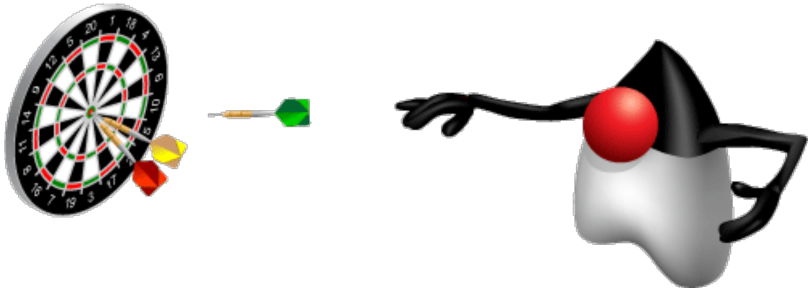
Java I/O Fundamentals

Objectives

After completing this lesson, you should be able to:

- Describe the basics of input and output in Java
- Read data from and write data to the console
- Use I/O streams to read and write files
- Read and write objects by using serialization



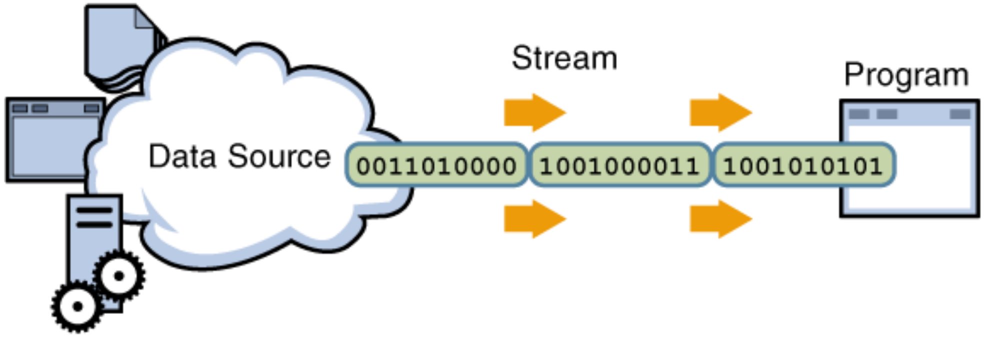
Java I/O Basics

The Java programming language provides a comprehensive set of libraries to perform input/output (I/O) functions.

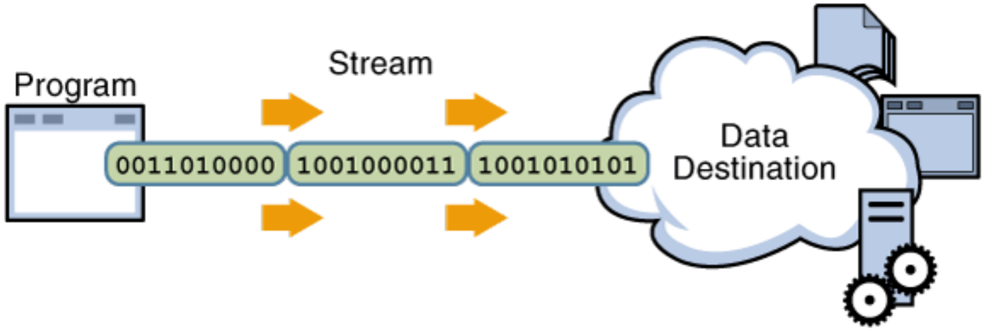
- Java defines an I/O channel as a stream.
- An I/O stream represents an input source or an output destination.
- An I/O stream can represent many different kinds of sources and destinations, including disk files, devices, other programs, and memory arrays.
- I/O streams support many different kinds of data, including simple bytes, primitive data types, localized characters, and objects.

I/O Streams

- A program uses an input stream to read data from a source, one item at a time.

