UBC OKANAGAN

COSC 111
Computer Programming I

Methods

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Introduction

Today, we will learn how to properly organize our code. That is,

- we are going to discuss the ***code organization***,
- NOT the program logic.

We will learn writing ***modular code***

- **Modular programming** is focuses on *designing* the software with an emphasis on separating the functionality into **modules**, each containing code that executes only one aspect of the desired functionality.

Problem decomposition involves breaking down a large problem into subproblems which are easier to solve. Dividing problems into subproblems is called ***divide and conquer***

Introduction

So far, we have been writing all our code in the main method.

It is not advised to write code in a *monolithic* fashion.

Example Problem: Find the sum of integers from 1 to 10.

```
Public static void main(String[] args){
    int sum = 0;
    for (int i = 1; i <= 10; i++)
      sum += i;
    System.out.println("Sum from 1 to 10 is " + sum);
}
```

Opening Problem

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

```
Public static void main(String[] args){
  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);
}
```

Repeated code!

Solution – Use methods

Methods can be used to:

- **reduce redundant coding** and enable **code reuse**
- **modularize code** and improve the quality of the program.

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

Write it once,

(re)use it many times!

```
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));
}
```

Method Structure

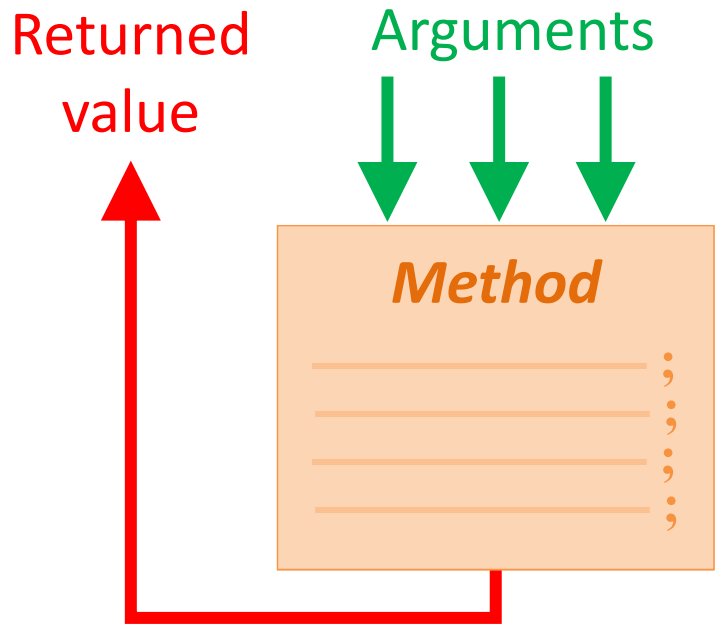
What is a method?

A method is a collection of statements that are grouped together to perform a specific **action**.

A method must have a name. Whenever we want to perform the method's action, we need to call (invoke) the method by its name.

When calling a method:

- It ***may*** receive ***input*** data
  - One or more arguments
- It ***may*** return ***output*** data
  - One returned value



Defining Methods

A method is a collection of statements that are grouped together to perform an operation. The syntax is as follows:

```
modifiers returnType methodName(parameters) {
    // Method body;
}
```

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

    int result;

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

    return result;
}
```

Define a method

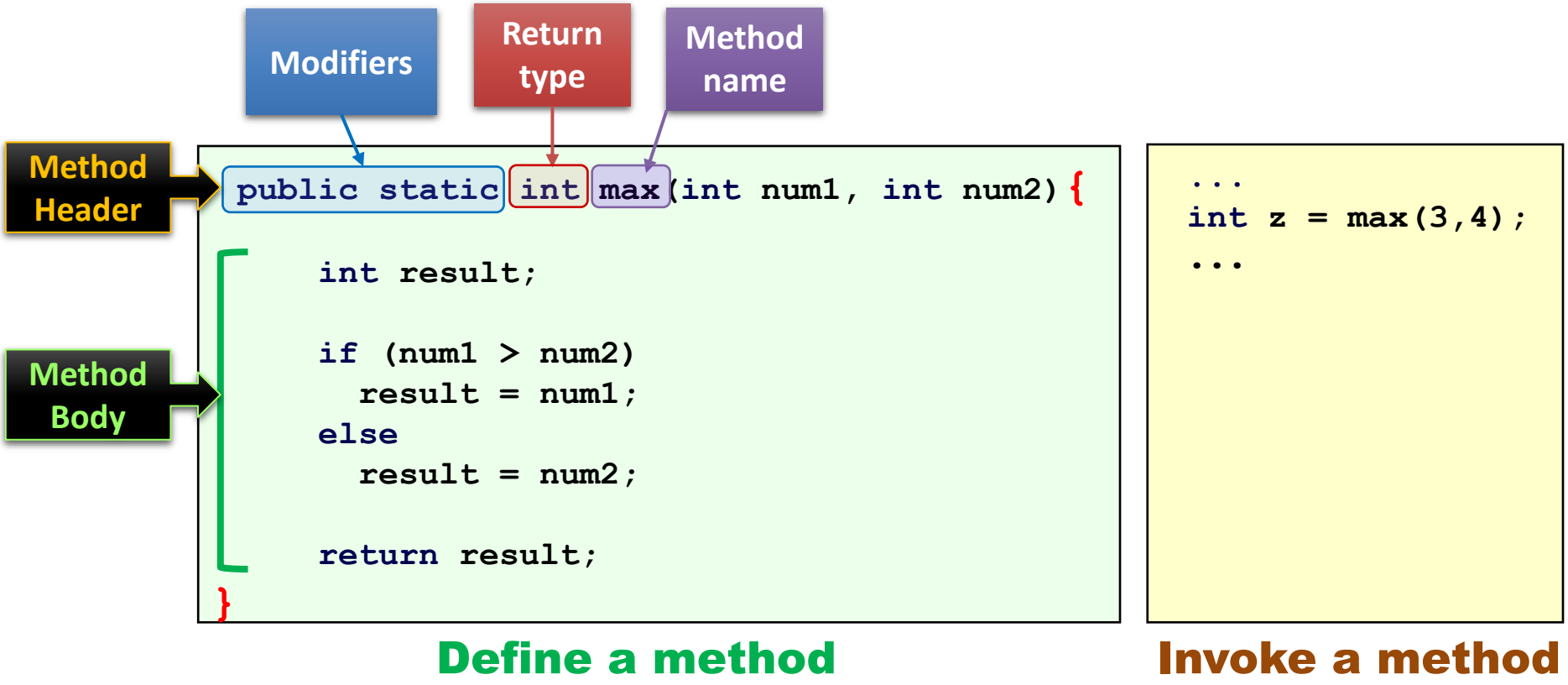
```
...
int z = max(3,4);
...
```

Invoke a method

Defining Methods

The **method header** specifies the *modifiers*, *return value type*, *method name*, and *parameters* of the method.

- A method may return a value. The returnValueType is the data type of the value the method returns.
- Some methods perform desired operations without returning a value. In this case, the returnValueType is the keyword **`void`**.

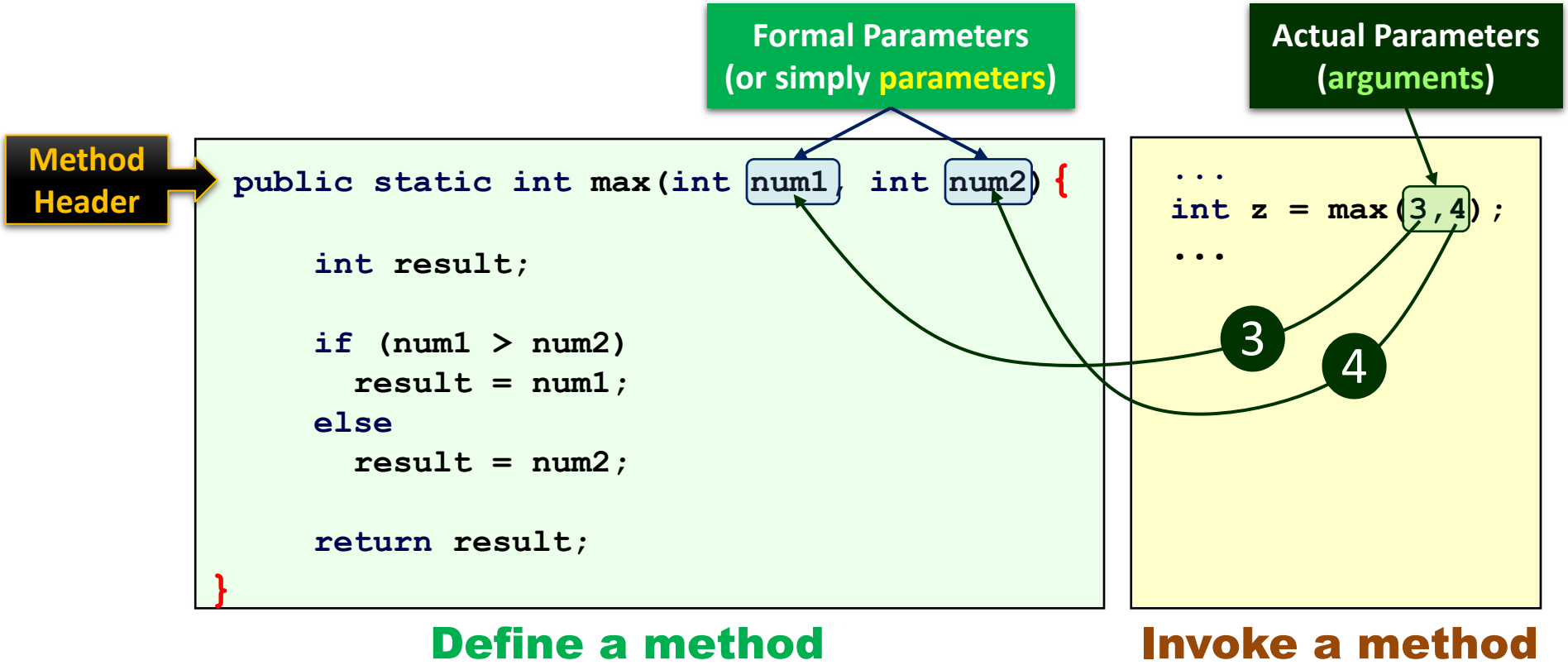


Parameters and Arguments

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

A parameter is like a placeholder: when a method is invoked, you pass a value to the parameter. This value is referred to as an ***actual parameter, or simply arguments.***

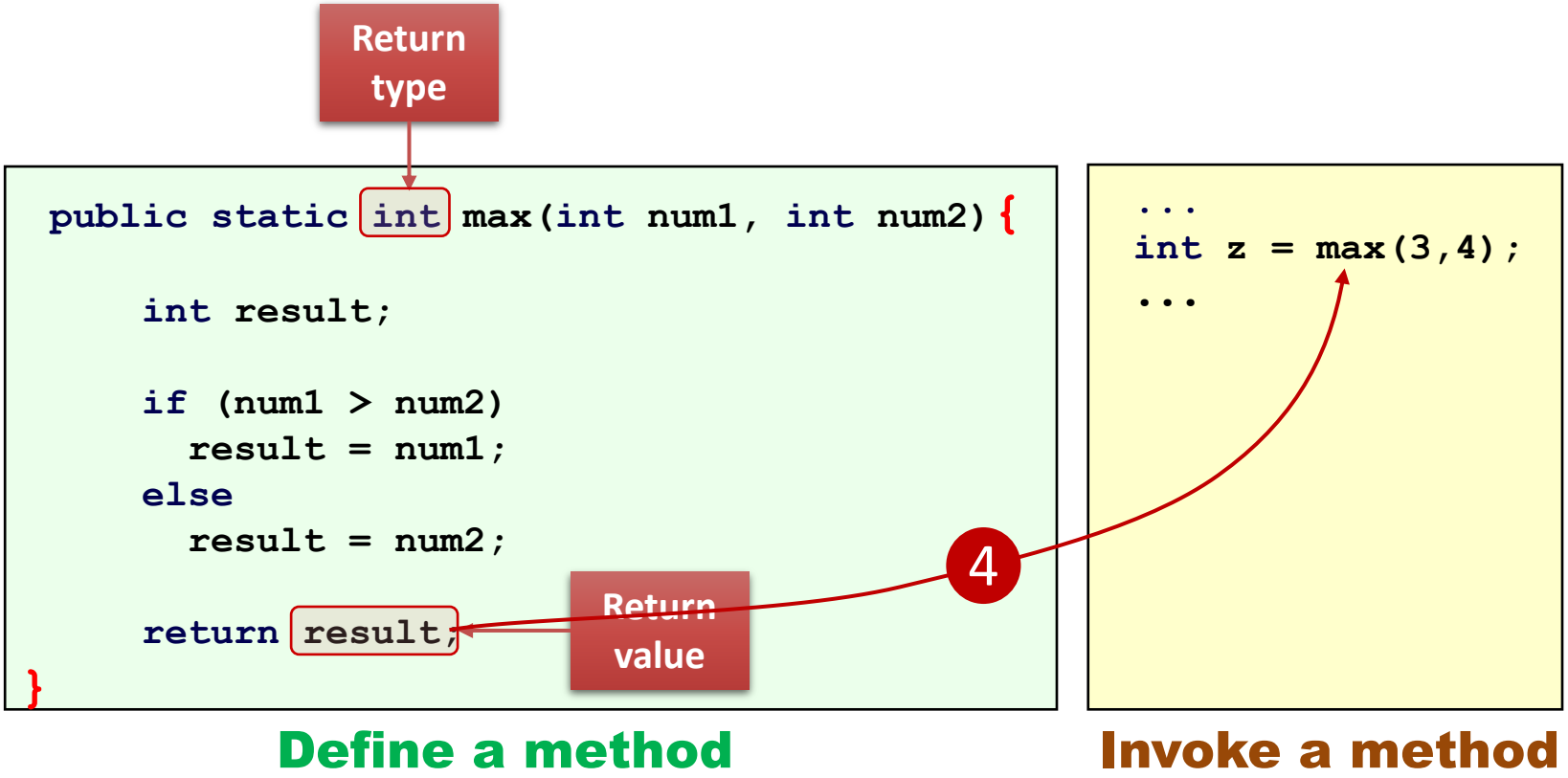
- you need to provide the arguments in the same order as their respective parameters in the method signature.



Return Value Type

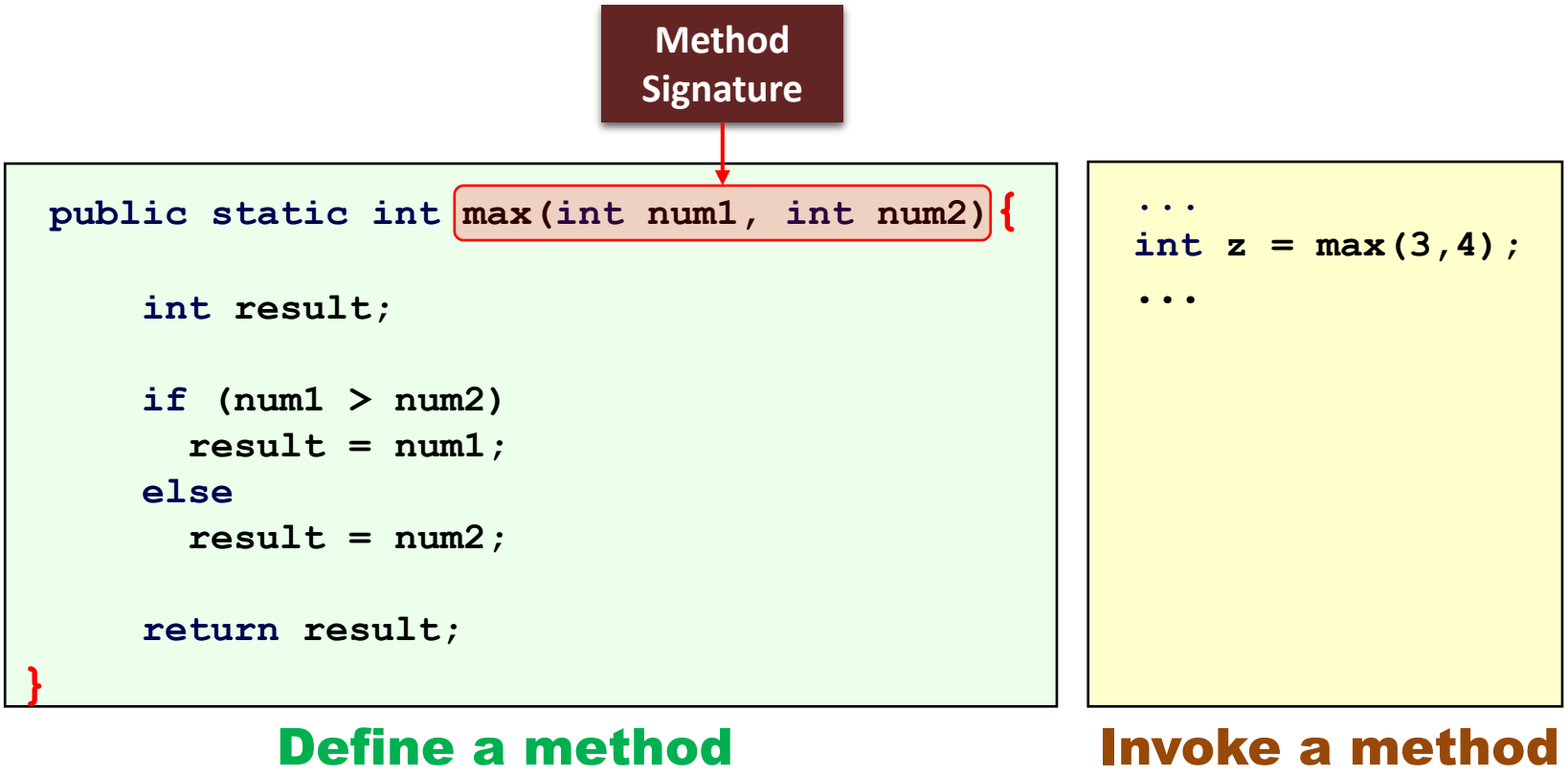
A method **may** return a value. The returnType is the data type of the value the method returns. If the method does not return a value, the returnType is the keyword **void**.

- For example, the returnValueType in the main method is void.



Method Signature

The method name and the parameter list together constitute the *method signature.*



Calling Methods

Calling Methods

To execute the method, you have to *call* or *invoke* it.

Two ways to call a method:

- **If a method returns a value**, a call to the method **is usually treated as a value.**
  - Example1:

```
int x = max(3, 4);
```

    calls **max(3, 4)** and assigns the result of the method to the variable **x.**
  - Example2:

```
System.out.println( max(3, 4) );
```

    prints the return value of the method call **max(3, 4).**
- **If a method returns void**, a call to the method must be **a statement.**
  - For example, the method **println** returns **void.** The following call is a statement:

```
System.out.println("Welcome to Java!");
```

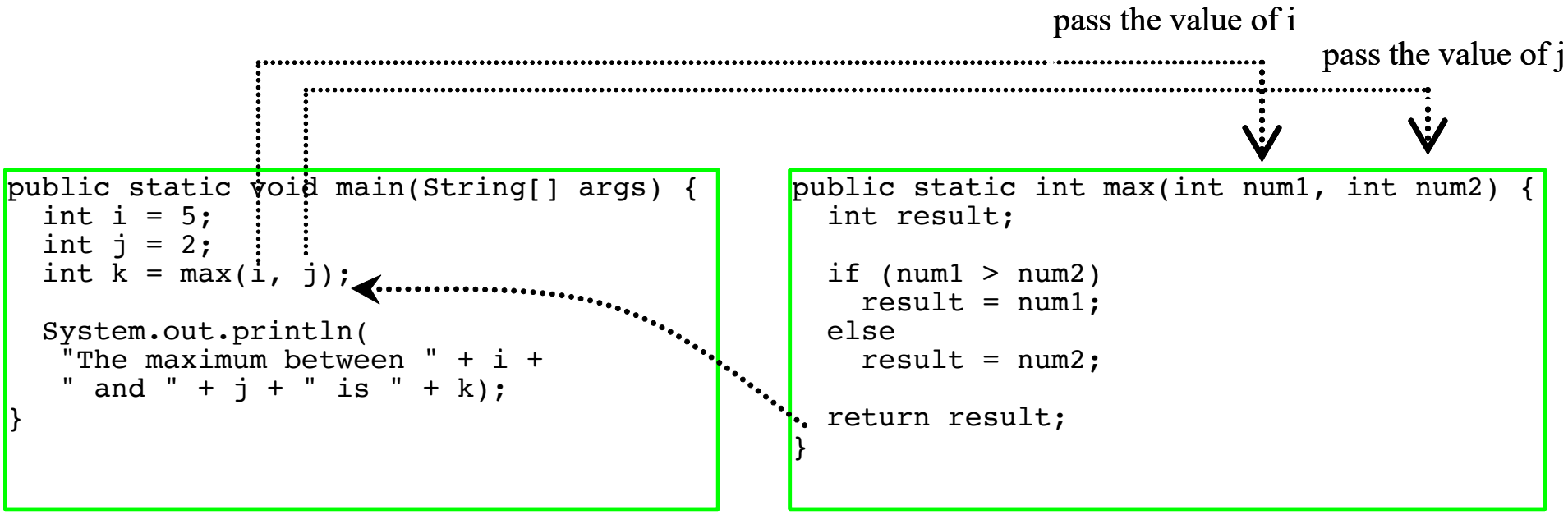
Calling Methods, cont.

Animation

When a program calls a method, program control is transferred to the called method. A called method returns control to the caller when

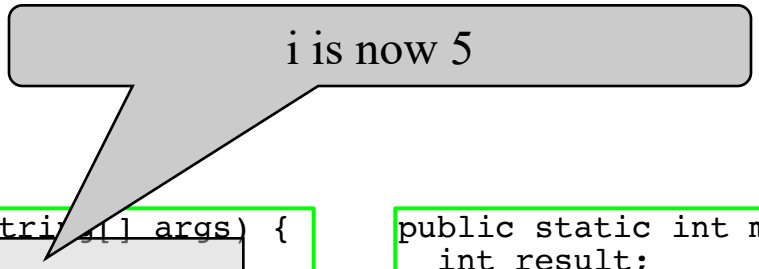
- its **return** statement is executed, or
- when its method-ending **closing brace** is reached.

Example: calling a method to return the largest of two int values



Trace Method Invocation

Animation




```
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);
}
```

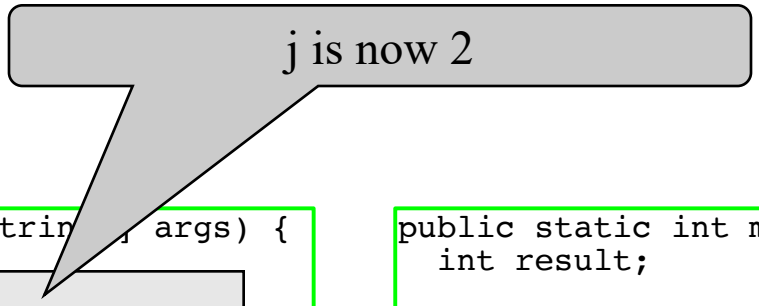
```
public static int max(int num1, int num2) {
  int result;

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

  return result;
}
```

Trace Method Invocation

Animation




```
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);
}
```

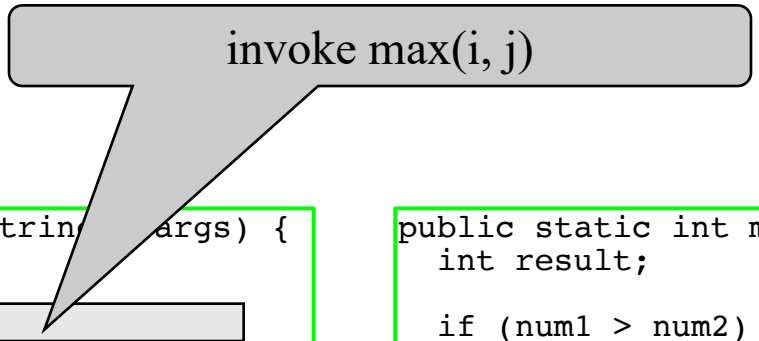
```
public static int max(int num1, int num2) {
  int result;

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

  return result;
}
```

Trace Method Invocation

Animation




```
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);
}
```

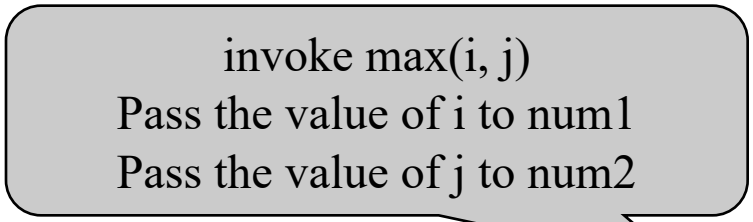
```
public static int max(int num1, int num2) {
  int result;

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

  return result;
}
```

Trace Method Invocation

Animation




```
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);
}
```

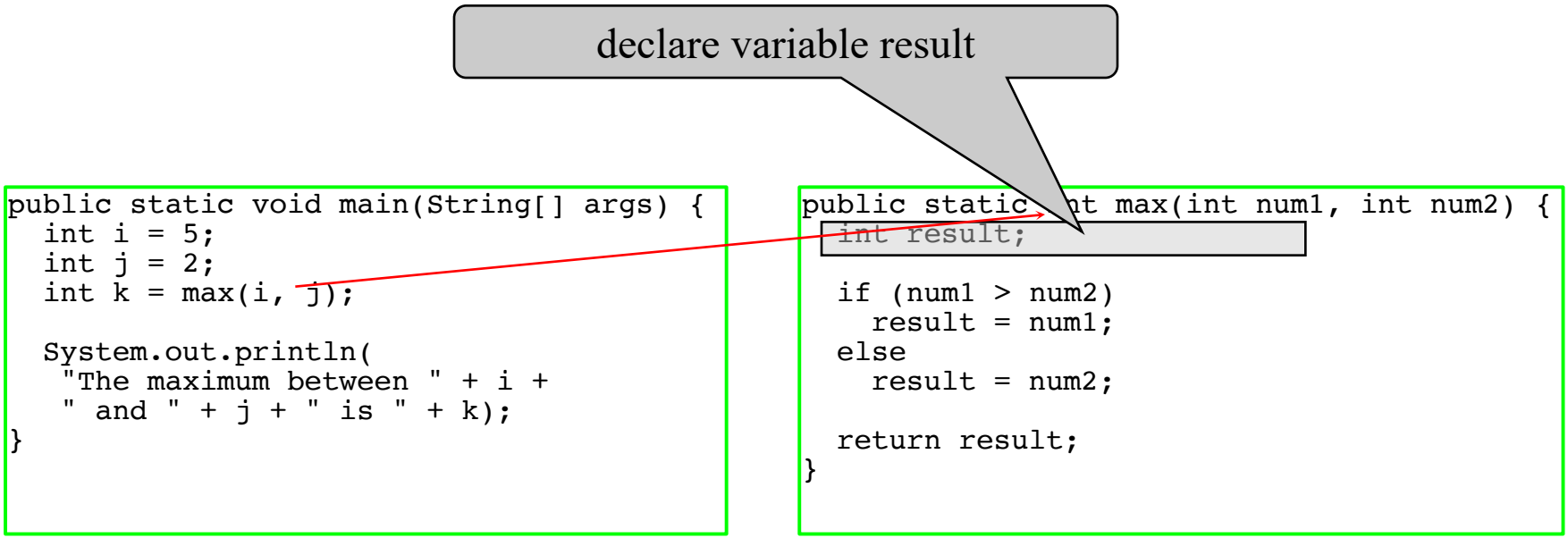
```
public static int max(int num1, int num2) {
  int result;

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

  return result;
}
```

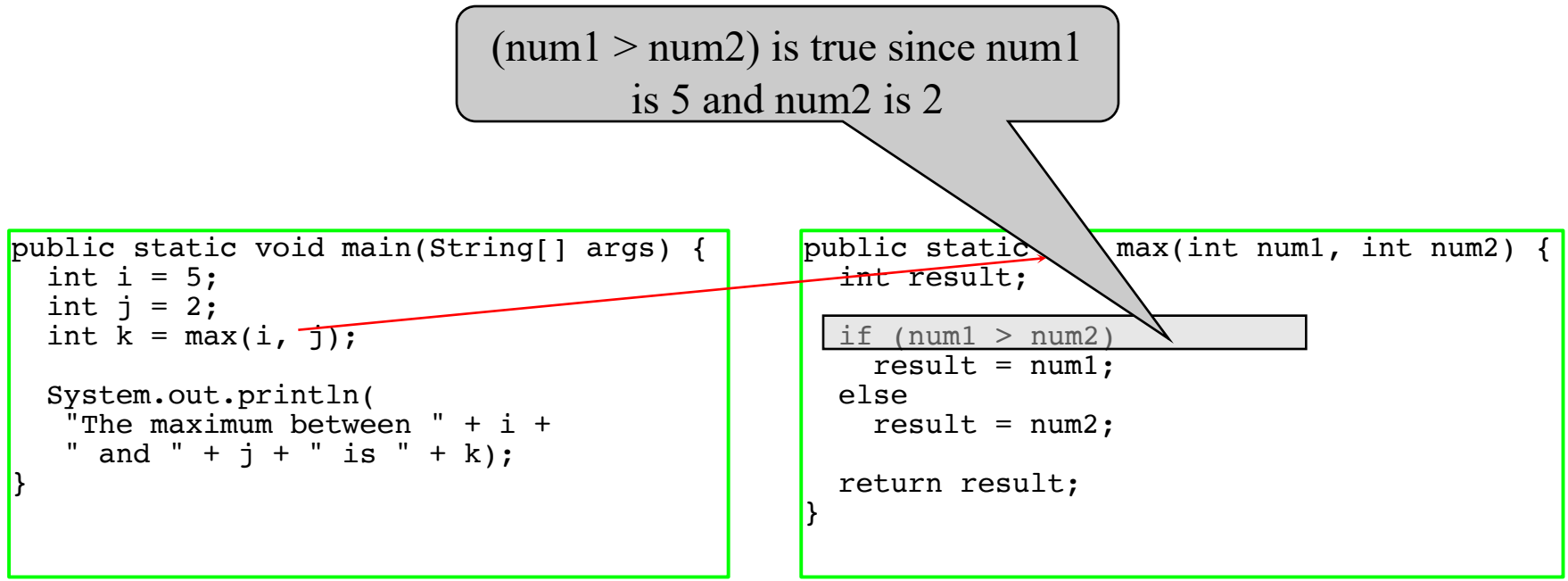
Trace Method Invocation

Animation



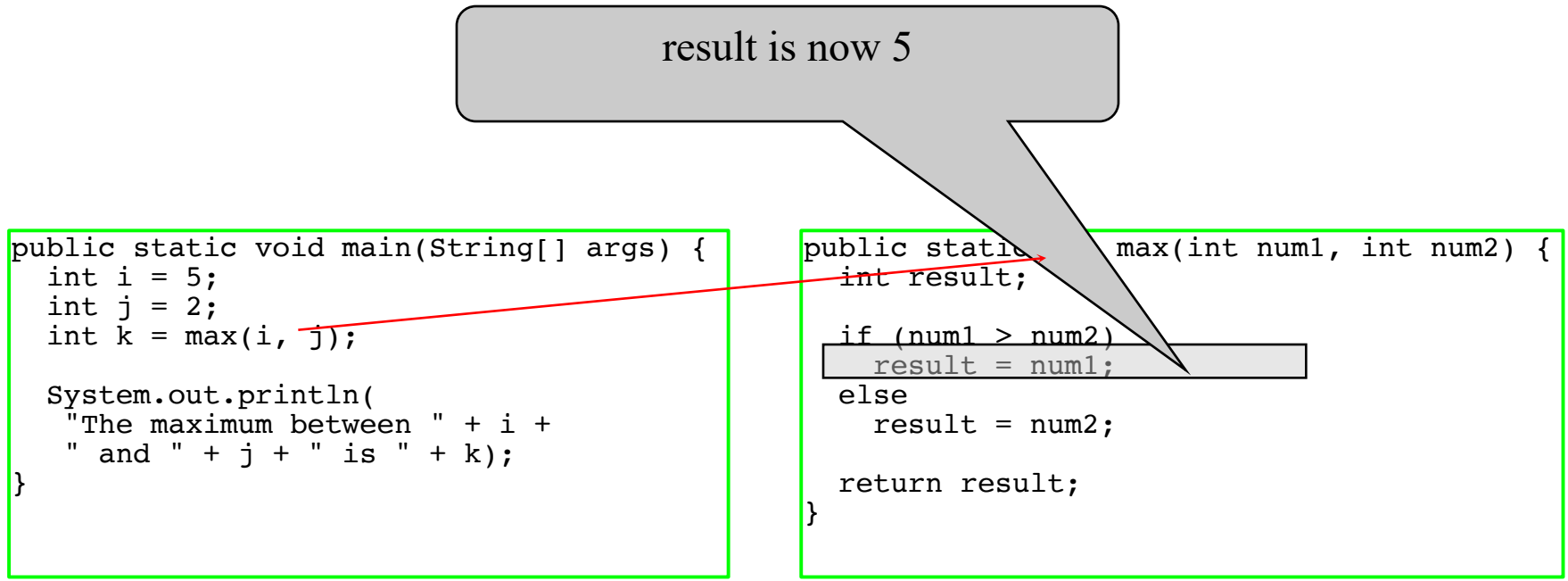
Trace Method Invocation

Animation



Trace Method Invocation

Animation



Trace Method Invocation

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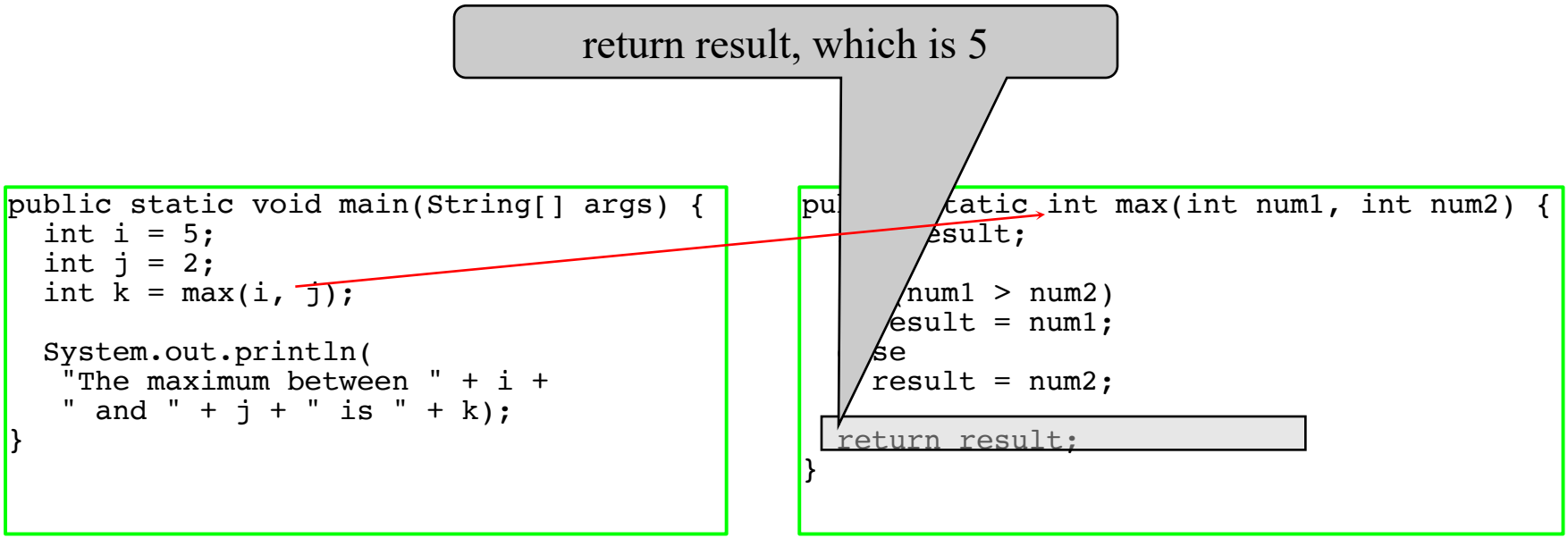
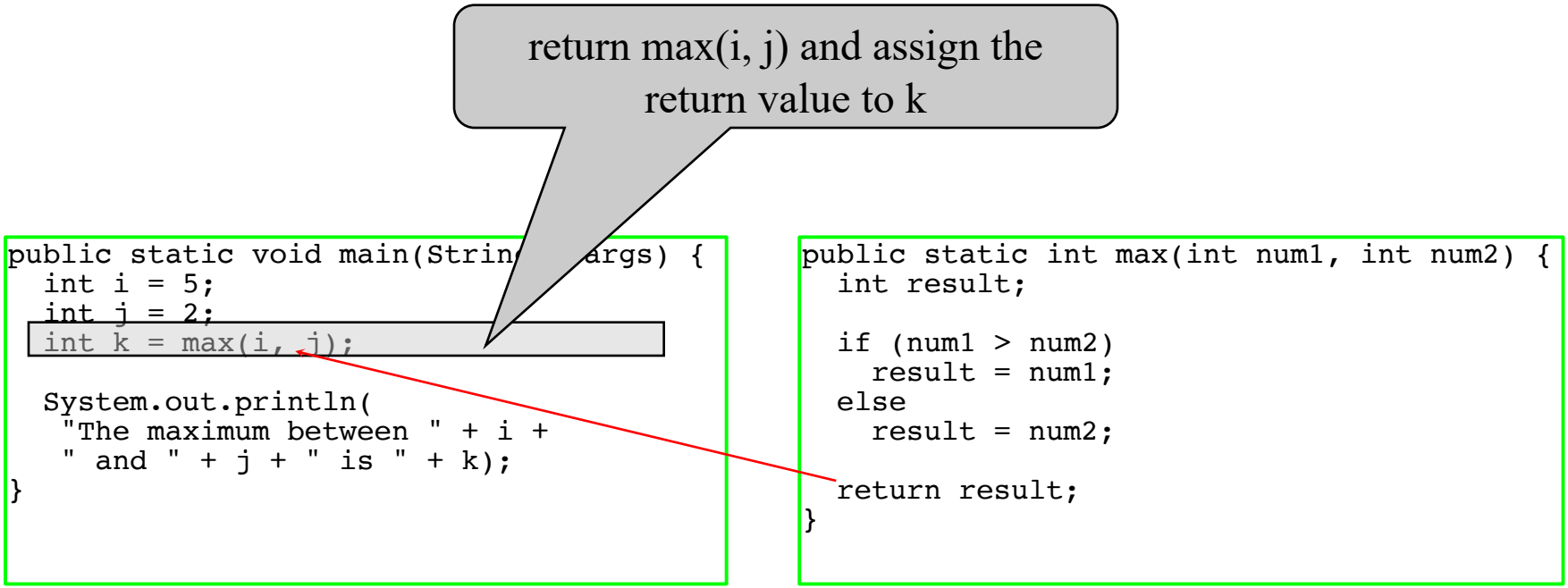


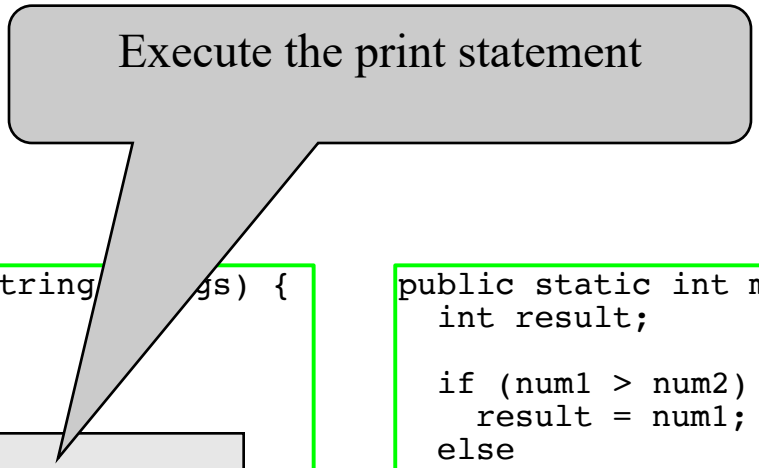
Trace Method Invocation

Animation



Trace Method Invocation

Animation




