The Java I/O System

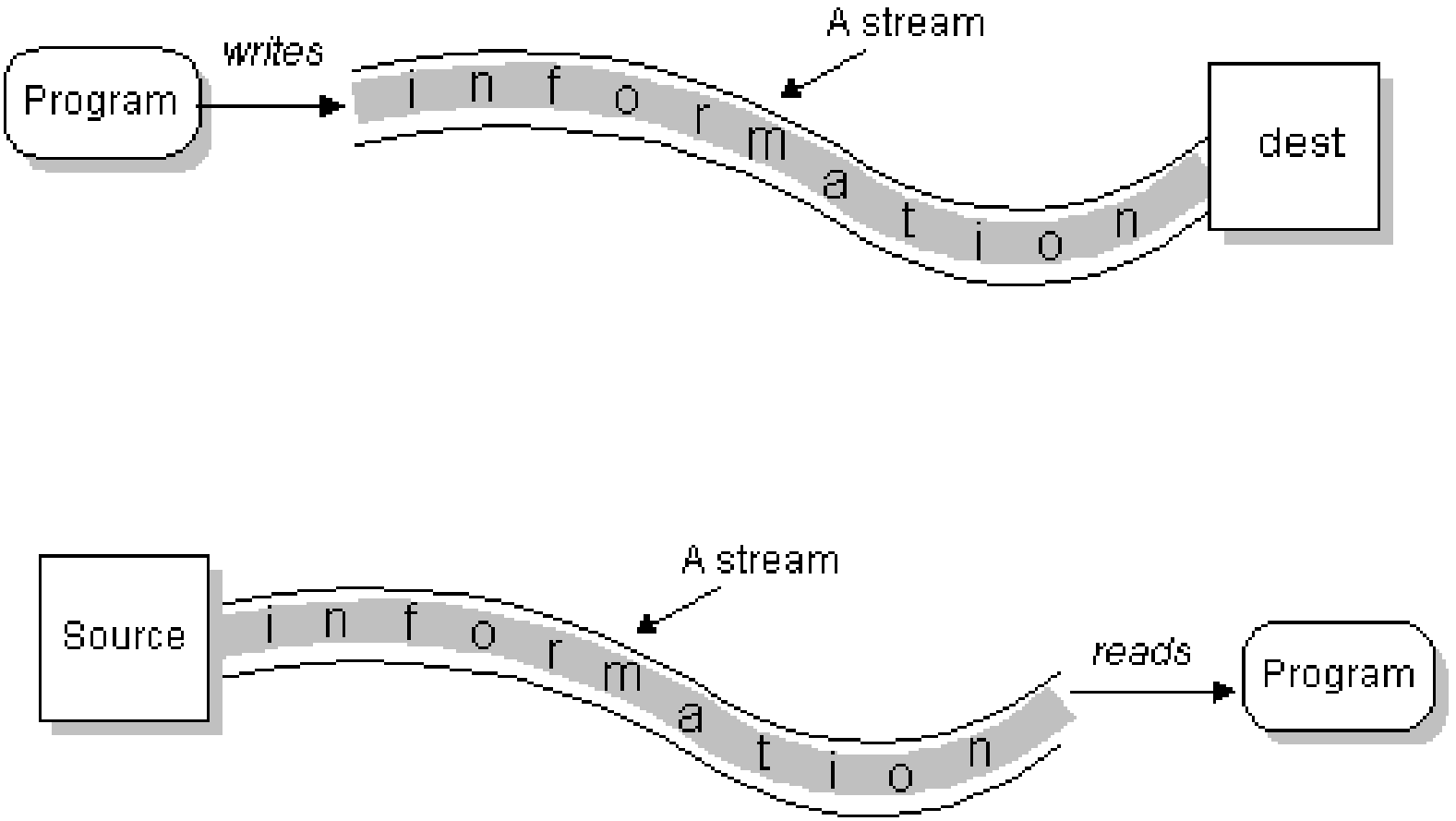
- Binary I/O streams (ascii, 8 bits)
  - **`InputStream`**
  - **`OutputStream`**
- The decorator design pattern
- Character I/O streams (Unicode, 16 bits)
  - **`Reader`**
  - **`Writer`**
- Comparing Binary I/O to Character I/O
- Files and directories
  - The class **`File`**
- Object Serialization
  - Light-weight persistence
- Will only look at the package **`java.io`** not **`java.nio`**.

