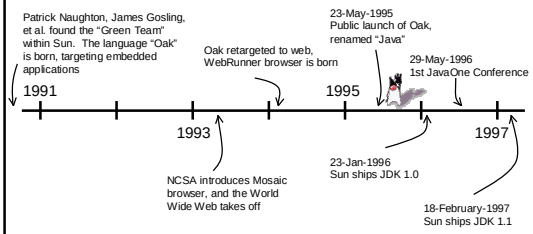
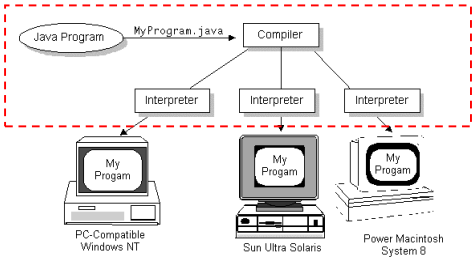
Java simple, object-oriented, distributed, interpreted, robust, secure, architecture neutral, portable, high-performance, multithreaded, and dynamic language."
— Sun

Alan Borning
(stolen from Greg J. Badros)
University of Washington
CSE 341, Spring 2002

Java: A Timeline



Java: The Language



Hello World!

HelloWorld.java

```
/** Application HelloWorld
    Just output "Hello World!" */
public class HelloWorld {
    public static void main(String[] args) {
        System.out.println("Hello World!");
    }
}
```


```
% javac HelloWorld.java
% java HelloWorld
Hello World!
```


Java vs. C++

```
/** Application HelloWorld  */
public class HelloWorld {
  public static void main(String[] args) {
    System.out.println("Hello World!");
  }
}
```

```
// Application HelloWorld

#include <iostream.h>

int main(int argc, char* argv[]) {
   cout << "Hello World!" << endl;
}
```


Unlike C++, Java has....

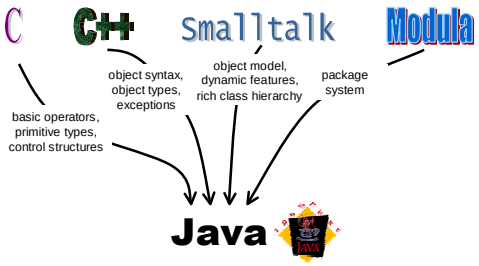
- No global functions — everything is in a class!
- Real String objects — not just char[]
- No pointers — everything is a reference
- No user operator overloading
- No preprocessor — cpp not needed
- unicode instead of ascii

Command Line Arguments

PrintArgs.java

```
/** Application PrintArgs
    prints the command line arguments */
public class PrintArgs {
    public static void main(String[] args) {
        for (int i = 0; i < args.length; i++)
            System.out.println(args[i]);
    }
}
```


Brewing Java



Java vs. C++, Revisited

JAVA

```
Ball ball = new Ball(50, 50);
PinballAnimationPane pap = new PinballAnimationPane();
pap.addObject(ball);
ball.animate();
```

C++ (pointer-style)

```
Ball *pball = new Ball(50,50);
PinballAnimationPane *pxpap = new PinballAnimationPane();
pxpap->addObject(pball);
pball->animate();
```

C++ (reference-style)

```
Ball ball(50,50);                   // creates ball on stack
PinballAnimationPane xpap();        // creates xpap on stack
xpap.addObject(ball);               // calls: addObject(Ball &b);
ball.animate();
```


Java's Hybrid Object Model

- Primitive types on stack
  - May be *wrapped* or *boxed* into a real object
    Integer anInteger = new Integer(43);
    (useful for storing in java.util.*'s collections)
  - Unboxed primitives very similar to in C++
- All object instances live in the heap (**not** stack)
  - all object creation is done with new
  - No "delete" — Java uses garbage collection, but also provides finalize() method

