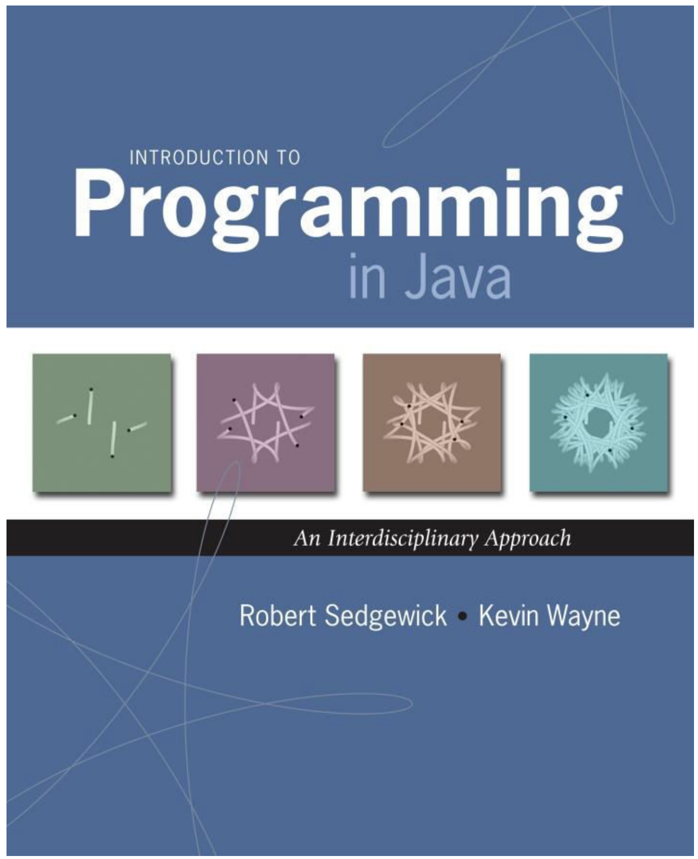
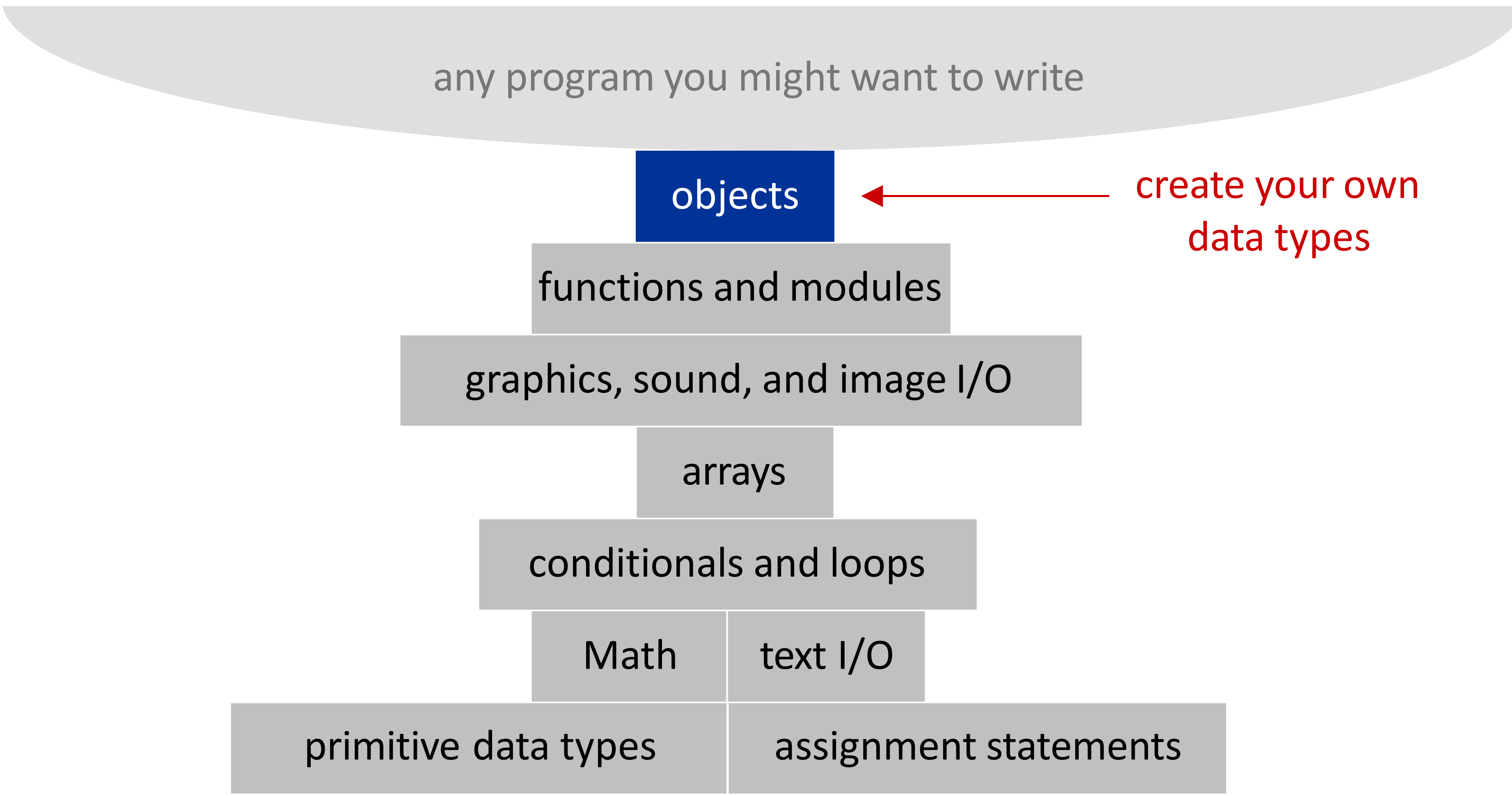
3.1 Objects


