Java's Input/Output

Java’s Hierarchy Input/Output Classes and Their Purpose

Introduction

- These slides introduce several input and output classes for special purposes, such as reading or writing a file.
- Some of these slides use the concept of inheritance.

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Types of Input/Output

	Data is text (characters and String)	Data in binary format
Sequential Access	▪ write to terminal ▪ text, html files ▪ printf( ), format( )	▪ not human readable ▪ efficient for space and computer read ▪ image, MP3, Word
Random Access		

What's in a File?

A file stores information or data as **bytes**.

We can store anything:

- An editor stores **text**. characters are translated to bytes.
- Can be 1 character = 1 byte or 1 char = 2 bytes ...
- Example: Eclipse stores Java src code as **text**

- Other applications store **binary data**.
- Example: MP3, JPEG, PNG

Basic Input Classes

`InputStream`	read input as bytes
`Reader` `InputStreamReader`	read input as characters
`BufferedReader`	read Strings, read entire lines

InputStream

Reads input as bytes -- one byte (or array) at a time.

Useful for reading data in binary format.

```
buffer = new StringBuffer( );
while ( true ) {
    int c = inputStream.read( );
    if ( c < 0 ) break; // end of input
    buffer.append( (char)c );
}
```

Do & test programming Idiom

This kind of code is common in C.

```
buffer = new StringBuffer( );
int c = 0;
while ( (c=inputStream.read( )) >=0 ) {
  buffer.append( (char)c );
}
```

InputStream with array of byte

It is more efficient to read many bytes at one time.

```
byte [] buff = new byte[80];
while ( true ) {
   int count = inputStream.read( buff );
   if ( count <= 0 ) break; // end
   // process the bytes in buff
}
```