Primitive types in Java

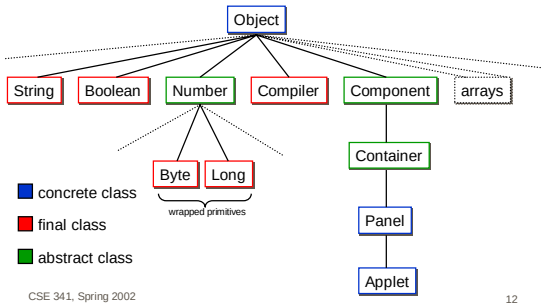
- boolean
- char (16-bit) //unicode
- byte (8-bit signed)
- short (16-bit signed)
- int (32-bit signed)
- long (64-bit signed)

} Integer types

- float (32-bit signed)
- double (64-bit signed)

} Floating point types

Java's Class Hierarchy



Java Documentation

HelloWorld Applet

HelloWorldApplet.java

```
import java.applet.*;  import java.awt.*;

public class HelloWorldApplet extends Applet {
   static final String message = "Hello World";
   private Font font;
   public void init() {   // one-time initialization
      font = new Font("Helvetica", Font.BOLD, 48);  }
   public void paint(Graphics g) {
      g.setColor(Color.yellow);          g.fillOval(10, 10, 330, 100);
      g.setColor(Color.red);
      g.drawOval(10, 10, 330, 100);      g.drawOval(9, 9, 332, 102);
      g.drawOval(8, 8, 334, 104);        g.drawOval(7, 7, 336, 106);
      g.setColor(Color.black);           g.setFont(font);
      g.drawString(message, 40, 75);
   } }
```


Running the HelloWorld Applet

HelloWorldApplet.html

```
<APPLET   code="HelloWorldApplet.class"
          width=350 height=120> Java Missing
</APPLET>
```

Add "." to your $CLASSPATH, then
% appletviewer HelloWorldApplet.html

Run on the .html file

Or use a web browser on the .html file ...

Methods: A Closer Look

```
public class Point {
  . . .
  public void move(int dx) {
    x += dx;
    moved();
  }
  private void moved() { . . }
  private int x, y;
}
```

```
public class Point {
  . . .
  public void move(int dx) {
    this.x += dx;
    this.moved();
  }
  private void moved() { . . }
  private int x, y;
}
```

- this is implicit on instance fields and methods
  - can be explicit if the field is hidden by a local or formal
  - analogous to self in Smalltalk
- also super keyword, as in Smalltalk (no C++ :: operator)
  - also used for constructor chaining with arguments

More on Methods

- Instance methods (no static keyword)
  - have implicit this argument
  - can use super keyword
  - no need to use "->" operator as in C++ just . operator since this, super are references
- static (class) methods
  - do not have implicit this argument
  - cannot use the super keyword

Default Arguments

- No language support— must use overloading instead

```
public class Point {
  public Point()              { this(0,0); }
  public Point(int x, int y)  { this.x =x; this.y=y; }
  public void move()          { move(1); }
  public void move(int dx)    { x += dx; }
  private int x, y;
}
```

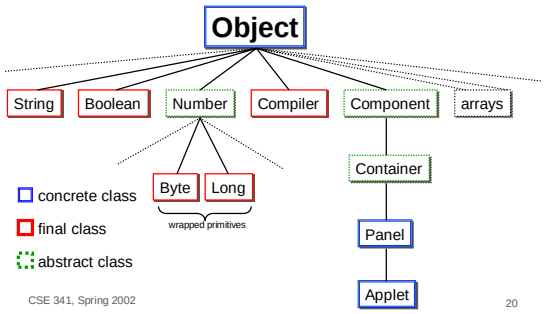
special use of "this"

Note: two different x's and y's

"Override" vs. "Overload"

- **Override**
  - replace a superclass's method with a specialized version
  - signatures must match
    (including return type; C++ permits narrowing of return types, Java does not)
- **Overload**
  - write several methods for a given class with the same name
  - language can disambiguate based on number or types of arguments

Java's Class Hierarchy



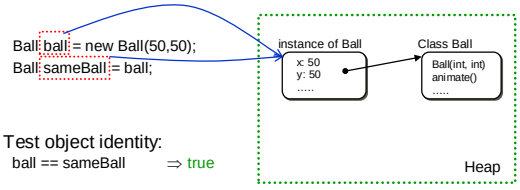
What can an Object do for you today?

