Recursion

Interpretation
vs
Compilation

Interpretation vs. Compilation

- Interpretation
  - Code is read and executed one statement at a time
- Compilation
  - Entire program is translated into another language
  - The translated code is interpreted

Interpretation

- Python, JavaScript, etc. are interpreted languages

- If you have errors:
  - They'll commonly be *run-time* errors
  - Program crashes as it's running

- Program runs immediately when you run it

Compilation

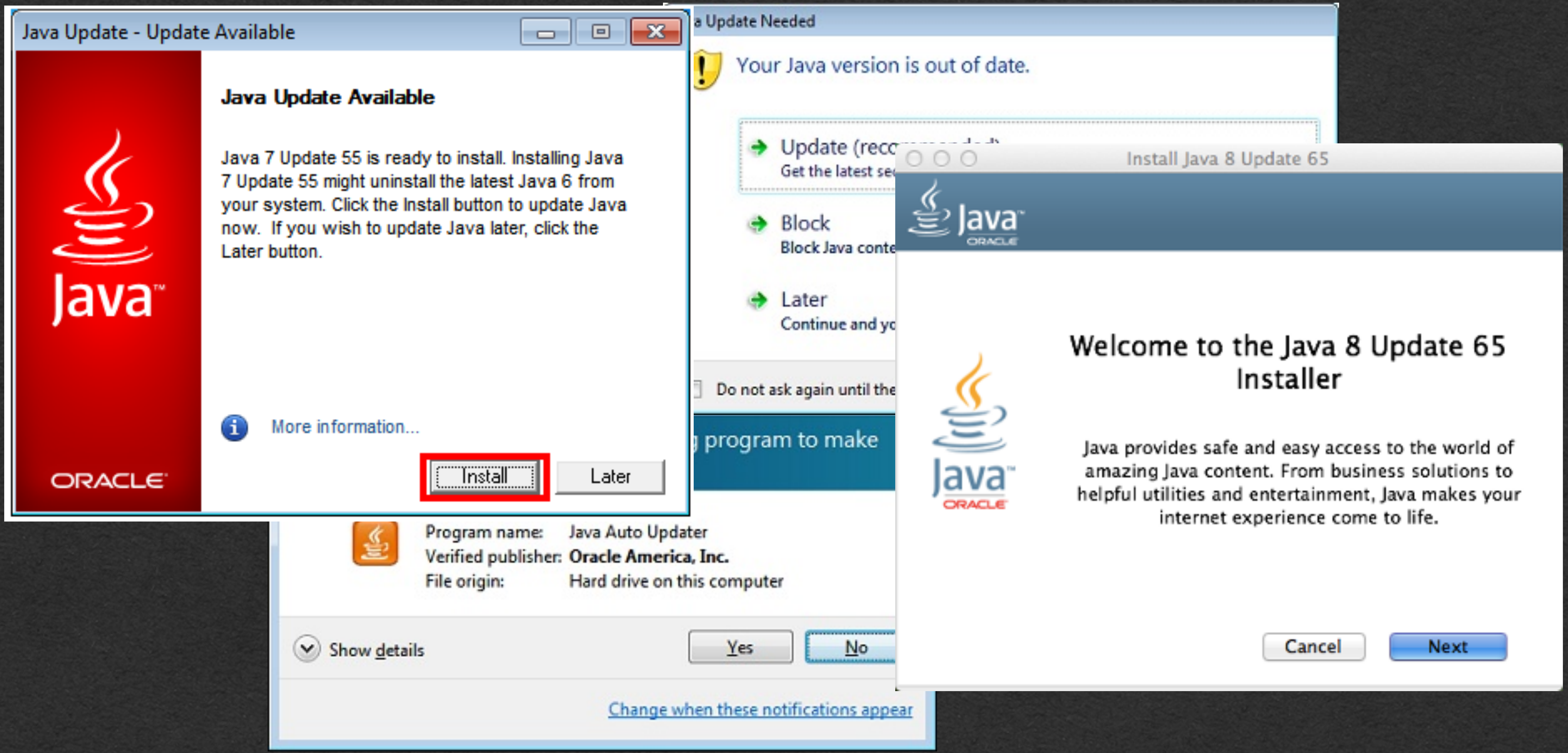
- Java, C, Scala, C++, etc. are compiled languages

- If you have errors:
    - They'll commonly be *compiler* errors
    - Compilers will check all syntax and types and alert us of any errors before they become run-time errors
    - Program fails to be converted into the target language and never runs

- Compilation takes time; Program does not run immediately

Compilation - Java

- Java compiles to Java Byte Code
- Executed by the Java Virtual Machine (JVM)
  - Installed on Billions of devices!



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Java Update Available

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a Update Needed

Your Java version is out of date.

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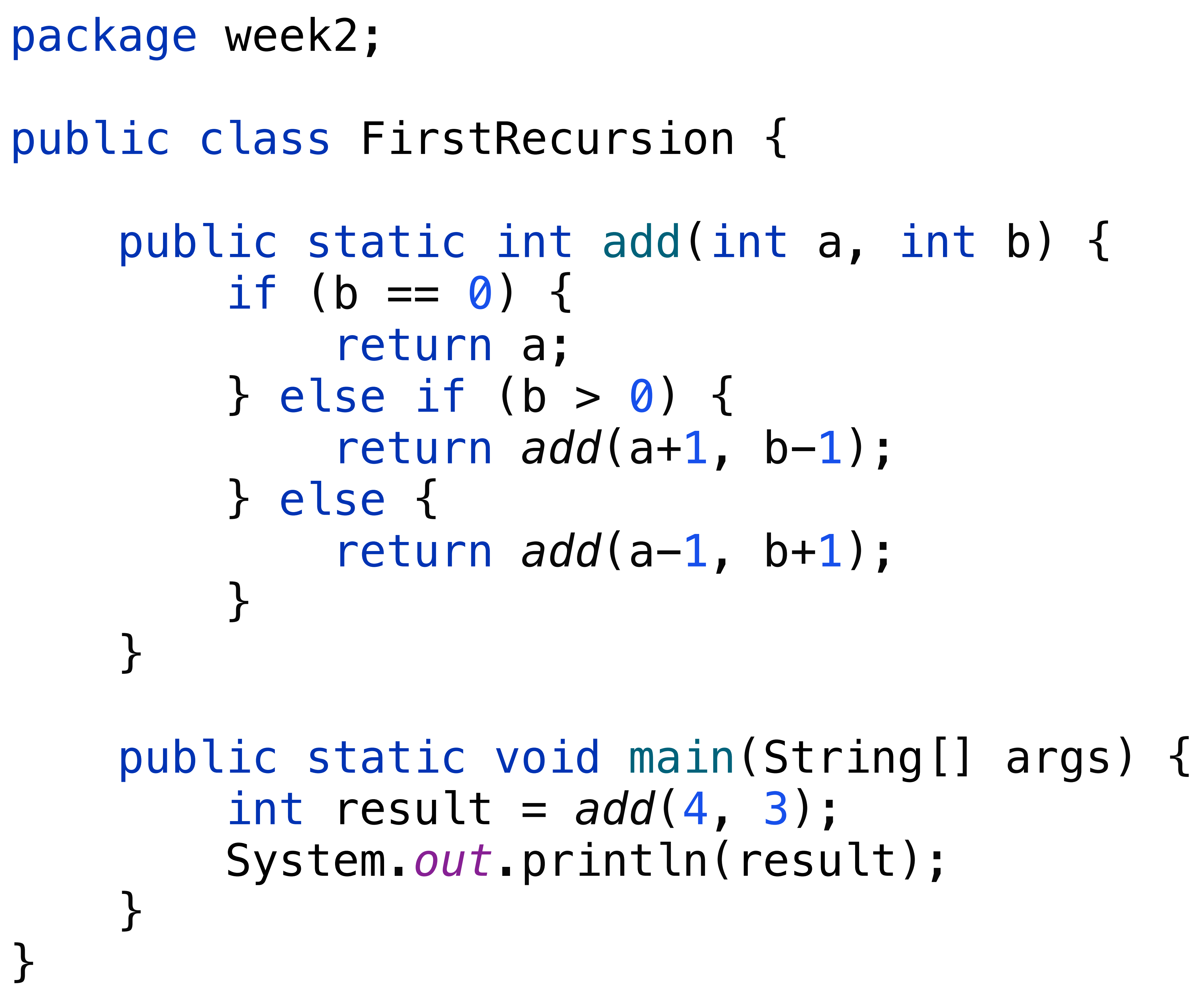
Recursion

Recursion



```java
package week2;

public class FirstRecursion {

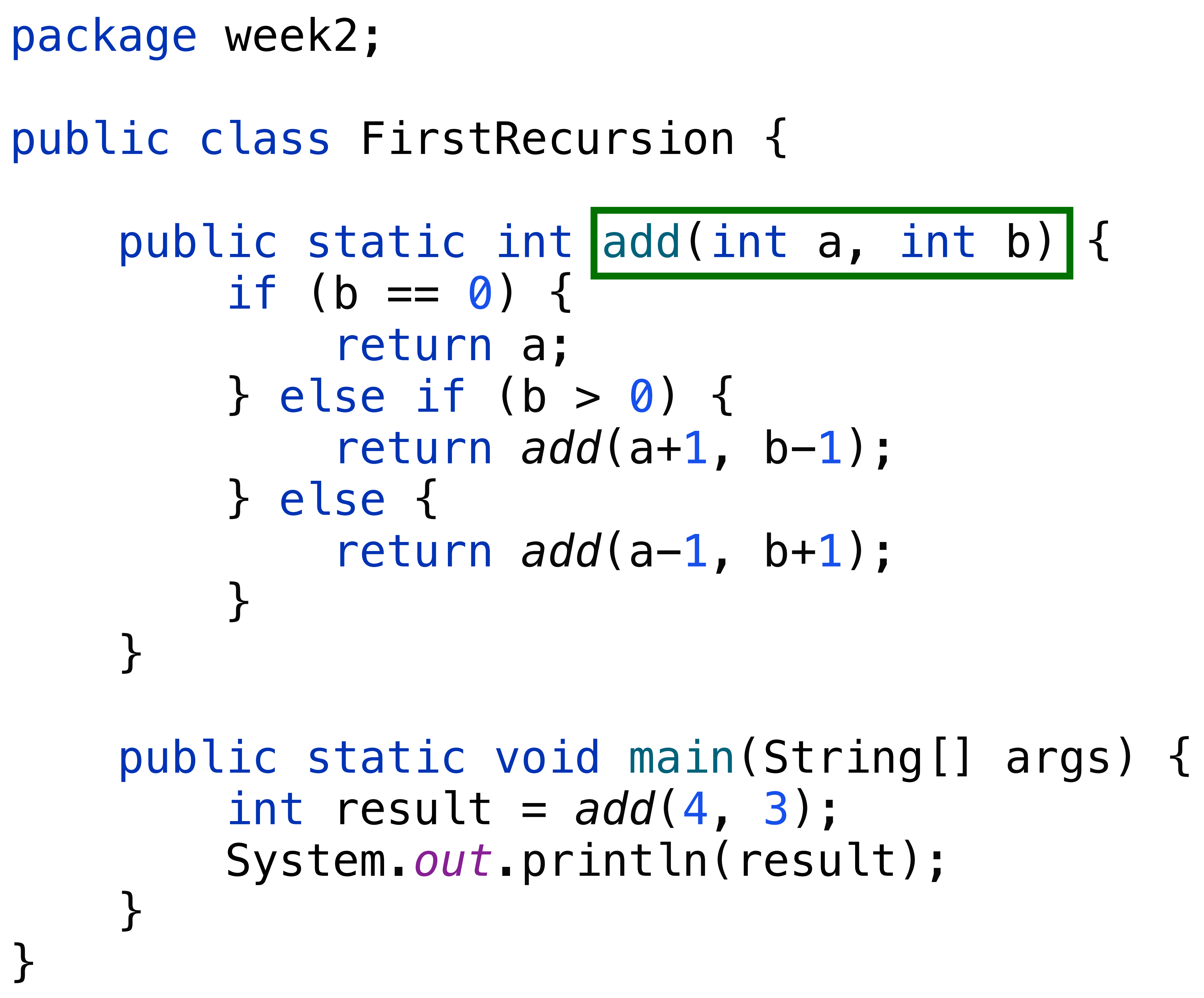
    public static int add(int a, int b) {
        if (b == 0) {
            return a;
        } else if (b > 0) {
            return add(a+1, b-1);
        } else {
            return add(a-1, b+1);
        }
    }

    public static void main(String[] args) {
        int result = add(4, 3);
        System.out.println(result);
    }
}
```

- Recursion:
  - When a method/function calls itself

- A recursive method is a method that calls itself

Recursion



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        int result = add(4, 3);
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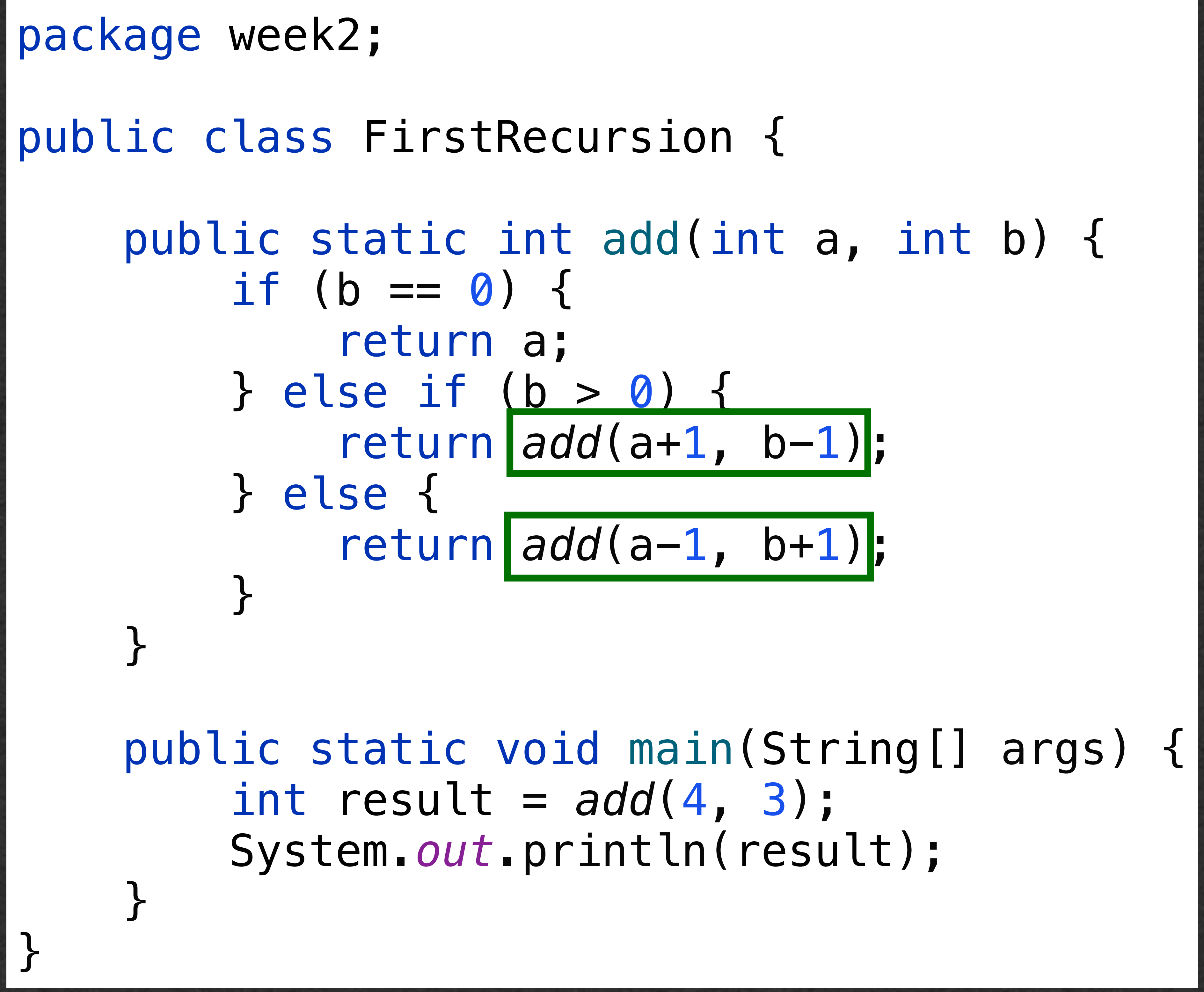
}
```

- We are defining a method named **add**

Recursion



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        }
    }

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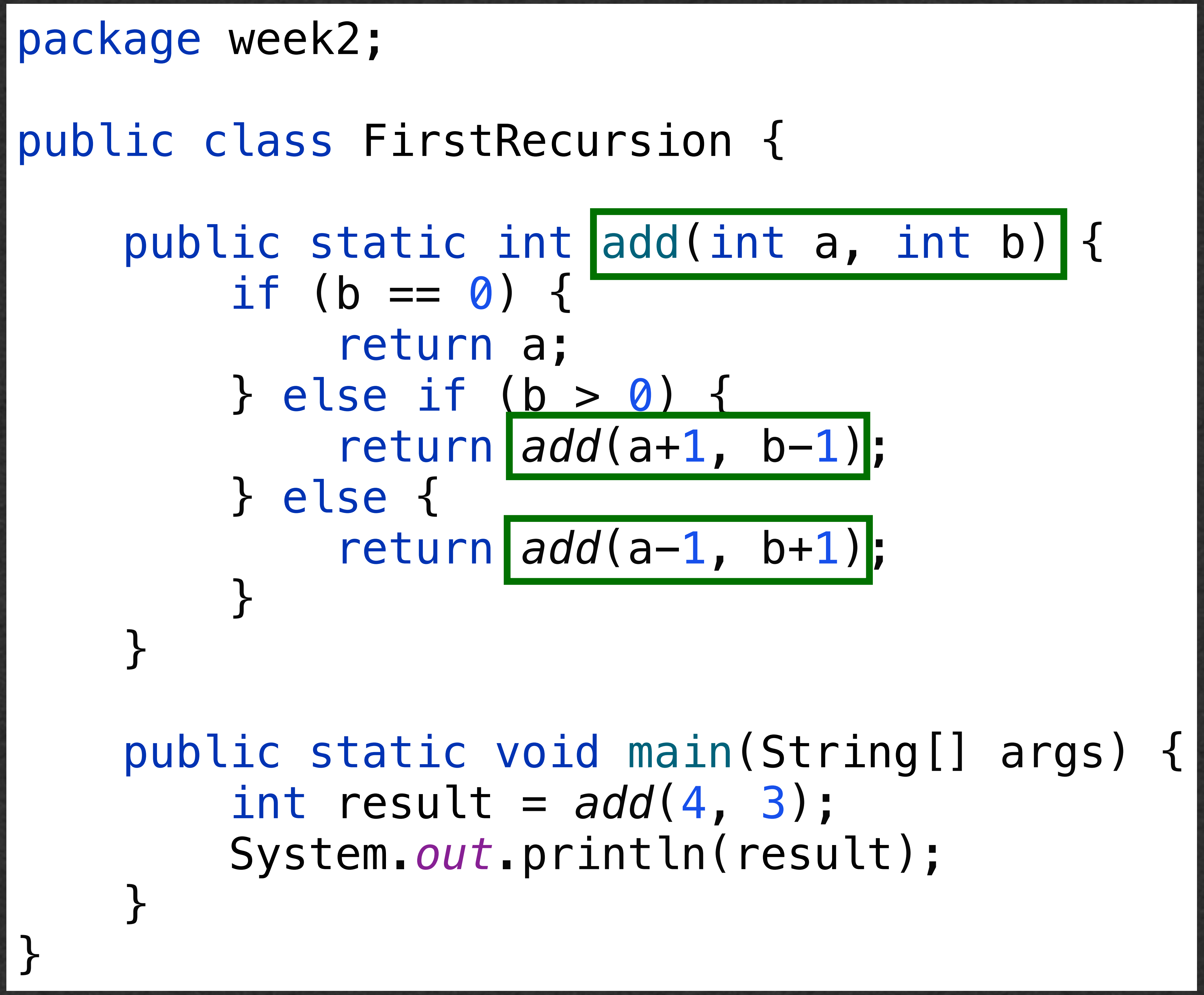
    }
}
```

