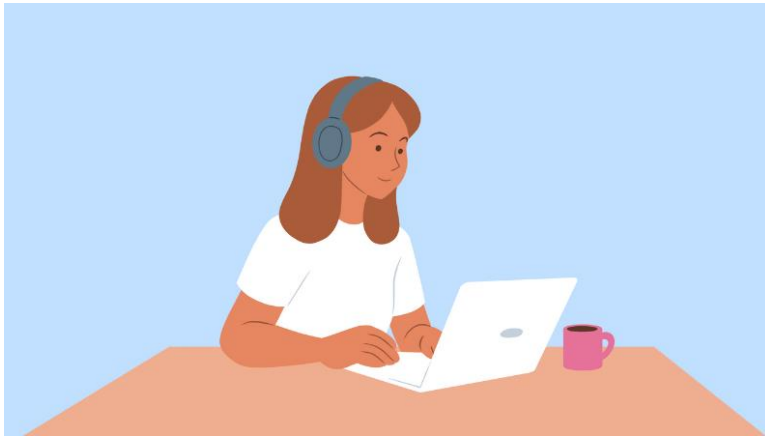


Chapter 5: Methods

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So Far...



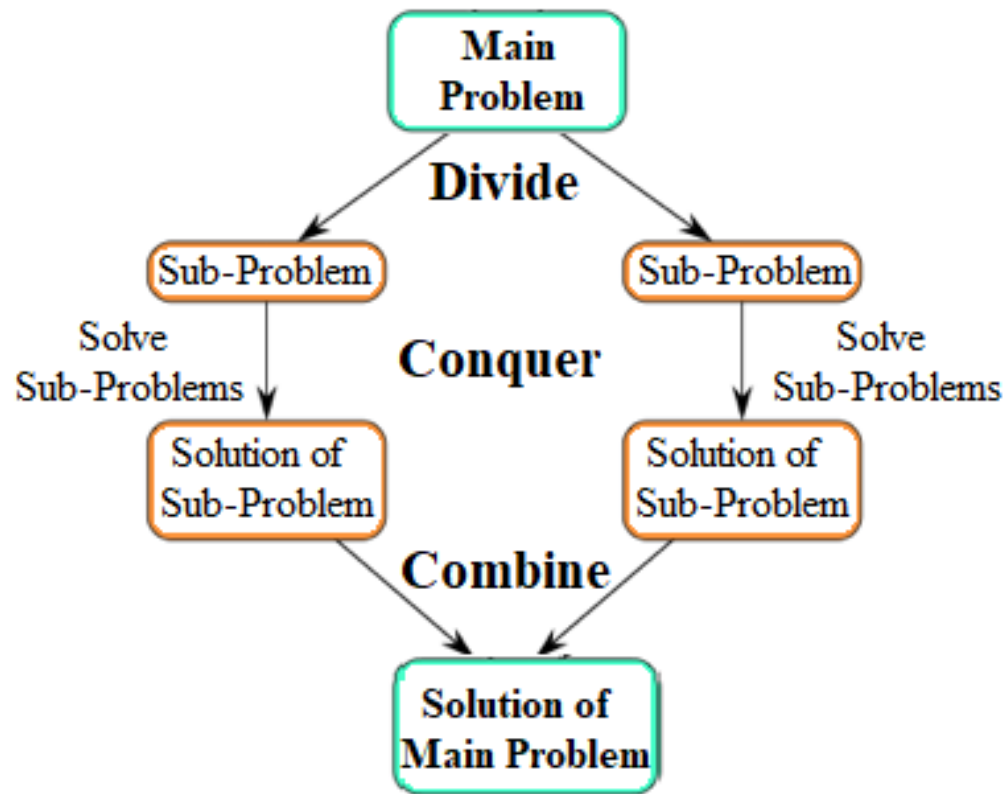
- ▶ The programs we have written so far solve simple problems
- ▶ They are short and everything fits well in a `main` method

What if you are asked to **solve complex problems?**

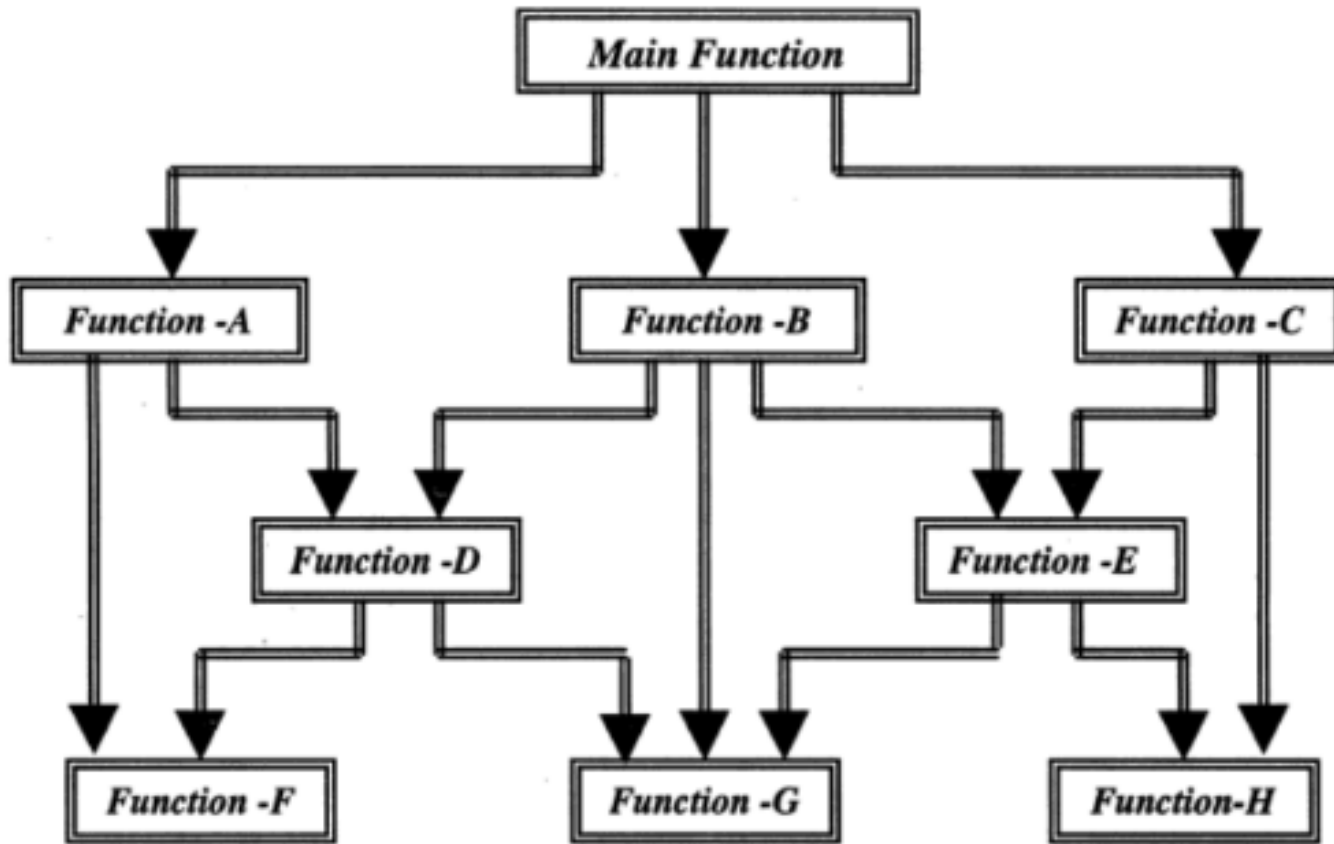
Write a giant `main` method?