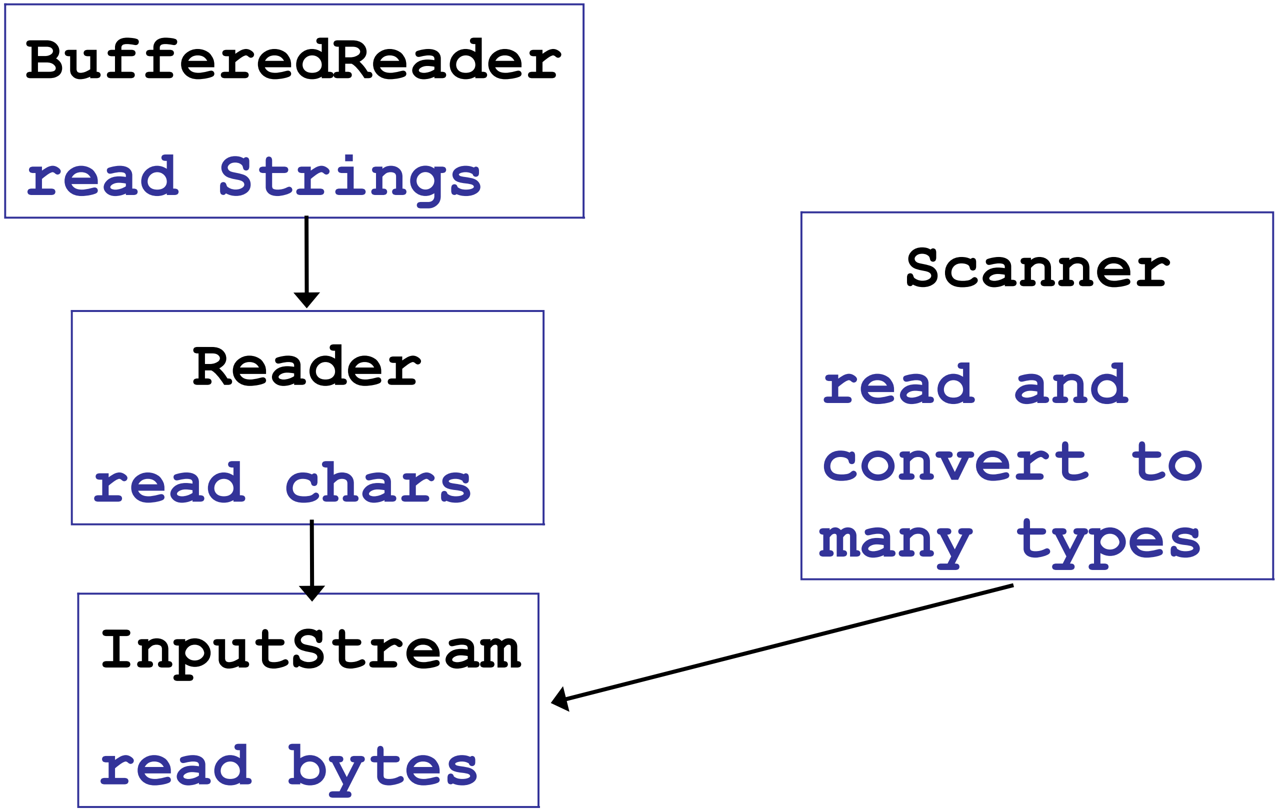
FileInputStream

- An InputStream connected to a file.
- Has many constructors.
- Works just like InputStream!

```
FileInputStream inputStream =
    new FileInputStream("c:/test.dat");

while ( true ) {
    int c = inputStream.read( );
    if ( c < 0 ) break; // end of input
    buffer.append( (char)c );
}
inputStream.close( );
```

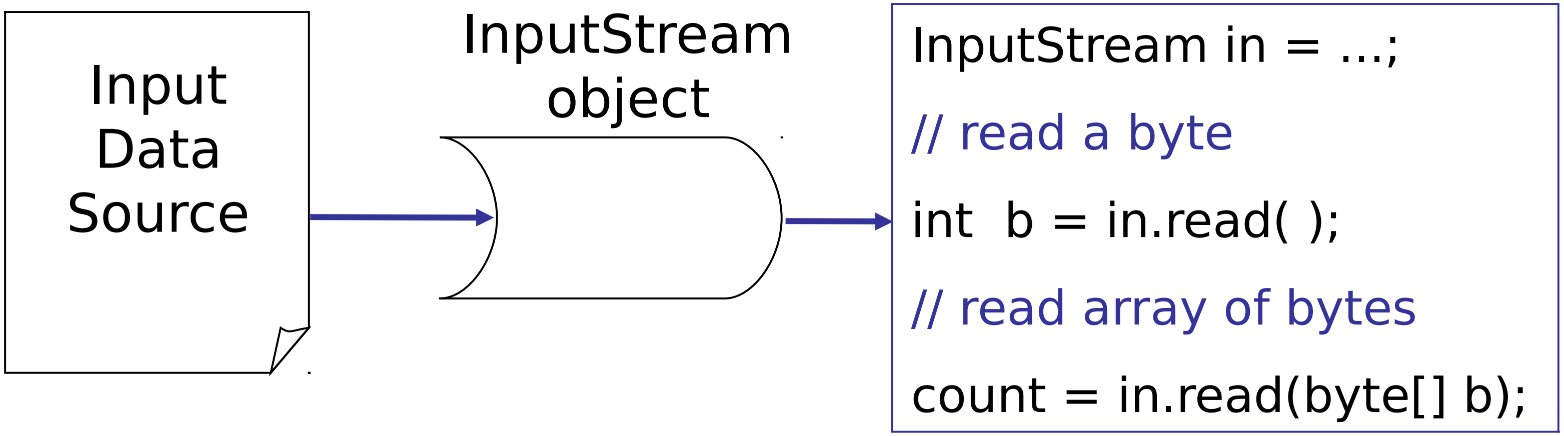
Input Classes Hierarchy

- Each layer "adapts" a lower layer to provide a different interface. They are **adaptors**.



