Public Service Announcement:

- CalSol, the UC Berkeley solar car team, is looking for new members.
- Preferably in MechE and EECS, but all welcome.
- See their web site, www.me.berkeley.edu/calsol, for more.

Readings:

- Chapters 7 and 8 in Head First Java.

Today:

- New in this lecture: the bare mechanics of "object-oriented programming."
- The general topic is: Writing software that operates on many kinds of data.

Overloading

Problem: How to get System.out.print(x) or stdout.put(x) to print x, regardless of type of x?

- In Scheme, one function can take an argument of any type, and then test the type.
- In Java, methods specify a single type of argument.
- Partial solution: overloading—multiple method definitions with the same name and different numbers or types of arguments.
- E.g., System.out has type java.io.PrintStream, which defines

  - void println() Prints new line.
  - void println(String s) Prints S.
  - void println(boolean b) Prints "true" or "false"
  - void println(char c) Prints single character
  - void println(int i) Prints I in decimal
  - etc.

- Each of these is a different function. Compiler decides which to call on the basis of arguments' types.

Generic Data Structures

Problem: How to get a "list of anything" or "array of anything"?

- Again, no problem in Scheme.
- But in Java, lists (such as IntList) and arrays have a single type of element.
- First, the short answer: any reference value can be converted to type java.lang.Object and back, so can use Object as the "generic (reference) type":

  ```
  Object[] things = new Object[2];
  things[0] = new IntList (3, null);
  things[1] = "Stuff";
  // Now ((IntList) things[0]).head == 3;
  // and ((String) things[1]).startsWith("St") is true
  // things[0].head Illegal
  // things[1].startsWith ("St") Illegal
  ```

Dynamic vs. Static Types

- Every value has a type—its dynamic type.
- Every container (variable, component, parameter), literal, function call, and operator expression (e.g. x+y) has a type—its static type.
- Therefore, every expression has a static type.

```
Object[] things = new Object[2];
things[0] = new IntList (3, null);
things[1] = "Stuff";
```
Type Hierarchies

- A container with (static) type T may contain a certain value only if that value "is a" T—that is, if the (dynamic) type of the value is a subtype of T. Likewise, a function with return type T may return only values that are subtypes of T.
- All types are subtypes of themselves (& that's all for primitive types)
- Reference types form a type hierarchy: some are subtypes of others. null's type is a subtype of all reference types.
- All reference types are subtypes of Object.

The Basic Static Type Rule

- Java is designed so that any expression of (static) type T always yields a value that "is a" T.
- Static types are "known to the compiler," because you declare them, as in

```
String x; // Static type of field
int f (Object s) { // Static type of call to f, and of parameter
    int y; // Static type of local variable
    // Static type of return value
}
```

- Compiler insists that in an assignment, \( L = E \), or function call, \( f(E) \), where

```
void f (SomeType L) { ... },
```

\( E \)'s static type must be subtype of \( L \)'s static type.
- Similar rules apply to \( E[i] \) (static type of \( E \) must be an array) and other built-in operations.
- Slight fudge: compiler will coerce "smaller" integer types to larger ones, float to double, and (from last lecture) between primitive types and their wrapper types.

Consequences of Compiler’s "Sanity Checks"

- This is a conservative rule. The last line of the following, which you might think is perfectly sensible, is illegal:

```
int[] A = new int[2];
Object x = A; // All references are Objects
A[i] = 0; // Static type of A is array...
```

\( x[i+1] = 1; // But not of x: ERROR \)

Compiler figures that not every Object is an array.

Q: Don't we know that \( x \) contains array value!?  
A: Yes, but still must tell the compiler, like this:

```
((int[])) x[i+1] = 1;
```

Defn: Static type of cast \( (T) E \) is \( T \).

Q: What if \( x \) isn't an array value, or is null?  
A: For that we have runtime errors—exceptions.

Overriding and Extension

- Notation so far is clumsy.

