CS410J: *Advanced Java Programming*

The Java^{TM} programming platform contains a set of class libraries. These standard libraries provide functionality that ranges from file compression to graphics. Here we will discuss some of Java's fundamental classes, useful utility classes, and tools for performing I/O.

The Standard Libraries

- `java.lang`
- `java.io`
- `java.util`

The `java.lang` package

The `java.lang` package contains classes, interfaces, and exceptions that are fundamental to the Java programming language

- `Object`, `Class`, `System`
- `String`, `StringBuilder`
- The "wrapper" classes
- A bunch of exceptions

`java.lang.Object`

`Object` is the root class in Java: Everything is an `Object`

Therefore, all objects have the following methods

- `equals`: Compares an `Object` to another
- `toString`: Returns a `String` representation of an `Object` (often invoked automagically)
- `hashCode`: Returns a hash code for an `Object`
- `clone`: Returns a copy of an `Object`
- `getClass`: Returns an instance of an `Object`'s "metaclass"
- `finalize`: Called when an `Object` is garbage collected (not a destructor!)
- `notify`, `notifyAll`, and `wait` are used in multi-threaded programs

`java.lang.String`

`String`s can be constructed from `byte` arrays, `char` arrays, or other `String`s

- `charAt`: Returns the `char` at a given offset into a `String`
- `compareTo`: Compares a `String` to another
- `endsWith`/`startsWith`: Determines if one `String` is a suffix/prefix of another
- `indexOf`: Finds an occurrence of a `char` in a `String`
- `length`: Returns the length of a `String`
- `replace`: Replaces all occurrences of one `char` with another
- `trim`: Removes leading and trailing whitespace from a `String`

java.lang.StringBuilder

Strings are immutable, StringBuilders* can be changed

- append: Appends something to a StringBuilder
  - The StringBuilder itself is returned
  - sb.append("Result: ").append(4);
- delete/deleteCharAt: Removes some number of chars from a StringBuilder
- insert: Inserts something into a StringBuilder
- length: Returns the length of a StringBuilder
- subString: Returns a portion of a StringBuilder as a String
- toString: Returns the contents of a StringBuilder as a String

*StringBuilder provides a better-performing alternative to the older StringBuffer class

The secret life of StringBuilder

The + operator is overloaded to concatenate Strings

In reality, javac compiles string concatenation into operations on a StringBuilder:

```
double temp;
System.out.println("Today's temp is " + temp);
```

Is really:

```
double temp;
StringBuilder sb = new StringBuilder();
sb.append("Today's temp is ");
sb.append(temp);
System.out.println(sb.toString());
```

So, remember that string concatenation creates a StringBuilder

- There is some overhead, so don't do it inside a tight loop
- Sometimes it is better to use a StringBuilder directly instead of concatentation

java.lang.System

Contains a number of system-level fields and methods

Static fields:

- out: A PrintStream for standard output (as in System.out.println("Hi"))
- err: A PrintStream for standard error
- in: An InputStream for standard in

Static methods:

- currentTimeMillis: Returns the current time in milliseconds since January 1, 1970
- exit: Shuts down the JVM with a given int exit code
- setOut, setErr, setIn: Reassigns the various "standard" streams

java.lang.Math

Math provides static methods for performing mathematical calculations on doubles

- abs, sqrt
- Trigonometric functions (cos, tan, asin, et. al.)
- ceil, floor
- exp, pow
- min, max
- toDegrees, toRadians
- random: Returns a random double between 0.0 and 1.0

The “wrapper” classes

Some things, such as they keys of a hash table, can only be `Objects`.

What if you wanted to key a hash table on an `int` value?

Java provides “wrapper” classes for all of the primitive types: `Boolean`, `Byte`, `Character`, `Double`, `Float`, `Integer`, `Long`, `Short`, `Void`

Each wrapper class has a method that returns the value of the primitive class represents: `intValue`, `charValue`, etc.

`java.lang.Boolean`

Class methods

- `valueOf`: Parses a `String` and returns its `boolean` value (case insensitive)

Instance methods

- `booleanValue`: Returns the `boolean` value for a `Boolean`
- `equals`: Compares this `Boolean` to another

`java.lang.Character`

Java supports the 16-bit Unicode standard for international character sets

A number of useful static methods

- `digit`: Returns the numeric (`int`) value of a `char`
- `forDigit`: Returns the `char` value for a number
- `isDigit`: Determines if a `char` is a digit
- `isLetter`: Determines if a `char` is a letter
- `isWhitespace`: Determines if a `char` is whitespace

Instance methods

- `charValue`: Returns the `char` value of a `Character`
- `compareTo`: Compares one `Character` to another

`java.lang.Number`

The numeric wrapper classes are subclasses of `Number`

Instance methods for converting between numeric types

- `byteValue`: Returns a `Number`’s value as a `byte`
- `doubleValue`
- `floatValue`
- `intValue`
- `longValue`
- `shortValue`

All of `Number`’s subclass have similar behavior

`java.lang.Integer`

Static methods:

- `parseInt`: Converts a `String` to an `int`
- `toBinaryString` Returns the binary representation of an `int` as a `String`
- `toHexString`
- `toOctalString`

Static fields:

- `MAX_VALUE`: The largest `int`
- `MIN_VALUE`: The smallest `int`

The Wide World of Exceptions

`java.lang.Throwable` is the base class for all exceptions

- `getMessage`: Returns a `String` message describing `Throwable` object
- `printStackTrace`: Prints a stack trace describing where in the code the `Throwable` was thrown
- JDK 1.4 added a `getCause` method that returns a `Throwable` that caused the other `Throwable` (chained exceptions) and a `getStackTrace` method that returns a representation of the location at which the throwable was thrown

`Throwable` has two subclasses

- `java.lang.Exception`s are the kinds of things a reasonable program may want to catch
- `java.lang.Error`s are truly not expected (e.g. running out of virtual memory), could happen at any time, and should not be caught

Big Bucket o' `java.lang` Exceptions

`Exception`s	
`ArithmeticException`	e.g. divide by zero
`ArrayIndexOutOfBoundsException`	
`ClassCastException`	Trying to cast an object to a type that it is not
`IllegalArgumentException`	
`NegativeArraySizeException`	
`NullPointerException`	Referencing an object that is `null`
`NumberFormatException`	Thrown when parsing numbers
`Error`s	
`OutOfMemoryError`	Garbage collected heap is full
`StackOverflowError`	Too much recursion

Checked versus Unchecked Exceptions

`java.lang.RuntimeException`s are often thrown by the Java Virtual Machine's runtime system

- Called "unchecked" exceptions because they do not need to be declared in a `throws` clause, nor do they have to be caught
- Examples include `ClassCastExecption` and `NullPointerException`
- Often easy to test for: "Look before you leap"

Other subclasses of `java.lang.Exception` must be explicitly thrown and caught

- These are "checked" exceptions
- Examples include `java.io.IOException`, `java.sql.SQLException`, and `java.awt.AWTException`
- Your exceptions should subclass `Exception`
- Checked exceptions make your code more explicit and easier to understand

Catching Multiple Kinds of Exceptions

A `try` block can have multiple `catch` blocks

- The type of the exception determines which `catch` block will be executed

```
try {
  openFile();

} catch (FileNotFoundException ex) {
  // prompt user for new file name

} catch (IOException ex) {
  // Print out error message and exit
}
```

Note that the `catch` statements have to be arranged according to the exception class hierarchy

```
try {
  openFile();

} catch (IOException ex) {

} catch (FileNotFoundException ex) {
  // Unreachable code.  Won't compile.
}
```

Assertions

JDK 1.4 added an assertion facility to the Java language

- `assert` $\mathit{Expression}_1$
- `assert` $\mathit{Expression}_1$ `:` $\mathit{Expression}_2$

If $\mathit{Expression}_1$ evaluates to `false`, then a `java.lang.AssertionError` is thrown

- $\mathit{Expression}_2$ is the detail message issued with the `AssertionError`

Assertions are used to verify that certain program facts are true

- For instance, after reading all of the bytes from a buffer, assert that the buffer is empty

