JAVA REVIEW

Lecture 2

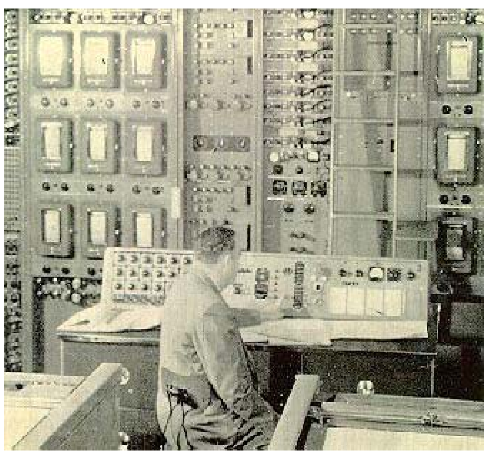
CS2110 Fall 2010

Think about representing graphs

- Last time we discussed idea of abstracting problems such as implementing a GPS tracking device for a bicycle into graph
  - Might imagine a “class” representing graphs
  - Other classes representing nodes, edges
  - Graph operations like *shortest path* used to solve problems like recommending the best route home
- But are computer programming languages well matched to this sort of thing?

Machine Language

- Used with the earliest electronic computers (1940s)
  - Machines use vacuum tubes instead of transistors
- Programs are entered by setting switches or reading punch cards
- All instructions are numbers



- Example code
  - **0110 0001 0000 0110**

    add reg1 6
- An idea for improvement
  - Use words instead of numbers
  - Result: Assembly Language

Assembly Language

- Idea: Use a program (an *assembler) to convert* assembly language into machine code
- Early assemblers were some of the most complicated code of the time (1950s)

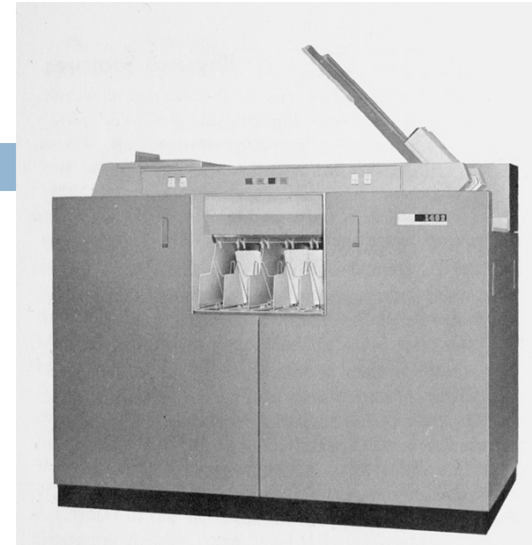
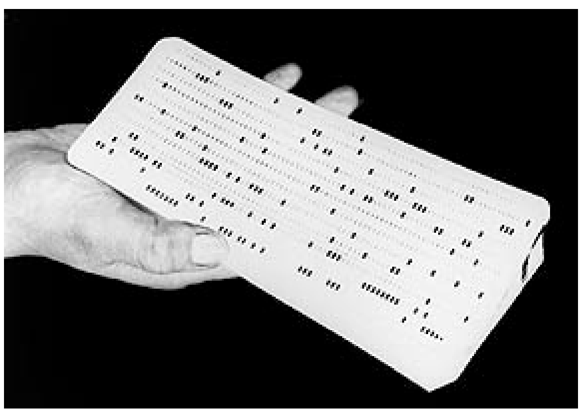


Figure 4. IBM 1402 Card Read-Punch

- Example code

```
ADD   R1   6
MOV   R1   COST
SET   R1   0
JMP   TOP
```

- Idea for improvement
  - Let's make it easier for humans by designing a high level computer language
- Result: high-level languages



High-Level Language

- Idea: Use a program (a *compiler or an interpreter) to* convert high-level code into machine code
- Pro
  - Easier for humans to write, read, and maintain code
- Con
  - The resulting program was usually less efficient than the best possible assembly-code
    - Waste of memory
    - Waste of time
- The whole concept was initially controversial