Divide and Conquer (分而治之)

Decompose a big/complex task into smaller one and solve each of them



Divide and Conquer (分而治之)



Objectives

- ▶ Method declaration and invocation
- ▶ Passing arguments
- ▶ Method call stack
- ▶ Method overloading
- ▶ Modular programming

Using Methods

```
public class MaximumFinder {
```

The class defines two methods

```
    public static double maximum(double x, double y, double z) {  
        double max = x;  
        if(y > max) max = y;  
        if(z > max) max = z;  
        return max;  
    }
```

Find the largest of 3 double values

```
    public static void main(String[] args) {  
        double result1 = maximum(3.1, 3.2, 3.0);  
        double result2 = maximum(70, 90, 10);  
        double result3 = maximum(45, 10.1, 1);  
        System.out.printf("%.1f %.1f %.1f", result1, result2, result3);  
    }  
}
```

Declaring a Method

修饰符

形式参数（形参）

Modifiers + Return type + Method name + Parameters


```
public static double maximum( double x, double y, double z ) {  
    double max = x;  
    if(y > max) max = y;  
    if(z > max) max = z;  
    return max;  
}
```

Method body contains one or more statements that perform the method's task

Return Type of Methods

Return type: the type of data the method returns to its caller (e.g., main method).

```
public static double maximum(double x, double y, double z) {  
    double max = x;  
    if(y > max) max = y;  
    if(z > max) max = z;  
    return max;  
}
```



A method may return


- **Nothing** (void)
- **Primitive values** (e.g., an integer)
- **References** to objects, arrays

```
void println()  
int nextInt()
```


Return Type of Methods

Return type: the type of data the method returns to its caller (e.g., main method).

```
public static double maximum(double x, double y, double z) {  
    double max = x;  
    if(y > max) max = y;  
    if(z > max) max = z;  
    return max;  
}
```




We can also **return** an expression:

```
return number1 + number2 + number3;
```

Method Parameters

A **comma-separated** list of **parameters**, meaning that the method requires additional information from the caller to perform its task.

```
public static double maximum( double x, double y, double z ) {  
    double max = x;  
    if(y > max) max = y;  
    if(z > max) max = z;  
    return max;  
}
```




A method can have 0, 1, or more parameters

Empty parentheses (0 parameter): the method does not need additional information to perform its task

Method Parameters

Each parameter must specify a **type** and an **identifier**

```
public static double maximum( double x, double y, double z ) {  
    double max = x;  
    if(y > max) max = y;  
    if(z > max) max = z;  
    return max;  
}
```



[Scope] A method's parameters are **local variables** of that method and can be used **only in that method's body**

Calling a Method

- ▶ In a method **definition**, you define what the method does.
- ▶ To execute the method, you have to **call** or **invoke** (调用) it

Arguments (实际参数/实参)

```
double result = maximum(1.0, 2.0, 3.0);
```



```
public static double maximum( double x, double y, double z ) {  
    ...  
}
```

The number, order and type of arguments (实参) and parameters (形参) must be consistent.

Calling a Method

- ▶ In a method **definition**, you define what the method does.
- ▶ To execute the method, you have to **call** or **invoke** (调用) it

Arguments (实际参数/实参)

```
double result = maximum(1.0, 2.0, 3.0);
```

```
System.out.println(maximum(1.0, 2.0, 3.0));
```

Calling a Method

- ▶ Before any method can be called, its arguments must be evaluated to determine their values
- ▶ If an argument is a method call, the method call must be performed to determine its return value

```
Math.pow( Math.pow(x2-x1, 2) + Math.pow(y2-y1, 2) , 0.5 );
```

Objectives

- ▶ Method declaration and invocation
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Passing Arguments in Method Calls

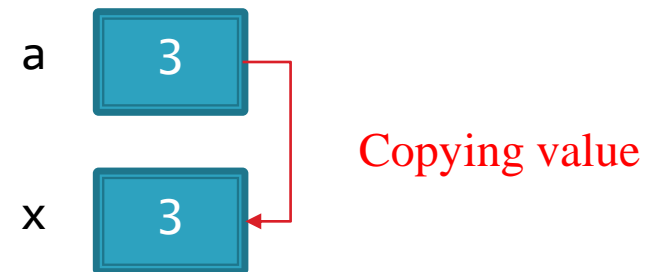
- ▶ In Java, all arguments are **passed by value** (按值传递), meaning that the method gets **a copy of all parameter values**
- ▶ A method call can pass two types of values to the called method:
 - Primitive types: passing copies of primitive values
 - Reference types: passing copies of references to objects.

