Chapter 17 Binary I/O

Motivations

Data stored in a text file is represented in human-readable form. Data stored in a binary file is represented in binary form. You cannot read binary files. They are designed to be read by programs. For example, Java source programs are stored in text files and can be read by a text editor, but Java classes are stored in binary files and are read by the JVM. The advantage of binary files is that they are more efficient to process than text files.

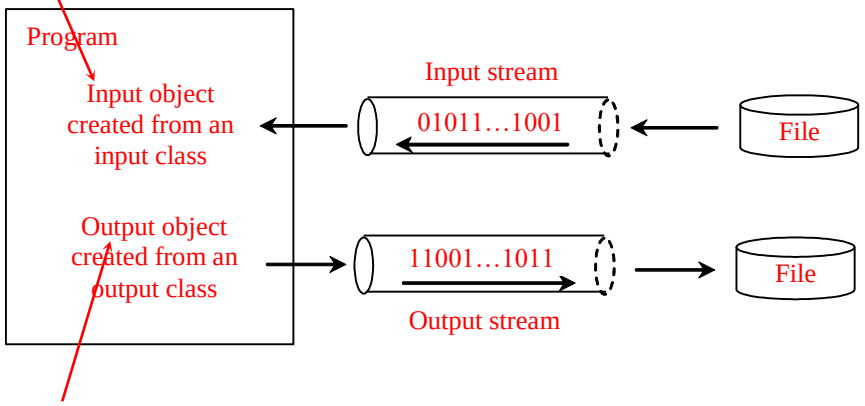
Objectives

- To discover how I/O is processed in Java (§17.2).
- To distinguish between text I/O and binary I/O (§17.3).
- To read and write bytes using FileInputStream and FileOutputStream (§17.4.1).
- To read and write primitive values and strings using DataInputStream/DataOutputStream (§17.4.3).
- To store and restore objects using ObjectOutputStream and ObjectInputStream, and to understand how objects are serialized and what kind of objects can be serialized (§17.6).
- To implement the Serializable interface to make objects serializable (§17.6.1).
- To serialize arrays (§17.6.2).
- To read and write the same file using the RandomAccessFile class (§17.7).

How is I/O Handled in Java?

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.

```
Scanner input = new Scanner(new File("temp.txt"));
System.out.println(input.nextLine());
```

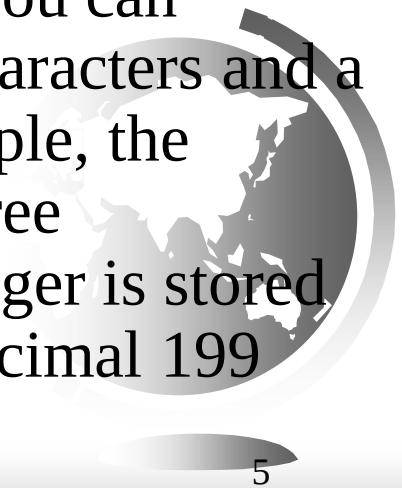



```
PrintWriter output = new PrintWriter("temp.txt");
output.println("Java 101");
output.close();
```

Text File vs. Binary File

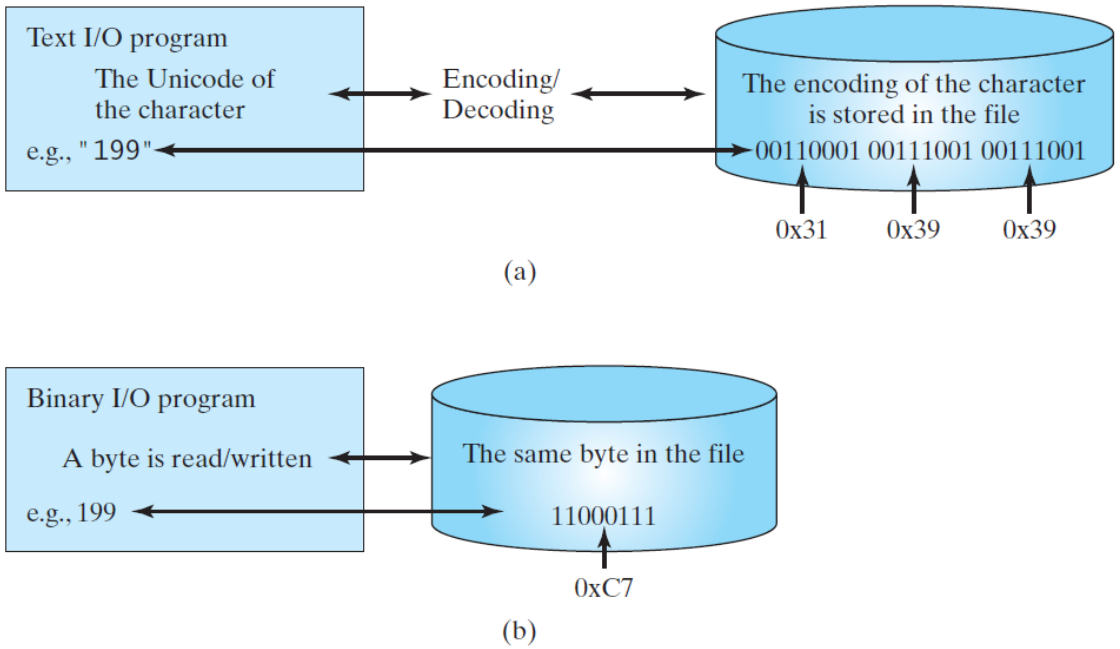
- Data stored in a text file are represented in human-readable form. Data stored in a binary file are represented in binary form. You cannot read binary files. Binary files are designed to be read by programs. For example, the Java source programs are stored in text files and can be read by a text editor, but the Java classes are stored in binary files and are read by the JVM. The advantage of binary files is that they are more efficient to process than text files.

- Although it is not technically precise and correct, you can imagine that a text file consists of a sequence of characters and a binary file consists of a sequence of bits. For example, the decimal integer 199 is stored as the sequence of three characters: '1', '9', '9' in a text file and the same integer is stored as a byte-type value C7 in a binary file, because decimal 199 equals to hex C7.