- Object clone()
  Return a duplicate copy of self
- boolean equals(Object obj)
  Defaults to == but can be overridden.
- String toString()
  Return printable representation of self
- int hashCode()
  Return a reasonable hash code for self
- Class getClass()
  Return the class object for self

More on equals()

```
public class Ball {
  public Ball(int x, int y)    { this.x =x; this.y=y; }

  public boolean equals(Object b) {
    // && doesn't evaluate its second arg unless
    //necessary
    return (b instanceof Ball &&
      x==b.x && y==b.y)
  }
}
```

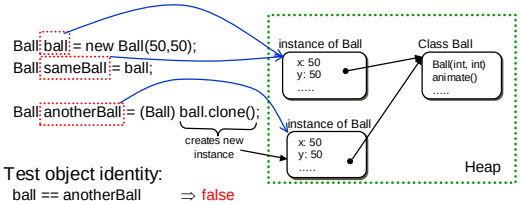

Objects and Identities



Test object identity:
ball == sameBall ⇒ true

Test object value's equality:
ball.equals(sameBall) ⇒ true

Cloning Objects



Test object identity:
ball == anotherBall ⇒ false

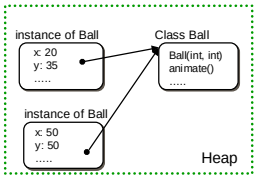
Test object value's equality:
ball.equals(anotherBall) ⇒ true

Changing a Ball

ball.setPosition(20,35);

sameBall

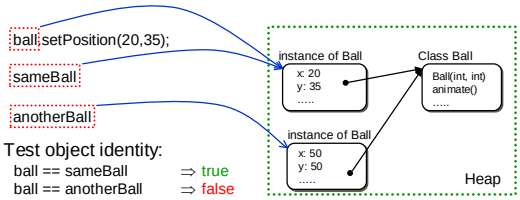
anotherBall



Test object identity:
- ball == sameBall ⇒ ???
- ball == anotherBall ⇒ ???

Test object value's equality:
- ball.equals(sameBall) ⇒ ???
- ball.equals(anotherBall) ⇒ ???

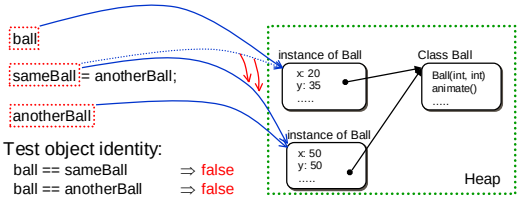
Inequality in Balls!



Test object identity:
- ball == sameBall ⇒ true
- ball == anotherBall ⇒ false

Test object value's equality:
- ball.equals(sameBall) ⇒ true
- ball.equals(anotherBall) ⇒ false

Assignment just changes the pointer



Test object identity:
- ball == sameBall ⇒ false
- ball == anotherBall ⇒ false

Test object value's equality:
- ball.equals(sameBalll) ⇒ false
- ball.equals(anotherBall) ⇒ false

Java variables hold...

- primitive

```
boolean foo;          // boolean, not bool as in C++
char aChar = 'a';     // 16 bit char (unicode)
```

- Object reference (may be null)

```
ColoredBall cball = new ColoredBall();
Ball ball = cball;
```

- Array reference

```
int[] intArray = { 1, 2, 3, 4, 5, };
String[] strArray = { "Hello", "World", };
// same as
String[] strArray = new String[2];
strArray[0] = new String("Hello");
strArray[1] = new String("World");
```

String literals actually invoke constructor e.g., new String("World")

Arrays

- Java arrays are 1st-class Objects
- 0-indexed
- Bounds checking performed
- Store/Retrieve using [] operator
  strArray[0] = strArray[1];
- Have implicit length field
  strArray.length ⇒ 2

A field, **not** a method!