FORTRAN

- Initial version developed in 1957 by IBM

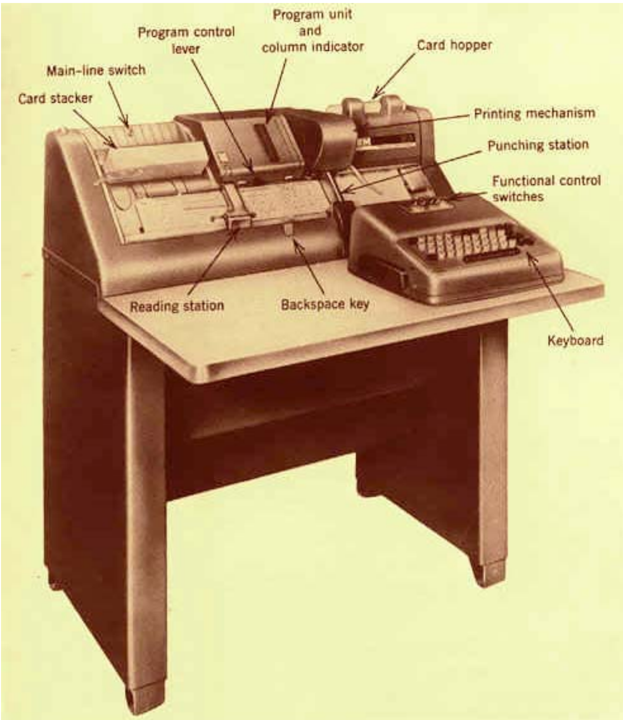


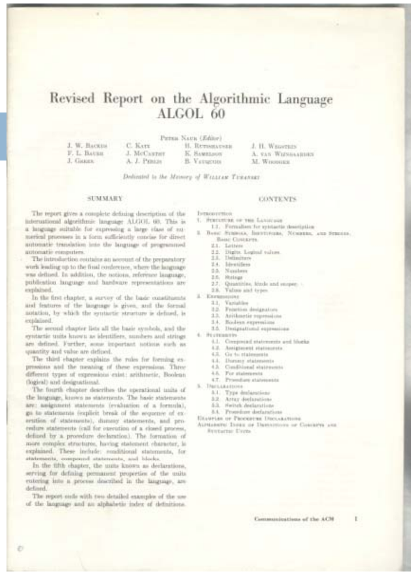
FIGURE 4.11 IBM 026 Keypunch (Courtesy IBM).

- Example code

```
C  SUM OF SQUARES
      ISUM = 0
      DO 100 I=1,10
      ISUM = ISUM + I*I
100   CONTINUE
```

- FORTRAN introduced many high-level language constructs still in use today
  - Variables & assignment
  - Loops
  - Conditionals
  - Subroutines
  - Comments

ALGOL



Revised Report on the Algorithmic Language
ALGOL 60

Peter Naur (Editor)

J. W. Backus, C. Katz, H. Rutishauser, J. H. Wegstein, F. L. Bauer, J. McCarthy, K. Samelson, A. van Wijngaarden, J. Green, A. J. Perlis, B. Vauquois, M. Woodger

SUMMARY

The report gives a complete defining description of the international algorithmic language ALGOL 60. This is a language suitable for expressing a large class of numerical processes in a form sufficiently concise for direct automatic translation into the language of programmed automatic computers.