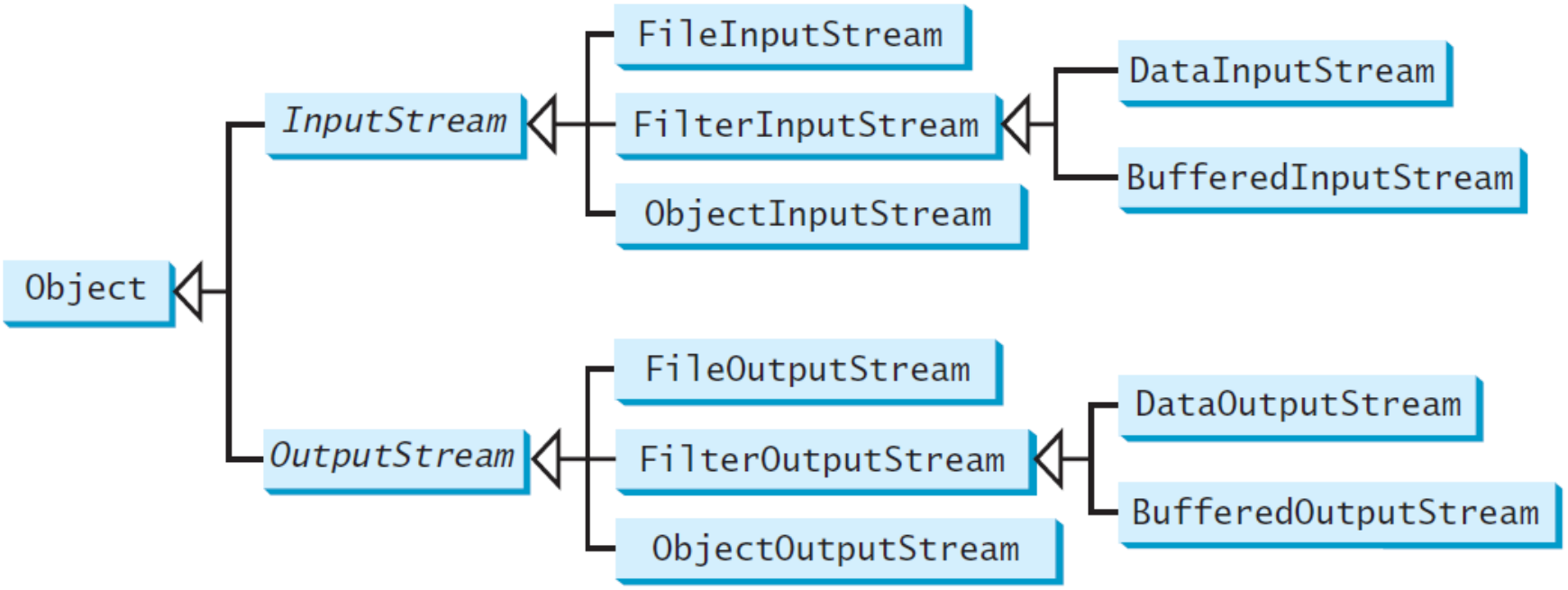


Binary I/O

Text I/O requires encoding and decoding. The JVM converts a Unicode to a file specific encoding when writing a character and coverts a file specific encoding to a Unicode when reading a character. Binary I/O does not require conversions. When you write a byte to a file, the original byte is copied into the file. When you read a byte from a file, the exact byte in the file is returned.



Binary I/O Classes



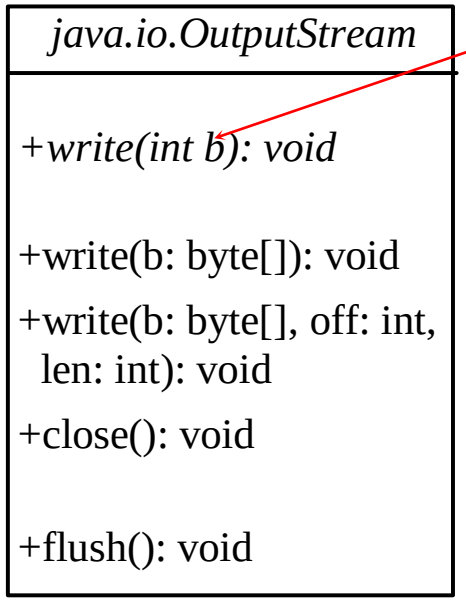
InputStream

The value returned is a byte as an int type.

java.io.InputStream	
+read(): int	Reads the next byte of data from the input stream. The value byte is returned as an int value in the range 0 to 255. If no byte is available because the end of the stream has been reached, the value –1 is returned.
+read(b: byte[]): int	Reads up to b.length bytes into array b from the input stream and returns the actual number of bytes read. Returns -1 at the end of the stream.
+read(b: byte[], off: int, len: int): int	Reads bytes from the input stream and stores into b[off], b[off+1], …, b[off+len-1]. The actual number of bytes read is returned. Returns -1 at the end of the stream.
+available(): int	Returns the number of bytes that can be read from the input stream.
+close(): void	Closes this input stream and releases any system resources associated with the stream.
+skip(n: long): long	Skips over and discards n bytes of data from this input stream. The actual number of bytes skipped is returned.
+markSupported(): boolean	Tests if this input stream supports the mark and reset methods.
+mark(readlimit: int): void	Marks the current position in this input stream.
+reset(): void	Repositions this stream to the position at the time the mark method was last called on this input stream.

OutputStream

The value is a byte as an int type.



Writes the specified byte to this output stream. The parameter b is an int value. (byte)b is written to the output stream.

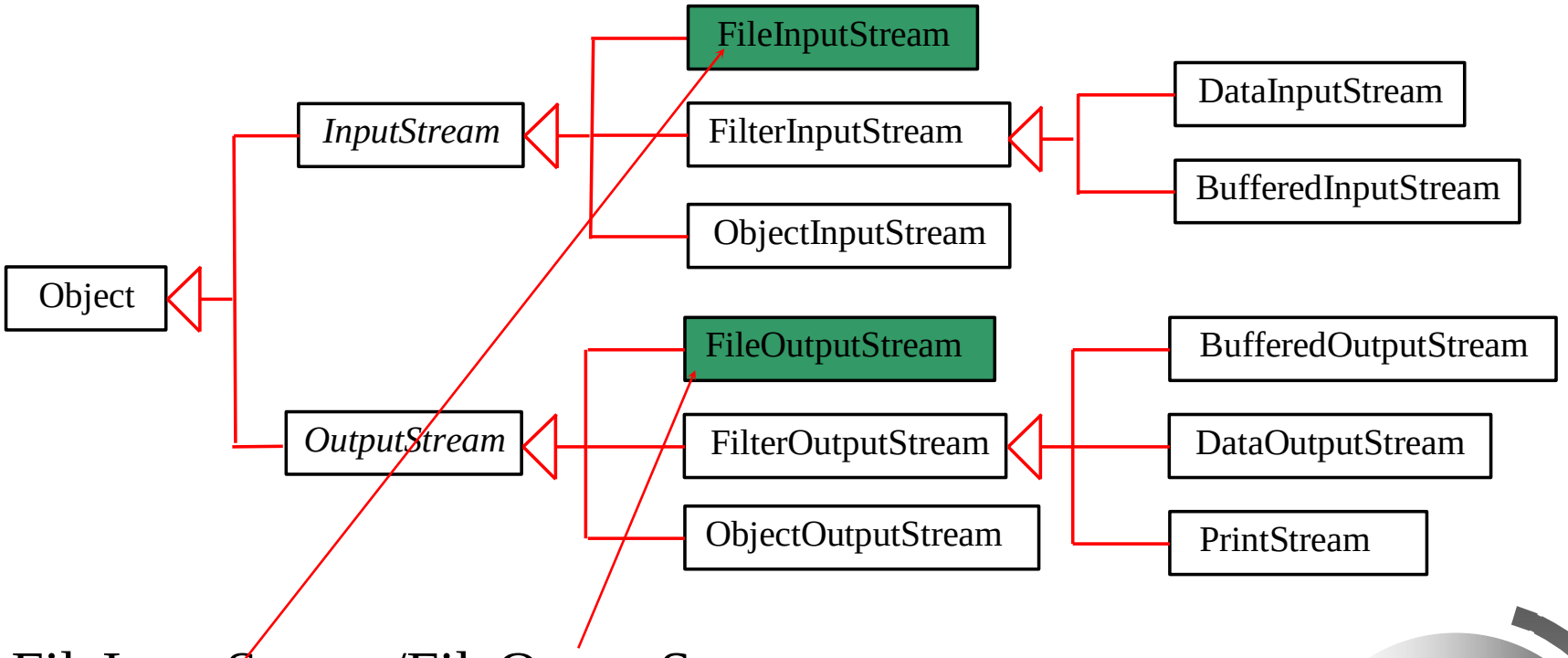
Writes all the bytes in array b to the output stream.