- We are defining a method named **add**

- And we call a method named **add**



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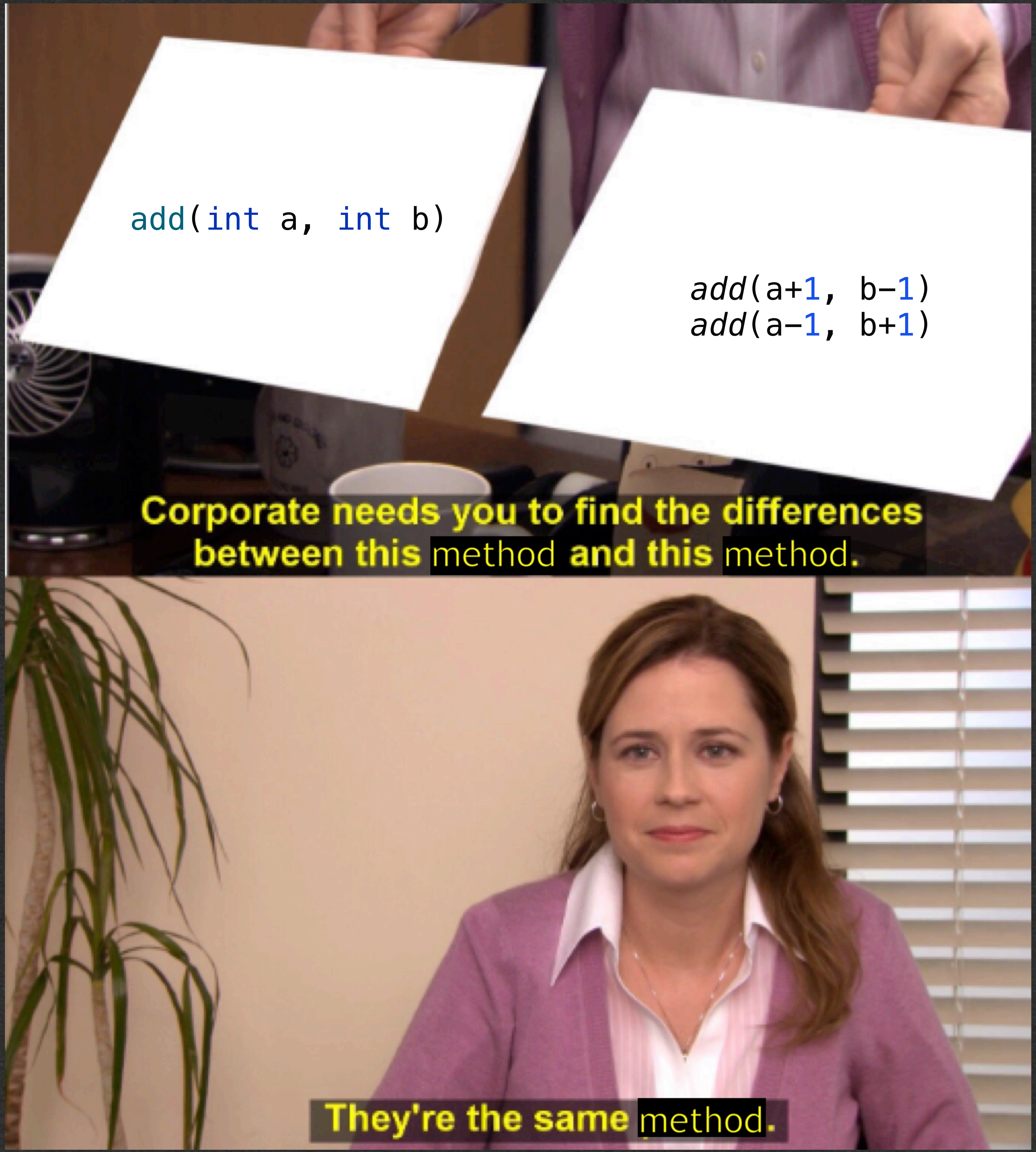
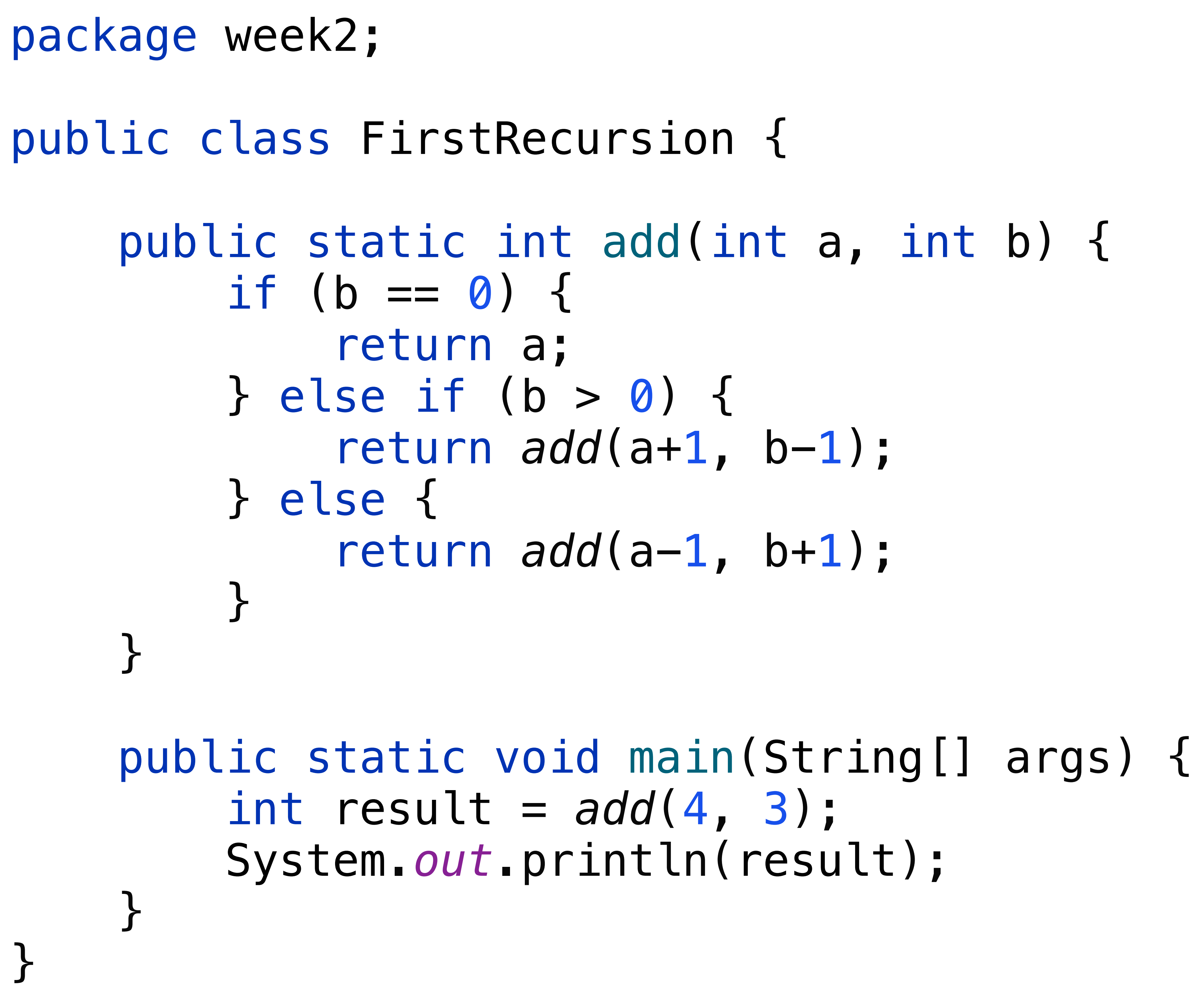

add(int a, int b)
add(a+1, b-1)
add(a-1, b+1)
Corporate needs you to find the differences between this method and this method.
They're the same method.

Recursion



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        }
    }

    public static void main(String[] args) {
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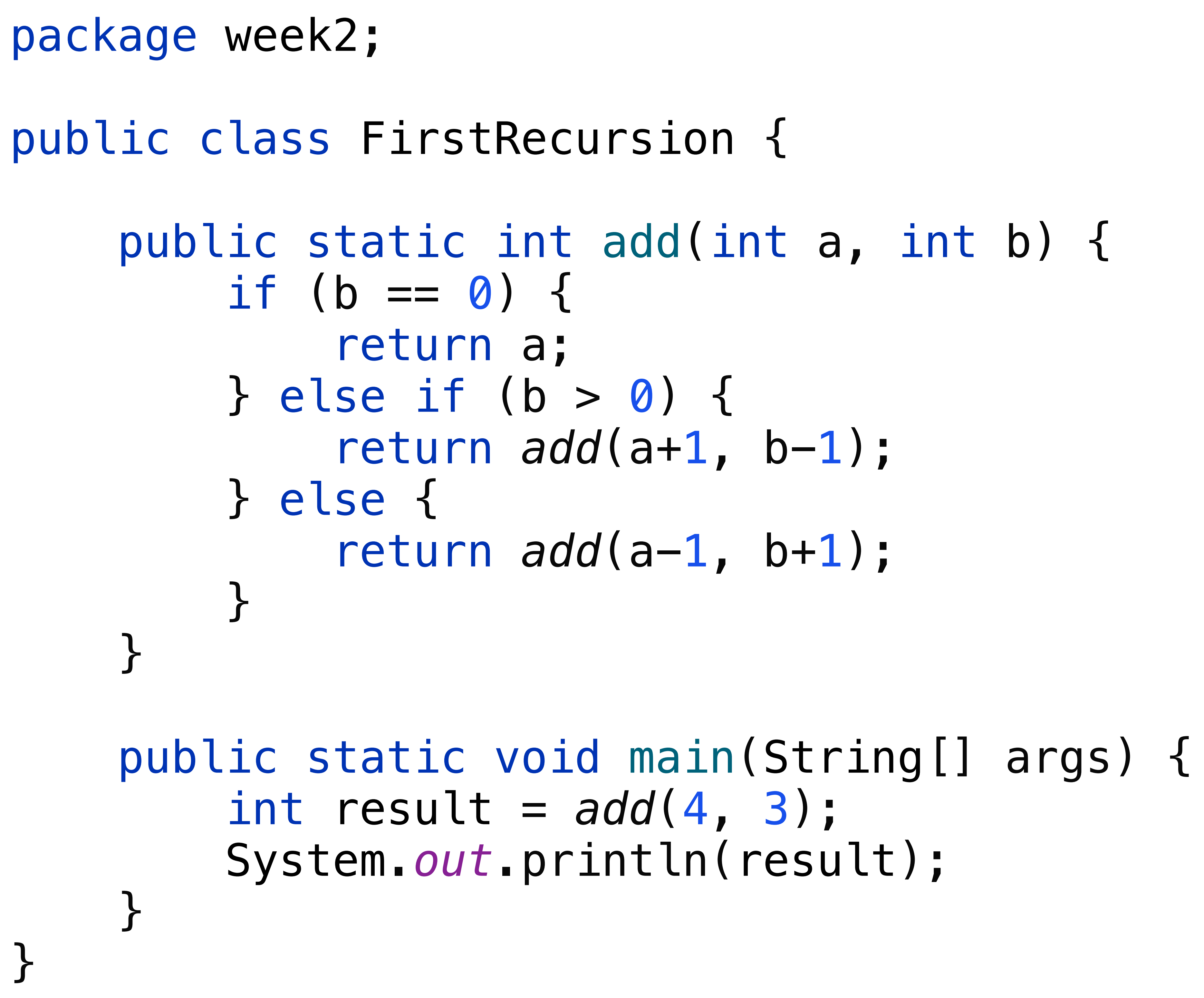
        System.out.println(result);
    }
}
```

- This **add** method calls itself!

- This is a recursive method.

Recursion