InputStream

- InputStream reads bytes and returns them.
- No interpretation of character sets.
- OK for binary data.
- **`Not good`** for character data using character set.



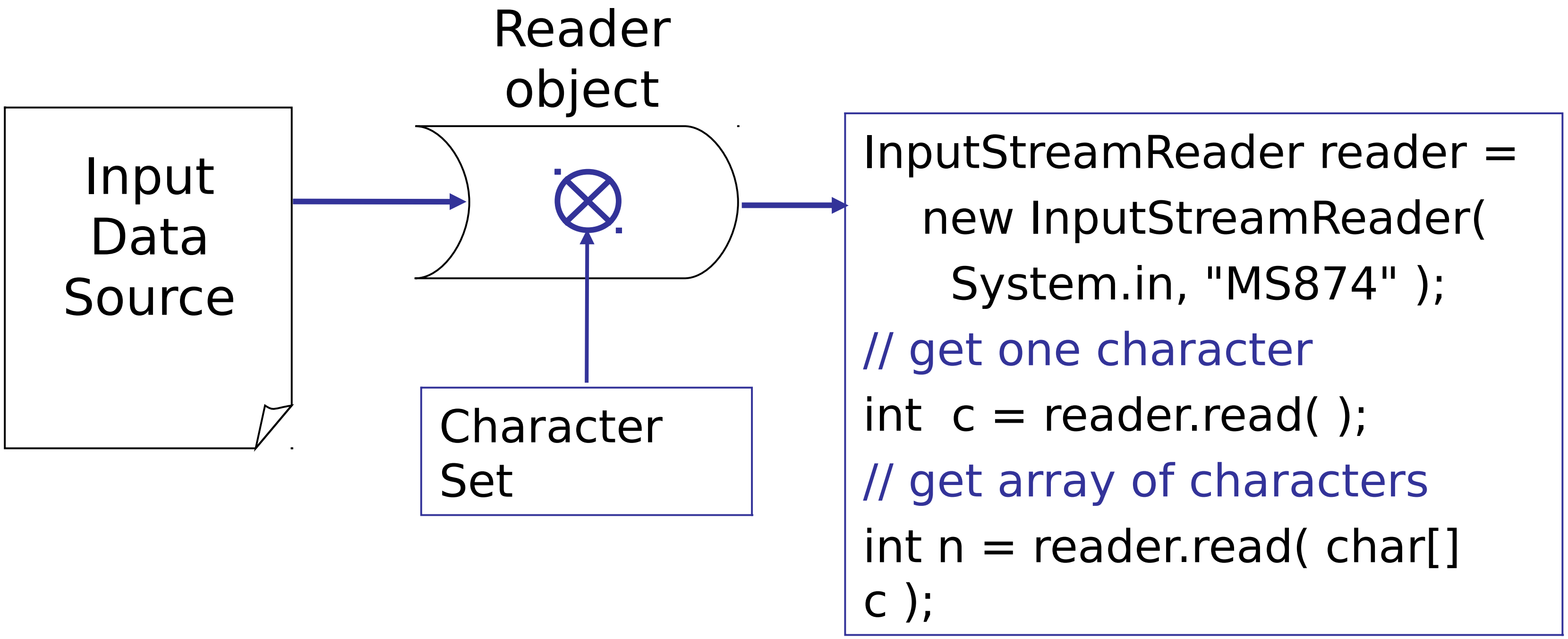
Input Data Source

InputStream object

```
InputStream in = ...;
// read a byte
int  b = in.read( );
// read array of bytes
count = in.read(byte[] b);
```

Reader

- Reader: reads bytes and converts to characters.
- Interpret bytes using a Character Set Encoding.
- Can handle any language... if you know the charset.



Reader object

Input Data Source

Character Set

```
InputStreamReader reader =
    new InputStreamReader(
      System.in, "MS874" );
// get one character
int  c = reader.read( );
// get array of characters
int n = reader.read( char[]
c );
```

InputStreamReader class

InputStreamReader is a kind of Reader.

