Methods

CSE160: Computer Science A: Honors

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- CAUTION: all execution paths need returns (if a value is returned)
- Scope of Local Variables
- Stepwise Refinement: Top-Down and Bottom-Up Implementation

Motivation: Opening Problem

Find multiple sums of integers:

- from 1 to 10,
- from 20 to 30,
- from 35 to 45,

…

Opening Problem

- Repeat/copy code:

```
int sum = 0;
for (int i = 1; i <= 10; i++)
  sum += i;
System.out.println("Sum from 1 to 10 is " + sum);

sum = 0;
for (int i = 20; i <= 30; i++)
  sum += i;
System.out.println("Sum from 20 to 30 is " + sum);

sum = 0;
for (int i = 35; i <= 45; i++)
  sum += i;
System.out.println("Sum from 35 to 45 is " + sum);
```

Opening Problem Solution

- Use 1 method and invoke it multiple times!

```
public static int sum(int i1, int i2) {
  int sum = 0;
  for (int i = i1; i <= i2; i++)
    sum += i;
  return sum;
}
```

```
public static void main(String[] args) {
  System.out.println("Sum from 1 to 10 is " + sum(1, 10));
  System.out.println("Sum from 20 to 30 is " + sum(20, 30));
  System.out.println("Sum from 35 to 45 is " + sum(35, 45));
}
```

Why write methods?

- To shorten your programs
  - avoid writing identical code twice or more
- To modularize your programs
  - fully tested methods can be trusted
- To make your programs more:
  - readable
  - reusable
  - testable
  - debugable
  - extensible and adaptable

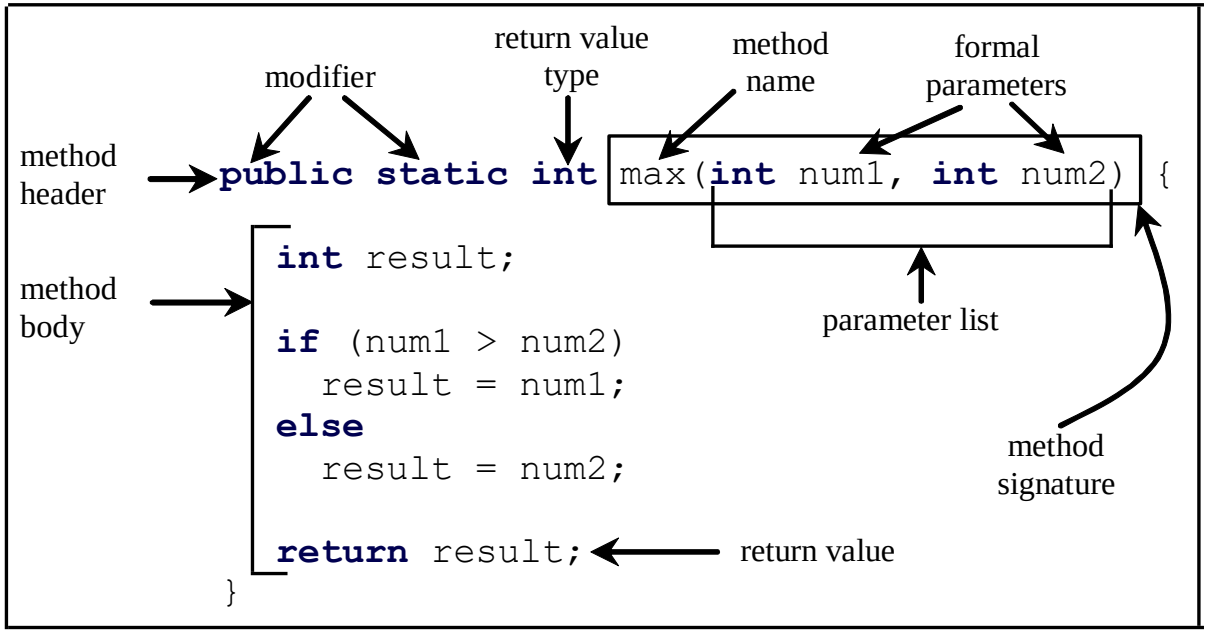
Rule of thumb

- If you have to perform some operation in more than in one place in your program, write a method to implement this operation and have other parts of the program use it

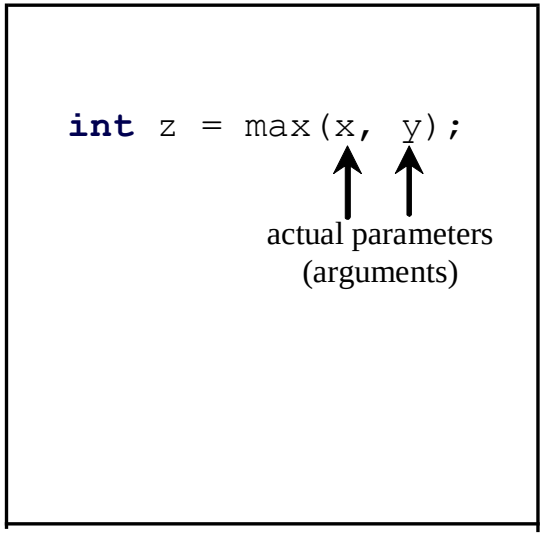
Defining Methods

- A *method* is a collection of statements that are grouped together to perform an operation.