CONTENTS

- ALGOL
  = ALGOrithmic Language
- Developed by an international committee
- First version in 1958 (not widely used)
- Second version in 1960 (become a major success)

- Sample code

```
comment Sum of squares
begin
        integer i, sum;
        for i:=1 until 10 do
                sum := sum + i*i;
end
```

- ALGOL 60 included *recursion*
  - Pro: easier to design clear, succinct algorithms
  - Con: too hard to implement; too inefficient

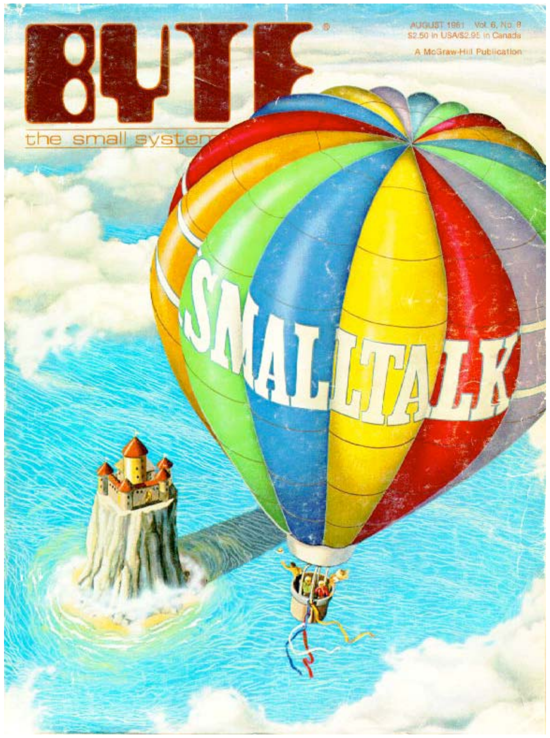
COBOL

- COBOL = COmmon Business Oriented Language
- Developed by the US government (about 1960)
  - Design was greatly influenced by Grace Hopper
- Goal: Programs should look like English
  - Idea was that *anyone* should be able to read and understand a COBOL program

- COBOL included the idea of *records* (a single data structure with multiple *fields,* each field holding a value)

Simula & Smalltalk

- These languages introduced and popularized *Object Oriented Programming (OOP)*
  - Simula was developed in Norway as a language for simulation in the 60s
  - Smalltalk was developed at Xerox PARC in the 70s
- These languages included
  - Classes
  - Objects
  - Subclassing and inheritance



Java – 1995 (James Gosling)

- Java includes
  - Assignment statements, loops, conditionals from FORTRAN (but syntax from C)
  - Recursion from ALGOL
  - Fields from COBOL
  - OOP from Simula & Smalltalk

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?”

Object orientation saves the day!

- For the first time we see a language in which ideas like building a general “graph class” can really be used to solve problems like “build software for a GPS bike tracker” or “solve a puzzle”
- Object oriented languages let us express abstract ideas, and then match them to real problems we face in real applications

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)
  - In languages like FORTRAN, COBOL most data is static.
  - Languages like C and C++ allow us to allocate memory at runtime, but don’t offer a lot of help for managing it

- 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…)

