Opening Problem

Find the sum of integers from 1 to 10, from 20 to 30, and from 35 to 45, respectively.

A Solution

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

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

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

Repeated Code

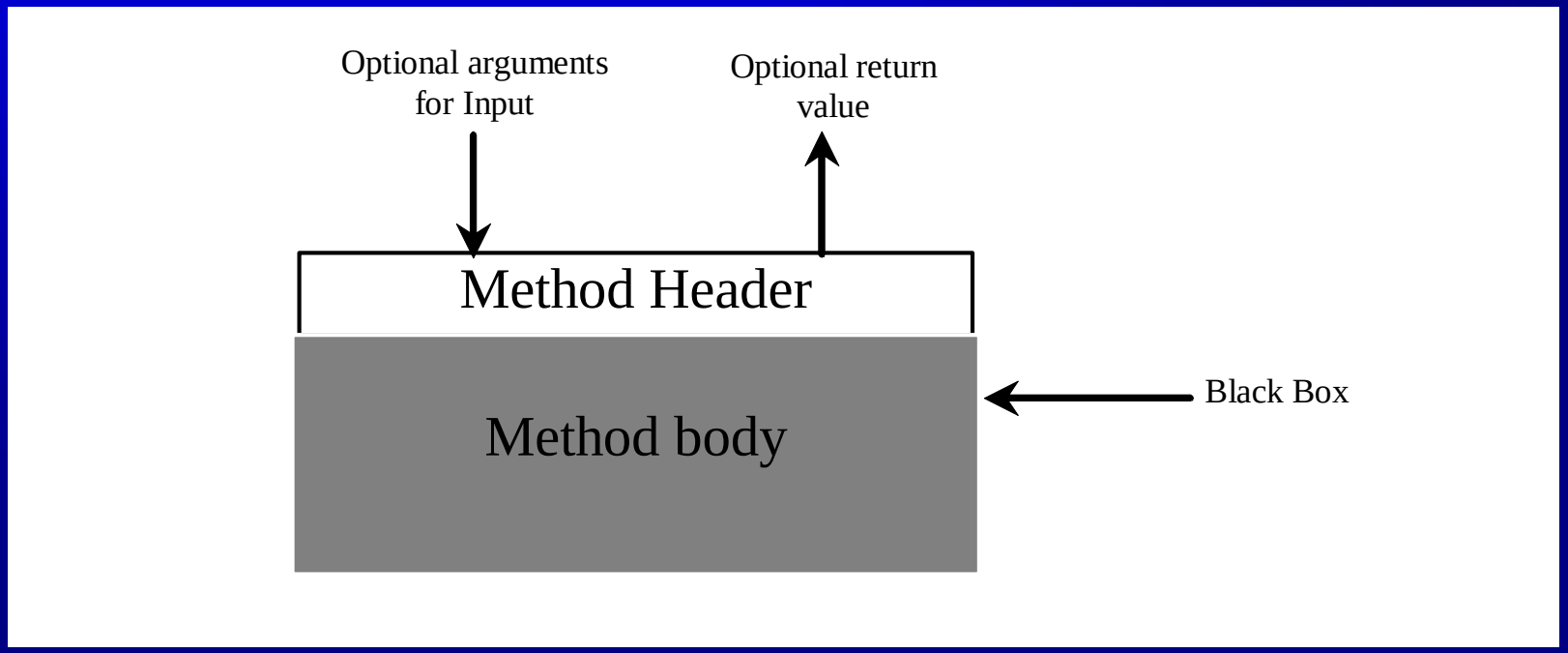
```
int sum = 0;
for (int i = 1; i <= 10; i++)
  sum = sum + i;
System.out.println("Sum from 1 to 10 is " + sum);

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

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

Solution Using Method *sum*

```
public class sumMethod {
  public static void main(String[] args)
  {
    int result = sum(1, 10);
    System.out.println("Sum from 1 to 10 is:\t" + result);

    result = sum(20, 30);
    System.out.println("Sum from 20 to 30 is:\t" + result);

    result = sum(35, 45);
    System.out.println("Sum from 35 to 45 is:\t" + result);
  }