```
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 vs. void

Methods returning values vs. void methods

Void method

```
public class TestVoidMethod {
  public static void main(String[] args) {
        System.out.print("Grade is ");
        printGrade(78.5);

        System.out.print("Grade is ");
        printGrade(59.5);
  }
  public static void printGrade(double score){
        if (score >= 90.0) {
            System.out.println('A');
        } else if (score >= 80.0) {
            System.out.println('B');
        } else if (score >= 70.0) {
            System.out.println('C');
        } else if (score >= 60.0) {
            System.out.println('D');
        } else {
            System.out.println('F');
        }
  }
}
```

Method that returns data

```
public class TestReturnGradeMethod {
  public static void main(String[] args) {
    System.out.println("Grade is "+getGrade(78.5));
    System.out.println("Grade is "+getGrade(59.5));
  }
  public static char getGrade(double score) {
    if (score >= 90.0)
        return 'A';
    else if (score >= 80.0)
        return 'B';
    else if (score >= 70.0)
        return 'C';
    else if (score >= 60.0)
        return 'D';
    else
        return 'F';
  }
}
```

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 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.

`return` statement in void methods

return is **not needed for a void** method.

BUT it can be used for terminating the method.

For example

```
public static void printGrade(double score) {
        if (score < 0 || score > 100) {
                System.out.println("Invalid score");
                return;
        }
        //other statements
}
```

Clicker Question

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

What is the output if we invoke the method using

```
nPrintln("ABC", 5);
```

A. Error

B. Nothing

C. Print ABC five times

D. Print ABC six times

Clicker Question

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

What is the output if we invoke the method using

```
nPrintln(5, "ABC");
```

A. Error

B. Nothing

C. Print ABC five times

D. Print ABC six times

Clicker Question

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

What is the output if we invoke the method using

```
nPrintln();
```

A. Error

B. Nothing

C. Print ABC five times

D. Print ABC six times

Practice

Identify and correct the errors in the following program:

```
public class Ex {
    public static void main(String[] args) {
        method1(3);
    }

    public static method1(int n, m) {
        n += m;
        method2(5.2);
    }

    public static int method2(int n) {
        if (n > 0)
            return 1;
        else if (n == 0)
            return 0;
        else if (n < 0)
            return -1;
    }
}
```

Wrong **number** arguments

No return type

m has no type

Wrong **type** of arguments

must have a return statement that the compiler knows it will run for sure.

Pass by Value

Pass by Value

When you invoke a method with an argument, the value of the argument is passed to the parameter. This is referred to as ***pass-by-value***.

```
public class Increment {
    public static void main(String[] args) {
        int x = 1;
        System.out.println("Before the call, x is " + x);
        increment(x);
        System.out.println("after the call, x is " + x);
    }

    public static void increment(int n) {
        n++;
        System.out.println("n inside the method is " + n);
    }
}
```

Output

```
Before the call, x is 1
n inside the method is 2
after the call, x is 1
```

Pass by Value, cont.

Another example on pass by value:

```
public class TestPassByValue {
    /** Main method */
    public static void main(String[] args) {
        int num1 = 1;
        int num2 = 2;
        System.out.println("Before invoking the swap method, num1 is " + num1 + " and num2 is " + num2);
        swap(num1, num2);
        System.out.println("After invoking the swap method, num1 is " + num1 + " and num2 is " + num2);
    }

    /** Swap two variables */
    public static void swap(int n1, int n2) {
        System.out.println("\tInside the swap method");
        System.out.println("\t\tBefore swapping, n1 is " + n1 + " and n2 is " + n2);
        // Swap n1 with n2
        int temp = n1;
        n1 = n2;
        n2 = temp;
        System.out.println("\t\tAfter swapping, n1 is " + n1 + " and n2 is " + n2);
    }
}
```

Output:

```
Before invoking the swap method, num1 is 1 and num2 is 2
        Inside the swap method
                Before swapping, n1 is 1 and n2 is 2
                After swapping, n1 is 2 and n2 is 1
After invoking the swap method, num1 is 1 and num2 is 2
```

Clicker Question

What is the output?

```
public static void main(String[] args){
   int x = 0;
   set10(x++);
   System.out.println(x);
}

public static void set10(int n) {
   n = 10;
}
```

A. 0

B. 1

C. 10

D. 11

Practice

Write a method that returns the number of days in a month. Use this header:

```
public static int daysInMonth(int month)
```

For example,

- `daysInMonth(3)` returns 31.
- `daysInMonth(4)` returns 30.

For simplicity, let's start by not checking for leap years.

- i.e. `daysInMonth(2)` will always return 28.

Your method should return -1 if an invalid month is given. For example:

- `daysInMonth(0)` returns -1
- `daysInMonth(14)` returns -1

In the lab exercises, you will develop a method isLeapYear that returns true if a given year is leap, and false otherwise. After you develop this method, use it here in order to return the correct number of days in February depending on year.

Overloading Methods

Overloading Methods

You can define several methods with **the same name** as long as their **signatures are different**. Java always calls the ***most specific method***.

```
public class TestMethodOverloading {
    /** Main method */
    public static void main(String[] args) {
        // Invoke the max method with int parameters
        System.out.println("The maximum of 3 and 4 is " + max(3, 4));
        // Invoke the max method with the double parameters
        System.out.println("The maximum of 3.0 and 5.4 is " + max(3.0, 5.4));
        // Invoke the max method with three double parameters
        System.out.println("The maximum of 3.0, 5.4, and 10.14 is " + max(3.0, 5.4, 10.14));
    }
    /** Method1: Return the max of two int values */
    public static int max(int num1, int num2) {
        if (num1 > num2) return num1;
        else return num2;
    }
    /** Method2: Find the max of two double values */
    public static double max(double num1, double num2) {
        if (num1 > num2) return num1;
        else return num2;
    }
    /** Method3: Return the max of three double values */
    public static double max(double num1, double num2, double num3) {
        return max(max(num1, num2), num3);
    }
}
```

Output

```
The maximum of 3 and 4 is 4
The maximum of 3.0 and 5.4 is 5.4
The maximum of 3.0, 5.4, and 10.14 is 10.14
```

Overloading Methods, cont.

Ambiguous Invocation *occurs when* there are **two or more possible matches** for the invocation of a method, but the compiler cannot determine the best match. Ambiguous invocation causes a compile error.

For example:

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

    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;
    }
}
```

Clicker Question

Given two method headers,

```
public static double m(double x,double y) //first method
public static double m(int x,double y)    //second method
```

Which one is invoked by the statement:

```
double z = m(4, 5.2);
```

A. First method

B. Second method

C. Error

Clicker Question

Given two method headers,

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public static double m(double x,double y) //first method
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```
public static double m(double x,double y) //first method
public static double m(int x,double y)    //second method
```

Which one is invoked by the statement:

```
double z = m(4.0, 5);
```

A. First method

B. Second method

C. Error

Clicker Question

Given two method headers,

```
public static double m(double x,int y)  //first method
public static double m(int x,double y)  //second method
```

Which one is invoked by the statement:

```
double z = m(4, 5);
```

A. First method

B. Second method

C. Error

Clicker Question

What is the output

```
public static void maim(String[] args){ m('a'); }

public static void m(int x)    { System.out.println("A:" + x); }
public static void m(double x){ System.out.println("B:" + x); }
public static void m(String x){ System.out.println("C:" + x); }
```

A. A:97

B. B:97.0

C. C:a

D. Error

Practice

Write three methods that count the number of letters, digits, and other characters in a string using the following header:

public static int countLetters(String s)

public static int countDigits(String s)

public static int countNonLetterOrDigit(String s)

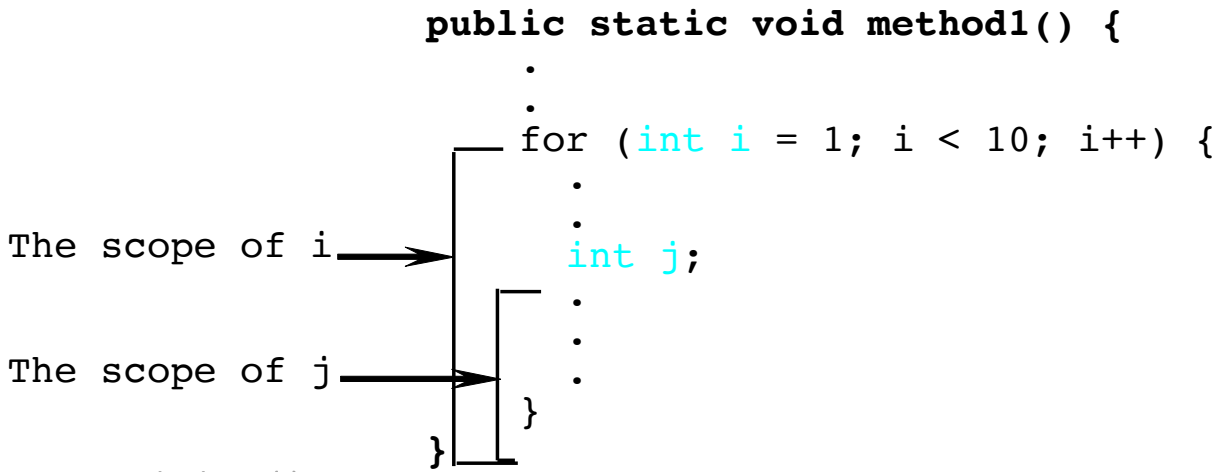
Write a test program that prompts the user to enter a string and displays the number of letters, digits, and other characters in the string.

The Scope of Variables

The Scope of Variables

The scope of a variable is the part of the program where the variable can be referenced.

- **A local variable**: a variable defined inside a method.
  - The scope of a local variable **starts from its declaration** and continues to the **end of the block that contains the variable.**
    - A **method parameter** is a local variable to that method. The scope of a method parameter covers the entire method.
    - A variable declared in the initial-action part of a **for**-loop header has its scope in the entire loop. However, a variable declared inside a **for**-loop body has its scope limited in the loop body from its declaration to the end of the block that contains the variable,



Scope of Local Variables, cont.

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

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 += i;
  }

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

Invalid code!

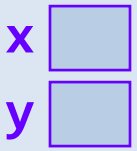
Same variable name twice?

You can have variables with the same name in different methods. Each method will use its own variable and won't be able to access the ones in the other methods.

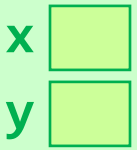
Example:

- Each of the two methods below has its own copy of the two local variables: x,y
  - i.e., each method will have its own memory space for x and y.
    - Remember that a variable is basically a label to a memory location.
- When a method refers to either x or y, it uses its own copy of x or y. And it doesn't have access to the other method's x or y.

```
Public static void plusOne(int x){
    int y = x + 1;
    System.out.print(y);
}
```




```
Public static void twoTimes(int x){
    int y = 2 * x;
    System.out.print(y);
}
```



Clicker Question

What is the output?

```
for (int i = 0; i <= 10; i++);
   System.out.print(i);
```

A. nothing

B. error

C. 11

D. The numbers 0,1,2,3,…,9

E. The numbers 0,1,2,3,…,10

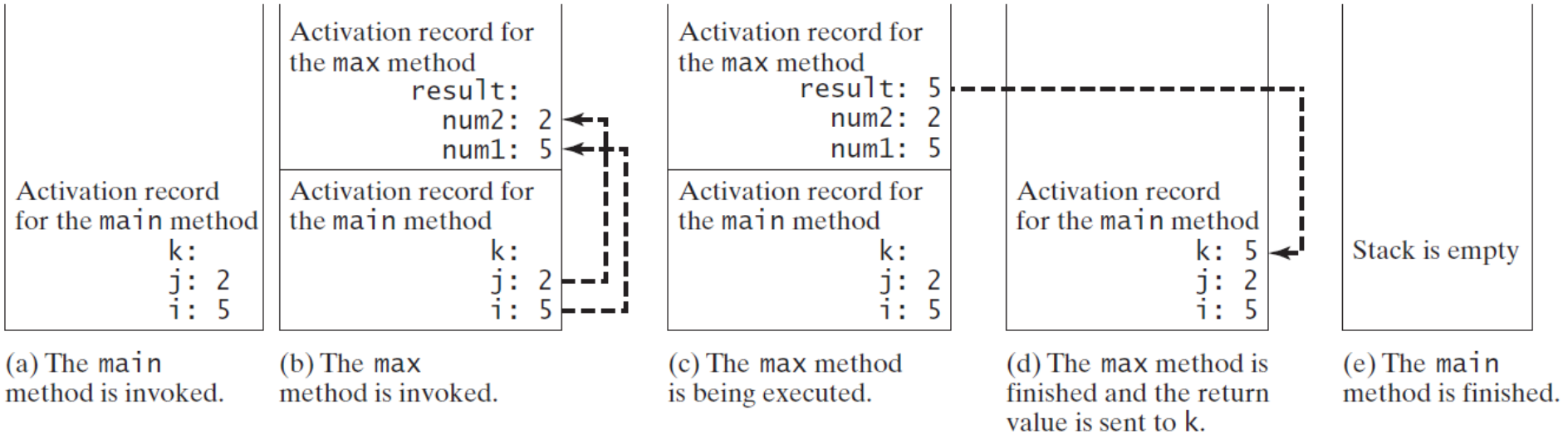
Call Stacks

Call Stacks

Each time a method is invoked, the system creates an ***activation record*** that **stores parameters and variables** for the method and places the activation record in an **area of memory** known as a call ***stack***.

- **When a method calls another method, the caller's activation record is kept intact, and a new activation record is created for the new method called.**

When a method finishes its work and returns to its caller, its activation record is removed from the call stack.



(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.

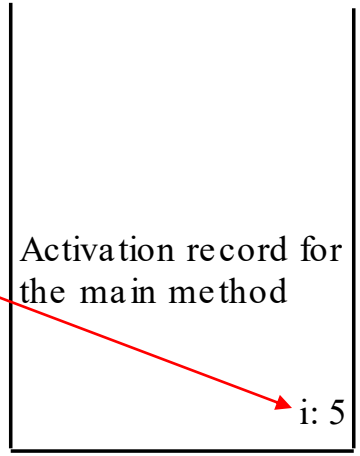
animation

Trace Call Stacks

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;
}
```



The main method is invoked.

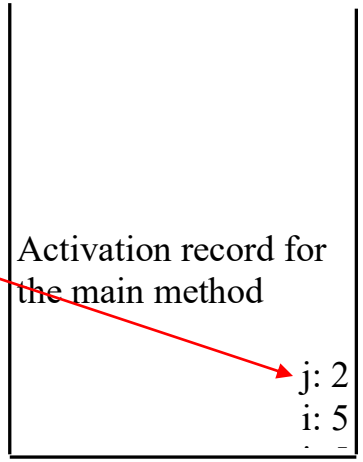
animation

Trace Call Stacks

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;
}
```



The main method
is invoked.