It reads the input and returns characters.

```
InputStream in = new FileInputStream( "test" );
InputStreamReader reader =
  new InputStreamReader(in);
// read a character
char b = (char) reader.read( );
// read several characters
char [ ] buff = new char[100];
int nchars = reader.read( buff, 0, 100);
// close the input stream
reader.close( );
```

Character Sets

Java API docs list names of character sets.

```
InputStreamReader reader
                    = new InputStreamReader( inputStream, "charset" );
```

Charset Name	Description
ASCII	ASCII 7-bit encoding
ISO8859_1	ISO 8859-1 Latin alphabet No. 1
Cp874	IBM (DOS) Thai encoding
MS874	MS Windows Thai encoding
TIS620	TIS-620, Thai encoding
UTF-8	8-bit UTF encoding
UTF-16	16-bit UTF encoding

BufferedReader class

BufferedReader reads input as Strings.

It uses a Reader to read characters

```
BufferedReader breader = new BufferedReader(
     new InputStreamReader( System.in ) );
// read a line
String s = breader.readLine( );
```

Buffered Reader methods:

`int read( )` - read next char

`int read(char[ ], start, count)` - read chars into array

`String readLine( )` - return a string containing rest of the line

`close( )` - close the reader

BufferedReader for File Input

To read from a file, create a BufferedReader around a FileReader.

The ready() method returns true if (a) input buffer contains data (e.g. reading from System.in or a pipe) or (b) underlying data source is not empty (reading from file).

```
BufferedReader bin = new BufferedReader(
     new FileReader( "mydata.txt" ) );
// read some lines
while( bin.ready( ) )
{
  String s = bin.readLine( );
  // do something with the string
}
bin.close( );
```

Input Streams and Readers

Java has a Reader class corresponding to common InputStream classes.

InputStream	**Reader**
InputStream	InputStreamReader
LineNumberInputStream	LineNumberReader
FilterInputStream	FilterReader
FileInputStream	FileReader
PipedInputStream	PipedReader
Reading Binary Data	
DataInputStream	use readChar() method of DataInputStream to interpret data as characters

InputStream Hierarchy

Java provides a *hierarchy* of classes for processing input from different sources and types.

Java Input Stream Class Hierararchy

- InputStream
  - ByteArrayInputStream
  - FileInputStream
  - PipedInputStream
  - ObjectInputStream
  - SequenceInputStream
  - FilterInputStream
    - DataInputStream (binary input)
    - BufferedInputStream
    - LineNumberInputStream
    - PushbackInputStream

These are "wrappers" for another input stream.

How to Read without Blocking

InputStream has an `available( )` method that returns the number of bytes waiting to be read.

Use this to read without blocking.

Reader classes have a `ready()` method.