  public static int sum (int num1, int num2)
  {
    int sum = 0;
    for (int i = num1; i <= num2; i++)
         sum = sum + i;
    return sum;
  }
}
```

What is a Method?

Think of a method as a black box that contains the detailed implementation for a specific task. The method may take use inputs (parameters) and may retune an out with a specific type.



Benefits of Methods

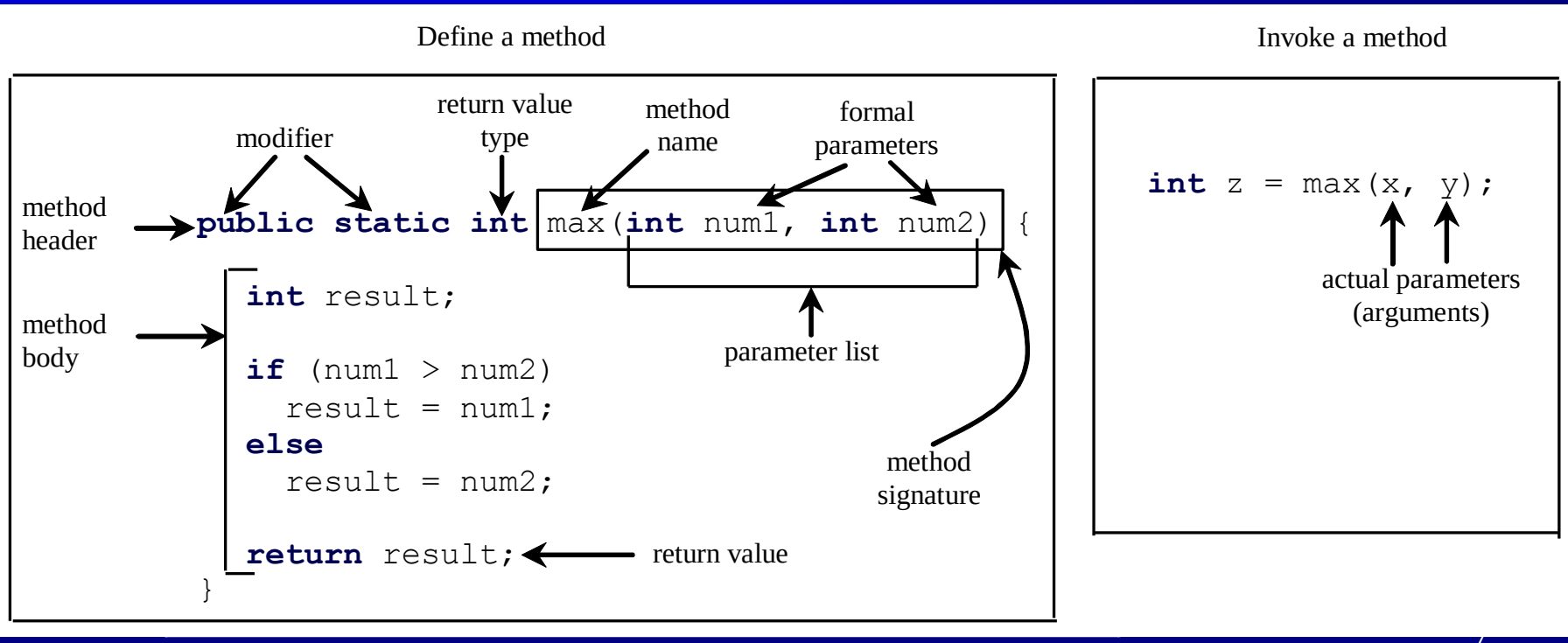
- Write a method once and reuse it anywhere
- Promotes Information hiding (hide the implementation from the user)
- Facilitate modularity (break the code into manageable modules)
- Reduce code complexity (better maintenance)

Defining Methods

A method has a *header* and a *body*.

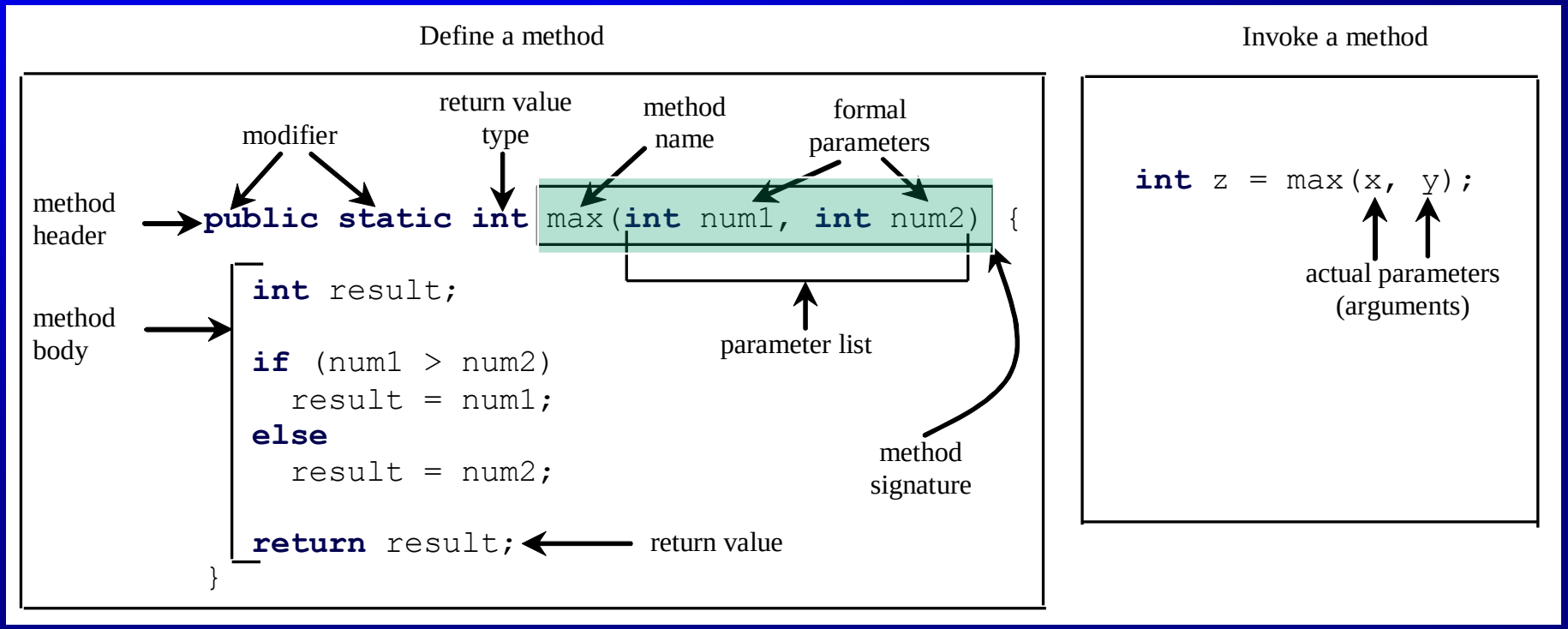
=> The *header* is the method declaration.

=> The *body* is a a collection of statements grouped together to perform an operation.