Assertions incur some runtime expense, so they must be explicitly enabled

- Assertions are enabled via the `-ea` switch to `java`
- Code executed by the assertion must have no side effects (e.g. changing the state of an object)

Using Assertions vs. Throwing Exceptions

Assertions should be used to verify the internal logic of a method

An exception (such as `IllegalArgumentException`) should be used to verify the inputs to a (public) method

- Remember, it is reasonable for a program to catch an `Exception`, but it shouldn't catch an `Error`

Using assertions:

```
public void setPort(int port) {
  if (port <= 1024) {
    throw new IllegalArgumentException();
  }
}

private int readPort() {
  int port = ...;  // Read from config file
  assert port > 1024 : port;
}
```

Assertions and Program Logic

Assertions are most useful to verify program logic

```
private String getDayString(int day) {
  switch (day) {
    case MONDAY:
      return "Monday";
    case TUESDAY:
      return "Tuesday";
    // ...
    default:
      assert false : "Unknown day: " + day;
  }
}
```

```
if (i % 3 == 0) {
  // ...
} else if (i % 3 == 1) {
  // ...
} else {
  assert i % 3 == 2;
  // ...
}
```

Using asserts will make your code better!

Cloning Objects

`Object`'s `clone` method returns a copy of an object

The copy usually has the same state and commonly

```
x.clone().equals(x)
```

But obviously,

```
x.clone() != x
```

By default, the JVM doesn't know how to make a copy of an object

- By default, the `clone` method throws a `CloneNotSupportedException`

If a class implements the `Cloneable` interface, invoking the `clone` method will automagically return a *shallow copy* of the receiving object

- JVM allocates a new instance of the class of the receiver – no constructor is invoked
- Fields of the clone have the same values as the receiver object
- Contents of the fields are not cloned (clone will refer to the same objects as the original)

Cloning Objects

In order to get a *deep copy*, `clone` should be overridden:

```
public class Grades implements Cloneable {
  private double[] grades;

  public Object clone() {
    Grades grades2 = (Grades) super.clone();
    grades2.grades = this.grades.clone();
    return grades2;
  }
}
```

Some notes:

- Invoking `super.clone()` creates a new object
- Arrays are cloneable (because they are `Object`s)
- Even though the overriden clone doesn't declare that it throws `CloneNotSupportedException`, it still has to be caught
  - Superclass (`Object`) may throw it – can't change the contract

Covariant Returns

In J2SE 1.5 methods may have *covariant returns*

- An overriding method may modify the return type of a method to be a subclass of the overridden method's return type

From `edu/pdx/cs410J/j2se15/CovariantReturns.java`

```
static abstract class Animal implements Cloneable {
  public abstract Object clone();
}

static class Human extends Animal {
  public Human clone() {
    return new Human();
  }
}

static class Student extends Human {
  public Student clone() {
    return new Student();
  }
}
```

Covariant Returns

If you were to decompile the class files you would see

- In `Human`'s class file the declared return type of `clone` is still `Object`
  - Binary compatibility with older code
- However, a **call** to `Human.clone()` is typed as returning a `Human`

Have to be careful with using covariant returns with third-party code

- If someone else subclassed the JDK 1.4 `Human`

```
class Professor extends Human {
  public Object clone() {
    return new Professor();
  }
}
```

The code wouldn't compile because `Object` is not a subclass of `Human`

Covariant returns of internal classes

Very often, applications have “external” APIs and “internal” APIs

- External APIs are for users (interfaces and abstract classes)

```
package com.college;

public interface Classroom { ... }

public interface University {
  public Classroom[] getClassrooms();
}
```

- Internal APIs contain implementation (classes)

```
package com.college.internal;

public class ClassroomImpl implements Classroom {

public class UniveristyImpl implements University
  public ClassroomImpl[] getClassrooms() { ... }
}
```

If the internal classes return internal types, the implementation code doesn’t have to cast

The `java.io` package

The classes and interfaces in the `java.io` package provide a myriad of facilities for performing I/O operations.

- `File` class that represents a file
- Classes for `byte`-based I/O (Streams)
- Classes for text-based I/O (Readers/Writers)

`java.io.File`

`File` represents a file and can be created from a `String` specifying its location or a `File` representing the directory that a named file resides in.

- `canWrite`: Determines whether or not a `File` can be written to
- `delete`: Deletes a `File`
- `exists`: Determines if a `File` exists
- `getName`: Returns the name of a `File`
- `isDirectory`: Determine if a `File` represents a directory
- `length`: Returns the size of a `File`
- `mkdir`: Creates the directory that a `File` represents
- `getParentFile`: Returns the directory containing this `File` as a `File`

Other `File` goodies

`File` has four important `static` fields

- `separator`/`separatorChar`: The string/character that separates portions of a file spec (`/` on UNIX)
- `pathSeparator`/`pathSeparatorChar`: The string/character that separates directories in a path (`:` on UNIX)

The `java.io` package contains two interfaces, `FileFilter` and `FilenameFilter`, which have an `accept` method that accepts/rejects a `File` based on some criteria (e.g. its name).

The filters are used as arguments to `File`’s `list` and `listFiles` methods.

- `list(FilenameFilter)` returns the names of all files that are accepted by a `FilenameFilter`
- `listFiles(FileFilter)` returns all of the `File`s that are accepted by a `FileFilter`

Example using Files and filters

```
package edu.pdx.cs410J.core;
import java.io.*;  // Must be imported

public class DirectoryFilter implements FileFilter {
  public boolean accept(File file) {
    if (file.isDirectory()) {
      return true;
    } else {
      return false;
    }
  }
}
```

```
package edu.pdx.cs410J.core;
import java.io.*;

public class JavaFilenameFilter
                       implements FilenameFilter {
  public boolean accept(File dir, String fileName) {
    if (fileName.endsWith(".java")) {
      return true;
    } else {
      return false;
    }
  }
}
```

Example using Files and filters

```
package edu.pdx.cs410J.core;
import java.io.*;

public class FindJavaFiles {
  private static FileFilter      dirFilter;
  private static FilenameFilter  javaFilter;

  private static void findJavaFiles(File dir) {
    File[] javaFiles = dir.listFiles(javaFilter);
    for (int i = 0; i < javaFiles.length; i++)
      System.out.println(javaFiles[i].toString());
    File[] dirs = dir.listFiles(dirFilter);
    for(int i = 0; i < dirs.length; i++)
      findJavaFiles(dirs[i]);
  }

  public static void main(String[] args) {
    File file = new File(args[0]);
    if (file.isDirectory()) {
      dirFilter = new DirectoryFilter();
      javaFilter = new JavaFilenameFilter();
      findJavaFiles(file);
    } else {
      System.err.println(file +
                         " is not a directory");
    }
  }
}
```

Example using Files and filters

```
$ cd ~whitlock/public_html/src
$ java -cp ~/classes edu.---.FindJavaFiles .
./edu/pdx/cs410J/AbstractAirline.java
./edu/pdx/cs410J/AbstractFlight.java
./edu/pdx/cs410J/AirportNames.java
./edu/pdx/cs410J/ParserException.java
./edu/pdx/cs410J/lang/Animal.java
./edu/pdx/cs410J/lang/Ant.java
./edu/pdx/cs410J/lang/Bee.java
./edu/pdx/cs410J/lang/Bird.java
./edu/pdx/cs410J/lang/Cow.java
./edu/pdx/cs410J/lang/DivTwo.java
...
./edu/pdx/cs410J/family/TextDumper.java
./edu/pdx/cs410J/family/Parser.java
./edu/pdx/cs410J/family/TextParser.java
./edu/pdx/cs410J/family/AddPerson.java
./edu/pdx/cs410J/family/NoteMarriage.java
```

Why is the FileFilter interesting?