Passing Primitive Type

The value is simply copied

```
public static void main(String[] args) {  
    int a = 3;  
    System.out.println("Before: " + a);  
  
    triple(a);  
    System.out.println("After: " + a);  
}  
  
public static void triple(int x) {  
    x *= 3;  
}
```

Before: 3
After: 3



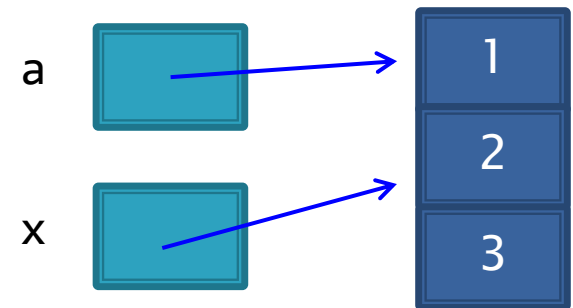
x becomes 9 after method call
a remains unchanged

Passing Reference Type

```
public static void main(String[] args) {  
    int[] a = {1, 2, 3};  
    System.out.println("Before: " + Arrays.toString(a));  
  
    triple(a);  
    System.out.println("After: " + Arrays.toString(a));  
}
```

Before: [1, 2, 3]
After: [3, 6, 9]

```
public static void triple(int[] x) {  
    for(int i = 0; i < x.length; i++)  
        x[i] *= 3;  
}
```



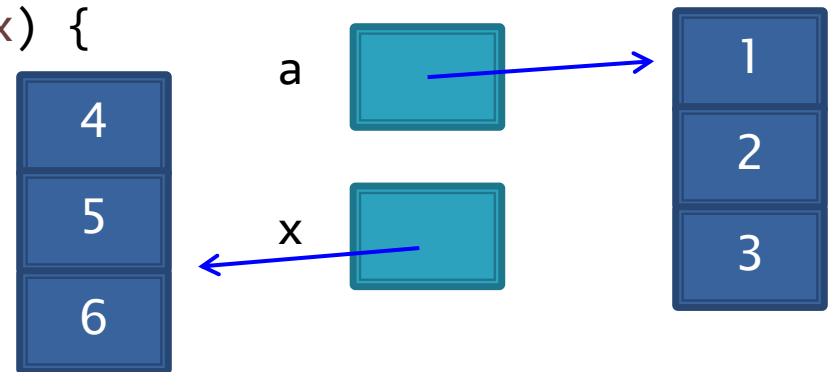
Copying value again. Difference is that the value is a memory address.

Passing Reference Type

```
public static void main(String[] args) {  
    int[] a = {1, 2, 3};  
    System.out.println("Before: " + Arrays.toString(a));  
  
    triple(a);  
    System.out.println("After: " + Arrays.toString(a));  
}
```

Before: [1, 2, 3]
After: [1, 2, 3]

```
public static void triple(int[] x) {  
    x = new int[]{4,5,6};  
}
```



Copying value, which is a memory address.

What's the output?

```
public static void main(String[] args) {  
    int[] arr = {1, 2, 3};  
    System.out.println("Before: " + Arrays.toString(a));  
  
    triple(arr[0]);  
    System.out.println("After: " + Arrays.toString(a));  
}  
  
public static void triple(int x) {  
    x *= 3;  
}
```

Using Command-Line Arguments

- ▶ We can pass arguments from the command line to an application by including a parameter of type `String[]` in the parameter list of `main`.

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

- ▶ By convention, this parameter is named `args`.
- ▶ When an application is executed using the `java` command, Java passes the command-line arguments that appear after the class name in the `java` command to the `main` method as `Strings` in the array `args`.

Q: Initialize an array by specifying its size, first element, and interval

```
java InitArray 5 0 4
```

Index	Value
0	0
1	4
2	8
3	12
4	16

```
java InitArray 8 1 2
```

Index	Value
0	1
1	3
2	5
3	7
4	9
5	11
6	13
7	15

Fig. 6.15 | Initializing an array using command-line arguments. (Part 3 of 3.)

```
1 // Fig. 6.15: InitArray.java
2 // Initializing an array using command-line arguments.
3
4 public class InitArray
5 {
6     public static void main( String[] args )
7     {
8         // check number of command-line arguments
9         if ( args.length != 3 )
10             System.out.println(
11                 "Error: Please re-enter the entire command, including\n" +
12                 "an array size, initial value and increment." );
13         else
14         {
15             // get array size from first command-line argument
16             int arrayLength = Integer.parseInt( args[ 0 ] );
17             int[] array = new int[ arrayLength ]; // create array
18
19             // get initial value and increment from command-line arguments
20             int initialValue = Integer.parseInt( args[ 1 ] );
21             int increment = Integer.parseInt( args[ 2 ] );
22
```

Fig. 6.15 | Initializing an array using command-line arguments. (Part I of 3.)

```

23      // calculate value for each array element
24      for ( int counter = 0; counter < array.length; counter++ )
25          array[ counter ] = initialValue + increment * counter;
26
27      System.out.printf( "%s%8s\n", "Index", "Value" );
28
29      // display array index and value
30      for ( int counter = 0; counter < array.length; counter++ )
31          System.out.printf( "%5d%8d\n", counter, array[ counter ] );
32      } // end else
33  } // end main
34 } // end class InitArray

```

java InitArray

Error: Please re-enter the entire command, including
an array size, initial value and increment.