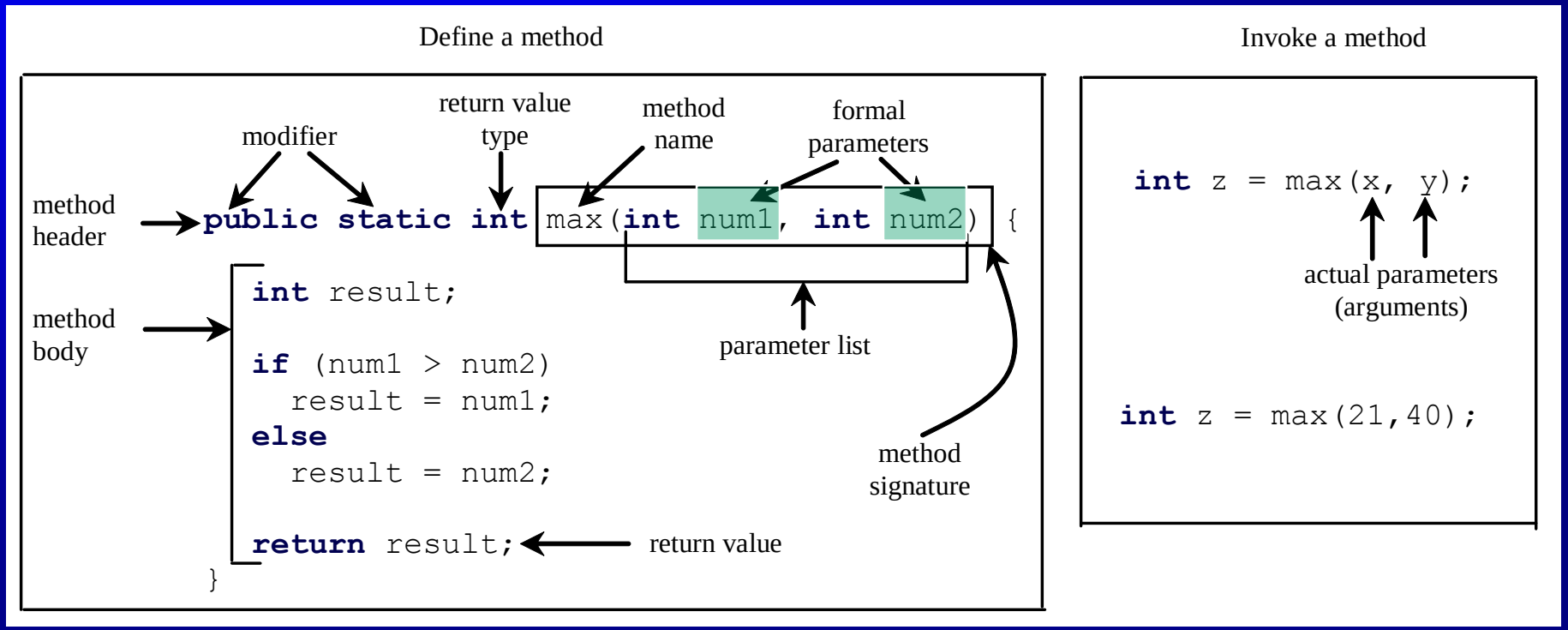
Method Signature

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



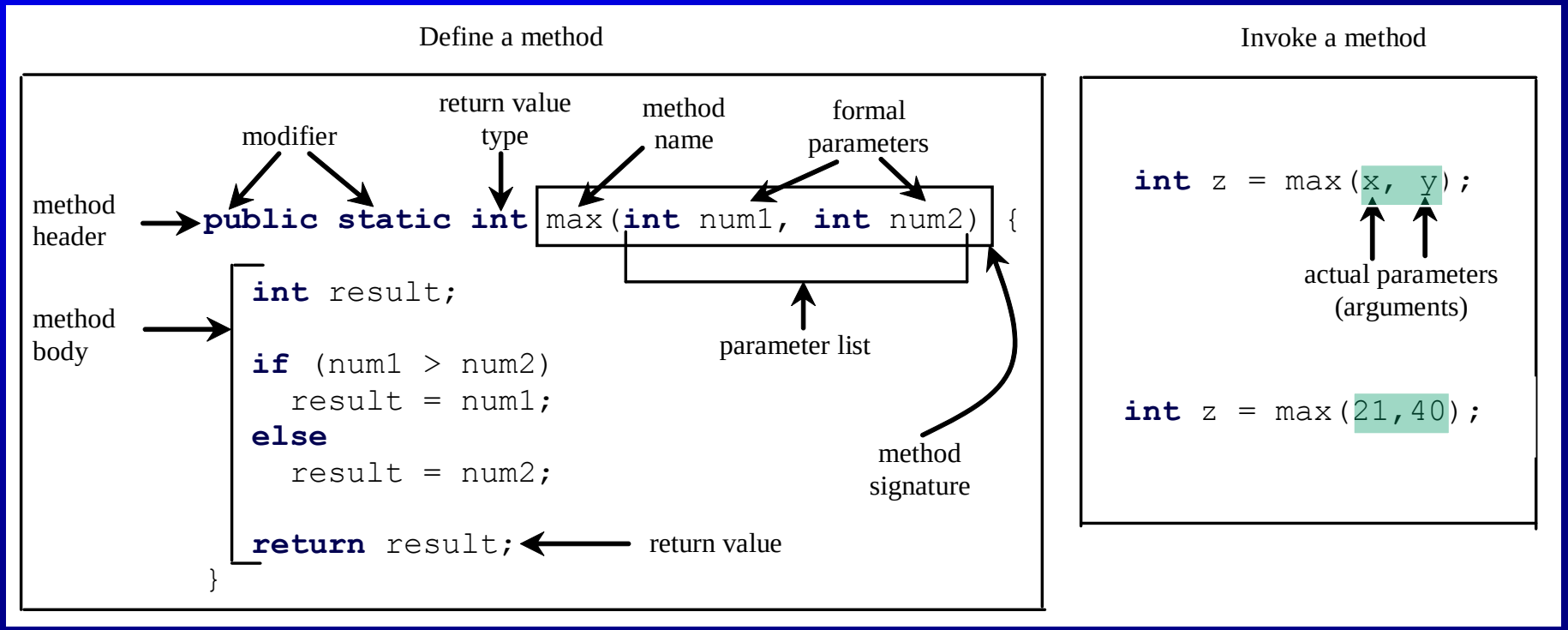
Formal Parameters

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



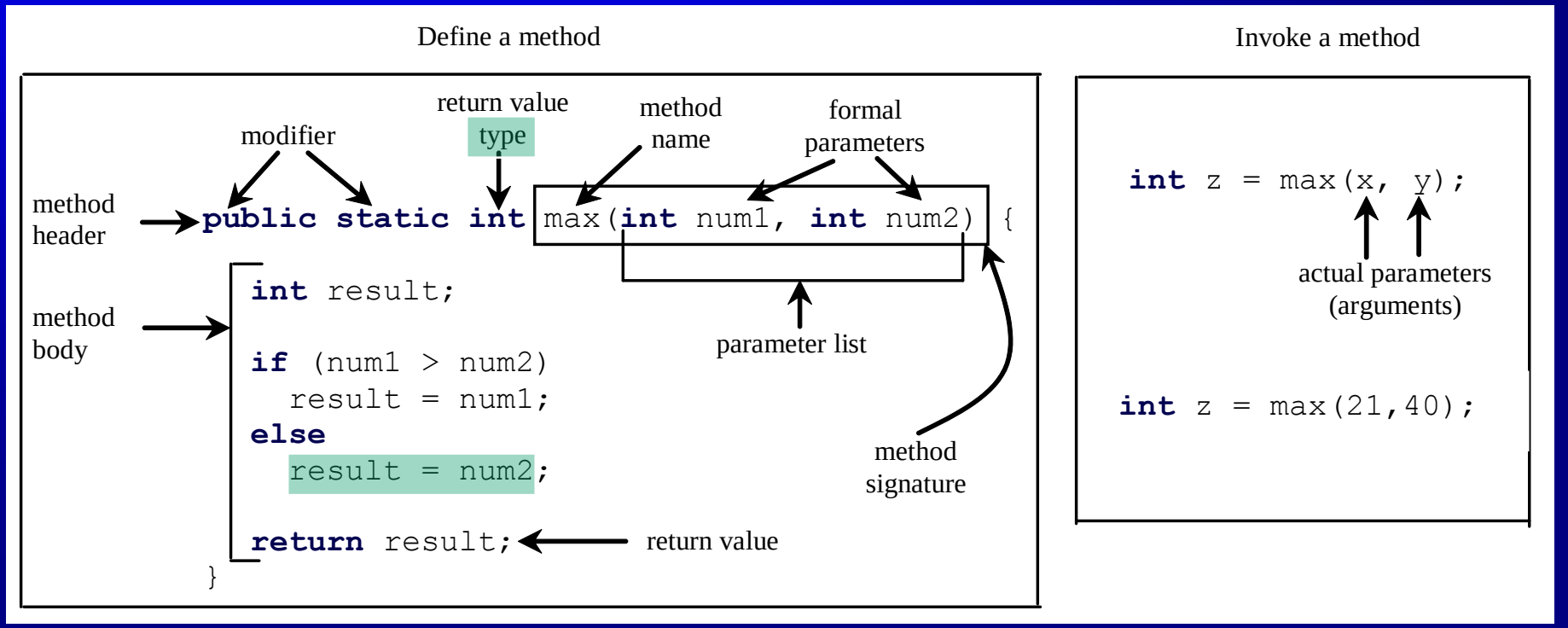
Actual Parameters

When a method is invoked, you pass a value to the parameter. This value is referred to as *actual parameter* or *argument*.



Return Value Type

A method may return a value. The returnValueType is the data type of the value the method returns. If the method does not return a value, the returnValueType is the keyword void.



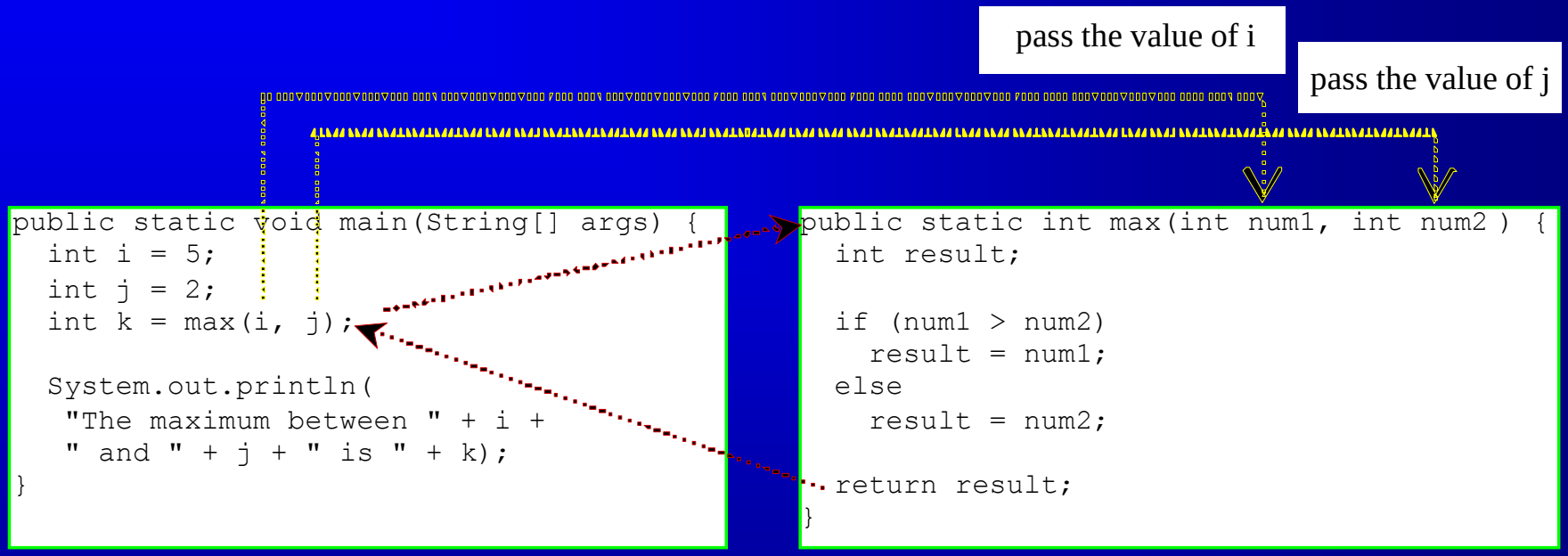
Calling Methods

Testing method **`max`**

This program demonstrates calling method **`max`** to return the largest of two **`int`** values.

animation

Calling Methods, cont.



animation

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;
}
```