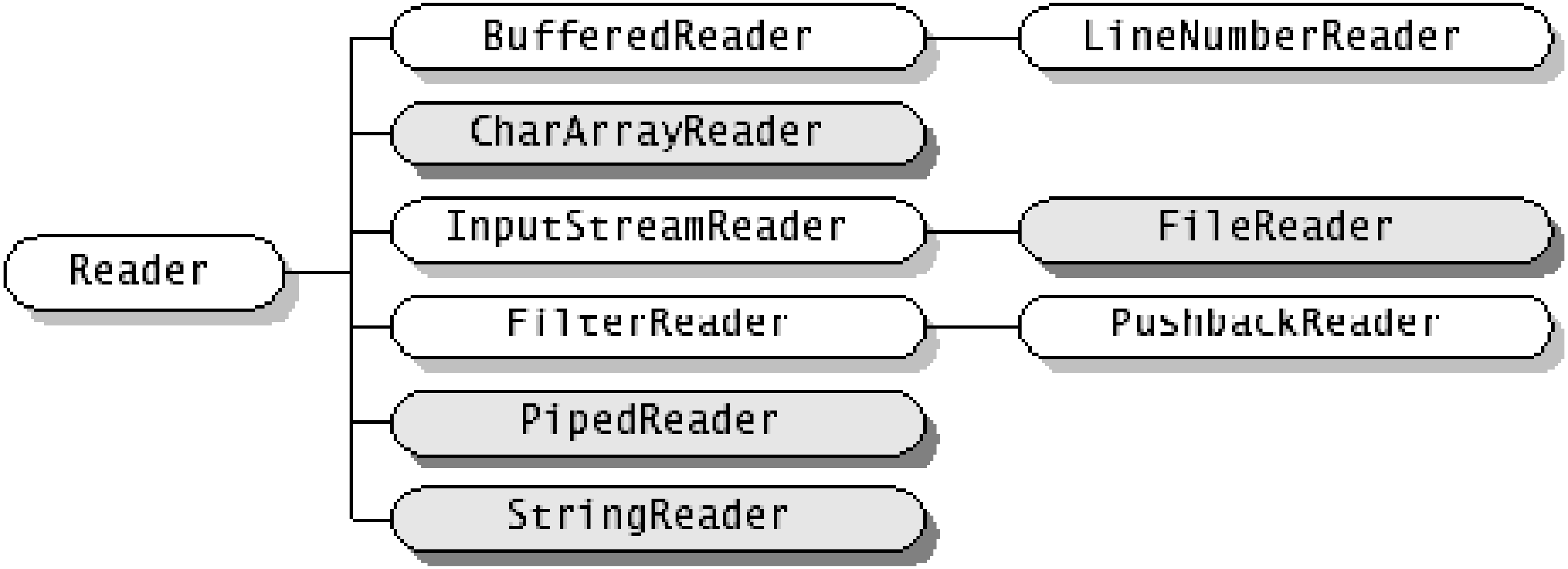
```
InputStream in = System.in;  // or whatever

// read whatever bytes are available
int size = in.available();
if ( size > 0 ) {
  byte [ ] b = new byte[size];
  in.read( b ); // this should not block
}
```

BufferedReader and End-of-Data

The `readLine( )` method returns `null` if the end of input stream is encountered. You can use this to read all data from a file.

```
String filename = "mydata.txt";
BufferedReader bin = new BufferedReader(
        new FileReader( filename ) );
// read all data
String s;
while( ( s = bin.readLine() ) != null )
{
    // process data in String s
    System.out.println( s.toUpperCase() );
}
file.close( );
```

Reader Class Hierarchy



Reading Binary Data

Examples:

- MP3 file, image file

Advantages:

- space efficient, can read quickly (little conversion)

```
InputStream instr = new FileInputStream( "mydata" );
DataInputStream data = new DataInputStream( instr );

try {
   int n = data.readInt( );         // 4 bytes
   double x = data.readDouble( ); // 8 bytes
   char c = data.readChar( );      // 2 bytes
}  catch ( IOException e ) { ... }
```

End-of-File for DataInputStream

- Throws EOFException if end of input encountered while reading.

```
InputStream fin = new FileInputStream( "mydata" );
DataInputStream data = new DataInputStream( fin );

double sum = 0;
while( true ) {
   try {
     double x = data.readDouble( ); // 8 bytes
     sum += x;
   } catch ( IOException e ) { ... }
   catch ( EOFException e ) { break; } // EOF
}
data.close( );
```

Scanner

`java.util.Scanner` is newer than the other classes.

`Scanner` "wraps" an InputStream or a String and provides parsing and data conversion.

```
// scanner wraps an InputStream
InputStream in = new FileInputStream(...);
Scanner scanner = new Scanner( in );
// scanner to parse a String
String s = "Peanuts 10.0 Baht";
Scanner scan = new Scanner( s );
```

Reading with Scanner

Can test for presence of data.