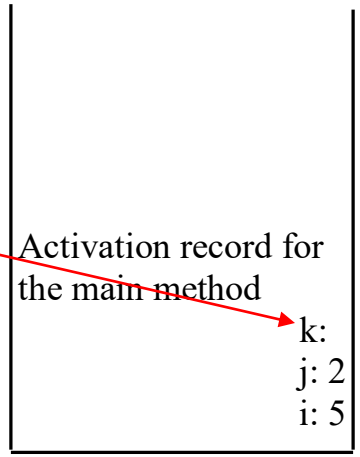
animation

Trace Call Stacks

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);
}
```

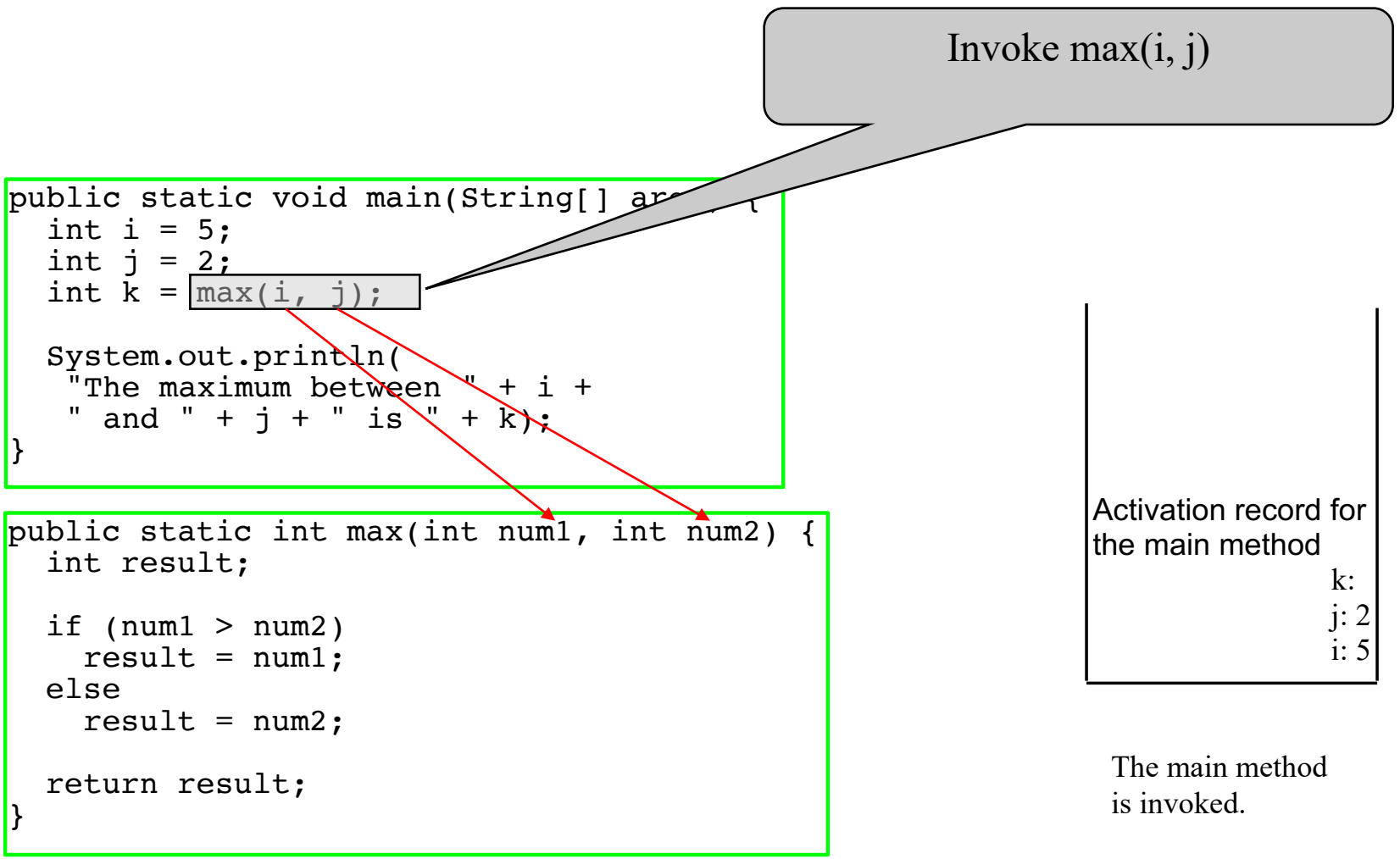
```
public static int max(int num1, int num2) {
  int result;

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

  return result;
}
```



The main method
is invoked.

animation

Trace Call Stacks



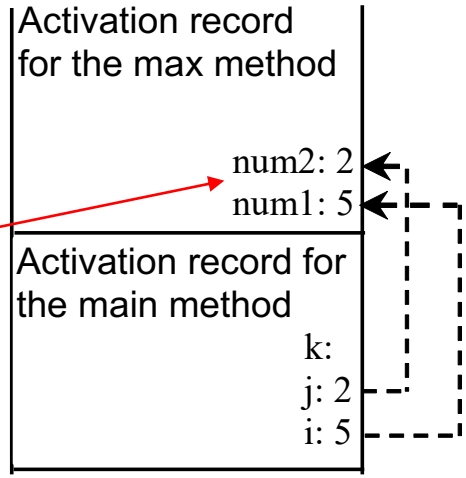
animation

Trace Call Stacks

```
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;
}
```

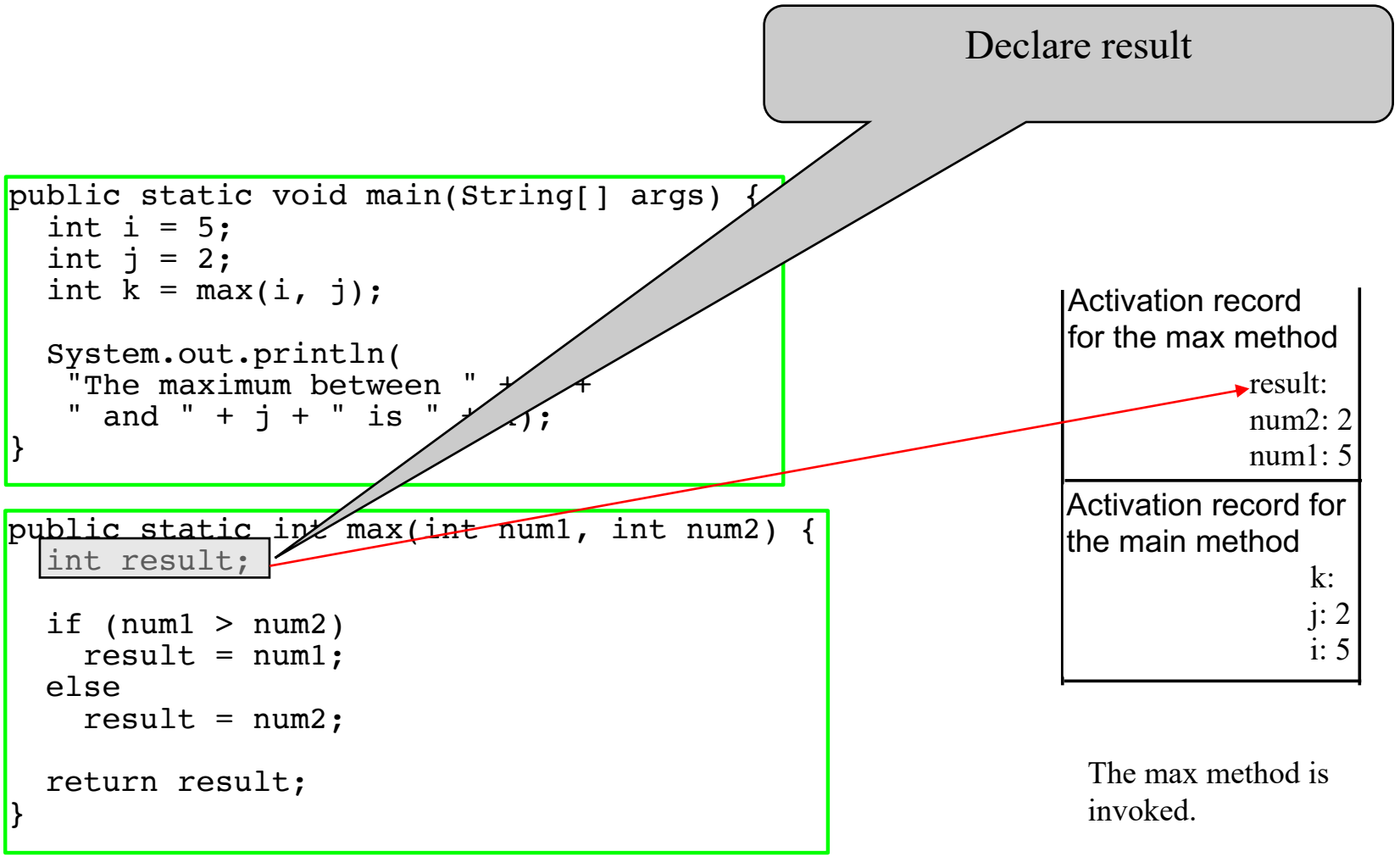
pass the values of i and j to num1 and num2



The max method is invoked.

animation

Trace Call Stacks



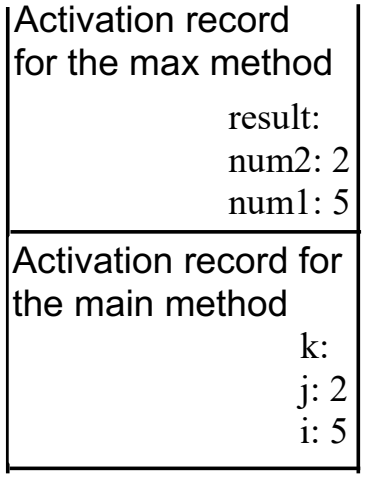
animation

Trace Call Stacks

(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);
}
```

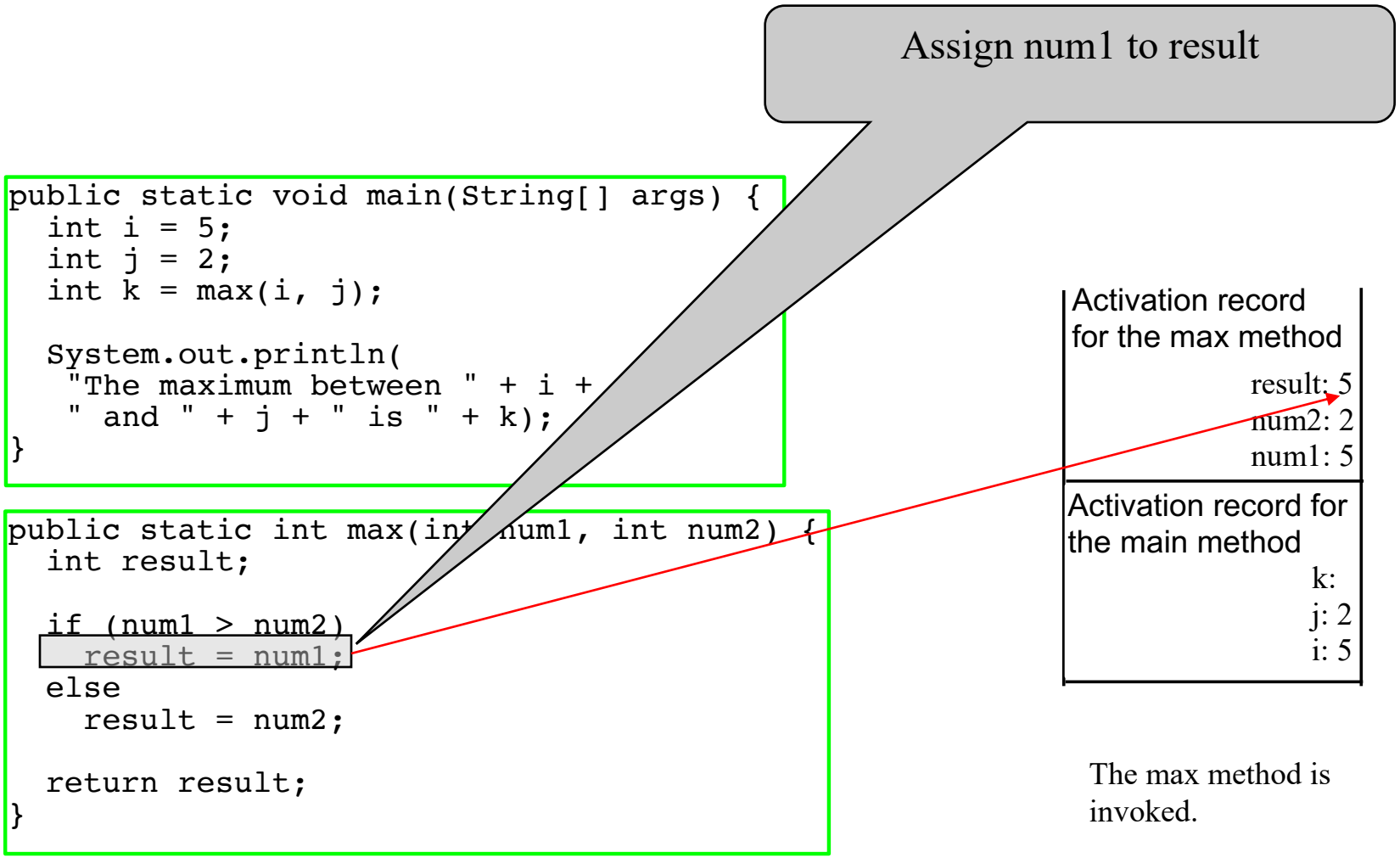
```
public static int max(int num1, int num2) {
  int result;

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

  return result;
}
```



The max method is invoked.

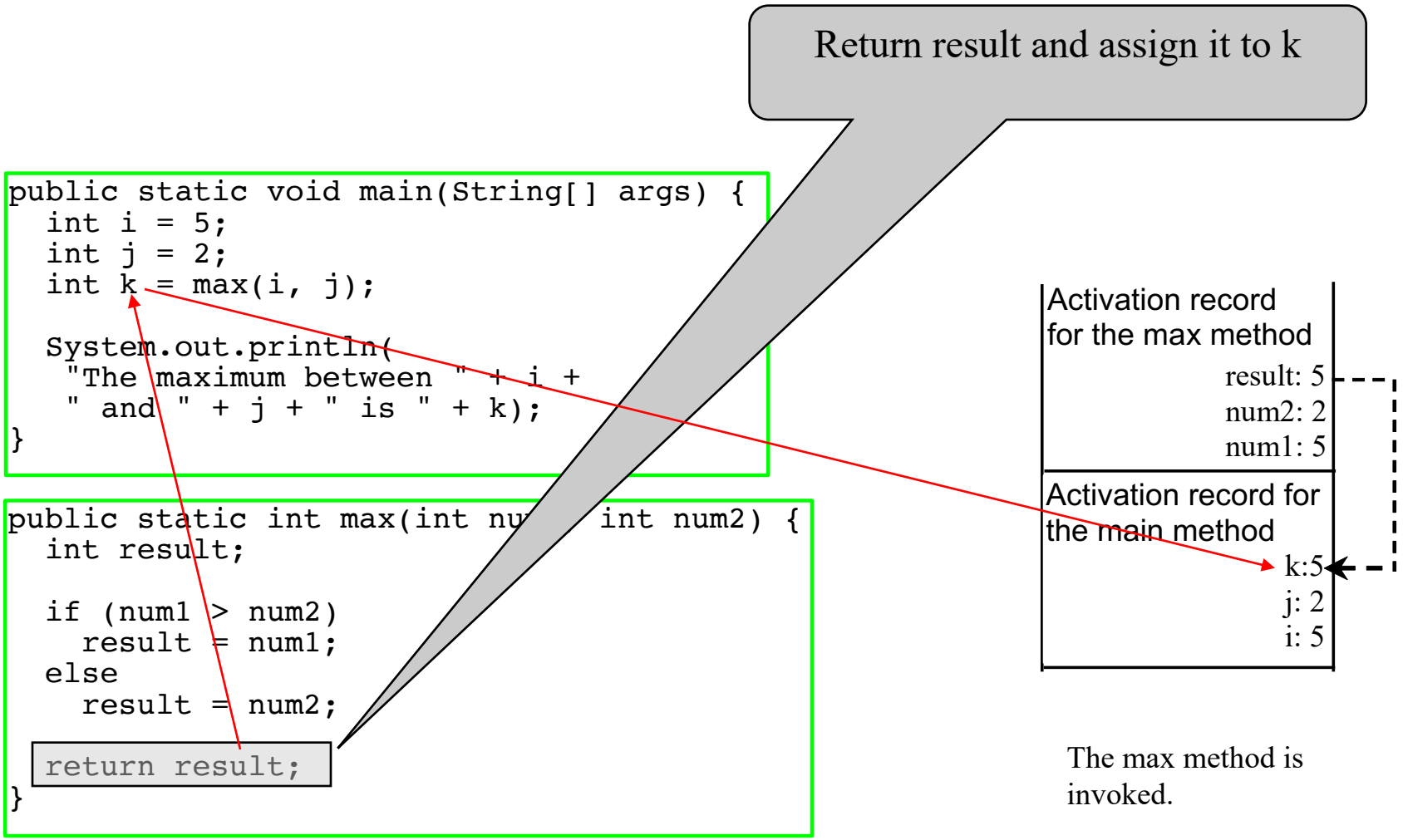
animation

Trace Call Stacks



animation

Trace Call Stacks



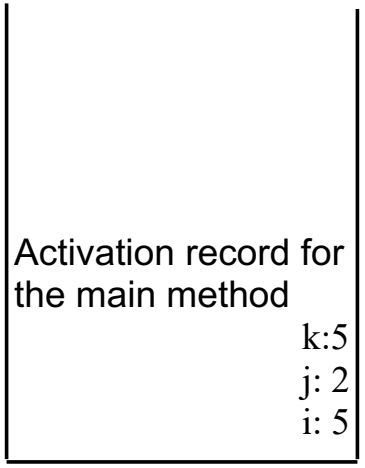
animation

Trace Call Stacks

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;
}
```



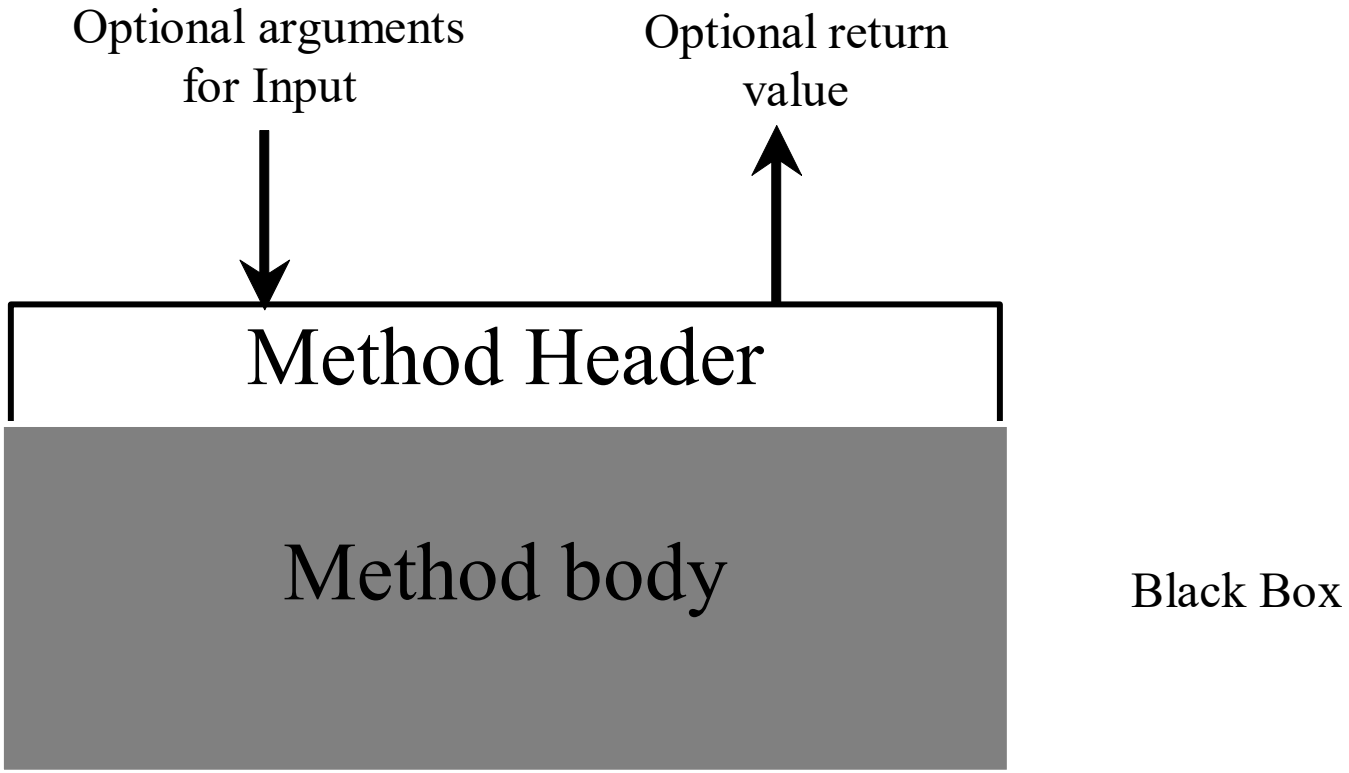
The main method is invoked.

Stepwise Refinement

Method Abstraction

You can think of the method body as a black box that contains the detailed implementation for the method.

- The details of the implementation are ***encapsulated*** in the method and ***hidden*** from whoever invokes the method.



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.

Stepwise Refinement – Example

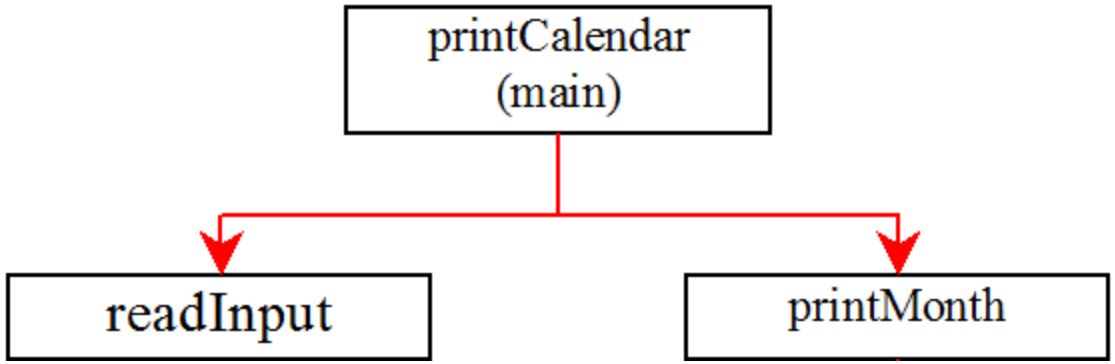
Example: Suppose you write a program that displays the calendar for a given month of the year. The program prompts the user to enter the year and the month, then displays the entire calendar for the month, as shown in the following sample run.