animation

Trace Method Invocation

j is now 2

```
public static void main(Strin[] 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;
}
```

animation

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;
}
```

animation

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;
}
```

animation

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;
}
```

animation

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;
}
```

animation

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;
}
```

animation

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    tatic int max(int num1, int num2) {
      esult;

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

  return result;
}
```

animation

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;
}
```

animation

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;
}
```

Program TestMax

```
//class TestMax
public class TestMax
{
  public static void main(String[] args) // main method
  {
    int i = 5;
    int j = 2;
    int k = max(i, j);
    System.out.println("The maximum of " + i + " and " + j + " is " + k);
  }

  public static int max(int num1, int num2) // method max
  {
    int result;
    if (num1 > num2)
       result = num1;
    else
       result = num2;

    return result;
  }
}
```

CAUTION

A return statement is required for a value-returning method. The method shown below in (a) is logically correct, but it has a compilation error because the Java compiler thinks it is possible that this method does not return any value.

```
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

```
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 *if (n < 0)* in (a), so that the compiler will see a return statement to be reached regardless of how the if statement is evaluated.

Reuse Methods from Other Classes

One of the benefits of methods is for reuse. The max method (being public method) can be invoked from any other class besides TestMax.

If you create a new class Test, you can invoke method max using ClassName.methodName (e.g., TestMax.max).

You need to compile both classes to be able call method max from class Test.

Remember? Math.pow(a,b); Math.sqrt(x);

Another Example

```
// illustration of methods in java
import java.util.*;
public class TestMethods {
   public static void main (String[] arge)
   { int a = 10, b = 20;
     int addResult = Add(a,b); //method call Add
     System.out.println("Sum of a and b is " + addResult);

     String myMessage = "Hello World!"; // call method PrintMessage
     printMessage(myMessage);
   }

   // method definition
   public static int Add(int x, int y)
   { return (x+y); }

   // method definition
   public static void printMessage(String message)
   {
     for (int i = 1; i <= 5; i++)
          System.out.println(message);
   }
}
```

Runtime Stack

Stop and Record…

Runtime Stack

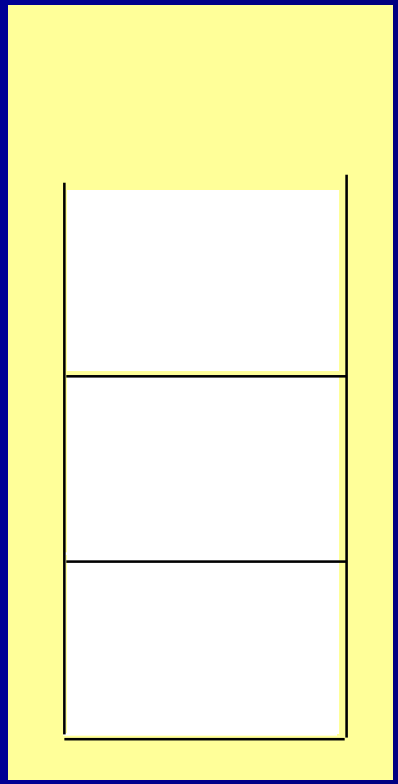
A runtime stack is a structure used to keep track of active (currently running) methods in the program, and order of method calls.

