

# CS61B Lecture #12

**Homework 4:** will be out tonight sometime.

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

**Test 1:** still scheduled for 10 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 {  
    void f () { ... }  
}
```

```
class Child extends Parent {  
    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 {  
    public IntList errs;  
    MyBad (IntList nums) { errs=nums; }  
}
```

```
try { ...  
} catch (MyBad e) {  
    ... 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=./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 `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`).

# 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:

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

– 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

```
// 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?  
    }  
}
```

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

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

# 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`.

# Quick Quiz

```
// Anonymous package
```

```
class A2 {  
    void g (SomePack.A1 x) {  
        x.f1 (); // ERROR  
        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`.

# Quick Quiz

```
// Anonymous package
```

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

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

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

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



# 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 (); // ERROR
        x.y1 = 3; // ERROR
    }
}

class B2 extends A1 {
    void h (SomePack.A1 x) {
        x.f1 (); // ERROR
        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`.

# Quick Quiz

```
// Anonymous package
```

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

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

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

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

# Quick Quiz

```
// Anonymous package
```

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

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

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

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

# Quick Quiz

```
// Anonymous package
```

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

```
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 ();    // ERROR  
        x.y1 = 3;  // OK?  
        f1();       // ERROR  
        y1 = 3;     // OK  
        x1 = 3;     // ERROR  
    }  
}
```

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

# Quick Quiz

```
// Anonymous package
```

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

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

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

- **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 {                  |
    void add (Object x);                     |
}                                              |
-----|
package utils;                                |
public class Utils {                          |
    public static Collector concat () {       |
        return new Concatenator ();          |
    }                                         |
}                                              |
-----|

/** 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 (); }
}
```

# 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 {  
    public Figure (int sides) {  
        ...  
    }...  
}
```

```
class Rectangle extends Figure {  
    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;  
    }  
}
```

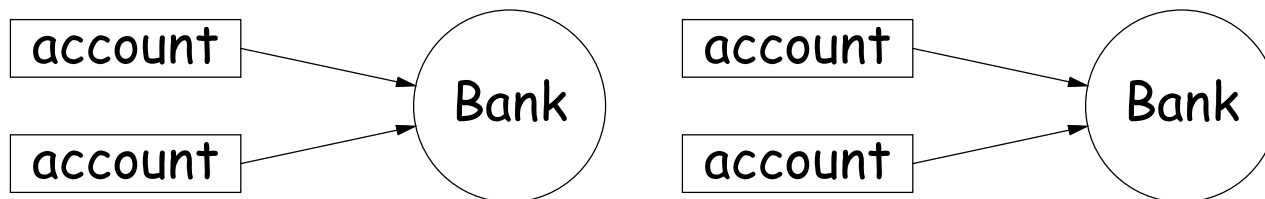
## Loose End #5: Nesting Classes

- 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 {  
    private void connectTo (...) {...}  
    public class Account {  
        public void call (int number) {  
            Bank.this.connectTo (...); ...  
        } // Bank.this means "the bank that  
    }    // created me"  
}
```

```
| Bank e = new Bank(...);  
| Bank.Account p0 =  
|     e.new Account (...);  
| Bank.Account p1 =  
|     e.new Account (...);  
|  
|
```

# 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
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*.

## 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**.