

Reminders:

- Please use `bug-submit` for submitting any programming problems you have with homework and projects.
- You *have* started Project #1, right? It's due in a week.
- Unlike homeworks, we don't autograde projects continuously until they are due. However, we will run the autograder once a day or so before the due date so that those who have kept ahead can get some additional help getting it right.

Today's Topics:

- Modularization facilities in Java.
- Wrapping up more loose ends and leaving explicit material on Java for now.

Readings for next week: *Assorted Materials on Java*, chap. 3 (already assigned) and 5; *Head First Java*, chap. 16; *Data Structures (Into Java)*, (Reader #2) chap. 1.

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- 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% setenv 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).

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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).

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

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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???
                                           |         y1.f (); // OK??!!?
public class C2 extends C1 {              |     }
    // 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.

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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.

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Quick Quiz

```
// Anonymous package
class A2 {
    void g (SomePack.A1 x) {
        x.f1 (); // OK?
        x.y1 = 3; // OK?
    }
}
package SomePack;
public class A1 {
    int f1() {
        A1 a = ...
        a.x1 = 3; // OK?
    }
    protected int y1;
    private int x1;
}
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.

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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.Utills.concat ();
-----|
package utils;                             |     c.add ("foo"); // OK
public class Utills {                     |     ... c.value (); // ERROR
    public static Collector concat () {    |     ((utils.Concatenator) c).value ()
        return new Concatenator ();       |     // ERROR
    }
}                                           |
-----|
/** NON-PUBLIC class that collects strings. */
class Concatenator 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 (); }
}
```

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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.*;`

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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.

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Loose End #3: 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:

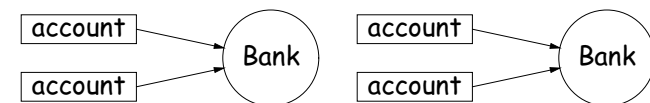
```
class Polynomial {  
  
    methods on polynomials  
  
    private Term[] terms;  
    private static class Term {  
        ...  
    }  
}
```

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

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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;
    }
}
```

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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 {
    void put (Object x);
    Object get ();
}

class Monitor implements Storage {
    int gets, puts;
    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
Storage S = something;
f (S);

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

- Monitor is called a *wrapper class*.

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Loose End #5: 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`.

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