Q: If I know Object variable \( x \) contains a String, why can’t I write, \( x.startsWith("this") \)?

A: \( startsWith \) is only defined on Strings, not on all Objects, so the compiler isn’t sure it makes sense, unless you cast.

But, if an operation were defined on all Objects, then you wouldn't need clumsy casting.

Example: \( .toString() \) is defined on all Objects. You can always say \( x.toString() \) if \( x \) has a reference type.

The default \( .toString() \) function is not very useful; on an IntList, would produce string like "IntList@2f6684"

But for any subtype of Object, you may override the default definition.
Overriding toString

- For example, if \( s \) is a String, \( s.toString() \) is the identity function (fortunately).
- For any type you define, you may supply your own definition, as we did in class \( \text{IntList} \):
  ```java
  public String toString () {
    StringBuffer b = new StringBuffer ();
    b.append (“[”);
    for (IntList L = this; L != null; L = L.tail)
      b.append (“ “ + L.head);
    b.append (“]”);
    return b.toString ();
  }
  ```
- If \( x = \text{new IntList} (3, \text{new IntList} (4, \text{null})) \), then \( x.toString() \) is "[3 4]".
- Conveniently, the "*" operator on Strings calls .toString when asked to append an Object, and so does the "%s" formatter for printf.
- With this trick, you can supply an output function for any type you define.

Extending a Class

- To say that class \( B \) is a direct subtype of class \( A \) (or \( A \) is a direct superclass of \( B \)), write
  ```java
  class B extends A { ... }
  ```
- By default, class ... extends java.lang.Object.
- The subtype inherits all fields and methods of its superclass (and passes them along to any of its subtypes).
- In class \( B \), you may override an instance method (not a static method), by providing a new definition with same signature (name, return type, argument types).
- I’ll say that a method and all its overrides form a dynamic method set.
- The Point: If \( f(...) \) is an instance method, then the call \( x.f(...) \) calls whatever overriding of \( f \) applies to the dynamic type of \( x \), regardless of the static type of \( x \).

Illustration

```java
class Worker {
  void work () {
    collectPay ();
  }
}
class Prof extends Worker {
  // Inherits work ()
}

class TA extends Worker {
  // Inherits work ()
}

Prof paul = new Prof ();
   | paul.work() ==> collectPay();
TA mike = new TA ();
   | mike.work() ==> doLab(); discuss(); ...
Worker wPaul = paul, wMike = mike;
   | wPaul.work() ==> collectPay();
   | wMike.work() ==> doLab(); discuss(); ...
```

Lesson: For instance methods (only), select method based on dynamic type. Simple to state, but we'll see it has profound consequences.

What About Fields and Static Methods?

```java
class Parent {
  int x = 0;
  static int y = 1;
  static void f() {
    System.out.printf ("Ahem!\n");
  }
  static int f(int x) {
    return x+1;
  }
}
class Child extends Parent {
  String x = "no";
  static String y = "way";
  static void f() {
    System.out.printf ("I wanna!\n");
  }
  static int f(int x) {
    return x+1;
  }
}
```

```
Child tom = new Child ();
   | tom.x ==> no  pTom.x ==> 0
Parent pTom = tom;
   | tom.y ==> way pTom.y ==> 1
   | tom.f() ==> I wanna! pTom.f() ==> Ahem!
   | tom.f(1) ==> 2 pTom.f(1) ==> 2
```

Lesson: Fields hide inherited fields of same name; static methods hide methods of the same signature.
Real Lesson: Hiding causes confusion; so understand it, but don't do it!
What's the Point?

• The mechanism described here allows us to define a kind of *generic* method.
• A superclass can define a set of operations (methods) that are common to many different classes.
• Subclasses can then provide different implementations of these common methods, each specialized in some way.
• All subclasses will have at least the methods listed by the superclass.
• So when we write methods that operate on the superclass, they will automatically work for all subclasses with no extra work.