Define a method



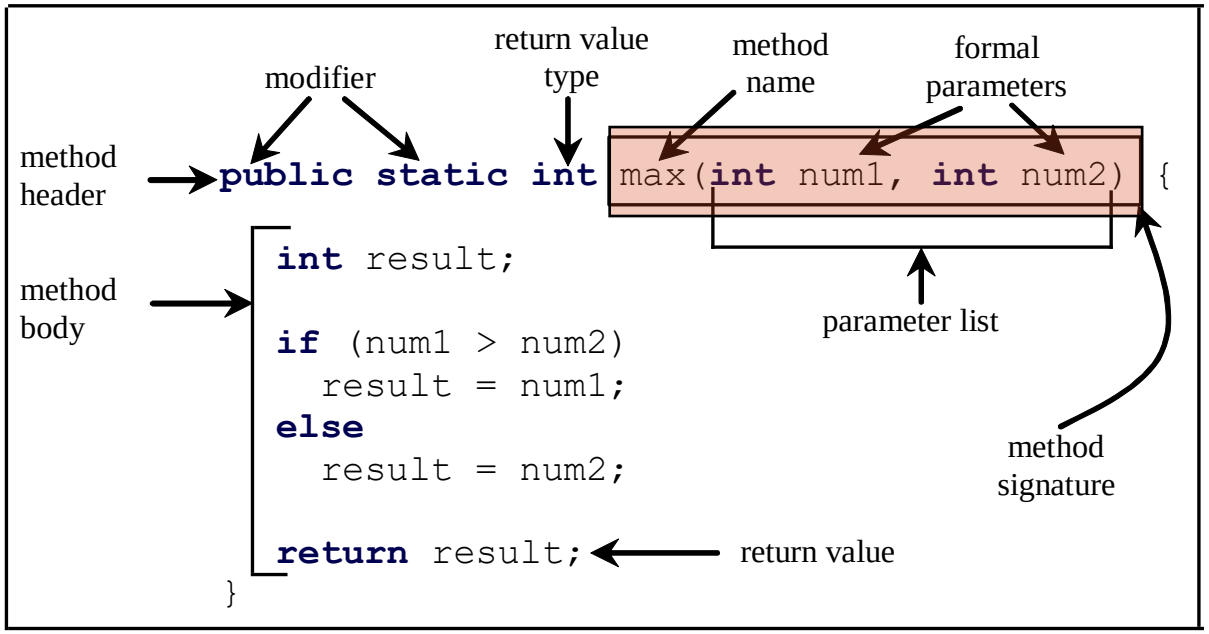
Invoke a method



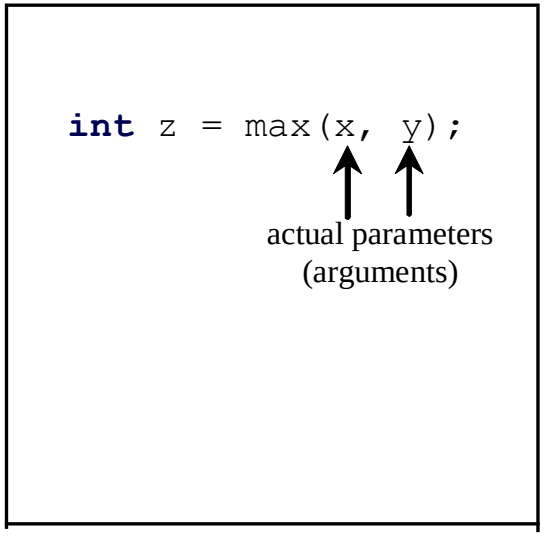
Method Signature

- *Method signature* is the combination of the method name and the parameter list.

Define a method

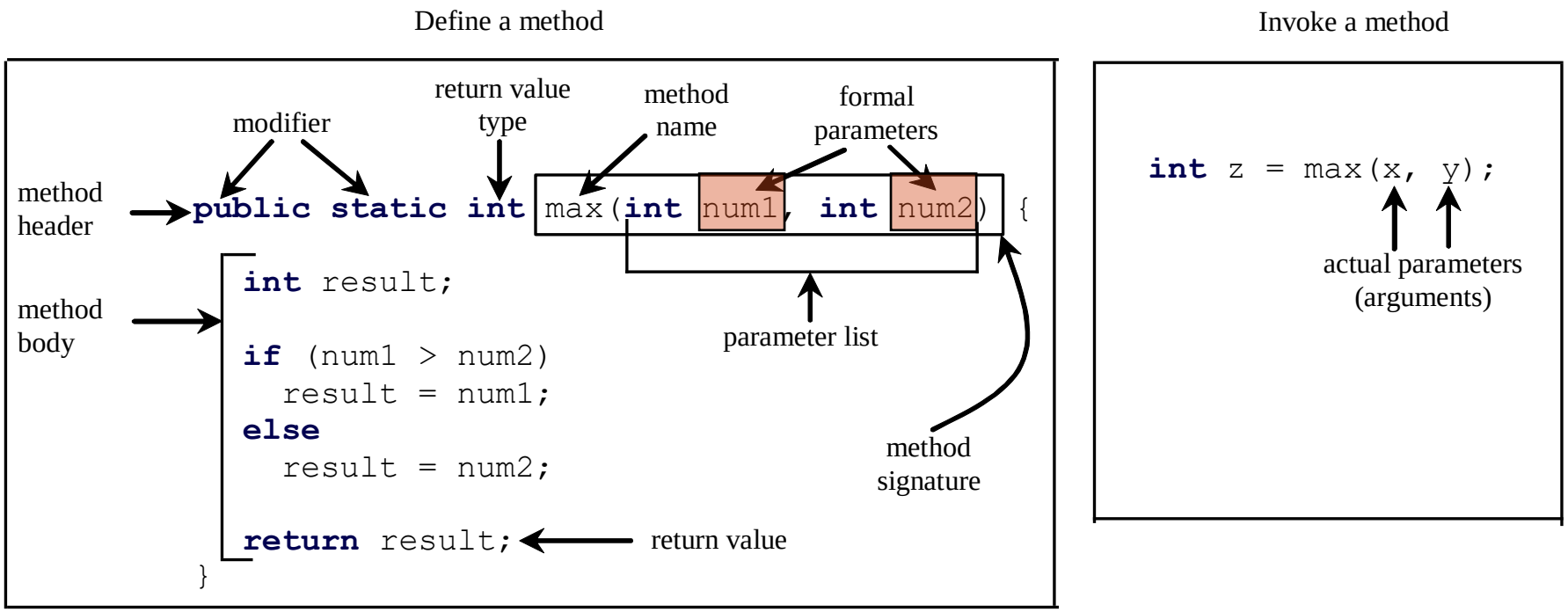


Invoke a method



Formal Parameters

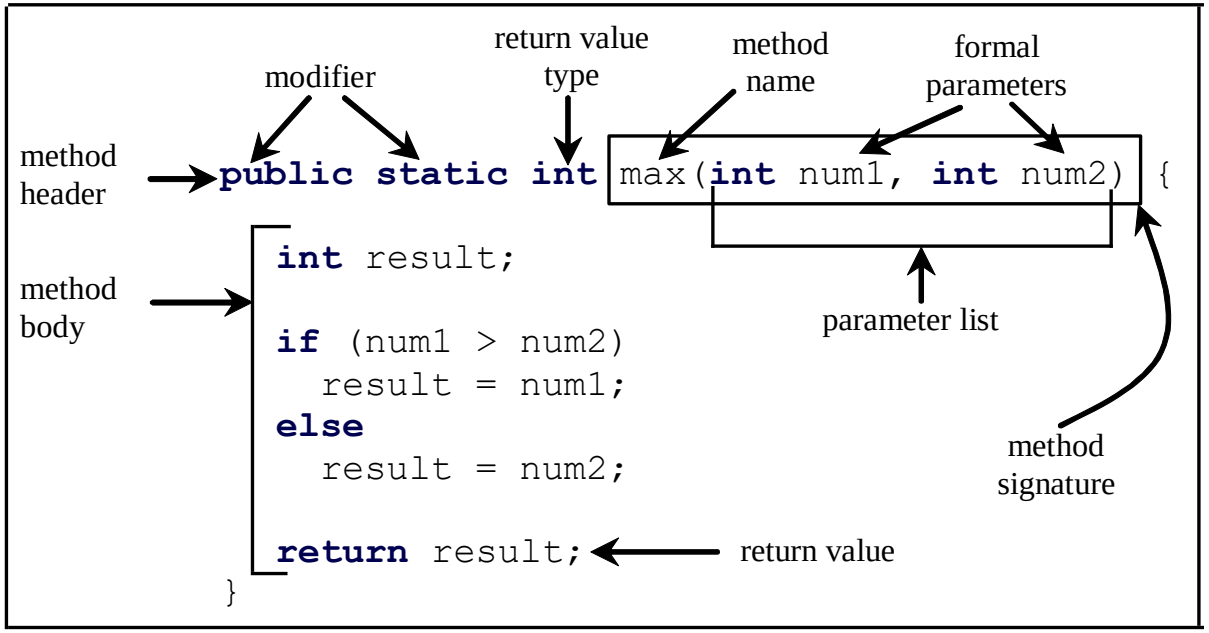
- The variables defined in the method header are known as *formal parameters*.



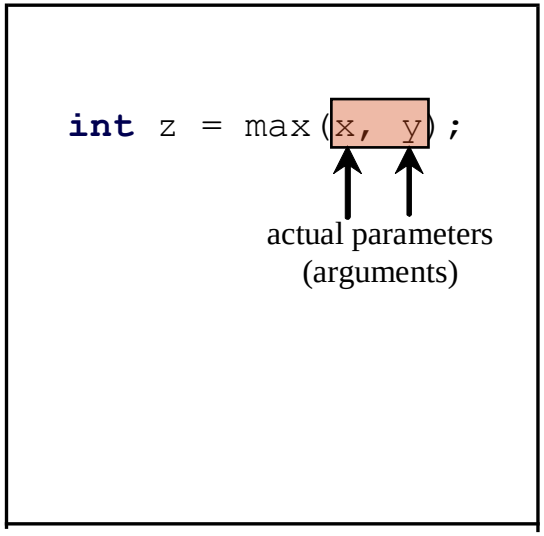
Actual Parameters

- When a method is invoked, you pass values to the formal parameter with *actual parameters* or *arguments*.