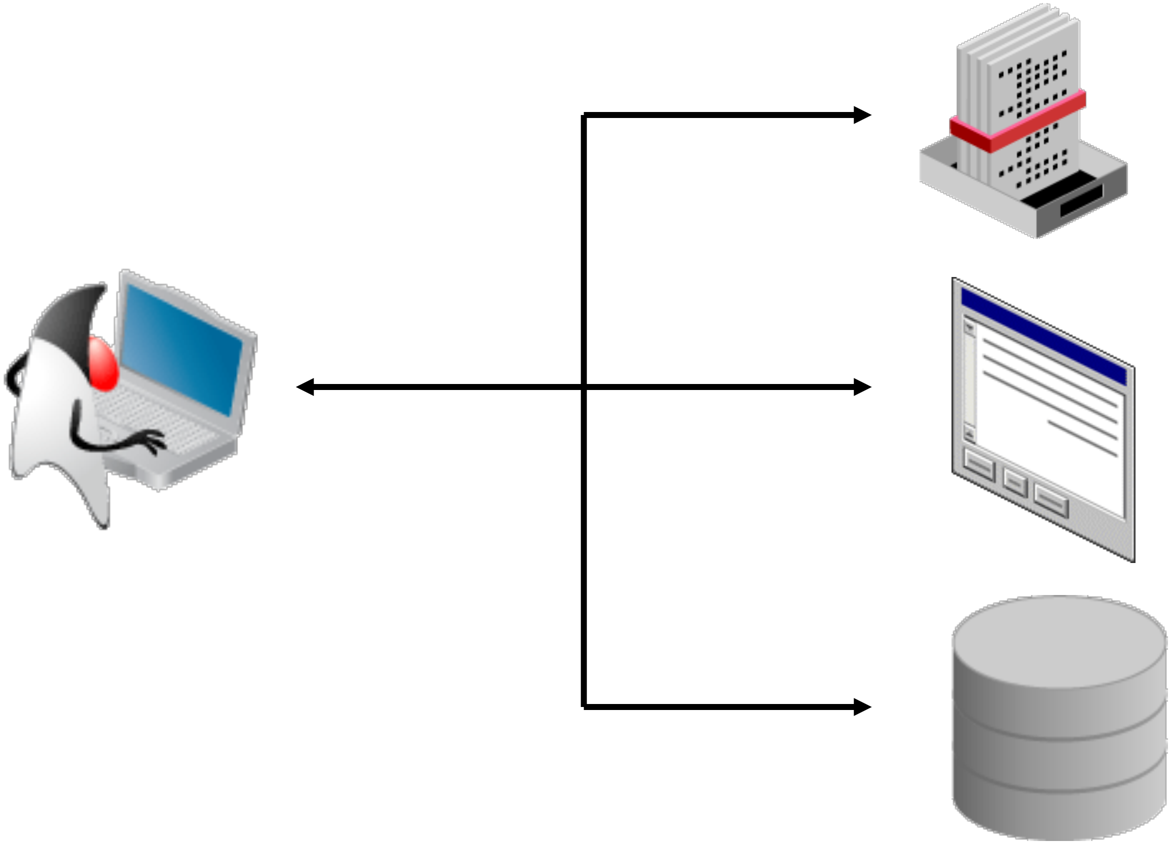


- A program uses an output stream to write data to a destination (sink), one item at time.



I/O Application

Typically, a developer uses input and output in three ways:



Files and directories

Console: (standard-in, standard-out)

Socket-based sources

Data Within Streams

- Java technology supports two types of streams: character and byte.
- Input and output of character data is handled by readers and writers.
- Input and output of byte data is handled by input streams and output streams:
  - Normally, the term *stream* refers to a byte stream.
  - The terms *reader* and *writer* refer to character streams.

Stream	Byte Streams	Character Streams
Source streams	`InputStream`	`Reader`
Sink streams	`OutputStream`	`Writer`

Byte Stream `InputStream` Methods

- The three basic `read` methods are:

```
int read()
int read(byte[] buffer)
int read(byte[] buffer, int offset, int length)
```

- Other methods include:

```
void close();             // Close an open stream
int available();          // Number of bytes available
long skip(long n);        // Discard n bytes from stream
```

Byte Stream `OutputStream` Methods

- The three basic `write` methods are:

```
void write(int c)
void write(byte[] buffer)
void write(byte[] buffer, int offset, int length)
```

- Other methods include:

```
void close(); // Automatically closed in try-with-resources
void flush(); // Force a write to the stream
```