Writes b[off], b[off+1], …, b[off+len-1] into the output stream.

Closes this output stream and releases any system resources associated with the stream.

Flushes this output stream and forces any buffered output bytes to be written out.

FileInputStream/FileOutputStream



FileInputStream/FileOutputStream associates a binary input/output stream with an external file. All the methods in FileInputStream/FileOuptputStream are inherited from its superclasses.

FileInputStream

To construct a FileInputStream, use the following constructors:

public FileInputStream(String filename)

public FileInputStream(File file)

A java.io.FileNotFoundException would occur if you attempt to create a FileInputStream with a nonexistent file.

FileOutputStream

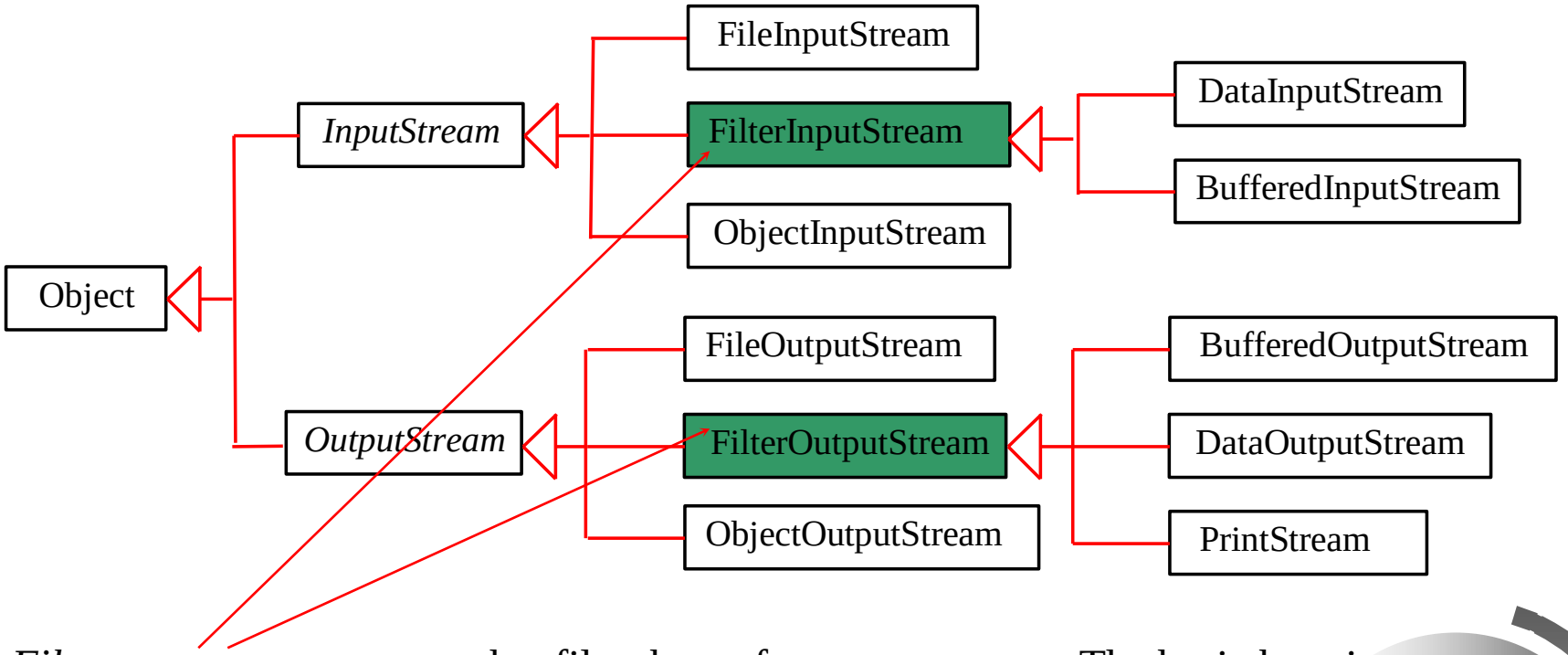
To construct a FileOutputStream, use the following constructors:

```
public FileOutputStream(String filename)
public FileOutputStream(File file)
public FileOutputStream(String filename, boolean append)
public FileOutputStream(File file, boolean append)
```

If the file does not exist, a new file would be created. If the file already exists, the first two constructors would delete the current contents in the file. To retain the current content and append new data into the file, use the last two constructors by passing true to the append parameter.

TestFileStream Run

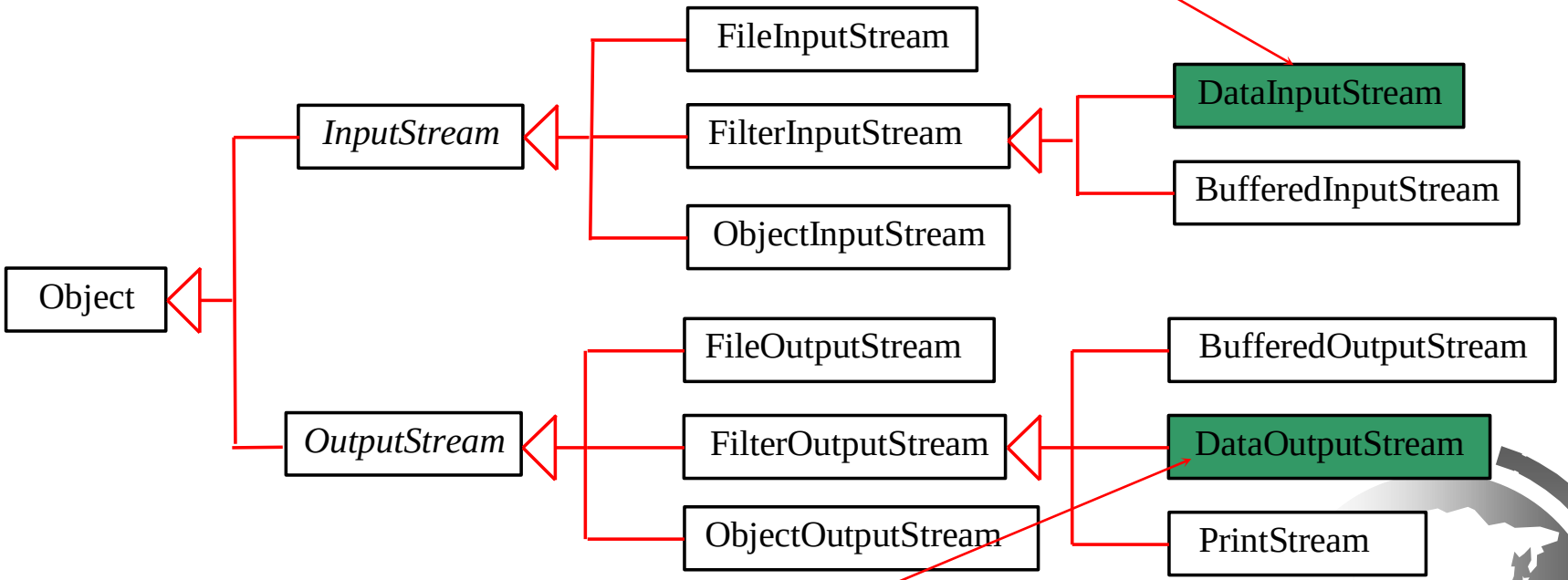
FilterInputStream/FilterOutputStream



Filter streams are streams that filter bytes for some purpose. The basic byte input stream provides a read method that can only be used for reading bytes. If you want to read integers, doubles, or strings, you need a filter class to wrap the byte input stream. Using a filter class enables you to read integers, doubles, and strings instead of bytes and characters. FilterInputStream and FilterOutputStream are the base classes for filtering data. When you need to process primitive numeric types, use DatInputStream and DataOutputStream to filter bytes.