Define a method



Invoke a method

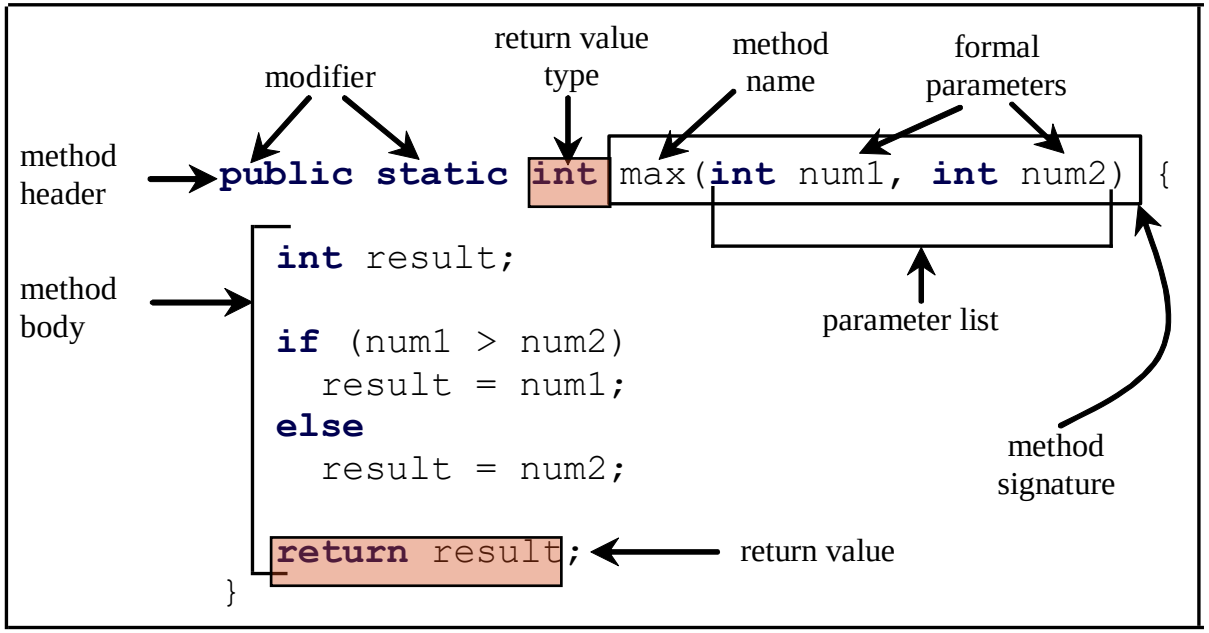


Return Value Type

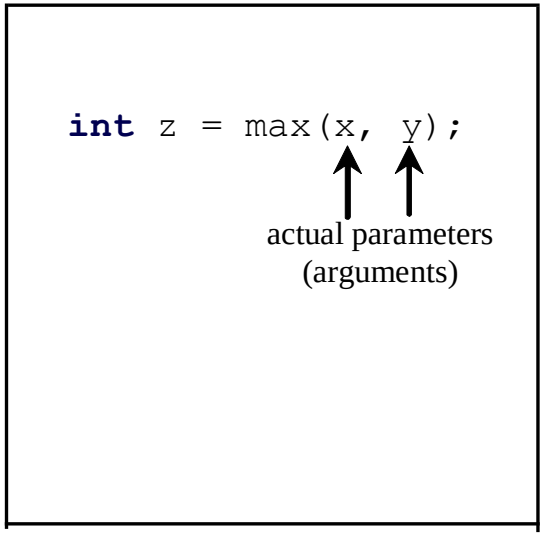
- A method may return a value

The *returnValueType* is the data type of the value the method returns.

Define a method



Invoke a method



If the method does not return a value, the returnValueType is the keyword void.

Calling Methods

pass the value of i

pass the value of j

```
public static void main(String[] args) {
  int i = 5;
  int j = 2;
  int k = max(i, j);

  System.out.println(
   "The maximum between " + i +
   " and " + j + " is " + k);
}
```

```
public static int max(int num1, int num2) {
  int result;

  if (num1 > num2)
    result = num1;
  else
    result = num2;

  return result;
}
```

Trace Method Invocation

i is now 5

```
public static void main(String[] args) {
  int i = 5;
  int j = 2;
  int k = max(i, j);

  System.out.println(
   "The maximum between " + i +
   " and " + j + " is " + k);
}
```

```
public static int max(int num1, int num2) {
  int result;

  if (num1 > num2)
    result = num1;
  else
    result = num2;

  return result;
}
```

Trace Method Invocation

j is now 2

```
public static void main(String[] args) {
  int i = 5;
  int j = 2;
  int k = max(i, j);

  System.out.println(
   "The maximum between " + i +
   " and " + j + " is " + k);
}
```

```
public static int max(int num1, int num2) {
  int result;

  if (num1 > num2)
    result = num1;
  else
    result = num2;

  return result;
}
```

Trace Method Invocation

invoke max(i, j)

```
public static void main(String[] args) {
  int i = 5;
  int j = 2;
  int k = max(i, j);

  System.out.println(
   "The maximum between " + i +
   " and " + j + " is " + k);
}
```

```
public static int max(int num1, int num2) {
  int result;

  if (num1 > num2)
    result = num1;
  else
    result = num2;

  return result;
}
```

Trace Method Invocation

invoke max(i, j)
Pass the value of i to num1
Pass the value of j to num2

```
public static void main(String[] args) {
  int i = 5;
  int j = 2;
  int k = max(i, j);

  System.out.println(
   "The maximum between " + i +
   " and " + j + " is " + k);
}
```

```
public static int max(int num1, int num2) {
  int result;

  if (num1 > num2)
    result = num1;
  else
    result = num2;

  return result;
}
```

Trace Method Invocation

declare variable result

```
public static void main(String[] args) {
  int i = 5;
  int j = 2;
  int k = max(i, j);

  System.out.println(
   "The maximum between " + i +
   " and " + j + " is " + k);
}
```

```
public static int max(int num1, int num2) {
  int result;

  if (num1 > num2)
    result = num1;
  else
    result = num2;

  return result;
}
```

Trace Method Invocation

(num1 > num2) is true since num1 is 5 and num2 is 2

```
public static void main(String[] args) {
  int i = 5;
  int j = 2;
  int k = max(i, j);

  System.out.println(
   "The maximum between " + i +
   " and " + j + " is " + k);
}
```

```
public static int max(int num1, int num2) {
  int result;

  if (num1 > num2)
    result = num1;
  else
    result = num2;

  return result;
}
```

Trace Method Invocation

result is now 5

```
public static void main(String[] args) {
  int i = 5;
  int j = 2;
  int k = max(i, j);

  System.out.println(
   "The maximum between " + i +
   " and " + j + " is " + k);
}
```

```
public static int max(int num1, int num2) {
  int result;

  if (num1 > num2)
    result = num1;
  else
    result = num2;

  return result;
}
```

Trace Method Invocation

return result, which is 5

```
public static void main(String[] args) {
  int i = 5;
  int j = 2;
  int k = max(i, j);

  System.out.println(
   "The maximum between " + i +
   " and " + j + " is " + k);
}
```

```
pu      catic int max(int num1, int num2) {
      esult;

    num1 > num2)
    esult = num1;
  se
   result = num2;

  return result;
}
```