Fig. 6.15 | Initializing an array using command-line arguments. (Part 2 of 3.)

Argument Promotion

- ▶ **Argument promotion**—converting an argument's value, if possible, to the type that the method expects to receive in its corresponding parameter

`Math.sqrt()` expects to receives a **double** argument, but it is ok to write `Math.sqrt(4)`: java converts the **int** value 4 to the **double** value 4.0

Promotion Rules

Specify which conversions are allowed (which conversions can be performed without losing data)

Type	Valid promotions
double	None
float	double
long	float or double
int	long, float or double
char	int, long, float or double
short	int, long, float or double (but not char)
byte	short, int, long, float or double (but not char)
boolean	None (boolean values are not considered to be numbers in Java)

Variable-Length Argument Lists

- ▶ With **variable-length argument lists**, you can create methods that receive an unspecified number of arguments.
- ▶ A type followed by an **ellipsis (...)** in a method's parameter list indicates that the method receives a variable number of arguments of that particular type.

```
public static double average(double... numbers)
```

- ▶ Can occur only once in a parameter list, and the ellipsis, together with its type, must be placed at the end of the parameter list.
- ▶ Java treats the variable-length argument list as an **array of the specified type.**

Example

```
public static double average(double... numbers) {    numbers: [10.0, 20.0]
    double total = 0.0;
    for(double d : numbers) total += d;           numbers: [10.0, 20.0, 30.0]
    return total / numbers.length;
}
```

```
public static void main(String[] args) {
    double d1 = 10.0, d2 = 20.0, d3 = 30.0;
    System.out.printf("average of d1 and d2: %f\n", average(d1, d2));
    System.out.printf("average of d1 ~ d3: %f\n", average(d1, d2, d3));
}
```

average of d1 and d2: 15.000000
average of d1 ~ d3: 20.000000

Objectives

- ▶ Method declaration and invocation
- ▶ Passing arguments
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Control flow for method calls