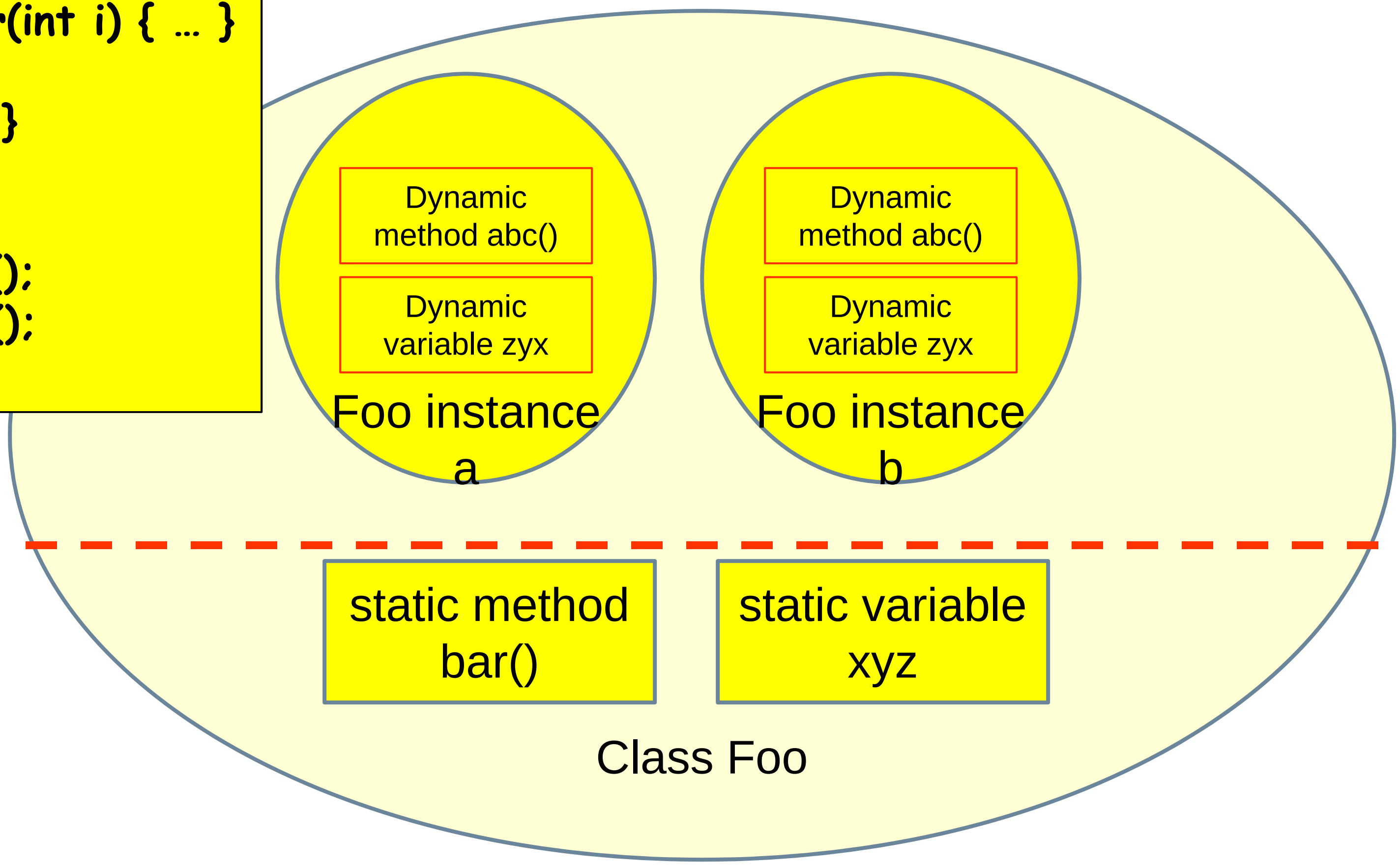
Static methods and variables

- If a method or a variable is declared “static” there will be just one instance for the class
  - Otherwise, we think of each object as having its own “version” of the method or variable
- Anyone can call a static method or access a static variable
- But to access a dynamic method or variable Java needs to know which object you mean

Static methods and variables

```
class Foo {
   static int xyz;
   static void bar(int i) { … }
   int zyx;
   void abc() { … }
}

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



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();
    }
}
```