Each active method has "activation record" on the stack. The record is the memory space for all local variables in the method.

The top activation record on the stack represents the currently running (active) method in the program.

The bottom activation record represents the main method often program.

Once a method is no longer active, it is removed from the stack (always the top record is removed).



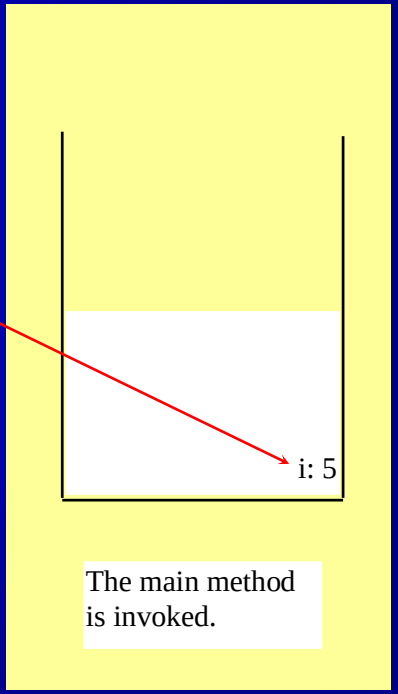
animation

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;
}
```



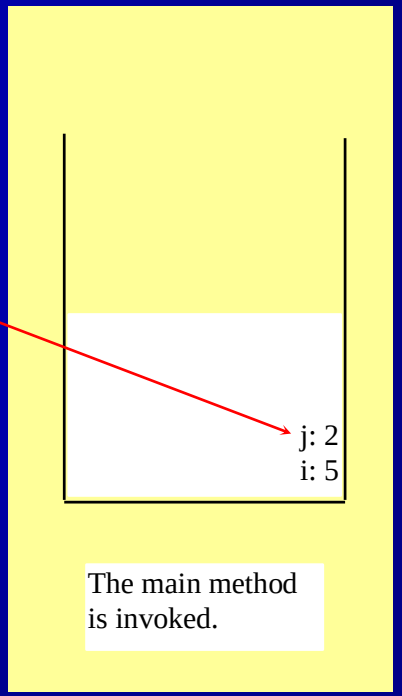
animation

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;
}
```



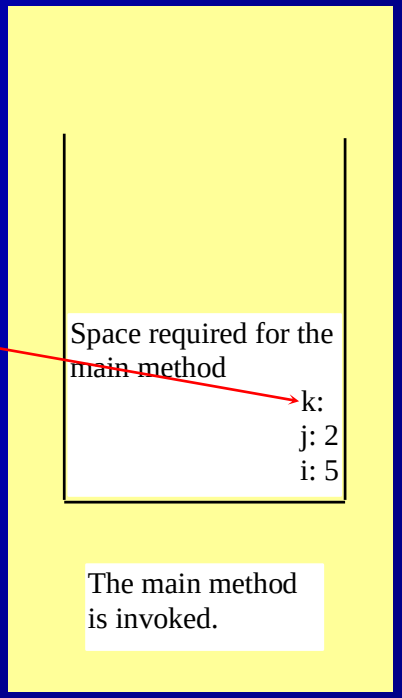
animation

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;
}
```



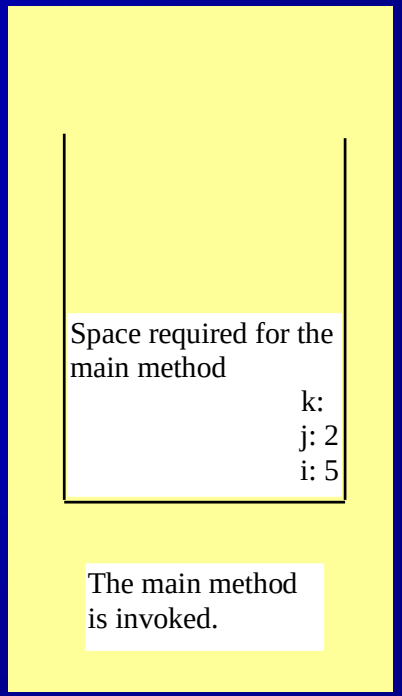
animation

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;
}
```



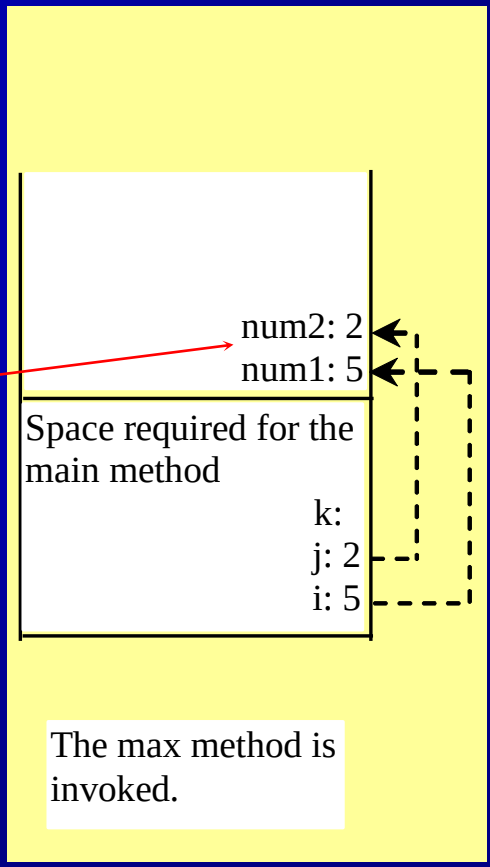
animation

Trace Call Stack

pass the values of i and j to num1 and 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;
}
```



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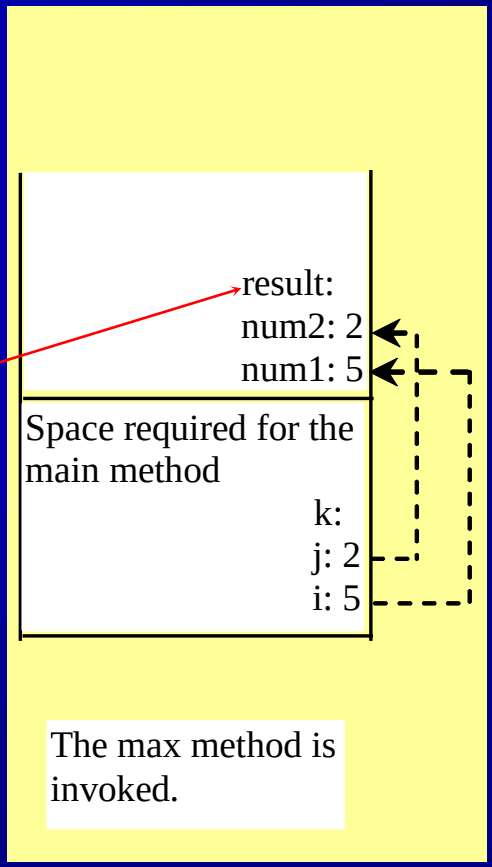
Trace Call Stack

pass the values of i and j to num1 and 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;
}
```



