# CS61B Lecture #8: Object-Oriented Mechanisms

**Announcements:**

- **Readings for Wednesday:** Chapters 8 and 9 of *Head-First Java*
- Project 0 will be out this evening.

**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"?

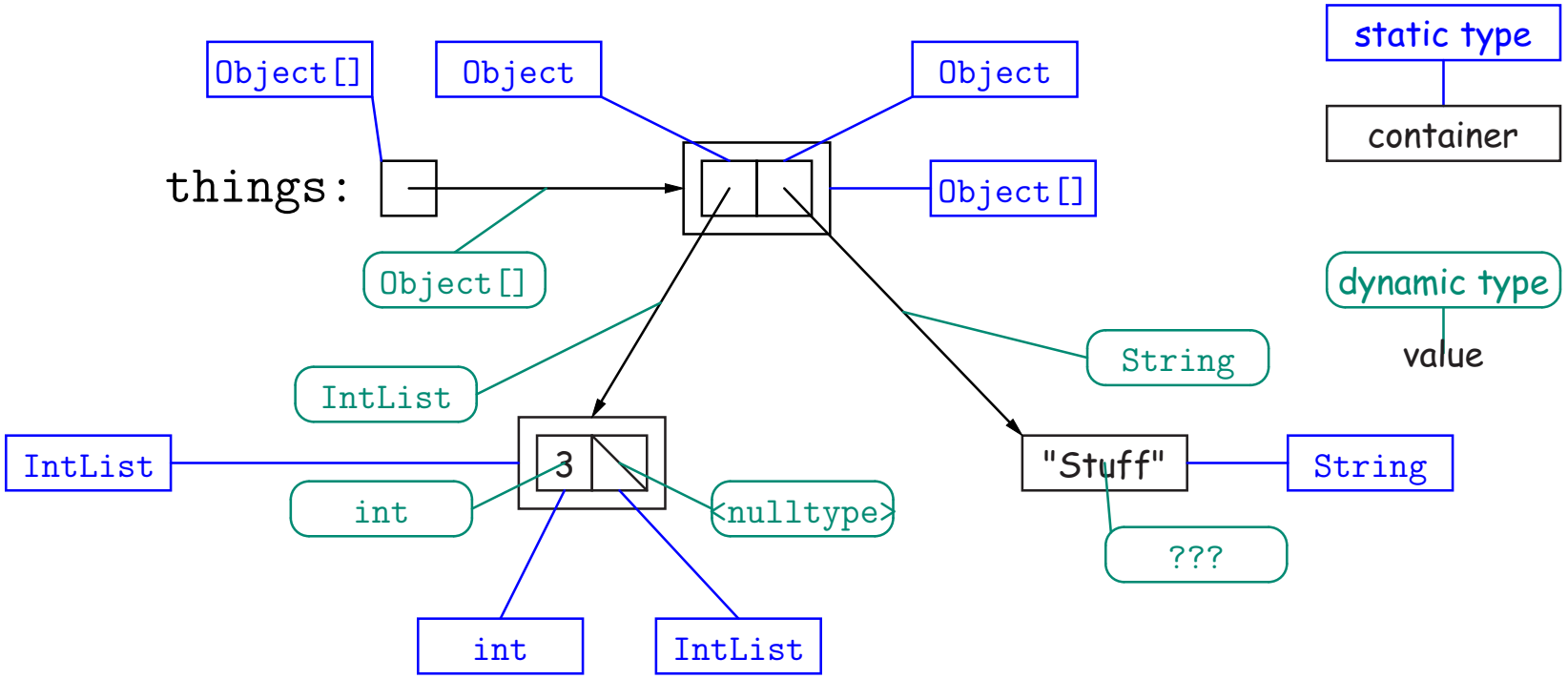
- Again, no problem in Scheme or Python.
- But in Java, lists (such as `IntList`) and arrays have a single type of element.
- First, the short answer: any reference value can be converted to type `java.lang.Object` and back, so can use `Object` as the "generic (reference) type":

```
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
```