Overview of The Java I/O System

- *Goal*: To provide an abstraction of all types of I/O
  - Memory
  - File
  - Directory
  - Network
- Express all configurations
  - Character, binary, buffered, etc.
- Different kinds of operations
  - Sequential, random access, by line, by word, etc.

The Stream Concept

- A *stream* is a sequential source of information used to transfer information from one source to another.



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Streams in Java

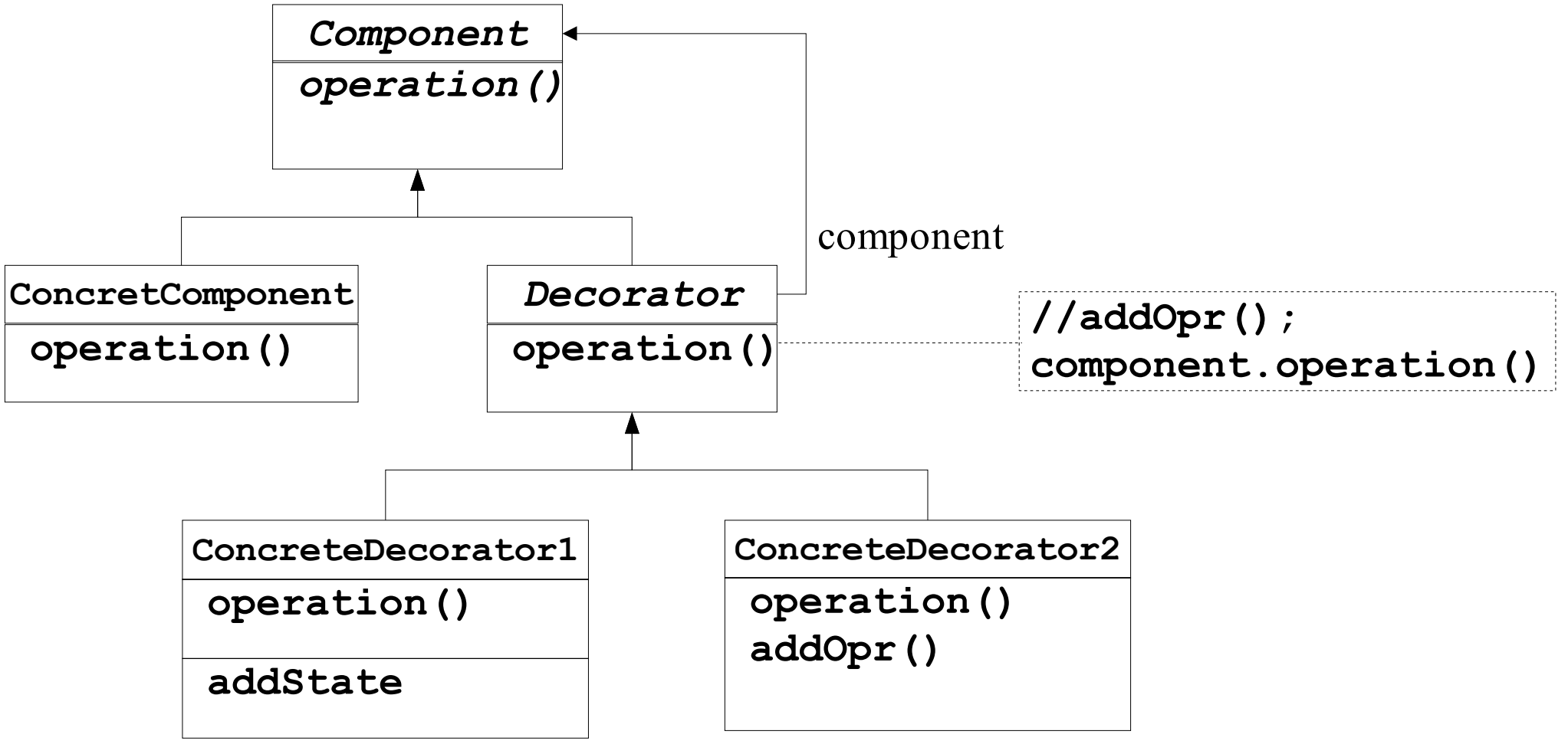
- There is a huge (and complicated) hierarchy of stream classes in Java.