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
    }
}
```

Relating Graphs to Puzzles and BikeRoutes

- Java provides a way to take a more abstracted idea, such as a "node in a graph" and specialize it
  - For example, we might have a "node in a graph representing a bike ride" and it would contain a GPS coordinate, the time it was measured, the slope of the hill, the cadence of the rider, etc.
  - These specialized graphs should support any operation you can perform on a normal graph, like asking for a path from A to B

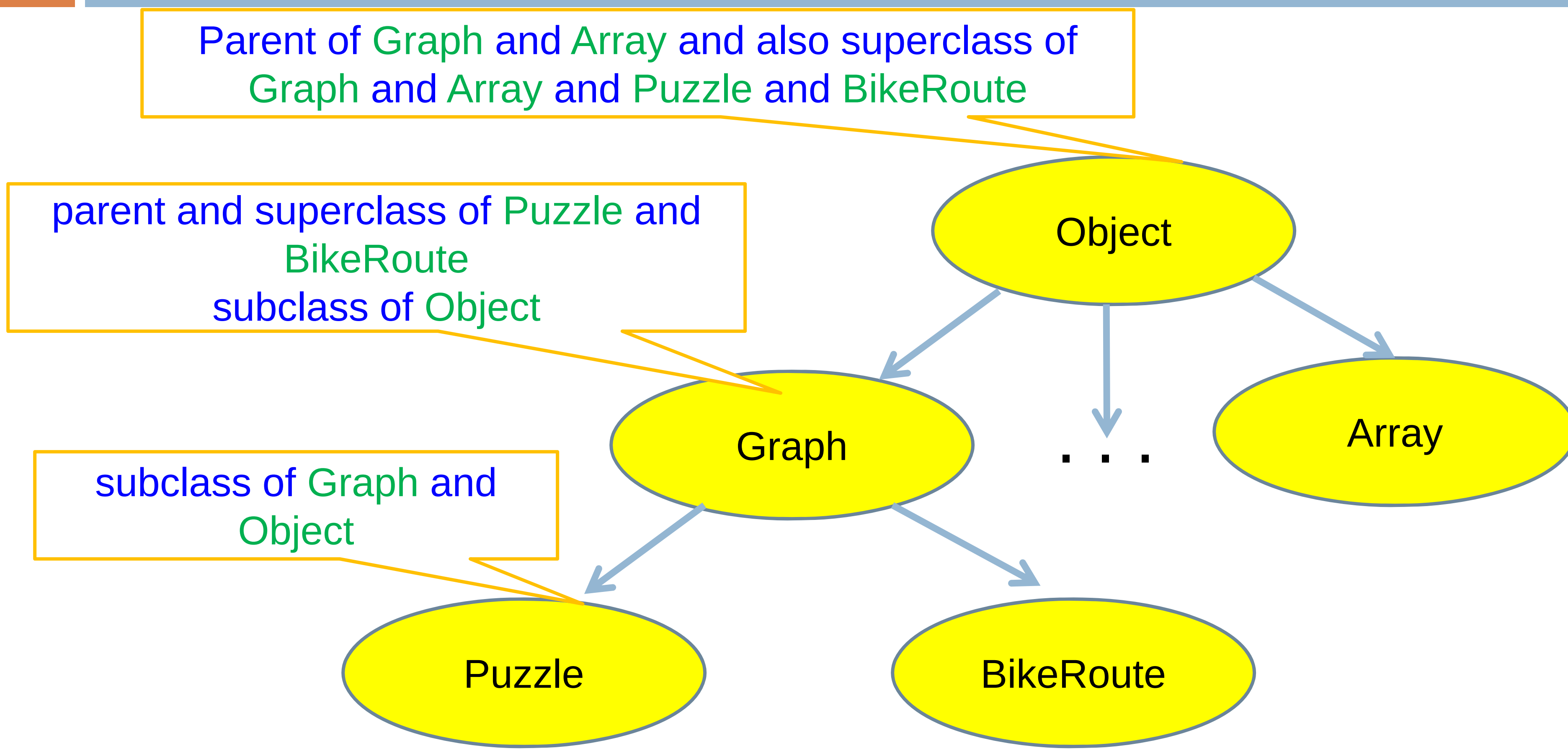
The basic idea

- Suppose we have a package that supports graphs and use it to represent a bike ride
- Now we can ask questions that have graph “aspects” and biking “aspects”
  - For example: “Find the part of my ride that was from Ithaca to Trumansburg on Route 79 via Mecklensburg. How fast was I riding?”
  - “Where was my energy output highest?”

Our challenge

- We want to implement general purpose packages to do things like implement graphs and perform operations on them
- But we also want to create specialized versions of objects like the nodes in the graphs, so that we can represent BikeRoutes and Puzzles and other nodes that have associated state
- For this we use the Class Heirarchy

Class Hierarchy



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

Using the class hierarchy

- Any operation that works on a “graph” can also be performed on a “bike route”
- But bike routes can support additional operations that don’t make sense on a “puzzle”
- This is a very powerful and flexible concept

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 2111");
    }

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

Static vs Instance Example