Byte Stream: Example

```
import java.io.FileInputStream; import java.io.FileOutputStream;
import java.io.FileNotFoundException; import java.io.IOException;

public class ByteStreamCopyTest {
    public static void main(String[] args) {
        byte[] b = new byte[128];
        // Example use of InputStream methods
        try (FileInputStream fis = new FileInputStream (args[0]);
             FileOutputStream fos = new FileOutputStream (args[1])) {
             System.out.println ("Bytes available: " + fis.available());
            int count = 0; int read = 0;
            while ((read = fis.read(b)) != -1) {
                 fos.write(b);
                count += read;
             }
             System.out.println ("Wrote: " + count);
         } catch (FileNotFoundException f) {
             System.out.println ("File not found: " + f);
         } catch (IOException e) {
             System.out.println ("IOException: " + e);
         }
     }
 }
```

Note that you must keep track of how many bytes are read into the byte array each time.

Character Stream `Reader` Methods

- The three basic `read` methods are:

```
int read()
int read(char[] cbuf)
int read(char[] cbuf, int offset, int length)
```

- Other methods include:

```
void close()
boolean ready()
long skip(long n)
boolean markSupported()
void mark(int readAheadLimit)
void reset()
```

Character Stream `Writer` Methods

- The basic `write` methods are:

```
void write(int c)
void write(char[] cbuf)
void write(char[] cbuf, int offset, int length)
void write(String string)
void write(String string, int offset, int length)
```

- Other methods include:

```
void close()
void flush()
```

Character Stream: Example

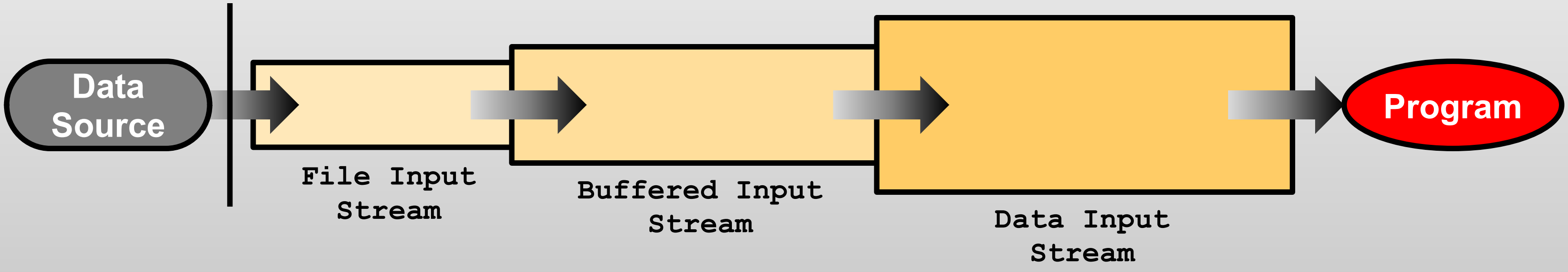
```java
import java.io.FileReader; import java.io.FileWriter;
import java.io.IOException; import java.io.FileNotFoundException;

public class CharStreamCopyTest {
    public static void main(String[] args) {
        char[] c = new char[128];
        // Example use of InputStream methods
        try (FileReader fr = new FileReader(args[0]);
             FileWriter fw = new FileWriter(args[1])) {
             int count = 0;
             int read = 0;
             while ((read = fr.read(c)) != -1) {
                  fw.write(c);
                 count += read;
             }
             System.out.println("Wrote: " + count + " characters.");
         } catch (FileNotFoundException f) {
             System.out.println("File " + args[0] + " not found.");
         } catch (IOException e) {
             System.out.println("IOException: " + e);
         }
     }
 }
```

Now, rather than a byte array, this version uses a character array.