INTRODUCTION TO
Programming
in Java
An Interdisciplinary Approach
Robert Sedgewick • Kevin Wayne

A Foundation for Programming



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Data Types

Data Types: set of values and associated operations

Primitive Types:

- values map directly to the machine representation
- ops map directly to machine instructions

Data Type	Set of Values	Operations
boolean	**true**, **false**	not, and, or, xor
int	**-2^{31}** to **$2^{31} - 1$**	add, subtract, multiply
double	any of 2^{64} possible reals	add, subtract, multiply

We want to write programs that handle other data types

- colors, pictures, strings, input streams, …
- complex numbers, vectors, matrices, polynomials, …
- points, polygons, charged particles, celestial bodies, …

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Objects

Objects: represent values and operations for more complex data types

- Object variables are called <u>fields</u>
- Object operations are called <u>methods</u>

Data Type	Set of Values	Operations
`Color`	24 bits	get red component, brighten
`Picture`	2D array of colors	get/set color of pixel (i, j)
`String`	sequence of characters	length, substring, compare

Objects can be created and referenced with variables

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Object-Oriented Programming

Programming paradigm that views a program as a collection of interacting objects

- In contrast, the conventional model views the program as a list of tasks (subroutines or functions)

We'll talk about how to:

- Create your own data types (set of values and operations)
- Use objects in your programs (e.g., manipulate objects)

Why would I want to use objects in my programs?

- Simplify your code
- Make your code easier to modify
- *Share an object with a friend*

Defining Your Own Objects with Classes

- Classes are blueprints or <u>prototypes</u> for new objects

- Classes define all <u>field</u> and <u>method</u> declarations

  … which are repeated for each new object created

- Using a class to create a new object is called *<u>instantiating</u>* an object

  … creating a new object <u>instance</u> of the class

- Classes often model real-world items

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The String Object

Fields:

- ???

Methods:

- **`boolean equals(String anotherString)`**
- **`int length()`**
- **`String substring(int beginIdx, int endIdx)`**
- **`String toLowerCase()`**
- **`String toUpperCase()`**
- **`...`**

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http://download.oracle.com/javase/1.4.2/docs/api/