```
package week2;

public class FirstRecursion {

    public static int add(int a, int b) {
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        }
    }

    public static void main(String[] args) {
        int result = add(4, 3);
        System.out.println(result);
    }
}
```

- Let's see how this work with a...

Memory Diagram!

Stack
Heap
IO
Global Variables
Create Global Variable
Stack Frames
Create Heap Object
Create IO Line

Name	Value
main	
result	7 Cross out
add	
a	4 Cross out
b	3 Cross out
add	
a	5 Cross out
b	2 Cross out
add	
a	6 Cross out
b	1 Cross out
add	
a	7 Cross out
b	0 Cross out

IO:

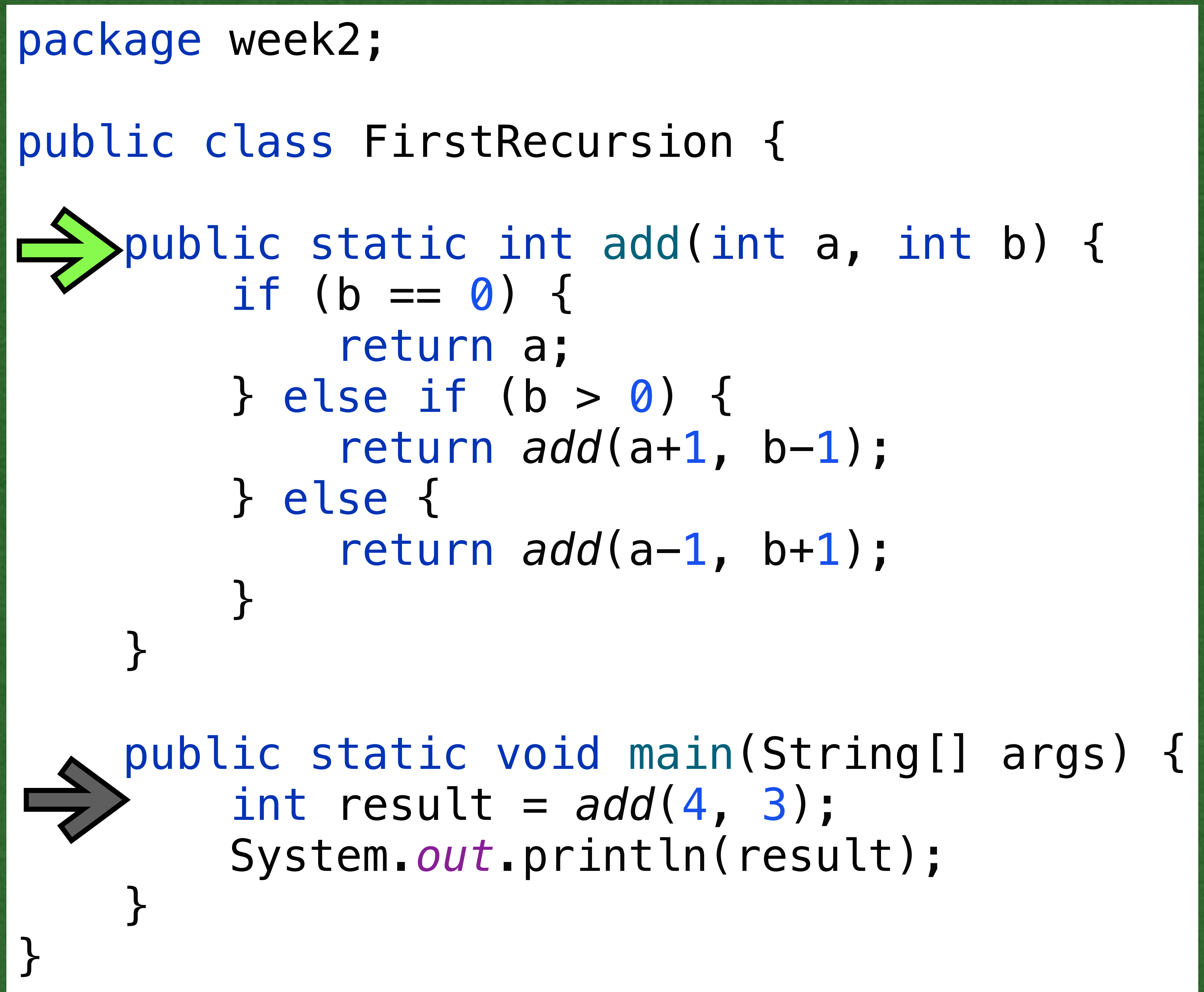
```
7
```

```java
package week3;

public class FirstRecursion {

    public static int add(int a, int b) {
        if (b == 0) {
            return a;
        } else if (b > 0) {
            return add(a+1, b-1);
        } else {
            return add(a-1, b+1);
        }
    }

    public static void main(String[] args) {
        int result = add(4, 3);
        System.out.println(result);
    }
}
```



```java
package week2;