I/O Stream Chaining

Input Stream Chain



Data Source

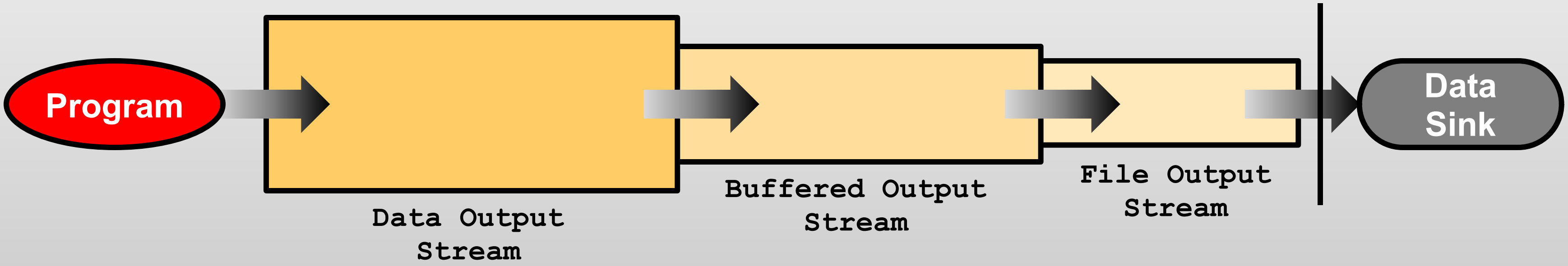
File Input Stream

Buffered Input Stream

Data Input Stream

Program

Output Stream Chain



Program

Data Output Stream

Buffered Output Stream

File Output Stream

Data Sink

Chained Streams: Example

```java
import java.io.BufferedReader; import java.io.BufferedWriter;
import java.io.FileReader; import java.io.FileWriter;
import java.io.FileNotFoundException; import java.io.IOException;

public class BufferedStreamCopyTest {
   public static void main(String[] args) {
       try (BufferedReader bufInput
                = new BufferedReader(new FileReader(args[0]));
            BufferedWriter bufOutput
                 = new BufferedWriter(new FileWriter(args[1]))) {
            String line = "";
            while ((line = bufInput.readLine()) != null) {
                 bufOutput.write(line);
                 bufOutput.newLine();
            }
        } catch (FileNotFoundException f) {
            System.out.println("File not found: " + f);
        } catch (IOException e) {
            System.out.println("Exception: " + e);
        }
    }
}
```

A `FileReader` chained to a `BufferedFileReader`: This allows you to use a method that reads a String.

The character buffer replaced by a `String`. Note that `readLine()` uses the newline character as a terminator. Therefore, you must add that back to the output file.

Console I/O

The `System` class in the `java.lang` package has three static instance fields: `out`, `in`, and `err`.

- The `System.out` field is a static instance of a `PrintStream` object that enables you to write to *standard output.*
- The `System.in` field is a static instance of an `InputStream` object that enables you to read from *standard input.*
- The `System.err` field is a static instance of a `PrintStream` object that enables you to write to *standard error.*

Writing to Standard Output

- The `println` and `print` methods are part of the `java.io.PrintStream` class.
- The `println` methods print the argument and a newline character (`\n`).
- The `print` methods print the argument without a newline character.
- The `print` and `println` methods are overloaded for most primitive types (`boolean`, `char`, `int`, `long`, `float`, and `double`) and for `char[]`, `Object`, and `String`.
- The `print(Object)` and `println(Object)` methods call the `toString` method on the argument.

Reading from Standard Input

```
public class KeyboardInput {

    public static void main(String[] args) {
        String s = "";
        try (BufferedReader in = new BufferedReader(new
InputStreamReader(System.in))) {
            System.out.print("Type xyz to exit: ");
            s = in.readLine();
            while (s != null) {
                System.out.println("Read: " + s.trim());
                if (s.equals("xyz")) {
                    System.exit(0);
                }
                System.out.print("Type xyz to exit: ");
                s = in.readLine();
            }
        } catch (IOException e) { // Catch any IO exceptions.
            System.out.println("Exception: " + e);
        }
    }
}
```

Chain a buffered reader to an input stream that takes the console input.