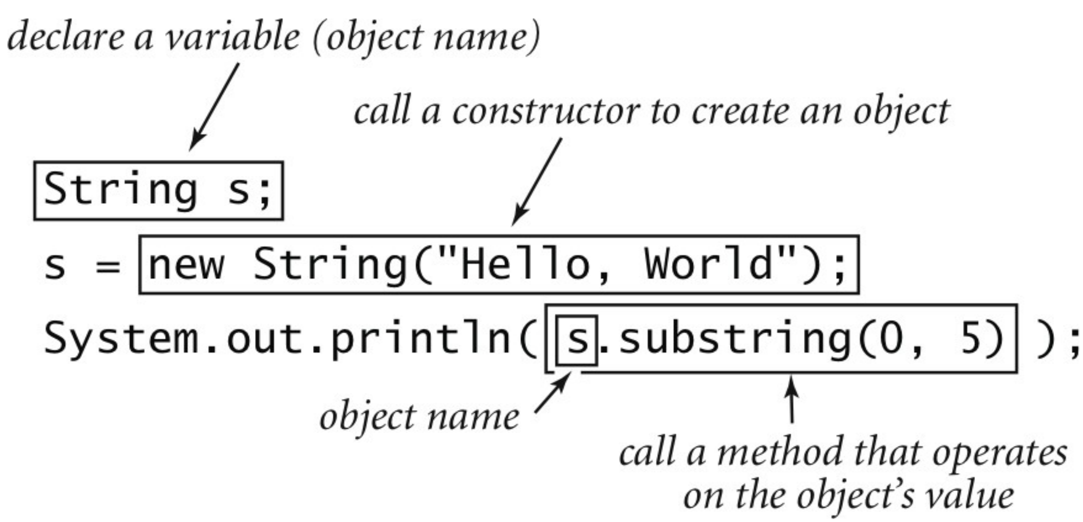
Constructors and Methods

To construct a new object:

- Use keyword `new` (to invoke constructor)
- Use name of data type (to specify which type of object) with associated parameters for the constructor

To apply an operation:

- Use name of object (to specify which object)
- Use the dot operator (to access a member of the object)
- Use the name of the method (to specify which operation)



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Constructors

- A special method that is used in order to instantiate an object

```
String s = new String("Hello World");
```

- If we made a Person class where you could create people with different names then you create a new person object by doing

```
Person p = new Person("Arvind");
```

- Rule – Constructor has the same name as the name of the class.

Encapsulation

Objects are said to <u>encapsulate</u> (hide) their details

- How an object is implemented is not important
- What it does is important

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Access Control

- Encapsulation is implemented using ***access control***.
  - Separates interface from implementation
  - Provides a boundary for the client programmer
- Visible parts of the class (the ***interface***)
  - can be used and/or changed by the client programmer.
- Hidden parts of the class (the ***implementation***)
  - Can be changed by the class creator without impacting any of the client programmer's code
  - Can't be corrupted by the client programmer

Access Control in Java

- ***Visibility modifiers*** provide access control to <u>instance variables</u> and <u>methods</u>.
  - ***public*** visibility - accessible by everyone, in particular the client programmer
    - A class' interface is defined by its public methods.
  - ***private*** visibility - accessible only by the methods within the class
  - Two others—***protected*** and **package**—outside the scope of this course

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Good Programming Practice

- Combine methods and data in a single class
- Label <u>all</u> instance variables as **private** for information hiding
  - The class has complete control over how/when/if the instance variables are changed
  - Fields primarily support class behavior
- Minimize the class' public interface
- Public interface should offer only those methods that a client needs in order to 'interact' with the class

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Using **this**

You can think of `this` as an implicit private reference to the current instance.

```
Date
=== public ====
Date()
int getYear()
  ...
=== private ===
int month
int day
int year
Datethis
  ...
```

```
Date b1 = new Date();
```

b1
C0

registers

addr	value	
C0	1	month
C1	1	day
C2	1900	year
C3	C0	this
C4	?	
C5	?	
C6	?	

main memory
(64-bit machine)

Note that `b1.year` and `b1.this.year` refer to the same field

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Comparing Declarations and Initializers

```
int       i;
int       j    = 3;
float     f    = 0.1;
float[]   f2   = new float[20];
String    s1   = "abc";
String    s2   = new String("abc");
Ball      b    = new Ball();

Ball[]    b2   = new Ball[20];
for (int i =0;  i < b2.length; i++) {
    b2[i]= new  Ball();
}
```

Where to Write Your Class

- Generally put each class in a separate file
- A class named MyClass is expected to be found in a file named MyClass.java
- Declare the class to be public
- This class can now be used as a 'data type' in your other programs

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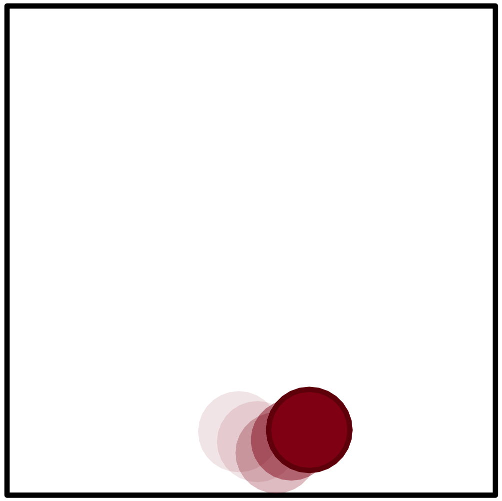
Bouncing Ball Object

- What do we want to have the ball do?
  (i.e., what methods should it have?)

