CS61B Lecture #12

Programming Contest: Coming up Saturday 5 October. See the contest announcement page, here.

Lateness: Yes, the lateness policy does extend to Project 0.

Test 1: still scheduled for 16 October in class.

Today:

- Exceptions.
- Modularization facilities in Java.
- Importing
- Nested classes.
- Using overridden method.
- Parent constructors.
- Type testing.

What to do About Errors?

- Large amount of any production program devoted to detecting and responding to errors.
- Some errors are external (bad input, network failures); others are internal errors in programs.
- When method has stated precondition, it's the client's job to comply.
- Still, it's nice to detect and report client's errors.
- In Java, we *throw exception objects*, typically:

  `throw new` *SomeException* `(`*optional description*`);`

- Exceptions are objects. By convention, they are given two constructors: one with no arguments, and one with a descriptive string argument (which the exception stores).
- Java system throws some exceptions implicitly, as when you dereference a null pointer, or exceed an array bound.

Catching Exceptions

- A **throw** causes each active method call to *terminate abruptly*, until (and unless) we come to a **try** block.
- Catch exceptions and do something corrective with **try**:

```
try {
    Stuff that might throw exception;
} catch (SomeException e) {
    Do something reasonable;
} catch (SomeOtherException e) {
    Do something else reasonable;
}
Go on with life;
```

- When *SomeException* exception occurs in "Stuff...," we immediately "do something reasonable" and then "go on with life."
- Descriptive string (if any) available as `e.getMessage()` for error messages and the like.

Exceptions: Checked vs. Unchecked

- The object thrown by **throw** command must be a subtype of `Throwable` (in `java.lang`).
- Java pre-declares several such subtypes, among them
  - `Error`, used for serious, unrecoverable errors;
  - `Exception`, intended for all other exceptions;
  - `RuntimeException`, a subtype of `Exception` intended mostly for programming errors too common to be worth declaring.
- Pre-declared exceptions are all subtypes of one of these.
- Any subtype of `Error` or `RuntimeException` is said to be *unchecked.*
- All other exception types are *checked.*

Unchecked Exceptions

- Intended for
  - Programmer errors: many library functions throw `IllegalArgumentException` when one fails to meet a precondition.
  - Errors detected by the basic Java system: e.g.,
    * Executing `x.y` when `x` is null,
    * Executing `A[i]` when `i` is out of bounds,
    * Executing `(String) x` when `x` turns out not to point to a `String`.
  - Certain catastrophic failures, such as running out of memory.
- May be thrown anywhere at any time with no special preparation.

Checked Exceptions

- Intended to indicate exceptional circumstances that are not necessarily programmer errors. Examples:
  - Attempting to open a file that does not exist.
  - Input or output errors on a file.
  - Receiving an interrupt.
- Every checked exception that can occur inside a method must either be handled by a `try` statement, or reported in the method's declaration.
- For example,

```
void myRead () throws IOException, InterruptedException { ... }
```

  means that myRead (or something it calls) *might* throw `IOException` or `InterruptedException`.
- Language Design: Why did Java make the following illegal?

```
class Parent {                  class Child extends Parent {
   void f () { ... }                void f () throws IOException { ... }
}                               }
```


Good Practice

- Throw exceptions rather than using print statements and System.exit everywhere,
- . . . because response to a problem may depend on the *caller*, not just method where problem arises.
- Nice to throw an exception when programmer violates preconditions.
- Particularly good idea to throw an exception rather than let bad input corrupt a data structure.
- Good idea to document when methods throw exceptions.
- To convey information about the cause of exceptional condition, put it into the exception rather than into some global variable:

```
class MyBad extends Exception {           try { ...
   public IntList errs;                   } catch (MyBad e) {
   MyBad (IntList nums) { errs=nums; }      ... e.errs ...
}                                         }
```


Package Mechanics

- Classes correspond to things being modeled (represented) in one's program.
- Packages are collections of "related" classes and other packages.
- Java puts standard libraries and packages in package `java` and `javax`.
- By default, a class resides in the *anonymous package*.
- To put it elsewhere, use a `package` declaration at start of file, as in

  `package database;`   *or*   `package ucb.util;`
- Sun's `javac` uses convention that class `C` in package `P1.P2` goes in subdirectory `P1/P2` of any other directory in the *class path*.
- Unix example:

```
nova% export CLASSPATH=.:$HOME/java-utils:$MASTERDIR/lib/classes/junit.jar
nova% java junit.textui.TestRunner MyTests
```

  Searches for TestRunner.class in ./junit/textui, ~/java-utils/junit/textui and finally looks for junit/textui/TestRunner.class in the junit.jar file (which is a single file that is a special compressed archive of an entire directory of files).