Similar to:

2-d and 3-d Arrays

- No special language support for 2-d arrays -- just make an array of arrays

```
public class myArray {
  public static void main (String[] args) {
    double [] [] mat = {{1., 2., 3., 4.}, {5., 6., 7., 8.},

                        {9., 10., 11., 12.}, {13., 14., 15., 16.}};
    for (int y = 0; y < mat.length; y++) {
      for (int x = 0; x < mat[y].length; x++)
        System.out.print(mat[y][x] + " ");
        System.out.println();   }}}
```

Strings

- The String class provides read-only strings and supports operations on them
- A String can be created implicitly either by using a quoted string (e.g. "HUB food") or by the concatenation of two String objects, using the + operator.

Strings are Immutable

Since you cannot modify existing strings, there are methods to create new strings from existing ones.

- public String substring(int beginIndex, int endIndex)
- public String replace(char oldChar, char newChar)
- public String concat(String str)
- public String toLowerCase()
- public String toUpperCase()
- public String trim()

Identifiers

- Everything has a globally-unique name

```
Java.lang.String
Java.util.Hashtable
Java.applet.Applet
EDU.Washington.grad.gjb.cassowary.Variable.toString()
```

Package name | Class name | Method name

- Pretty wordy, so...

import statement

- Two forms:
  - import java.util.HashTable;
    Just make the HashTable class available from package java.util
  - import EDU.Washington.grad.gjb.cassowary.*;
    Make all classes from package available on demand
- Always an implicit "import java.lang.*"
- Permits using simple (short) names

How Java Finds a Class...

- Package names mirror the directory structure
- package statement informs the compiler

./EDU/Washington/grad/gjb/cassowary/Variable.java

```
package EDU.Washington.grad.gjb.cassowary;

public class Variable extends AbstractVariable {
    ...
}

class Helper { ... }
```


Compilation of Source File

```
% ls
Variable.java
% javac Variable.java
% ls
Variable.java
Variable.class
Helper.class
```

One java source file may create multiple .class files containing the byte-compiled code

Class Access Protection

```
package EDU.Washington.grad.gjb.cassowary;

public class Variable extends AbstractVariable {
    . . .
}

class Helper { ... }
```

- Only one public class per file
- No specifier ⇒ package protection
  - visible to all classes in the package
  - no "package" keyword — remember it is a statement

Private: most restrictive access modifier

```
public class Point {
  private int x, y;
  void setXY(int x, int y) {
    this.x = x; this.y = y;
  }
  protected void move(int x, int y) {
    setXY(this.x+x, this.y+y);
  }
  public int getX() { return x; }
  public int getY() { return y; }
}
```

same class	class in same package	subclass in different package	non-subclass, different package	
Y	N	N	N	private
Y	Y	N	N	*package*
Y	Y	Y	N	protected
Y	Y	Y	Y	public

Java Accessibility vs. C++

- No "friend" keyword
- Every field or method has an access specifier (no "public:" sections)
- Default is package-visibility which has no associated keyword (not private)

No Need for Forward Declarations

```
public class Point {                          Definition
  private PointColor c;                       Use
  // setXY(int,int) used below before its definition in the source
  protected void move(int x, int y) { setXY(this.x+x, this.y+y); }
  void setXY(int x, int y) { this.x = x; this.y = y; }
  private int x, y;
} // no trailing semicolon (C++ requires one)

// PointColor already used above before this definition
class PointColor {
  byte red, green, blue;
}
```


