Topic 10

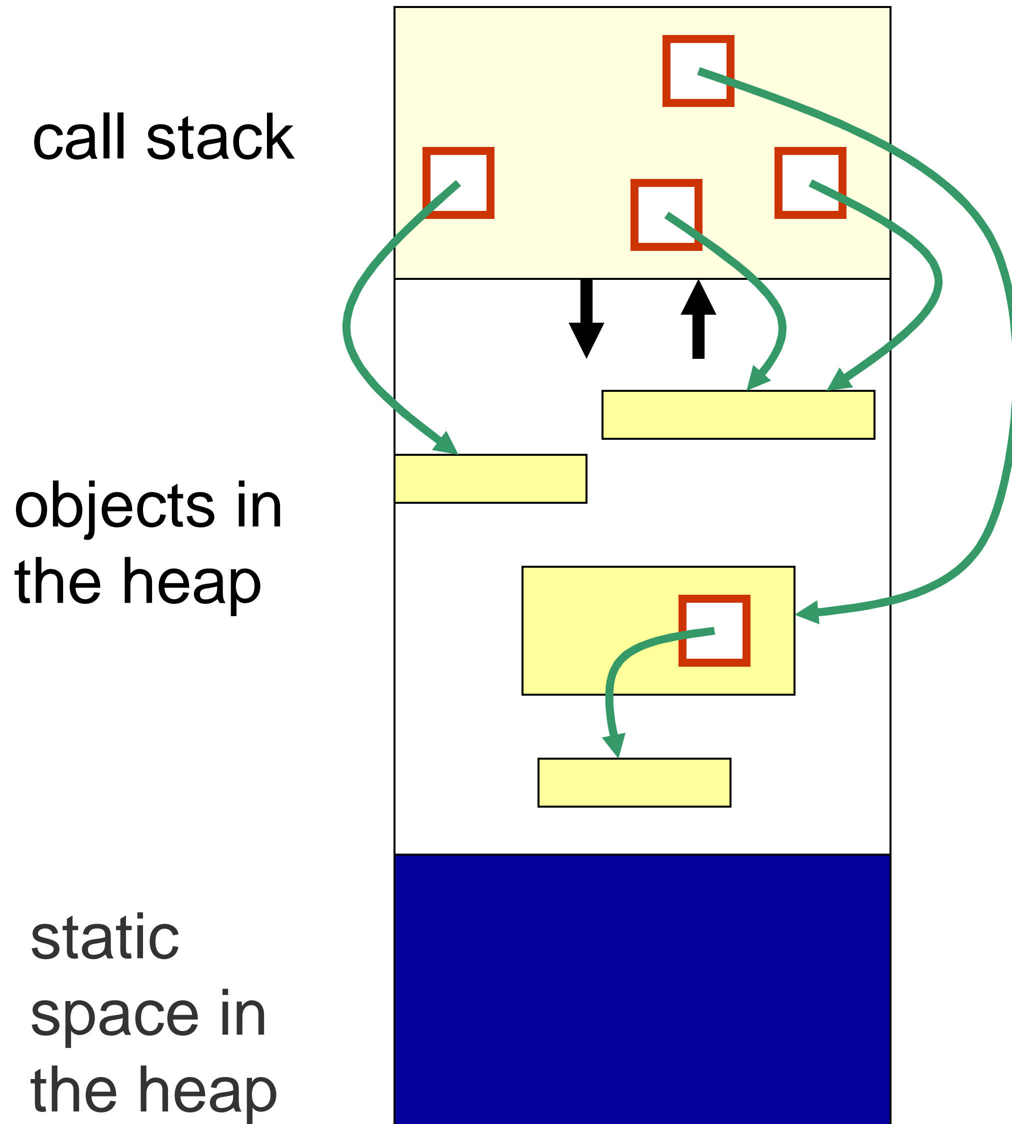
# Java Memory Management

# Memory Allocation in Java

- When a program is being executed, separate areas of memory are allocated for each
  - class
  - interface
  - object
  - running method

# Memory Allocation in Java

- ***Call stack / runtime stack***
  - Used for *method* information *while the method is being executed*
    - Local variables
    - Formal parameters
    - Return value
    - Where method should return to
- ***Heap***
  - Used for
    - ***Static*** information (interfaces and classes)
    - ***Instance*** information (objects)




# Memory allocated to your program

# Memory Allocation in Java

- ***Example***: What happens when an object is created by **new**, as in
  Person friend = new Person(…);

  - The reference variable has memory allocated to it on the ***call stack***
  - The object is created using memory in the ***heap***

# Runtime Stack

- ***Call stack (runtime stack)*** is the memory space used for *method* information *while a method is being run*
- When a method is invoked, a ***call frame*** (or ***activation record*** ) for that method is created and "pushed" onto the call stack
  - All the information needed during the execution of the method is grouped together in the call frame

# Call Frame (Activation Record) for a Method

**Return value**

**Local variables**

**Formal Parameters**

**Return address**

# Call Frame (Activation Record)

- A ***call frame*** contains:
  - Address to return to after method ends
  - Method's formal parameter variables
  - Method's local variables
  - Return value (if any)

- Note that the values in a call frame are accessible ***only*** while the corresponding method is being executed!