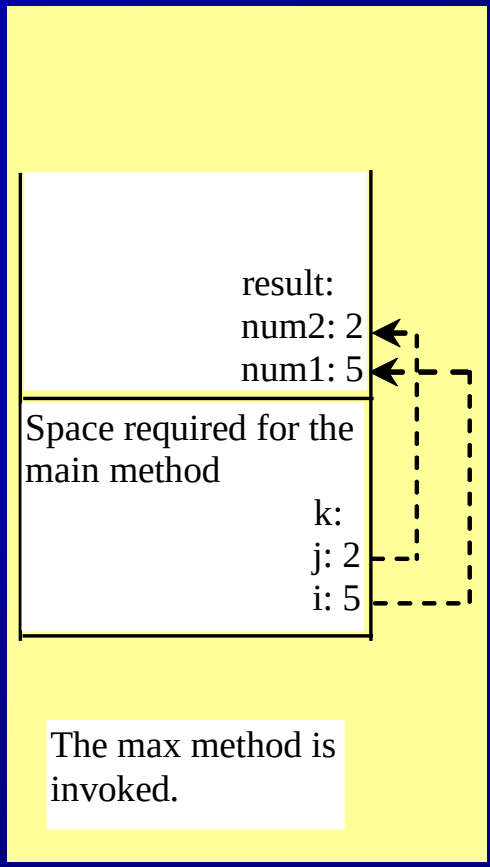
animation

Trace Call Stack

(num1 > num2) is true

```
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;
}
```



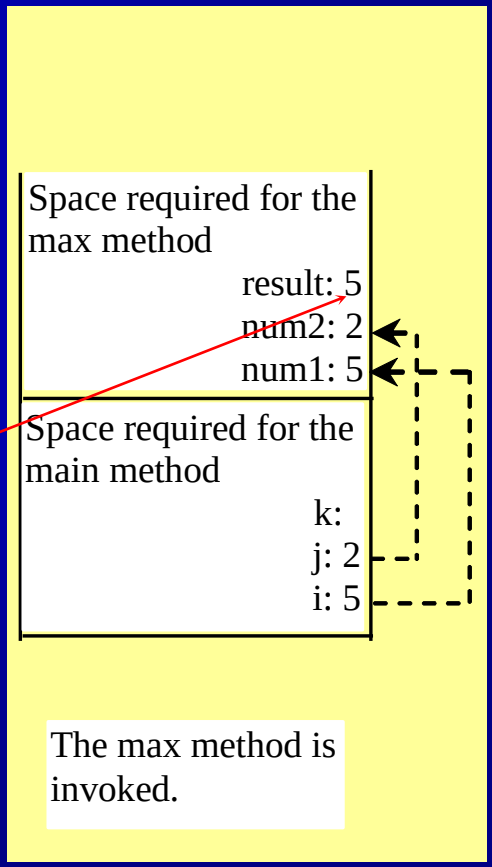
animation

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



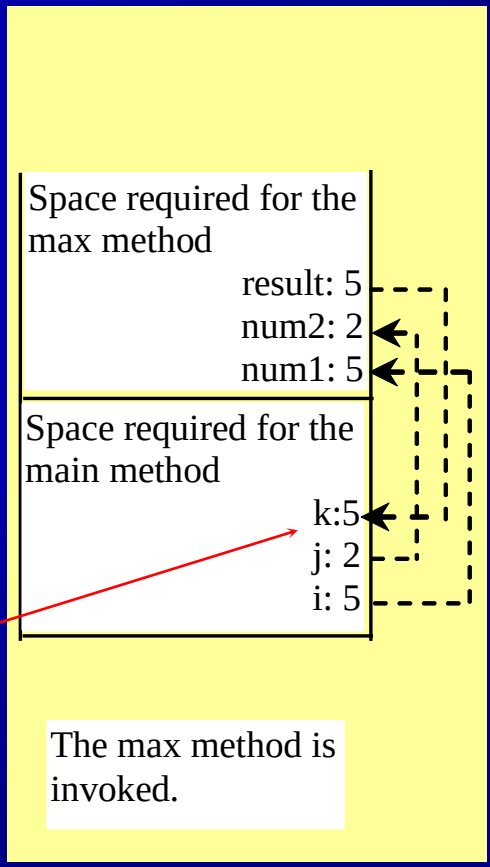
animation

Trace Call Stack

Return result and assign it 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;
}
```



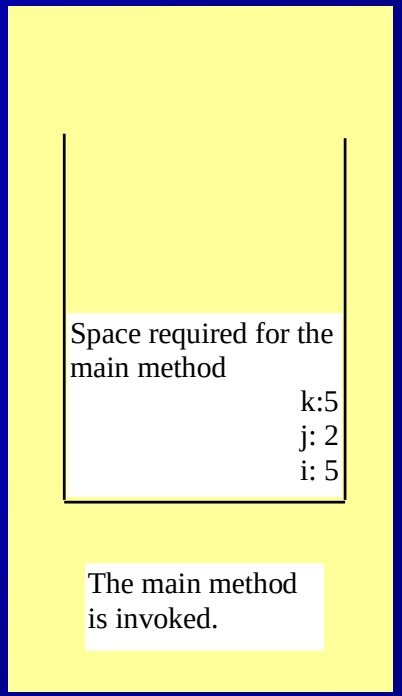
animation

Trace Call Stack

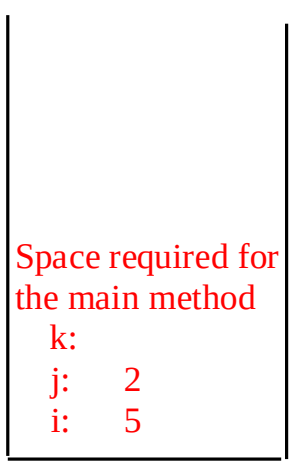
Execute print statement