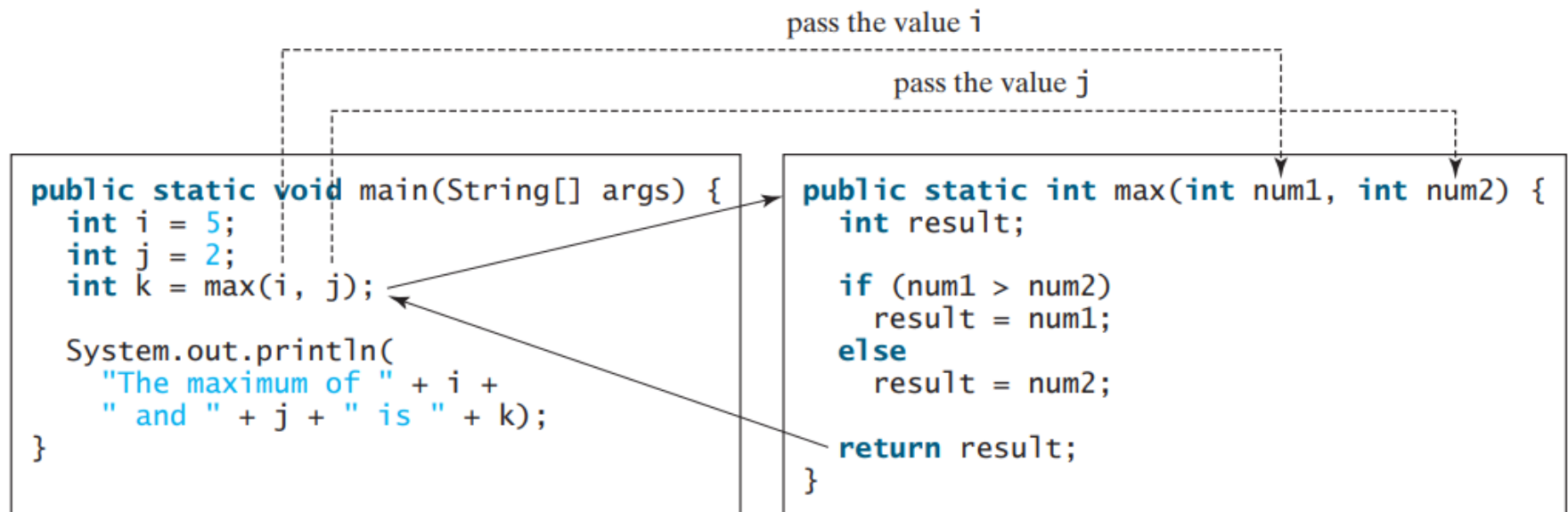


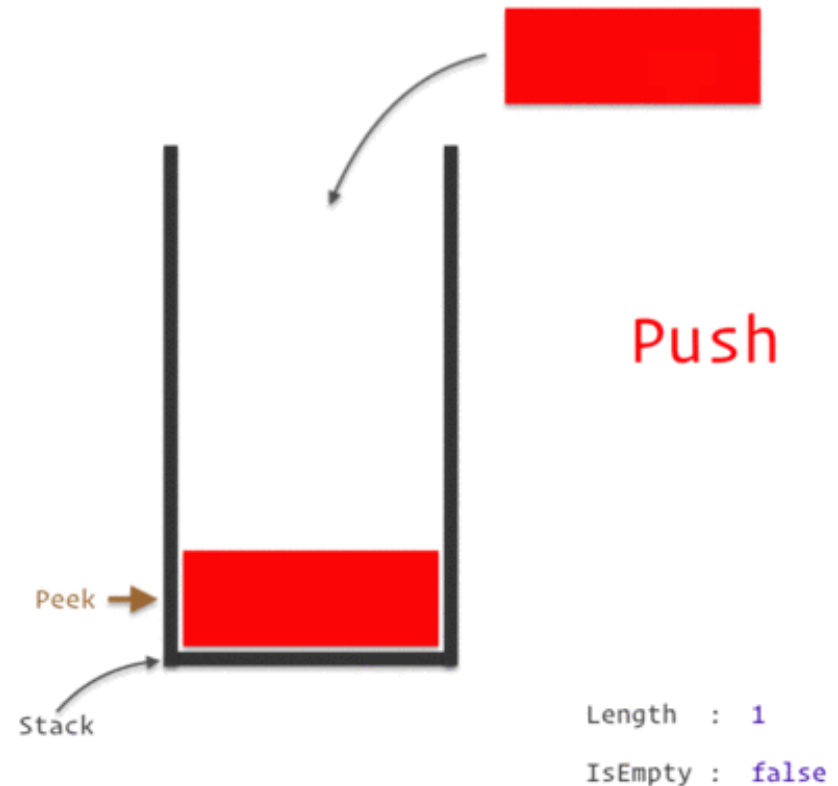
FIGURE 6.2 When the `max` method is invoked, the flow of control transfers to it. Once the `max` method is finished, it returns control back to the caller.

Method-Call Stack

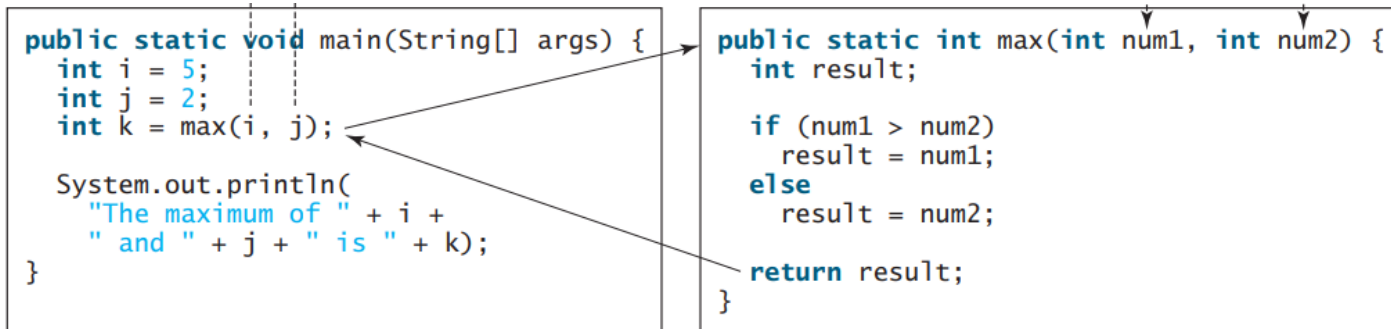
- ▶ Each time a method is invoked, the system creates an **activation record** (激活记录) that stores **parameters** and **variables** for the method and places the activation record in an area of memory known as a **call stack** (方法调用栈)

Method-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 and **pushed** to the stack.
- ▶ When a method finishes its work and returns to its caller, its activation record is **popped** from the call stack.
- ▶ A call stack stores the activation records in a **last-in, first-out** fashion: The activation record for the method that is invoked last is removed first from the stack.



Method-Call Stack

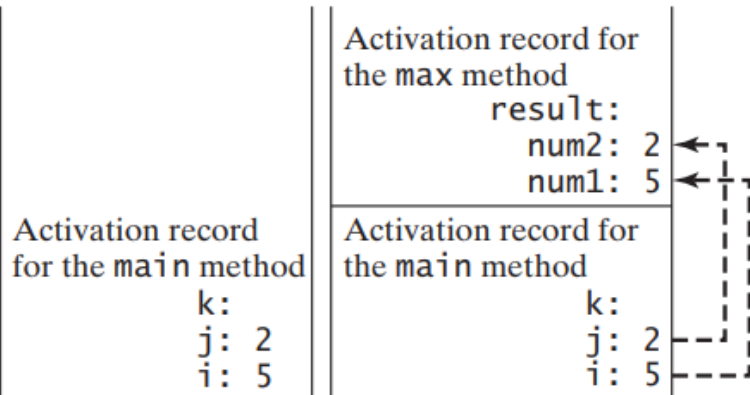
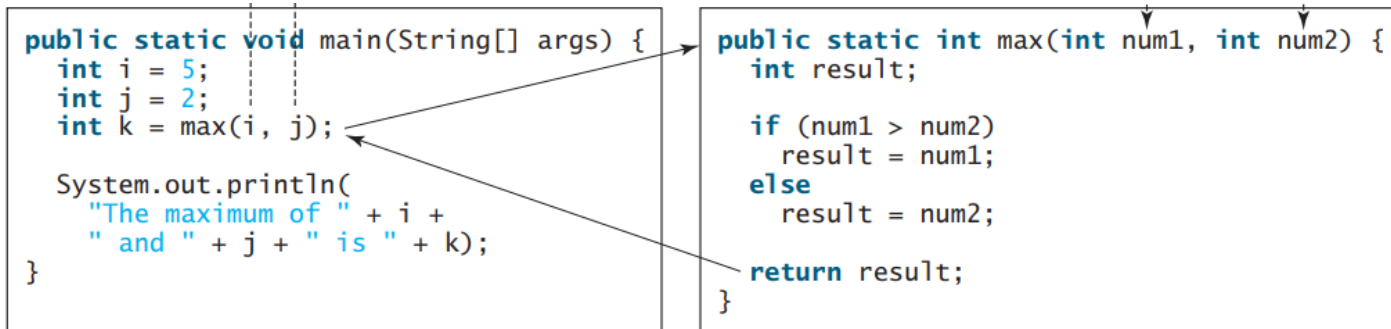


Activation record
for the `main` method

k:
j: 2
i: 5

(a) The `main` method is invoked.