Instance of `DirectoryFilter` and `JavaFilenameFilter` do not have any state (fields)

- An object encapsulates **behavior**

The responsibility of filtering files is partitioned between the `File` API and your code:

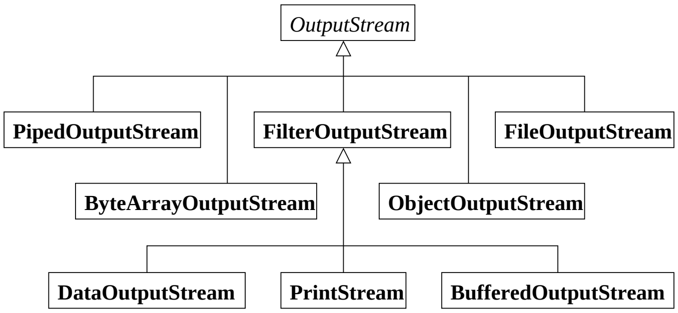
- `File` knows how to apply the filter, but doesn't know the criteria under which to filter

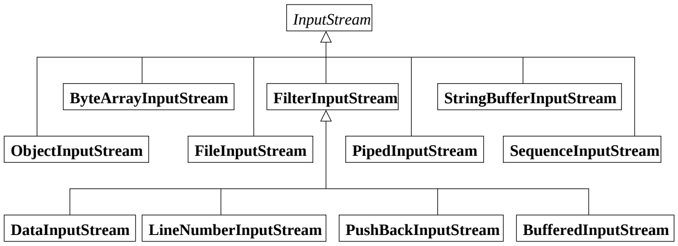
- You know what you want to filter, but `File` takes care of doing the grunt work

`File` **delegates** some of its work to the filter's `accept` method

Streams: I/O in bytes

The `java.io` package in JDK 1.0 contained two hierarchies of classes for performing `byte`-based stream I/O





`java.io.OutputStream`

An `OutputStream` is an abstract class that writes `bytes` and has the following methods:

- `write`: Writes `bytes` to the stream
- `close`: Closes the stream and releases any resources associated with it
- `flush`: Sends all pending output to the stream

Some `OutputStreams`

- `ByteArrayOutputStream`: Writes to a `byte` array
- `PipedOutputStream`: Used with a `PipedInputStream` to send data between threads
- `ObjectOutputStream`: Writes `Objects` to a stream

`java.io.FileOutputStream`

A `FileOutputStream` write `bytes` to a file

Constructed from a `File` or a file's name, may throw a `FileNotFoundException`

`java.io.FilterOutputStream`

A `FilterOutputStream` is built around another `OutputStream` and performs some processing on its bytes

- `BufferedOutputStream`: Buffers the data to be written
- `DataOutputStream`: Writes Java's primitive types in a machine-independent format
- `PrintStream`: Writes data in a human-readable format, doesn't throw exceptions
  - `System.out` and `System.err` are `PrintStreams`
  - Has `print` and `println` methods for all types
  - The `hasError` method determines if an error has occurred

An example using `OutputStreams`

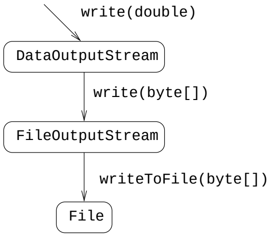
```
package edu.pdx.cs410J.core;
import java.io.*;

public class WriteDoubles {
  static PrintStream err = System.err;

  public static void main(String[] args) {
    FileOutputStream fos = null;
    try {
      fos = new FileOutputStream(args[0]);
    } catch(FileNotFoundException ex) {
      err.println("** No such file: " + args[0]);
      System.exit(1);
    }
    DataOutputStream dos = new DataOutputStream(fos);
    for(int i = 1; i < args.length; i++) {
      try {
        double d = Double.parseDouble(args[i]);
        dos.writeDouble(d);
      } catch(NumberFormatException ex) {
        err.println("** Not a double: " + args[i]);
      } catch(IOException ex) {
        err.println("** " + ex);
        System.exit(1);
      }
    }
  }
}
```

An example using `OutputStream`s

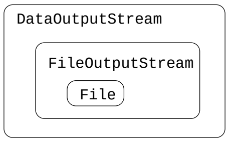
```
$ java -cp ~/classes edu.---.WriteDoubles \
  doubles.out 1.23 2.34 3.45
```

If you were to `cat doubles.out` you would see garbage because `double.out` is a binary file.

Behavior Delegation



Object Composition (the “object onion”)



`java.io.InputStream`

`InputStream`s read `byte`s and have the following methods:

- `available`: Returns the number of bytes that can be read without blocking
- `close`: Closes the stream
- `read`: Reads `byte`s into a `byte` array. Returns the number of `byte`s read, -1 if done.
- `skip`: Skips over some number of `byte`s in the stream

Some `InputStream`s:

- `ByteArrayInputStream`: `InputStream` behavior over a `byte` array
- `PipedInputStream`: Used with a `PipedOutputStream` to send data between threads
- `SequenceInputStream`: Read from multiple `InputStream`s in a given order

`java.io.FileInputStream`

`FileInputStream` is used for reading `byte`s from a file

Constructed from a `File` or a file’s name, may throw a `FileNotFoundException`

`java.io.FilterInputStream`

A `FilterInputStream` is built around another `InputStream` and processes the `byte`s that are read

- `BufferedInputStream`: Buffer the input read from another `InputStream`
- `DataInputStream`: Used to read Java’s primitive types
- `PushbackInputStream`: Allows you to push `byte`s back into the stream

An example using `InputStream`s

```
package edu.pdx.cs410J.core;
import java.io.*;
public class ReadDoubles {
  static PrintStream out = System.out;
  static PrintStream err = System.err;
  public static void main(String args[]) {
    FileInputStream fis = null;
    try {
      fis = new FileInputStream(args[0]);
    } catch(FileNotFoundException ex) {
      err.println("** No such file: " + args[0]);
    }
    DataInputStream dis = new DataInputStream(fis);
    while (true) {
      try {
        double d = dis.readDouble();
        out.print(d + " ");
        out.flush();
      } catch(EOFException ex) {
        break;         // All done reading
      } catch(IOException ex) {
        err.println("** " + ex);
        System.exit(1);
      }
    }
    out.println("");
  }
}
```

An example using `InputStream`s

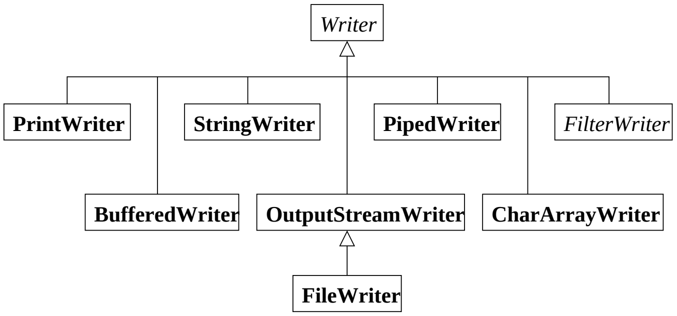
```
$ java -cp ~/classes edu.---.ReadDoubles \
  doubles.out
1.23 2.34 3.45
```

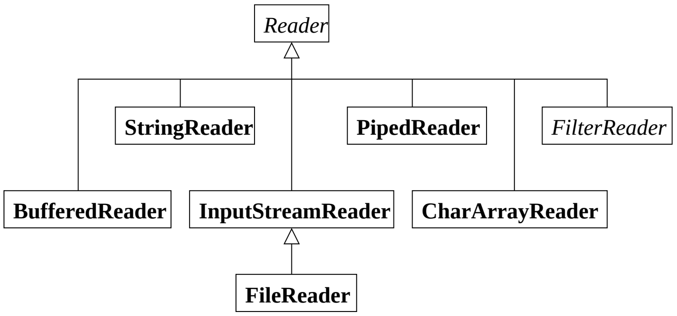
There's no nice way of telling when a `DataInputStream` is done – have to catch an `EOFException` – yuch!