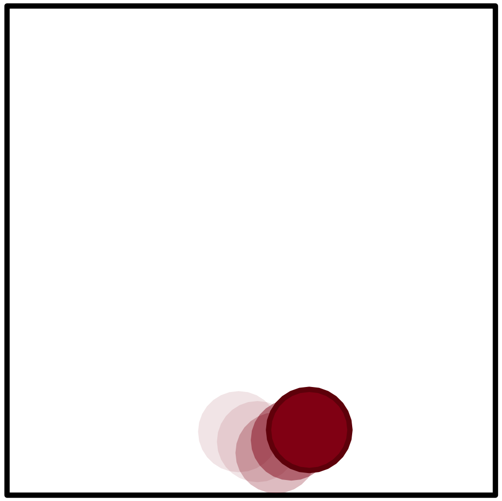


- What initial parameters should we specify in the constructor?

Bouncing Ball Object

- What do we want to have the ball do?

  (i.e., what methods should it have?)
  - void draw() : "Ball, draw thyself!"
  - void update() : simulate the ball's motion



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Bouncing Ball Object

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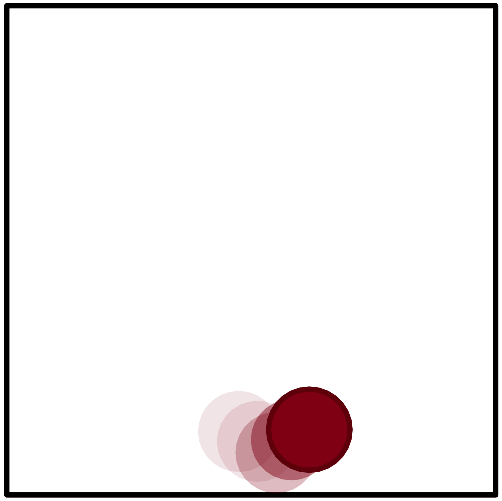

- What initial parameters should we specify in the constructor?
  - Ball() : creates a ball at a random location
  - Ball (int x, int y) : creates a ball at (x, y)

These methods constitute the ball's API (Application Programming Interface)

Bouncing Ball Object

Given only the API, we can use the object in a program:

```
static Ball[] balls = new Ball[20];

public class BouncingBallStdDraw {

    public static void main(String[] args) {
        for (int i=0; i< balls.length; i++){
            balls[i] = new Ball();
        }
        for (int i =0; i <300; i++){
            StdDraw.clear();
            for (int j=0; j < balls.length; j++)
                balls[j].draw();
            StdDraw.show(200);
            for (int j=0; j< balls.length; j++)
                balls[j].update();
        }
    }
}
```

Declare an array of Balls.

```
Ball
-------------------
Ball()
Ball(int x, int y)
void draw()
void update()
```

New objects are created with the ***new*** keyword.

Methods of objects stored in the array are accessed using dot-notation.

Object References

- Allow client to manipulate an object as a single entity
- Essentially a machine address (pointer)

```
Ball b1 = new Ball();
b1.update();
b1.update();

Ball b2 = new Ball();
b2.update();

b2 = b1;
b2.update();
```

addr	value
C0	0
C1	0
C2	0
C3	0
C4	0
C5	0
C6	0
C7	0
C8	0
C9	0
CA	0
CB	0
CC	0

main memory
(64-bit machine)