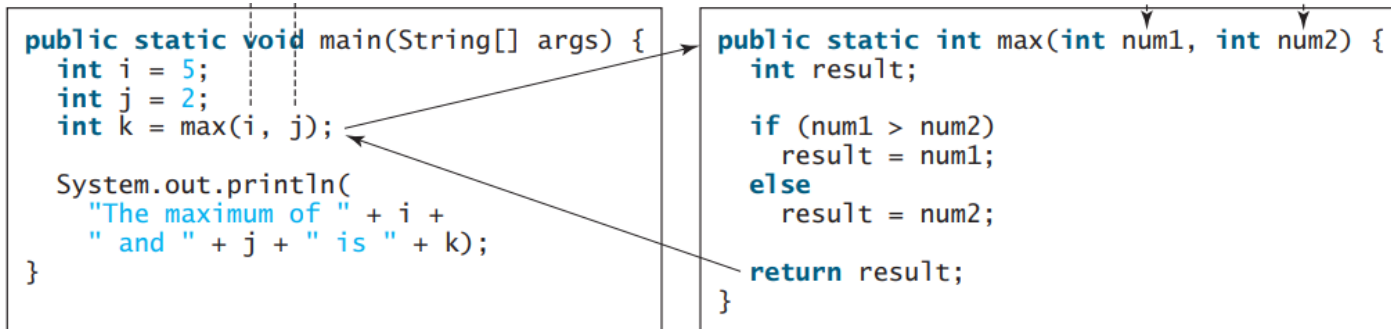
Method-Call Stack



(a) The `main` method is invoked.

(b) The `max` method is invoked.

Method-Call Stack



Activation record for the main method	
k:	
j:	2
i:	5

(a) The main method is invoked.

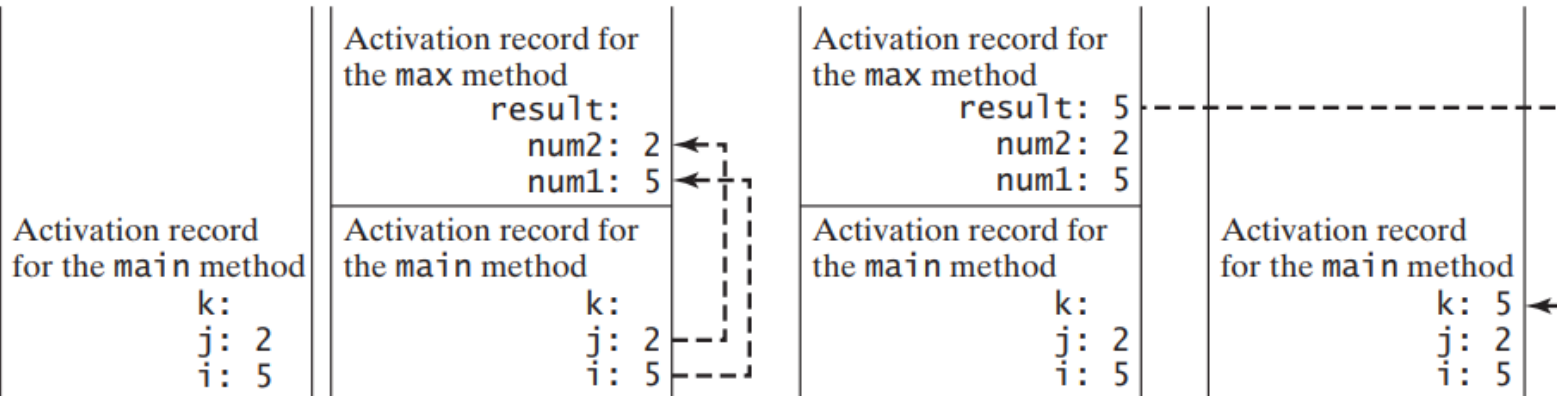
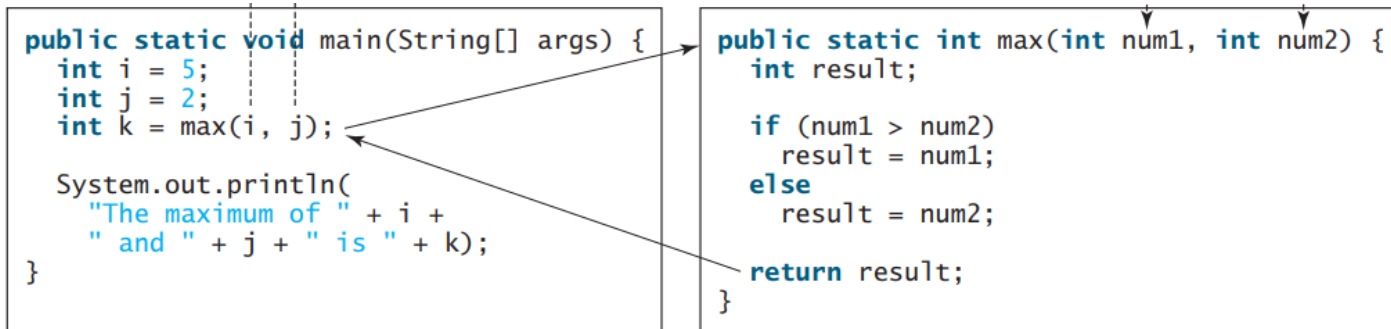
Activation record for the max method	
result:	
num2:	2
num1:	5
Activation record for the main method	
k:	
j:	2
i:	5

(b) The max method is invoked.

Activation record for the max method	
result:	5
num2:	2
num1:	5
Activation record for the main method	
k:	
j:	2
i:	5

(c) The max method is being executed.