Note the use of `print` and `flush`

Handling text I/O: Writers and Readers

Streams worked well for `byte` data, but working with text data was awkward. JDK 1.1 introduced writers and readers:





`java.io.Writer`

`Writer` is an abstract class and writes characters to some destination. It has methods such as

- `write`: Writes characters or strings
- `close`: Closes a `Writer`
- `flush`: Sends all pending text to the destination

Some `Writers`

- `BufferedWriter`: Buffers text before writing it to the destination
- `CharArrayWriter`: Writes text to a `char` array
- `FilterWriter`: Abstract class for writing filtered text streams
- `PipedWriter`: Used with a `PipedReader` to send text between threads
- `OutputStreamWriter`: Converts `char`s to `byte`s and sends them to an `OutputStream`

`java.io.PrintWriter`

A `PrintWriter` prints formatted text to another `Writer` or an `OutputStream`

Like a `PrintStream` in that it has `print` and `println` methods, but flushing is not automatic

`java.io.StringWriter`

`StringWriter` is a `Writer` that writes to a `String`

- `getBuffer`: Returns the `StringBuilder` written to
- `toString`: Returns the `String` being written to

`java.io.FileWriter`

A `FileWriter` writes text to a file

The file is specified by a `File` object or the file's name

Example using `Writer`s

```
package edu.pdx.cs410J.core;
import java.io.*;

public class WriteToFile {
  private static PrintWriter err;

  public static void main(String[] args) {
    // Wrap a PrintWriter around System.err
    err = new PrintWriter(System.err, true);

    try {
      Writer writer = new FileWriter(args[0]);

      // Write command line arguments to the file
      for(int i = 1; i < args.length; i++) {
        writer.write(args[i]);
        writer.write('\n');
      }

      // All done
      writer.flush();
      writer.close();

    } catch(IOException ex) {
      err.println("** " + ex);
    }
  }
}
```

Example using `Writer`s

```
$ java -cp ~/classes edu.---.WriteToFile \
  text.out This is some text
$ cat text.out
This
is
some
text
```

Note how we “wrapped” a `PrintWriter` around a `PrintStream`

This abstraction helps simplify programming by hiding what’s really going on

You don’t know what you’re writing to and, more importantly, you don’t care!

`java.io.Reader`

`Reader` is an abstract class for reading character data from a source

- `read`: Reads `char`s
- `ready`: Determines if a `Reader` has more text to read
- `close`: Closes a `Reader`
- `skip`: Skips some number of characters

Some `Reader`s

- `CharArrayReader`: Reads from a `char` array
- `FilteredReader`: Abstract class for reading filtered character streams
- `PipedReader`: Used with a `PipedWriter` to send text between threads
- `StringReader`: Reads from a `String`
- `InputStreamReader`: Reads from an `InputStream`
- `BufferedReader`: Buffers the text it reads
  - Has a `readLine` method

Example using `Reader`s

```
package edu.pdx.cs410J.core;
import java.io.*;

public class ReadFromConsole {
  public static void main(String[] args) {
    InputStreamReader isr =
      new InputStreamReader(System.in);
    BufferedReader br = new BufferedReader(isr);
    StringWriter text = new StringWriter();

    while (true) {
      try {
        // Read a line from the console
        String line = br.readLine();

        if (line.equals("-1")) {
          break;
        } else {
          text.write(line + " ");
        }
      } catch(IOException ex) {
        System.err.println("** " + ex);
        System.exit(1);
      }
    }
    System.out.println(text);
  }
}
```

Example using `Reader`s

```
$ java -cp ~/classes edu.---.ReadFromConsole
Does
this
program
work?
-1
Does this program work?
```

Closing Streams

To free up system resources, streams (and readers/writers) should be closed by invoking their `close` method, often in a `finally` block

- It's easy to forget to call close
- And `close` may throw an `IOException`

```
public void printTextFile(File file)
  throws IOException {

  BufferedReader br =
    new BufferedReader(new FileReader(file));
  try {
    while (br.ready()) {
      System.out.println(br.readLine());
    }

  } catch (IOException ex) {
    System.err.println(ex);
    throw ex;

  } finally {
    if (br != null) {
      br.close();
    }
  }
}
```

Automatically Closing Streams

In Java 7, a new "try with resources" language feature was added: A `try` statement can declare instances of `java.lang.AutoCloseable` that are automatically closed when the `try` block is exited

- The `java.io.Closeable` interface that is implemented by most I/O classes subclasses `AutoCloseable`

```
public void printTextFile(File file)
  throws IOException {

  try (BufferedReader br =
         new BufferedReader(new FileReader(file))) {
    while (br.ready()) {
      System.out.println(br.readLine());
    }

  } catch (IOException ex) {
    System.err.println(ex);
  }
}
```

Now you don't need to remember to `close` the reader

The utility classes

The `java.util` package contains a number of useful and handy classes

- `StringTokenizer`, `Vector`, `Hashtable`, `Stack`
- The collection classes
- `Date`, `Calendar`, `Locale`
- System properties

`java.util.StringTokenizer`

A `StringTokenizer` is used to parse a `String`[*]

The constructor takes the `String` to be parsed and a `String` whose characters delimit tokens (by default whitespace delimits tokens)

- `countTokens`: Returns the number of tokens remaining
- `nextToken`: Returns the next token in the `String`
- `hasMoreTokens`: Are there more tokens to be returned?

[*] JDK 1.4 added a regular expression package to Java (`java.util.regex`) that provides Perl-like regex

`StringTokenizer` example

```
package edu.pdx.cs410J.core;

import java.util.*;

public class ParseString {
  /**
   * The second <code>String</code> from the
   * command line contains the parsing delimiters.
   */
  public static void main(String[] args) {
    String string = args[0];
    String delimit = args[1];
    StringTokenizer st;
    st = new StringTokenizer(string, delimit);

    while (st.hasMoreTokens()) {
      String token = st.nextToken();
      System.out.println("Token: " + token);
    }
  }
}
```

```
$ java -cp ~/classes edu.---.ParseString \
   This,is,a:sentence. ,:
Token: This
Token: is
Token: a
Token: sentence.
```

The Original Collection Classes

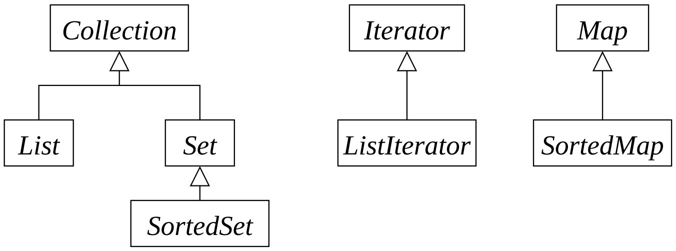
The first Java release contained several classes for collecting objects together:

- `Vector`: A growable, ordered collection of objects
- `Stack`: A `Vector` with push/pop
- `Hashtable`: Maps objects to objects

While these classes were very useful, they tended to be bulky and slow.

Collection Classes

First of all, a hierarchy of interfaces in `java.util`



`java.util.Collection` groups objects together

- `add`: Adds an `Object` to a `Collection`
- `contains`: Determines if a `Collection` contains an `Object`
- `isEmpty`: Determines if a `Collection` is empty
- `iterator`: Returns an `Iterator` over a `Collection`
- `remove`: Removes an `Object` from a `Collection`
- `size`: Returns the number of elements in a `Collection`

`java.util.List`

The elements of a `List` are 0-indexed

- `add`: Adds an `Object` at a given index
- `get`: Returns the `Object` at a given index
- `set`: Sets the `Object` at a given index
- `listIterator` Returns a `ListIterator` over a `List`

`java.util.Set`

`Set`s are unordered and each element in a `Set` is unique

The `equals` method is used to determine the equality of two `Object`s

`java.util.SortedSet`

A `Set` whose elements are ordered

Has methods like `first` and `last`

`java.util.Iterator`

An `Iterator` is used to iterate over the `Object`s in a collection

- `hasNext`: Determines if there are any more elements to be iterated over
- `next`: Returns the next element to be examined
- `remove`: Removes the element returned by `next` from the underlying collection (not always implemented)