Convert next token into any primitive or get entire line as String.

```
Scanner scanner = new Scanner("3 dogs .5");
if ( scanner.hasNextInt() )
    n = scanner.nextInt();
if ( scanner.hasNext() )
    word = scanner.next();
if ( scanner.hasNextDouble() )
    x = scanner.nextDouble();
// read and discard rest of this line
scanner.nextLine();
```

Parsing with Scanner

Can change separator character.

Can search using regular expressions.

```
Scanner scanner = new Scanner("aa,bb,999");
scanner.useDelimiter(",");
String word = scanner.next(); // = "aa"
String w = scanner.findInLine("\\d\\d\\d");
// w is "999"
\d is a regular expression for a digit 0-9
```

Output Classes

Three layers, just like Input hierarchy

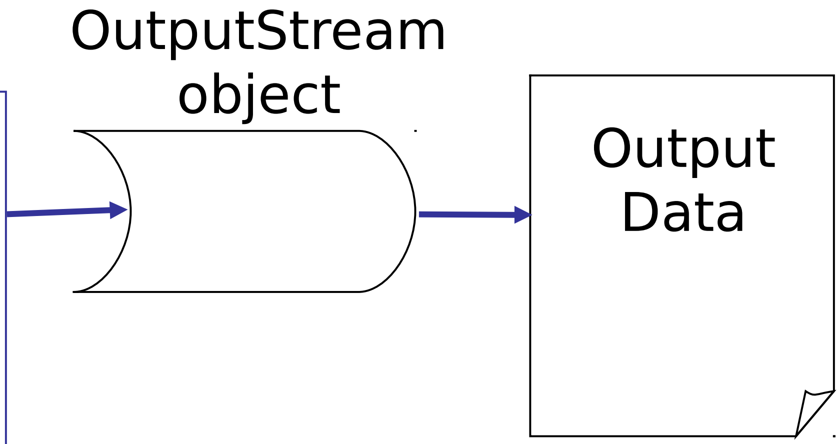
- OutputStream: outputs bytes (low level)
- Writer: outputs characters (convert to bytes)
- BufferedWriter: outputs strings and lines. buffers data

Formatter: utility for creating formatted output. Can be used as a pre-filter for an output stream or output to any *Appendable* object.

OutputStream

- OutputStream writes bytes to some output sink.
- No interpretation of character sets.
- Works OK for text in system's default character set.

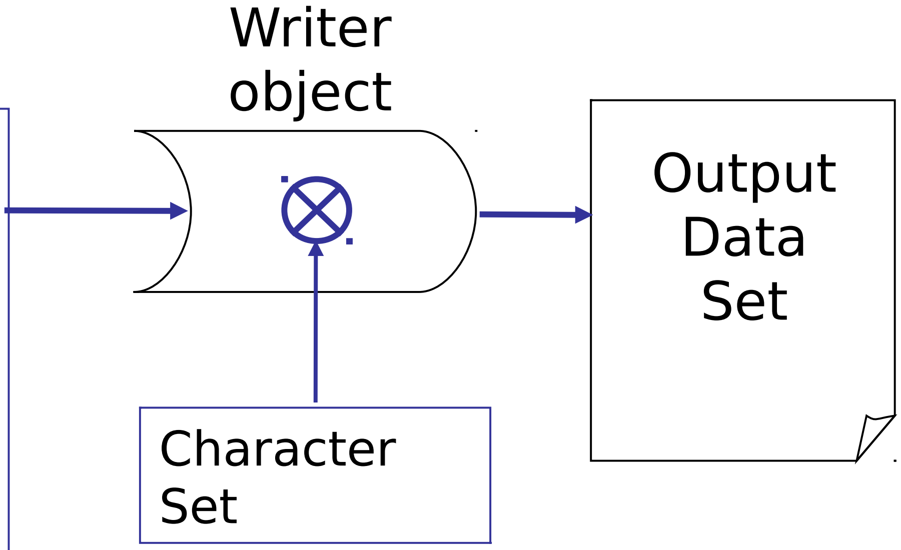
```
OutputStream out = ... ;
// write 1 byte
out.write( b );
// write array of bytes
out.write( byte[ ] b );
// flush buffered data
out.flush( );
// close output stream
out.close( );
```



