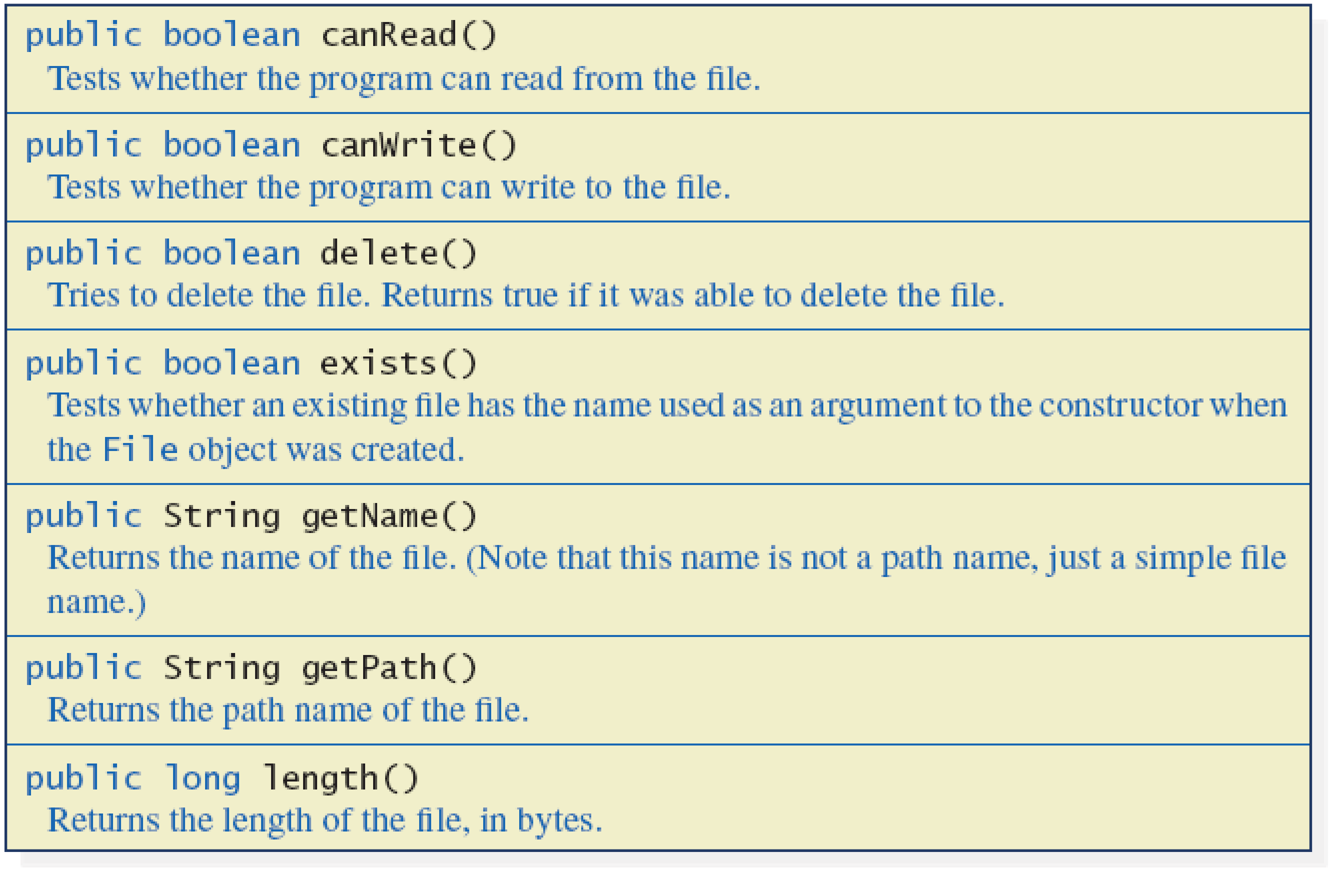
- Files opened in our examples assumed to be in same folder as where program run
- Possible to specify path names
  - Full path name
  - Relative path name
- Be aware of differences of pathname styles in different operating systems

Methods of the Class File

- Recall that a **`File`** object is a system-independent abstraction of file's path name
- Class **`File`** has methods to access information about a path and the files in it
  - Whether the file exists
  - Whether it is specified as readable or not
  - Etc.

Methods of the Class File

- Figure 14.5 Some methods in class **`File`**



`public boolean canRead()`	Tests whether the program can read from the file.
`public boolean canWrite()`	Tests whether the program can write to the file.
`public boolean delete()`	Tries to delete the file. Returns true if it was able to delete the file.
`public boolean exists()`	Tests whether an existing file has the name used as an argument to the constructor when the `File` object was created.
`public String getName()`	Returns the name of the file. (Note that this name is not a path name, just a simple file name.)
`public String getPath()`	Returns the path name of the file.
`public long length()`	Returns the length of the file, in bytes.

Defining a Method to Open a Stream

- Method will have a `String` parameter
  - The file name
- Method will return the stream object
- Will throw exceptions
  - If file not found
  - If some other I/O problem arises
- Should be invoked inside a `try` block and have appropriate `catch` block

Defining a Method to Open a Stream

- Example code

```
public static PrintWriter openOutputTextFile(String fileName)
                           throws FileNotFoundException, IOException
{
    PrintWriter toFile = new PrintWriter(fileName);
    return toFile;
}
```

- Example call

```
PrintWriter outputStream = null;
try
{
    outputStream = openOutputTextFile("data.txt");
}
< appropriate catch block(s) >
```

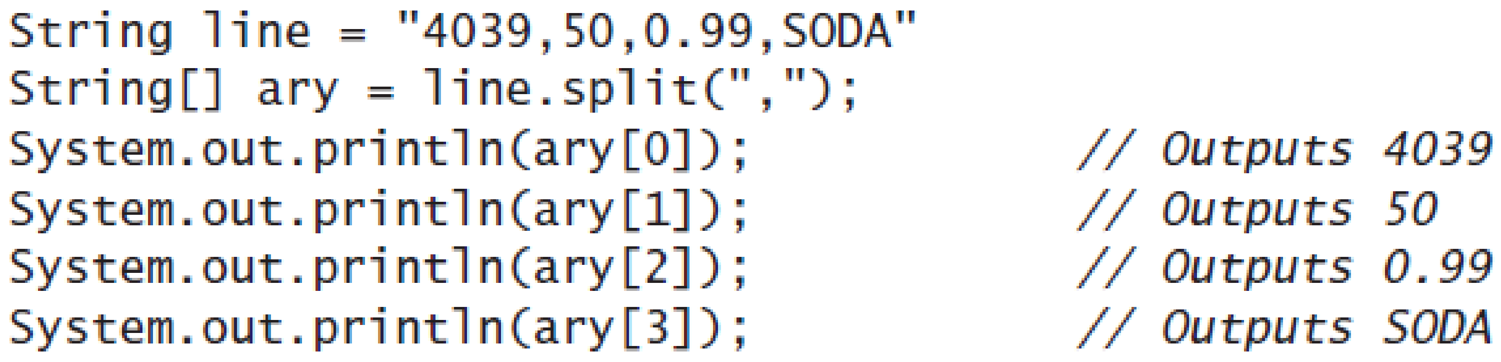
Case Study
Processing a Comma-Separated Values File

- A comma-separated values or CSV file is a simple text format used to store a list of records
- Example from log of a cash register's transactions for the day:

```
SKU,Quantity,Price,Description
4039,50,0.99,SODA
   9100,5,9.50,T-SHIRT
1949,30,110.00,JAVA PROGRAMMING TEXTBOOK
5199,25,1.50,COOKIE
```

Example Processing a CSV File

- View program that calculates total sales, listing 14.5 **`class TransactionReader`**
- Uses the split method which puts strings separated by a delimiter into an array



```
String line = "4039,50,0.99,SODA"
String[] ary = line.split(",");
System.out.println(ary[0]);             // Outputs 4039
System.out.println(ary[1]);             // Outputs 50
System.out.println(ary[2]);             // Outputs 0.99
System.out.println(ary[3]);             // Outputs SODA
```