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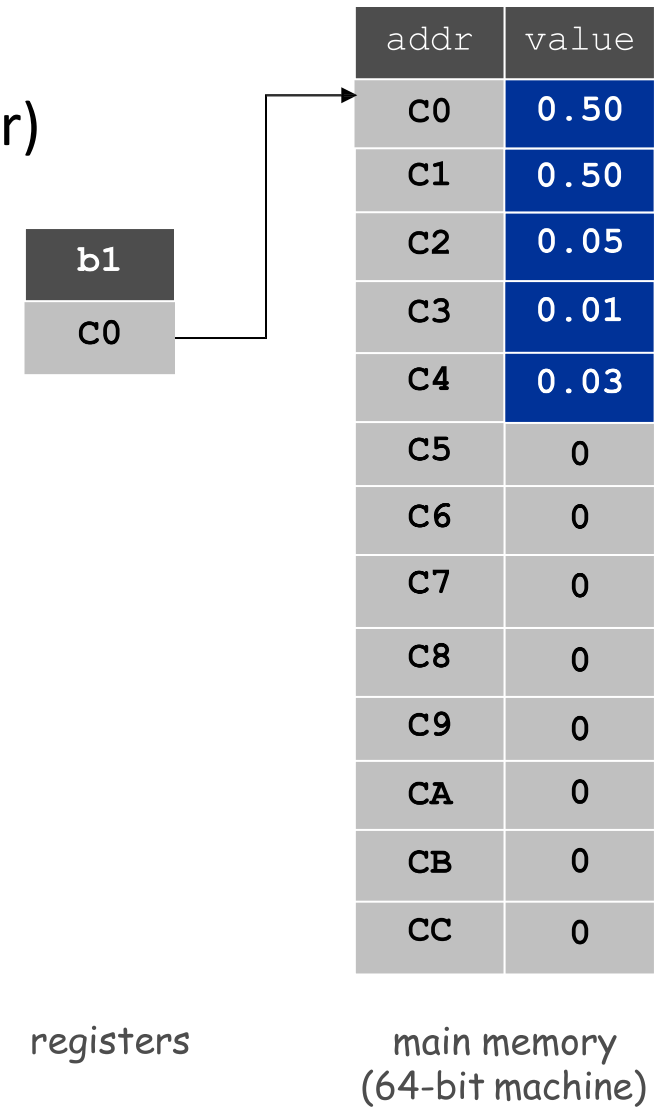

Object References

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Ball b1 = new Ball();
b1.update();
b1.update();

Ball b2 = new Ball();
b2.update();

b2 = b1;
b2.update();
```

b1
C0

registers

addr	value
C0	0.55
C1	0.51
C2	0.05
C3	0.01
C4	0.03
C5	0
C6	0
C7	0
C8	0
C9	0
CA	0
CB	0
CC	0

main memory (64-bit machine)

Object References

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```
Ball b1 = new Ball();
b1.update();
b1.update();

Ball b2 = new Ball();
b2.update();

b2 = b1;
b2.update();
```

b1
C0

registers

addr	value
C0	0.60
C1	0.52
C2	0.05
C3	0.01
C4	0.03
C5	0
C6	0
C7	0
C8	0
C9	0
CA	0
CB	0
CC	0

main memory
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Object References