Trace Method Invocation

return max(i, j) and assign the return value to k

```
public static void main(String[] args) {
  int i = 5;
  int j = 2;
  int k = max(i, j);

  System.out.println(
   "The maximum between " + i +
   " and " + j + " is " + k);
}
```

```
public static int max(int num1, int num2) {
  int result;

  if (num1 > num2)
    result = num1;
  else
    result = num2;

  return result;
}
```

Trace Method Invocation

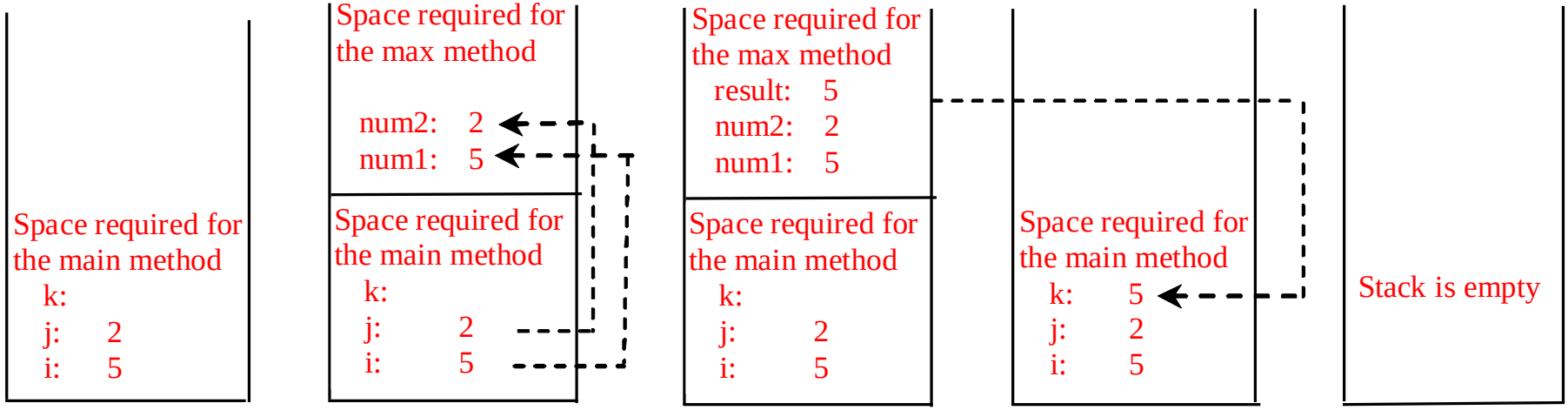
Execute the print statement

```
public static void main(String[] args) {
  int i = 5;
  int j = 2;
  int k = max(i, j);

  System.out.println(
   "The maximum between " + i +
   " and " + j + " is " + k);
}
```

```
public static int max(int num1, int num2) {
  int result;

  if (num1 > num2)
    result = num1;
  else
    result = num2;

  return result;
}
```

Call Stacks

Methods are executed using a stack data structure



(a) The main method is invoked.

(b) The max method is invoked.

(c) The max method is being executed.

(d) The max method is finished and the return value is sent to k.

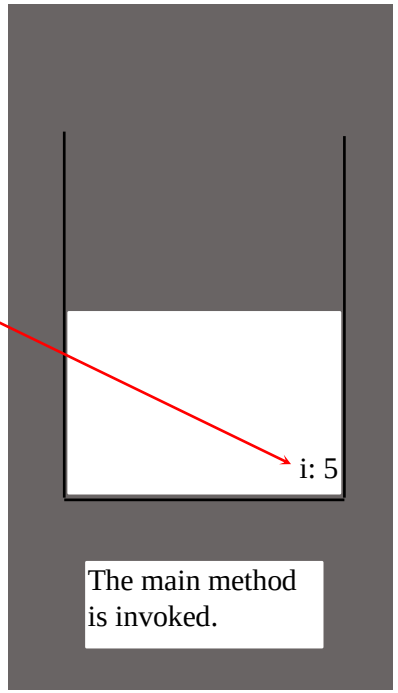
(e) The main method is finished.

Trace Call Stack

i is declared and initialized

```
public static void main(String[] args) {
  int i = 5;
  int j = 2;
  int k = max(i, j);

  System.out.println(
   "The maximum between " + i +
   " and " + j + " is " + k);
}
```

```
public static int max(int num1, int num2) {
  int result;

  if (num1 > num2)
    result = num1;
  else
    result = num2;

  return result;
}
```

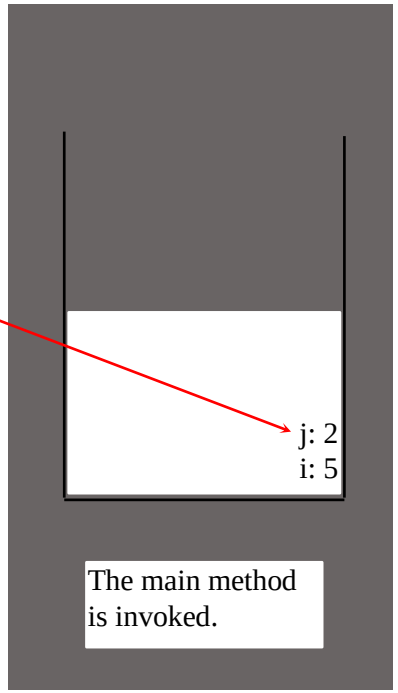


Trace Call Stack

j is declared and initialized

```
public static void main(String[] args) {
  int i = 5;
  int j = 2;
  int k = max(i, j);

  System.out.println(
   "The maximum between " + i +
   " and " + j + " is " + k);
}
```

```
public static int max(int num1, int num2) {
  int result;

  if (num1 > num2)
    result = num1;
  else
    result = num2;

  return result;
}
```

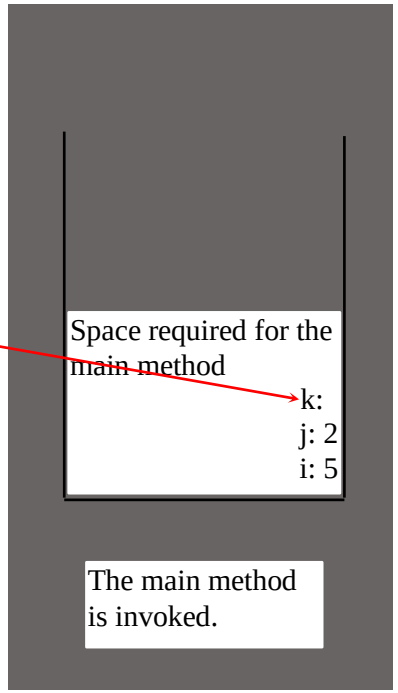


Trace Call Stack

Declare k

```
public static void main(String[] args) {
  int i = 5;
  int j = 2;
  int k = max(i, j);

  System.out.println(
   "The maximum between " + i +
   " and " + j + " is " + k);
}
```

```
public static int max(int num1, int num2) {
  int result;

  if (num1 > num2)
    result = num1;
  else
    result = num2;

  return result;
}
```

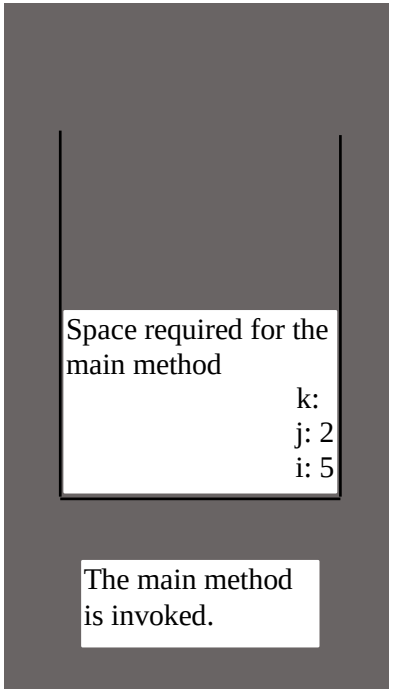


Trace Call Stack

Invoke max(i, j)

```
public static void main(String[] args) {
  int i = 5;
  int j = 2;
  int k = max(i, j);

  System.out.println(
   "The maximum between " + i +
   " and " + j + " is " + k);
}
```

```
public static int max(int num1, int num2) {
  int result;

  if (num1 > num2)
    result = num1;
  else
    result = num2;

  return result;
}
```

