In theory, you already know Java…

- Classes and objects
- Static vs instance fields and methods
- Primitive vs reference types
- Private vs public vs package
- Constructors
- Method signatures
- Local variables
- Arrays
- Subtypes and Inheritance, Shadowing

… but even so

- Even standard Java features have some subtle aspects relating to object orientation and the way the type system works
- Let's touch on a few of these today
- We picked topics that will get you thinking about Java the way that we think about it!

Java is object oriented

- In most prior languages, code was executed line by line and accessed variables or record
- In Java, we think of the data as being organized into objects that come with their own methods, which are used to access them
  - This shift in perspective is critical
  - When coding in Java one is always thinking about "which object is running this code?"

Dynamic and Static

- Some kinds of information is "static"
  - There can only be one instance
  - Like a "global variable" in C or C++ (or assembler)
- Object-oriented information is more "dynamic"
  - Each object has its own private copy
  - When we create a new object, we make new copies of the variables it uses to keep its state
- In Java this distinction becomes very important

Names

- The role of a name is to tell us
  - Which class is being referenced, although sometimes this is clear from the context
  - Which object is being referenced, unless we're talking about a static method or a static variable
- Example
  - System.out.println(a.serialNumber)
    - out is a static field in class System
    - The value of System.out is an instance of a class that has an instance method println(int)
- If an object must refer to itself, use this
  - this.i = i;

The main Method

Can be called from anywhere

Associated with the class; don't need an instance (an object) to invoke it

No return value

Method must be named **main**

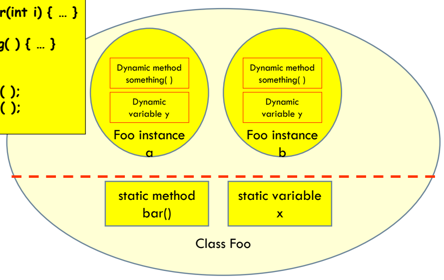
```
public static void main(String[] args) {
...
}
```

Parameters passed to program on command line or, in Eclipse, can be defined in the "Run" configuration dialog box (which the same as the "Debug" one…)

Static methods and variables

```
class Foo {
    static int x;
    static void bar(int i) { … }
    int y;
    void something( ) { … }
}

Foo a = new Foo( );
Foo b = new Foo( );
a.bar(b.y);
```



Static methods and variables

```
class Thing {
    static int s_val;         // One for the whole class
    int o_val;                //  Each object will have its own personal copy

    static void s_method()  // Anyone can call this
    {
         s_val++;             // Legal: increments the shared variable s_val
         o_val = s_val;       // Illegal: Which version of o_val do we mean?
         o_method(s_val);     // Illegal: o_method needs an object reference
    }

    void o_method()
    {
         s_val++;          // Legal
         this.s_val++;     // Illegal: s_val belongs to the class, not object
         o_val = s_val;    // Legal:  same as this.o_val = s_val
         s_method();       // Legal:  calls the class method s_method()
         o_method();       // Legal:  same as this.o_method();
    }
} // end class Thing
```

Avoiding trouble

- Use of static methods is discouraged
- Keep in mind that "main" is a static method
  - Hence anything main calls needs to have an associated object instance, or itself be static

```
class Thing {
    int counter;
    static int sequence;

    public static void main(String[] args)
    {
        int c = ++counter;     // Illegal: counter is associated with an
                               // object of type Thing.  But which object?
        int s = ++sequence;    // Legal: sequence is static too
    }
}
```

Constructors

- Called to create new instances of a class
- Default constructor initializes all fields of the class to default values (0 or null)

```
class Thing {
   int val;

   Thing(int val) {
      this.val = val;
   }

   Thing( ) {
      this(3);
   }
}
```

```
Thing one = new Thing(1);
Thing two = new Thing(2);
Thing three = new Thing( );
```

What about non-class variables?

- Those are *not* automatically initialized, you need to do it yourself!
- Can cause confusion

```
class Thing {
   int val;

   Thing(int val) {
      int undef;
      this.val = val+undef;
   }

   Thing( ) {
      this(3);
   }
}
```

this.val was automatically initialized to zero, but undef has no defined value! Yet the declaration looks very similar! In what way did it differ?

Finalizers

- Like constructors but called when the object is deallocated
- Might not happen when you expected
  - Garbage collector decides when to actually deallocate an object
  - So objects can linger even when you no longer have a reference to them!
  - For this reason, we tend not to use finalizers – they add an undesired form of unpredictability

Static Initializers

- Run once when class is loaded
- Used to initialize static objects

```
class StaticInit {
    static Set<String> courses = new HashSet<String>();
    static {
        courses.add("CS 2110");
        courses.add("CS 6110");
    }

    public static void main(String[] args) {
        ...
    }
}
```