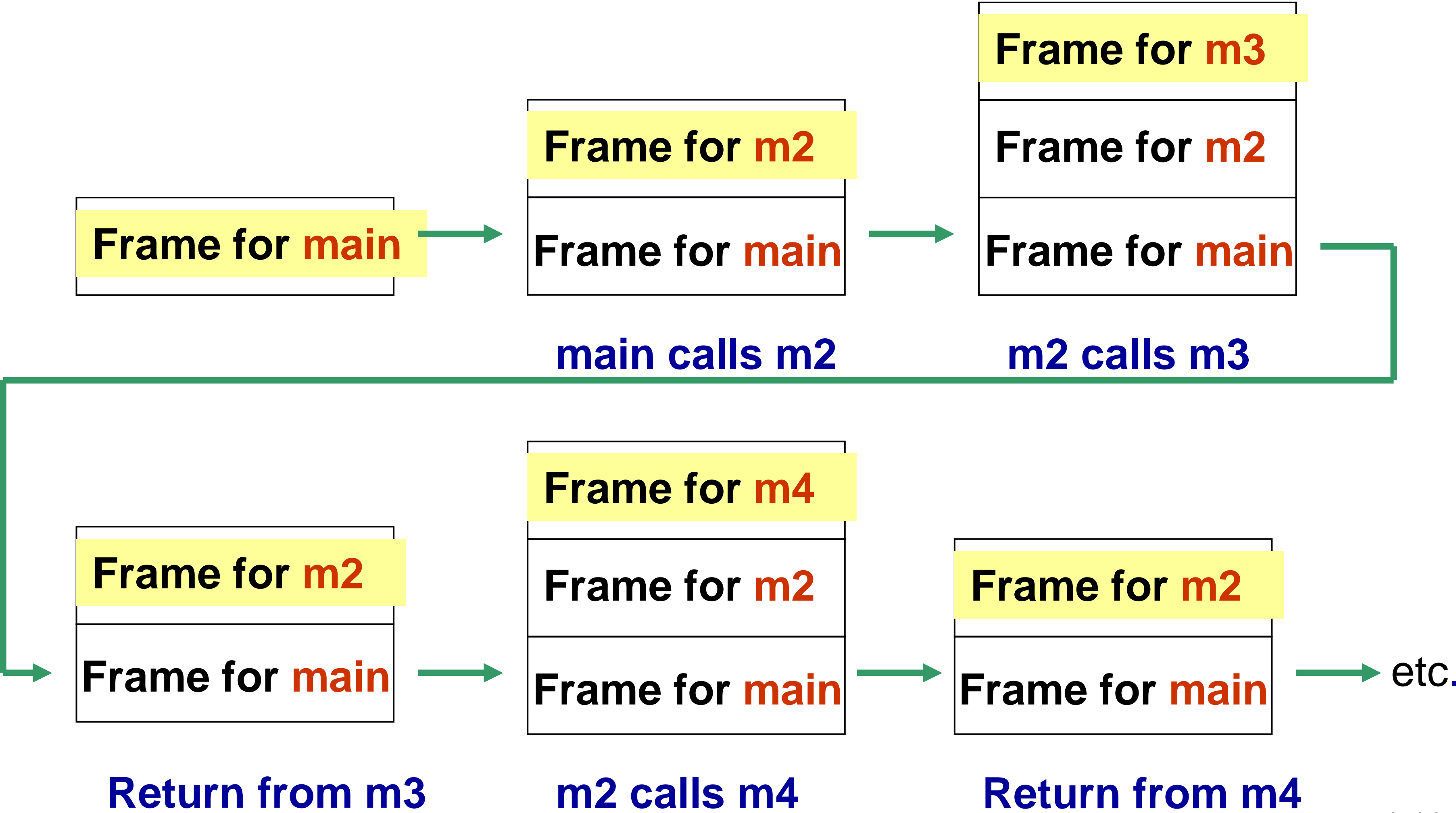
```
public class CallStackDemo
{
    public static void m2( )
    {
        System.out.println("Starting m2");
        System.out.println("m2 calling m3");
        m3();
        System.out.println("m2 calling m4");
        m4();
        System.out.println("Leaving m2");
        return;
    }
    public static void m3( )
    {
        System.out.println("Starting m3");
        System.out.println("Leaving m3");
        return;
    }
```