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```

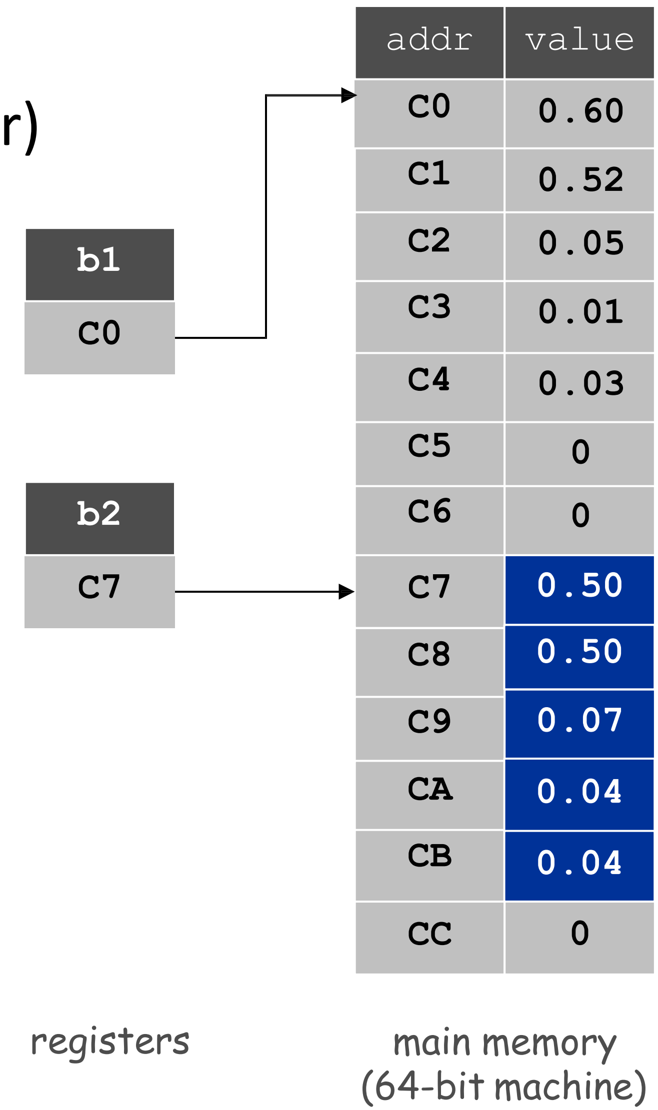

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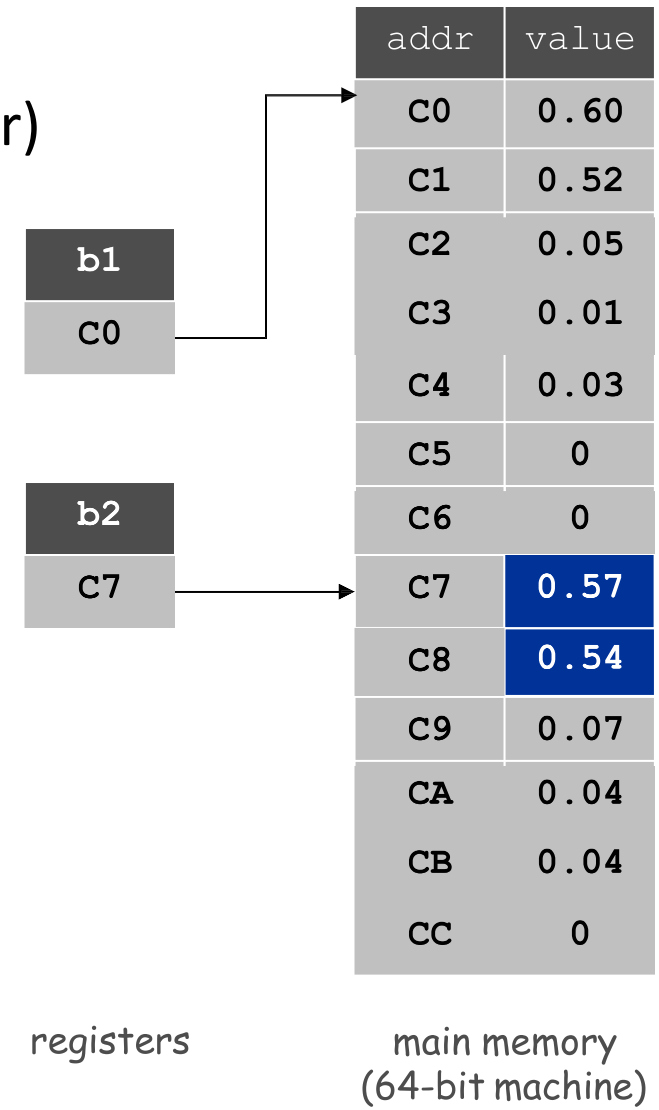
```



Object References

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b1.update();
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b2.update();

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```
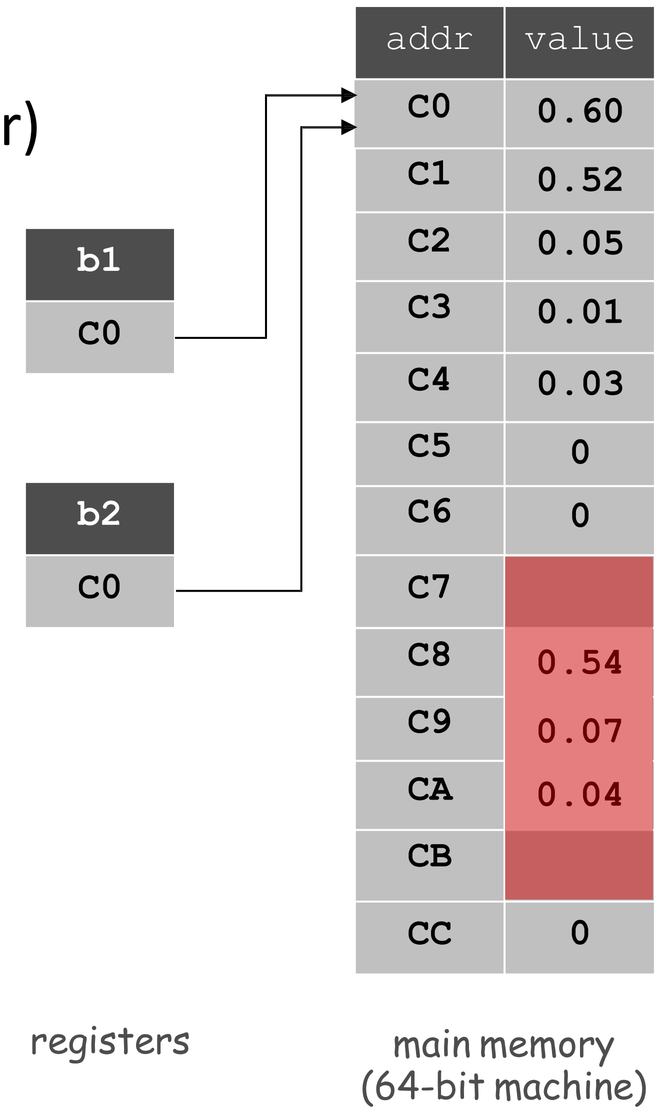



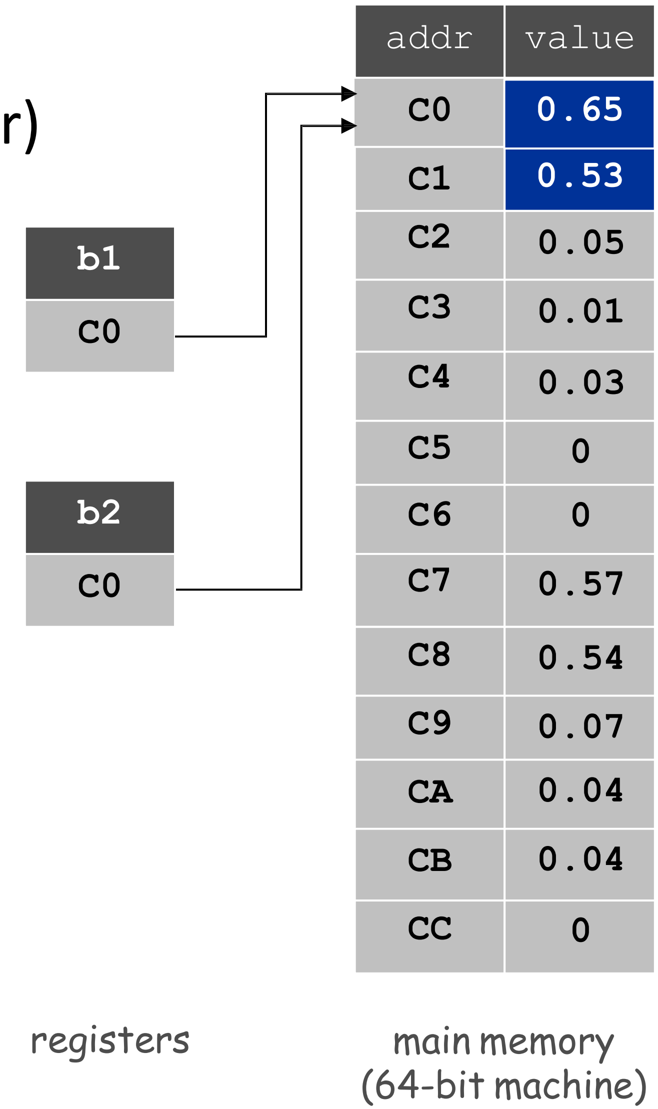
`C7 - CB` can be reused for other variables. Known as garbage collection in java.

Object References

- Allow client to manipulate an object as a single entity
- Essentially a machine address (pointer)