Writer

- Writer converts UNICODE characters to bytes.
- Interprets chars according to character set encoding.
- Can handle any language (if you know the charset).

```
OutputStreamWriter out =
    new OutputStreamWriter(
      System.out, "MS874");
// write one character
out.write( c );
// write array of characters
char [] ca = ...;
out.write( ca );
```



Writer object

Character Set

Output Data Set

Output Streams and Writers

Java has several classes derived from OutputStream and Writer. Each class handles a particular output sink.

OutputStream	**Writer**
OutputStream	OutputStreamWriter
FilterOutputStream	FilterWriter
FileOutputStream	FileReader
PipedOutputStream	PipedWriter
	StringWriter
Writing Binary Data	
DataOutputStream	use writeChar() or writeChars() methods to output UNICODE characters

Handling Exceptions

The Java input and output methods will throw an IOException if there is an error in any input/output operation such read(), write(), or print(). Your program must deal with this exception in one of two ways:

1. Throw the exception..

```
public void myMethod throws IOException( ) {
   // read and process the input
}
```

2. Catch the exception and take some action. This is illustrated on the next slide.

Catching an Exception

```
BufferedReader myfile;
try {
   myfile = new BufferedReader(
         new FileReader( filename ) );
} catch (IOException e) {
   System.out.println(
         "Couldn't open file" + filename);
   return;
}
// read a line from file
try {
   String s = myfile.readLine( );
   // do something with string
} catch (IOException e) {
   System.out.println("Exception "+e
    + " while reading file.");
}
```

Using Files

The FileInputStream, FileOutputStream, FileReader, and FileWriter classes operate on File objects.

Create a File object by specifying the filename (and optional path):

```
File file1 = new File("input.txt");  // in "current" directory
File file2 = new File("/temp/input.txt");  // in temp dir
File file3 = new File("\\temp\\input.txt"); // same thing
File file4 = new File("/temp", "input.txt"); // same thing
File dir = new File("/temp");    // open directory as file
```

These commands **do not create** a file in the computer's file system. They only create a File object in Java.

Testing Files

The File class has methods to:

- test file existence and permissions
- create a file, delete a file
- get file properties, such as path

```
File file = new File( "/temp/input.txt" );  // file object

if ( file.exists( ) && file.canRead( ) )       // OK to read
    FileInputStream fin = new FileInputStream(file);

if ( ! file.exists( ) ) file.createNewFile( );  // create a file!
if ( file.canWrite( ) )            // OK to write
    FileOutputStream fout = new FileOutputStream(file);
```

More File Operations

File objects can tell you their size, location (path), modification time, etc.   See the Java API for File.

```
File file = new File("/temp/something.txt"); // file object

if ( file.isFile() ) {
    /* this is an ordinary file */
    long length = file.length( );
    long date = file.lastModified( );
}

if ( file.isDirectory() ) {
    /* this is a directory */
    File files [] = file.listFiles();  // read directory
}
```

File Copy Example

Copy a file. Realistically, you should test file existence and permissions, catch IOException, etc.

```
File infile = new File("/temp/old.txt");
File outfile = new File("/temp/new.txt");
if ( outfile.exists( ) ) outfile.delete( );
outfile.createNewFile( );

FileReader fin = new FileReader( infile );
FileWriter fout = new FileWriter( outfile );
// reading char at a time is very inefficient
int c;
while ( (c = fin.read()) >= 0 ) fout.write(c);
fin.close();
fout.flush();
fout.close();
```

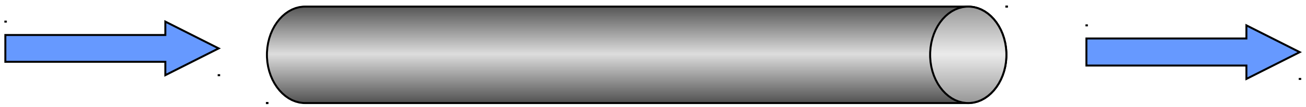
Pipes

Reading and writing pipes: one method writes data into the pipe, another method reads data from the pipe.