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        }
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    }
}
```
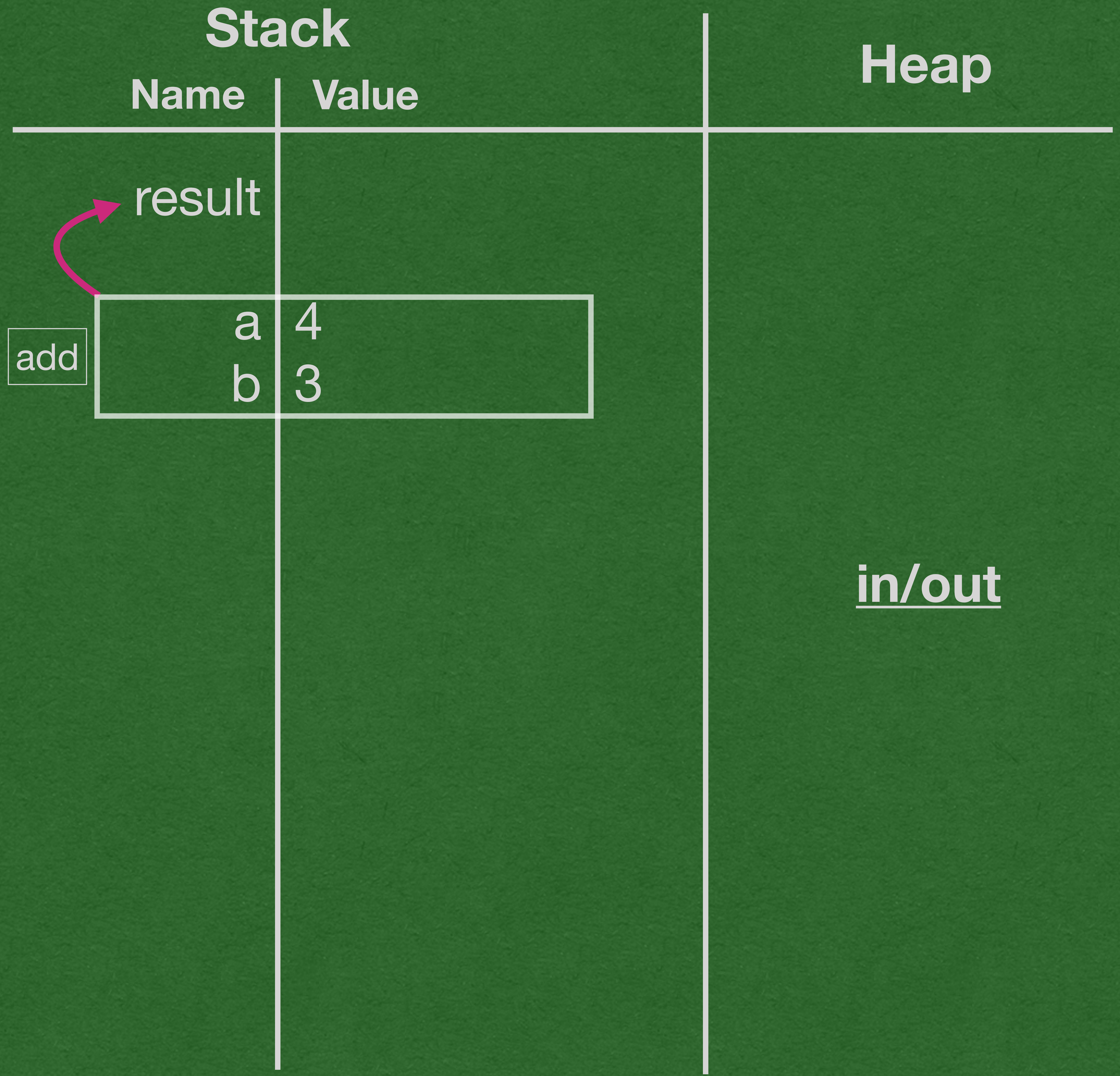
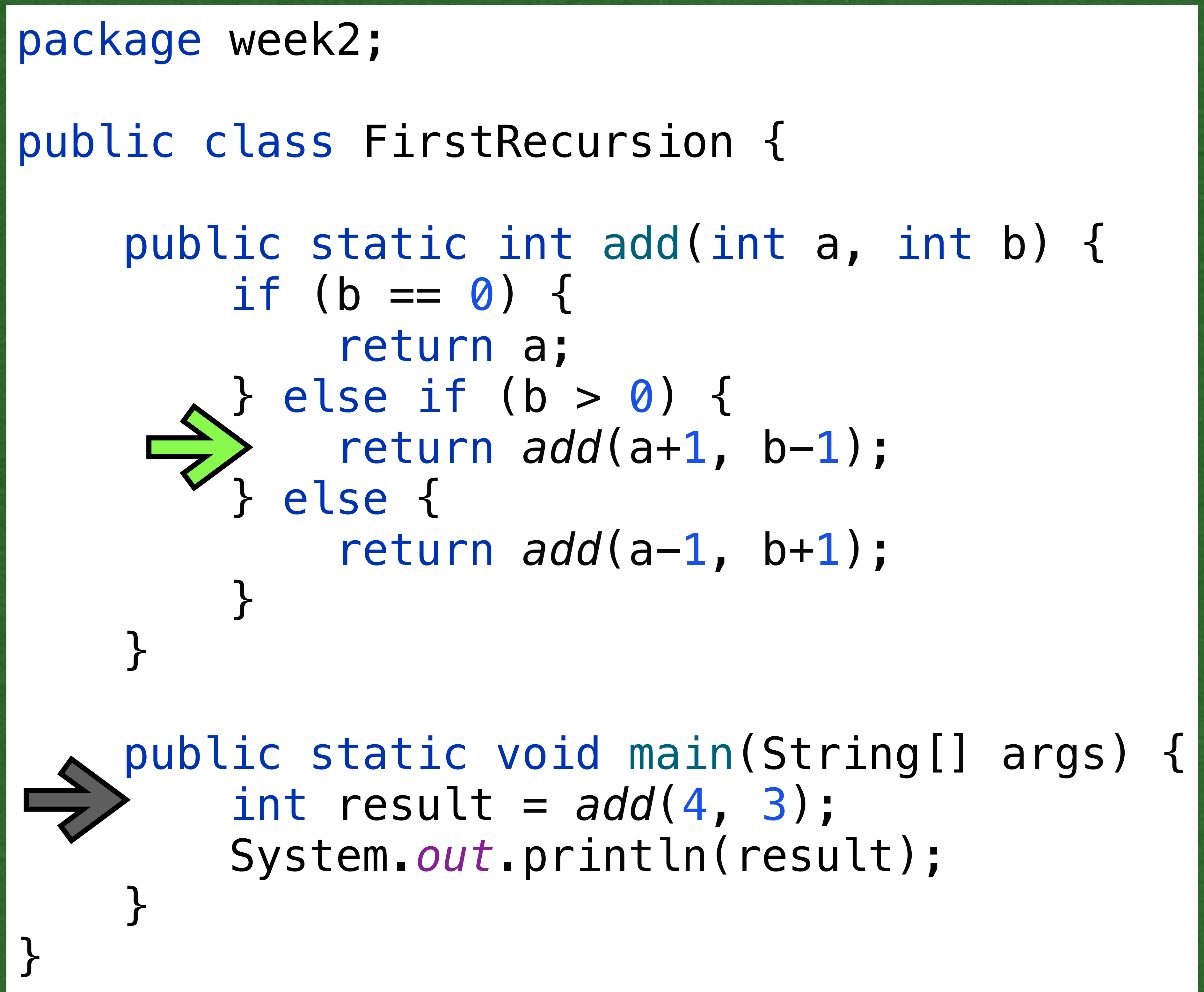



Name	Value
result	
a	4
b	3

- The diagram starts with a method call
- Add a stack frame on the stack with the parameters of the method call



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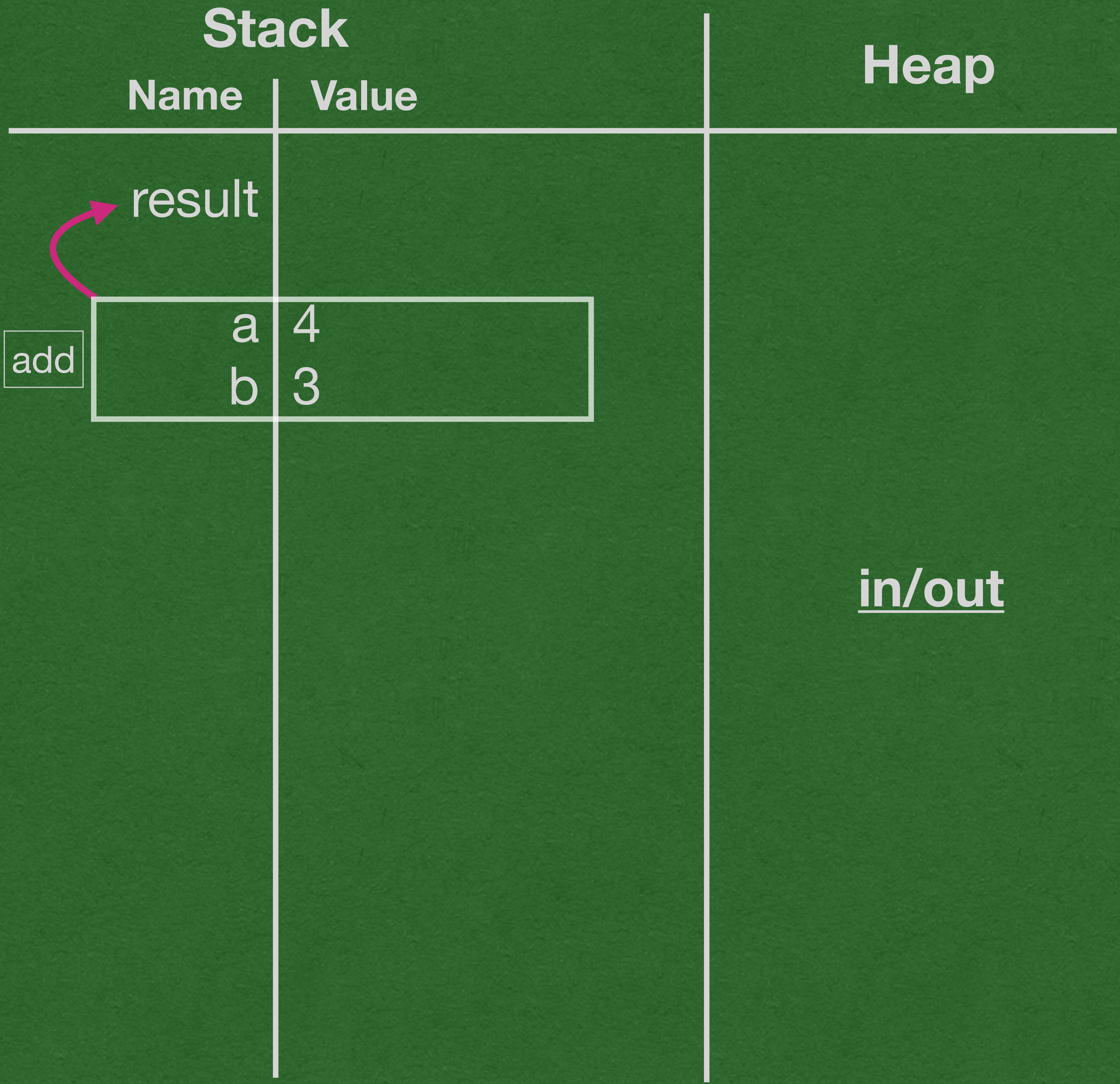
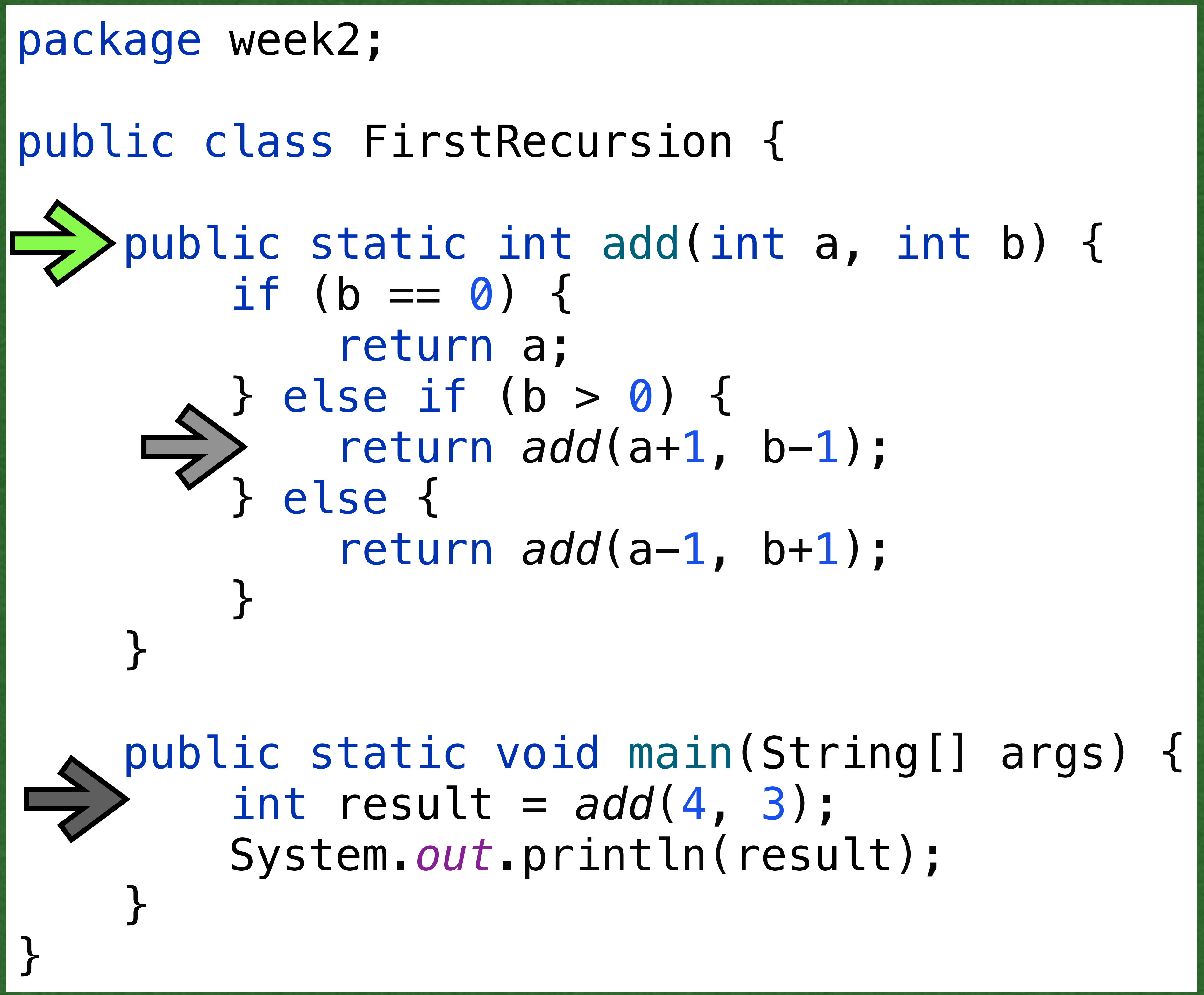


- We reach the recursive call
- The trick:
  - There is none. Treat this as any other method call



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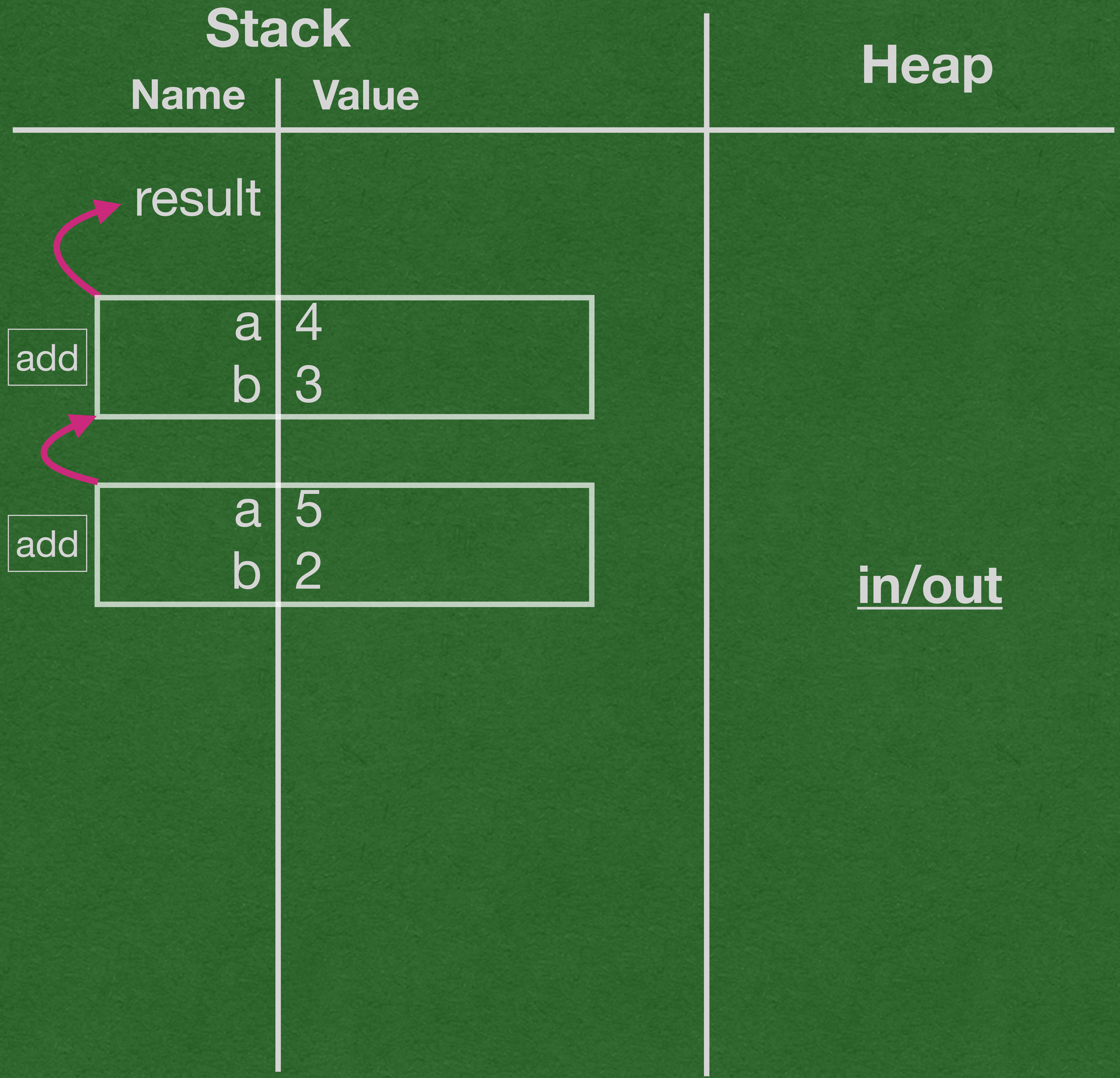
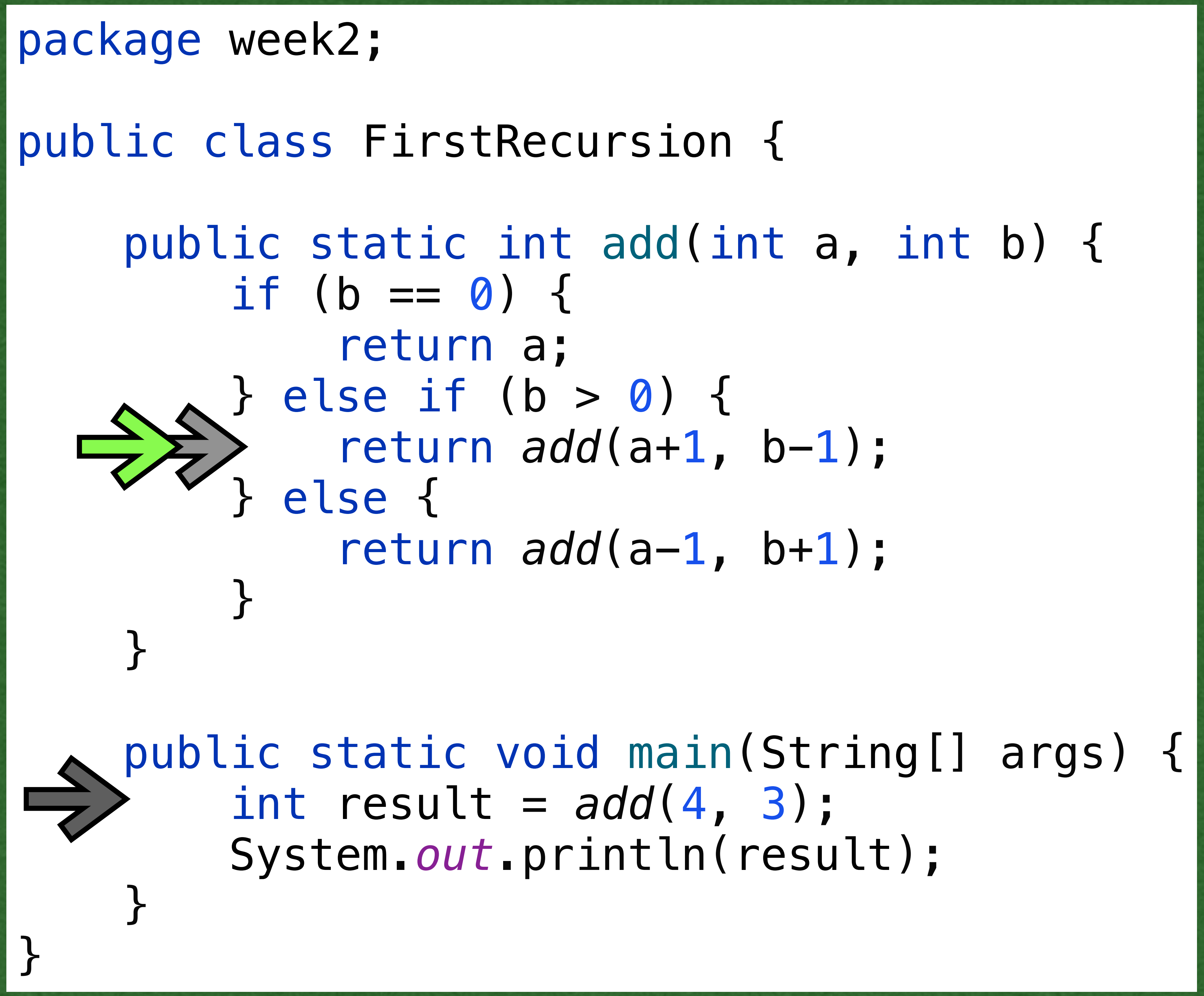


- Add the stack frame a parameters to the stack just like any other method call