DataInputStream/DataOutputStream

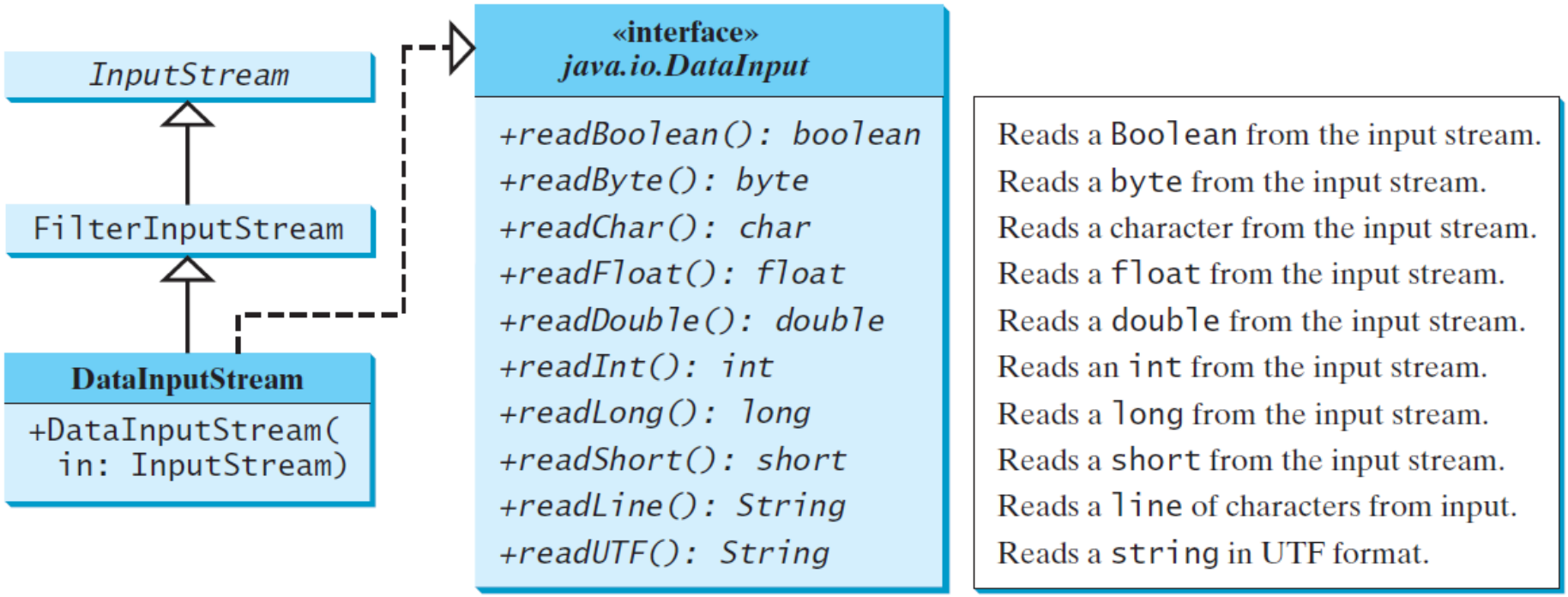
DataInputStream reads bytes from the stream and converts them into appropriate primitive type values or strings.



DataOutputStream converts primitive type values or strings into bytes and output the bytes to the stream.

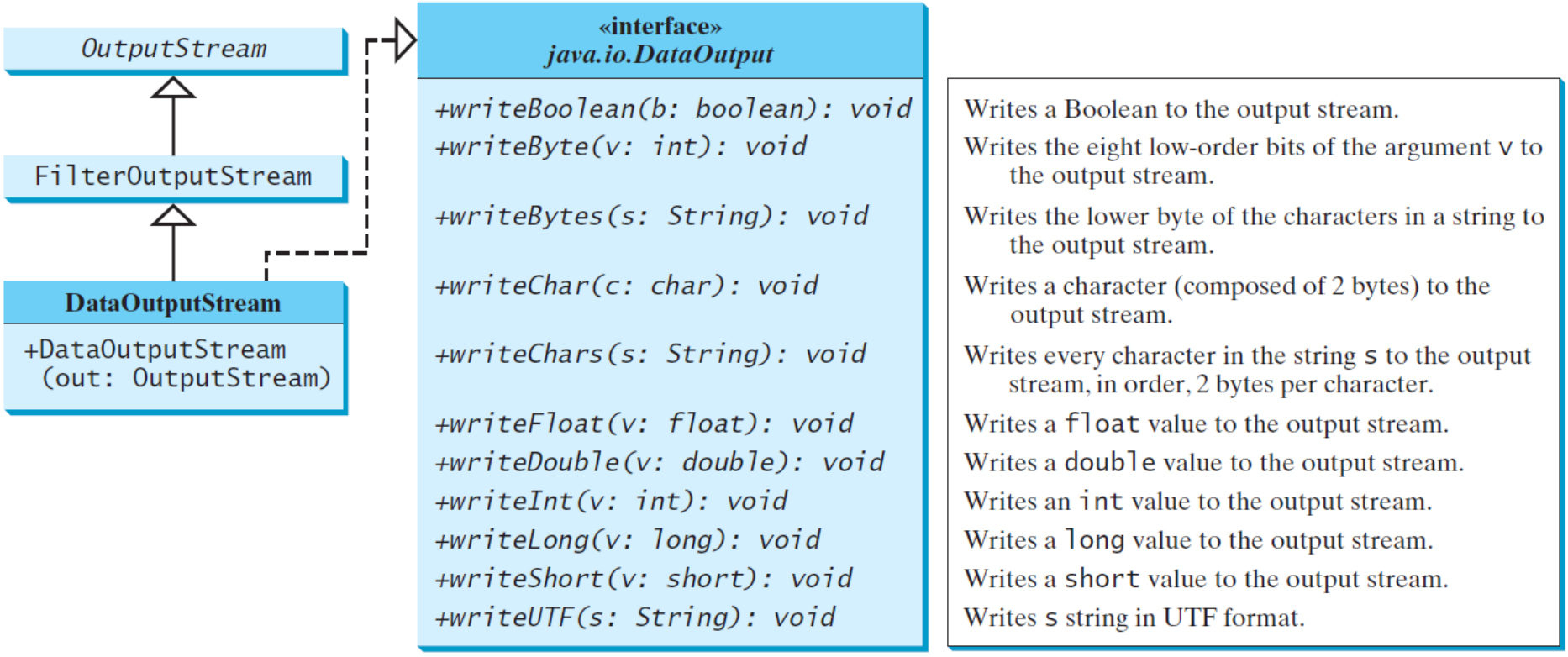
DataInputStream

DataInputStream extends FilterInputStream and implements the DataInput interface.



DataOutputStream

DataOutputStream extends FilterOutputStream and implements the DataOutput interface.