```
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
```

How would you get started on such a program?

- We shall use an approach called Top-Down Design.
  - the problem is first broken into subproblems, each of which is further broken into subproblems, and so on.

Stepwise Refinement – Example, cont.

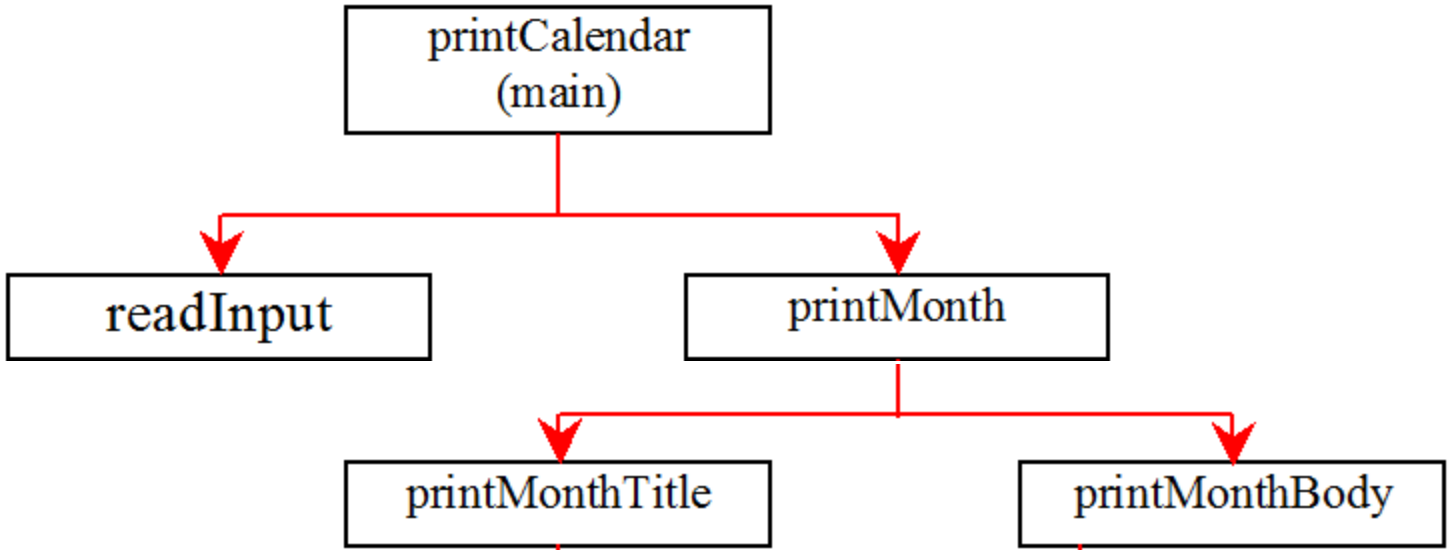


The **printCalendar** problem is broken into

- Get input from the user (**readInput**), and
- Print the calendar for the month (**printMonth**).

At this stage, you should be concerned with what the subproblems will achieve, not with how to get input and print the calendar for the month.

Stepwise Refinement – Example, cont.

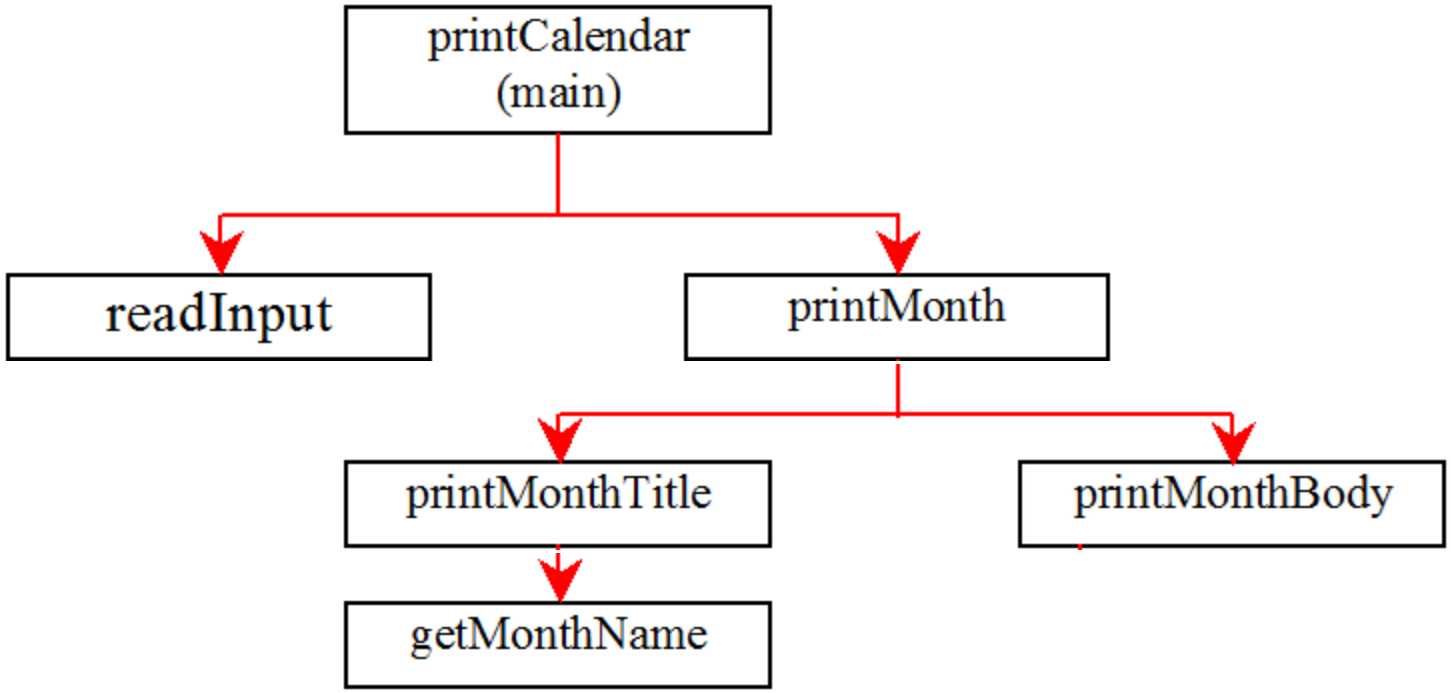


You can use **Scanner** to read input for the year and the month.

The **printMonth** problem is broken into

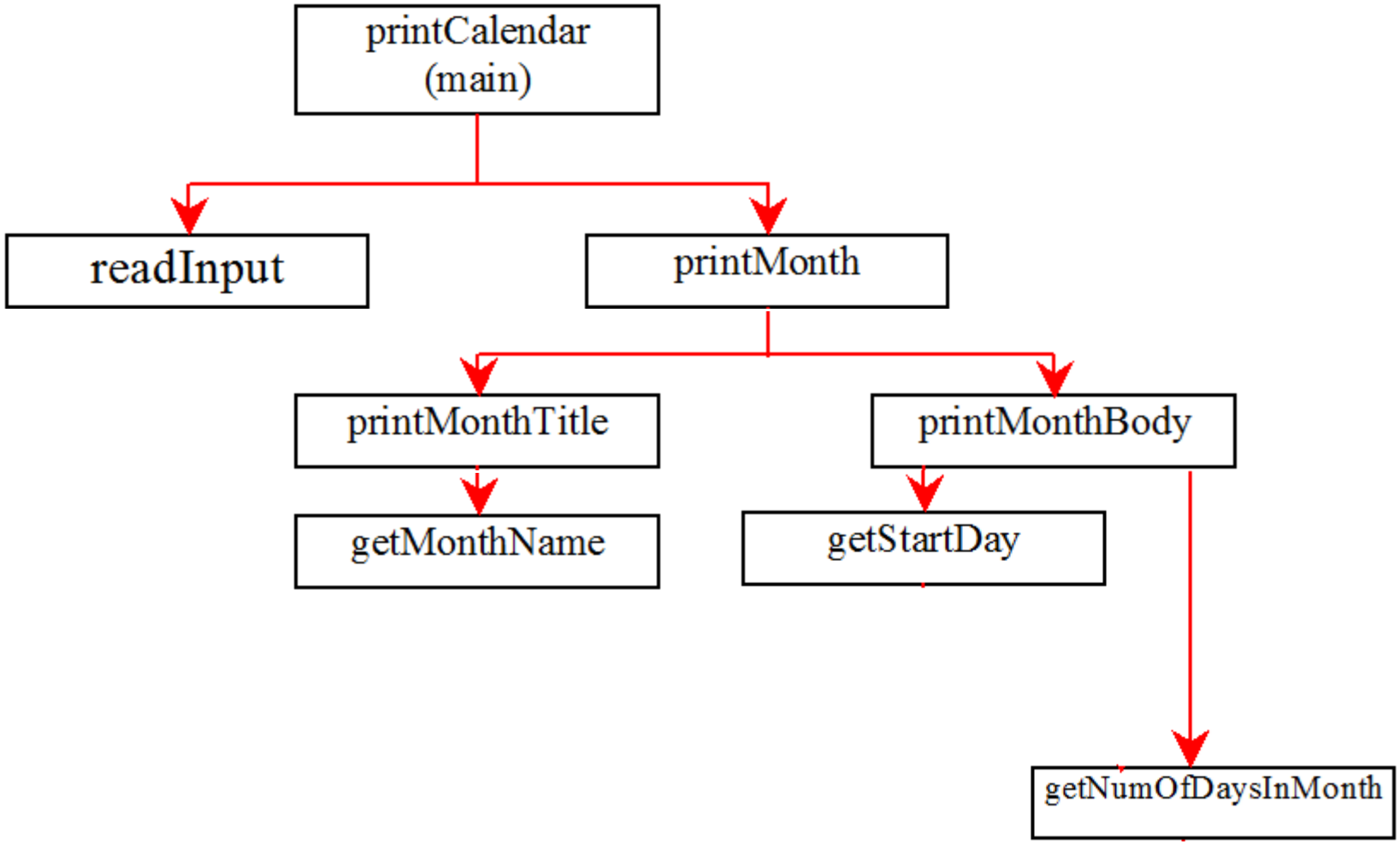
- print the month title (**printMonthTitle**) and
- print the month body (**printMonthBody**)

Stepwise Refinement – Example, cont.



The month title consists of three lines: month and year, a dashed line, and the names of the seven days of the week. You need to get the month name (e.g., January) from the numeric month (e.g., 1). This is accomplished in **getMonthName**

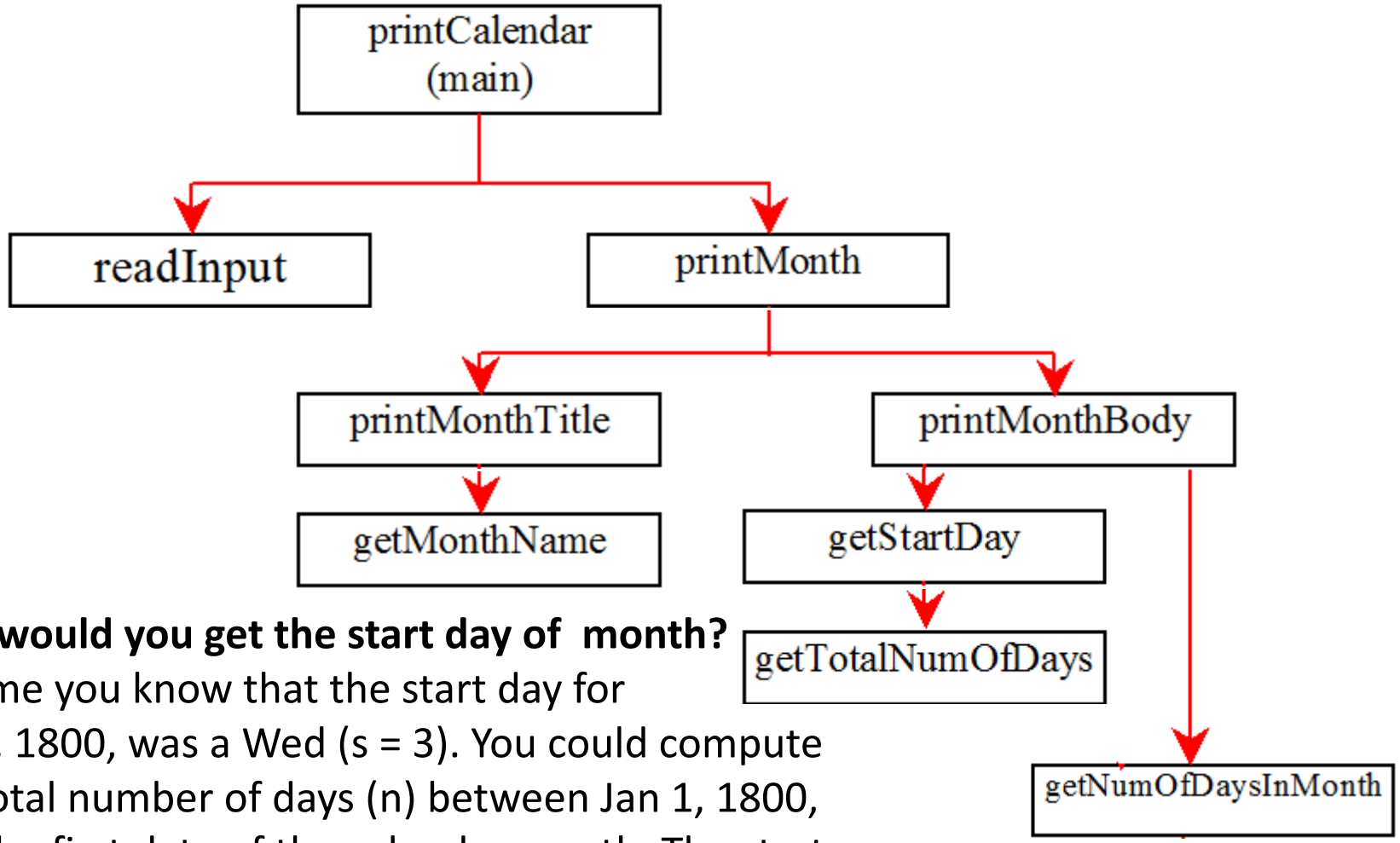
Stepwise Refinement – Example, cont.



In order to print the month body, you need to know:

- which day of the week is the first day of the month (**getStartDay**) and
- how many days the month has (**getNumberOfDaysInMonth**)

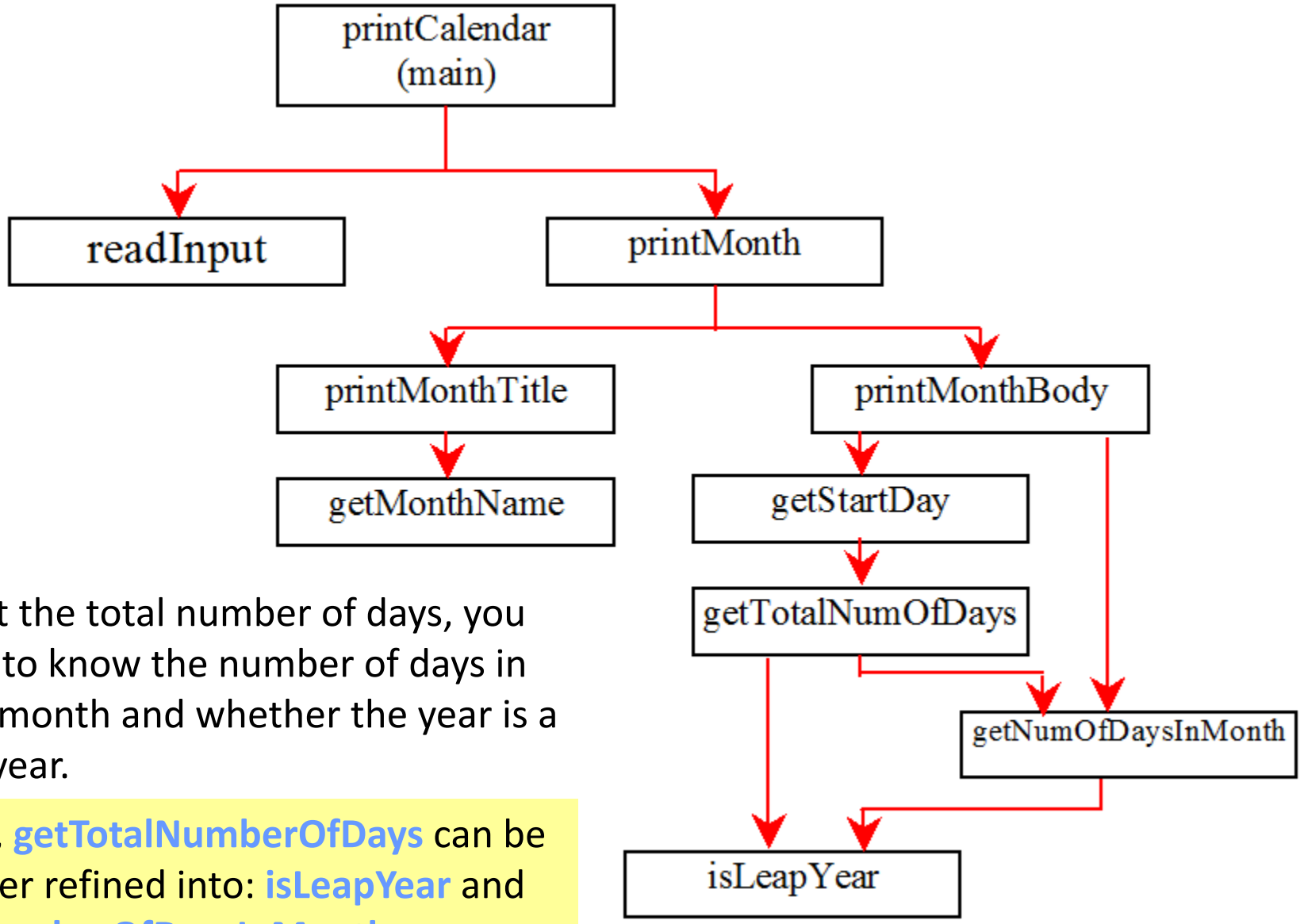
Stepwise Refinement – Example, cont.



How would you get the start day of month?
Assume you know that the start day for Jan 1, 1800, was a Wed (s = 3). You could compute the total number of days (n) between Jan 1, 1800, and the first date of the calendar month. The start day for the calendar month is (n + s) % 7.

Thus, the **getStartDay** problem needs to **getTotalNumberOfDays**

Stepwise Refinement – Example, cont.



To get the total number of days, you need to know the number of days in each month and whether the year is a leap year.

Thus, **getTotalNumberOfDays** can be further refined into: **isLeapYear** and **getNumberOfDaysInMonth**

Stepwise Refinement – Example, cont.

Given the previous design, your program may begin like this:

```
public class PrintCalendar {
  public static void main(String[] args) {
      Scanner input = new Scanner(System.in);
      // Prompt the user to enter month/year
      System.out.print("Enter full year (e.g., 2012): ");
      int year = input.nextInt();
      System.out.print("Enter month as a number between 1 and 12: ");
      int month = input.nextInt();
      // Print calendar for the month of the year
      printMonth(year, month);
  }
  /** Stubs for different methods may look like this */
  public static void printMonth(int year, int month) {}
  public static void printMonthTitle(int year, int month) {}
  public static void printMonthBody(int year, int month) {}
  public static String getMonthName(int month) {return "January"; /*dummy value*/}
  public static int getStartDay(int year, int month) {return 1; /*dummy value*/}
  public static int getTotalNumberOfDays(int year,int month){return 10000;/*dummy value*/}
  public static int getNumberOfDaysInMonth(int year,int month) {return 31;/*dummy value*/}
  public static Boolean isLeapYear(int year) {return true; /* A dummy value*/}
}
```

Stepwise Refinement – Example, cont.

The next step is to work on the implementation details for each method (and adjust your design if necessary).

- Section 6.11.3 in the textbook includes the details for each method as well as the complete program.

Benefits of Stepwise Refinement

Simpler Program

Reusing Methods

Easier Developing, Debugging, and Testing

Better Facilitating Teamwork

Debugging

Remember: Programming Errors

3 types of errors:

- Syntax Errors
  - Detected by the compiler
  - aka *compilation errors*

```
public class Errors {
    public static   main(String[] args) {
        System.out.println("Welcome to Java");
    }
}
```

- Runtime Errors
  - Causes the program to abort during the runtime.

```
public class Errors {
    public static void main(String[] args) {
        System.out.println(1 / 0);
    }
}
```

Can't divide by zero

- Logic Errors
  - Produces incorrect result during the runtime
  - no error message is shown

```
public class Errors {
    public static void main(String[] args) {
        System.out.println("35 Celsius in Fahrenheit:");
        System.out.println((9 / 5) * 35 + 32);
    }
}
```

Output is incorrect due to wrong formula

Debugging your code

Debugging is the act of finding and correcting errors in a system.

A common **reason for computer errors** is our **lack of precision** in specifying instructions to the computer

As a programmer, you need to know how to debug your code.

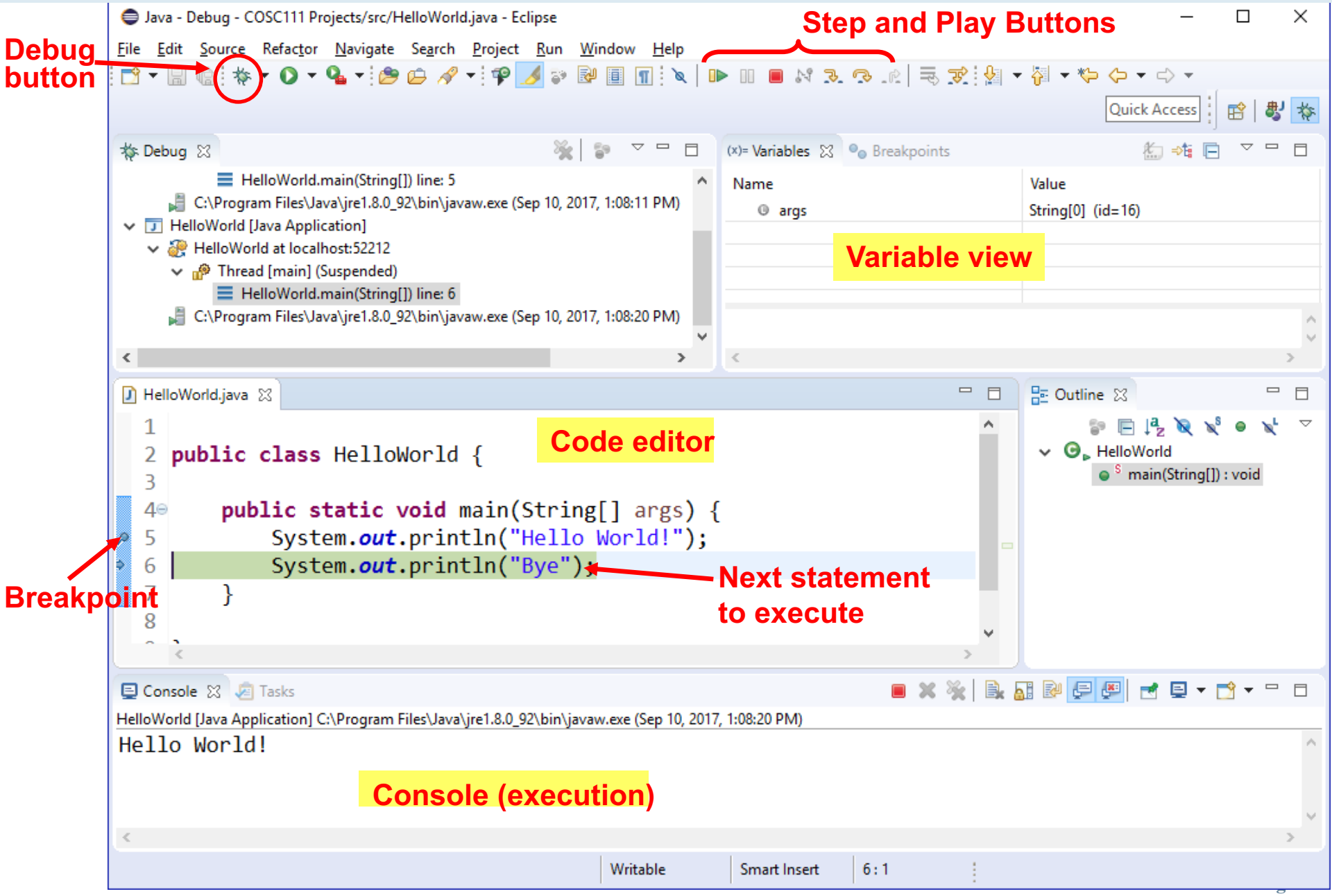
Eclipse provides us with tools to help us identify the source of errors our code.

Both Syntax and Runtime errors are easily found whenever they occur (with the help with the error message that appears on the console).

- Syntax errors are identified before compilation.
- Runtime errors are identified while the program is running.

Logic errors can be located using Eclipse Debugger

Remember: Eclipse: Debugging and Breakpoints



Basic concepts

Debugger: a tool that allows you to run a program interactively while watching how your code runs and how the variables change.

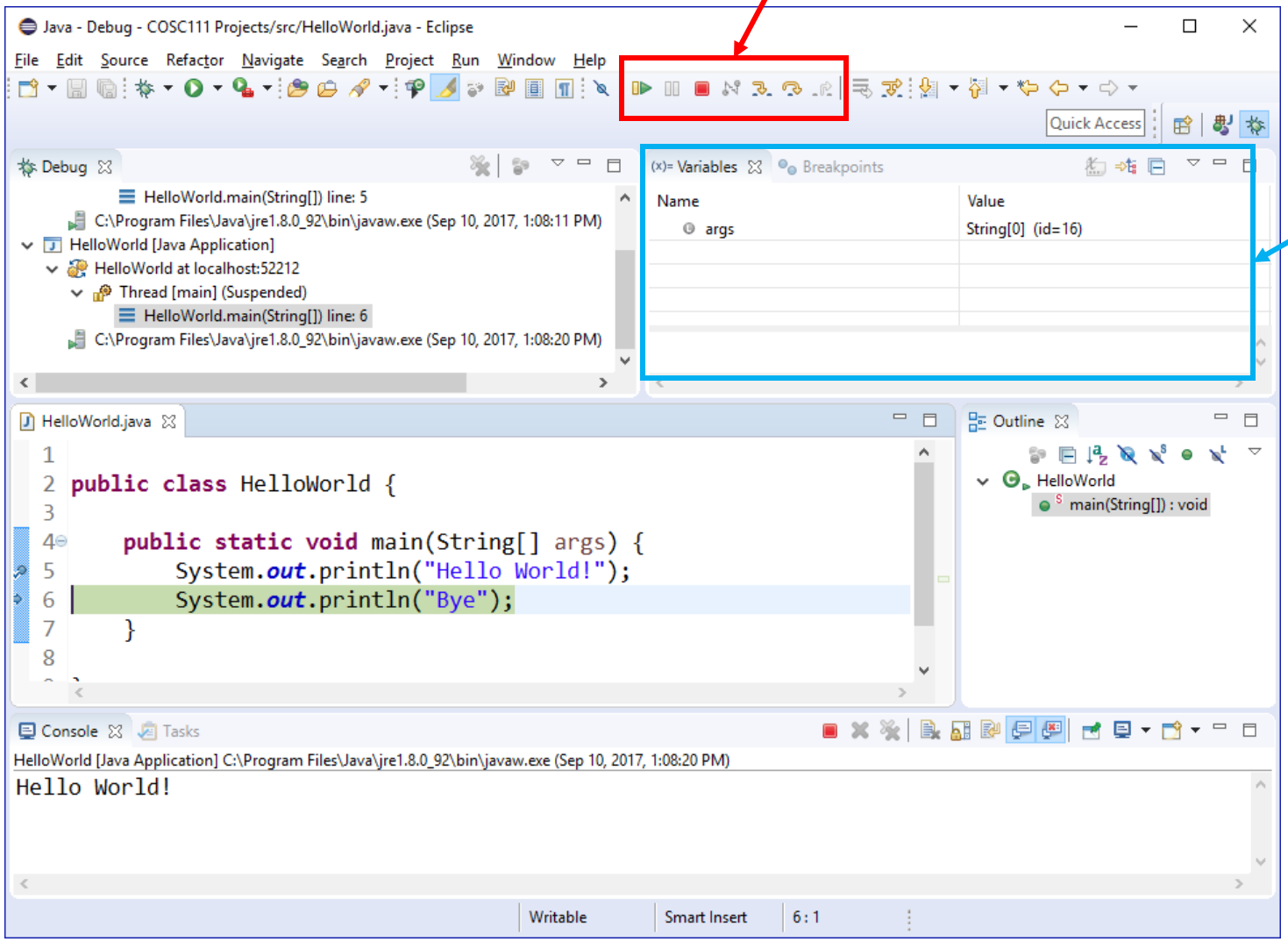
- To start debugging your code, do one of the following:
  - right click on the class file and select *Debug As → Java Application*
  - From the *Run menu*, choose *Debug*.
  - Click the debug button.
- This will open the Debug perspective in Eclipse.
  - You can switch to the default Java perspective by choosing Window menu → Open perspective → Java Browsing.

Breakpoint: a point in your source code where the program execution stops during debugging.

- Once the program stops, you can inspect the variables and run the program in a controlled manner.
- To define a breakpoint in your program, do one of the following:
  - double-click in the left margin of the Java editor in Eclipse.
  - right-click in the left margin and select Toggle Breakpoint.

Basic concepts, cont'd

Code execution can be controlled from here



Variables can be monitored here

Code Execution Controls

When your code stops at a breakpoint, you can use the following to control the execution of your program:

- Resume (F8) 
  - Continue execution till the next breakpoint.
- Step over (F6) 
  - Execute the given statement and move to the next one. If the statement contains a method, the debugger will **not** go into each line of the method.
- Step into (F5) 
  - Runs the same as “step over” if the statement does not contain a method. But if it does, the debugger will enter the method and continue debugging there.
- Step out (F7) 
  - get out of a method back to the statement where the method was called.

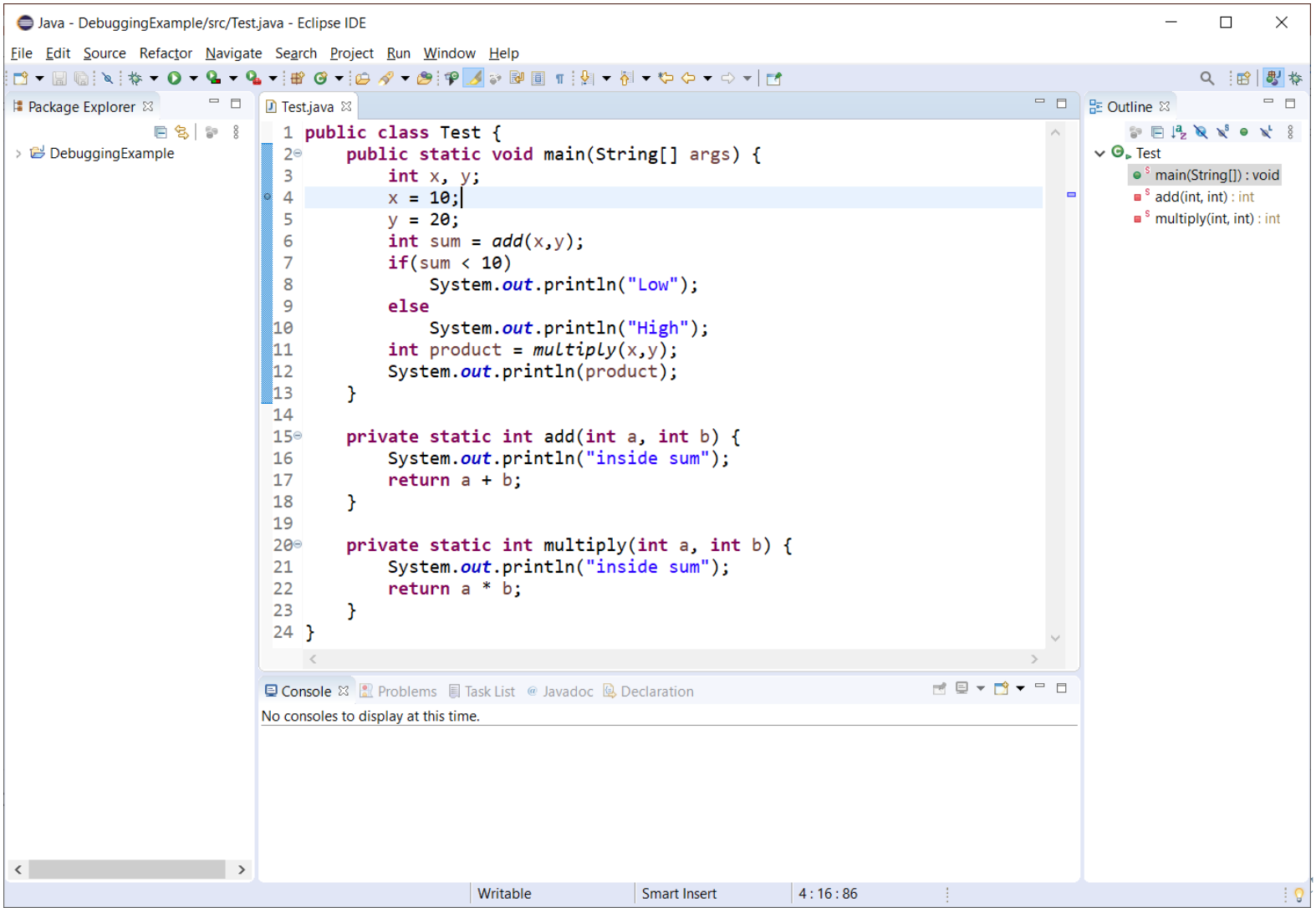
Try this …

Create a class called Test1 (or any name of your choice) with this code in eclipse and then follow the steps on the following few slides.