- The return arrow points to the stack frame that called the method



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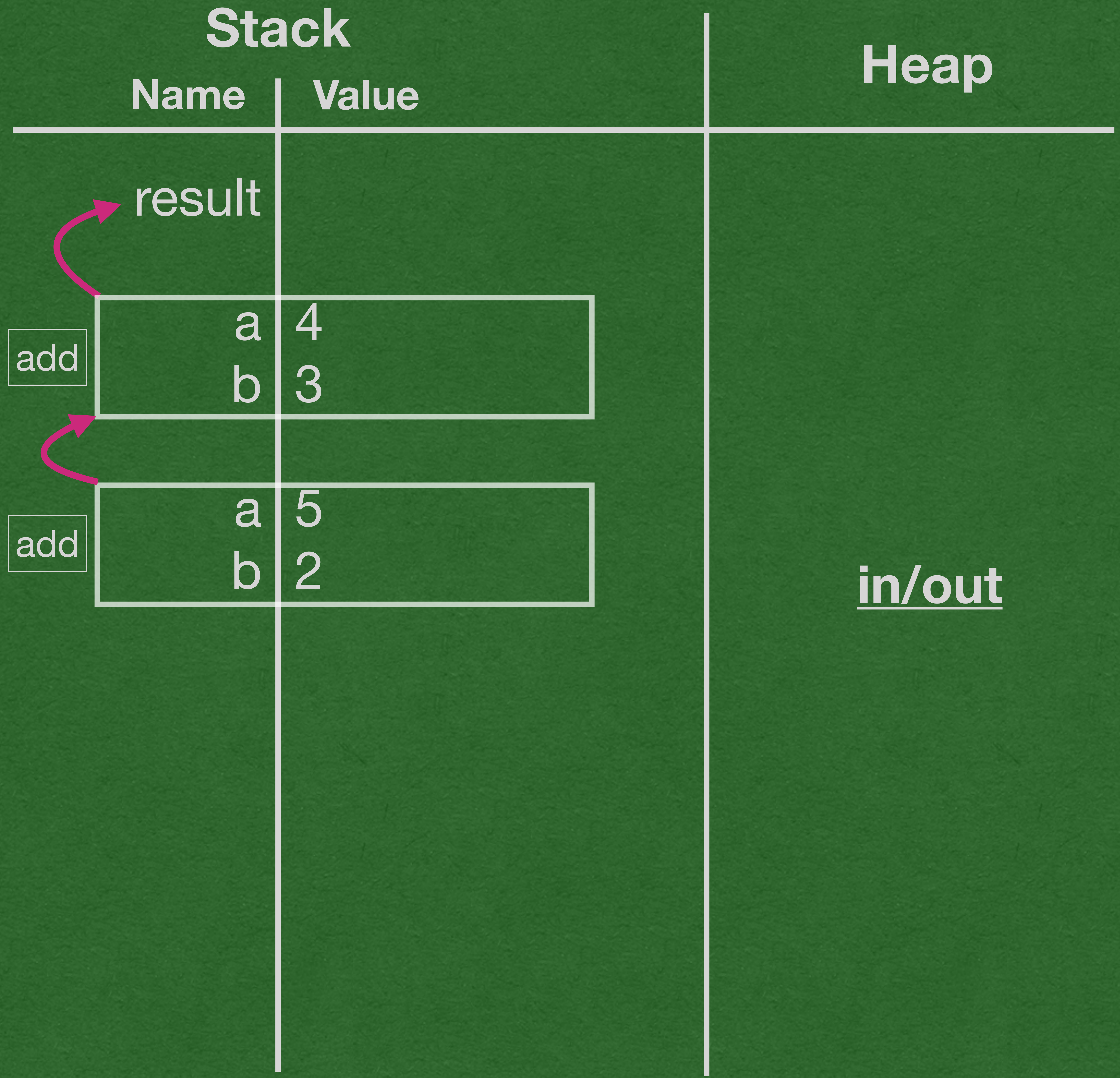
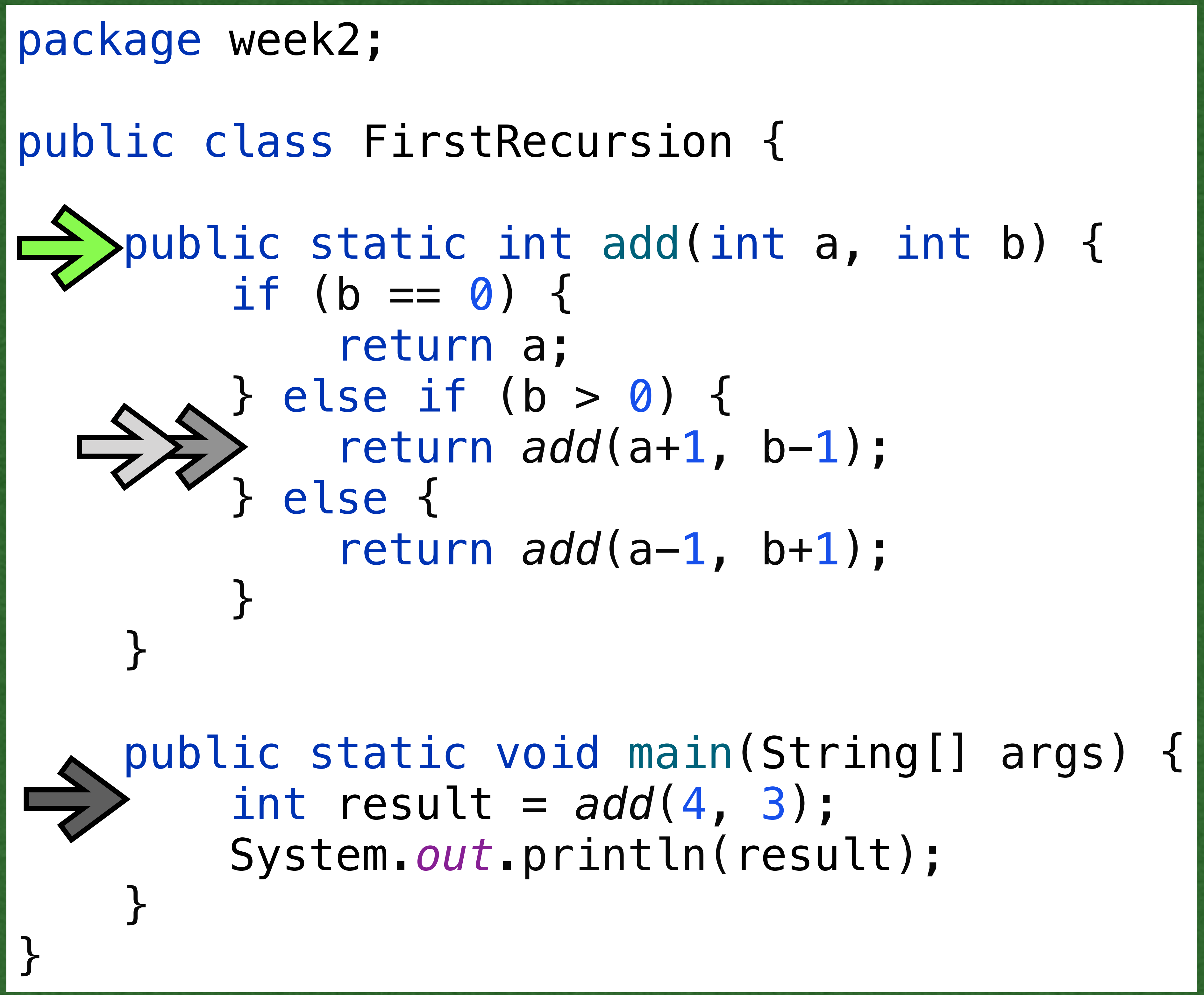


- We get to the next recursive call
- Do it again!



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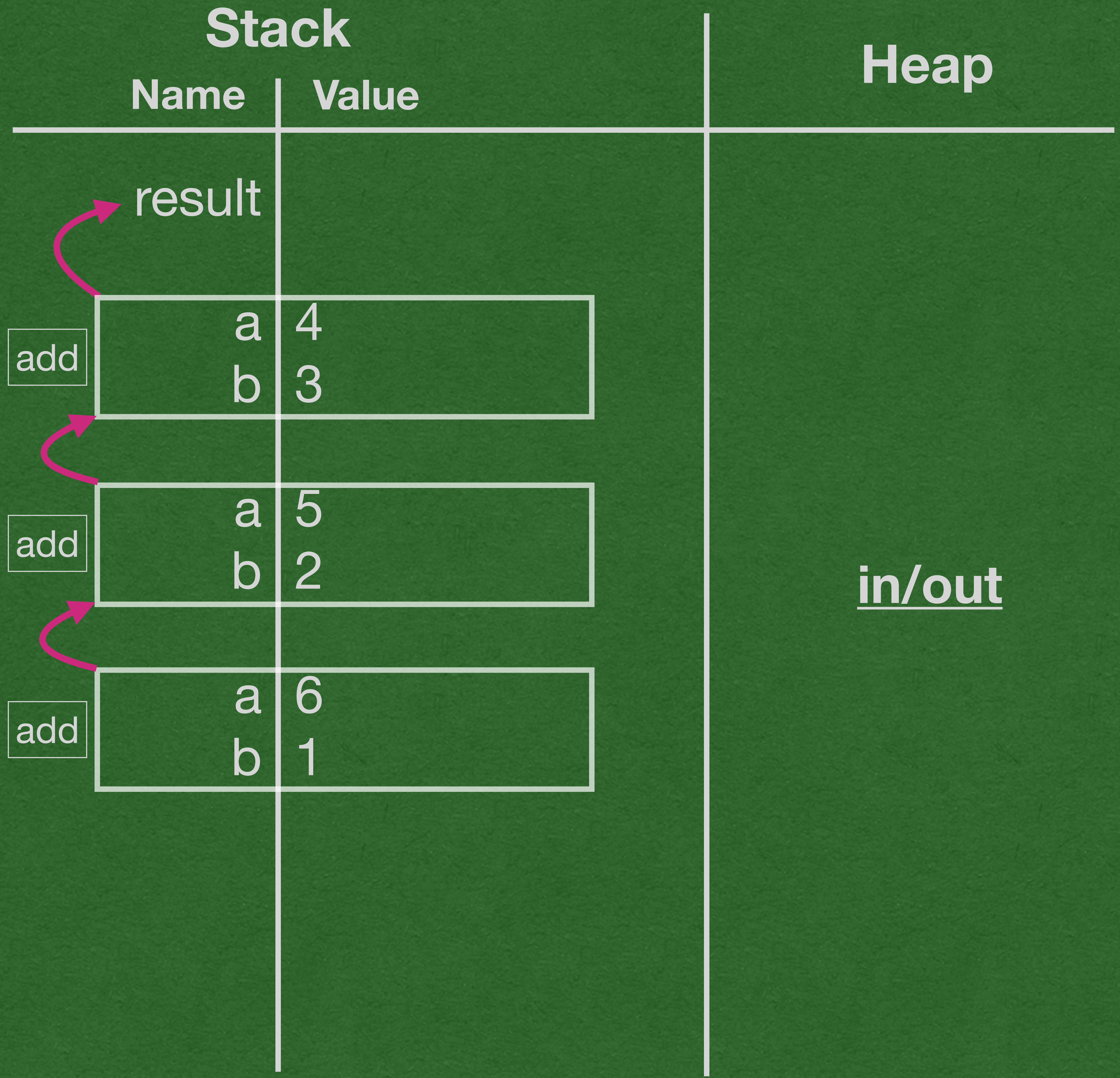
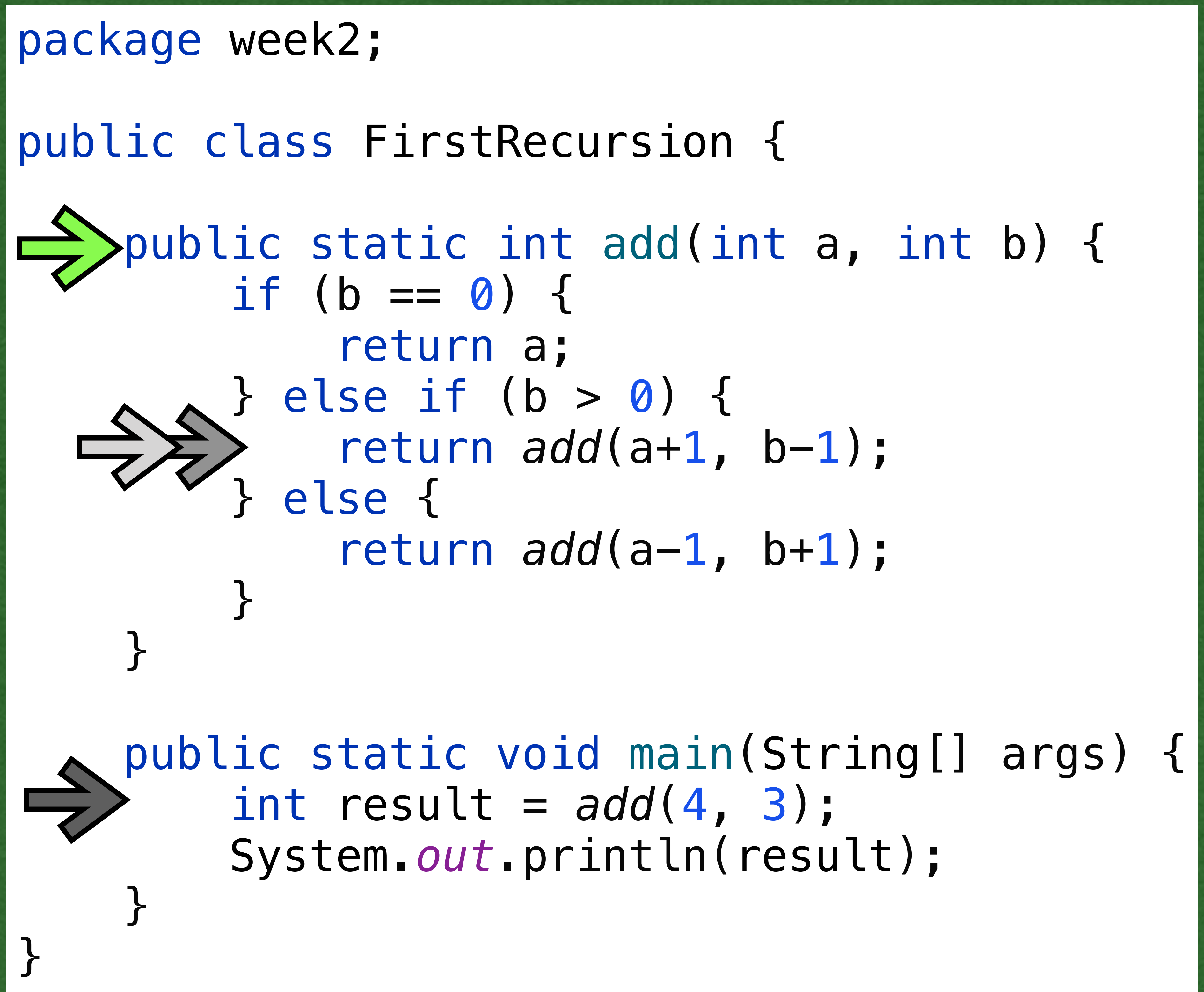


Stack

Heap

Name	Value
result	
a	4
b	3
a	5
b	2
a	6
b	1

- We have 3 frames on the stack (plus the main stack frame)
- Only the frame on the top of the stack is active



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    }

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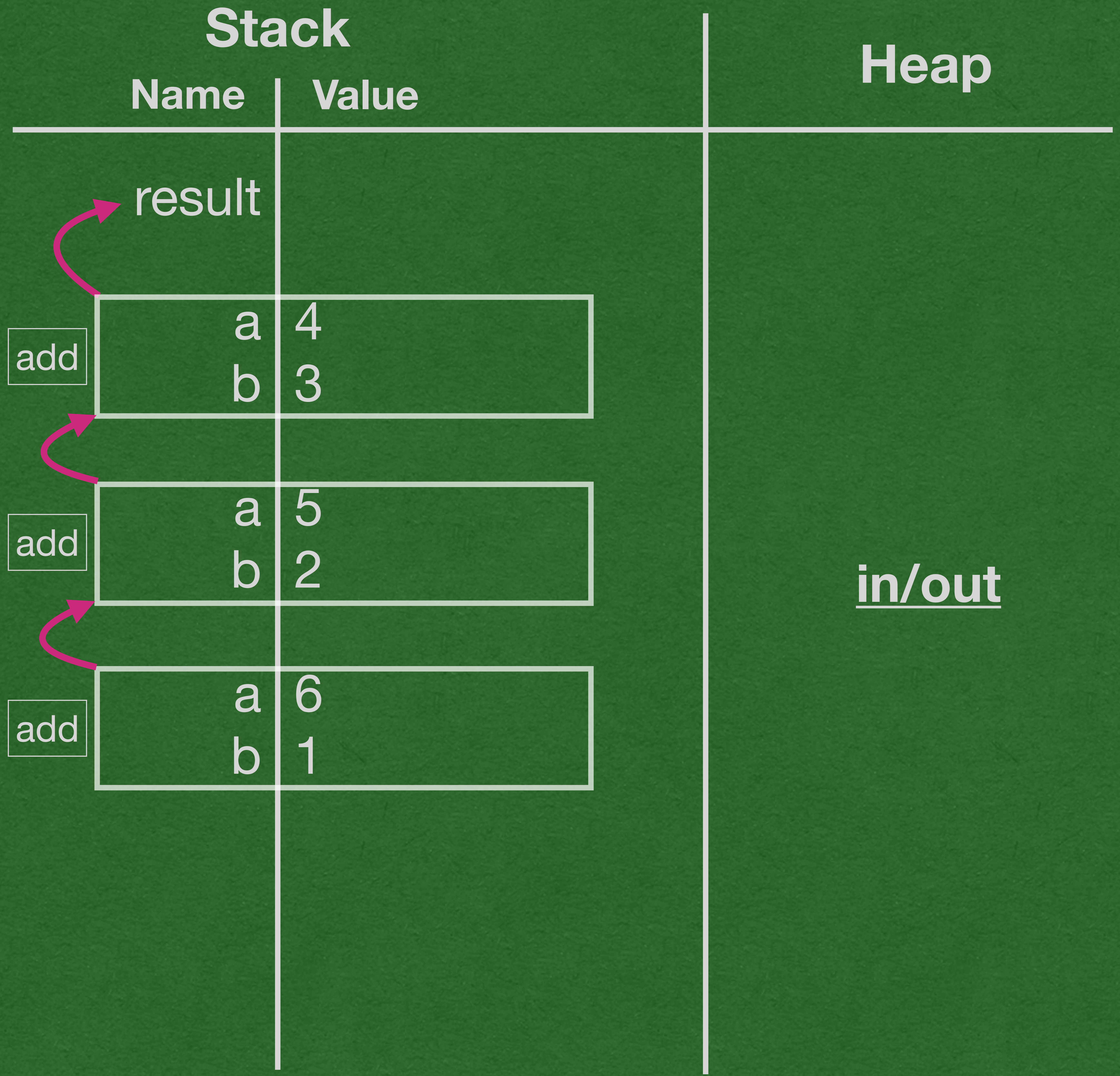


Stack