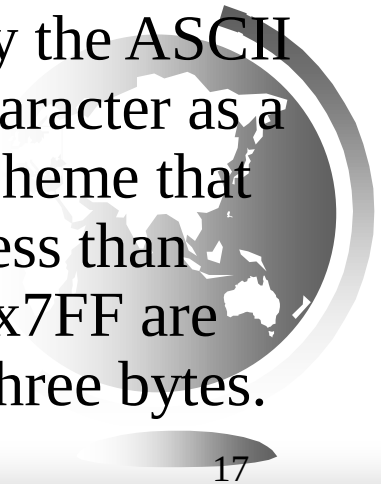


Characters and Strings in Binary I/O

A Unicode consists of two bytes. The writeChar(char c) method writes the Unicode of character c to the output. The writeChars(String s) method writes the Unicode for each character in the string s to the output.

Why UTF-8? What is UTF-8?

UTF-8 is a coding scheme that allows systems to operate with both ASCII and Unicode efficiently. Most operating systems use ASCII. Java uses Unicode. The ASCII character set is a subset of the Unicode character set. Since most applications need only the ASCII character set, it is a waste to represent an 8-bit ASCII character as a 16-bit Unicode character. The UTF-8 is an alternative scheme that stores a character using 1, 2, or 3 bytes. ASCII values (less than 0x7F) are coded in one byte. Unicode values less than 0x7FF are coded in two bytes. Other Unicode values are coded in three bytes.



Using DataInputStream/DataOutputStream

Data streams are used as wrappers on existing input and output streams to filter data in the original stream. They are created using the following constructors:

```
public DataInputStream(InputStream instream)
public DataOutputStream(OutputStream outstream)
```

The statements given below create data streams. The first statement creates an input stream for file **in.dat**; the second statement creates an output stream for file **out.dat**.

```
DataInputStream infile =
  new DataInputStream(new FileInputStream("in.dat"));
DataOutputStream outfile =
  new DataOutputStream(new FileOutputStream("out.dat"));
```

TestDataStream Run

Concept of pipe line

int, double, string …

01000110011 …

int, double, string …

01000110011 …

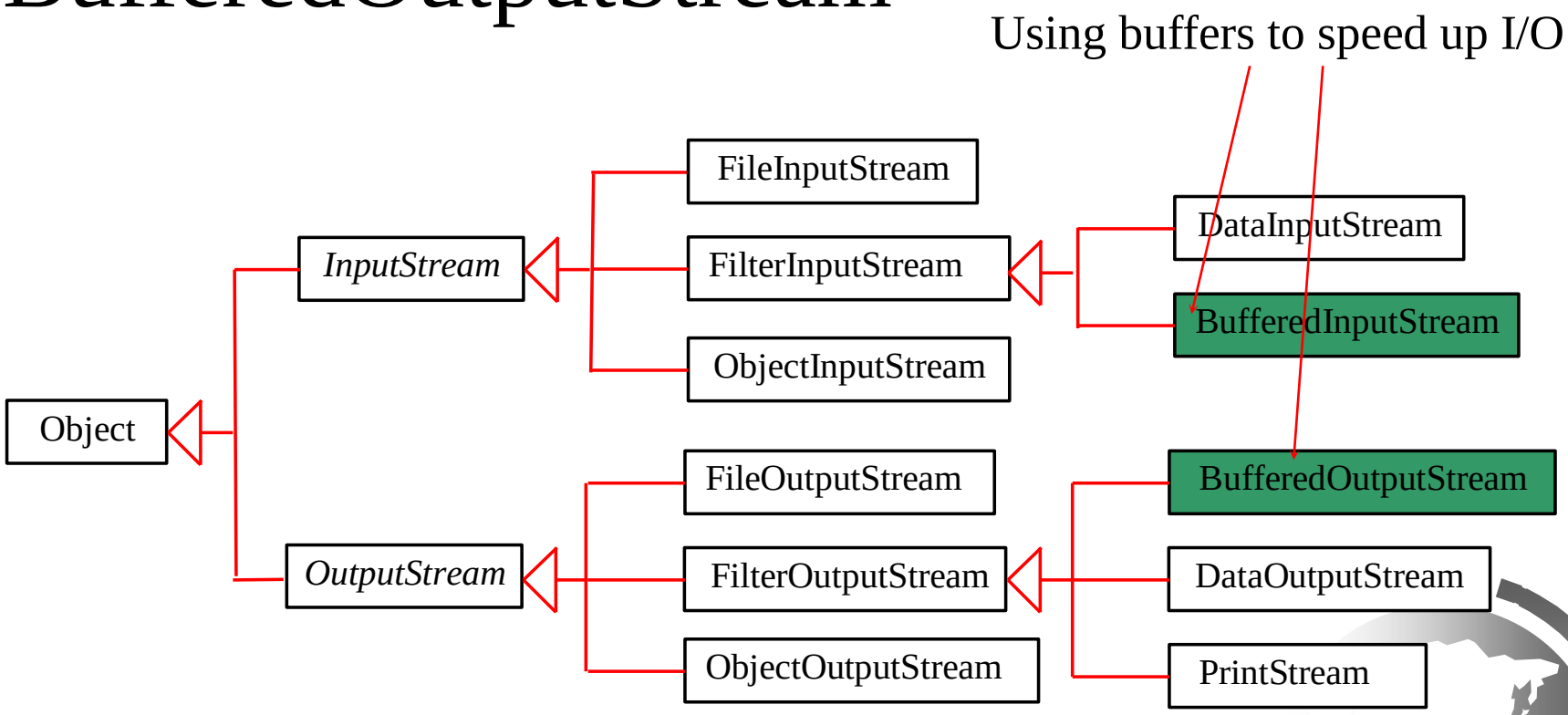
Order and Format

CAUTION: You have to read the data in the same order and same format in which they are stored. For example, since names are written in UTF-8 using writeUTF, you must read names using readUTF.

Checking End of File

TIP: If you keep reading data at the end of a stream, an EOFException would occur. So how do you check the end of a file? You can use input.available() to check it. input.available() == 0 indicates that it is the end of a file.

BufferedInputStream/ BufferedOutputStream

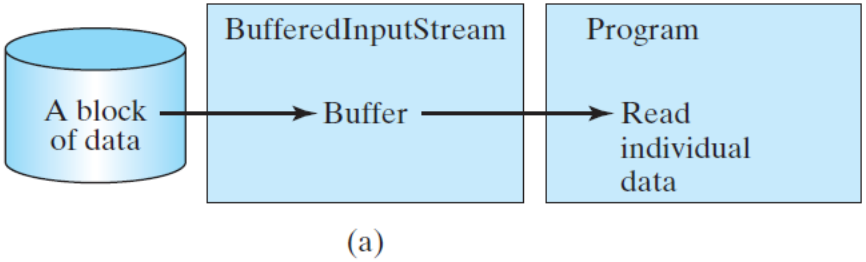


BufferedInputStream/BufferedOutputStream does not contain new methods. All the methods BufferedInputStream/BufferedOutputStream are inherited from the InputStream/OutputStream classes.

