CS61B Lecture #8: Object-Oriented Mechanisms

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)` to print `x`, regardless of type of `x`?

- In Scheme or Python, one function can take an argument of any type, and then test the type (if needed).
- 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 or Python.
- 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
```

And Primitive Values?

- Primitive values (ints, longs, bytes, shorts, floats, doubles, chars, and booleans) are not really convertible to `Object`.
- Presents a problem for "list of anything."
- So Java introduced a set of *wrapper types*, one for each primitive type:

Prim.	Ref.	Prim.	Ref.	Prim.	Ref.
byte	Byte	short	Short	int	Integer
long	Long	char	Character	boolean	Boolean
float	Float	double	Double		

- One can create new wrapper objects for any value (*boxing*):

```
Integer Three = new Integer(3);
Object ThreeObj = Three;
```

and vice-versa (*unboxing*):

```
int three = Three.intValue();
```

Autoboxing

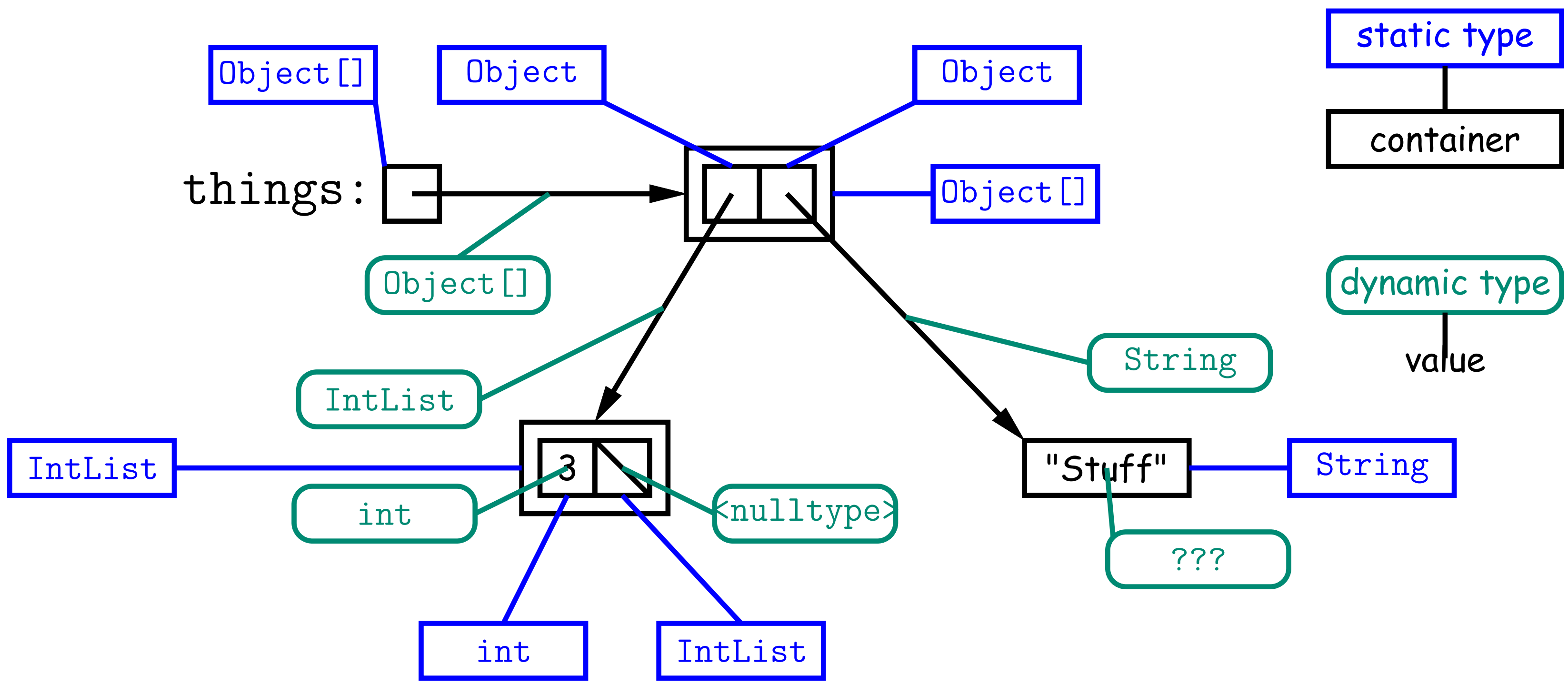
Boxing and unboxing are automatic (in many cases):

```
Integer Three = 3;
int three = Three;
int six = Three + 3;

Integer[] someInts = { 1, 2, 3 };
for (int x : someInts) {
    System.out.println(x);
}