Heap

Name | Value

result

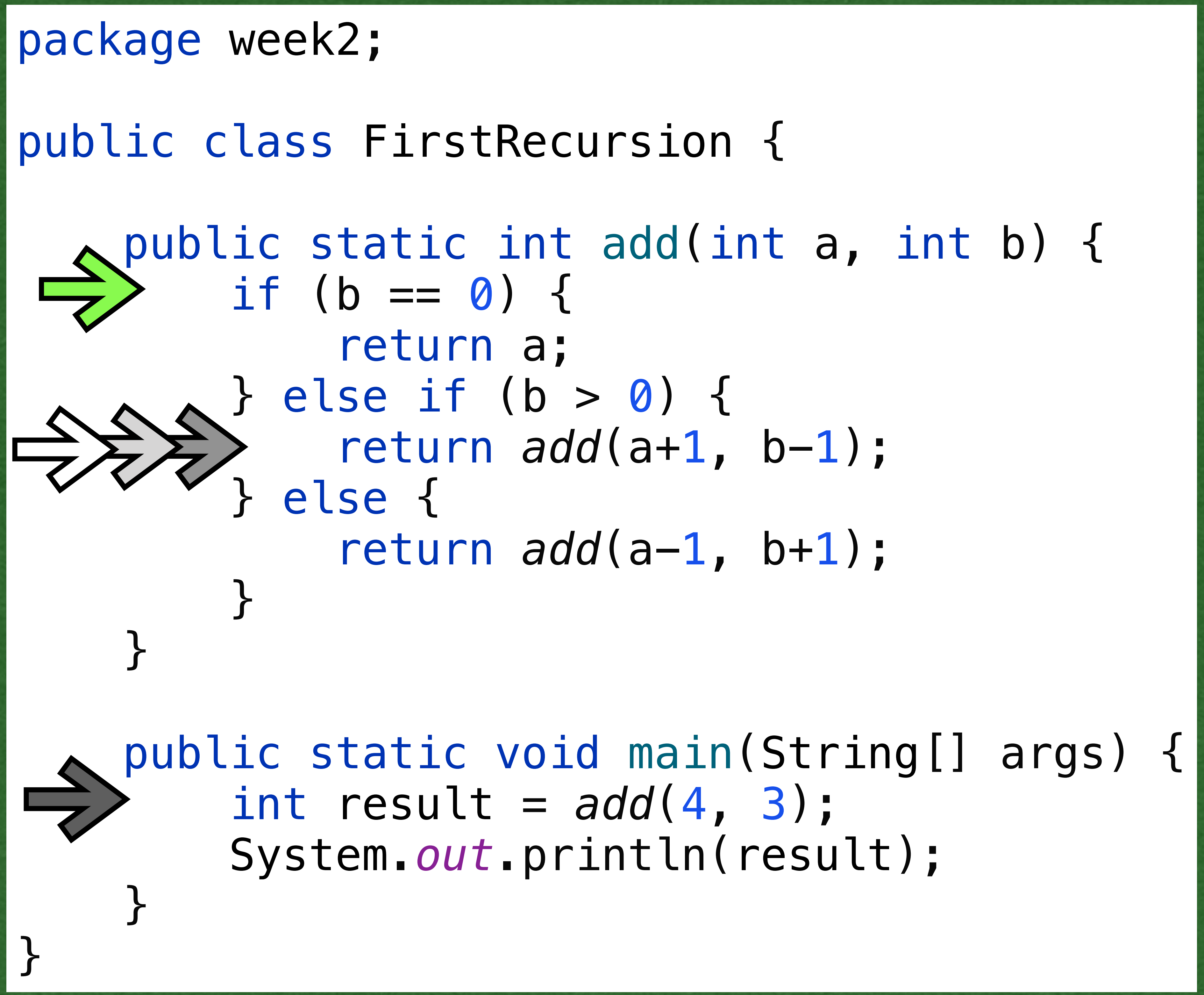
add
a 4
b 3

add
a 5
b 2

add
a 6
b 1

in/out

- The other stack frames are waiting until they are back on top of the stack



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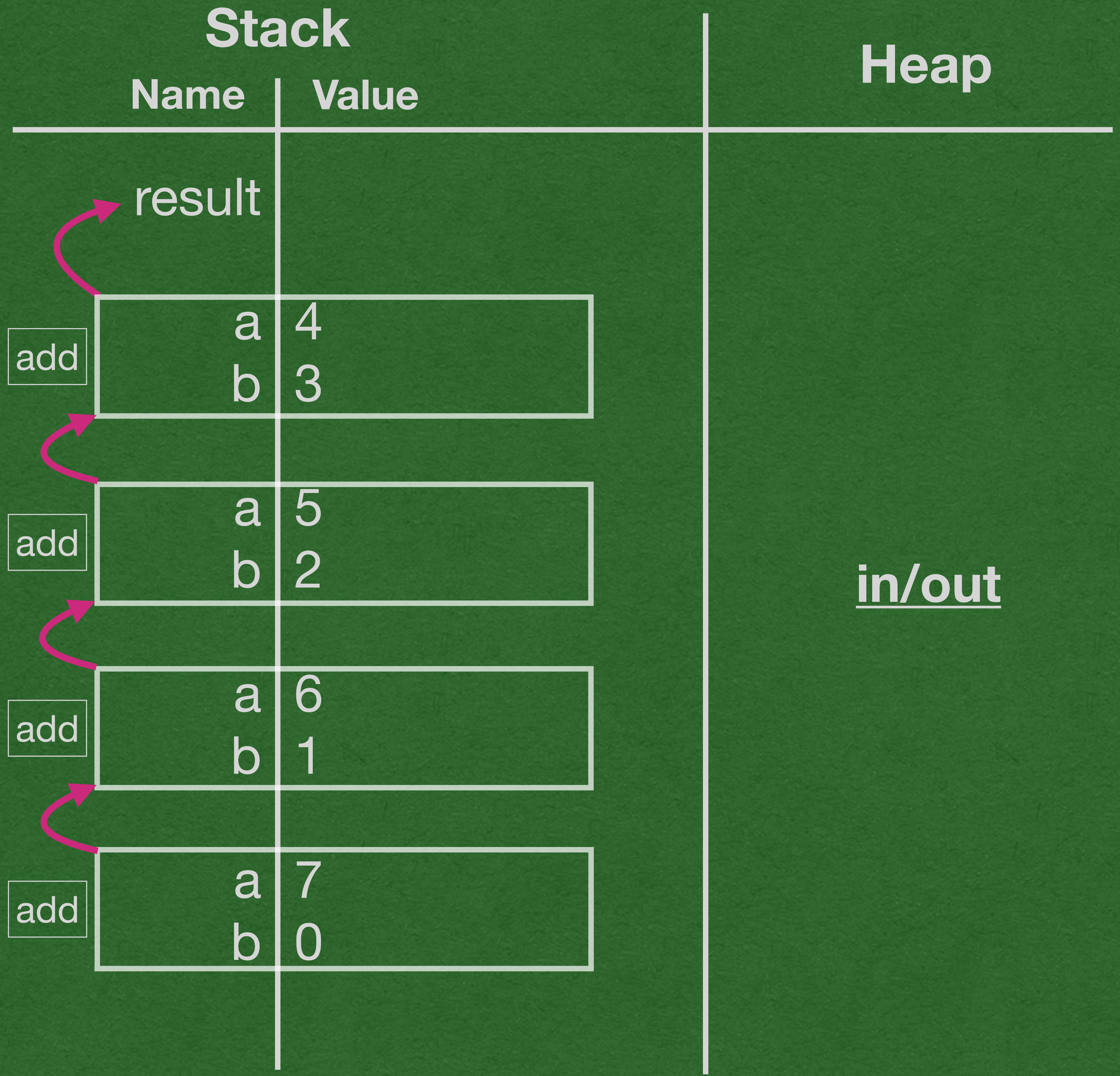
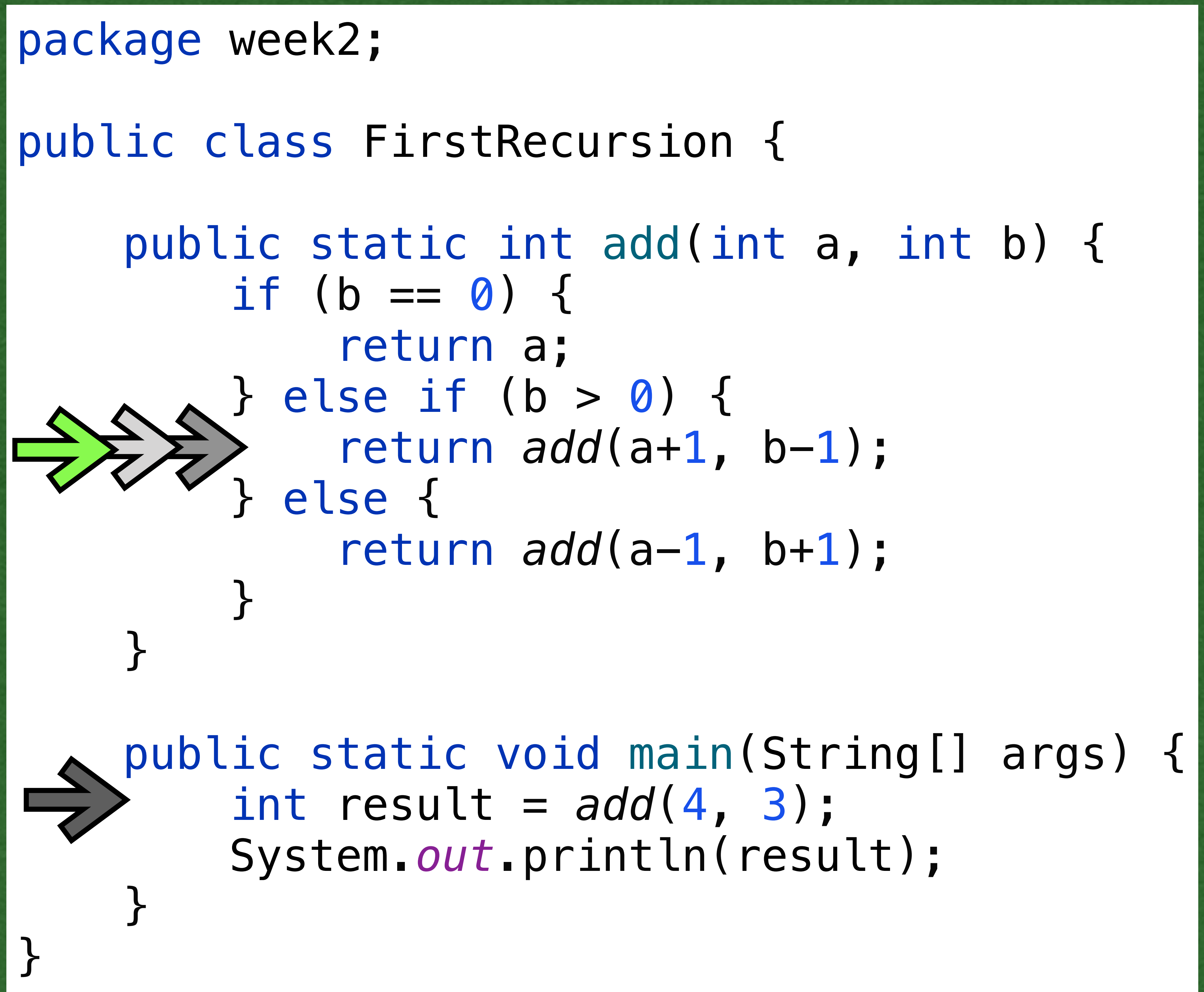


Stack

Heap

	Name	Value
	result	
add	a	4
	b	3
add	a	5
	b	2
add	a	6
	b	1
add	a	7
	b	0

- Call the method again
- This time, the first condition is true



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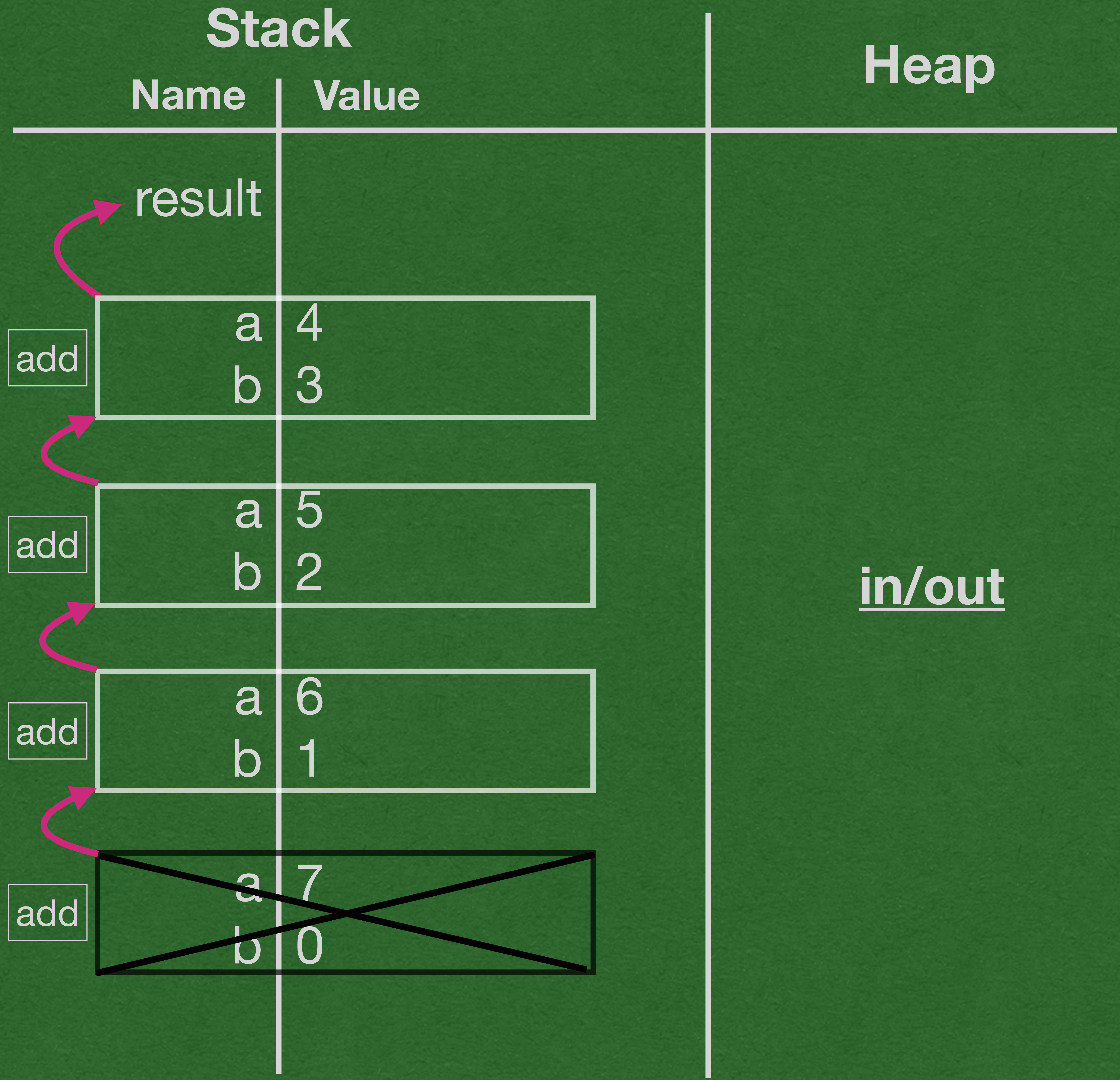
        } else {
            return add(a-1, b+1);
        }
    }

    public static void main(String[] args) {
        int result = add(4, 3);
        System.out.println(result);
    }
}
```