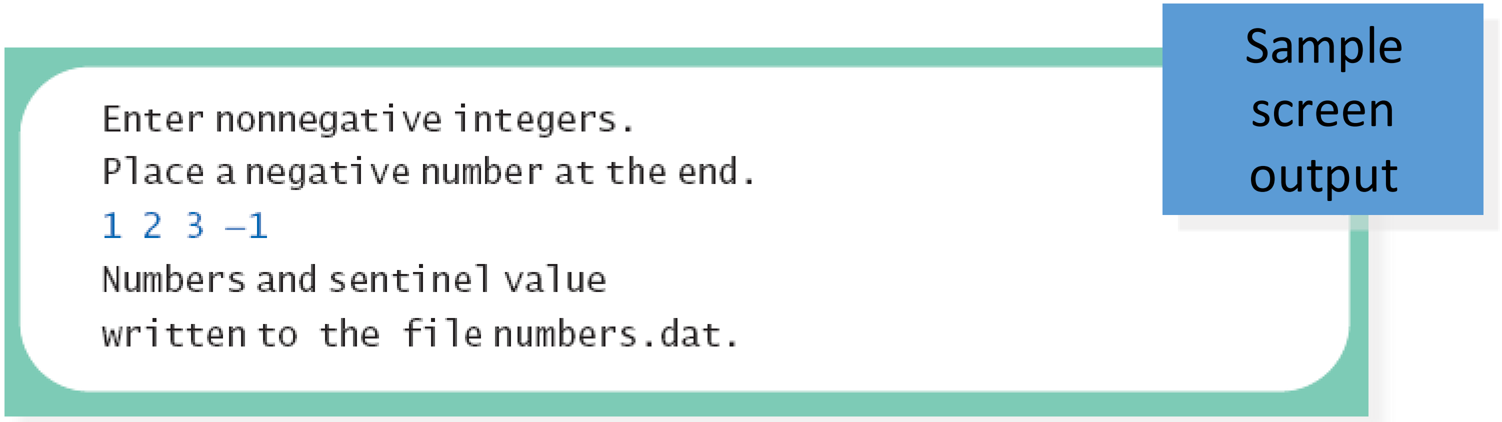
Basic Binary-File I/O

- Creating a Binary File
- Writing Primitive Values to a Binary File
- Writing Strings to a Binary File
- The Class **`EOFException`**
- Programming Example: Processing a File of Binary Data

Creating a Binary File

- Stream class **`ObjectOutputStream`** allows files which can store
  - Values of primitive types
  - Strings
  - Other objects
- View program which writes integers,
  listing 14.6 **`class BinaryOutputDemo`**

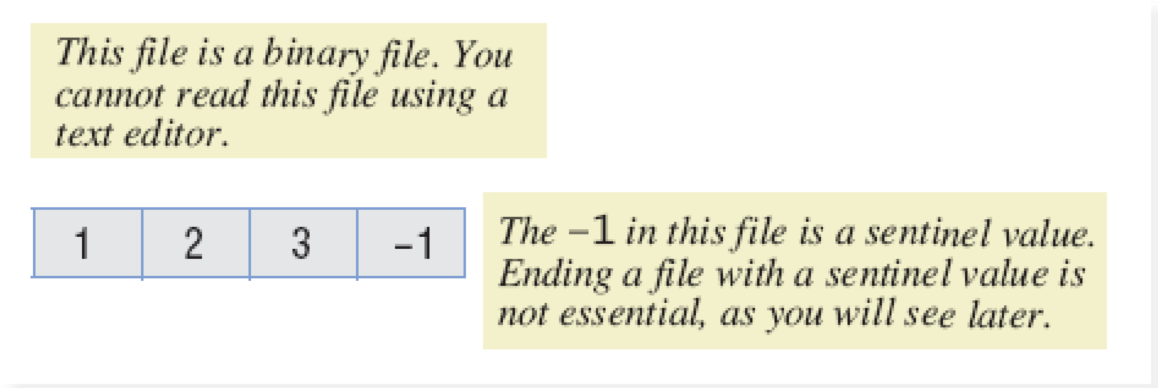
Creating a Binary File


```
Enter nonnegative integers.
Place a negative number at the end.
1 2 3 -1
Numbers and sentinel value
written to the file numbers.dat.
```

- Note the line to open the file
  - Constructor for `ObjectOutputStream` cannot take a `String` parameter
  - Constructor for `FileOutputSream` can

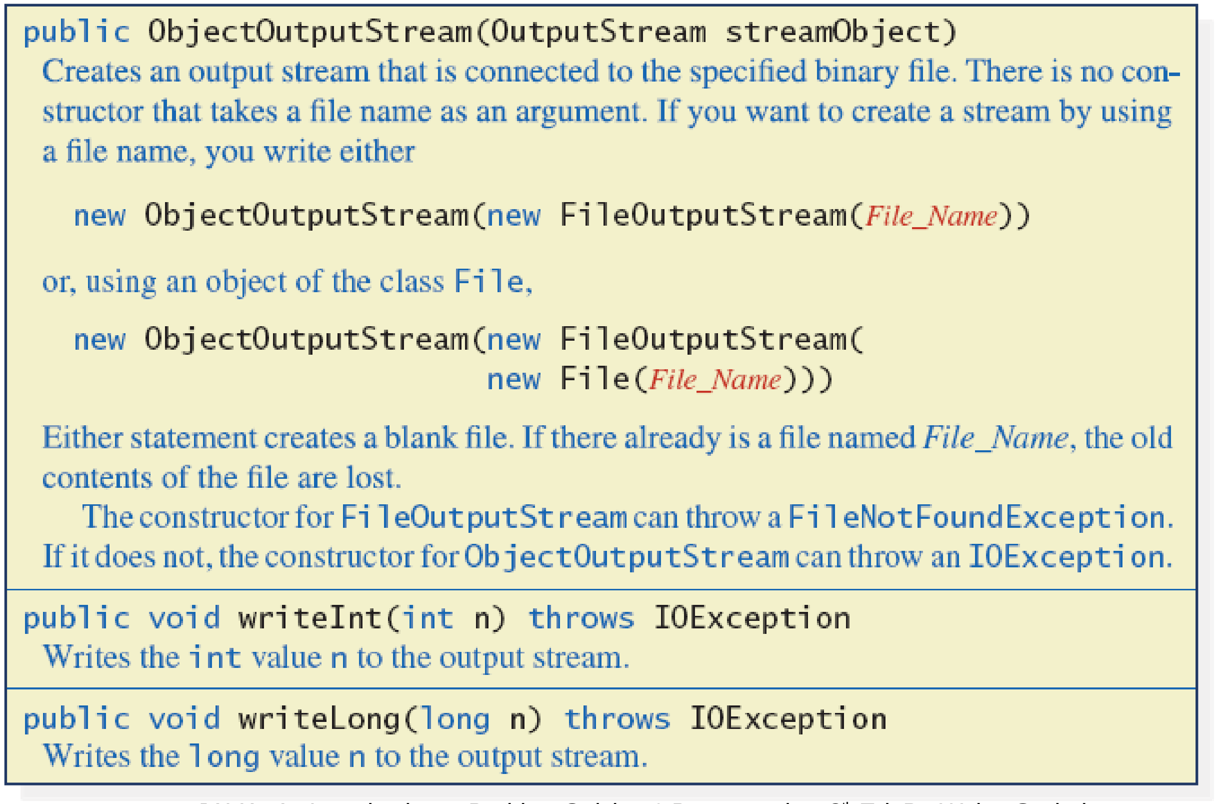
Writing Primitive Values to a Binary File

- Method println not available
  - Instead use writeInt method
  - View in listing 14.6
- Binary file stores numbers in binary form
  - A sequence of bytes
  - One immediately after another


This file is a binary file. You cannot read this file using a text editor.
1
2
3
-1
The −1 in this file is a sentinel value. Ending a file with a sentinel value is not essential, as you will see later.

