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.

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*

piler decides which to call on the basis of arguments' types.

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
```


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();
```



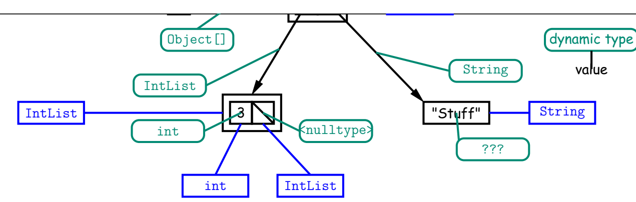
```
Integer Three = 3;
int three = Three;
int six = Three + 3;

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

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

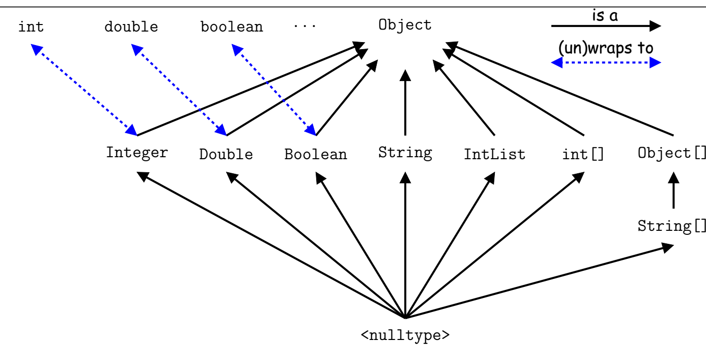
- Every *container* (variable, component, parameter), literal, function call, and operator expression (e.g. x+y) has a type—its *static type*.
- Therefore, every *expression* has a static type.

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

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.



(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.

a subset of those of int (shorts are representable as 16-bit integers, ints 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.

- 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.

- 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.

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

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.

```
                collectPay();
              }
            }
```

```
class Prof extends     | class TA extends Worker {
Worker {               |   void work() {
  // Inherits          |     while (true) {
work()                 |       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(); ...
```



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


Real Lesson: Hiding causes confusion, so understand it, but don't do it!

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.