- Overview of the stream hierarchy
  - **`Reader`**, root in unicode input hierarchy
  - **`Writer`**, root in unicode output hierarchy
  - **`InputStream`**, root in binary input hierarchy
  - **`OutputStream`**, root in binary output hierarchy

- All abstract classes.

The Decorator Design Pattern

- Wrap classes in “decorators” to add functionality.

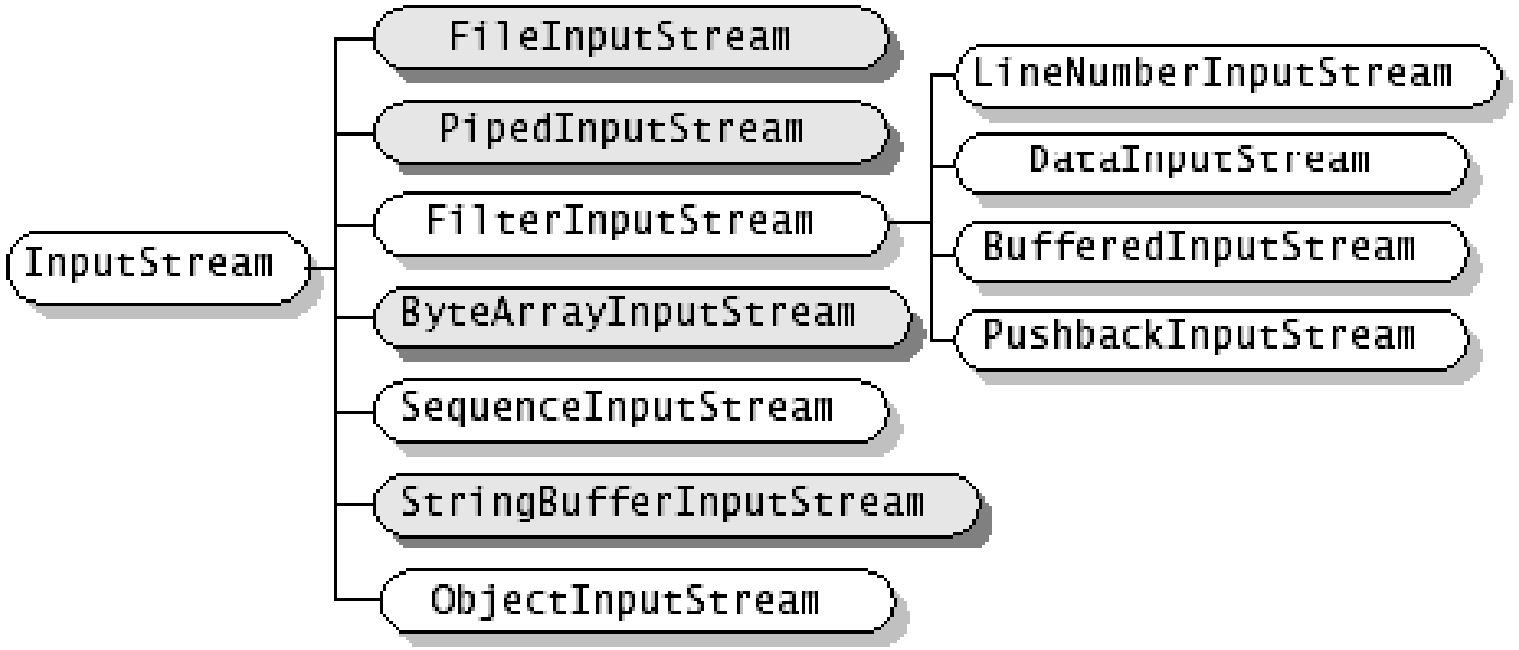


Decorator Pattern and Java I/O

- Two issues with I/O
  - What are you talking to (*n*).
  - The way you are talking to it (*m*).