Writing Primitive Values to a Binary File

- Figure 14.6a Some methods in class **ObjectOutputStream**



```
public ObjectOutputStream(OutputStream streamObject)
```

Creates an output stream that is connected to the specified binary file. There is no constructor that takes a file name as an argument. If you want to create a stream by using a file name, you write either

```
new ObjectOutputStream(new FileOutputStream(File_Name))
```

or, using an object of the class `File`,

```
new ObjectOutputStream(new FileOutputStream(
                        new File(File_Name)))
```

Either statement creates a blank file. If there already is a file named *File_Name*, the old contents of the file are lost.

The constructor for `FileOutputStream` can throw a `FileNotFoundException`. If it does not, the constructor for `ObjectOutputStream` can throw an `IOException`.

```
public void writeInt(int n) throws IOException
```

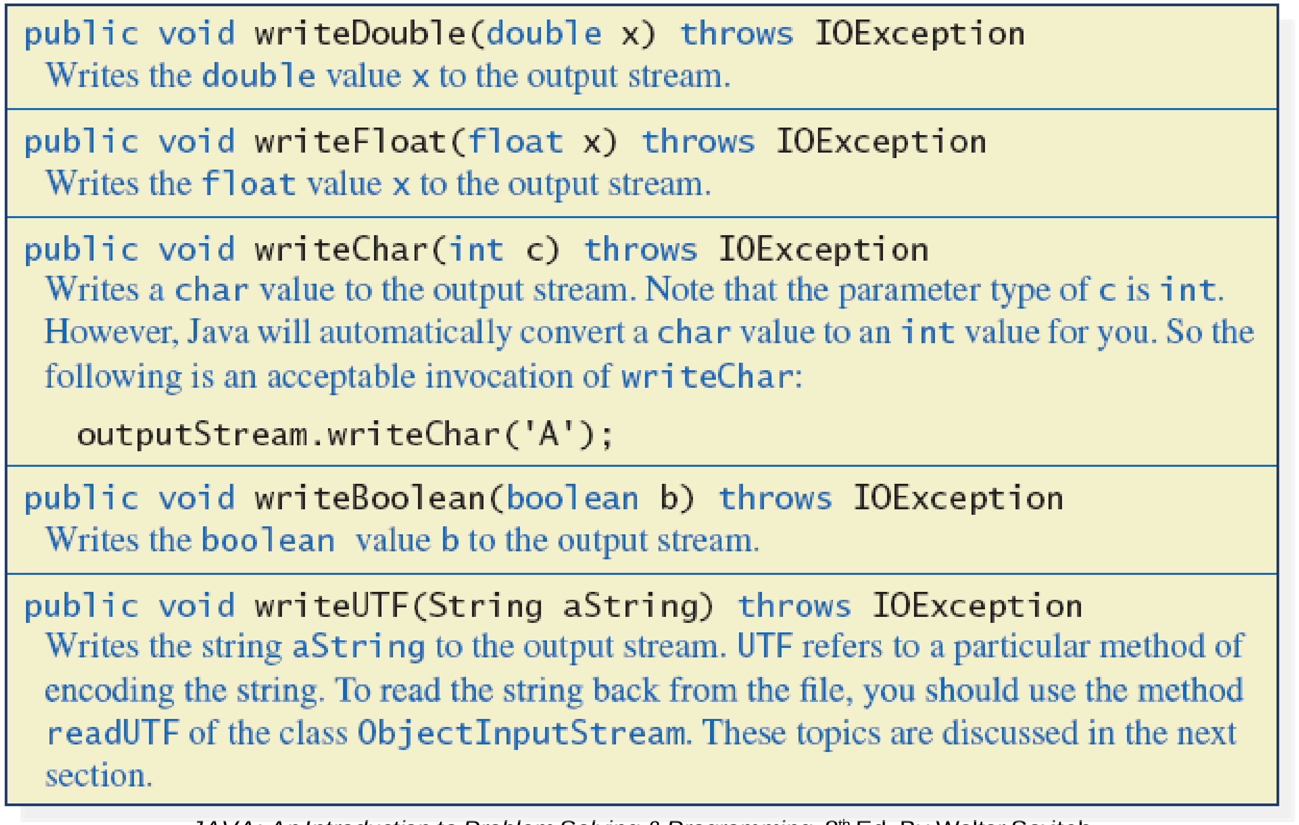
Writes the `int` value `n` to the output stream.

```
public void writeLong(long n) throws IOException
```

Writes the `long` value `n` to the output stream.

Writing Primitive Values to a Binary File

- Figure 14.6b Some methods in class **`ObjectOutputStream`**



```
public void writeDouble(double x) throws IOException
```
Writes the `double` value `x` to the output stream.

```
public void writeFloat(float x) throws IOException
```
Writes the `float` value `x` to the output stream.

```
public void writeChar(int c) throws IOException
```
Writes a `char` value to the output stream. Note that the parameter type of `c` is `int`. However, Java will automatically convert a `char` value to an `int` value for you. So the following is an acceptable invocation of `writeChar`:

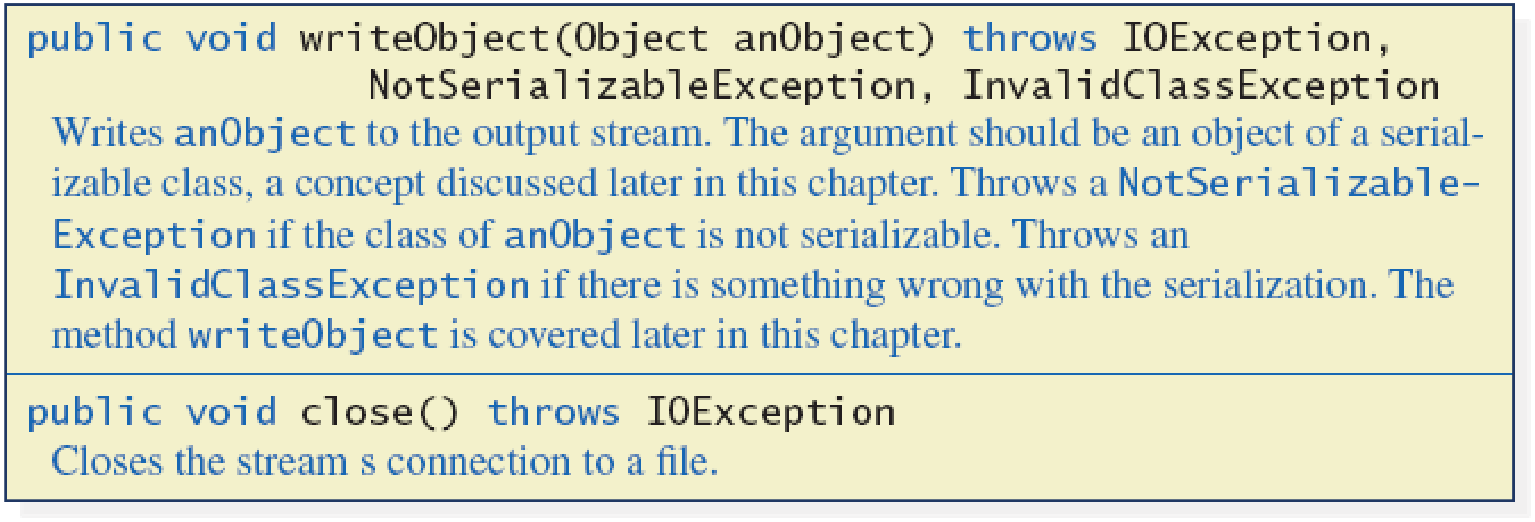
```
  outputStream.writeChar('A');
```

```
public void writeBoolean(boolean b) throws IOException
```
Writes the `boolean` value `b` to the output stream.

```
public void writeUTF(String aString) throws IOException
```
Writes the string `aString` to the output stream. UTF refers to a particular method of encoding the string. To read the string back from the file, you should use the method `readUTF` of the class `ObjectInputStream`. These topics are discussed in the next section.