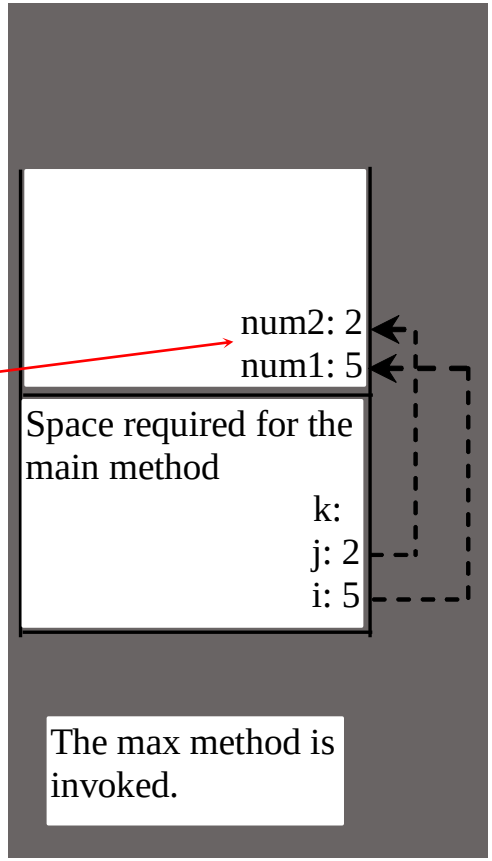


Trace Call Stack

```
public static void main(String[] args) {
  int i = 5;
  int j = 2;
  int k = max(i, j);

  System.out.println(
   "The maximum between " + i +
   " and " + j + " is " + k);
}
```

```
public static int max(int num1, int num2) {
  int result;

  if (num1 > num2)
    result = num1;
  else
    result = num2;

  return result;
}
```

pass the values of i and j to num1 and num2

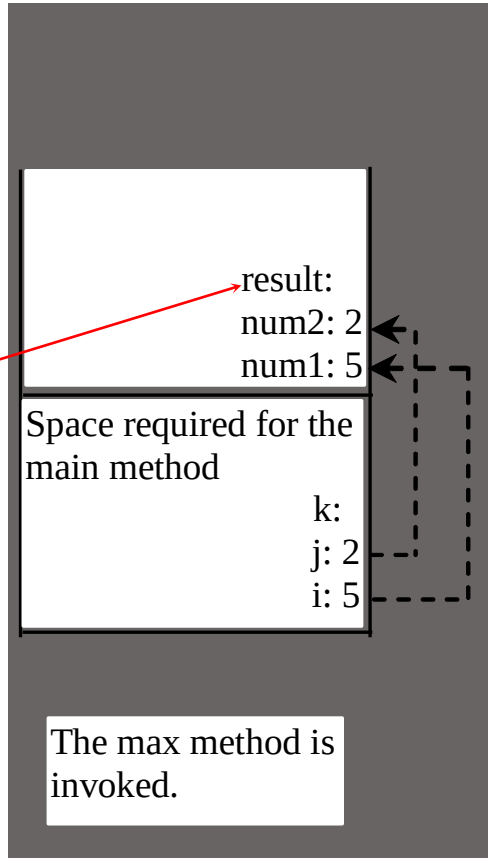


Trace Call Stack

```
public static void main(String[] args) {
  int i = 5;
  int j = 2;
  int k = max(i, j);

  System.out.println(
   "The maximum between " + i +
   " and " + j + " is " + k);
}
```

```
public static int max(int num1, int num2) {
  int result;

  if (num1 > num2)
    result = num1;
  else
    result = num2;

  return result;
}
```

pass the values of i and j to num1 and num2

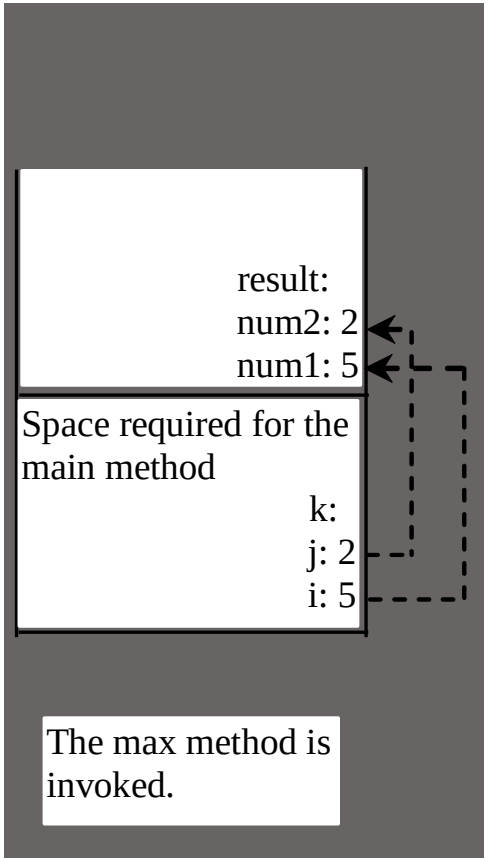


Trace Call Stack

```
public static void main(String[] args) {
  int i = 5;
  int j = 2;
  int k = max(i, j);

  System.out.println(
   "The maximum between " + i +
   " and " + j + " is " + k);
}
```

```
public static int max(int num1, int num2) {
  int result;

  if (num1 > num2)
    result = num1;
  else
    result = num2;

  return result;
}
```

(num1 > num2) is true

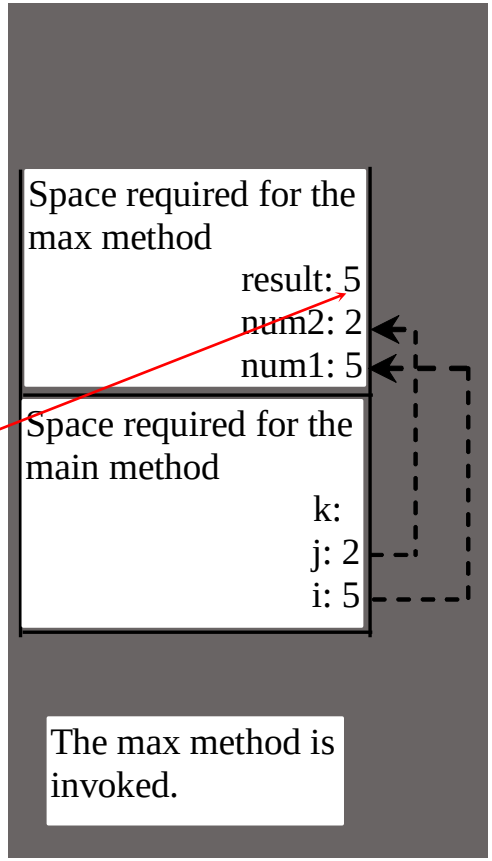


Trace Call Stack

```
public static void main(String[] args) {
  int i = 5;
  int j = 2;
  int k = max(i, j);

  System.out.println(
   "The maximum between " + i +
   " and " + j + " is " + k);
}
```

```
public static int max(int num1, int num2)
  int result;

  if (num1 > num2)
    result = num1;
  else
    result = num2;

  return result;
}
```