Channel I/O

Introduced in JDK 1.4, a channel reads bytes and characters in blocks, rather than one byte or character at a time.

```
import java.io.FileInputStream; import java.io.FileOutputStream;
import java.nio.channels.FileChannel; import java.nio.ByteBuffer;
import java.io.FileNotFoundException; import java.io.IOException;

public class ByteChannelCopyTest {
    public static void main(String[] args) {
        try (FileChannel fcIn = new FileInputStream(args[0]).getChannel();
             FileChannel fcOut = new FileOutputStream(args[1]).getChannel()) {
            ByteBuffer buff = ByteBuffer.allocate((int) fcIn.size());
            fcIn.read(buff);
            buff.position(0);
            fcOut.write(buff);
        } catch (FileNotFoundException f) {
            System.out.println("File not found: " + f);
        } catch (IOException e) {
            System.out.println("IOException: " + e);
        }
    }
}
```

Create a buffer sized the same as the file size, and then read and write the file in a single operation.

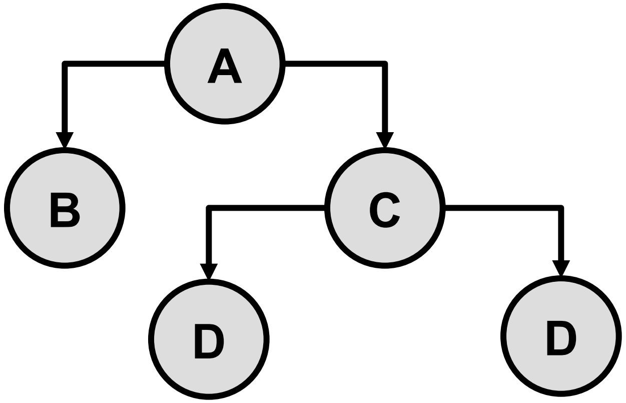
Persistence

Saving data to some type of permanent storage is called persistence. An object that is persistent-capable can be stored on disk (or any other storage device), or sent to another machine to be stored there.

- A non-persisted object exists only as long as the Java Virtual Machine is running.
- Java serialization is the standard mechanism for saving an object as a sequence of bytes that can later be rebuilt into a copy of the object.
- To serialize an object of a specific class, the class must implement the `java.io.Serializable` interface.

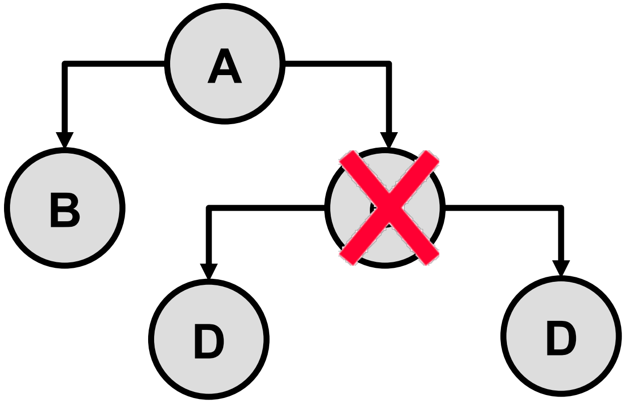
Serialization and Object Graphs

- When an object is serialized, only the fields of the object are preserved.
- When a field references an object, the fields of the referenced object are also serialized, if that object's class is also serializable.
- The tree of an object’s fields constitutes the *object graph*.



Transient Fields and Objects

- Some object classes are not serializable because they represent transient operating system–specific information.
- If the object graph contains a non-serializable reference, a `NotSerializableException` is thrown and the serialization operation fails.
- Fields that should not be serialized or that do not need to be serialized can be marked with the keyword `transient`.



Transient: Example

```
public class Portfolio implements Serializable {
    public transient FileInputStream inputFile;
    public static int BASE = 100;
    private transient int totalValue = 10;
    protected Stock[] stocks;
}
```

`static` fields are not serialized.

Serialization includes all of the members of the `stocks` array.

- The field access modifier has no effect on the data field being serialized.
- The values stored in static fields are not serialized.
- When an object is deserialized, the values of static fields are set to the values declared in the class. The value of non-static transient fields is set to the default value for the type.