Method-Call Stack



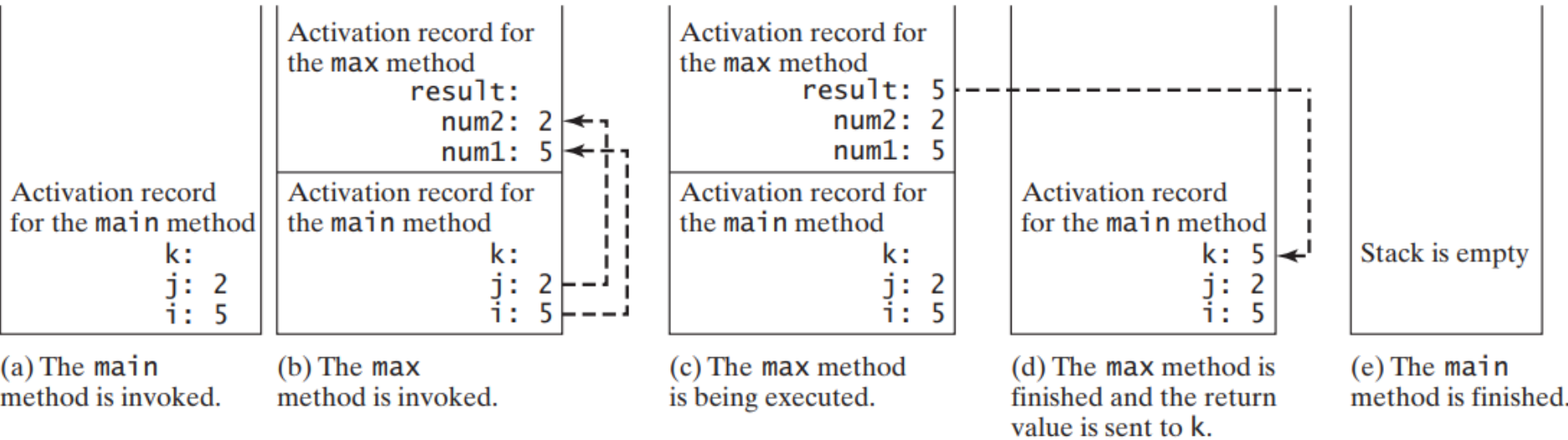
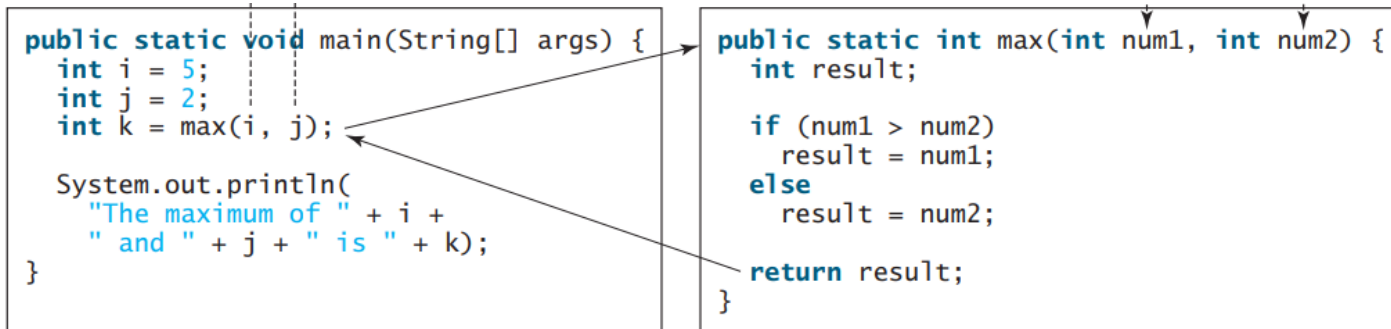
(a) The main method is invoked.

(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.

Method-Call Stack



Inspecting the Call Stack

```
public class StackDemo{  
    public static void main(String[] args) {  
        int x = 10;  
        caller1(x);  
    }  
  
    public static int caller1(int y) {  
        return caller2(y);  
    }  
  
    public static int caller2(int y) {  
        return caller3(y);  
    }  
  
    public static int caller3(int y) {  
        return y/0;  
    }  
}
```

Frames

✓ "main"@1 in group "main": RUNNING

caller3:18, StackDemo (*lecture6*)

caller2:14, StackDemo (*lecture6*)

caller1:10, StackDemo (*lecture6*)

main:6, StackDemo (*lecture6*)

Exception in thread "main" java.lang.ArithmeticException Create breakpoint : / by zero
at lecture6.StackDemo.caller3([StackDemo.java:18](#))
at lecture6.StackDemo.caller2([StackDemo.java:14](#))
at lecture6.StackDemo.caller1([StackDemo.java:10](#))
at lecture6.StackDemo.main([StackDemo.java:6](#))

Objectives

- ▶ Method declaration and invocation
- ▶ Passing arguments
- ▶ Method call stack
- ▶ Method overloading
- ▶ Modular programming

Method Signature

- ▶ Method signature (方法签名): A combination of the method's **name** and the **number**, **types** and **order** of its parameters.
- ▶ Compiler distinguishes methods by their **signatures**

```
public double calculateAnswer(double wingSpan, int numberOfEngines,  
                             double length, double grossTons) {  
    //do the calculation here  
    return 0.0;  
}
```

Signature: calculateAnswer(double, int, double, double)

Method Overloading (方法重载)

- ▶ Methods of the same name can be declared in the same class, as long as they have different sets of parameters
- ▶ Used to create several methods that perform the same/similar tasks on **different types** or **different numbers** of arguments
 - **Java compiler** selects the appropriate method to call by examining the number, types and order of the arguments in the call

static double	max(double a, double b)
static float	max(float a, float b)
static int	max(int a, int b)
static long	max(long a, long b)

```
int a = 2;  
int b = 3;  
Math.max(a, b);
```

Which version of max?