```
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);
}
```

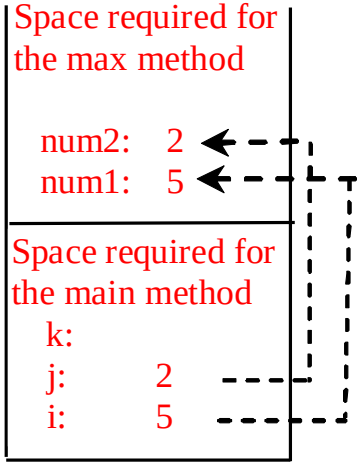
```
public static int max(int num1, int num2) {
  int result;

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

  return result;
}
```



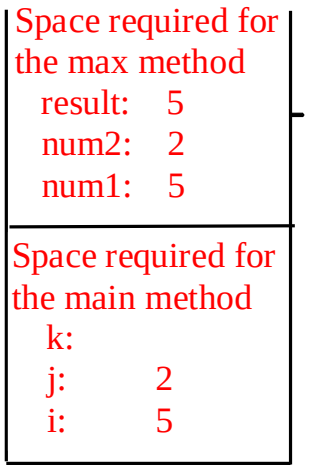
Call Stacks



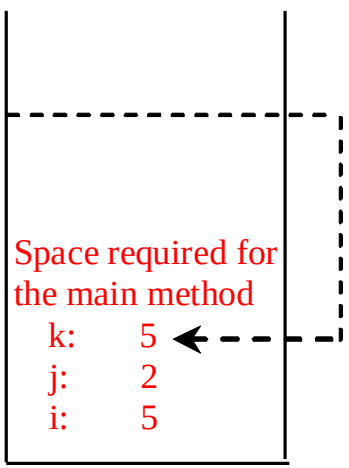
(a) The main method is invoked.



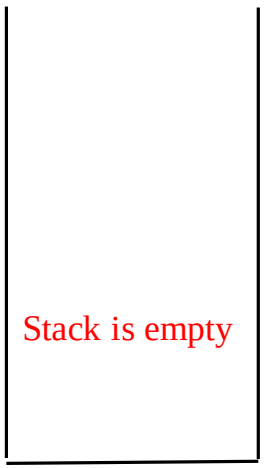
(b) The max method is invoked.



(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.

`void` Method

This type of method does not return a value. The method performs some actions.

```
public static void Even_Odd(int n)
{
  if ((n % 2) == 0)
    System.out.println(n + " is Even.");
  else
    System.out.println(n + " is Odd.");
}
```

See Listing 6.2, page 209, for example method:

`public static void printGrade(double score)`

Passing Parameters

```
public static void nPrintln(String message, int n)
{
  for (int i = 0; i < n; i++)
     System.out.println(message);
}
```

Suppose you invoke the method using

```
nPrintln("Welcome to Java", 5);
```

What is the output?

Suppose you invoke the method using

```
nPrintln("Computer Science", 15);
```

What is the output?

Pass by Value

It means that the value of the actual parameter (when a variable) is copied into the formal parameter.

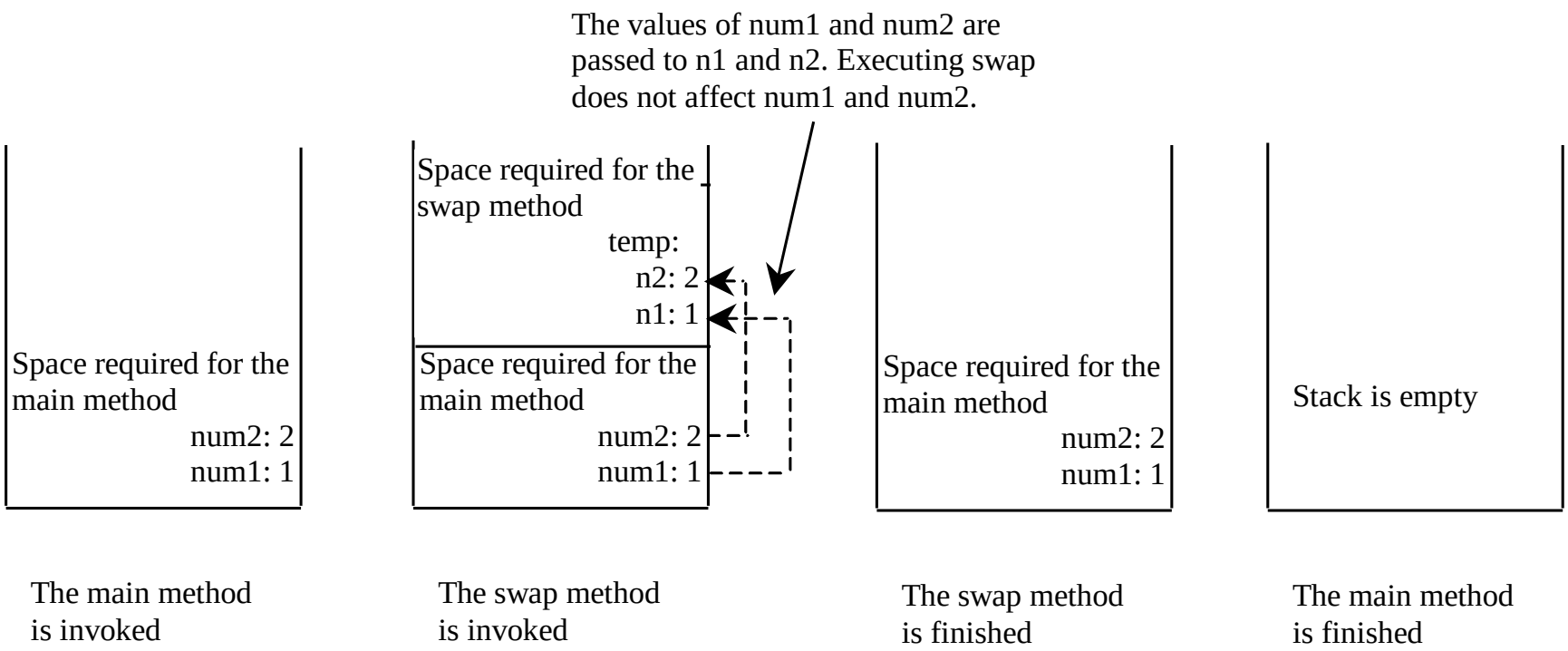
Whatever changes made to the formal parameter are local to the method and do not affect/change the value of the actual parameter.

Classic example: The Swap method.

Pass by Value Example