`java.util.ListIterator`

`ListIterator`s can iterate in both directions

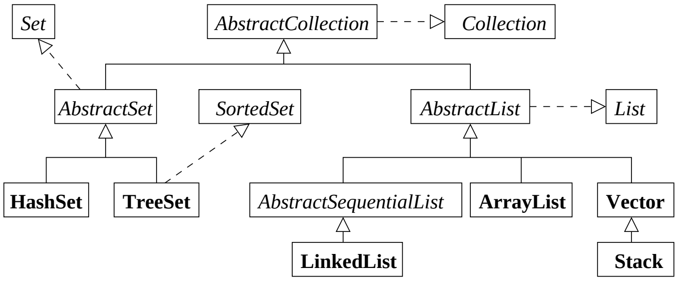
- `add`: Inserts an `Object` into the underlying list
- `hasPrevious`: Determines whether or not there is a previous element in the list
- `previous`: Returns the previous element in the underlying list
- `nextIndex`/`previousIndex`: Returns the index of the element that would be returned by `next`/`previous`

`java.util.Map`

A `Map` maps *key* objects to *value* objects

- `put`: Creates a mapping from one `Object` to another in a `Map`
  - Invokes the key's `hashCode` method
- `get`: Returns the value `Object` associated with a given key `Object`
- `containsKey`: Determines if an `Object` is a key in the mapping
- `containsValue`: Determines if an `Object` is a value in the mapping
- `keySet`: Returns the keys in a `Map` as a `Set`
- `values`: Returns the values in a `Map` as a `Collection`
- `entrySet`: Returns the mappings in a `Map` as a `Set`

Abstract collection classes



To ease the implementation of collection classes, several abstract base classes are provided:

- `java.util.AbstractCollection`
- `java.util.AbstractList`: Backed by a random access data structure (e.g. array)
- `java.util.AbstractSequentialList`: Backed by a sequential access data structure (e.g. linked list)
- `java.util.AbstractMap`
- `java.util.AbstractSet`

Concrete implementations of collections

In the `java.util` package: `List`s

- `ArrayList`: `List` backed by an array
- `LinkedList`: `List` back by a linked list, provides stack-like behavior
- `Vector`: Implements the `List` interface

`Map`s

- `HashMap`: Constant-time `get` and `put`
- `TreeMap`: Sorted keys gives $\log(n)$ `get` and `put`
- `IdentityHashMap`: Key comparison based on identity (==) instead of `equals` method
- `LinkedHashMap`: Keeps track of insertion order of mappings

`Set`s

- `HashSet`: `Set` backed by a hash table
- `TreeSet`: `SortedSet` backed by a red-black tree

Example using collections

```
package edu.pdx.cs410J.core;
import java.util.*;      // Must be imported!

public class Collections {

  /** Prints the contents of a Collection */
  private static void print(Collection c) {
    Iterator iter = c.iterator();
    while (iter.hasNext()) {
      Object o = iter.next();
      System.out.println(o);
    }
  }

  public static void main(String[] args) {
    Collection c = new ArrayList();
    c.add("One");
    c.add("Two");
    c.add("Three");
    print(c);
    System.out.println("");

    Set set = new HashSet(c);
    set.add("Four");
    set.add("Two");
    print(set);
  }
}
```

Working with our example

```
$ java -cp ~/classes edu.---.Collections
One
Two
Three

One
Three
Four
Two
```

Note order of `ArrayList` and that a `HashSet` contains unique values

Abstraction is key: “Program to the interface”

Storing primitives in collection

Collections take `Object`s, but `int`s, `double`s,`boolean`s, etc. are not `Object`s

Use the wrapper classes to create `Object`s that represent the primitives:

```
package edu.pdx.cs410J.core;
import java.util.*;

public class WrapperObjects {
  public static void main(String[] args) {
    Collection c = new ArrayList();
    c.add(new Integer(4));
    c.add(new Double(5.3));
    c.add(new Boolean(false));

    System.out.println(c);
  }
}
```

Autoboxing of primitive types

J2SE 1.5 provides automatic conversion of primitives to wrapper objects in a procedure called “autoboxing”

- Autoboxing is applied to variable and field assignments, the arguments to method calls, and casting

```
package edu.pdx.cs410J.j2se15;
import java.util.*;

public class Autoboxing {
  public static void main(String[] args) {
    // Note that Integer.valueOf returns an Integer
    int i = Integer.valueOf("123");

    List list = new ArrayList();
    list.add(i);
    int j = (Integer) list.get(0);
  }
}
```

Strongly typing collections

Originally, collections could only contain `Object`s

“Generic types” introduced in Java 5 allow you to specify the type of objects that a collection may contain

- `List<String>` is pronounced “a list of strings”
- `List<Long> longs = new ArrayList<Long>();`
- Attempting to a non-`Long` to `longs` will caused a compilation error:
  - `longs.add("This will not compile")`

Generics add some complexity to the type system

Even though a `String` is an `Object`, an `ArrayList<String>` is **not** a `List<Object>`

Otherwise, you could do this:

```
List<String> ls = new ArrayList<String>();
List<Object> lo = ls;
lo.add(new Integer(42));  // Bad!
```

Because the compiler cannot determine that `lo` may actually only contain `String`s, the language disallows the assignment.

Generics added some complexity to the language

Being forced to include all of the generic types in a variable declaration made for hard-to-read code:

```
List<Map<String, String>> data =
  new ArrayList<Map<String, String>>();
```

Java 7 introduced the generics “diamond” that infers the generic types on the left side of the assignment:

```
List<Map<String, String>> data = new ArrayList<>();
```

Iterating over collections

What happens when a collection is modified while it is being iterated over?

```
package edu.pdx.cs410J.core;
import java.util.*;

public class ModifyWhileIterating {
  public static void main(String[] args) {
    List<String> list = new ArrayList<String>();
    list.add("one"); list.add("two");

    Iterator<String> iter = list.iterator();
    while (iter.hasNext()) {
      String s = iter.next();
      if (s.equals("one")) {
        list.add(0, "start");
      }
    }
  }
}
```

```
$ java -cp ~/classes edu.---.ModifyWhileIterating
Exception in thread "main"
  java.util.ConcurrentModificationException
```

Iterating over collections

Most `Iterators` are *fail-fast*

- If the underlying collection is modified (e.g. it size changes), then subsequent calls to `next` will result in a `ConcurrentModificationException`
- To safely modify an underlying collection, use `Iterator`'s `remove` method

Fail-fast iterators have the benefit of immediately detecting when they are out-of-date

- Iterator fails quickly instead of allowing potential non-deterministic (or simply incorrect) behavior

However, you should not rely on a `ConcurrentModificationException` always being thrown:

- Replacing an item in a `List` (using `put`) may not cause the iterator to fail
- Fail-fast behavior should only be used to detect bugs

Iterators and the enhanced `for` loop

The enhanced `for` loop syntax can be used with `Collections`* as well as arrays

```
Collection coll = ...
for (Object o : coll) {
  System.out.println(o);
}
```

See `edu.pdx.cs410J.j2se15.EnhancedForLoop`

This syntax is compact, but you cannot reference the `Iterator` object

- Can't `remove` an element from the `Collection` while you're iterating over it

*Actually, any object that implements the `java.lang.Iterable` interface

Example working with `Map`s

```
package edu.pdx.cs410J.core;

import edu.pdx.cs410J.lang.*;
import java.util.*;

public class Farm {
  /** Prints the contents of a Map. */
  private static void print(Map<String, Animal> map)
    for (String key : map.keySet()) {
      Animal value = map.get(key);
      String s = key + " -> " + value;
      System.out.println(s);
    }
  }

  public static void main(String[] args) {
    Map<String, Animal> farm = new HashMap<>();
    farm.put("Old MacDonald",
             new Human("Old MacDonald"));
    farm.put("Bossie", new Cow("Bossie"));
    farm.put("Clyde", new Sheep("Clyde"));
    farm.put("Louise", new Duck("Louise"));

    print(farm);
  } }
```