- Solution no. 1
  - Make a class for every combination
  - *n* * *m* classes, not flexible, hard to extend
- Solutions no. 2
  - Java filter streams (decorators) are added dynamically to create the functionality needed.
  - *n* + *m* classes
  - Input decorator: **`FilterInputStream`**
  - Output decorator: **`FilterOutputStream`**

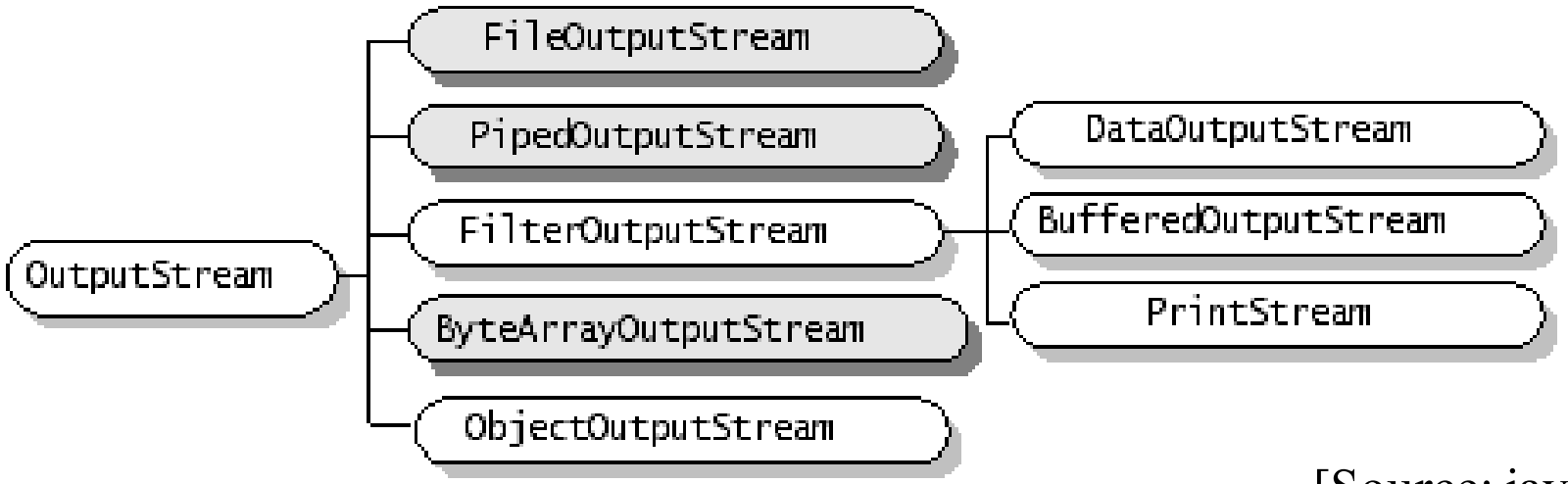
`InputStream` Hierarchy



[Source: java.sun.com]

- **`InputStream`**, the abstract component root in decorator pattern
- **`FileInputStream`**, etc. the concrete components
- **`FilterInputStream`**, the abstract decorator
- **`LineNumberInputStream`**, **`DataInputStream`**, etc. concrete decorators

`OutputStream` Hierarchy



[Source: java.sun.com]

- **`OutputStream`**, the abstract component root in decorator pattern
- **`FileOutputStream`**, etc. the concrete components
- **`FilterOutputStream`**, the abstract decorator
- **`PrintStream`**, **`DataOutputStream`**, etc. concrete decorators

`InputStream` Types

Type of InputStream	*Reads From*
`ByteArrayInputStream`	Block of memory
`StringBufferInputStream`	**`String`** (note *not* **`StringBuffer`**)
`PipedInputStream`	Pipe (in another thread)
`FileInputStream`	File
`SequencedInputStream`	Combines **`InputStream`**s
`ObjectInputStream`	Objects from an **`InputStream`**

Concrete Components

`OutputStream` Types

Type of OutputStream	*Reads From*
`ByteArrayOutputStream`	Block of memory
`PipedOutputStream`	Pipe (in another thread)
`FileOutputStream`	File
`ObjectOutputStream`	Objects to a **`OutputStream`**

Concrete Components

FilterInputStream

- **DataInputStream**
  - Full interface for reading built-in types
  - For portable reading of data between different OS platforms
- **BufferedInputStream**
  - Adds buffering to the stream (do this by default)
- **LineNumberInputStream**
  - Only adds line numbers
- **PushbackInputStream**
  - One-character push pack for scanners (lexers)

Concrete Decorators

FilterOutputStream

- **DataOutputStream**
  - Full interface for writing built-in types
  - For portable writing of data between different OS platforms
  - Example: **System.out.println**
- **PrintStream**
  - Allows primitive formatting of data for display (not printf!)
  - Not for storage use DataOutputStream for this
- **BufferedOutputStream**
  - Adds buffering to output (do this by default!)