Assign num1 to result

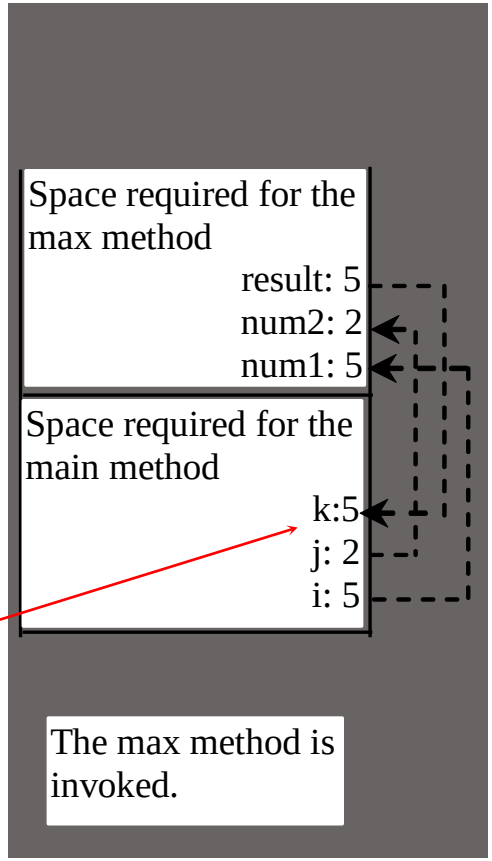


Trace Call Stack

```
public static void main(String[] args) {
  int i = 5;
  int j = 2;
  int k = max(i, j);

  System.out.println(
   "The maximum between " + i +
   " and " + j + " is " + k);
}
```

```
public static int max(int num1, int num2
  int result;

  if (num1 > num2)
    result = num1;
  else
    result = num2;

  return result;
}
```

Return result and assign it to k

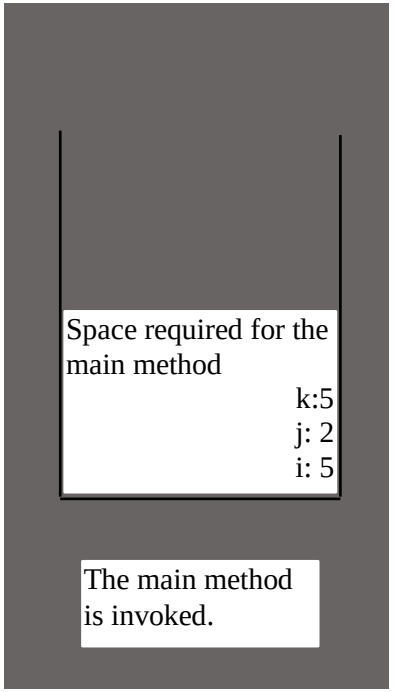


Trace Call Stack

Execute print statement

```
public static void main(String[] args) {
  int i = 5;
  int j = 2;
  int k = max(i, j);

  System.out.println(
   "The maximum between " + i +
   " and " + j + " is " + k);
}
```

```
public static int max(int num1, int num2) {
  int result;

  if (num1 > num2)
    result = num1;
  else
    result = num2;

  return result;
}
```

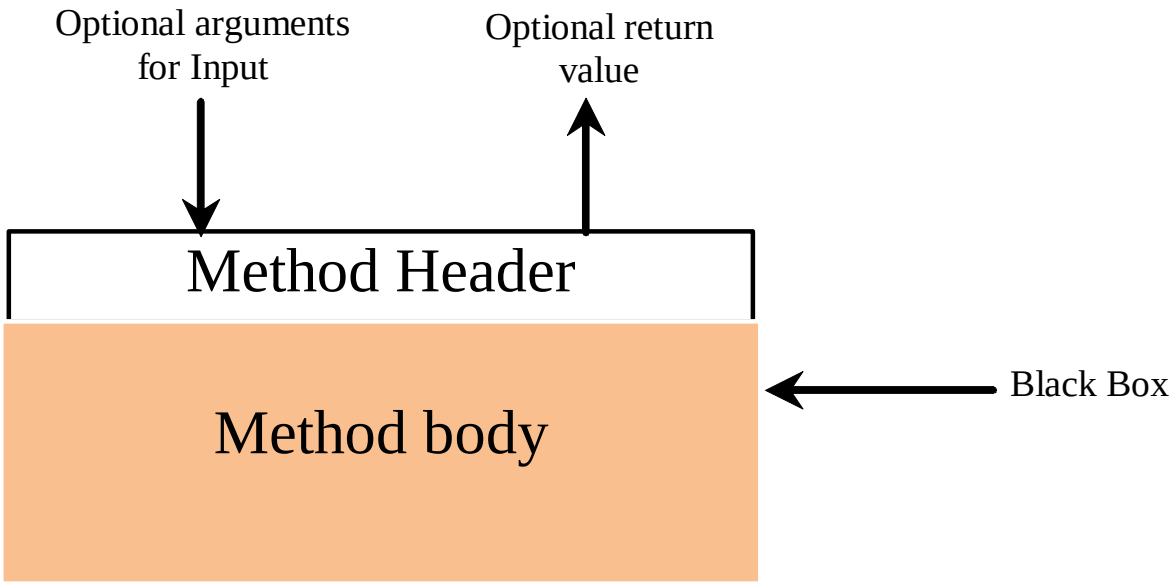


Benefits of Methods

1. Reuse: Write a method once and reuse it anywhere.
2. **Method Abstraction and Information hiding:**
   - Hide the implementation from the user.
     - Reduces complexity of the program.

Method Abstraction

Application Programming Interface (API) = the method body is a black box that contains the detailed implementation for the method.



Javadoc

- The API for a class is documented using the Javadoc.
- Generate Javadoc for your project in Eclipse with:
  1. Project -> Generate Javadoc
  2. Check the box next to the project/package/file for which you are creating the javadoc
  3. In the "Destination" field browse to find the desired destination (for example, the doc directory of the current project).
  4. Leave everything else as it is.
  5. Click "Finish" and open "index.html"

Java - file:/C:/workspace/cse114/doc/index.html - Eclipse SDK

File Edit Navigate Search Project Run AURA SILK Window Help

Open Project
Close Project
Build All Ctrl+B
Build Project
Build Working Set
Clean...
✔ Build Automatically
Generate Javadoc...
Properties

Package Explorer

- cse114
  - src
  - JRE System Library
  - doc
    - class-use
    - index-files
    - resources
    - allclasses-frame.html
    - allclasses-noframe.html
    - average.html
    - constant-values.html
    - deprecated-list.html
    - help-doc.html
    - index.html
    - ISBN.html
    - overview-tree.html
    - package-frame.html
    - package-list
    - package-summary.html
    - package-tree.html
    - package-use.html
    - pattern.html
    - stylesheet.css

test_01

file://C:/workspace/cse114/doc/index.html

Package Class Use Tree Deprecated

Prev Class Next Class Frames No Fra

Summary: Nested | Field | Constr | Method Detail

Class pattern

java.lang.Object
pattern

```
public class pattern
extends java.lang.Object
```

Constructor Summary

Constructors
Constructor and Description
pattern()