Access Modifiers

- Access modifiers (**private, public, protected**) do not add anything to the power of Java.
- Basically allow a programmer to declare what classes are supposed to need to access ("know about") what declarations.
- In Java, are also part of security—prevent programmers from accessing things that would "break" the runtime system.
- Accessibility always determined by static types.
  - To determine correctness of writing `x.f()`, look at the definition of `f` in the *static type* of `x`.
  - Why? Because the rules are supposed to be enforced by the compiler, which only knows static types of things (static types don't depend on what happens at execution time).

The Access Rules

- Suppose we have two packages (not necessarily distinct) and two distinct classes:

```
package P1;
public class C1 ... {
  // A member named M,
  A int M ...
  void h (C1 x)
    { ... x.M ... } // OK.
}
```

```
package P2;
class C2 extends C3 {
  void f (P1.C1 x) {... x.M ...} // OK?
  // C4 a subtype of C2 (possibly C2 itself)
  void g (C4 y) {... y.M ...  } // OK?
}
```

- The access `x.M` is
  - Legal if $\mathcal{A}$ is **public**;
  - Legal if $\mathcal{A}$ is **protected** and $P1$ is $P2$;
  - Legal if $\mathcal{A}$ is *package private* (default—no keyword) and $P1$ is $P2$;
  - Illegal if $\mathcal{A}$ is **private**.
- Furthermore, if $C3$ is $C1$, then `y.M` is also legal under the conditions above, or if $\mathcal{A}$ is **protected** (i.e., even if $P1$ is not the same as $P2$).

What May be Controlled

- Classes and interfaces that are not nested may be public or package private (we haven't talked explicitly about nested types yet).
- Members—fields, methods, constructors, and (later) nested types—may have any of the four access levels.
- May *override* a method only with one that has *at least* as permissive an access level.
  - Reason: avoid inconsistency:

```
package P1;                          | package P2;
public class C1 {                    | class C3 {
  public int f () { ... }            |   void g (C2 y2) {
}                                    |     C1 y1 = y2
                                     |     y2.f (); // Bad???
public class C2 extends C1 {         |     y1.f (); // OK??!!?
  // Actually a compiler error; pretend  |   }
  // it's not and see what happens   | }
  int f () { ... }
}
```

  - That is, there's no point in restricting C2.f, because access control depends on static types, and C1.f is public.

Intentions of this Design

- **public** declarations represent *specifications*—what clients of a package are supposed to rely on.
- *package private* declarations are part of the *implementation* of a class that must be known to other classes that assist in the implementation.
- **protected** declarations are part of the implementation that subtypes may need, but that clients of the subtypes generally won't.
- **private** declarations are part of the implementation of a class that only that class needs.

Quick Quiz

```
package SomePack;
public class A1 {
  int f1() {
    A1 a = ...
    a.x1 = 3; // OK?
  }
  protected int y1;
  private int x1;
}
```

```
// Anonymous package

class A2 {
  void g (SomePack.A1 x) {
    x.f1 ();  // OK?
    x.y1 = 3; // OK?
  }
}

class B2 extends A1 {
  void h (SomePack.A1 x) {
    x.f1 ();  // OK?
    x.y1 = 3; // OK?
    f1();     // OK?
    y1 = 3;   // OK?
    x1 = 3;   // OK?
  }
}
```

- **Note:** Last three lines of h have implicit **this.**'s in front. Static type of **this** is B2.

Access Control Static Only

"Public" and "private" don't apply to dynamic types; it is possible to call methods in objects of types you can't name:

```
package utils;                              | package mystuff;
/** A Set of things. */                     |
public interface Collector {                | class User {
  void add (Object x);                      |    Collector c =
}                                           |      utils.Utils.concat ();
----------------------------                |
package utils;                              |    c.add ("foo");  // OK
public class Utils {                        |    ... c.value (); // ERROR
  public static Collector concat () {       |    ((utils.Concatenator) c).value ()
    return new Concatenator ();             |                    // ERROR
  }                                         |
}                                           ----------------------------------

/** NON-PUBLIC class that collects strings. */
class Concatenater implements Collector {
  StringBuffer stuff = new StringBuffer ();
  int n = 0;
  public void add (Object x) { stuff.append (x); n += 1; }
  public Object value () { return stuff.toString (); }
}
```


Loose End #1: Importing

- Writing `java.util.List` every time you mean `List` or `java.lang.regex.Pattern` every time you mean `Pattern` is annoying.
- The purpose of the **import** clause at the beginning of a source file is to define abbreviations:
  - `import java.util.List;` means "within this file, you can use `List` as an abbreviation for `java.util.List`.
  - `import java.util.*;` means "within this file, you can use *any* class name in the package `java.util` without mentioning the package."
- Importing does *not* grant any special access; it *only* allows abbreviation.
- In effect, your program always contains `import java.lang.*;`

Loose End #2: Static importing

- One can easily get tired of writing `System.out` and `Math.sqrt`. Do you really need to be reminded with each use that `out` is in the `java.lang.System` package and that `sqrt` is in the Math package (duh)?
- Both examples are of *static* members. New feature of Java allows you to abbreviate such references:
  - `import static java.lang.System.out;` means "within this file, you can use `out` as an abbreviation for `System.out`.
  - `import static java.lang.System.*;` means "within this file, you can use *any* static member name in `System` without mentioning the package.
- Again, this is *only* an abbreviation. No special access.
- Alas, you can't do this for classes in the anonymous package.