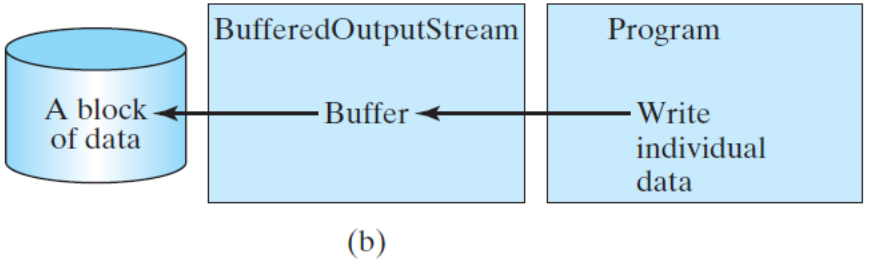
Constructing BufferedInputStream/BufferedOutputStream

```
// Create a BufferedInputStream
public BufferedInputStream(InputStream in)
public BufferedInputStream(InputStream in, int bufferSize)

// Create a BufferedOutputStream
public BufferedOutputStream(OutputStream out)
public BufferedOutputStream(OutputStreamr out, int bufferSize)
```



(a)

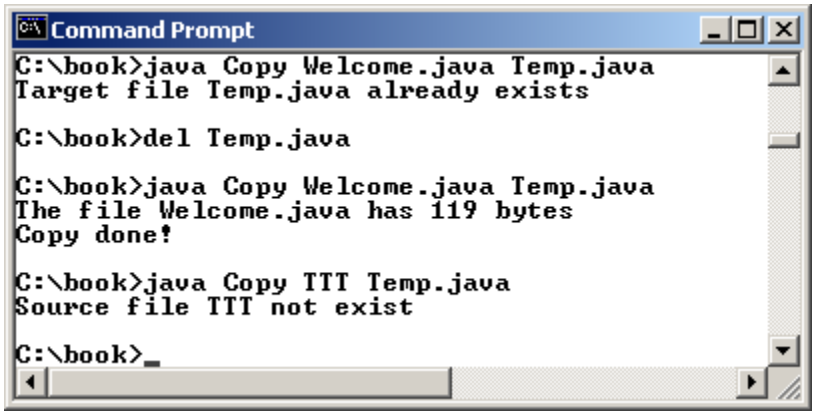


(b)

Case Studies: Copy File

This case study develops a program that copies files. The user needs to provide a source file and a target file as command-line arguments using the following command:

java Copy source target



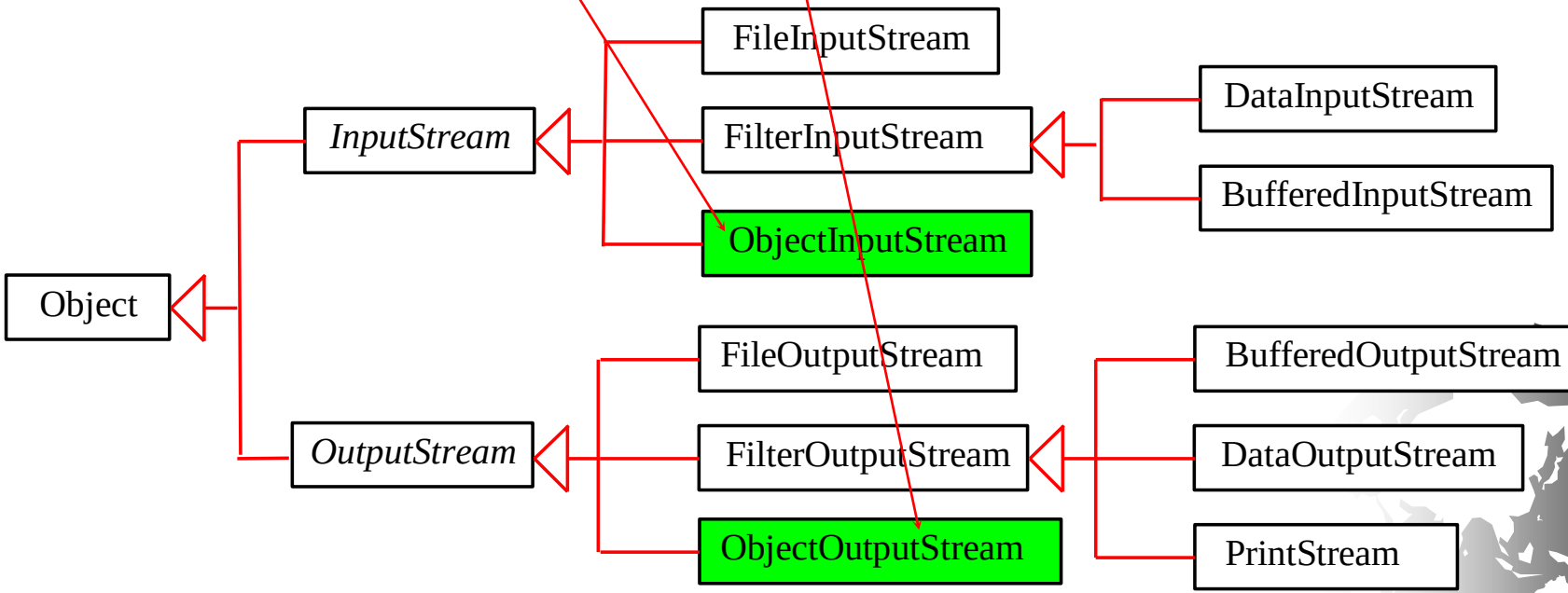
The program copies a source file to a target file and displays the number of bytes in the file. If the source does not exist, tell the user the file is not found. If the target file already exists, tell the user the file already exists.