Serial Version UID

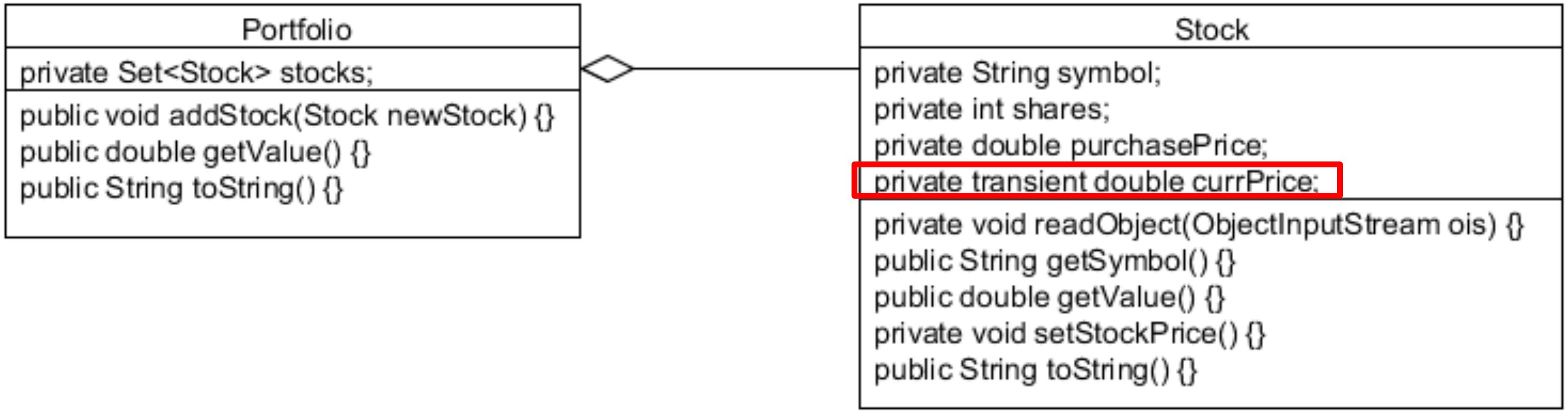
- During serialization, a version number, serialVersionUID, is used to associate the serialized output with the class used in the serialization process.
- After deserialization, the serialVersionUID is checked to verify that the classes loaded are compatible with the object being deserialized.
- If the receiver of a serialized object has loaded classes for that object with different serialVersionUID, deserialization will result in an `InvalidClassException`.
- A serializable class can declare its own serialVersionUID by explicitly declaring a field named `serialVersionUID` as a static final and of type long:

```
private static long serialVersionUID = 42L;
```

Serialization: Example

In this example, a Portfolio is made up of a set of Stocks.

- During serialization, the current price is not serialized, and is, therefore, marked `transient`.
- However, the current value of the stock should be set to the current market price after deserialization.



Portfolio

private Set<Stock> stocks;

public void addStock(Stock newStock) {}
public double getValue() {}
public String toString() {}

Stock

private String symbol;
private int shares;
private double purchasePrice;
private transient double currPrice;

private void readObject(ObjectInputStream ois) {}
public String getSymbol() {}
public double getValue() {}
private void setStockPrice() {}
public String toString() {}

Writing and Reading an Object Stream

```
public static void main(String[] args) {
    Stock s1 = new Stock("ORCL", 100, 32.50);
    Stock s2 = new Stock("APPL", 100, 245);
    Stock s3 = new Stock("GOOG", 100, 54.67);
    Portfolio p = new   Portfolio(s1, s2, s3);
    try (FileOutputStream fos = new FileOutputStream(args[0]);
         ObjectOutputStream out = new ObjectOutputStream(fos)) {
        out.writeObject(p);
    } catch (IOException i) {
         System.out.println("Exception writing out Portfolio: " + i);
    }
    try (FileInputStream fis = new FileInputStream(args[0]);
         ObjectInputStream in = new ObjectInputStream(fis)) {
        Portfolio newP = (Portfolio)in.readObject();
    } catch (ClassNotFoundException | IOException i) {
        System.out.println("Exception reading in Portfolio: " + i);
 }
```

`Portfolio` is the root object.

The `writeObject` method writes the object graph of `p` to the file stream.

The `readObject` method restores the object from the file stream.