## *Example:* a Typical Calling Sequence

```
    public static void m4( )
    {
        System.out.println("Starting m4");
        System.out.println("Leaving m4");
        return;
    }


    public static void main(String args[ ])
    {
        System.out.println("Starting main");
        System.out.println("main calling m2");
        m2( );
        System.out.println("Leaving main");
    }
}
```

# Call Stack for a Typical Calling Sequence



# Call Stack for a Typical Calling Sequence

- When the **main** method is invoked:
  - A call frame for main is created and pushed onto the runtime stack
- When **main** calls the method **m2**:
  - A call frame for m2 is created and pushed onto the runtime stack
- When **m2** calls **m3**:
  - A call frame for m3 is created and pushed onto the runtime stack
- When **m3** terminates, its call frame is popped off and control returns to **m2**

# Call Stack for a Typical Calling Sequence

- When **m2** now calls **m4**:
  - What happens next?
  - What happens when **m4** terminates?
- What happens when **m2** terminates?
- What happens when **main** terminates? Its call frame is popped off and control returns to the operating system

# Call Frames

- We will now look at some examples of what is in a call frame for a method
  - First for simple variables
  - Then for reference variables

# Example: Call Frames - Simple Variables

```
public class CallFrameDemo1
{
    public static double square(double n){
        double temp;
        temp = n * n;
        return temp;
    }

    public static void main(String args[ ])        {
        double x = 4.5;
        double y;
        y = square(x);
        System.out.println("Square of " + x + " is " + y);
    }
}
```

# Call Frames – Example 1

***Draw a picture of the call frames on the call stack:***

- What will be in the call frame for the **main** method?
  - Address to return to in operating system
  - Variable **args**
  - Variable **x**
  - Variable **y**
- What will be in the call frame for the method **square**?
  - Address to return to in main
  - Variable **n**
  - Variable **temp**
  - Return value

# Discussion

- There will be a call frame on the call stack for ***each*** method called. So what other call frame(s) will be pushed onto the call stack for our example?
- Which call frames will be on the call stack at the same time?

# Heap Space

- ***Static space***: contains ***one*** copy of each class and interface named in the program
  - Contains their static variables, and methods
- ***Object space***:
  - Information is stored about ***each*** object:
    - Value of its instance variables
    - Type of object (i.e. name of class)

# Object Creation

- Now let's look at reference variables …
- Memory is allocated in the ***heap*** area when an object is created using **new**
  - The reference variable is put in the call frame on the runtime stack
  - The object is created using memory in the heap

```
public class CallFrameDemo2 {

    private static void printAll(String s1, String s2, String s3){
            System.out.println(s1.toString( ));
            System.out.println(s2.toString( ));
            System.out.println(s3.toString( ));
     }
    public static void main(String args[ ]) {
            String str1, str2, str3;

            str1 = new String(" string 1 ");
            str2 = new String(" string 2 ");
            str3 = new String(" string 3 ");

            printAll(str1, str2, str3);
     }
}
```

***Example***: **Call Frames-Reference Variables**

# Call Frames – Example 2

***Draw a picture of the call stack and of the heap as the program executes***

- What will be the *sequence of call frames* on the call stack?

for main

for String constructor for str1 – then popped off

for String constructor for str2 – then popped off

for String constructor for str3 – then popped off

for printAll

for toString for str1 – then popped off

for System.out.println – then popped off

etc.

# Call Frames – Example 2

- What will be in the call frame for **main**? (and in the heap?)
  - Address to return to in operating system
  - Variable **args**
  - Variable **str1**
    - Initially?
    - After return from String constructor?
  - Variable **str2**
  - Variable **str3**

- What will be in the call frame for **printAll**?

# Memory Deallocation

- What happens when a method returns?
  - On the runtime stack:
    - The call frame is automatically popped off when the method returns
    - So, that memory is ***deallocated***

# Memory Deallocation

- What happens to objects on the heap?
  - An object stays on the heap even if there is no longer a variable referencing it!
  - So, Java has automatic ***garbage collection***
    - It regularly identifies objects which no longer have a variable referencing them, and ***deallocates*** that memory