```
public class TestPassByValue {
  public static void main (String[] arge){
    int num1 = 1;
    int num2 = 2;
    System.out.println("Before calling Swap: num1 = " + num1 +
        "  num2 = " + num1 + "\n");
    swap(num1, num2);
    System.out.println("After calling Swap:  num1 = " + num1 +
        "  num2 = " + num2 + "\n");
   }

   public static void swap(int n1, int n2){ // method swap
      System.out.println("Inside swap, before Swapping : n1 = " +
          n1 + "  n2 = " + n1 + "\n");
      int temp = n1;
      n1 = n2;
      n2 = temp;
      System.out.println("Inside swap, after Swapping:   n1 = " +
          n1 + "  n2 = " + n2 + "\n");
   }
}
```

Pass by Value Runtime Stack



Modularizing Code

Modularization is software design concept that calls for writing code in modules.

Methods (as modules) can be used to reduce redundant coding and enable code reuse.

Methods can also be used to modularize code and improve the quality of the program.

Starting page 215, see listings 6.6 (GCD), 6.7 (Prime numbers), and 6.8 (converting decimal to hexadecimal). Each has at least one methods in addition to method `main()`.

Overloading Methods

Overloading is making a method to work with different types of parameters.

Example: Overloading the `max` Method

```
public static int max(int num1, int num2)
{
  if (num1 > num2)
    return num1;
  else
    return num2;
}

public static double max(double num1, double num2)
{
  if (num1 > num2)
    return num1;
  else
    return num2;
}
```

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*. Ambiguous invocation is a compilation error.

Ambiguous Invocation

```
public class AmbiguousOverloading {
  public static void main(String[] args) {
    System.out.println(max(1,2)); //Error
  }

  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;
  }
}
```

Scope of Local Variables

Local variable: a variable defined inside a method.

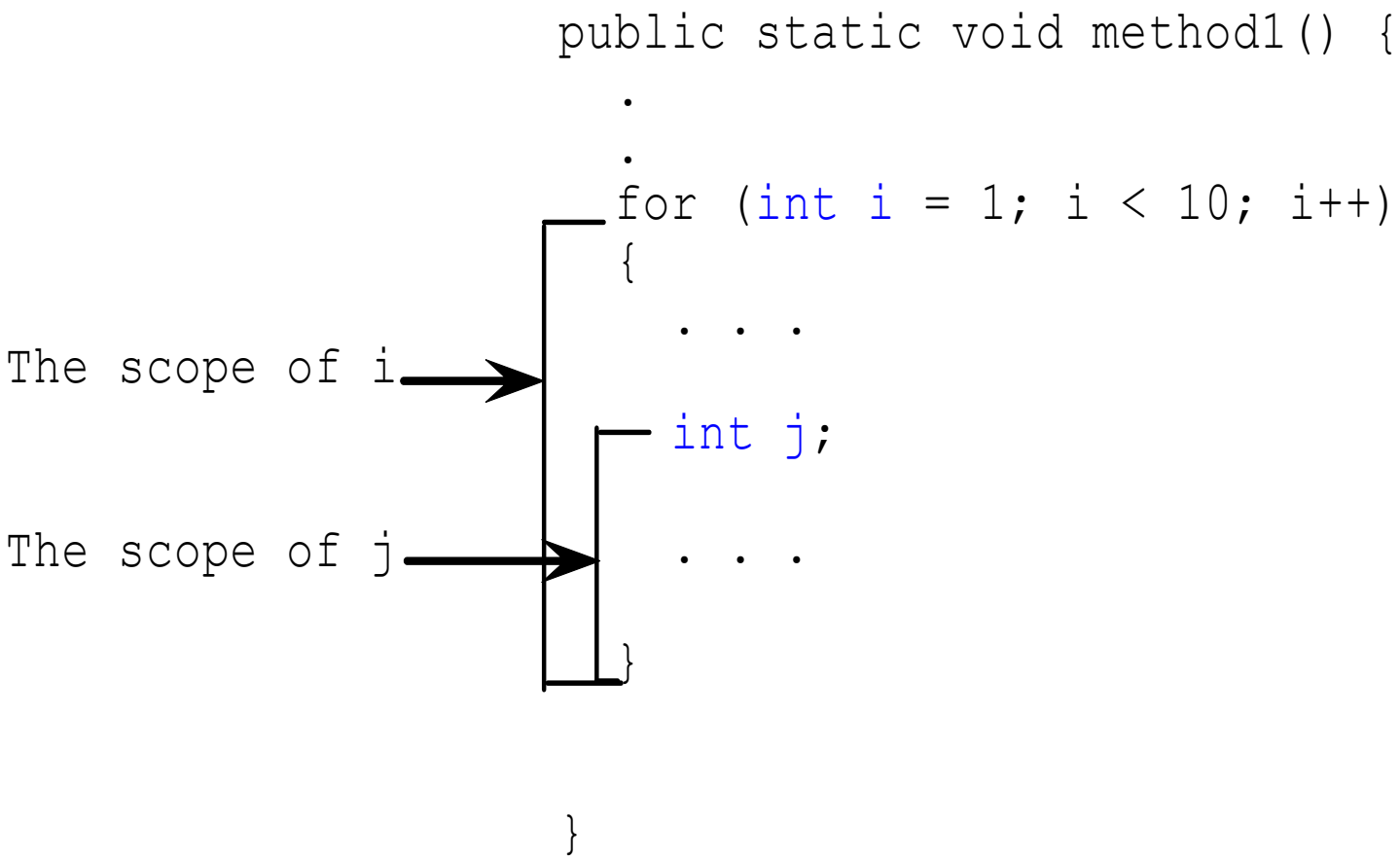
Scope: the part of the program where the variable can be referenced (accessible).

The scope of a local variable (also known as life-time) starts from its declaration point and continues to the end of the **block** that contains the variable. A local variable must be declared before it can be used.

Java Rule:

You can declare a local variable with the same name multiple time in different ***non-nesting blocks*** in a method, ***but you cannot declare a local variable twice in nested blocks.***

Scope of Local Variables, cont.



Scope of Local Variables, cont.

It is fine to declare i in two non-nesting blocks

```
public static void method1() {
  int x = 1;
  int y = 1;

  for (int i = 1; i < 10; i++) {
    x = x + i;
  }

  for (int i = 1; i < 10; i++) {
    y = y + i;
  }
}
```

It is wrong to declare i in two nesting blocks

```
public static void method2() {

  int i = 1;
  int sum = 0;

  for (int i = 1; i < 10; i++)
    sum = sum + i;
  }

}
```

Scope of Local Variables, cont.

```
// Homework: code with errors, can you find them?
public static void incorrectMethod()
{
  int x = 1;
  int y = 1;
  for (int i = 1; i < 10; i++)
  {
    int x = 0;
    int t = 0;
    x = x + i;
  }
  i = i + 10;
  y = y + 10;
  t = t + 10;
}
```