- This stack frame returns 7
- The frame is removed from the stack and the next frame regains control

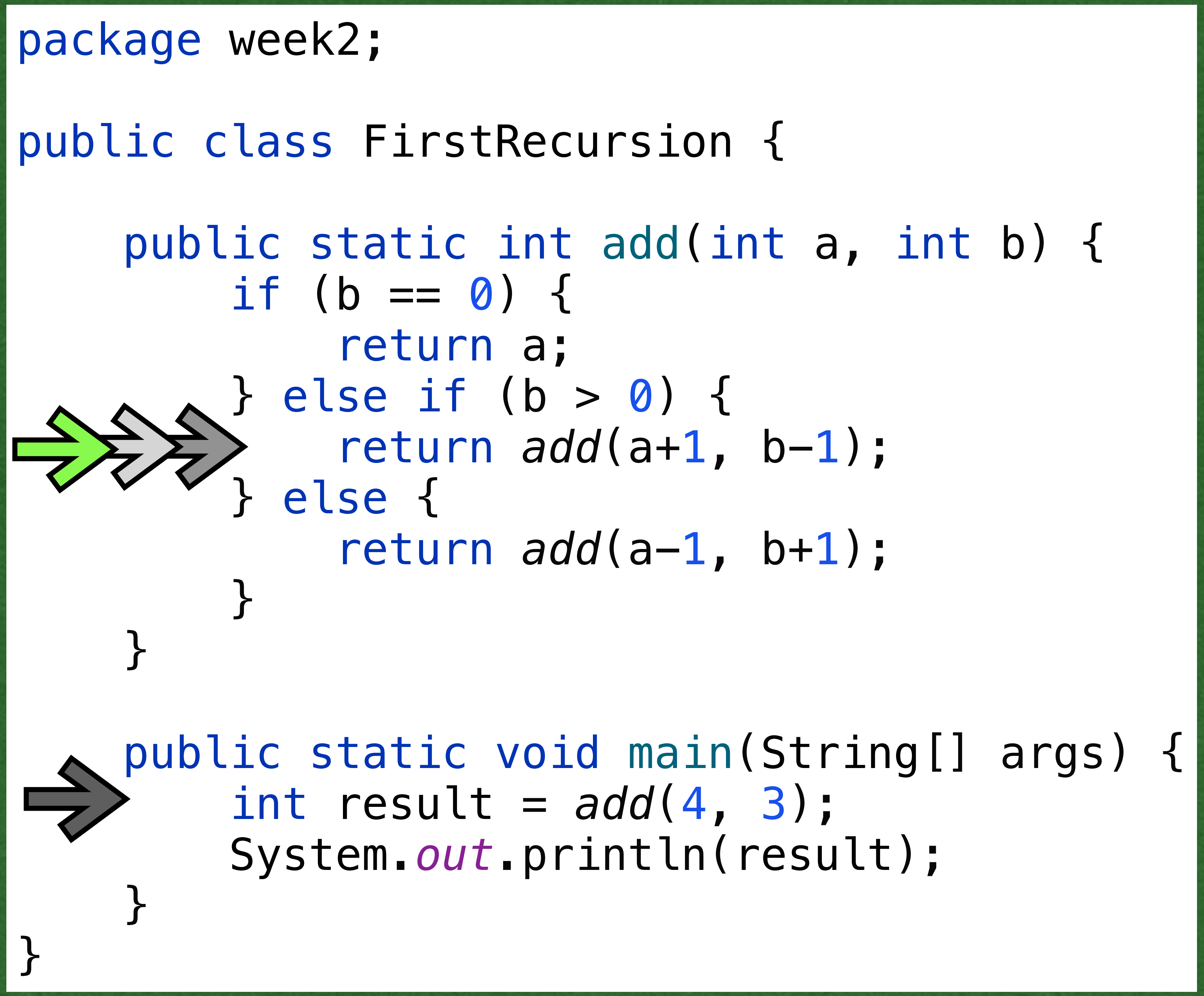


Stack

Heap

	Name	Value
	result	
add	a	4
	b	3
add	a	5
	b	2
add	a	6
	b	1
add	a	7
	b	0

in/out



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    }

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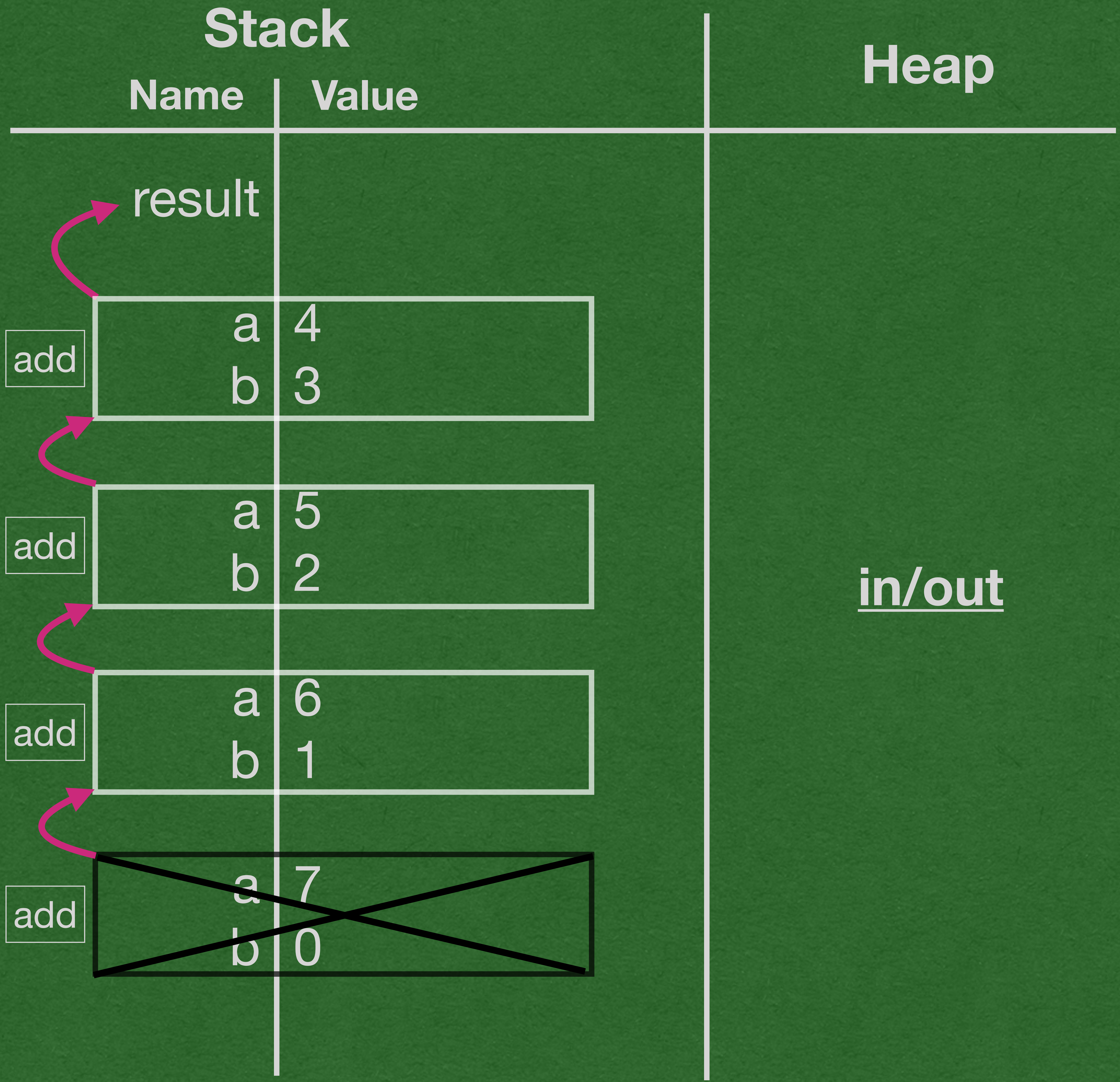
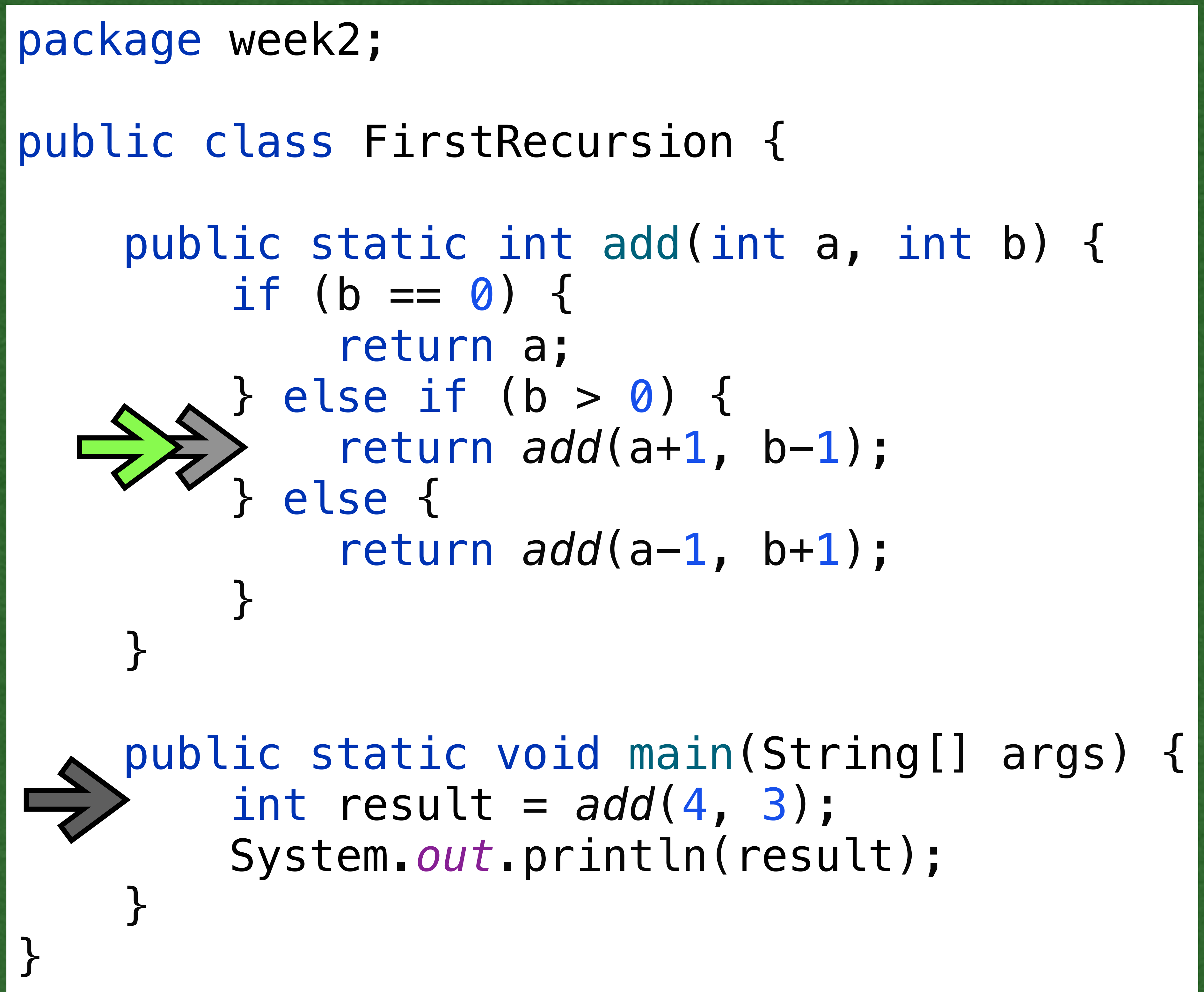


- This frame called add(6, 1)
  - The method call evaluated to 7



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        } else {
            return add(a-1, b+1);
        }
    }

    public static void main(String[] args) {
        int result = add(4, 3);
        System.out.println(result);
    }
}
```
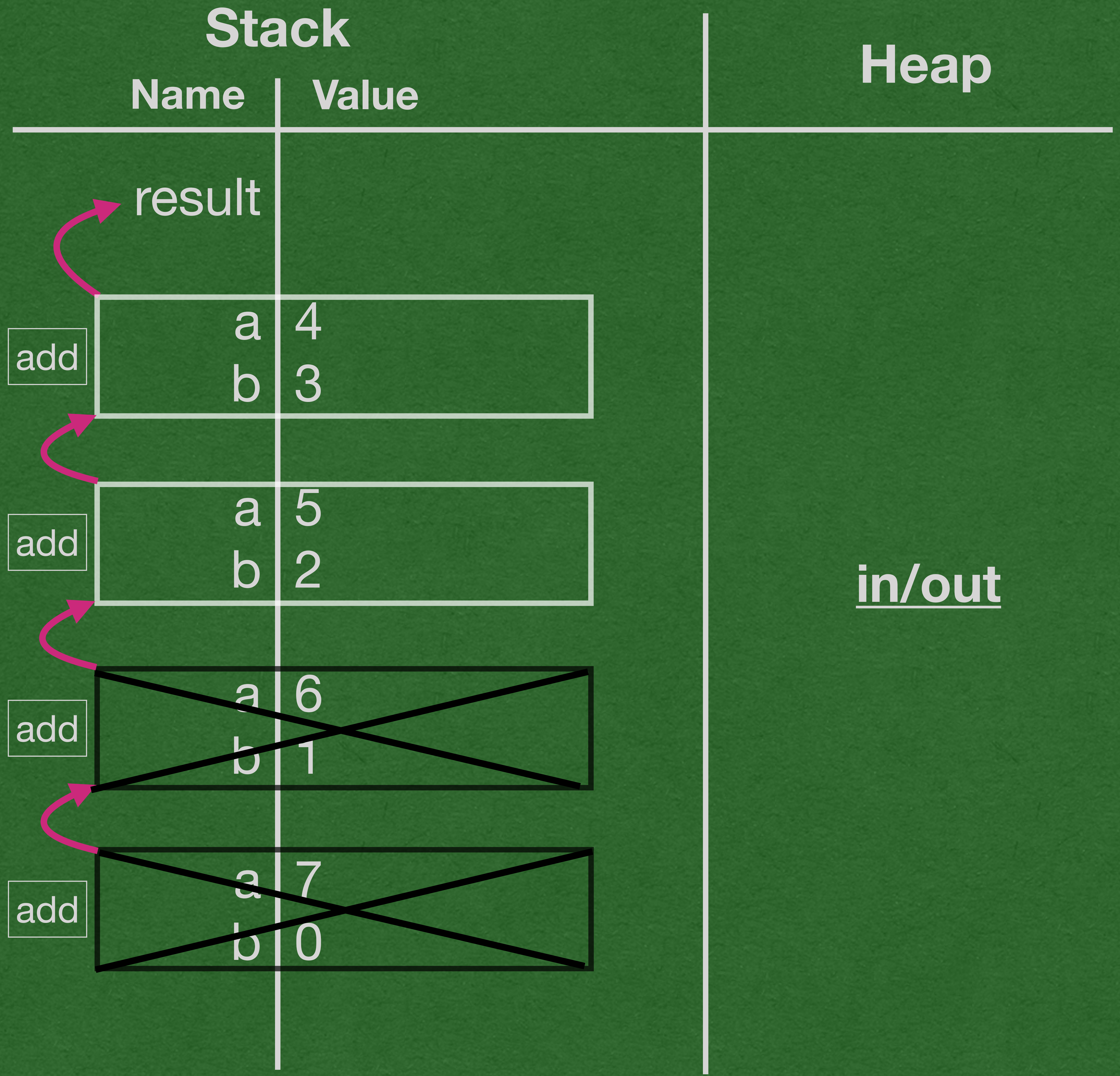
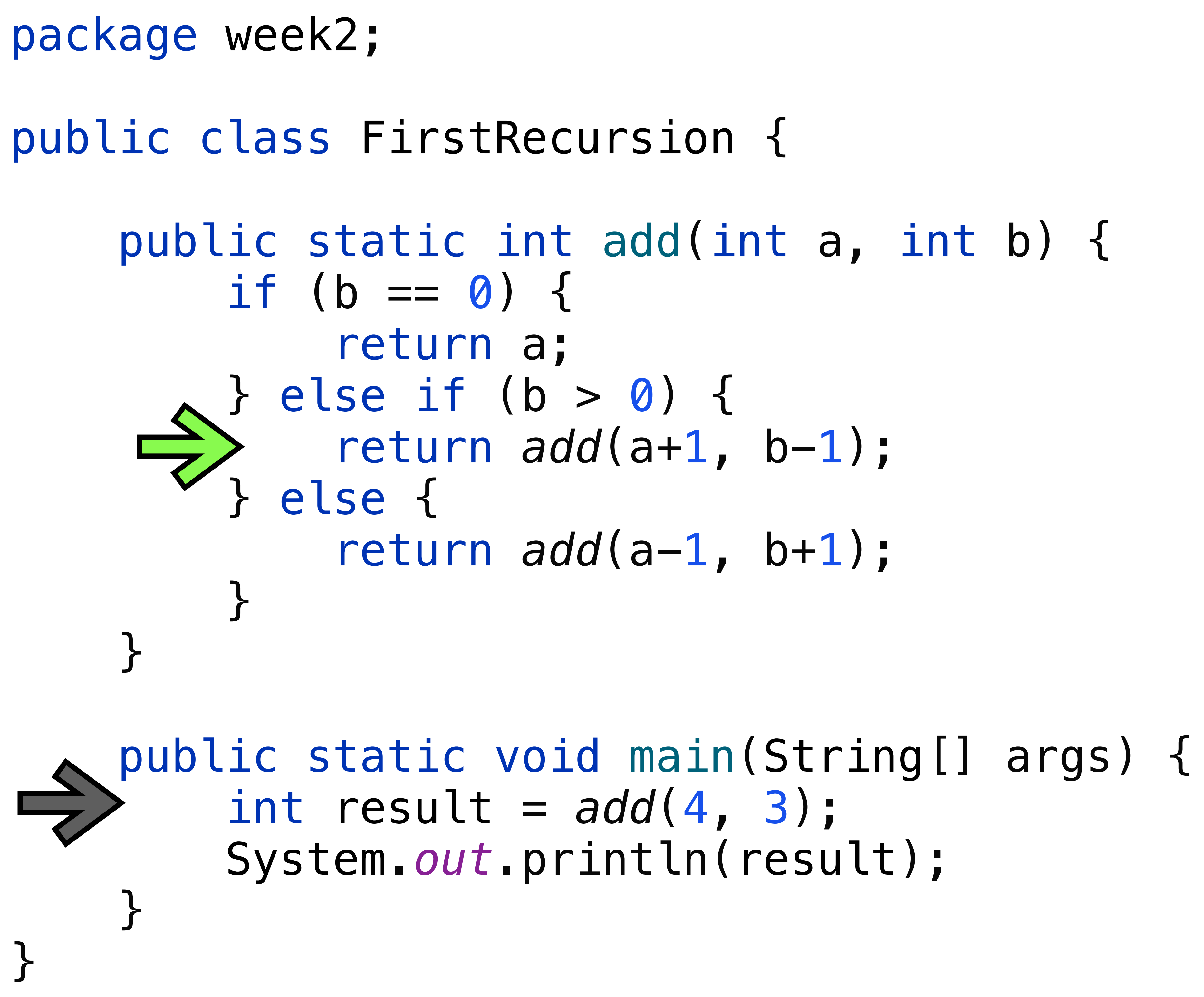

- Returns the value 7
- This frame is removed from the stack
- Control goes to the next frame on the stack





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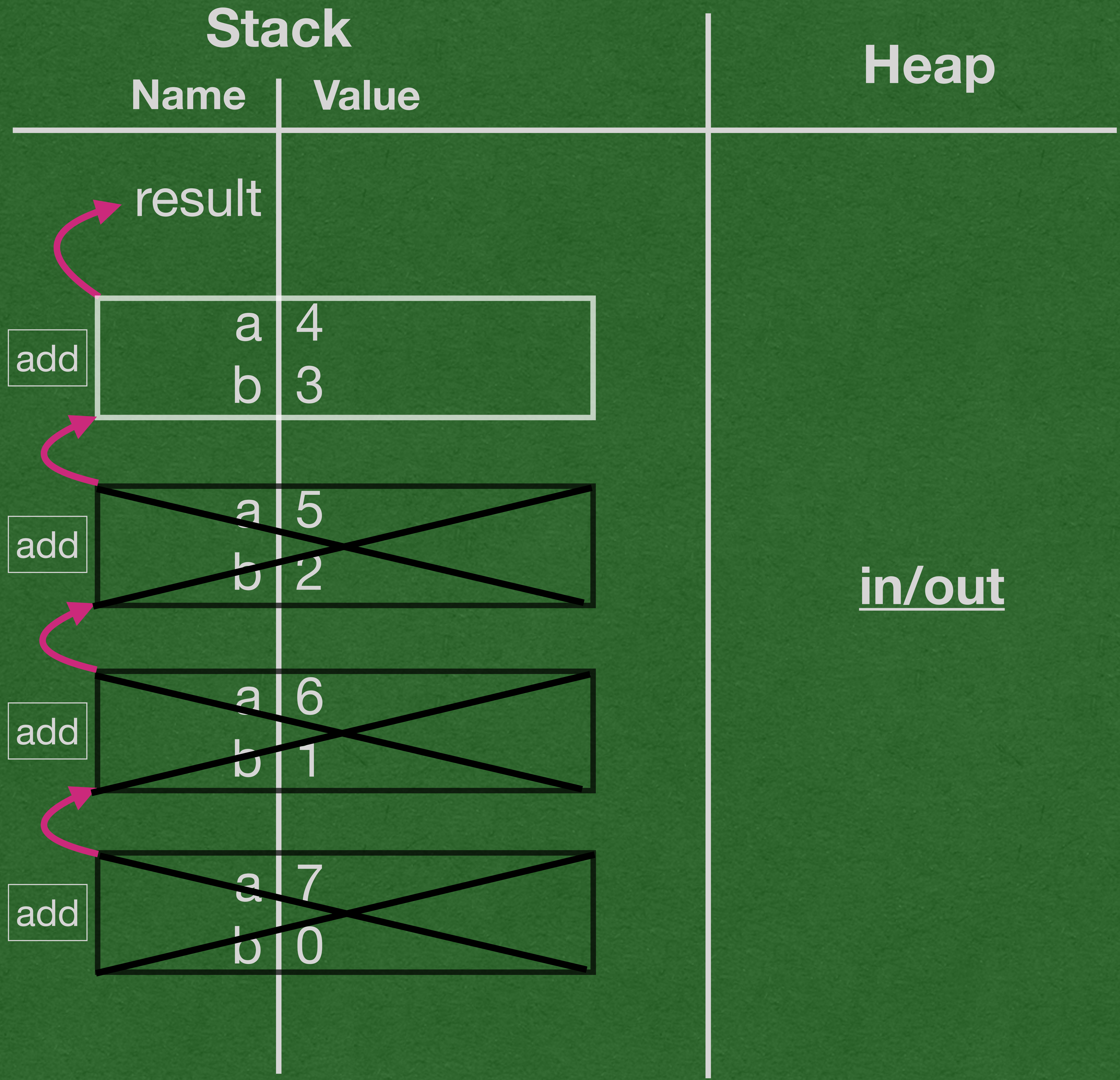
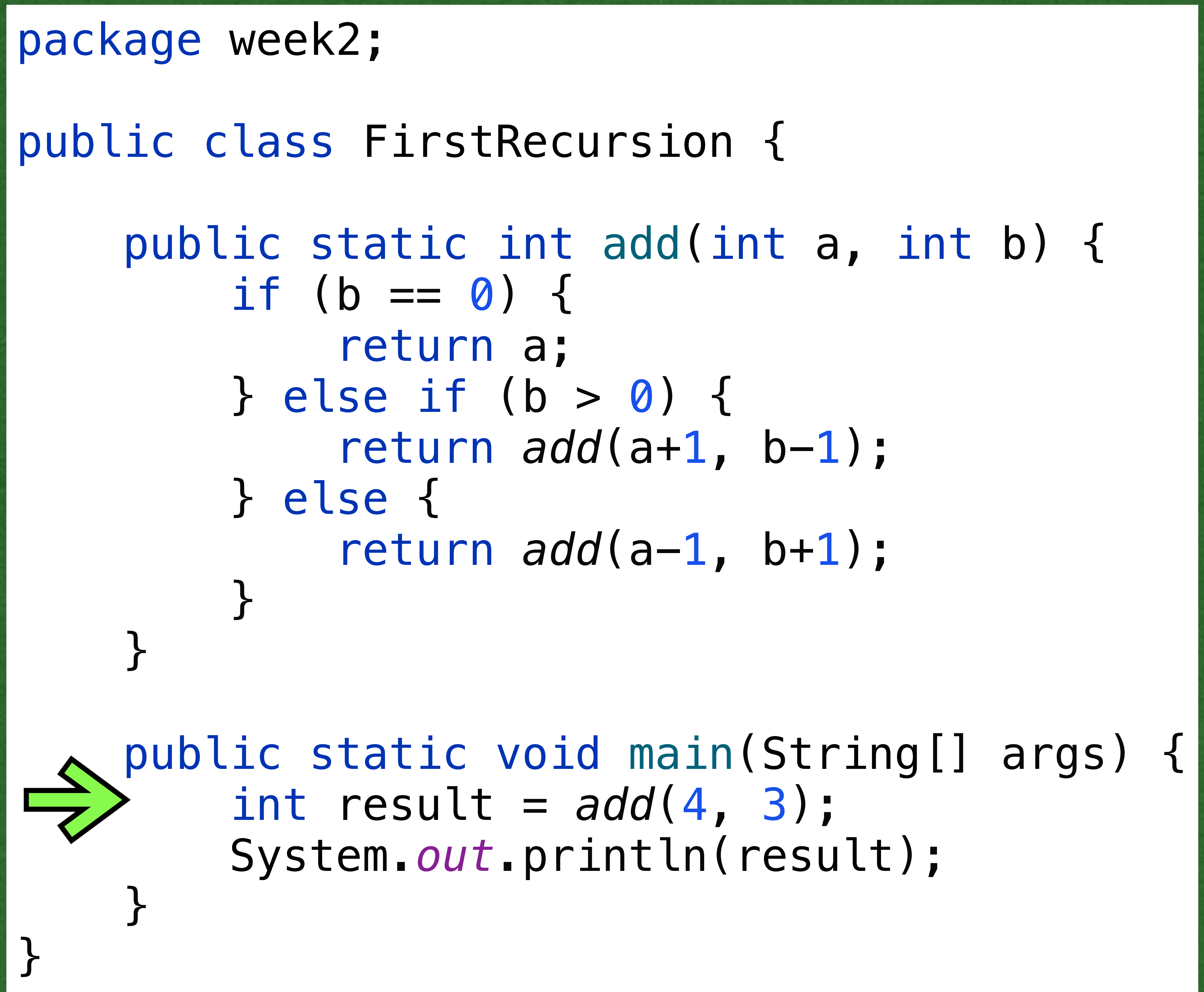
    }

    public static void main(String[] args) {
        int result = add(4, 3);
        System.out.println(result);
    }
}
```