Copy Run

Optional

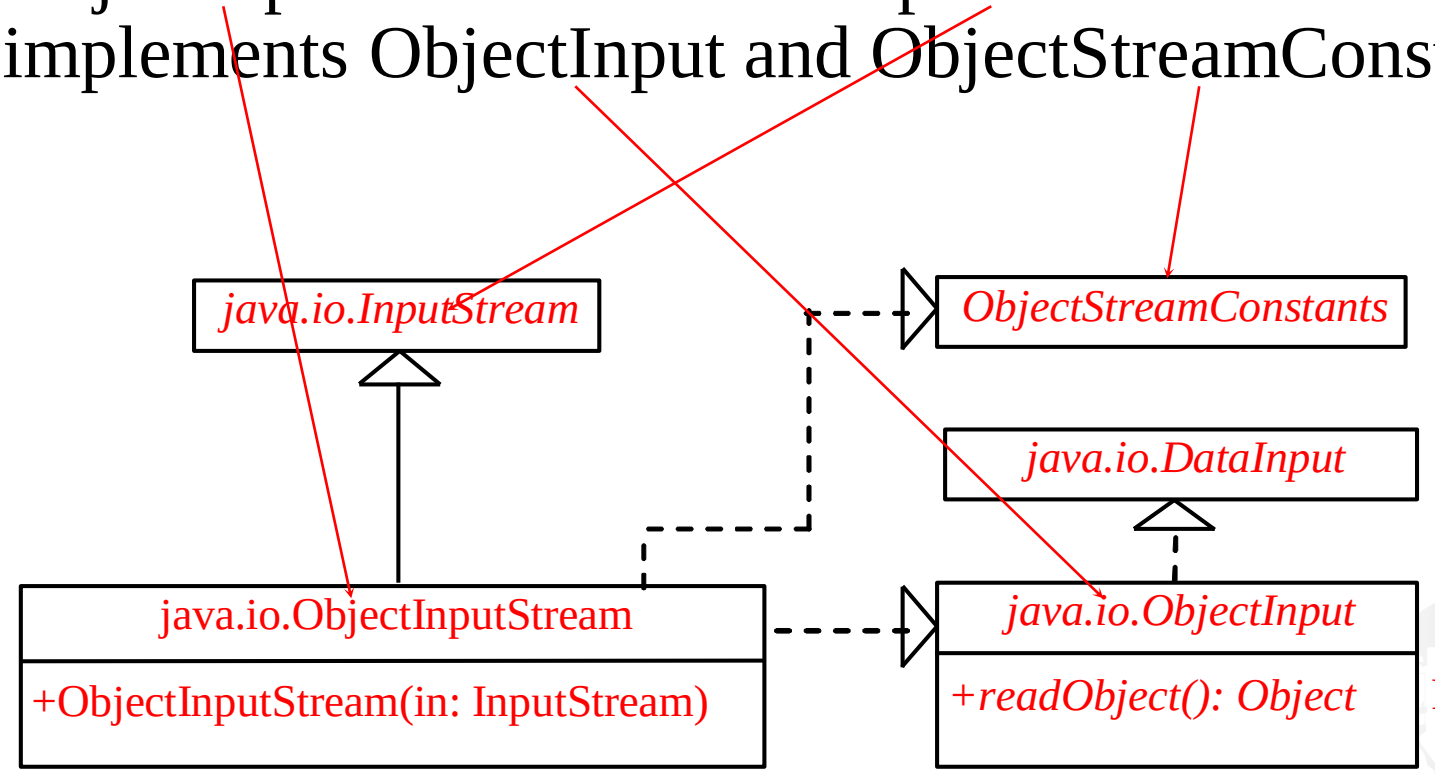
Object I/O

DataInputStream/DataOutputStream enables you to perform I/O for primitive type values and strings.
ObjectInputStream/ObjectOutputStream enables you to perform I/O for objects in addition for primitive type values and strings.



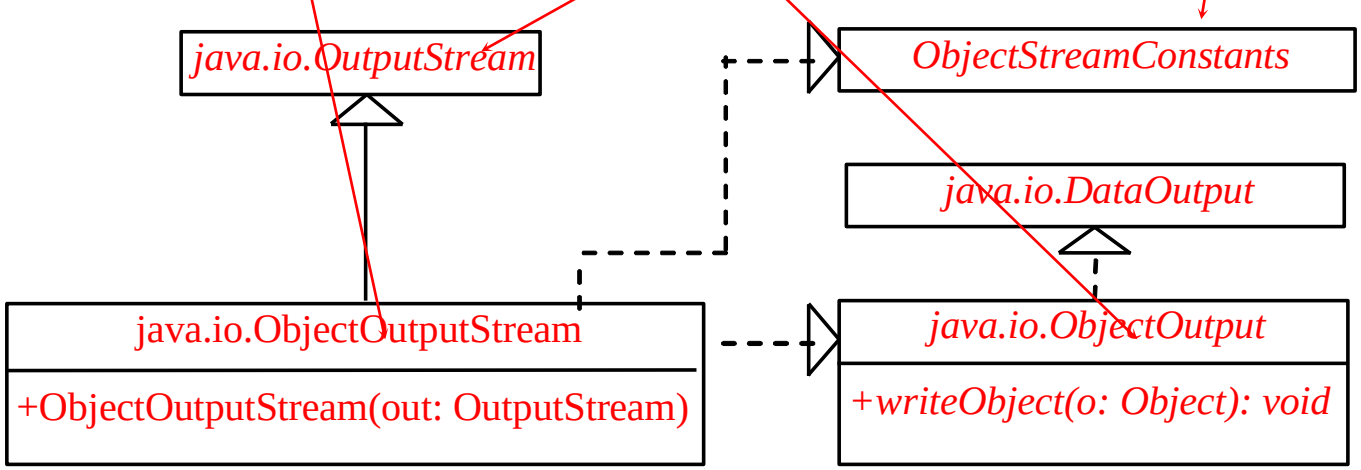
ObjectInputStream

ObjectInputStream extends InputStream and implements ObjectInput and ObjectStreamConstants.



ObjectOutputStream

ObjectOutputStream extends OutputStream and implements ObjectOutput and ObjectStreamConstants.

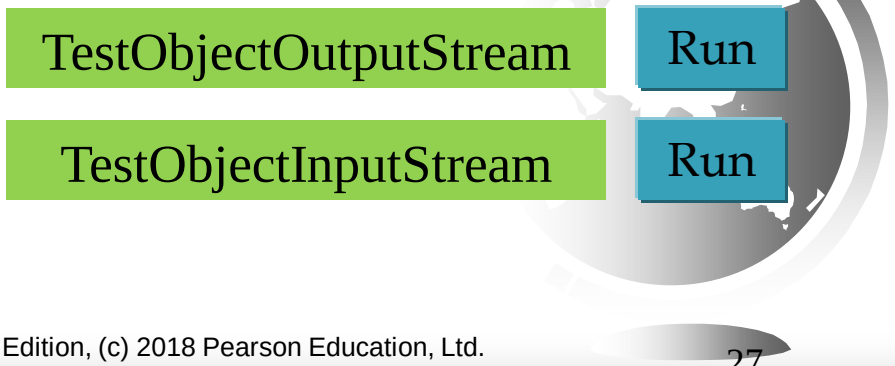


Using Object Streams

You may wrap an ObjectInputStream/ObjectOutputStream on any InputStream/OutputStream using the following constructors:

```
// Create an ObjectInputStream
public ObjectInputStream(InputStream in)

// Create an ObjectOutputStream
public ObjectOutputStream(OutputStream out)
```



The `Serializable` Interface

Not all objects can be written to an output stream. Objects that can be written to an object stream is said to be *serializable*. A serializable object is an instance of the java.io.Serializable interface. So the class of a serializable object must implement Serializable.

The Serializable interface is a marker interface. It has no methods, so you don't need to add additional code in your class that implements Serializable.

Implementing this interface enables the Java serialization mechanism to automate the process of storing the objects and arrays.

The `transient` Keyword

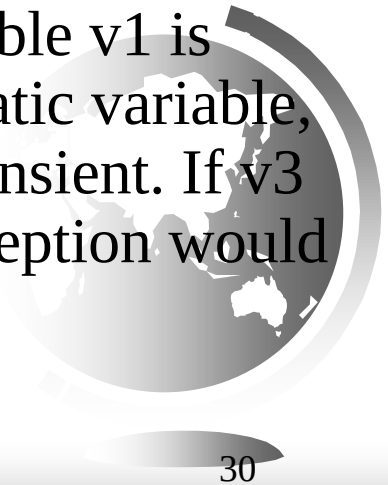
If an object is an instance of Serializable, but it contains non-serializable instance data fields, can the object be serialized? The answer is no. To enable the object to be serialized, you can use the transient keyword to mark these data fields to tell the JVM to ignore these fields when writing the object to an object stream.

The `transient` Keyword, cont.

Consider the following class:

```
public class Foo implements java.io.Serializable {
  private int v1;
  private static double v2;
  private transient A v3 = new A();
}
class A { } // A is not serializable
```

When an object of the Foo class is serialized, only variable v1 is serialized. Variable v2 is not serialized because it is a static variable, and variable v3 is not serialized because it is marked transient. If v3 were not marked transient, a java.io.NotSerializableException would occur.



Serializing Arrays

An array is serializable if all its elements are serializable. So an entire array can be saved using writeObject into a file and later restored using readObject. Here is an example that stores an array of five int values and an array of three strings, and reads them back to display on the console.