Writing Primitive Values to a Binary File

- Figure 14.6c Some methods in class `ObjectOutputStream`



```
public void writeObject(Object anObject) throws IOException,
                NotSerializableException, InvalidClassException
```

Writes `anObject` to the output stream. The argument should be an object of a serializable class, a concept discussed later in this chapter. Throws a `NotSerializableException` if the class of `anObject` is not serializable. Throws an `InvalidClassException` if there is something wrong with the serialization. The method `writeObject` is covered later in this chapter.

```
public void close() throws IOException
```

Closes the stream s connection to a file.

Writing Strings to a Binary File

- Use method **`writeUTF`**
- Example

```
outputStream.writeUTF("Hi Mom");
```

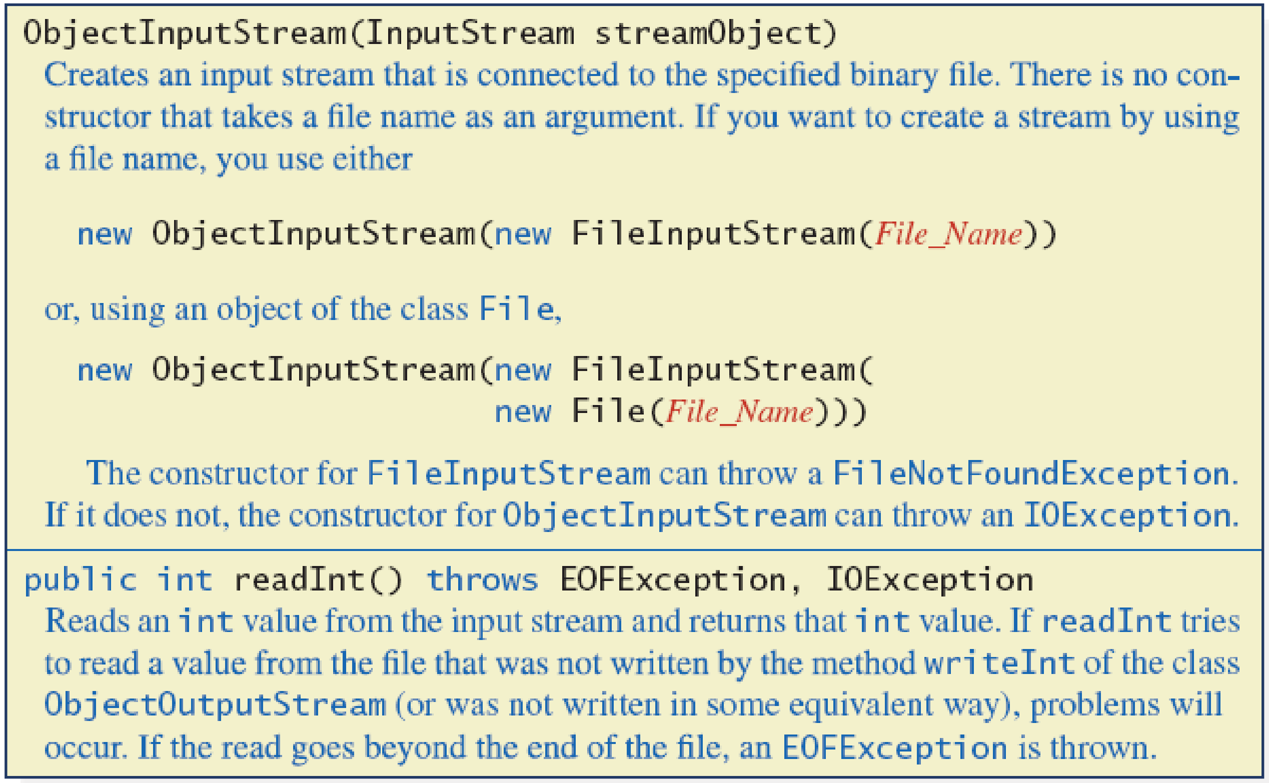
- UTF stands for *Unicode Text Format*
- Uses a varying number of bytes to store different strings
  - Depends on length of string
  - Contrast to **`writeInt`** which uses same for each

Reading from a Binary File

- File must be opened as an **`ObjectInputStream`**
- Read from binary file using methods which correspond to write methods
    - Integer written with **`writeInt`** will be read with **`readInt`**
- Be careful to read same type as was written

Reading from a Binary File

- Figure 14.7a Some methods of class **`ObjectInputStream`**



`ObjectInputStream(InputStream streamObject)`

Creates an input stream that is connected to the specified binary file. There is no constructor that takes a file name as an argument. If you want to create a stream by using a file name, you use either

```
new ObjectInputStream(new FileInputStream(File_Name))
```

or, using an object of the class `File`,

```
new ObjectInputStream(new FileInputStream(
                      new File(File_Name)))
```

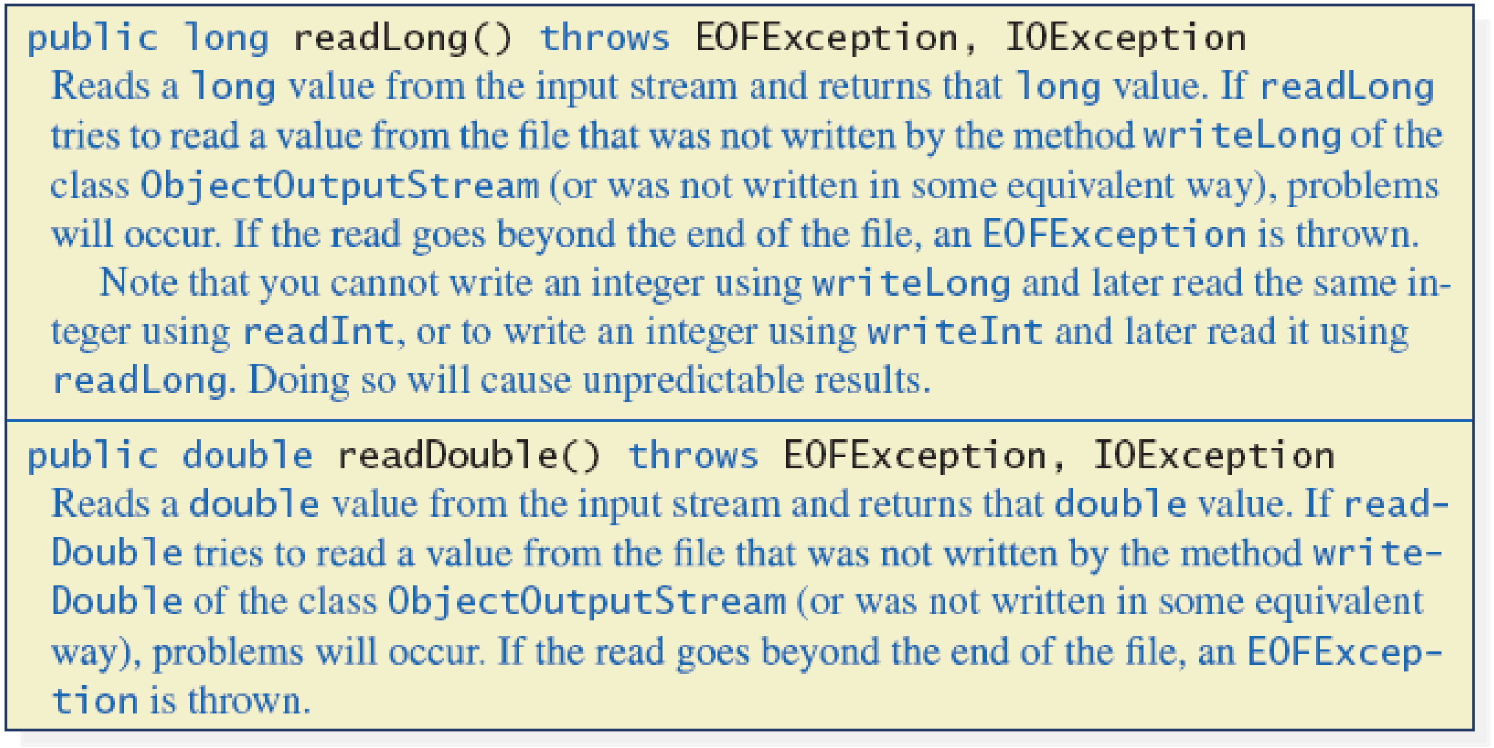
The constructor for `FileInputStream` can throw a `FileNotFoundException`. If it does not, the constructor for `ObjectInputStream` can throw an `IOException`.