Static vs Instance Example

```
class Widget {
    static int nextSerialNumber = 10000;
    int serialNumber;
    Widget() {
        serialNumber = nextSerialNumber++;
    }
    public static void main(String[] args) {
        Widget a = new Widget();
        Widget b = new Widget();
        Widget c = new Widget();
        System.out.println(a.serialNumber);
        System.out.println(b.serialNumber);
        System.out.println(c.serialNumber);
    }
}
```

Names

- Refer to *my* static and instance fields & methods by (unqualified) name:
  - serialNumber
  - nextSerialNumber
- Refer to *static* fields & methods *in another class* using name of the class
  - Widget.nextSerialNumber
- Refer to *instance* fields & methods of *another object* using name of the object
  - a.serialNumber

Overloading of Methods

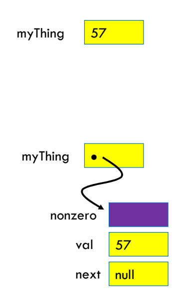
- A class can have several methods of the same name
  - But all methods must have different *signatures*
  - The *signature* of a method is its name plus the types of its parameters
- Example: String.valueOf(...) in Java API
- There are 9 of them:
  - valueOf(boolean);
  - valueOf(int);
  - valueOf(long);
  - ...
- Parameter types are part of the method's signature

Example: Overloading "compareTo"

- Many classes extend an object that supports an interface called "comparable". If you do this you can override these methods:
  - **equals()**: a.equals(b), returns true/false
  - **compareTo()**: a.compareTo(b): returns -/0/+
  - **hashCode()**: a.hashCode: usually you return data.hashCode() for some data object in a that represents a's "value" (perhaps a string or a number)
- Overriding *all three* methods allows Java utilities that sort arrays to operate on your class
- But one warning: if you override these methods you must override *all* of them

Primitive vs Reference Types

- Primitive types
  - int, short, long, float, byte,
  - char, boolean, double
- Efficient
  - 1 or 2 words
  - Not an Object—unboxed
- Reference types
  - Objects and arrays
  - String, int[], HashSet
  - Usually require more memory
  - Can have special value null
  - Can compare null with ==, !=
  - Generates NullPointerException if you try to dereference null



Comparing Reference Types

- Comparing objects (or copying them) isn't easy!
  - You need to copy them element by element
  - Compare objects using the "equals" method, which implements "deep equality"
- Example: suppose we have
  - Person A = new Person("Fred"), B = new Person("Fred");
  - What will A == B return?
  - Need to use A.equals(B)

False! A and B are different Persons even though their <u>values</u> are the same. (Beware that this ought to be the same behaviour for Strings, but isn't since they're immutable!)

Comparing Reference Types

- You can define "equals" for your own classes
- Do this by overriding the built in "equals" method:

  boolean equals(Object x);
- But if you do this, must also override Object.hashCode() (more on this later)

== with primitive types

- Puzzle: why do Integer comparisons work?
  - Integer I = 7;
  - (I == 7)? *True, but not obvious why!*
  - (I == new Integer(7)) *False*
- … the first comparison only works because Java auto-unboxes I to compare it with int 7.
- If it had autoboxed the 7, the comparison would have failed! Lucky Java gets this right...

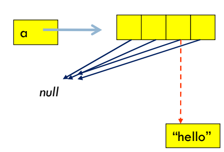
Arrays

- Arrays are reference types
- Array *elements* can be reference types or primitive types
  - E.g., int[] or String[] or Rhubarb[]
- **a** is an array, **a.length** is its length
  - Its elements are

    a[0], a[1], ..., a[a.length-1]
  - The length is fixed when the array is first allocated using « new »

String[] a = new String[4];

a[2] = "hello"

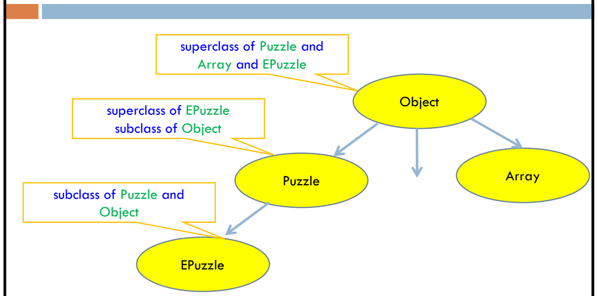


a.length = 4

Accessing Array Elements Sequentially

```
public class CommandLineArgs {
    public static void main(String[] args) {
        System.out.println(args.length);
        // old-style
        for (int i = 0; i < args.length; i++) {
            System.out.println(args[i]);
        }
        // new style
        for (String s : args) {
            System.out.println(s);
        }
    }
}
```

Class Hierarchy



Every class (except **Object**) has a unique immediate superclass, called its *parent*

Inheritance

- A subclass *inherits* the methods of its superclass
- Example: methods of the Object superclass:
  - equals(), as in A.equals(B)
  - toString(), as in A.toString()
  - … others we'll learn about later in the course
- … every object thus supports toString()!