Working with our `Map` example

```
$ java -cp ~/classes edu.---.Farm
Clyde -> Clyde says Baa
Bossie -> Bossie says Moo
Old MacDonald -> Old MacDonald says Hello
Louise -> Louise says Quack
```

Note that the order in which the elements were added to the `HashMap` has nothing to do with the order in which the `Iterator` visits them

Note also:

- `Maps` use the key object's `hashCode` method to determine the bucket in which to search
- Each element in the bucket's collision chain is compared to the key object using its `equals` method

So, if instances of your own classes are to be used as keys in a `Map`

- You should override `equals` and `hashCode`
- Note that two objects that are equal must have the same hash code

Comparing Objects

Objects that implement the `java.lang.Comparable` interface are said to have a *natural ordering*

- Instances of `String`, `Integer`, `Double`, etc. are all `Comparable`
- `Comparable`'s `compareTo` method compares the receiver (x) object to another object (y)
  - if $x < y$, a negative `int` should be returned
  - if $x == y$, zero should be returned*
  - if $x > y$, a positive `int` should be returned
- `Comparable` has a generic type that specifies the class of object it can compare itself to
  - Often you compare an object to another object of its same type

Unless instructed otherwise, classes and methods that sort objects (such as `SortedSets`) will respect their natural ordering

*Should have the same semantics as the `equals` method

An example of Natural Ordering

Instances of `Cereal` are naturally sorted alphabetically by their name

```
package edu.pdx.cs410J.core;
import java.util.*;

public class Cereal implements Comparable<Cereal> {
  private String name;
  private double price;

  // <snip>

  public int compareTo(Cereal c2) {
    return this.getName().compareTo(c2.getName());
  }

  public boolean equals(Object o) {
    if (o instanceof Cereal) {
      Cereal other = (Cereal) o;
      return this.getName().equals(other.getName());
    }
    return false;
  }

  public int hashCode() {
    return this.getName().hashCode();
  }
```

An example of Natural Ordering

```
  public static void main(String[] args) {
    SortedSet<Cereal> set = new TreeSet<Cereal>();
    set.add(new Cereal("Total", 3.56));
    set.add(new Cereal("Raisin Bran", 2.65));
    set.add(new Cereal("Sugar Crisps", 2.38));

    for (Cereal c : set) {
      System.out.println(c);
    }
  }
}
```

Running the example...

```
$ java -cp ~/PSU/src/classes edu.---.Cereal
Raisin Bran $2.65
Sugar Crisps $2.38
Total $3.56
```

Natural ordering allows the author of the class to specify how instances of that class are compared

Custom Sorted Collections

The `java.util.Comparator` interface is used to sort objects by criteria other than their natural ordering

- A `Comparator` specifies a *total ordering* over a set of objects
- A `Comparator`'s `compare` method compares two objects and returns an `int` with the same meaning as `Comparable`'s `compareTo` method
- A `Comparator` may or may not choose to respect the `equals` method of the objects that it is comparing
- `Comparator` has a generic type that specifies the type of object that is compared

`Comparator`s can be used to create `TreeSet`s and `TreeMap`s

An example `Comparator`

Compares boxes of `Cereal` based on their price

```
package edu.pdx.cs410J.core;

import java.util.*;

public class CerealComparator
               implements Comparator<Cereal> {
  public int compare(Cereal o1, Cereal o2) {
    double price1 = o1.getPrice();
    double price2 = o2.getPrice();

    if (price1 > price2) {
      return 1;
    } else if (price1 < price2) {
      return -1;
    } else {
      return 0;
    }
  }

  // Continued..
```

An example `Comparator`

```
  public static void main(String[] args) {
    Set<Cereal> set =
      new TreeSet<Cereal>(new CerealComparator());
    set.add(new Cereal("Cap'n Crunch", 2.59));
    set.add(new Cereal("Trix", 3.29));
    set.add(new Cereal("Count Chocula", 2.59));
    set.add(new Cereal("Froot Loops", 2.45));

    // Print out the cereals
    for (Cereal c : set) {
      System.out.println(c);
    }
  }
}
```

```
$ java -cp ~/classes edu.---.CerealComparator
Froot Loops $2.45
Cap'n Crunch $2.59
Trix $3.29
```

Why wasn't Count Chocula printed out?

Helpful collection functions

The `java.util.Collections` class* contains helpful `static` methods for working with collections

- `max(Collection)` returns the largest element in a collection (uses natural ordering)
- `nCopies(int, Object)` returns a `List` contains `n` copies of a given object
- `singleton(Object)` returns an immutable `Set` that contains only the given object
- `sort(List, Comparator)` sorts a list using the given comparator
- `unmodifiableMap(Map)` returns a `Map` that cannot be modified that has the same contents as the input `Map`
  - Attempts to modify the `Map` throw an `UnsupportedOperationException`

*This class cannot be instantiated.

Helpful collection functions

The `java.util.Arrays` class contains `static` methods for working with arrays

- `asList(Object[])` returns a `List` that is backed by a given array
  - Changes to the list will "write through" to the backing array
- `binarySearch(int[], int)` returns the array index at which the given `int` occurs
- `equals(int[], int[])` returns whether or not two arrays have the same contents
- `fill(int[], int)` populates each element of an array with the given value
- `sort(int[])` sorts an array in-place

Each of these methods is overloaded to operate on the different kinds of arrays (`double[]`, `Object[]`, etc.)

Type-safe enumerations

J2SE 1.5 provides an `enum` facility* that is like a class, but has a set of pre-defined instances ("constants")

- The `enum` is similar to a class in that it has its own namespace (can be referenced via an `import static`)
- Unlike `static final` fields, the values of references are not compiled into the class
  - Can change `enum` values without having to recompile all of your code
- Have useful `toString`, `equals`, and `hashCode` methods (can be used with `Collections`)
- `enums` can implement interfaces, are `Serializable` and `Comparable`, and can be used in a `switch` statement
- Compile-time type safety (constants are no longer just `ints`)

*Based on Item 21 from Joshua Bloch's *Effective Java* book

An example of a type-safe enumeration

```
package edu.pdx.cs410J.j2se15;
import java.util.*;

public class EnumeratedTypes {
  private enum Day { SUNDAY, MONDAY, TUESDAY,
       WEDNESDAY, THURSDAY, FRIDAY, SATURDAY }

  private static String enEspanol(Day day) {
    switch (day) {
    case SUNDAY:
      return "Domingo";
    case MONDAY:
      return "Lunes";
    case TUESDAY:
      return "Martes";
    case WEDNESDAY:
      return "Miercoles";
    case THURSDAY:
      return "Jueves";
    case FRIDAY:
      return "Viernes";
    case SATURDAY:
      return "Sabado";
    default:
      String s = "Unknown day: " + day;
      throw new IllegalArgumentException(s);
    }
  }
```

Type-safe enumerations

```
  public static void main(String[] args) {
    SortedSet<Day> set = new TreeSet<Day>();
    set.add(Day.WEDNESDAY);
    set.add(Day.MONDAY);
    set.add(Day.FRIDAY);

    System.out.print("Sorted days: ");
    for (Day day : set) {
      System.out.print(day + " ");
    }

    System.out.print("\nEn espanol: ");
    for (Day day : set) {
      System.out.print(enEspanol(day) + " ");
    }
    System.out.println("");
  }

$ java -cp ~/classes edu.---.EnumeratedTypes
Sorted days: MONDAY WEDNESDAY FRIDAY
En espanol: Lunes Miercoles Viernes
```

Type-safe enumerations implementation

enums are compiled into Java inner classes

- All enums extend the java.lang.Enum class that provides methods like equals, hashCode, and ordinal
- The only non-final method of Enum is toString – the rest is taken care of for you

The compiler adds two interesting static methods to the enum class:

- values returns an array of each enumeration instance

  ```
  for (Coin coin : Coin.values()) {
    System.out.println(coin);
  }
  ```

- valueOf return the enumerated instance with the given name

  ```
  Coin dime = Coin.valueOf("DIME");
  ```

Type-safe enumeration with added behavior

You can also attach additional behavior to enumerated types:

```
package edu.pdx.cs410J.j2se15;

public class NumericOperators {
  private abstract enum Operation {
    PLUS {
      double eval(double x, double y) {
        return x + y;
      }
      char getSymbol() { return ’+’; }
    };

    MINUS {
      double eval(double x, double y) {
        return x - y;
      }
      char getSymbol() { return ’-’; }
    };

    // Method declarations follow enumerations
    abstract double eval(double x, double y);
    abstract char getSymbol();
  }
```

Type-safe enumeration with added behavior

```
  public static void main(String[] args) {
    Operation[] ops = { Operation.PLUS,
        Operation.MINUS, Operation.TIMES,
        Operation.DIVIDE };
    for (Operation op : ops) {
      System.out.println("5 " + op.getSymbol() +
                         " 2 = " + op.eval(5, 2));
    }
  }
}

$ java -cp ~/classes edu.---.NumericOperators
5 + 2 = 7.0
5 - 2 = 3.0
5 * 2 = 10.0
5 / 2 = 2.5
```

java.util.Properties

Properties instances map Strings to Strings and are usually used to store configuration information about the JVM or an application.