```
public class Test1 {
  public static void main(String[] args) {
     int x, y;
     x = 10;
     y = 20;
     int sum = add(x,y);
     if(sum < 10)
       System.out.println("Low");
     else
       System.out.println("High");
     int product = multiply(x,y);
     System.out.println(product);
  }

  private static int add(int a, int b) {
     System.out.println("inside sum");
     return a + b;
  }

  private static int multiply(int a, int b) {
     System.out.println("inside sum");
     return a * b;
  }
}
```

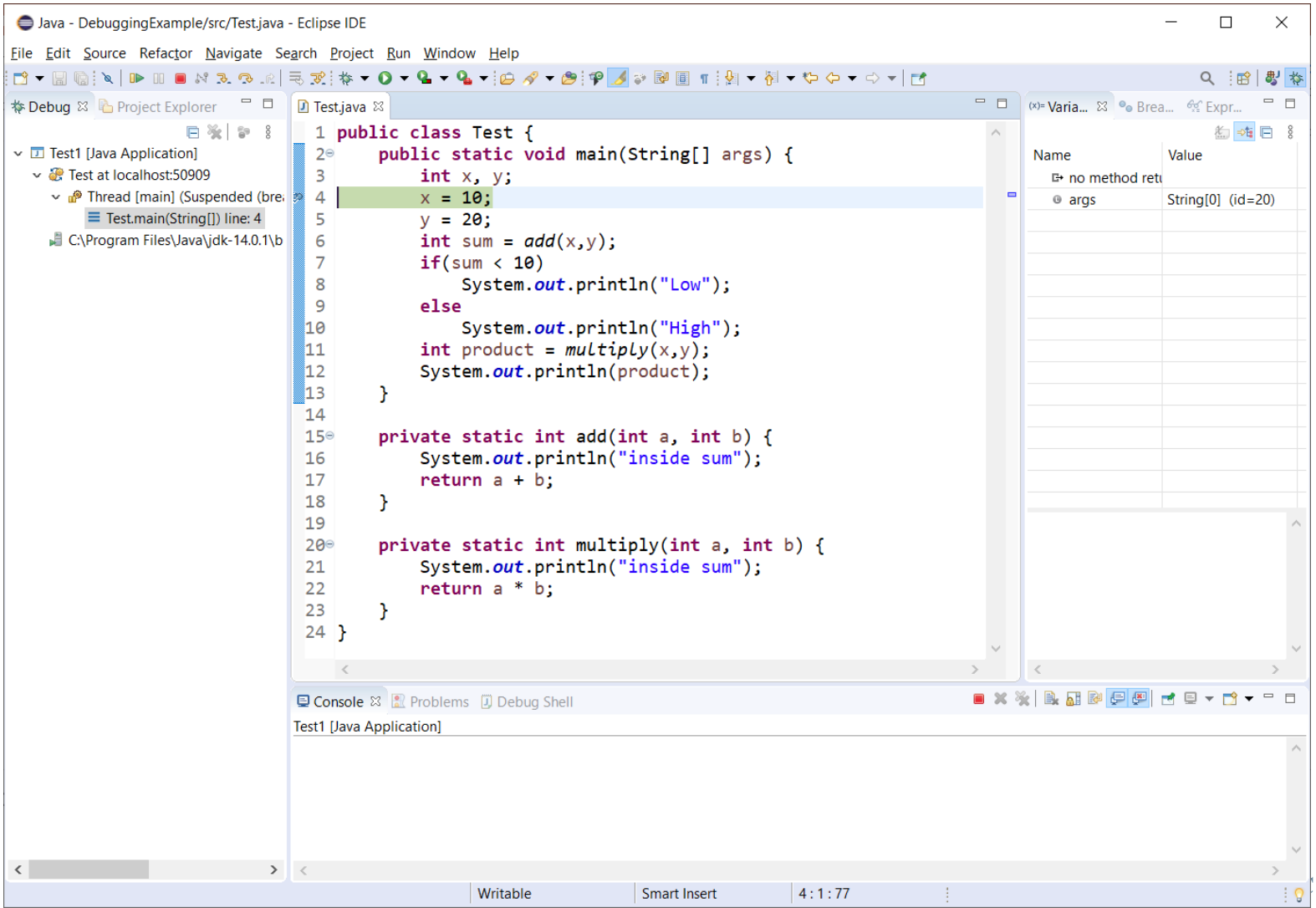
Tutorial

1) Set a breakpoint at statement #4, i.e. at x = 10;



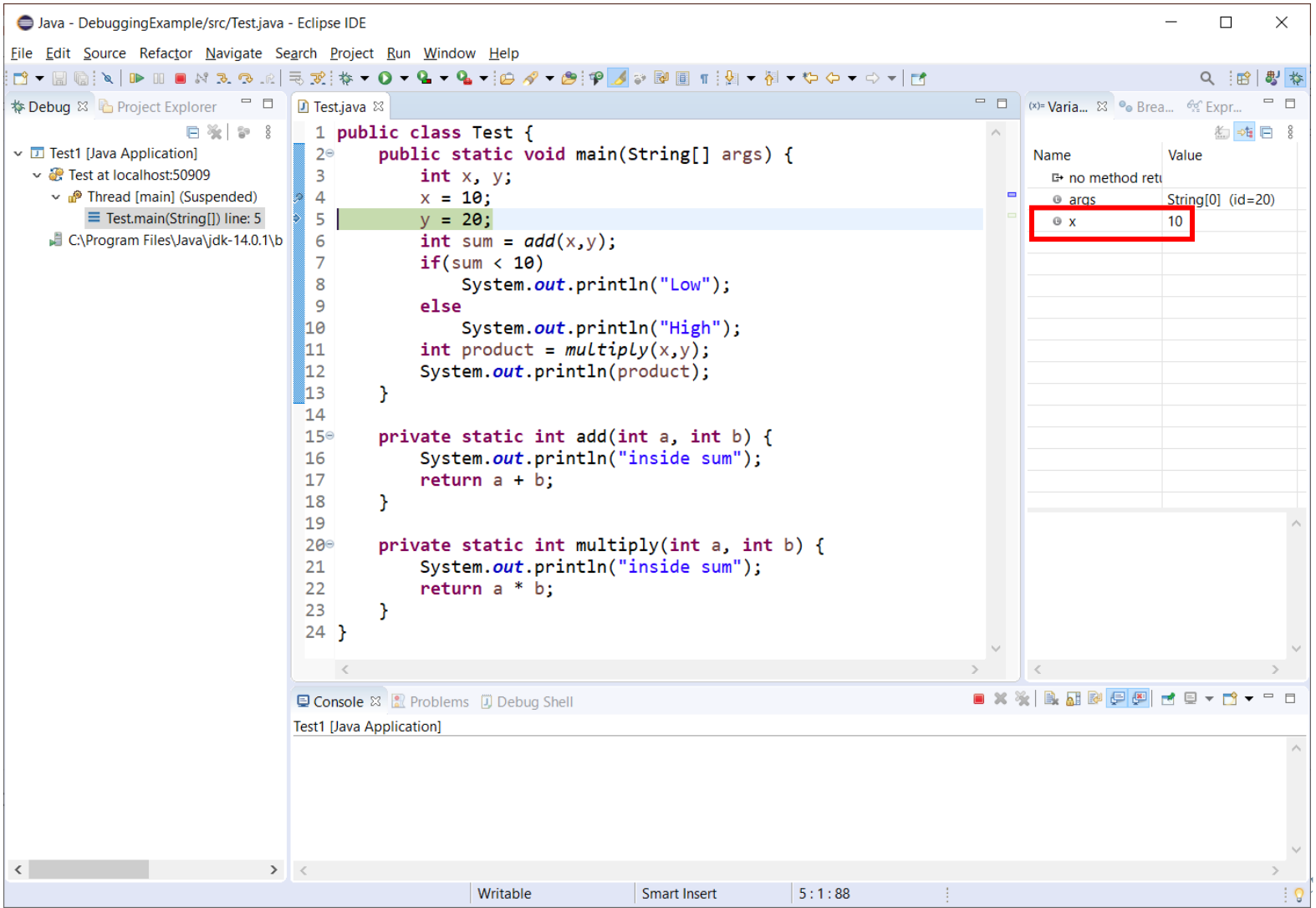
Tutorial, cont'd

2) Start the debugger. Note how the execution is suspended at the breakpoint. The statement highlighted in green has not been executed yet.



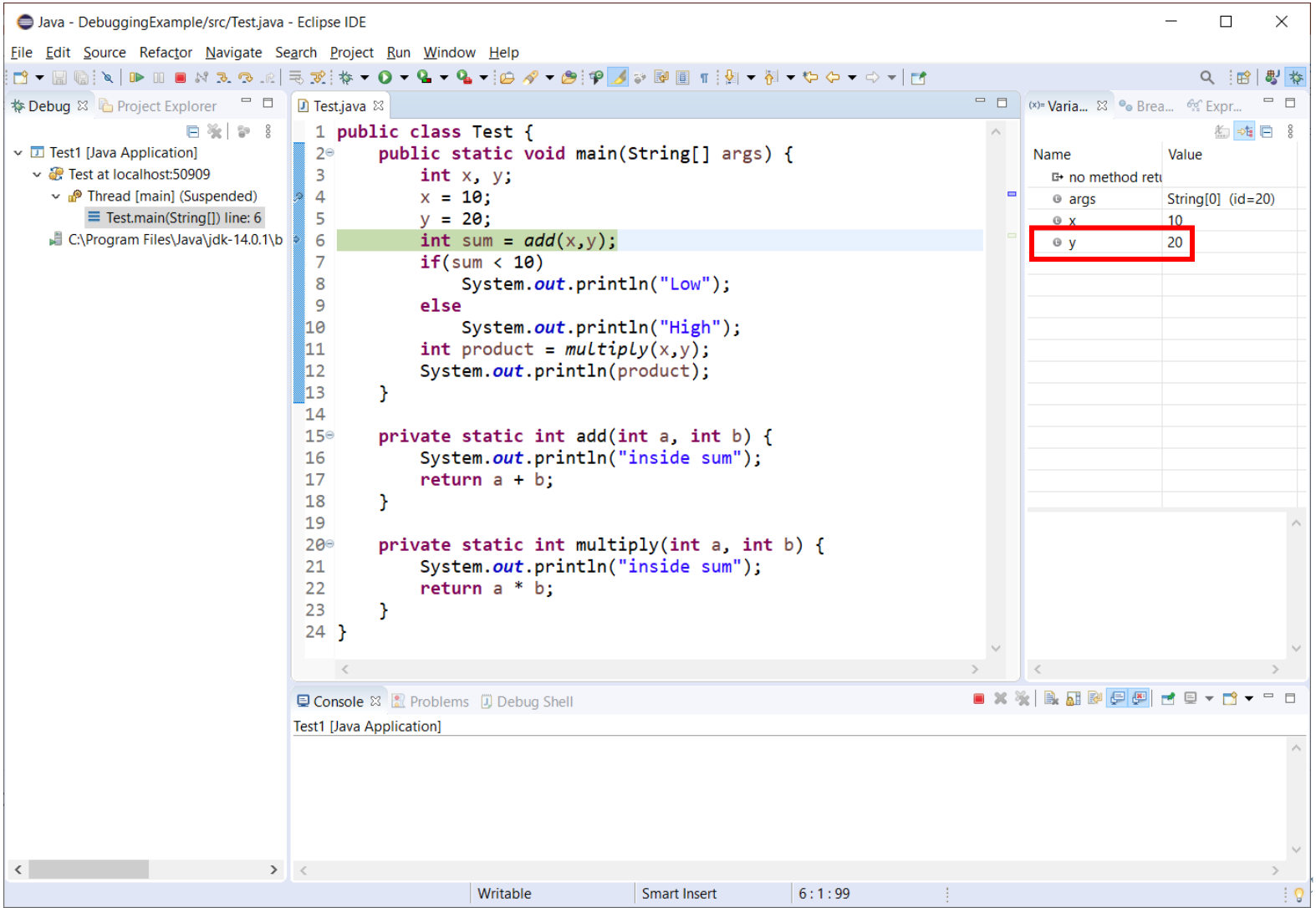
Tutorial, cont'd

3) Proceed by hitting F5 (step into) – this will set x to 10, and move to next statement. Note how x is not added to the variable list on the right.



Tutorial, cont'd

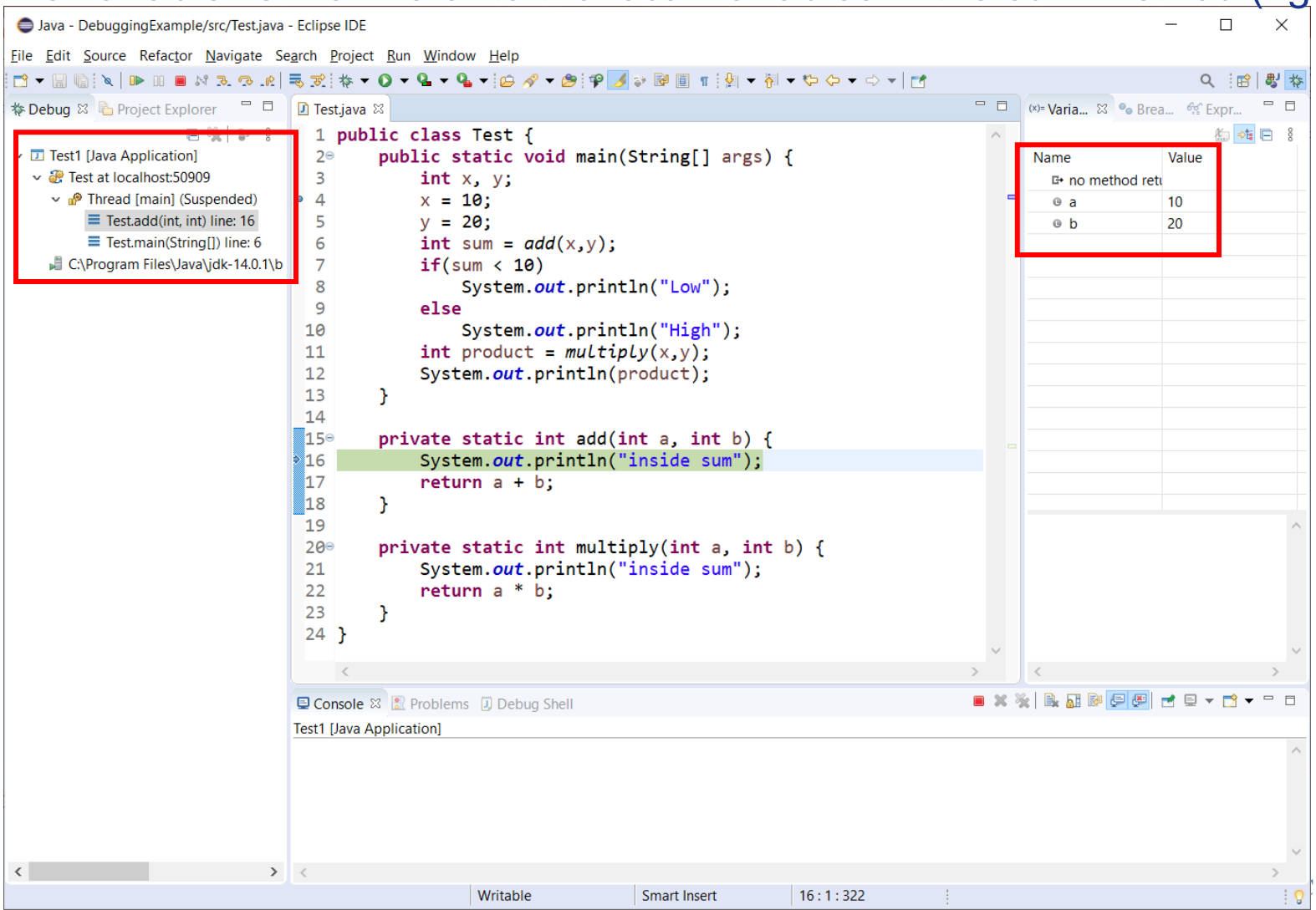
4) Press F5 (step into) again – this will set y to 20 and add it to the variable list, then move to next statement.



Tutorial, cont'd

5) Press F5 (step into) again – this will take you into the sum method. Note:

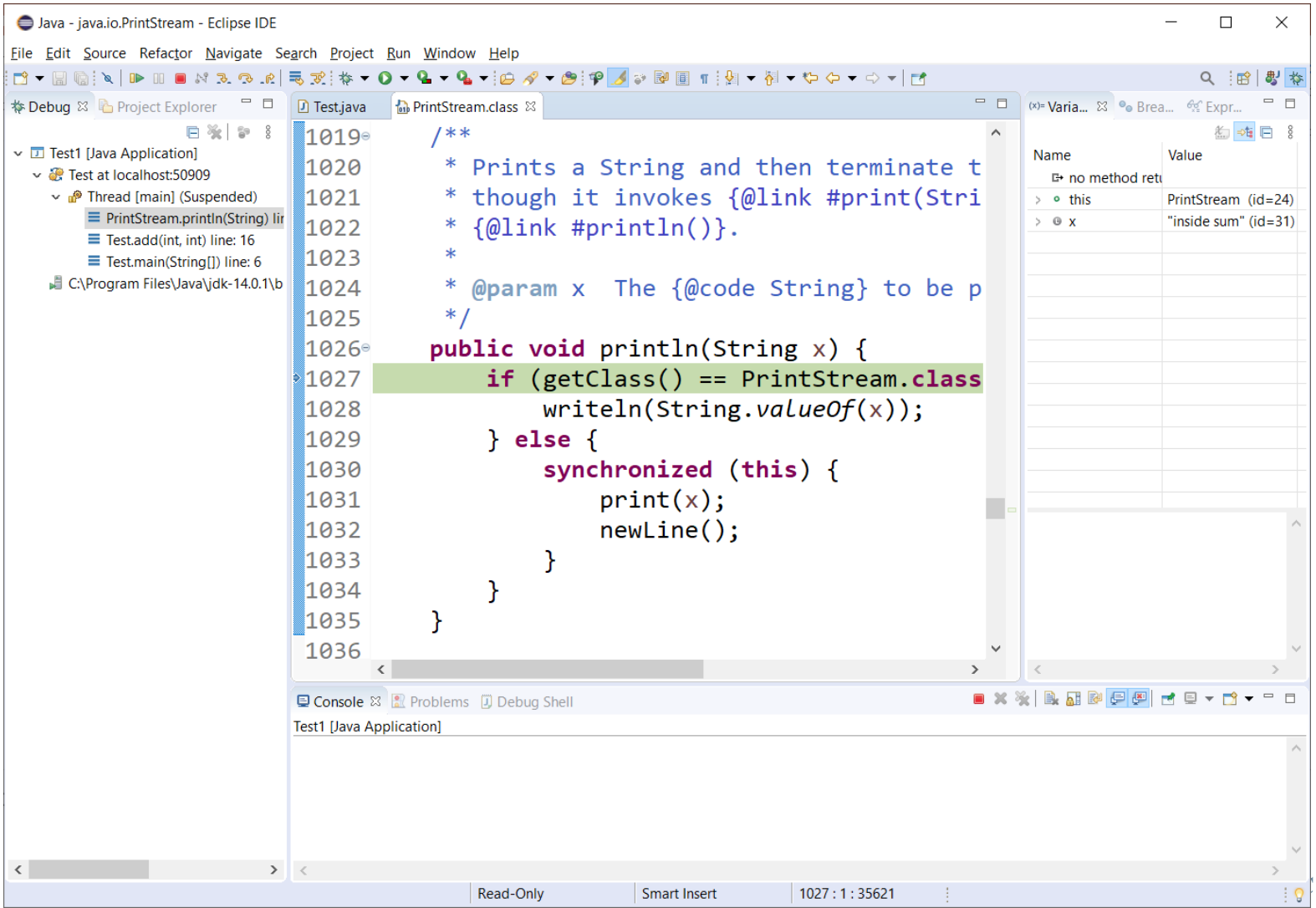
- The call stack now refers to the sum method (on the left)
- The variable list now refer to the local variables in the sum method (right)



Tutorial, cont'd

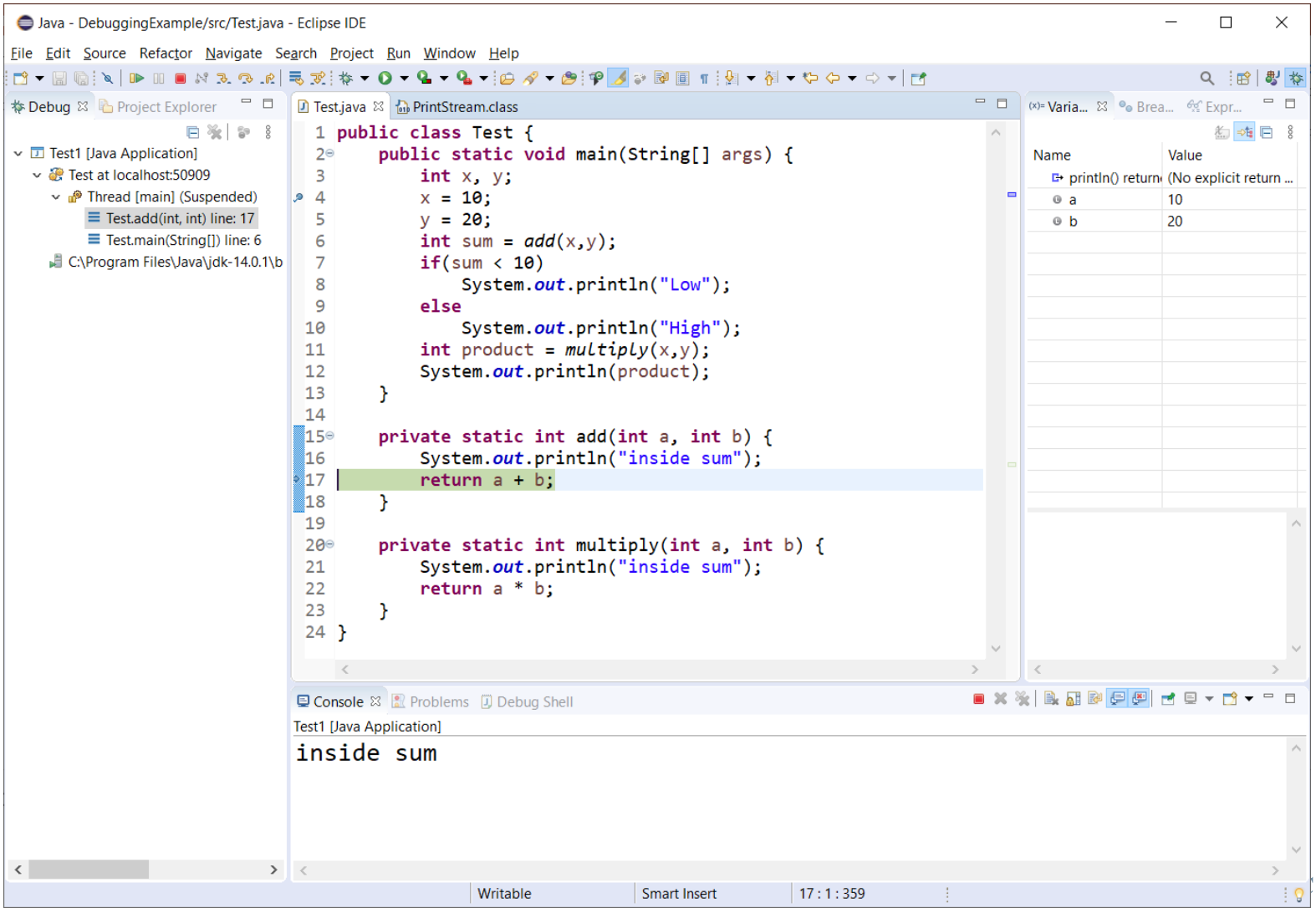
6) Press F5 (step into) again – note how we went into the println() method.

- We should have pressed on F6 (step over) to run the println() method without going into it. However, we will fix this in the next step.



Tutorial, cont'd

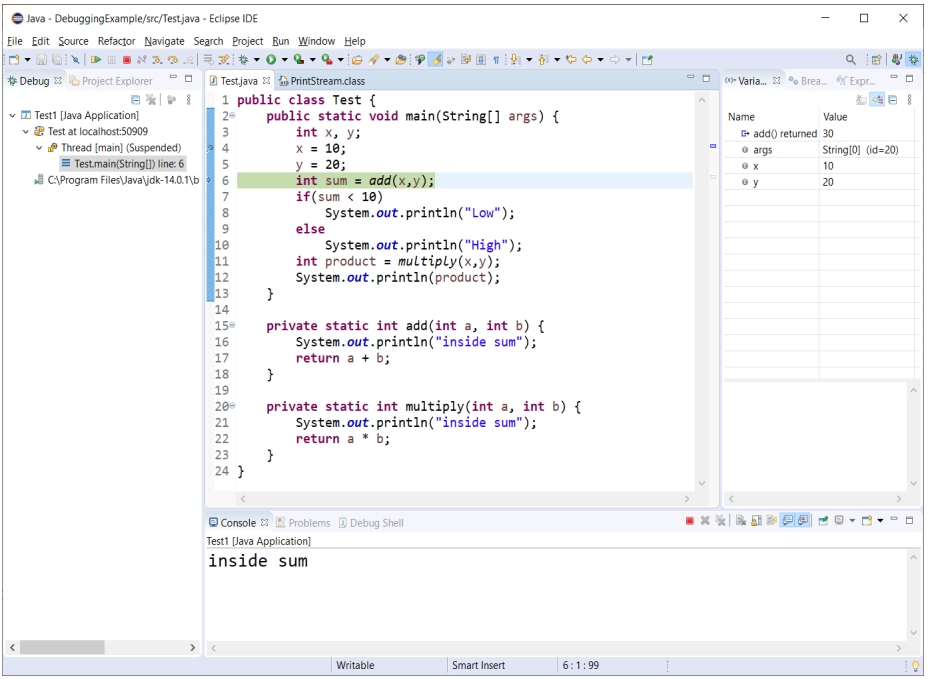
7) Press F7 (step out) to finish the execution of the println() method and get out of it back to your program.

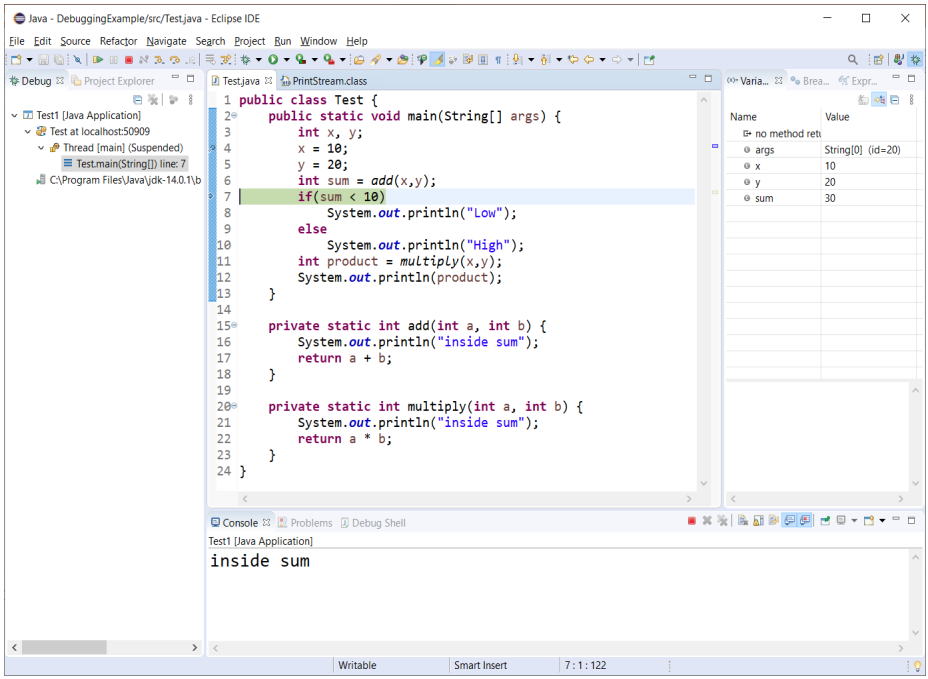


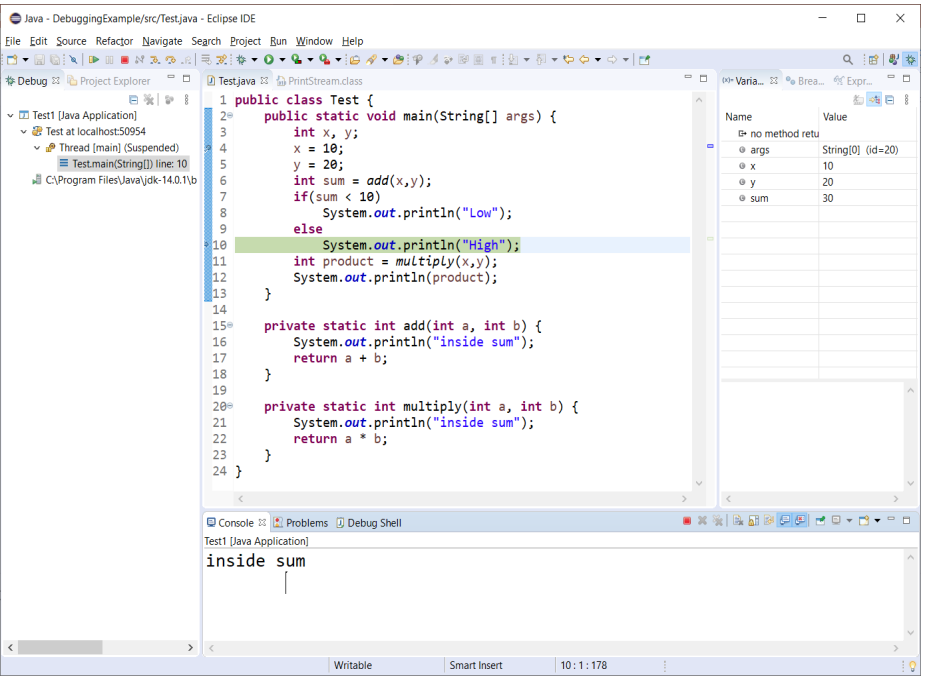
Tutorial, cont'd

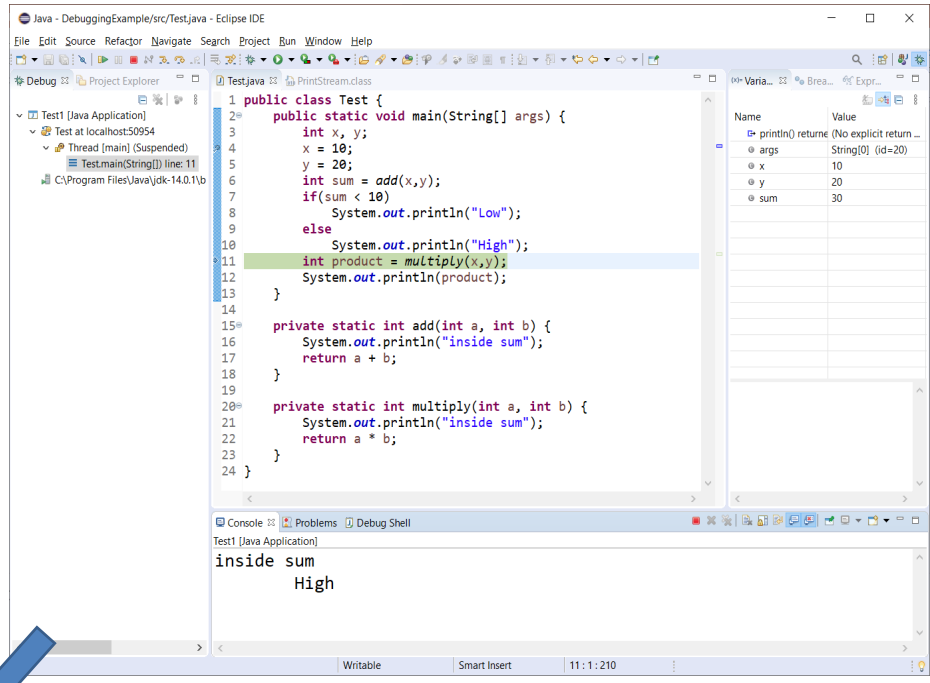
8) Press F6 (step over) a few more times and note:

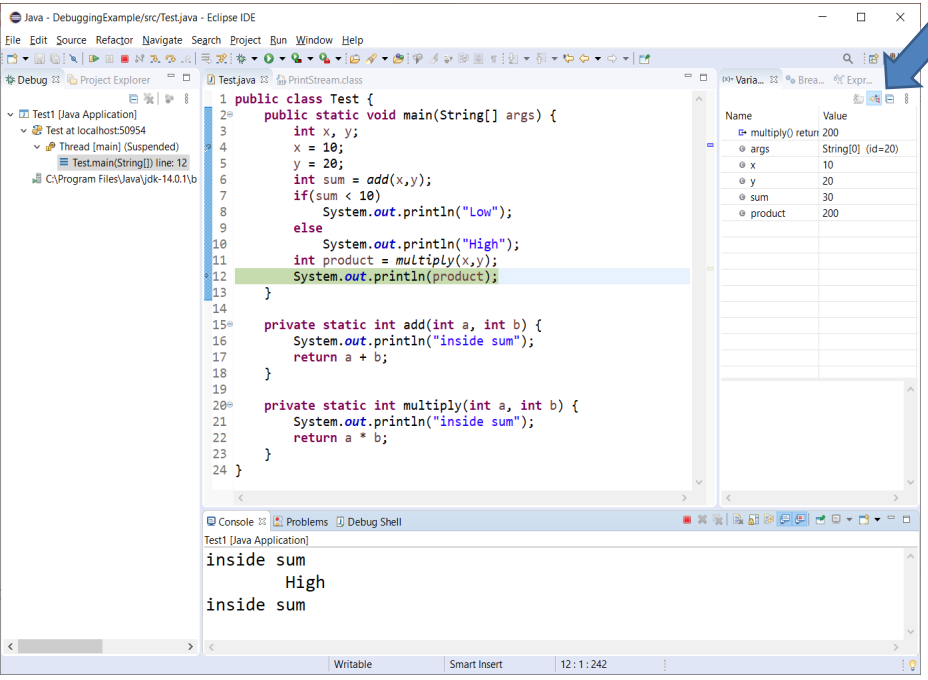
- how the variables change after you execute every statement.
- Which statements run or skipped (e.g. in the if-statement)
- How we don't get into any methods (neither println() nor multiply()).

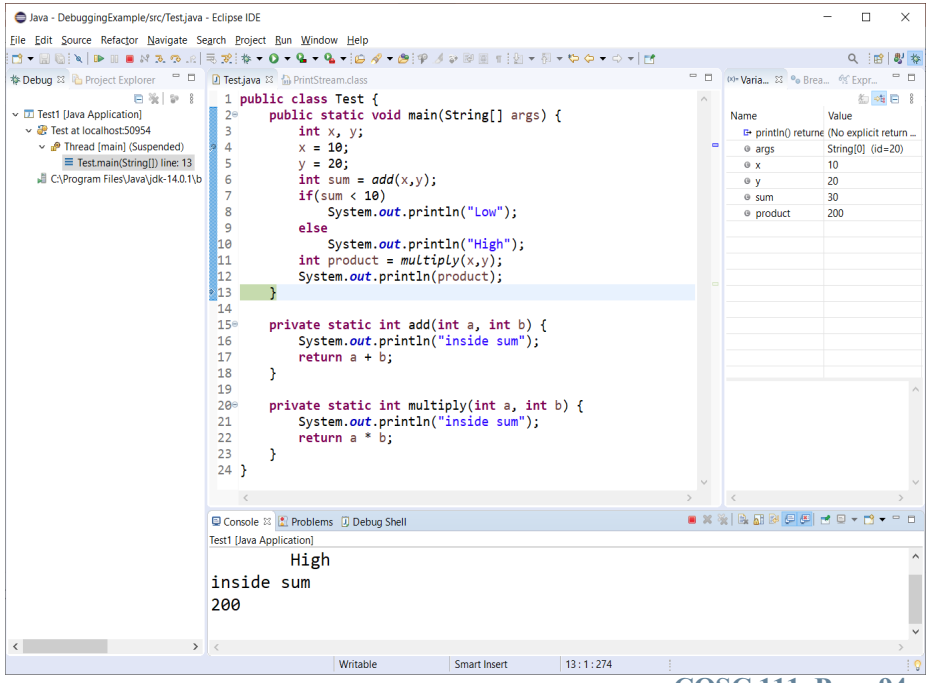





Java - DebuggingExample/src/Test.java - Eclipse IDE
File Edit Source Refactor Navigate Search Project Run Window Help
Test1 [Java Application]
Test at localhost:50954
Thread [main] (Suspended)
Test.main(String[]) line: 10
C:\Program Files\Java\jdk-14.0.1\b
1 public class Test {
2 public static void main(String[] args) {
3 int x, y;
4 x = 10;
5 y = 20;
6 int sum = add(x,y);
7 if(sum < 10)
8 System.out.println("Low");
9 else
10 System.out.println("High");
11 int product = multiply(x,y);
12 System.out.println(product);
13 }
14
15 private static int add(int a, int b) {
16 System.out.println("inside sum");
17 return a + b;
18 }
19
20 private static int multiply(int a, int b) {