# Dynamic vs. Static Types

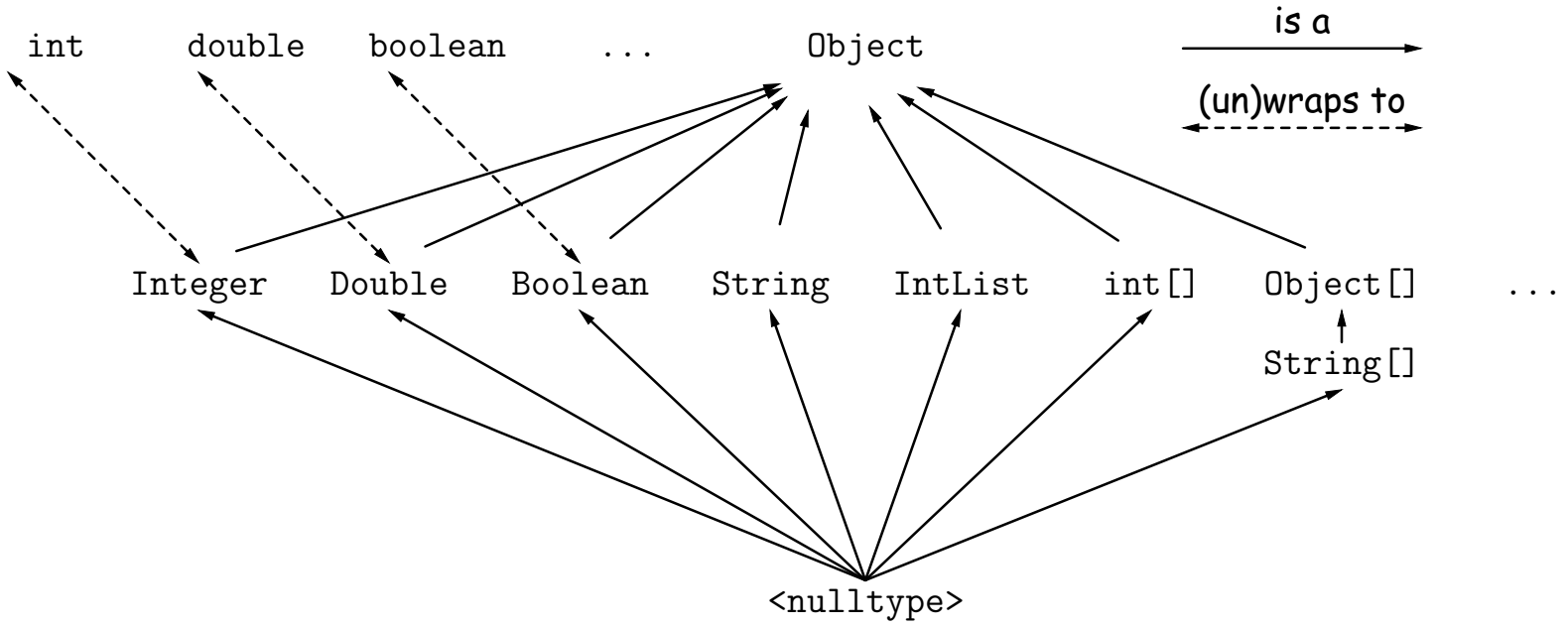
- Every *value* has a type—its *dynamic type*.
- Every *container* (variable, component, parameter), literal, function call, and operator expression (e.g. `x+y`) has a type—its *static type*.
- Therefore, every *expression* has a static type.

```
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
```

  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.
- 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. 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 *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 adam = new TA();         | adam.work()  ==> doLab(); discuss(); ...
Worker wPaul = paul,        | wPaul.work() ==> collectPay();
       wAdam = adam;        | wAdam.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 {
  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");
  }
}
```

---

```
Child  tom = new Child();
Parent pTom = tom;
```

```
tom.x    ==> no
tom.y    ==> way
tom.f()  ==> I wanna!
tom.f(1) ==> 2
```

```
pTom.x    ==> 0
pTom.y    ==> 1
pTom.f()  ==> Ahem!
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.