- setProperty: Set a named property to a given value
- getProperty: Returns the value of a property with a given name
- list: Prints the contents of the Properties to a PrintStream
- load: Loads properties from some source (e.g. a file)
- store: Stores properties in a format suitable for use with load

Properties implements the Map interface

- Note that put will not complain if you add a non-String property

The JVM system properties

The JVM maintains a `Properties` object that contains various JVM settings known as *system properties*

System properties may be set with the `-D` option to `java`

Accessing the JVM's system properties:

- `System.getProperties`: Returns the system's `Properties` instance
- `System.getProperty`: Returns the value of a given named system property

Wrapper classes have static "`get`" methods that decode system properties as a given primitive type

- `Integer.getInteger`, `Boolean.getBoolean`

Example using system properties

```
package edu.pdx.cs410J.core;

import java.util.*;

public class SystemProperties {
  /**
   * Print out the system properties and check
   * to see if the "edu.pdx.cs410J.Debug"
   * property has been set on the command line.
   */
  public static void main(String[] args) {
    // Print out some properties
    Properties props = System.getProperties();
    props.list(System.out);

    // Is the "edu.pdx.cs410J.Debug" property set?
    String name = "edu.pdx.cs410J.Debug";
    boolean debug = Boolean.getBoolean(name);
    System.out.print("\nAre we debugging? ");
    System.out.println((debug ? "Yes." : "No."));
  }
}
```

Example using system properties

```
$ java -Dedu.pdx.cs410J.Debug=true -cp ~/classes \
  edu.pdx.cs410J.core.SystemProperties
-- listing properties --
java.vm.version=1.5.0-b64
java.vm.vendor=Sun Microsystems Inc.
path.separator=:
java.vm.name=Java HotSpot(TM) Client VM
user.dir=/u/whitlock/public_html/src
java.runtime.version=1.5.0-b64
os.arch=sparc
java.io.tmpdir=/var/tmp/
line.separator=

os.name=SunOS
java.class.version=49.0
os.version=5.9
user.home=/u/whitlock
edu.pdx.cs410J.Debug=true             <--
java.specification.version=1.5
user.name=whitlock
java.class.path=/u/whitlock/jars/examples.jar
java.home=/pkgs/jdk1.5/jre
user.language=en
file.separator=/

Are we debugging? Yes.
```

`java.util.Date`

The `Date` class represents a date and a time as the number of milliseconds since midnight on January 1, 1970.

- `after` Determines if a `Date` occurs after another
- `before`
- `getTime` Returns the aforementioned number of milliseconds

A `Date` instantiated with the zero-argument constructor represents the current date/time.

Support for internationalization and multiple day/time formats complicates Java's day/time facility.

- `java.util.Calendar`
- `java.text.DateFormat`

See `edu.pdx.cs410J.core.AroundTheWorld`

java.util.Calendar

A Calendar is used to get information (e.g. the day of the week) about a Date.

Calendar has a number of static int fields

- Info about days: DAY_OF_MONTH, DAY_OF_YEAR, YEAR
- Info about time: HOUR, MINUTE, SECOND

Calendar instance methods:

- setTime: Sets the Date for a Calendar
- add: Adds to one of a date's fields (e.g. MONTH)
- get: Returns the value of a date's field

All of Calendar's constructors are protected. How do we get a Calendar to work with?

Calendar's static getInstance method returns a Calendar instance.

An example using Date and Calendar

```
package edu.pdx.cs410J.core;

import java.util.*;

public class Today {
  public static void main(String[] args) {
    Date today = new Date();
    Calendar cal = Calendar.getInstance();
    cal.setTime(today);

    int dayOfWeek = cal.get(Calendar.DAY_OF_WEEK);
    int dayOfYear = cal.get(Calendar.DAY_OF_YEAR);
    int weekOfMonth =
      cal.get(Calendar.WEEK_OF_MONTH);

    StringBuilder sb = new StringBuilder();
    sb.append("Today is " + today + "\n");
    sb.append("It's been " + today.getTime() +
              "ms since the epoch.");
    sb.append("\nIt is the " + dayOfWeek +
              "th day of the week \nand the " +
              dayOfYear + "th day of the year.  ");
    sb.append("\nWe are in the " + weekOfMonth +
              "th week of the month.");

    System.out.println(sb.toString());
  }
}
```

Working with our Date and Calendar example

```
$ java -cp ~/classes edu.---.Today
Today is Thu Jul 28 15:31:11 PDT 2005
It's been 1122589871595ms since the epoch.
It is the 5th day of the week
and the 209th day of the year.
We are in the 5th week of the month.
```

The fact that the representation of a date (Date) is separate from how it is accessed (via a Calendar) makes Java's time facility more modular.

Different Calendars can treat time differently

- Gregorian calendar
- Hebrew calendar
- Chinese calendar

java.text.DateFormat

The DateFormat class is used to format Dates into Strings (format) and convert Strings into Dates (parse).

- DateFormat.SHORT: 6/17/94 9:37 PM
- DateFormat.MEDIUM: Jun 17, 1994 9:37:45 PM
- DateFormat.LONG: June 17, 1994 9:37:45 PM PDT
- DateFormat.FULL: Friday, June 17, 1994 9:37:45 PM PDT

Like Calendar, you use static methods to get an instance of DateFormat

- getTimeInstance: Returns a DateFormat for formatting/parsing a time (9:37 PM)
- getDateInstance: Returns a DateFormat for formatting/parsing a date (6/17/94)
- getDateTimeInstance: Returns a DateFormat for formatting/parsing both a date and time (6/17/94 9:37 PM)
- setLenient: Sets how strict parsing should be

Working with DateFormat

```
package edu.pdx.cs410J.core;

import java.text.*;
import java.util.*;

public class FormattedDate {
  public static void main(String[] args) {
    // Glue args together into one String
    StringBuilder sb = new StringBuilder();
    for(int i = 0; i < args.length; i++) {
      sb.append(args[i] + " ");
    }

    Date date = null;
    int f = DateFormat.MEDIUM;

    DateFormat df =
      DateFormat.getDateTimeInstance(f, f);

    try {
      date = df.parse(sb.toString().trim());

    } catch(ParseException ex) {
      System.err.println("** Bad date: " + sb);
      System.exit(1);
    }

    // Continued...
```

Working with DateFormat

```
    f = DateFormat.SHORT;
    df = DateFormat.getDateTimeInstance(f, f);
    System.out.println("SHORT: " + df.format(date));

    f = DateFormat.MEDIUM;
    df = DateFormat.getDateTimeInstance(f, f);
    System.out.println("MEDIUM: " + df.format(date));

    f = DateFormat.LONG;
    df = DateFormat.getDateTimeInstance(f, f);
    System.out.println("LONG: " + df.format(date));

    f = DateFormat.FULL;
    df = DateFormat.getDateTimeInstance(f, f);
    System.out.println("FULL: " + df.format(date));
  }
}
```

```
$ java -cp ~/classes edu.---.FormattedDate \
  Jun 17, 1994 9:37:45 PM
SHORT: 6/17/94 9:37 PM
MEDIUM: Jun 17, 1994 9:37:45 PM
LONG: June 17, 1994 9:37:45 PM PDT
FULL: Friday, June 17, 1994 9:37:45 PM PDT
```