21 System.out.println("inside sum");
22 return a * b;
23 }
24 }
Name Value
no method retu
args String[0] (id=20)
x 10
y 20
sum 30
Console Problems Debug Shell
Test1 [Java Application]
inside sum
Writable Smart Insert 10 : 1 : 178


Java - DebuggingExample/src/Test.java - Eclipse IDE
File Edit Source Refactor Navigate Search Project Run Window Help
Test1 [Java Application]
Test at localhost:50954
Thread [main] (Suspended)
Test.main(String[]) line: 11
C:\Program Files\Java\jdk-14.0.1\b
1 public class Test {
2 public static void main(String[] args) {
3 int x, y;
4 x = 10;
5 y = 20;
6 int sum = add(x,y);
7 if(sum < 10)
8 System.out.println("Low");
9 else
10 System.out.println("High");
11 int product = multiply(x,y);
12 System.out.println(product);
13 }
14
15 private static int add(int a, int b) {
16 System.out.println("inside sum");
17 return a + b;
18 }
19
20 private static int multiply(int a, int b) {
21 System.out.println("inside sum");
22 return a * b;
23 }
24 }
Name Value
println() returne (No explicit return ...
args String[0] (id=20)
x 10
y 20
sum 30
Console Problems Debug Shell
Test1 [Java Application]
inside sum
High
Writable Smart Insert 11 : 1 : 210


Java - DebuggingExample/src/Test.java - Eclipse IDE
File Edit Source Refactor Navigate Search Project Run Window Help
Test1 [Java Application]
Test at localhost:50954
Thread [main] (Suspended)
Test.main(String[]) line: 12
C:\Program Files\Java\jdk-14.0.1\b
1 public class Test {
2 public static void main(String[] args) {
3 int x, y;
4 x = 10;
5 y = 20;
6 int sum = add(x,y);
7 if(sum < 10)
8 System.out.println("Low");
9 else
10 System.out.println("High");
11 int product = multiply(x,y);
12 System.out.println(product);
13 }
14
15 private static int add(int a, int b) {
16 System.out.println("inside sum");
17 return a + b;
18 }
19
20 private static int multiply(int a, int b) {
21 System.out.println("inside sum");
22 return a * b;
23 }
24 }
Name Value
multiply() retur 200
args String[0] (id=20)
x 10
y 20
sum 30
product 200
Console Problems Debug Shell
Test1 [Java Application]
inside sum
High
inside sum
Writable Smart Insert 12 : 1 : 242


Java - DebuggingExample/src/Test.java - Eclipse IDE
File Edit Source Refactor Navigate Search Project Run Window Help
Test1 [Java Application]
Test at localhost:50954
Thread [main] (Suspended)
Test.main(String[]) line: 13
C:\Program Files\Java\jdk-14.0.1\b
1 public class Test {
2 public static void main(String[] args) {
3 int x, y;
4 x = 10;
5 y = 20;
6 int sum = add(x,y);
7 if(sum < 10)
8 System.out.println("Low");
9 else
10 System.out.println("High");
11 int product = multiply(x,y);
12 System.out.println(product);
13 }
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15 private static int add(int a, int b) {
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18 }
19
20 private static int multiply(int a, int b) {
21 System.out.println("inside sum");
22 return a * b;
23 }
24 }
Name Value
println() returne (No explicit return ...
args String[0] (id=20)
x 10
y 20
sum 30
product 200
Console Problems Debug Shell
Test1 [Java Application]
High
inside sum
200
Writable Smart Insert 13 : 1 : 274