Call-by-value

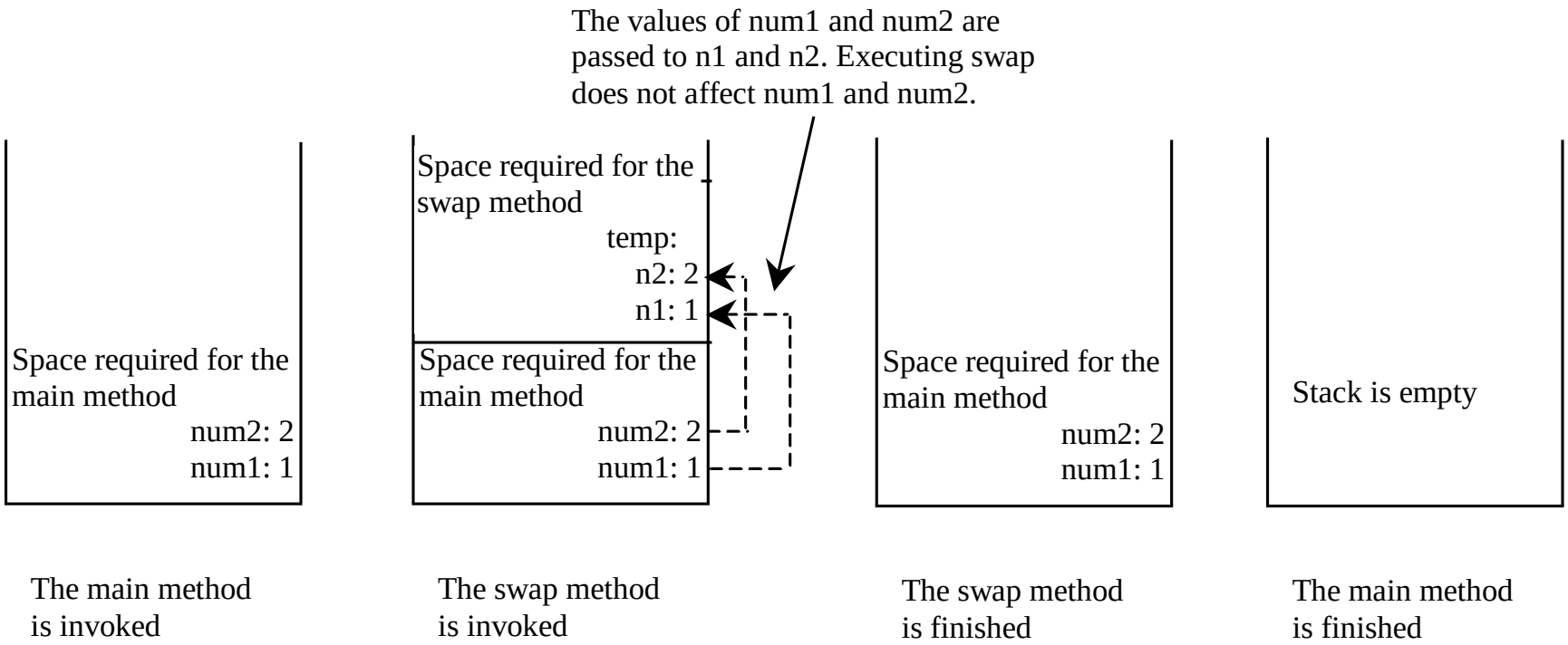
- Method formal parameters are ***copies of the original data***.
- Consequence?
  - methods <u>cannot</u> assign („=“) new values to primitive type formal arguments and <u>affect the original passed variables</u>.
- Why?
  - changing argument values changes the copy, not the original.

```
public class Test1 {
    public static void main(String[] args) {
        int num = 1;
        m(num);
        System.out.println(num); // still 1
    }
    public static void m(int n) {
        n = 2;
    }
}
```

Trying to swap the values in 2 args.

```
public class Test {
   public static void main(String[] args) {
         int num1 = 1;
         int num2 = 2;
         swap(num1,num2);
         System.out.println(num1 + " " + num2);//still 1 2
   }
   public static void swap(int n1, int n2) {
         int temp = n1;
         n1 = n2;
         n2 = temp;
         System.out.println(n1 + " " + n2); // 2 1
   }
}
```

Call-by-value



Overloading

- ***Method overloading*** is the ability to create multiple methods of the same name with different signatures and implementations:

```
public class Overloading {
  public static int max(int num1, int num2) {
    if (num1 > num2)
      return num1;
    return num2;
  }
  public static double max(double num1, double num2) {
    if (num1 > num2)
      return num1;
    return num2;
  }
  public static void main(String[] args) {
    System.out.println(max(1, 2)); // 2 (as an int)
    System.out.println(max(1, 2.3)); // 2.3 (as a double)
  }
}
```

Overloading & Ambiguous Invocation

- Overloaded methods must differ either by the types of their parameters or by arity (i.e., number of arguments)
- Method/Call ***matching*** is the process to find the method implementation for the call:
  - it uses a "***best match***" algorithm to cast the actual parameters' types to the formal parameter types
  - For example:

```
System.out.println(max(1.5, 2)); // 2.0 (as a double)
System.out.println(max(1, 2.5)); // 2.5 (as a double)
```

Overloading & Ambiguous Invocation

- Sometimes there may be two or more possible matches for an invocation of a method, but the compiler cannot determine the most specific match.
  - This is referred to as *ambiguous invocation*. and it is a compilation error.

Overloading & Ambiguous Invocation

```
public class AmbiguousOverloading {
  public static double max(int num1, double num2) {
    if (num1 > num2)
      return num1;
    else
      return num2;
  }
  public static double max(double num1, int num2) {
    if (num1 > num2)
      return num1;
    else
      return num2;
  }
  public static void main(String[] args) {
    System.out.println(max(1, 2)); // compiler error here
  }
}
```

CAUTION: all execution paths

- A <u>return</u> statement is required for a <u>value-returning</u> method.

The method shown below has a compilation error because the Java compiler thinks it possible that this method does not return any value if the condition is false in the last if statement.

```java
public static int sign(int n) {
  if (n > 0)
    return 1;
  else if (n == 0)
    return 0;
  else if (n < 0)
    return -1;
}
```

(a)

Should be →

```java
public static int sign(int n) {
  if (n > 0)
    return 1;
  else if (n == 0)
    return 0;
  else
    return -1;
}
```

(b)

To fix this problem, delete *<u>if (n < 0)</u>* in (a), so that the compiler will see a <u>return</u> statement to be reached regardless of how the <u>if</u> statement is evaluated.

Scope of Local Variables

- Remember that a *local variable* is a variable defined inside a method.
  - The *scope* of a variable the part of the program where the variable can be referenced.
    - In Java, the scope of a local variable starts from its declaration and continues to the end of the block that contains the variable
    - A nested block cannot redefine a local variable:

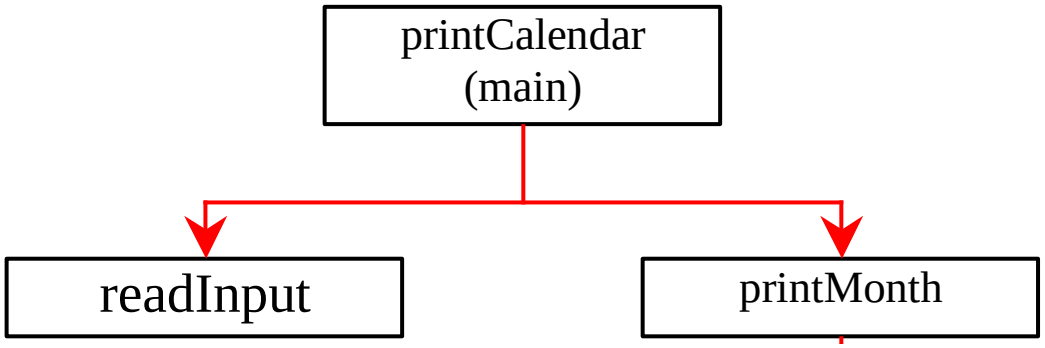
```
public static void correctMethod() {
  int x = 1;
  int y = 1;
  for (int i = 1; i < 10; i++) {
    // int x = 0; // Syntax error
    x += i;
  }
}
```