`public int readInt() throws EOFException, IOException`

Reads an `int` value from the input stream and returns that `int` value. If `readInt` tries to read a value from the file that was not written by the method `writeInt` of the class `ObjectOutputStream` (or was not written in some equivalent way), problems will occur. If the read goes beyond the end of the file, an `EOFException` is thrown.

Reading from a Binary File

- Figure 14.7b Some methods of class `ObjectInputStream`



`public long readLong() throws EOFException, IOException`

Reads a `long` value from the input stream and returns that `long` value. If `readLong` tries to read a value from the file that was not written by the method `writeLong` of the class `ObjectOutputStream` (or was not written in some equivalent way), problems will occur. If the read goes beyond the end of the file, an `EOFException` is thrown.

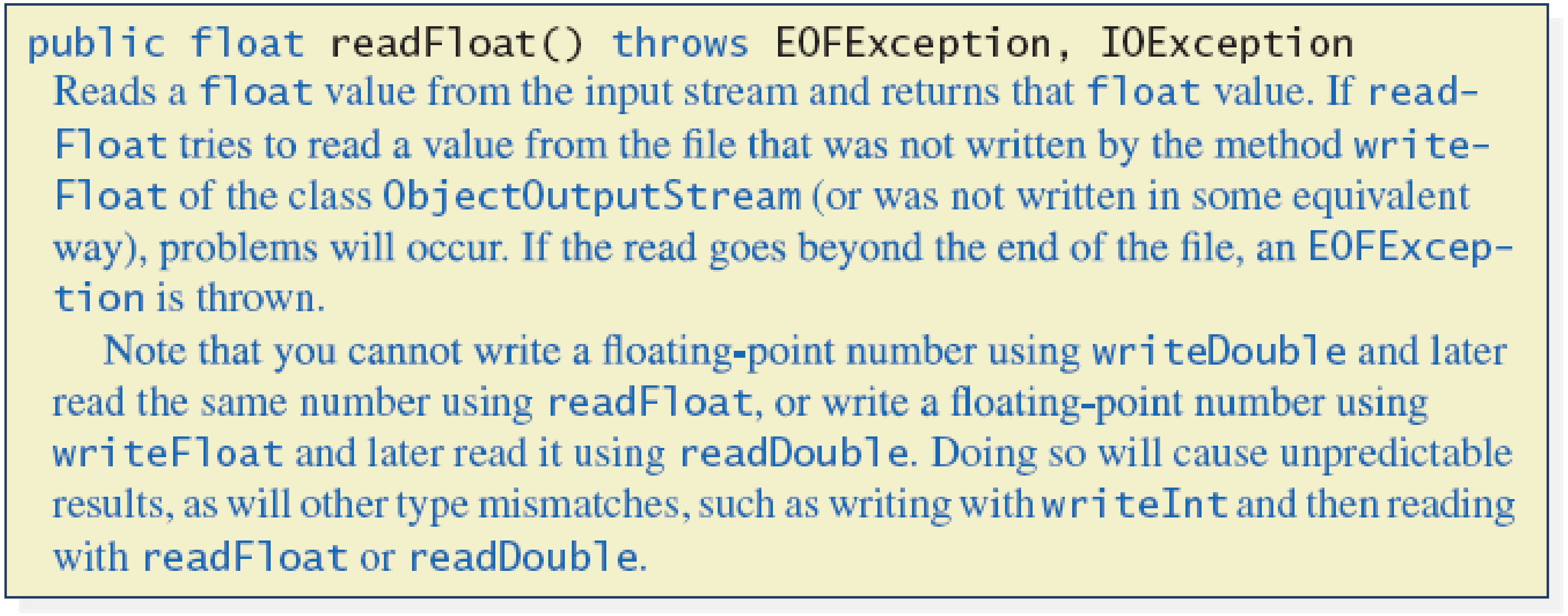
Note that you cannot write an integer using `writeLong` and later read the same integer using `readInt`, or to write an integer using `writeInt` and later read it using `readLong`. Doing so will cause unpredictable results.

`public double readDouble() throws EOFException, IOException`

Reads a `double` value from the input stream and returns that `double` value. If `readDouble` tries to read a value from the file that was not written by the method `writeDouble` of the class `ObjectOutputStream` (or was not written in some equivalent way), problems will occur. If the read goes beyond the end of the file, an `EOFException` is thrown.

Reading from a Binary File

- Figure 14.7c Some methods of class `ObjectInputStream`



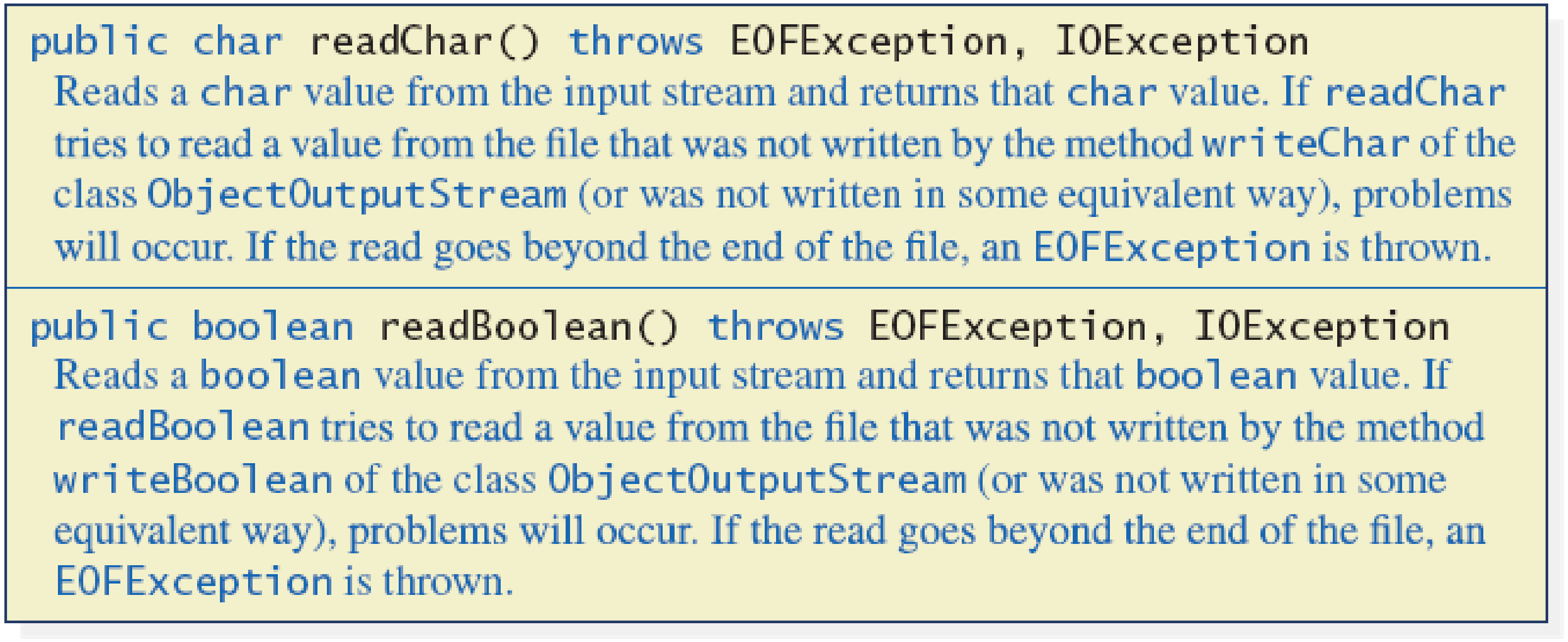
`public float readFloat() throws EOFException, IOException`

Reads a `float` value from the input stream and returns that `float` value. If `readFloat` tries to read a value from the file that was not written by the method `writeFloat` of the class `ObjectOutputStream` (or was not written in some equivalent way), problems will occur. If the read goes beyond the end of the file, an `EOFException` is thrown.