Final Fields

```
public final class Circle {
  private final double MY_PI = 3.1415;
  public double area() { return MY_PI * r*r; }
}
```

- final fields correspond to C++'s "const"
- final fields cannot be changed once initialized
- cannot use final in function signatures
  (less flexible than C++— const is an unused reserved word in Java)

Ball and CBall Example

BallExample/Ball.java

```
package BallExample;
public class Ball implements Bounceable {
    private int x, y;
    public Ball(int x, int y) {
        this.x=x; this.y = y;
    }
    public void Bounce() {
        System.err.println("Ball bounces");
    }
    static public void ClassFn() {
        System.err.println("Ball.ClassFn()");
    }
}
```

BallExample/CBall.java

```
package BallExample;
public class CBall extends Ball {
    private int colorSelector;
    public CBall(int x, int y) {
        super(x,y);        // chain constructors
        colorSelector = 0; // for black
    }
    public void Bounce() {
        System.err.println("CBall bounces");
    }
    static public void ClassFn() {
        System.err.println("CBall.ClassFn()");
    }
}
```

Inheritance Mechanisms

- extends *superclass*
  - similar to ": public" in C++
  - for expressing an "is-a" relation
- implements *superinterface*
  - similar in use to C++'s multiple inheritance
  - for expressing an "is-capable-of" or "knows-how-to" relation

Accessing Inherited Methods

- As previously discussed, the keyword this refers to the object on which the method was invoked (even if the method itself was found by chasing up the superclass hierarchy).
- The keyword super functions similarly, except that the method lookup starts in the superclass of the class in which the method was found.

Java Interfaces

```
public interface Bounceable {
    public void Bounce();
    private void BounceNow();  // error
}
```

```
public interface BounceDropable
                    extends Bounceable {
    public void Drop();
}
```

- Interfaces can only specify public methods
- Similar to protocols in Smalltalk
- May be used as a type for a variable
- Can specify sub-interfaces
  and can extend multiple interfaces at a time

Bounceable Interface

BallExample/Bounceable.java

```
package BallExample;
public interface Bounceable {
    public void Bounce();
}
```

Errors?

Output?

BallExample/BallTest.java

```
package BallExample;
public class BallTest {
    public static void main(String[] args) {
        Ball b1 = new Ball(10,10);
        Ball b2 = new CBall(20,20);
        Bounceable b3 = new Ball(30,30);
        Bounceable b4 = new CBall(40,40);

        b1.Bounce();        b2.Bounce();
        b3.Bounce();        b4.Bounce();

        b1.ClassFn();       b2.ClassFn();
        b3.ClassFn();       b4.ClassFn();

        CBall cb1 = (CBall) b1;
        CBall cb2 = (CBall) b2;
        cb2.ClassFn();
    }  } // end class
```


Ball Example Output and Errors

```
% java BallExample.BallTest
Ball bounces
CBall bounces
Ball bounces
CBall bounces
Ball.ClassFn()
Ball.ClassFn()
CBall.ClassFn()
```

BallExample/BallTest.java

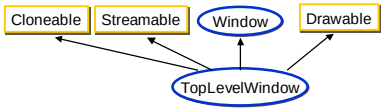
```
package BallExample;
public class BallTest {
    public static void main(String[] args) {
        Ball b1 = new Ball(10,10);
        Ball b2 = new CBall(20,20);
        Bounceable b3 = new Ball(30,30);
        Bounceable b4 = new CBall(40,40);

        b1.Bounce();        b2.Bounce();
        b3.Bounce();        b4.Bounce();

        b1.ClassFn();       b2.ClassFn();
// compile time errors
//      b3.ClassFn();       b4.ClassFn();

//      CBall cb1 = (CBall) b1;  ClassCastException
        CBall cb2 = (CBall) b2;  // ok
        cb2.ClassFn();
    }  } // end class
```