Stepwise Refinement

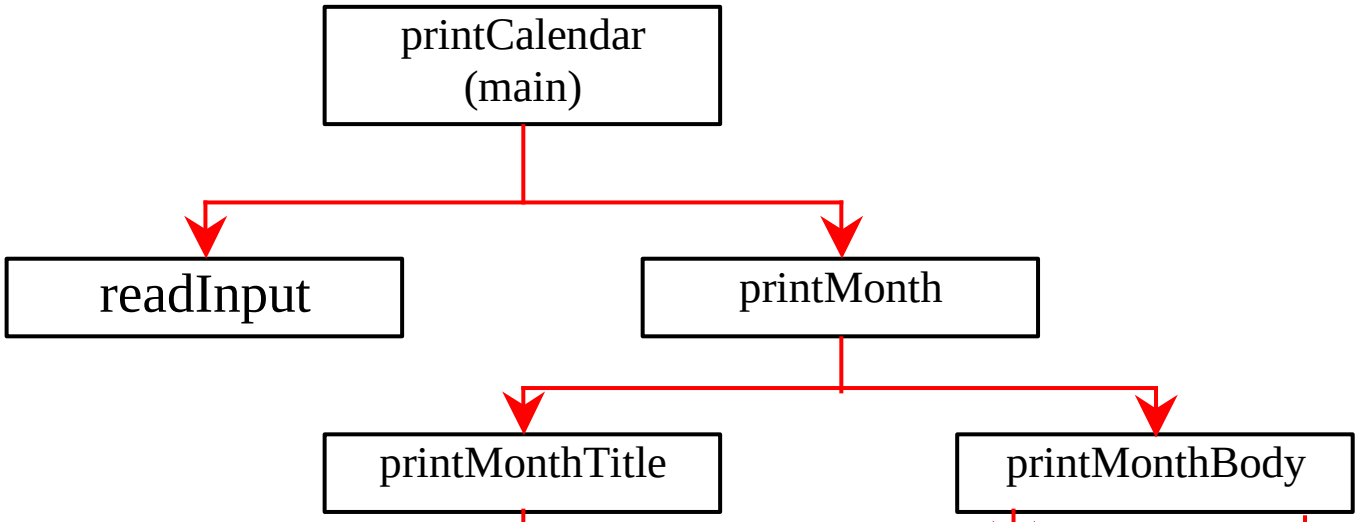
- The concept of method abstraction can be applied to the process of developing programs.
  - When writing a large program, you can use the "*divide and conquer*" strategy, also known as ***stepwise refinement***, to decompose it into subproblems
  - The subproblems can be further decomposed into smaller, more manageable problems.
- For example, consider a PrintCalendar program:

```
Command Prompt
C:\book>java PrintCalendar
Enter full year (e.g., 2001): 2009
Enter month in number between 1 and 12: 4
         April 2009
-----------------------------
 Sun Mon Tue Wed Thu Fri Sat
                  1   2   3   4
   5   6   7   8   9  10  11
  12  13  14  15  16  17  18
  19  20  21  22  23  24  25
  26  27  28  29  30

C:\book>_
```

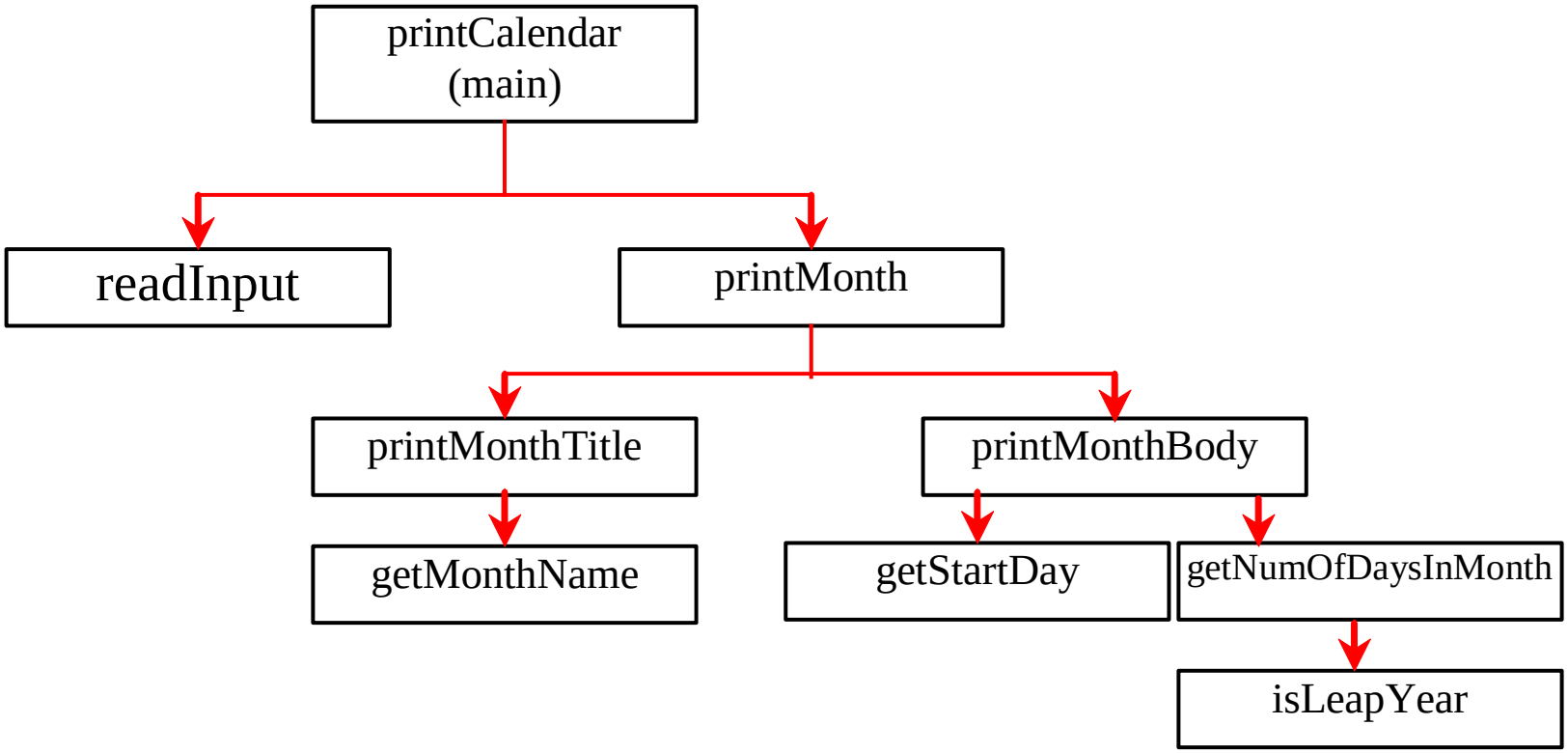
Design Diagram



Design Diagram



Design Diagram



Implementation: Top-Down

- The ***top-down*** approach is to implement one method in the structure chart at a time from the top to the bottom
  - Stubs can be used for the methods waiting to be implemented
    - A ***stub*** is a simple but incomplete version of a method.

```
/** A stub for getStartDay may look like this */
public static int getStartDay(int year, int month) {
        return 1; // A dummy value
}
```

  - The use of stubs enables you to test invoking the method from a caller.
- Implement the main method first and then use a stub for the printMonth method.
  - Then implement the methods one by one starting from the top

Implementation: Bottom-Up

- ***Bottom-up approach*** is to implement one method in the structure chart at a time from the bottom to the top.
  - For each method implemented, write a test program to test only that method

- Both top-down and bottom-up methods are fine.
  - Both approaches implement the methods incrementally and help to isolate programming errors and makes debugging easy.
  - Most of the time, they are used together

Benefits of Stepwise Refinement

- Simpler Program
- Reusing Methods
- Easier Developing, Debugging, and Testing
- Better Facilitating Teamwork