Overriding

- A method in a subclass overrides a method in superclass if:
  - both methods have the same name,
  - both methods have the same signature (number and type of parameters and return type), and
  - both are static methods or both are instance methods
- *Methods* are dispatched according to the runtime type of the actual, underlying object *(cf example coming up!!!)*

Accessing Overridden Methods

- Suppose a class Child overrides a method m in its parent
  - Methods in Child can invoke the overridden method in the parent as
    - super.m()
  - In particular, can invoke the overridden method in the overriding method! This can be very useful.
- Caveat: cannot compose super more than once as in
  - super.super.m() ---- *not kosher!*

Unexpected Consequences

- An overriding method cannot have more restricted access than the method it overrides

```
class A {
    public int samename() {…}
}
class B extends A {
    private int samename() {…} // illegal !
}

A foo = new B(); // upcasting
foo.samename();  // would invoke private method in
                 // class B at runtime, were it to be legal
```

… a nasty example

```
class A {
    int i = 1;
    int f() { return i; }
}
class B extends A {
    int i = 2;                          // Shadows variable i in class A.
    int f() { return -i; }              // Overrides method f in class A.
}
public class Override_test {
    public static void main(String args[]) {
        B b = new B();
        System.out.println(b.i);        // Refers to B.i; prints 2.
        System.out.println(b.f());      // Refers to B.f(); prints -2.
        A a = (A) b;                    // Cast b to an instance of class A.
        System.out.println(a.i);        // Now refers to A.i; prints 1;
        System.out.println(a.f());      // Still refers to B.f(); prints -2;
    }
}
```

The "runtime" type of "a" is "B"!

Shadowing

- Like overriding, but for fields instead of methods
  - Superclass: variable v of some type
  - Subclass: variable v perhaps of some other type
  - Method in subclass can access shadowed variable using super.v
  - Variable references are resolved using static binding (i.e., at compile-time), not dynamic binding (i.e., not at runtime)
- Variable reference r.v uses the static (declared) type of the variable r, not the runtime type of the object referred to by r
- Shadowing variables is bad medicine and should be avoided

… back to our earlier example

```
class A {
    int i = 1;
    int f() { return i; }
}
class B extends A {
    int i = 2;                                   // Shadows variable i in class A.
    int f() { return -i; }                       // Overrides method f in class A.
}
public class override_test {
    public static void main(String args[]) {
        B b = new B();
        System.out.println(b.i);                 // Refers to B.i; prints 2.
        System.out.println(b.f());               // Refers to B.f(); prints -2.
        A a = (A) b;                             // Cast b to an instance of class A.
        System.out.println(a.i);                 // Now refers to A.i; prints 1;
        System.out.println(a.f());               // Still refers to B.f(); prints -2;
    }
}
```

The "declared" or "static" type of "a" is "A"!

Array vs ArrayList vs HashMap

Three extremely useful constructs (see Java API)

- **Array**
  - Storage is allocated when array created; cannot change
  - Extremely fast lookups
- **ArrayList** (in **java.util**)
  - An "extensible" array
  - Can append or insert elements, access i'th element, reset to 0 length
  - Lookup is slower than an **array**
- **HashMap** (in **java.util**)
  - Save data indexed by keys
  - Can lookup data by its key
  - Can get an iteration of the keys or values
  - Storage allocated as needed but works best if you can anticipate need and tell it at creation time.

HashMap Example

- Create a HashMap of numbers, using the names of the numbers as keys:

```
Map<String, Integer> numbers
                  = new HashMap<String, Integer>();
numbers.put("one", new Integer(1));
numbers.put("two", new Integer(2));
numbers.put("three", new Integer(3));
```

- To retrieve a number:

```
Integer n = numbers.get("two");
```

- Returns null if the HashMap doesn't contain key
  - Can use numbers.containsKey(key) to check this

Generics and Autoboxing

- Old (pre-Java 5)

```
Map numbers = new HashMap();
numbers.put("one", new Integer(1));
Integer s = (Integer)numbers.get("one");
```

- New (generics)

```
Map<String, Integer> numbers =
new HashMap<String, Integer>();
numbers.put("one", new Integer(1));
Integer s = numbers.get("one");
```

- New (generics + autoboxing)

```
Map<String, Integer> numbers =
new HashMap<String, Integer>();
numbers.put("one", 1);
int s = numbers.get("one");
```

Experimentation

- All of this adds up to some pretty confusing stuff you'll need to learn!
- Don't be afraid to experiment by writing little code fragments and seeing if they compile and what they do.

- But don't write random code hoping that it might work by some miracle.
- Examples in the Sun online JDK manual can be really helpful!
  - Cut and paste from Sun JDK manual is *not* considered to be a violation of academic integrity.
  - So go for it!

Debugging

- Debugging
  - **Do not just make random changes, hoping something will work. This never works.**
  - Think about what could cause the observed behavior
  - Isolate the bug. Focus on the first thing that goes wrong.
- An IDE helps by providing a *Debugging Mode*
  - Can set breakpoints, step through the program while watching chosen variables
  - When program pauses at breakpoint, or dies, can look at values of variables it was using