

## CS61B Lecture #8: Object-Oriented Mechanisms

**Readings for Lab:** Scan the on-line Javadoc documentation for List, ArrayList, LinkedList, Iterator, ListIterator, Set, TreeSet, in the java.util package.

**Readings for Wednesday:** Chapters 8 and 9 of *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.

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## Overloading

**Problem:** How to get `System.out.print(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.

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## 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
```

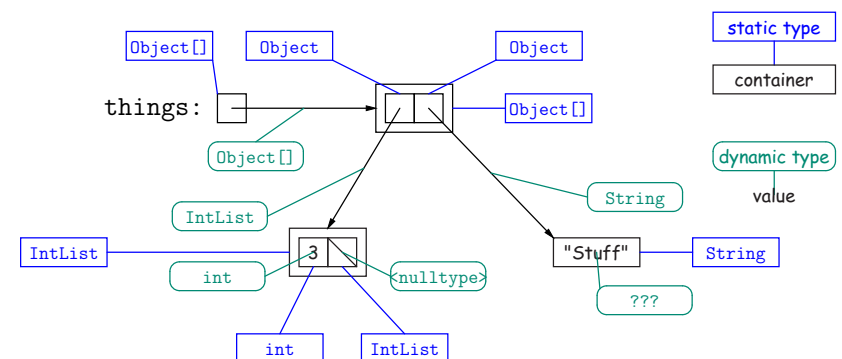
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## Dynamic vs. Static Types

- 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";
```

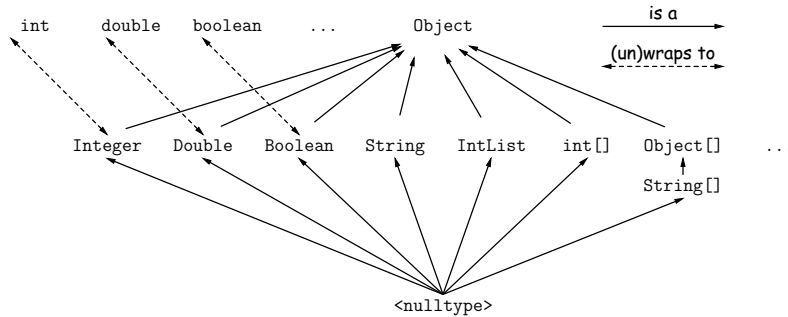


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## Type Hierarchies

- 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.



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## 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.

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## 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.

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## 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.

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## 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.

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## 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`.

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## 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.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.

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## 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 (); | 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!

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## 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.