Types vs. Classes

- Types
  - variables have types
  - used for checking validity of method invocations
  - may be an interface
- Classes
  - objects (i.e. instances) have classes
  - used for dynamic dispatch
    (binding of non-static function call)
  - Each class has a corresponding type —
    that hierarchy of types mirrors the class hierarchy

Multiple Inheritance in Java

- A Java class can extend (subclass) another class and implement multiple interfaces




```
public class TopLevelWindow extends Window
    implements Drawable, Cloneable, Streamable
    { . . . }
```


Abstract Methods and Abstract Classes

```
// Note abstract keyword is used for the class, too
public abstract class Shape {
  public abstract void rotate(int);     // no definition
  public abstract double area();        // no definition
}
```

- abstract methods correspond to C++'s "pure virtual functions" (But C++ uses "=0" syntax, and permits an implementation)
- abstract methods must be overridden in concrete subclasses
- Only abstract classes can have abstract methods (C++ infers abstract classes, Java requires you mark the class explicitly)

Final Methods

```
public class Circle {
  ....
  public final double area() { return Math.PI * r*r; }
  double r;           // radius
}
```

- final methods cannot be overriden
- final methods may be inlined (no "inline" keyword)
- similar to non-virtual member functions in C++ (but those can be overriden, they just do not dispatch dynamically)

Final Classes

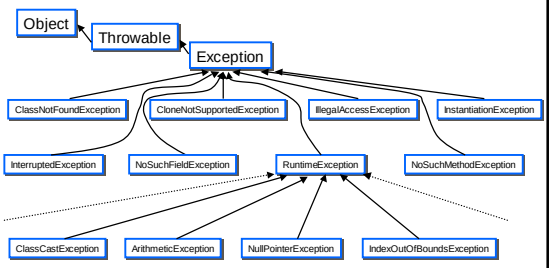
```
public final class Circle {
  ....
  public double area() { return Math.PI * r*r; }
  double r;           // radius
}
```

- final classes cannot be subclassed — they are leafs in the class hierarchy
- methods in final classes are implicitly final
- provides compiler with optimization opportunities

try { throw } and catch, finally (exceptions)

```
class ExceptionExample {
  static public void main(String args[]) {
    try {
      // allocate some resource (besides memory)
      doSomething();
      if (!FThingsAreOkay()) {
        throw new RuntimeException("Things not ok");
      }
      doSomethingElse();
    } catch (RuntimeException e) {
      System.err.println("Runtime Exception: " + e);
    } catch (Exception e) {              // similar to "catch (..)" in C++
      System.err.println("Exception: " + e);
    } finally {                          // finally is not in C++
      // cleanup resource
    } }
```


Exception Hierarchy



Threads


```
public class Pendulum extends Applet implements Runnable {
   private Thread myThread;
   public void start() {
      if (myThread == null) {
         myThread = new Thread(this,"Pendulum");
         myThread.start();
      }
   }
   public void run() {
      while (myThread != null) {
         try { myThread.sleep(100); }
         catch (InterruptedException e) { /* do nothing */ }
         myRepaint();
      }
    }
   public void stop() { myThread.stop(); myThread = null; }
}
```

set thread's target to this Pendulum class, and use its run() method

Ref: Boone's *Java Essentials for C and C++ Programmers*

Summary: What Java Left Out from C++

- No stack objects, only heap objects
- No destructors, only finalize() method
- No pointers, everything is a reference
- No delete, garbage collector instead
- No const, only final (methods, fields, classes)
- No templates, no preprocessor
- No operator overloading
- No multiple inheritance of classes
- No enumerations or typedefs

Summary: What Java Put In (vs. C++)

- Garbage collector
- Object-rooted, rich class hierarchy
  Strings, first-class arrays with bounds checking
- Package system with import
- interface, implements, extends, abstract
- finally blocks, static/instance initializers
- Secure and portable JavaVM, threads
- Dynamic reflection capabilities, inner classes
- JavaDoc system