```
Ball b1 = new Ball();
b1.update();
b1.update();

Ball b2 = new Ball();
b2.update();

b2 = b1;
b2.update();
```

Moving `b2` also moves `b1` since they are aliases that reference the same object.



Pass-By-Value

Arguments to methods are always passed by value.

- Primitive types: passes copy of value of actual parameter.
- Objects: passes copy of reference to actual parameter.

```
public class PassByValue {
   static void update(int a, int[] b, String c) {
      a    = 7;
      b[3] = 7;
      c    = "seven";
      StdOut.println(a + " " + b[3] + " " + c);
   }
   public static void main(String[] args) {
      int a = 3;
      int[] b = { 0, 1, 2, 3, 4, 5 };
      String c = "three";
      StdOut.println(a + " " + b[3] + " " + c);
      update(a, b, c);
      StdOut.println(a + " " + b[3] + " " + c);
   }
}
```

```
% java PassByValue
3 3 three
7 7 seven
```

Overloaded Constructors

```
public class Date {
   private int month;      // 1 - 12
   private int day;        // 1 - 31
   private int year;       // 4 digits

   // no-argument constructor
   public Date() {
     month = 1;
     day = 1;
     year = 1900;
   }

   // alternative constructor
   public Date(int month, int day, int year) {
     this.month = month;
     this.day = day;
     this.year = year;
   }