- The next frame returns the value 7 that it received from the previous frame



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    public static void main(String[] args) {
        int result = add(4, 3);
        System.out.println(result);
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```
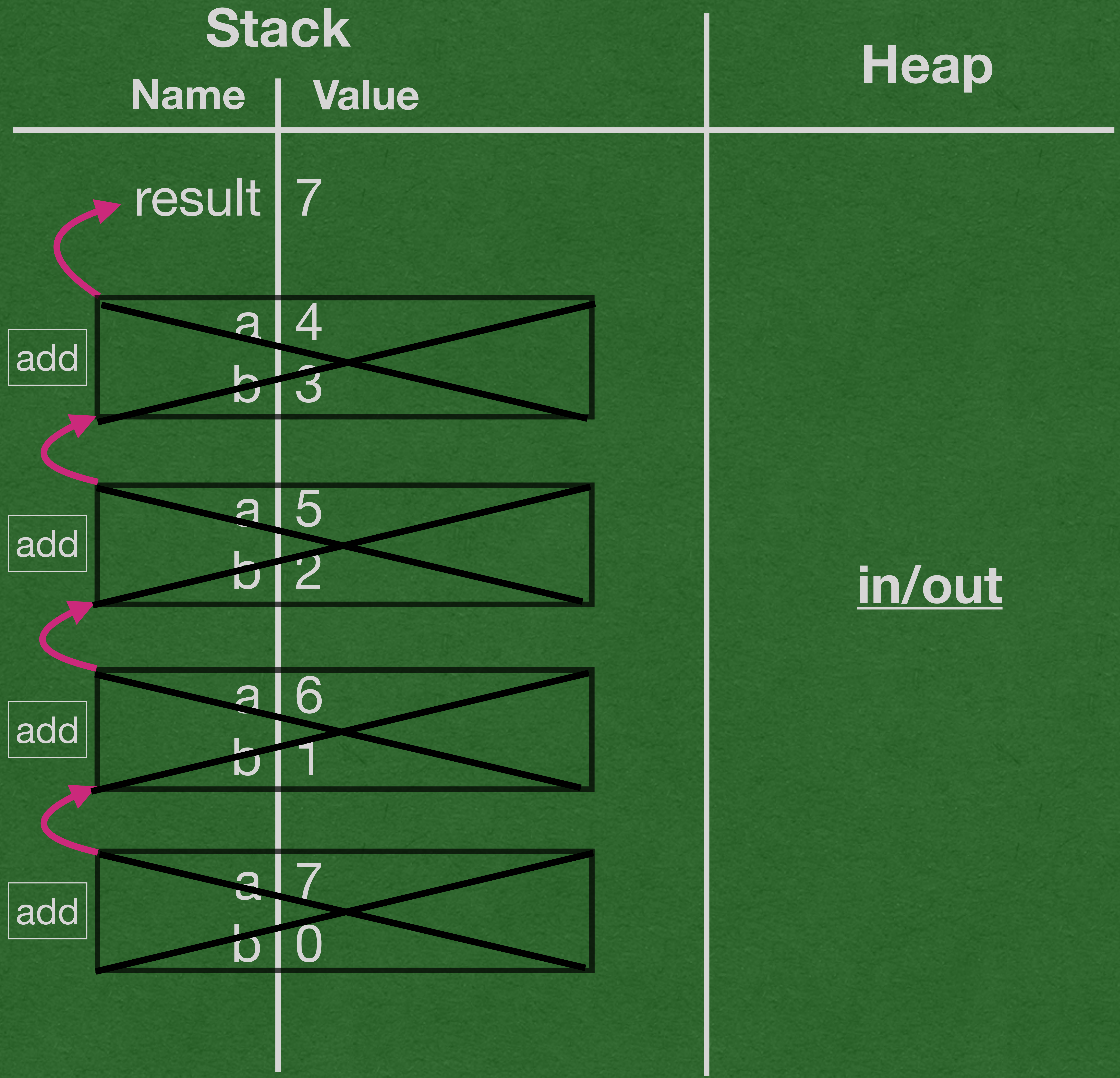



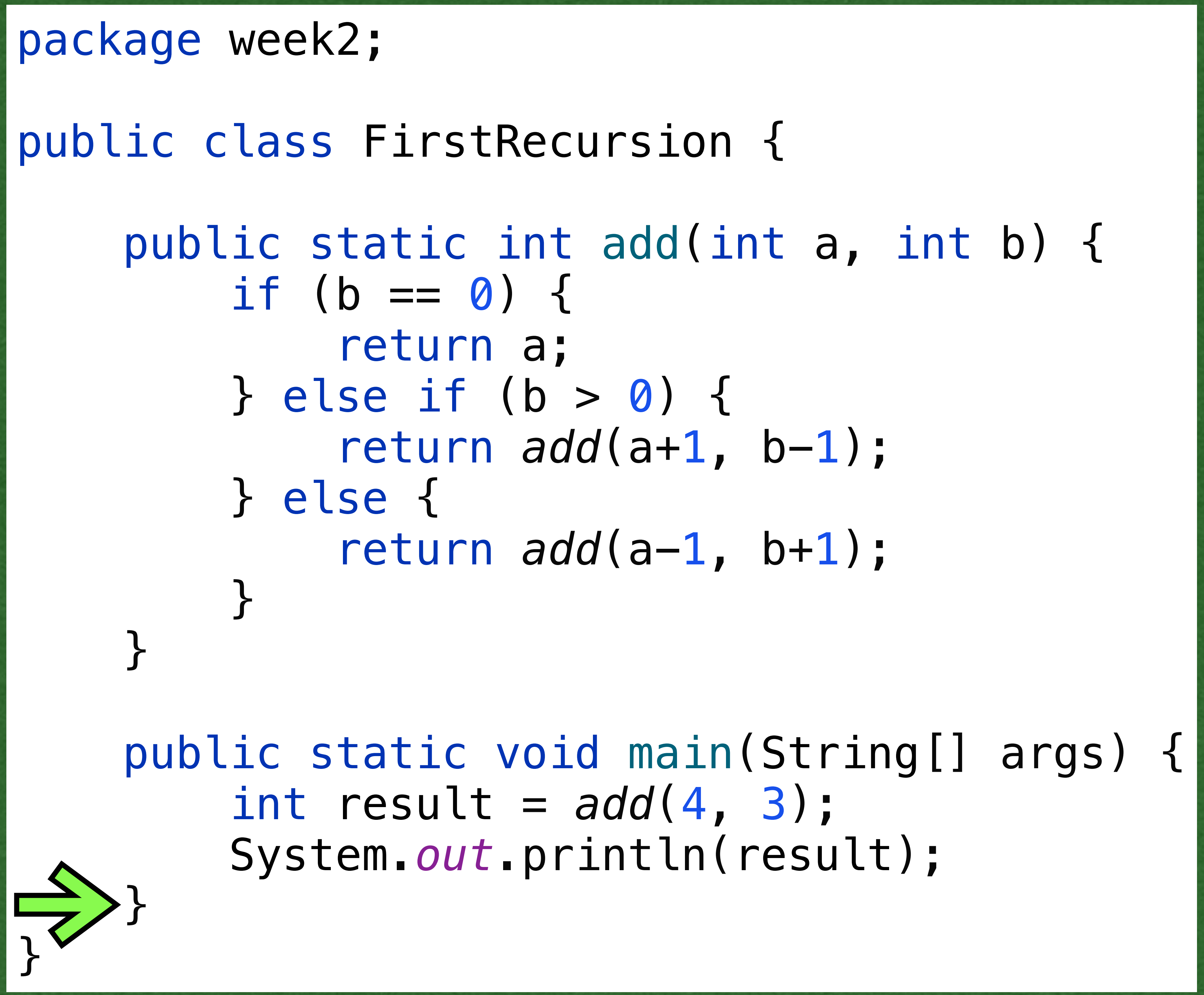
Stack

Name	Value
result	7
add a	4
b	3
add a	5
b	2
add a	6
b	1
add a	7
b	0

Heap

in/out

- Return 7 to the main stack frame



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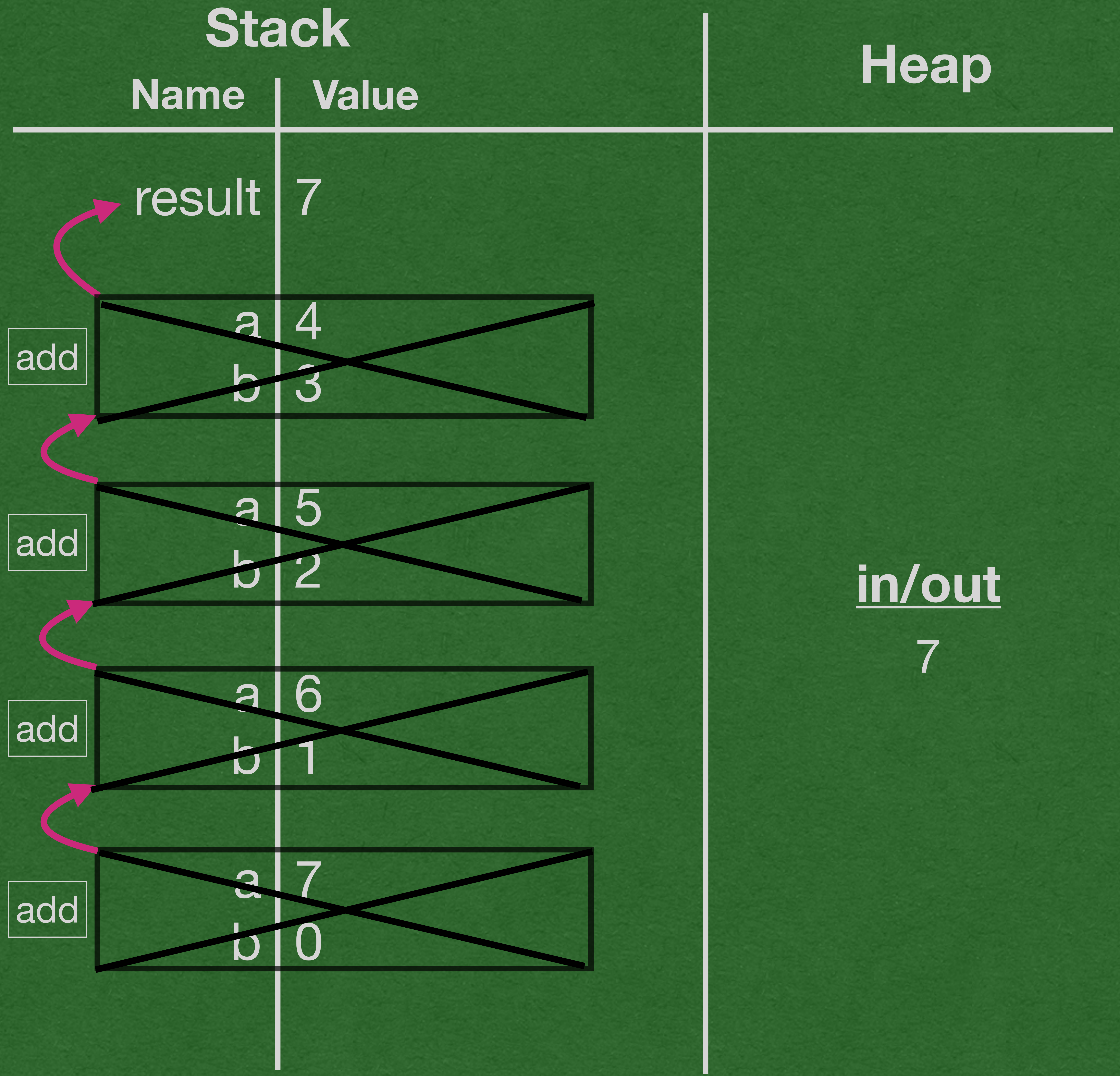

- Print 7 to the screen
- End the program

Stack
Heap
IO
Global Variables
Create Global Variable
Stack Frames
Create Heap Object
Create IO Line
Cross out

IO: 7

Name	Value
main	
result	7
add	
a	4
b	3
add	
a	5
b	2
add	
a	6
b	1
add	
a	7
b	0

```
package week3;

public class FirstRecursion {

    public static int add(int a, int b) {
        if (b == 0) {
            return a;
        } else if (b > 0) {
            return add(a+1, b-1);
        } else {
            return add(a-1, b+1);
        }
    }

    public static void main(String[] args) {
        int result = add(4, 3);
        System.out.println(result);
    }
}

```

Stack
Heap
IO
Global Variables
Create Global Variable
Stack Frames
Create Heap Object
Create IO Line
Cross out

Name	Value
main	
result	7
add	
a	4
b	3
add	
a	5
b	2
add	
a	6
b	1
add	
a	7
b	0

7 ×

```java
package week3;

public class FirstRecursion {

    public static int add(int a, int b) {
        if (b == 0) {
            return a;
        } else if (b > 0) {
            return add(a+1, b-1);
        } else {
            return add(a-1, b+1);
        }
    }

    public static void main(String[] args) {
        int result = add(4, 3);
        System.out.println(result);
    }
}
```