Very useful for multi-threaded applications.

```
PipedOutputStream pout =
 new PipedOutputStream();
```

```
PipedInputStream pin =
 new PipedInputStream(pout);
```



```
PipedOutputStream pout = new PipedOutputStream();

PipedInputtStream pin = new PipedInputStream( pout );

PrintStream out = new PrintStream( pout );

BufferedInputStream in = new BufferedInputStream( pin );

out.println("data into the pipe");  // write to the pipe

String s = in.readLine( );  // read from the pipe
```

Access Order

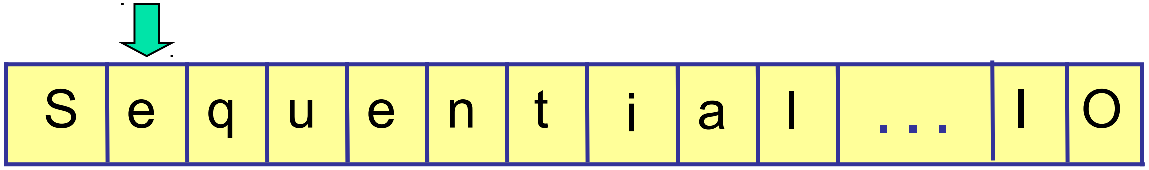
InputStream and Readers read the input from start to end.

OutputStream and Writers write the output from start to end.

This is called Sequential Access.

Sequential Access

- Read/write everything starting from the beginning.
- Sequential:
  - Cannot "back up" and reread or rewrite something.
  - Cannot "jump" to arbitrary location in stream.
- InputStream and OutputStream use sequential I/O.
- InputStream has a **`skip(n)`**, but it is still sequential.

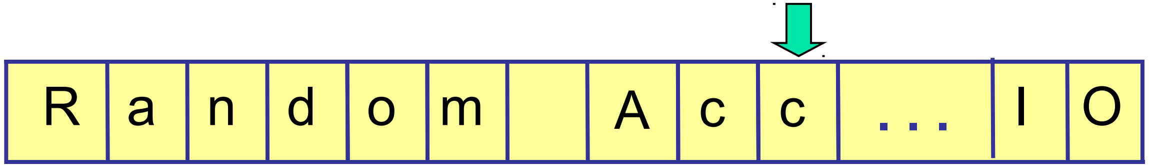


S	e	q	u	e	n	t	i	a	l	. . .	I	O

```
int a = instream.read( ); // read a = 'S'
byte [ ] b = new byte[10];
int count = instream.read( b );   // read next 10 bytes
```

Random Access

- Can move to any location using **seek( )** method.
- Can move forward and backward.
- Only makes sense for files.



R	a	n	d	o	m		A	c	c	. . .	I	O

```
File file = new File( "c:/data/myfile.txt" );
RandomAccessFile rand =
           new RandomAccessFile(file, "r");
rand.seek( 9L ); // goto byte 9
int b = rand.read( );
```

RandomAccessFile

- Random Access I/O means you can move around in the file, reading/writing at any place you want.
- For output, you can even write *beyond* the end of file.
- Use **`seek( )`** to move current position.

```
RandomAccessFile ra = new RandomAccessFile("name", "rw");
ra.seek( 100000L );  // go to byte #100000
byte [ ] b = new byte[1000];
// all "read" methods are binary, like DataInputStream
ra.readFully( b );   // read 1000 bytes
ra.seek( 200000L );  // go to byte #200000
ra.write( b );
```

More Information

In the Sun Java Tutorials (online)

I/O: Reading and Writing
http://java.sun.com/docs/books/tutorial/essential/io/

Handling Errors with Exceptions
http://java.sun.com/docs/books/tutorial/essential/exceptions/