System.out.println(someInts[0]);
    // Prints Integer 1, but NOT unboxed.
```

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.

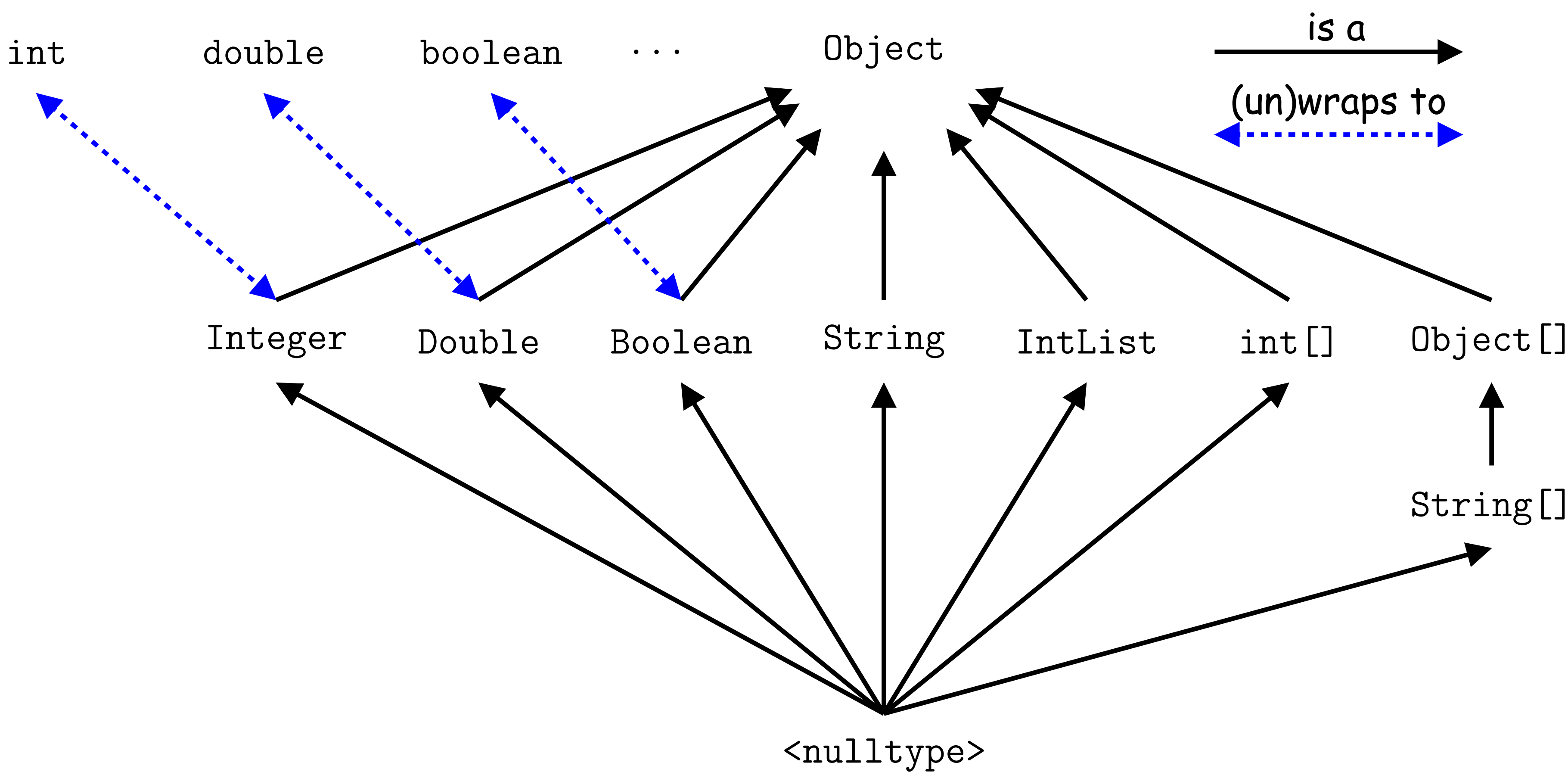
```
Object[] things = new Object[2];
things[0] = new IntList(3, null);
things[1] = "Stuff";
```



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`.

Java Library Type Hierarchy (Partial)



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
```

  or they are pre-declared by the language (like 3).

- 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.

Coercions

- The values of type `short`, for example, are a subset of those of `int` (`short`s are representable as 16-bit integers, `int`s as 32-bit integer)
- But we *don't* say that `short` is a subtype of `int`, because they don't quite behave the same.
- Instead, we say that values of type `short` can be *coerced* (converted) to a value of type `int`.
- Leads to a slight fudge: compiler will silently coerce "smaller" integer types to larger ones, `float` to `double`, and (as just seen) between primitive types and their wrapper types.
- So,

```
short x = 3002;
int y = x;
```

works without complaint.

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 `String`s, not on all `Object`s, so the compiler isn't sure it makes sense, unless you cast.
- But, if an operation *were* defined on all `Object`s, then you *wouldn't* need clumsy casting.
- Example: `.toString()` is defined on all `Object`s. 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. For example, in `IntList`, could add

```
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 = new IntList(3, new IntList(4, 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

  ```
  class B extends A { ... }
  ```

- By default, `class ... extends java.lang.Object`.
- The subtype *inherits* all fields and methods of its direct 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 overridings 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

```
class Worker {
  void work() {
    collectPay();
  }
}
```

```
class Prof extends Worker {
  // Inherits work()
}
```

```
class TA extends Worker {
  void work() {
    while (true) {
      doLab(); discuss(); officeHour();
    }
  }
}
```

```
Prof paul = new Prof();         | paul.work()   ==> collectPay();
TA daniel = new TA();           | daniel.work()  ==> doLab(); discuss(); ...
Worker wPaul = paul,            | wPaul.work() ==> collectPay();
       wDaniel = daniel;        | wDaniel.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?

```
class Parent {                                class Child extends Parent {
  int x = 0;                                    String x = "no";
  static int y = 1;                             static String y = "way";
  static void f() {                             static void f() {
     System.out.printf("Ahem!%n");                 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.