Serialization Methods

An object being serialized (and deserialized) can control the serialization of its own fields.

```
public class MyClass implements Serializable {
    // Fields
    private void writeObject(ObjectOutputStream oos) throws IOException {
        oos.defaultWriteObject();
        // Write/save additional fields
        oos.writeObject(new java.util.Date());
    }
}
```

`defaultWriteObject` is called to perform the serialization of this class' fields.

- For example, in this class, the current time is written into the object graph.
- During deserialization, a similar method is invoked:

```
private void readObject(ObjectInputStream ois) throws
ClassNotFoundException, IOException {}
```

readObject: Example

```
public class Stock implements Serializable {
    private static final long serialVersionUID = 100L;
    private String symbol;
    private int shares;
    private double purchasePrice;
    private transient double currPrice;

    public Stock(String symbol, int shares, double purchasePrice) {
        this.symbol = symbol;
         this.shares = shares;
         this.purchasePrice = purchasePrice;
         setStockPrice();
     }

     // This method is called post-serialization
     private void readObject(ObjectInputStream ois)
                             throws IOException, ClassNotFoundException {
         ois.defaultReadObject();
         // perform other initialization
         setStockPrice();
     }
}
```

Stock `currPrice` is set by the `setStockPrice` method during creation of the Stock object, but the constructor is not called during deserialization.

Stock `currPrice` is set after the other fields are deserialized.

Summary

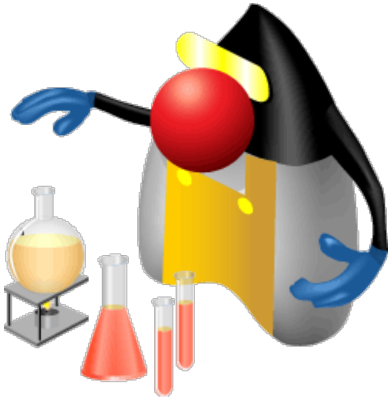
In this lesson, you should have learned how to:

- Describe the basics of input and output in Java
- Read data from and write data to the console
- Use streams to read and write files
- Write and read objects by using serialization

Practice 13-1 Overview: Writing a Simple Console I/O Application

This practice covers the following topics:

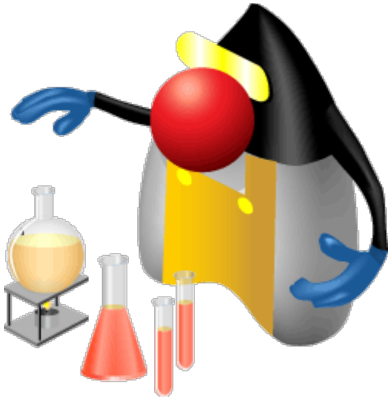
- Writing a main class that accepts a file name as an argument
- Using `System` console I/O to read a search string
- Using stream chaining to use the appropriate method to search for the string in the file and report the number of occurrences
- Continuing to read from the console until an exit sequence is entered



Practice 13-2 Overview: Serializing and Deserializing a `ShoppingCart`

This practice covers the following topics:

- Creating an application that serializes a `ShoppingCart` object that is composed of an `ArrayList` of `Item` objects
- Using the `transient` keyword to prevent the serialization of the `ShoppingCart` total. This will allow items to vary their cost.
- Using the `writeObject` method to store today's date on the serialized stream
- Using the `readObject` method to recalculate the total cost of the cart after deserialization and print the date that the object was serialized



Quiz

The purpose of chaining streams together is to:

a. Allow the streams to add functionality
b. Change the direction of the stream
c. Modify the access of the stream
d. Meet the requirements of JDK 7

Quiz

To prevent the serialization of operating system–specific fields, you should mark the field:

a. `private`

b. `static`

c. `transient`

d. `final`

Quiz

Given the following fragments:

```
public MyClass implements Serializable {
    private String name;
    private static int id = 10;
    private transient String keyword;
    public MyClass(String name, String keyword) {
        this.name = name; this.keyword = keyword;
    }
}
```

```
MyClass mc = new MyClass ("Zim", "xyzzy");
```

Assuming no other changes to the data, what is the value of `name` and `keyword` fields after deserialization of the `mc` object instance?

a. `Zim, ""`

b. `Zim, null`

c. `Zim, xyzzy`

d. `"", null`