Loose End #3: Parent constructors

- In lecture notes #5, talked about how Java allows implementer of a class to control all manipulation of objects of that class.
- In particular, this means that Java gives the constructor of a class the first shot at each new object.
- When one class extends another, there are two constructors—one for the parent type and one for the new (child) type.
- In this case, Java guarantees that one of the parent's constructors is called first. In effect, there is a call to a parent constructor at the beginning of every one of the child's constructors.
- You can call the parent's constructor yourself. By default, Java calls the "default" (parameterless) constructor.

```
class Figure {                       class Rectangle extends Figure {
  public Figure (int sides) {            public Rectangle () {
     ...                                    super (4);
  }...                                   }...
}                                    }
```


Loose End #4: Using an Overridden Method

- Suppose that you wish to *add* to the action defined by a superclass's method, rather than to completely override it.
- The overriding method can refer to overridden methods by using the special prefix super.
- For example, you have a class with expensive functions, and you'd like a memoizing version of the class.

```
class ComputeHard {
  int cogitate (String x, int y) { ... }
  ...
}

class ComputeLazily extends ComputeHard {
  int cogitate (String x, int y) {
    if (already have answer for this x and y) return memoized result;
    else
       int result = super.cogitate (x, y);
       memoize (save) result;
       return result;
 }
}
```


Loose End #5: Nesting Classes

- Sometimes, it makes sense to *nest* one class in another. The nested class might
  - be used only in the implementation of the other, or
  - be conceptually "subservient" to the other
- Nesting such classes can help avoid name clashes or "pollution of the name space" with names that will never be used anywhere else.
- Example: Polynomials can be thought of as sequences of terms. Terms aren't meaningful outside of Polynomials, so you might define a class to represent a term *inside* the Polynomial class:

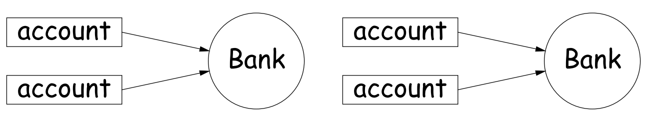
```
class Polynomial {

  methods on polynomials

  private Term[] terms;
  private static class Term {
    ...
  }
}
```


Inner Classes

- Last slide showed a static nested class. Static nested classes are just like any other, except that they can be private or protected, and they can see private variables of the enclosing class.
- Non-static nested classes are called *inner classes.*
- Somewhat rare (and syntax is odd); used when each instance of the nested class is created by and naturally associated with an instance of the containing class, like Banks and Accounts:




```
class Bank {                                 | Bank e = new Bank(...);
  private void connectTo (...) {...}         | Bank.Account p0 =
  public class Account {                     |     e.new Account (...);
    public void call (int number) {          | Bank.Account p1 =
       Bank.this.connectTo (...); ...        |     e.new Account (...);
    } // Bank.this means "the bank that      |
  }   // created me"                         |
 }                                           |
```

Trick: Delegation and Wrappers

- Not always appropriate to use inheritance to extend something.
- Homework gives example of a `TrReader`, which *contains* another `Reader`, to which it *delegates* the task of actually going out and reading characters.
- Another example: an "interface monitor:"

```
interface Storage {    | class Monitor implements Storage {
  void put (Object x); |   int gets, puts;
  Object get ();       |   private Storage store;
}                      |   Monitor (Storage x) { store = x; gets = puts = 0; }
                       |   public void put (Object x) { puts += 1; store.put (x); }
                       |   public Object get () { gets += 1; return store.get (); }
                       |  }
```

- So now, you can *instrument* a program:

```
// ORIGINAL                          // INSTRUMENTED
Storage S = something;               Monitor S = new Monitor (something);
f (S);                               f(S);
                                     System.out.println (S.gets + " gets");
```

- `Monitor` is called a *wrapper class*.

Loose End #6: instanceof

- It is possible to ask about the dynamic type of something:

```
void typeChecker (Reader r) {
  if (r instanceof TrReader)
    System.out.print ("Translated characters: ");
  else
    System.out.print ("Characters: ");
  ...
}
```

- However, this is *seldom* what you want to do. Why do this:

```
if (x instanceof StringReader)
  read from (StringReader) x;
else if (x instanceof FileReader)
  read from (FileReader) x;
...
```

  when you can just call `x.read()`?!

- In general, use instance methods rather than **instanceof**.