Note that you cannot write a floating-point number using `writeDouble` and later read the same number using `readFloat`, or write a floating-point number using `writeFloat` and later read it using `readDouble`. Doing so will cause unpredictable results, as will other type mismatches, such as writing with `writeInt` and then reading with `readFloat` or `readDouble`.

Reading from a Binary File

- Figure 14.7d Some methods of class **`ObjectInputStream`**

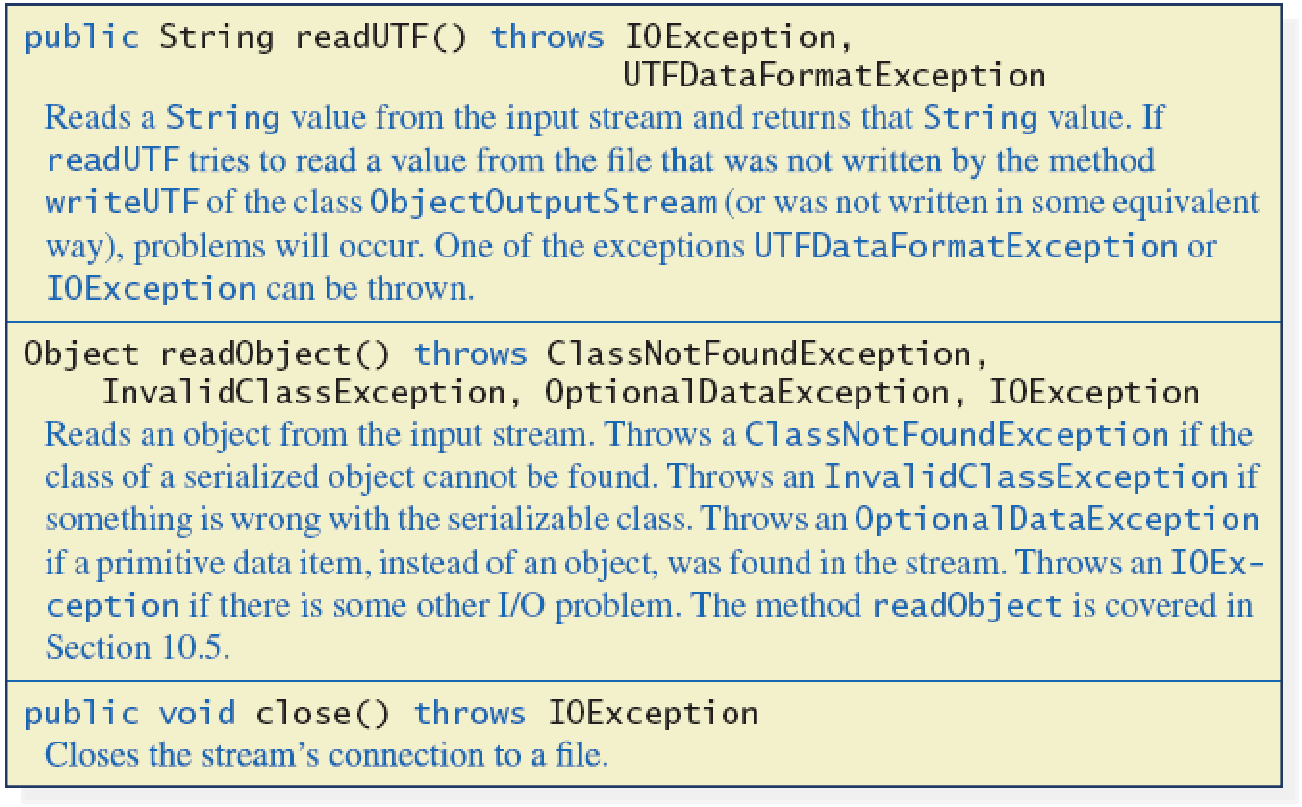


```
public char readChar() throws EOFException, IOException
```
Reads a `char` value from the input stream and returns that `char` value. If `readChar` tries to read a value from the file that was not written by the method `writeChar` of the class `ObjectOutputStream` (or was not written in some equivalent way), problems will occur. If the read goes beyond the end of the file, an `EOFException` is thrown.

```
public boolean readBoolean() throws EOFException, IOException
```
Reads a `boolean` value from the input stream and returns that `boolean` value. If `readBoolean` tries to read a value from the file that was not written by the method `writeBoolean` of the class `ObjectOutputStream` (or was not written in some equivalent way), problems will occur. If the read goes beyond the end of the file, an `EOFException` is thrown.

Reading from a Binary File

- Figure 14.7e Some methods of class **ObjectInputStream**



```
public String readUTF() throws IOException,
                                UTFDataFormatException
```

Reads a String value from the input stream and returns that String value. If readUTF tries to read a value from the file that was not written by the method writeUTF of the class ObjectOutputStream (or was not written in some equivalent way), problems will occur. One of the exceptions UTFDataFormatException or IOException can be thrown.

```
Object readObject() throws ClassNotFoundException,
    InvalidClassException, OptionalDataException, IOException
```

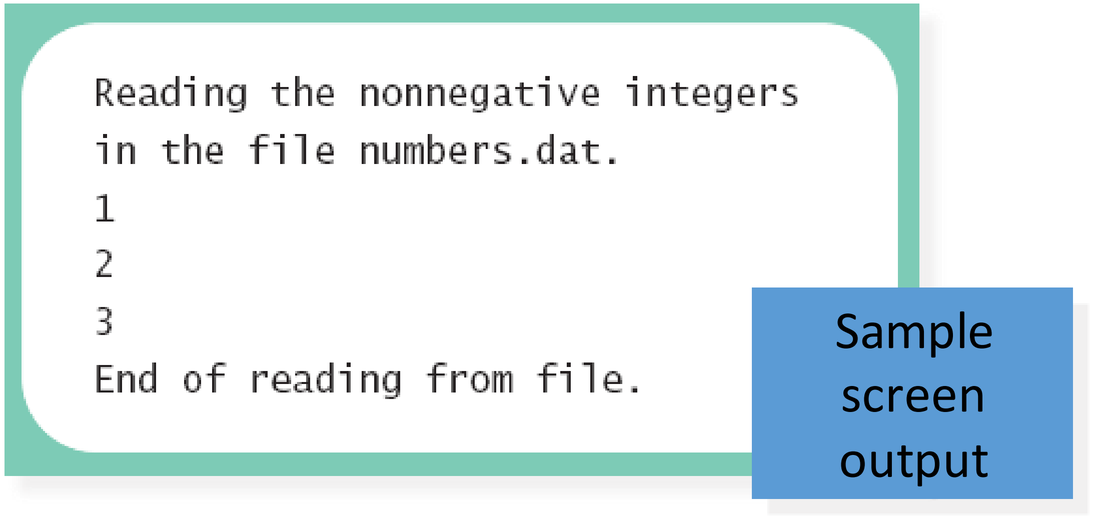
Reads an object from the input stream. Throws a ClassNotFoundException if the class of a serialized object cannot be found. Throws an InvalidClassException if something is wrong with the serializable class. Throws an OptionalDataException if a primitive data item, instead of an object, was found in the stream. Throws an IOException if there is some other I/O problem. The method readObject is covered in Section 10.5.

```
public void close() throws IOException
```

Closes the stream's connection to a file.