Concrete Decorators

`OutputStream`, Example

```
import java.io.*; // [Source: java.sun.com]
public class DataIODemo {
  public static void main(String[] args) throws IOException {
      // where to write to
      DataOutputStream out =
          new DataOutputStream(
            new FileOutputStream("invoice1.txt"));

      // alternative also using a buffer decorator
      DataOutputStream out =
          new DataOutputStream(
              new BufferedOutputStream(
                  new FileOutputStream("invoice1.txt")));
```

`OutputStream`, Example, cont.

```
import java.io.*; // [Source: java.sun.com]
public class DataIODemo {
  public static void main(String[] args) throws IOException {
        snip
        double[] prices = { 19.99, 9.99, 15.99, 3.99, 4.99 };
        int[] units = { 12, 8, 13, 29, 50 };
        String[] descs = { "Java T-shirt",
                           "Java Mug",
                           "Duke Juggling Dolls",
                           "Java Pin",
                           "Java Key Chain" };
        for (int i = 0; i < prices.length; i ++) {
            out.writeDouble(prices[i]);
            out.writeChar('\t');       // add a tab
            out.writeInt(units[i]);
            out.writeChar('\t');       // add a tab
            out.writeChars(descs[i]);
            out.writeChar('\n');       // add a newline
        }
        out.close();
```

`InputStream`, Example

```
// read it in again
DataInputStream in =
   new DataInputStream(
     new FileInputStream("invoice1.txt"));

// alternative also using a buffer decorator
DataInputStream in =
    new DataInputStream(
        new BufferedInputStream (
            new FileInputStream("invoice1.txt")));


double price;
int unit;
StringBuffer desc;
double total = 0.0;
```

`InputStream`, Example, cont.

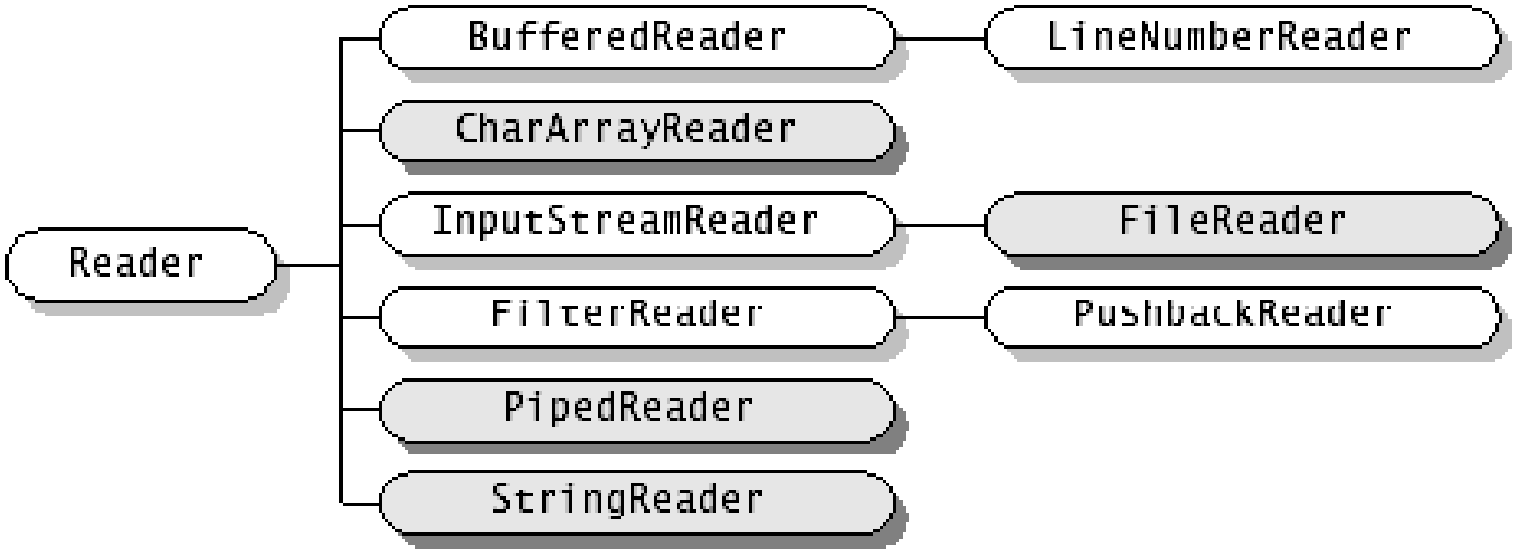
```
try {
     while (true) {
        price = in.readDouble();
        in.readChar();        // throws out the tab
        unit = in.readInt();
        in.readChar();        // throws out the tab
        char chr;
        desc = new StringBuffer(20);
        char lineSep =
            System.getProperty("line.separator").charAt(0);
        while ((chr = in.readChar()) != lineSep)
            desc.append(chr);
                System.out.println("You've ordered " +
                    unit + " units of " +
                    desc + " at $" + price);
                total = total + unit * price;
            }
        } catch (EOFException e) {
        }
        System.out.println("For a TOTAL of: $" + total);
        in.close();
}
```