```
16
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

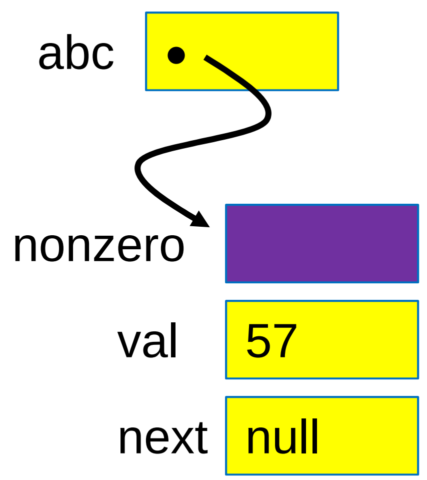
Example: Overloading “compareTo”

- 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
  - String A = "Fred", B = "Fred";
  - What will A == B return?
  - Need to use A.equals(B)

False! A and B are different strings even though their <u>value</u> is the same.

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)

== versus .equals

- A few wrong and then correct examples

What you wrote	How to write it correctly
"xy" == "xy"	**“xy".equals("xy")**
"xy" == "x" + "y"	**"xy".equals("x" + "y")**
“xy" == new String("xy“)	**"xy".equals(new String("xy"))**

== wit … es

“Integer” is an **object** containing an “int” as its underlying value type

- 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...

== with primitive types

```
Integer I;
(I == null)?   Uninitialized
(I == 0)?      Null ref. ex.
```

```
Integer I = new Integer(0);
(I == null)?   False
(I == 0)?      True
```

```
int i;
(i == null)?  Undefined
(i == 0)?     Uninitialized
```

```
static int i;
(i == null)?  Undefined
(i == 0)?     True
```

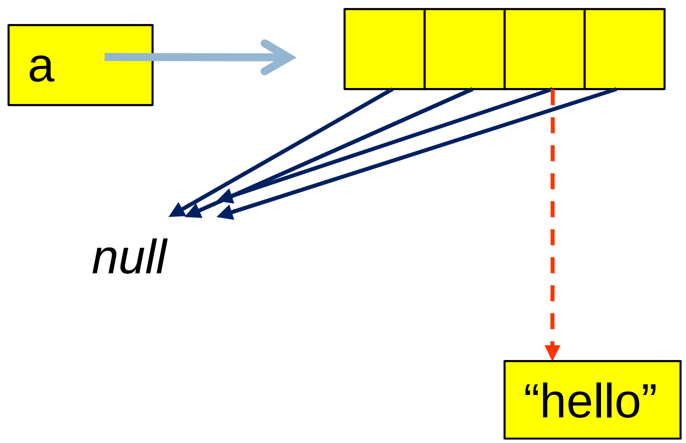
Arrays

- Arrays are reference types
- Array *elements* can be reference types or primitive types
  - E.g., **int[]** or **String[]**
- **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"