Method Overloading

- ▶ Method calls **cannot** be distinguished by **return type**. If you have overloaded methods only with different return types:
 - `int square(int a)`
 - `double square(int a)`
- ▶ and you called the method as follows
 - `square(2);`
- ▶ the compiler will be confused (since return type is ignored)
- ▶ Hence, there will be compilation error for defining multiple methods with the same signatures

Method Overloading

`System.out.println`
are also overloaded

`println()`

Terminates the current line by writing the line separator string.

`println(boolean x)`

Prints a boolean and then terminate the line.

`println(char x)`

Prints a character and then terminate the line.

`println(char[] x)`

Prints an array of characters and then terminate the line.

`println(double x)`

Prints a double and then terminate the line.

`println(float x)`

Prints a float and then terminate the line.

`println(int x)`

Prints an integer and then terminate the line.

`println(long x)`

Prints a long and then terminate the line.

`println(Object x)`

Prints an Object and then terminate the line.

`println(String x)`

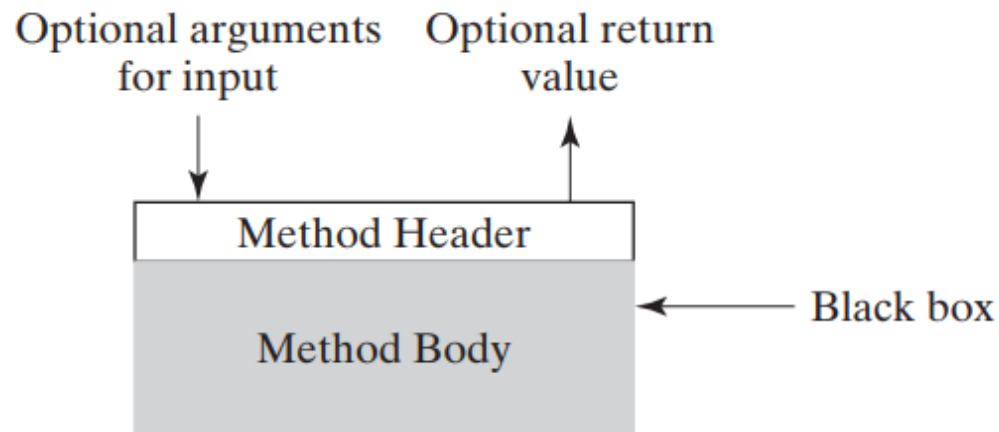
Prints a String and then terminate the line.

Objectives

- ▶ Method declaration and invocation
- ▶ Passing arguments
- ▶ Method call stack
- ▶ Method overloading
- ▶ **Modular programming**

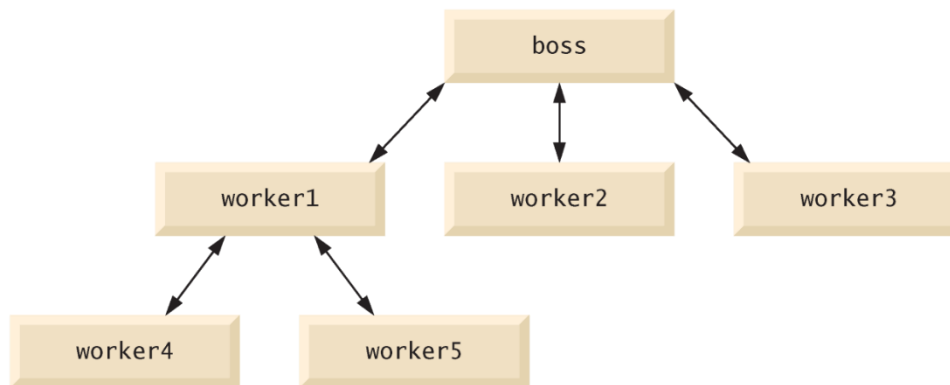
Method Abstraction

- ▶ **Method abstraction** separates the use of a method from its implementation.
- ▶ Clients can use the methods without knowing its implementation details



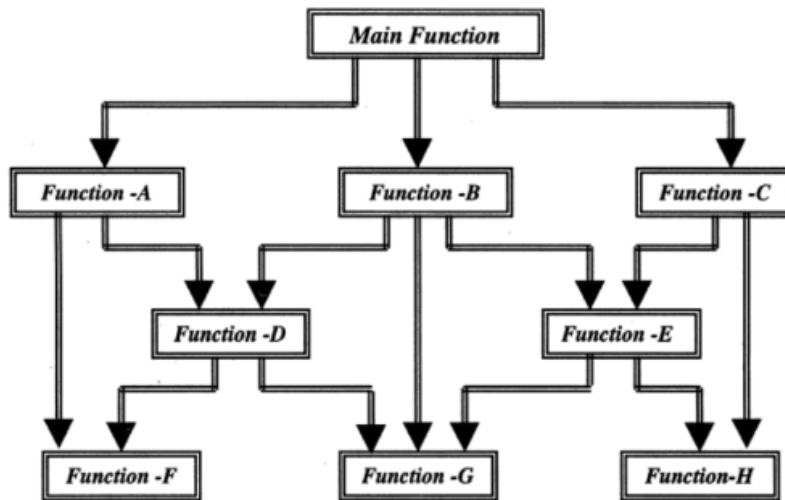
Program Modules

- ▶ Similar to the hierarchical form of management
 - A boss (the caller) asks a worker (the callee) to perform a task and report back (return) the results after completing the task
 - The boss method does not know how the worker method performs its designated tasks (method complexity is hidden)
 - The worker may also call other worker methods, unknown to the boss



Benefits of Modular Programming

(模块化编程)



- ▶ Improved readability
- ▶ Reduce duplication
- ▶ Improve reusability
- ▶ Easier to update, test, and fix
- ▶ Easy collaboration

Modular programming facilitate the **design**, **implementation**, **operation** and **maintenance** of large programs