A more flexible format: SimpleDateFormat

java.text.SimpleDateFormat lets you specify a String that specifies the format of the date to parse/format

Symbol	Meaning	Presentation
G	era	Text
y	year	Number
M	month in year	Text & Number
d	day in month	Number
h	hour in am/pm (1-12)	Number
H	hour in day (0-23)	Number
m	minute in hour	Number
s	second in minute	Number
S	millisecond	Number
E	day in week	Text
D	day in year	Number
F	day of week in month	Number
w	week in year	Number
W	week in month	Number
a	am/pm marker	Text
k	hour in day (1-24)	Number
K	hour in am/pm (0-11)	Number
z	time zone	Text
’	escape for text	Delimiter
’’	single quote	Literal

Using SimpleDateFormat

```
package edu.pdx.cs410J.core;

import java.text.*;
import java.util.*;

public class SimpleDate {
  public static void main(String[] args) {
    DateFormat df = new SimpleDateFormat(args[0]);
    Date now = new Date();
    System.out.println(df.format(now));
  }
}
```

Alphabetical characters must be escaped:

```
$ java edu.---.SimpleDate "E M d, y G ’at’ h:mm a z"
Sun 4 29, 01 AD at 3:59 PM PDT
```

The more times a symbol occurs in the format string, the more verbose the format:

```
$ java edu.---.SimpleDate \
  "EEEE MMM d, yyyy G ’at’ h:mm a zzzz"
Sunday Apr 29, 2001 AD at 3:59 PM Pacific Daylight Ti
```

Many kinds of DateFormats

Again we've seen how the presentation of a date (`DateFormat`) is separated from the date itself (`Date`).

This mechanism allows us to display dates in a variety of ways.

The `java.util.Locale` class represents a certain language/country combination.

There is a `DateFormat` for each `Locale` that parses and formats dates according to the local convention.

For instance, in the `FRANCE` locale, a date is printed as:

```
samedi 30 septembre 2000 17 h 01 GMT-07:00
```

Variable-length argument lists

J2SE 1.5 introduced language syntax for specifying a variable number of arguments ("varargs") to a method (think `printf` in C)

- Prior to this feature, methods had to be overloaded to take one, two, three, etc. arguments, or you had to pass in an array
- Now there is a special keyword `...` that indicates that there are multiple arguments
- The vararg is treated like an array in the method body
  - Varargs have a `length` and are zero-indexed
- A method can only have one variable-length argument list
  - Only the last argument to a method can have variable length
- The argument to `Arrays.asList` has variable arguments

  ```
  List l = Arrays.asList("One", "Two", "Three");
  ```

Variable-length argument lists

An example of a variable-length argument list:

```
package edu.pdx.cs410J.j2se15;

public class VarArgs {

  private static void printSum(String header,
                               int... ints) {
    int sum = 0;
    for (int i : ints) {
      sum += i;
    }
    System.out.print(header);
    System.out.println(sum);
  }

  public static void main(String[] args) {
    printSum("1+2+3 = ", 1, 2, 3);
    printSum("1+2+3+4+5 = ", 1, 2, 3, 4, 5);
    printSum("2+4+6+8 = ", 2, 4, 6, 8);
  }
}
```

J2SE 1.5 text formatting

One of the deficiencies of Java's text formatting capabilities was that you had to invoke `print` (or `StringBuilder.append`) multiple times, or you had to create an `Object` array to pass to a `java.text.MesageFormat`'s `format` method

Variable-length argument lists allow the Java API to provide C-style `printf` and `scanf` behavior

- A `printf` method has been added to `java.io.PrintStream`
- Most of the formatting work is done by the `java.util.Formatter` class
- `Formatter` supports formatting the primitive types (`int`, etc.), `String`s, `Calendar`s, etc.
- A new method `String.format()` offers the functionality of `sprintf` (formatting to a `String`)
- The format is a superset of what is offered in C, but attempts to convert incompatible types (a `Calendar` to an `int`) will result in an exception being thrown

Format string syntax

The general form of the format string is:

```
%[argument$][flags][width][.precision]conversion
```

- The `argument` is the index of the argument in the varargs list
- `flags` are characters that modify the output format
- `width` is the minimum number of characters that should be written for the argument
- `precision` usually restricts the number of characters that should be written (dates and times do not have a precision)
- `conversion` is a character that indicates how the argument should be formatted

Format string syntax

This table summarizes the various conversion characters

`b`	"boolean" `true` or `false`
`h`	"hashcode (`arg.hashCode()` in hexadecimal)
`s`	"string" `toString` is invoked
`c`	"character"
`d`	"decimal integer"
`o`	"octal"
`x`	"hexadecimal"
`e`	"floating point" (in scientific notation)
`f`	"floating point"
`g`	"floating point" (scientific for large exponents)
`a`	"floating point" (significant and exponent)
`t`	"time" (data and time)
`%`	literal percent
`n`	"newline" (platform-specific line separator)

Formatting times

The `t` conversion character can be followed by one of the following (like POSIX `strftime`):

`H`	"Hour of day" (00 - 23)
`I`	"12-hour hour" (01 - 12)
`k`	"24-hour hour" (0 - 23)
`l`	"12-hour hour" (1 - 12)
`M`	"minute" (00 - 59)
`S`	"second" (00 - 60)
`L`	"millisecond" (000 - 999)
`N`	"nanosecond" (000000000 - 999999999)
`p`	am/pm
`T`	AM/PM
`z`	RFC 822 time zone offset (e.g. -0800)
`Z`	String time zone (PDT)
`s`	Seconds since epoch
`E`	Milliseconds since epoch

Formatting dates

The `t` conversion character can be followed by one of the following (like POSIX `strftime`):

`B`	"full month" (e.g. January)
`b`	"short month" (e.g. Jan)
`A`	"full day of week" (e.g. Sunday)
`a`	"short day of week" (e.g. Sun)
`Y`	"four-digit year"
`y`	"two-digit year"
`j`	"day of year"
`m`	"two-digit month"
`d`	"two-digit day of month"
`e`	"day of month" (one or two digits)

The following flags can be applied to format strings:

`-`	"left justified"
`^`	"upper case"
`#`	"alternate form"
`+`	numerics will always have a sign
	positive numerics have leading space
`0`	numerics are zero-padded
`,`	numerics have grouping separators
`(`	negative numerics are enclosed in parentheses

An example of using formatting

```
package edu.pdx.cs410J.j2se15;

import java.io.PrintStream;
import java.util.Calendar;

public class Formatting {
  public static void main(String[] args) {
    PrintStream out = System.out;
    out.printf("%s%n", "Hello World");

    Calendar today = Calendar.getInstance();
    out.printf("Today’s date is: %tm/%td/%tY%n",
               today, today, today);
    out.printf("The current time is: %tl:%tM %tp%n",
               today, today, today);

    out.printf("%f/%.2f = %f%n", 2.0, 3.0, (2.0/3.0))

    for (int i = 0; i < 3; i++) {
      out.printf("%5s%5s%5s%n", i, i+1, i+2);
    }

    out.printf("%-10s%s%n", "left", "right");
  }
}
```

Summary

Java’s standard class libraries provide a vast array of functionality

- Basic language features: `String`, `StringBuilder`, `Class`, “wrapper” classes, `Math`
- Facilities for performing `byte`-based or character-based I/O: `File`, `OutputStream`, `PrintStream`, `FileWriter`, `BufferedReader`
- Handy utilities: `Date`, `Calendar`, `BitSet`, `StringTokenizer`
- Collection classes: `Vector`, `List`, `Iterator`, `HashMap`, `Comparator`