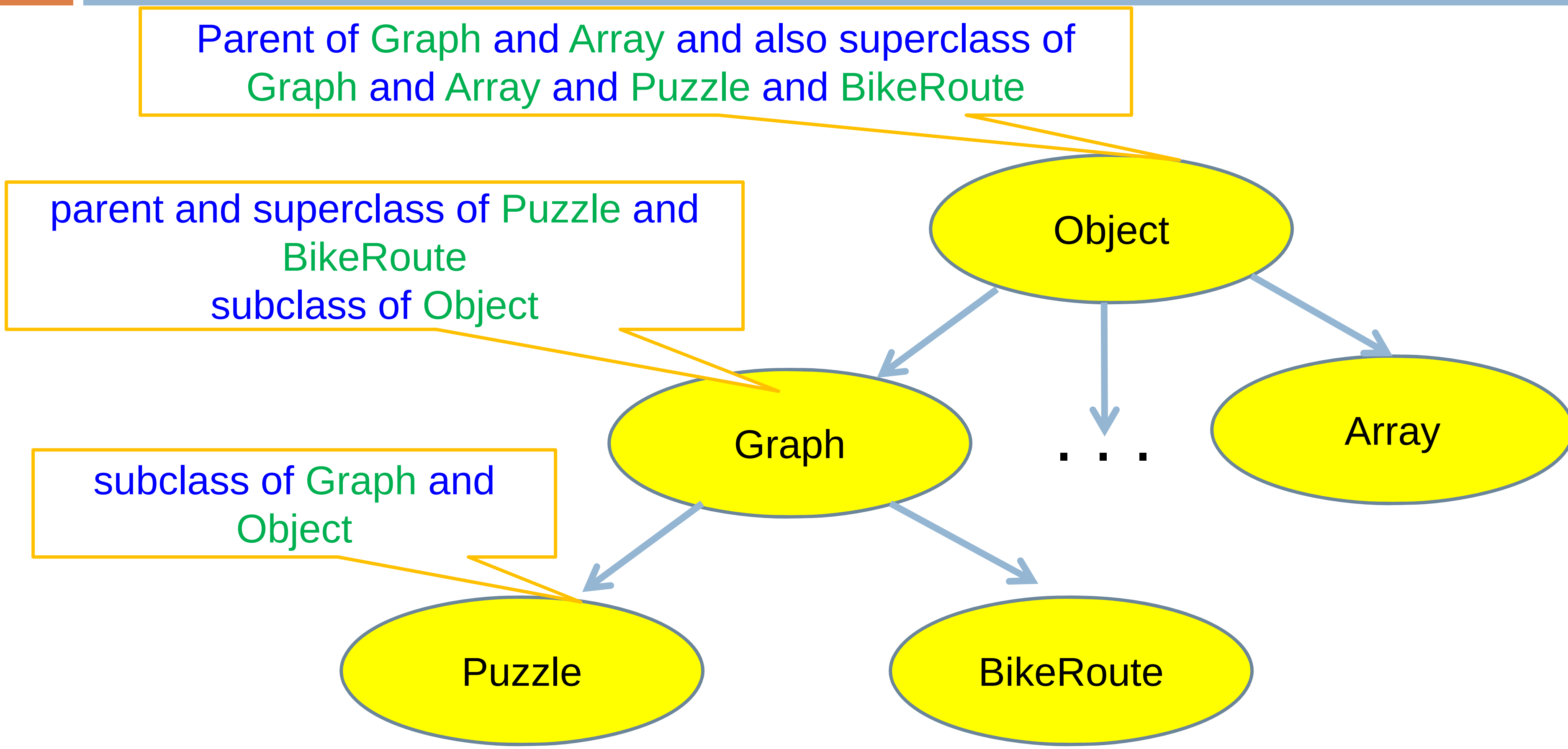


a.length = 4

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);
        }
    }
}
```

Let’s Revisit the 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

Accessing Overridden Methods

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

Unexpected Consequences

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

```
class A {
    public int m() {...}
}
class B extends A {
    private int m() {...} //illegal!
}

A foo = new B(); // upcasting
foo.m();         // would invoke private method in
                 // class B at runtime
```

… 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.
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public class override_test {
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        B b = new B();
        System.out.println(b.i);               // Refers to B.i; prints 2.
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        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”!