   ...
}
```

```
// 1 Jan 1900
Date d1 = new Date();

// 30 Oct 2013
Date d2 = new Date(10, 30, 2013);
```

Note the usage of the this keyword to avoid the obvious ambiguity

Accessors & Mutator

- Class *behavior* <u>may</u> allow access to, or modification of, individual private instance variables.
- Accessor method
  - retrieves the value of a private instance variable
  - conventional to start the method name with `get`
- Mutator method
  - changes the value of a private instance variable
  - conventional to start the name of the method with `set`
- Gives the client program <u>indirect</u> access to the instance variables.

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More Accessors and Mutators

Question: Doesn't the use of accessors and mutators defeat the purpose of making the instance variables `private`?

Answer: **No**

- The class implementer decides which instance variables will have accessors.
- Mutators can:
  - validate the new value of the instance variable, and
  - decide whether or not to actually make the requested change.

Accessor and Mutator Example

```
public class Date {
   private int month;   // 1 - 12
   private int day;     // 1 - 31
   private int year;    // 4-digit year

   // accessors return the value ofprivatedata
   public int getMonth()  { return month; }

   // mutators can validate the new value
   publicboolean  setMonth(intmonth)  {
   if (1 <= month && month <= 12) {
        this.month = month;
        return true;
    }
    else // this is an invalid month
       return false;
    }
   }
   // rest of class definition follows
}
```

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Accessor/Mutator Caution

- In general you should NOT provide accessors and mutators for all private instance variables.
  - Recall that the principle of encapsulation is best served with a *limited class interface*.

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Private Methods

- Methods may be private.
  - Cannot be invoked by a client program
  - Can only be called by other methods within the same class definition
  - Most commonly used as ″helper″ methods to support top-down implementation of a public method

Private Method Example

```
public class Date {
   private int month;    // 1 - 12
   private int day; //  1 - 31
   private int year;     // 4-digit year

   // accessors return the value of private data
   public int getMonth()  { return month; }

   // mutators can validate the new value
   public boolean setMonth(int month) {
    if (isValidMonth(month)) {
        this.month = month;
        return true;
    }
    else // this is an invalid month
       return false;
   }

   // helper method - internal use only
   private boolean isValidMonth(int month) {
     return 1 <= month && month <= 12;
   }
}
```

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Static and Final

Static Variable

- A ***static variable*** belongs to the class as a whole, not just to one object.

- There is only one copy of a static variable per class.
  - All objects of the class can read and change this static variable.

- A static variable is declared with the addition of the modifier `static`.

```
static int myStaticVariable = 0;
```

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Static Variable

- The most common usage of a static variable is in order to keep track of the number of instances of an object.
- Assume class called Human. There is some 'controlling' class which creates humans (new Human()) and it also is responsible for the death of humans.
- We would like to keep track of the number of Humans. One way to do this would be have a static variable in the Human class which gets incremented upon child birth and decremented upon death.

Static Constants

- A ***static constant*** is used to symbolically represent a constant value.
  - The declaration for a static constant includes the modifier **final**, which indicates that its value cannot be changed:

```
public static final float PI = 3.142;
```

- It is not necessary to instantiate an object to access a static variable, constant or method.
- When referring to such a constant outside its class, use the name of its class in place of a calling object.

```
float radius = MyClass.PI * radius * radius;
```

Rules for Static Methods

- Static methods have no calling/host object (they have no **this**).
- Therefore, static methods <u>cannot</u>:
  - Refer to any instance variables of the class
  - Invoke any method that has an implicit or explicit **this** for a calling object
- Static methods <u>may</u> invoke other static methods or refer to static variables and constants.
- A class definition may contain both static methods and non-static methods.

main = Static Method

Note that the method header for main( ) is

```
public static void main(String[] args)
```

Being static has two effects:

- main can be executed without an object.
- ″Helper″ methods called by main must also be static.
  - Hence public static when you were first introduced to functions

Any Class Can Have a main( )

- Every class can have a public static method name main( ).
- Java will execute the main that exists in whichever class you choose to run

```
java <className>
```

- A convenient way to write test code for your class.

Static Review

- Given the skeleton class definition below

```
public class C {
  public int a = 0;
  public static int b = 1;

  public void f() {…}
  public static void g() {…}
}
```

- Can body of f() refer to a?
- Can body of f() refer to b?
- Can body of g() refer to a?
- Can body of g() refer to b?
- Can f() call g()?
- Can g() call f()?

For each, explain why or why not.

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