Reading from a Binary File

- View program to read, listing 14.7
  `class BinaryInputDemo`



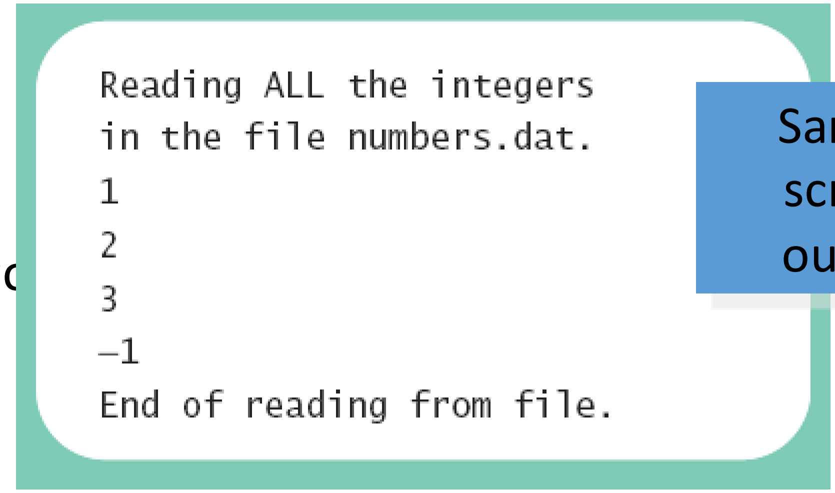
```
Reading the nonnegative integers
in the file numbers.dat.
1
2
3
End of reading from file.
```

The Class **`EOFException`**

- Many methods that read from a binary file will throw an **`EOFException`**
  - Can be used to test for end of file
  - Thus can end a reading loop
- View example program, listing 14.8
  class **`EOFExceptionDemo`**

The Class **EOFException**

- Note the -1 formerly needed as a sentinel value is now also read



```
Reading ALL the integers
in the file numbers.dat.
1
2
3
-1
End of reading from file.
```

Sample screen output

- Always a go ave a sentinel value

Programming Example

- Processing a file of binary data
  - Asks user for 2 file names
  - Reads numbers in input file
  - Doubles them
  - Writes them to output file
- View processing program, listing 14.9
  class **`Doubler`**

Binary-File I/O, Objects & Arrays

- Binary-File I/O with Objects of a Class
- Some Details of Serialization
- Array Objects in Binary Files

Binary-File I/O with Class Objects

- Consider the need to write/read objects other than `Strings`
  - Possible to write the individual instance variable values
  - Then reconstruct the object when file is read
- A better way is provided by Java
  - *Object serialization* – represent an object as a sequence of bytes to be written/read
  - Possible for any class implementing **`Serializable`**

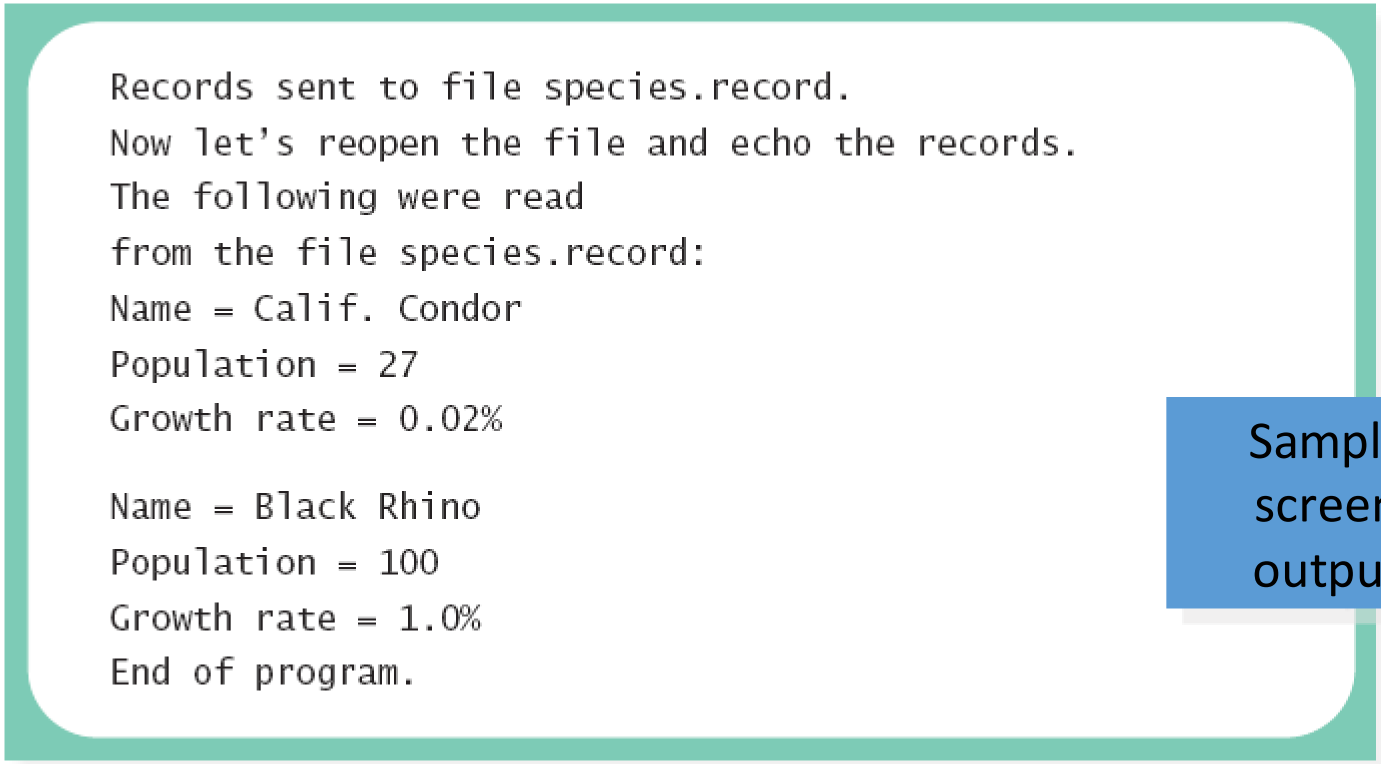
Binary-File I/O with Class Objects

- Interface **`Serializable`** is an empty interface
  - No need to implement additional methods
  - Tells Java to make the class serializable (class objects convertible to sequence of bytes)
- View sample class , listing 14.10
  `class Species`

Binary-File I/O with Class Objects

- Once we have a class that is specified as **`Serializable`** we can write objects to a binary file
  - Use method **`writeObject`**
- Read objects with method **`readObject();`**
  - Also required to use typecast of the object
- View sample program, listing 14.11
  `class ObjectIODemo`

Binary-File I/O with Class Objects



```
Records sent to file species.record.
Now let's reopen the file and echo the records.
The following were read
from the file species.record:
Name = Calif. Condor
Population = 27
Growth rate = 0.02%

Name = Black Rhino
Population = 100
Growth rate = 1.0%
End of program.
```

Sample screen output

Some Details of Serialization

- Requirements for a class to be serializable
  - Implments interface `Serializable`
  - Any instance variables of a class type are also objects of a serializable class
  - Class's direct superclass (if any) is either serializable or defines a default constructor