`Reader` and **`Writer`** Classes

- Added in Java 1.1
- Not meant to replace **`InputStream`** and **`OutputStream`**
- Internationalization Unicode support
- Efficiency, designed to solved efficiency problems

- Structured in class hierarchies similar to the **`InputStream`** and **`OutputStream`** hierarchies
  - Are also using the decorator design pattern

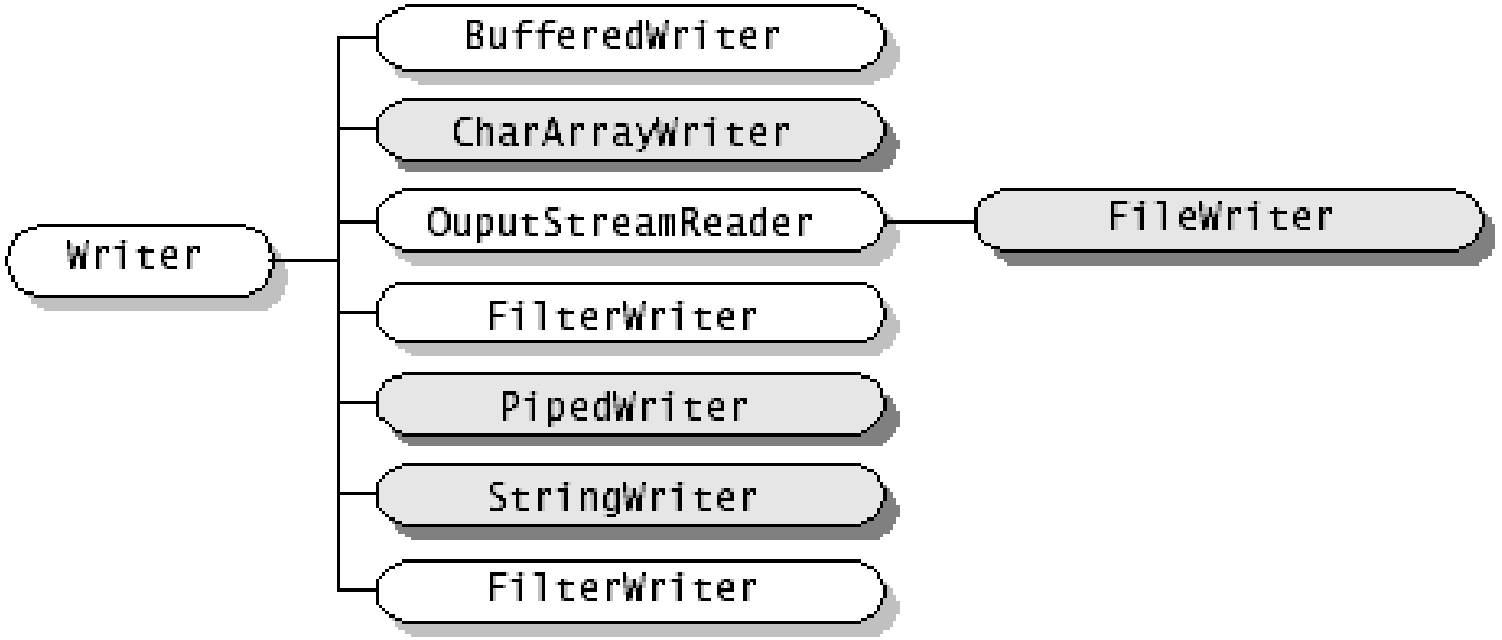
Reader Class Hierarchy



- **Reader**, the abstract component root in decorator pattern
- **BufferedReader**, etc. the concrete components
- **FilterReader**, the abstract decorator
- **PushbackReader**, concrete decorators