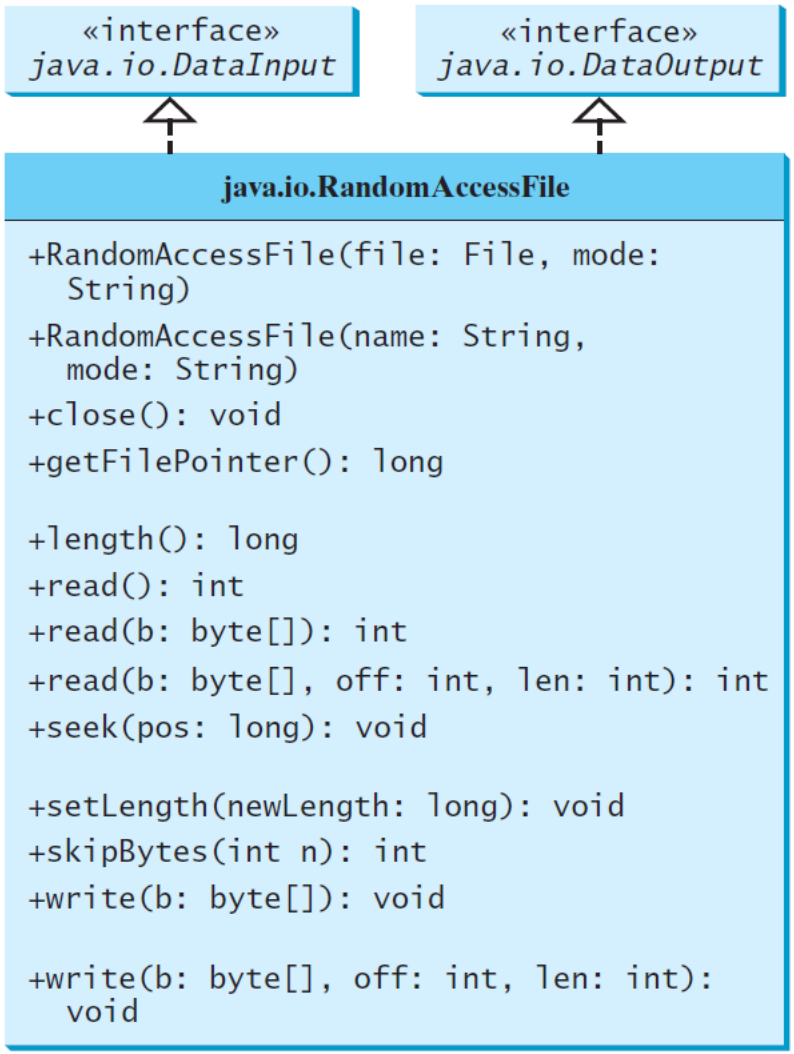
TestObjectStreamForArray

Run

Random Access Files

All of the streams you have used so far are known as *read-only* or *write-only* streams. The external files of these streams are *sequential* files that cannot be updated without creating a new file. It is often necessary to modify files or to insert new records into files. Java provides the RandomAccessFile class to allow a file to be read from and write to at random locations.

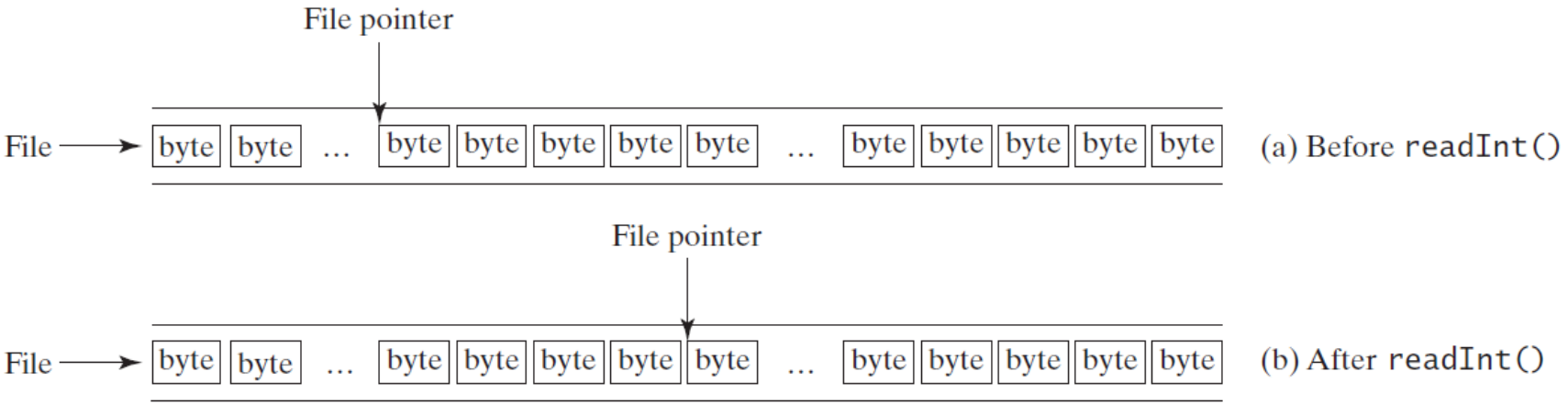
RandomAccessFile



`+RandomAccessFile(file: File, mode: String)`	Creates a `RandomAccessFile` stream with the specified `File` object and mode.
`+RandomAccessFile(name: String, mode: String)`	Creates a `RandomAccessFile` stream with the specified file name string and mode.
`+close(): void`	Closes the stream and releases the resource associated with it.
`+getFilePointer(): long`	Returns the offset, in bytes, from the beginning of the file to where the next `read` or `write` occurs.
`+length(): long`	Returns the number of bytes in this file.
`+read(): int`	Reads a byte of data from this file and returns –1 at the end of stream.
`+read(b: byte[]): int`	Reads up to `b.length` bytes of data from this file into an array of bytes.
`+read(b: byte[], off: int, len: int): int`	Reads up to `len` bytes of data from this file into an array of bytes.
`+seek(pos: long): void`	Sets the offset (in bytes specified in `pos`) from the beginning of the stream to where the next `read` or `write` occurs.
`+setLength(newLength: long): void`	Sets a new length for this file.
`+skipBytes(int n): int`	Skips over `n` bytes of input.
`+write(b: byte[]): void`	Writes `b.length` bytes from the specified byte array to this file, starting at the current file pointer.
`+write(b: byte[], off: int, len: int): void`	Writes `len` bytes from the specified byte array, starting at offset `off`, to this file.

File Pointer

A random access file consists of a sequence of bytes. There is a special marker called *file pointer* that is positioned at one of these bytes. A read or write operation takes place at the location of the file pointer. When a file is opened, the file pointer sets at the beginning of the file. When you read or write data to the file, the file pointer moves forward to the next data. For example, if you read an int value using readInt(), the JVM reads four bytes from the file pointer and now the file pointer is four bytes ahead of the previous location.



`RandomAccessFile` Methods

Many methods in `RandomAccessFile` are the same as those in `DataInputStream` and `DataOutputStream`. For example, `readInt()`, `readLong()`, `writeDouble()`, `readLine()`, `writeInt()`, and `writeLong()` can be used in data input stream or data output stream as well as in `RandomAccessFile` streams.

`RandomAccessFile` Methods, cont.

```
void seek(long pos) throws IOException;
```

Sets the offset from the beginning of the `RandomAccessFile` stream to where the next read or write occurs.

```
long getFilePointer() IOException;
```

Returns the current offset, in bytes, from the beginning of the file to where the next read or write occurs.

`RandomAccessFile` Methods, cont.

`long length()IOException`

Returns the length of the file.

`final void writeChar(int v) throws IOException`

Writes a character to the file as a two-byte Unicode, with the high byte written first.

`final void writeChars(String s) throws IOException`

Writes a string to the file as a sequence of characters.

RandomAccessFile Constructor

```
RandomAccessFile raf =
  new RandomAccessFile("test.dat", "rw");
  // allows read and write


RandomAccessFile raf =
  new RandomAccessFile("test.dat", "r");
  // read only
```

A Short Example on RandomAccessFile

TestRandomAccessFile Run