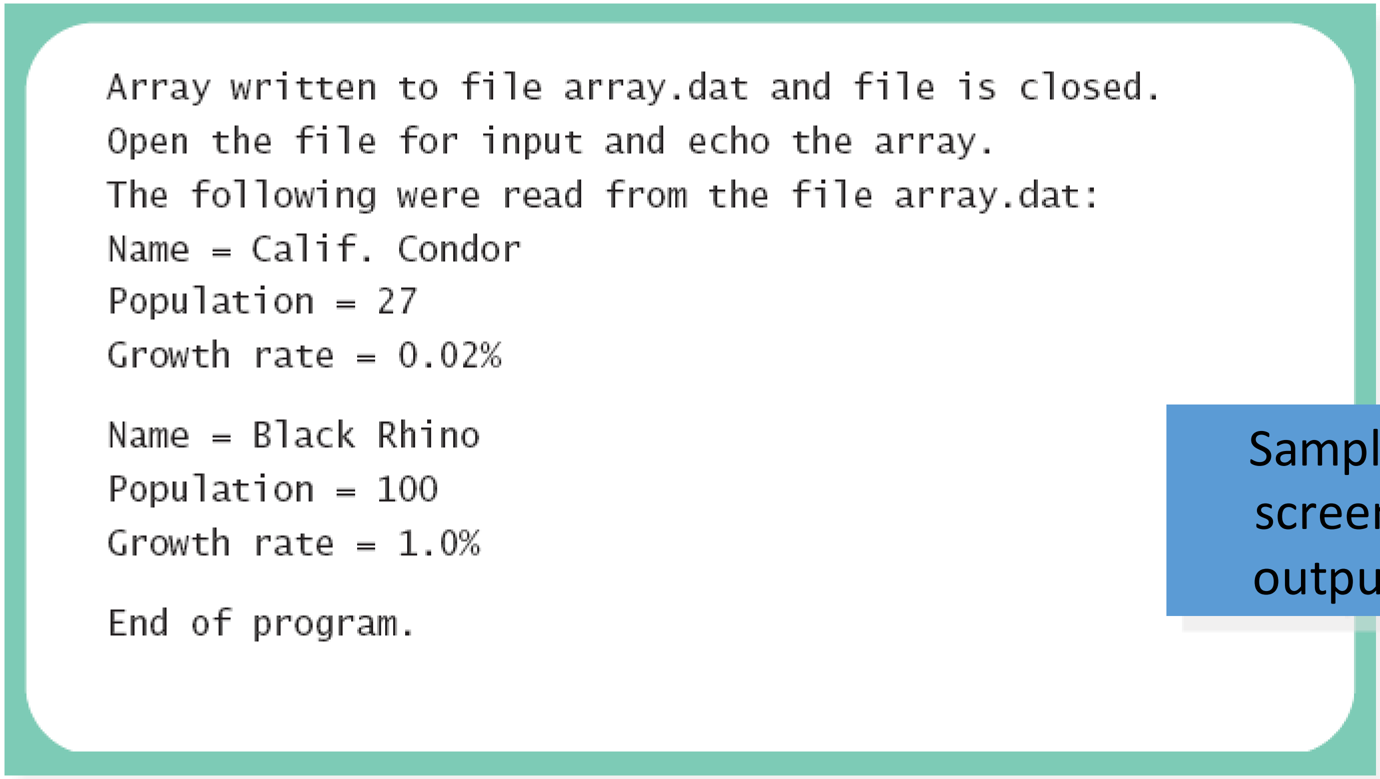
Some Details of Serialization

- Effects of making a class serializable
  - Affects how Java performs I/O with class objects
  - Java assigns a *serial number* to each object of the class it writes to the `ObjectOutputStream`
  - If same object written to stream multiple times, only the serial number written after first time

Array Objects in Binary Files

- Since an array is an object, possible to use `writeObject` with entire array
  - Similarly use `readObject` to read entire array
- View array I/O program, listing 14.12
  class ArrayIODemo

Array Objects in Binary Files



```
Array written to file array.dat and file is closed.
Open the file for input and echo the array.
The following were read from the file array.dat:
Name = Calif. Condor
Population = 27
Growth rate = 0.02%

Name = Black Rhino
Population = 100
Growth rate = 1.0%

End of program.
```

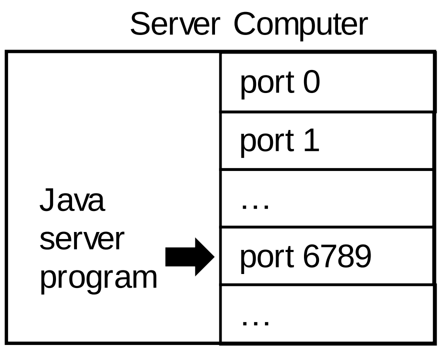
Sample screen output

Introduction to Sockets and Networking

- Classes such as Scanner and PrintWriter can be used with any data stream – such as communicating over a network using streams
- Java uses sockets
  - A socket consists of the address that identifies the remote computer and a port ranging from 0 to 65535
  - The process of communicating between a client and server is shown in the following figure

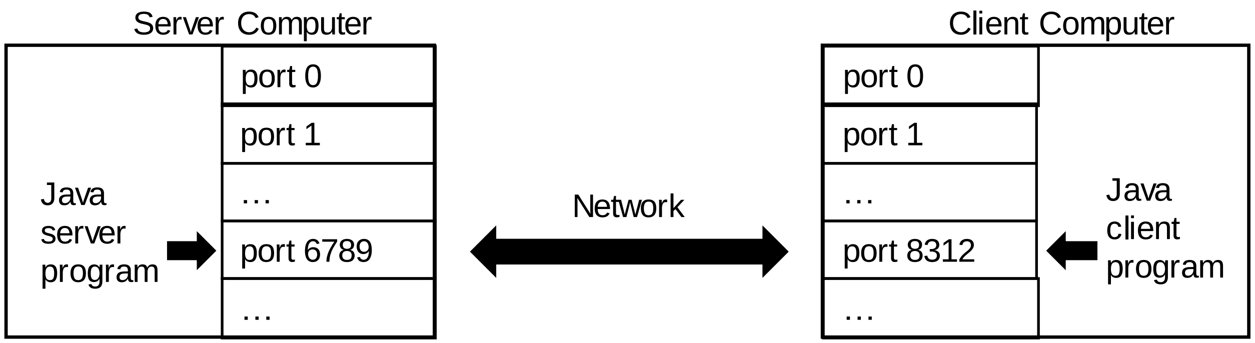
FIGURE 14.8 Client/Server Network Communication via Sockets

1. The Java server program listens and waits for a connection on port 6789. Different programs may be listening on other ports.



In Listing 14.14 the server and client are running on the same computer which is identified by the special address of "localhost".

2. The Java client program connects to the server on port 6789. It uses a local port that is assigned automatically, in this case, port 8312.



3. The Java server program can now communicate over a socket bound locally to port 6789 and remotely to the client's address at port 8312, while the client communicates over a socket bound locally to port 8312 and remotely to the server's address at port 6789.

Introduction to Sockets and Networking

- Server program
  - Listen for a connection on a specified port; when one is made:
    - Create a Scanner with an InputStreamReader based on the socket that the server will listen on; use this for input from a client
    - Create a PrintWriter with the socket to send data to the client
  - See Listing 14.13
- Client program
  - Initiate a connection to the server on a specified port
  - Create a Scanner to read from the socket
  - Create a PrintWriter to send to the socket
  - Set Listing 14.14

The URL Class

- The URL class gives us a simple way to read from a webpage
  - Thanks to polymorphism we can create a Scanner that is linked to a website
  - The example outputs the text from wikipedia

```
URL website = new
URL("http://www.wikipedia.org");
Scanner inputStream = new Scanner(
    new InputStreamReader(website.openStream()));

while (inputStream.hasNextLine())
{
  String s = inputStream.nextLine();
  System.out.println(s);
}
inputStream.close();
```

Summary

- Files with characters are text files
  - Other files are binary files
- Programs can use `PrintWriter` and `Scanner` for I/O
- Always check for end of file
- File name can be literal string or variable of type `String`
- Class `File` gives additional capabilities to deal with file names

Summary

- Use `ObjectOutputStream` and `ObjectInputStream` classes enable writing to, reading from binary files
- Use `writeObject` to write class objects to binary file
- Use `readObject` with type cast to read objects from binary file
- Classes for binary I/O must be serializable