[Source: java.sun.com]

`Writer` Class Hierarchy



[Source: java.sun.com]

- **`Writer`**, the abstract component root in decorator pattern
- **`BufferedWriter`**, etc. the concrete components
- **`FilterWriter`**, the abstract decorator
- No concrete decorators

`Reader` and **`Writer`** Types

- Transport to and from main memory
  - **`CharArrayReader`**, **`CharArrayWriter`**
  - **`StringReader`**, **`StringWriter`**
- Transport to and from pipelines (networking)
  - **`PipedReader`**, **`PipedWriter`**
- Transport to and from files
  - **`FileReader`**, **`FileWriter`**
- **`DataOutputStream`** unaltered from Java 1.0 to 1.1

Character Based Streams

- **`InputStreamReader`**
  - Reads platform characters and delivers Unicode characters to the Java program.
- **`OutputStreamWriter`**
  - Writes Unicode characters to platform dependent characters.
- **`PrintWriter`**
  - Writes Java primitive data types to file.

`FileReader` and `FileWriter`, Example

```
import java.io.*;

public class Copy {
    public static void main(String[] args) throws IOException
    {
        FileReader in = new FileReader(new File(args[0]));
        FileWriter out = new FileWriter(new File(args[1]));
        int c;
        do{
            c = in.read();
            if(c != -1) {
                out.write(c);
            }
        } while (c != -1);

        in.close();
        out.close();
    }
}
```

Binary vs. Character Based I/O Overview

InputStream	Reader convert: InputStreamReader
OutputStream	Writer convert: OutputStreamWriter
FileInputStream	FileReader
FileOutputStream	FileWriter
StringBufferedInputStream	StringReader (better name)
N/A	StringWriter
ByteArrayInputStream	CharArrayReader
ByteArrayOutputStream	CharArrayWriter
PipedInputStream	PipedReader
PipedOutputStream	PipedWriter

Binary vs. Character Filter Overview

• FilterInputStream	• FilterReader
• FilterOutputStream	• FilterWriter (abstract class)
• BufferedInputStream	• BufferedReader (has a readline())
• BufferedOutputStream	• BufferedWriter
• DataInputStream	• Use DataInputStream or BufferedReader
• PrintStream	• PrintWriter
• LineNumberInputStream	• LineNumberReader
• PushbackInputStream	• PushbackReader

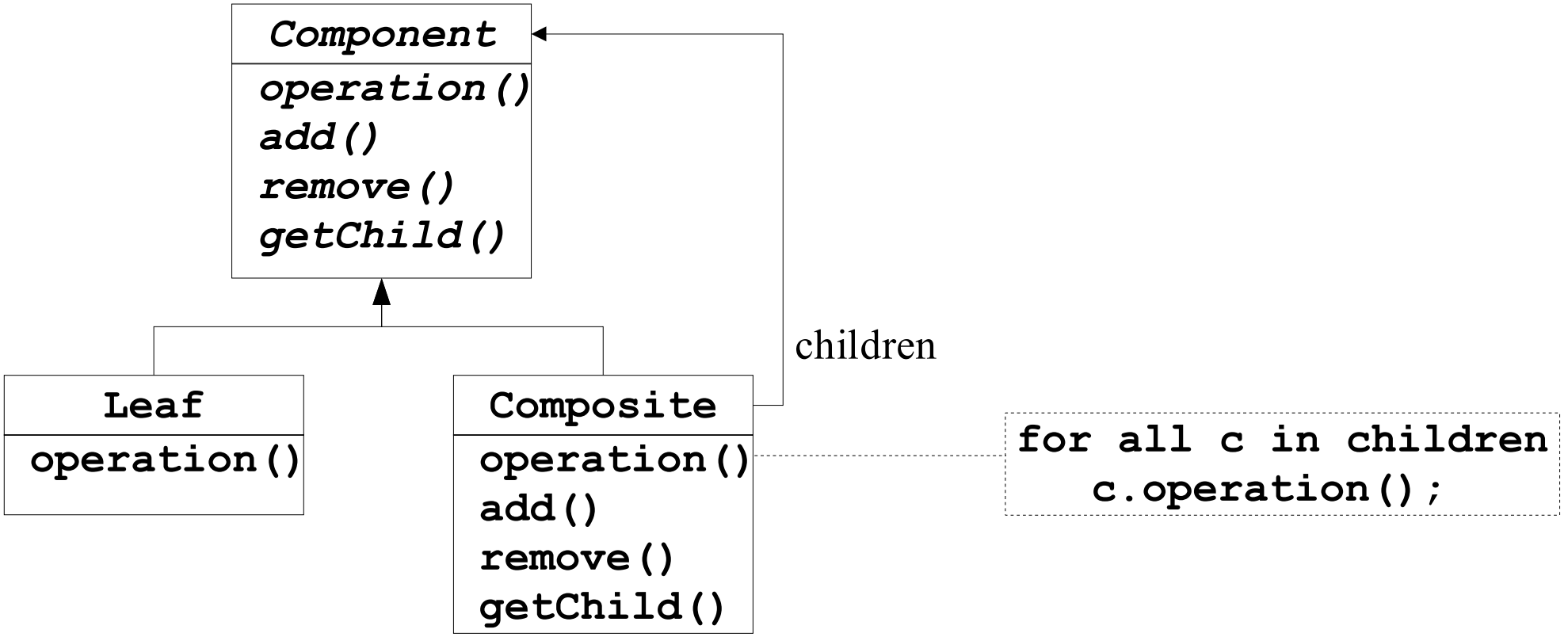
Representing the File System

- File systems varies between operating system, i.e.,
  - Path separators
  - Permissions in Unix
  - Directories on the Mac
  - Drive letters on Windows
- Needs an abstraction to hide the differences
  - To make Java program platform independent.

The `File` Class

- Refers to one or more file names, i.e., not a handle to a file
  - Composite design pattern
- To get an array of file names. Call the `list()` method.

The Composite Pattern, Again



The `File` Class, Example

```
import java.io.*;
public class DirectoryList {
   public static void main(String[] args) throws IOException{
      File dir = new File(args[0]);

      if(dir.isDirectory() == false) {
         if (dir.exists() == false)
            System.out.println("There is no such dir!");
         else
            System.out.println("That file is not a dir.");
      }
      else {
         String[] files = dir.list();
         System.out.println
            ("Files in dir \"" + dir + "\":");
         for (int i = 0; i < files.length; i++)
            System.out.println(" " + files[i]);
      }
   }
}
```

Object Serialization

- Very hard to do in other programming languages!!!
- Class must implement the **`Serializable`** interface
- Uses
  - Output: **`ObjectOutputStream`**
    - **`writeObject()`**
  - Input: **`ObjectInputStream`**
    - **`readObject()`**
- All relevant parts (the web of object) are serialized.
- Lightweight persistence
  - used in RMI (send objects across a network)
  - used in JavaBeans

Object Serialization, Example

```
// Write an object to disk
ObjectOutputStream out =
   new ObjectOutputStream(
      new FileOutputStream("mycars.dat"));

Car myToyota = new Car();
out.writeObject(myToyota);
```

```
// Read an object from disk
ObjectInputStream in =
   new ObjectInputStream(
      new FileInputStream("mycars.dat"));
Car myToyota = (Car)in.readObject();
```

Summary

- Streams a large class hierarchy for input and output.
  - The decorator pattern is the key to understanding it
- The decorator design pattern may seem strange
  - Very flexible, but requires extra coding in clients.
- There is no C-like printf functionality
  - This is annoying
- For objects to live between program invocations use the **`Serializable`** interface.
- **`java.nio`** packages goal speed
  - Look at it if you needed it in your projects

`FilterStream`, Example

```
import java.io.*;

class StreamFilterExample{
 public static void main(String[] args) throws IOException {
  DataInputStream din = new DataInputStream(
                              new BufferedInputStream(
                                new FileInputStream(
                                  new File("numbers.dat"))));

  int i;
  boolean b;
  i = din.readInt();
  b = din.readBoolean();
  System.out.println("i = " + i + ". b = " + b);
  din.close();
 }
}
```