CSE 1322
Module 4 – Part 1

Recursion: The Function Stack

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Function Stack – What is it?

- Also known as Call Stack.
- It is a special region in memory that we use to temporarily store the information of active functions (methods) calls during the execution of the program.

Function Stack – Stack

- We are going to cover this later in the semester.
- A stack is a Last-In, First-Out (LIFO) data structure.
- This means that the last item added, is the first one removed.
- Think of a stack of pancakes, most likely you start eating from the pancake at the top.

Function Stack – Stack

- We are going to cover this later in the semester.
- A stack is a Last-In, First-Out (LIFO) data structure.
- This means that the last item added, is the first one removed.
- Think of a stack of pancakes, most likely you start eating from the pancake at the top.
- Meaning that the one of the top pancake was placed last in the plate, while the bottom pancake was the first one placed in the plate.

Function Stack

- The Function Stack behaves the same.
- The first function added into the stack will usually always be the first item in the stack.
- While the main method is still active, our program is still active.
- Whenever we do a method call, we add another function into the stack.
- When the method call is resolved, we delete it from the stack.

Function Stack

- The running function will always be at the “top” of the stack.
- Any functions below the top stack, is “waiting” for the top stack to resolve.

Function Stack

```java
public class Main {
    public static void method2(){
        System.out.println("Method 2 was called");
    }

    public static void method1(){
        System.out.println("Method 1 was called");
        method2();
        System.out.println("Method 1 still alive");
    }

    public static void main(String[] args) {
        method2();
        method1();
        System.out.println("Finished!");
    }
}
```

Week-8/Function-Stack/Main.java

Function Stack

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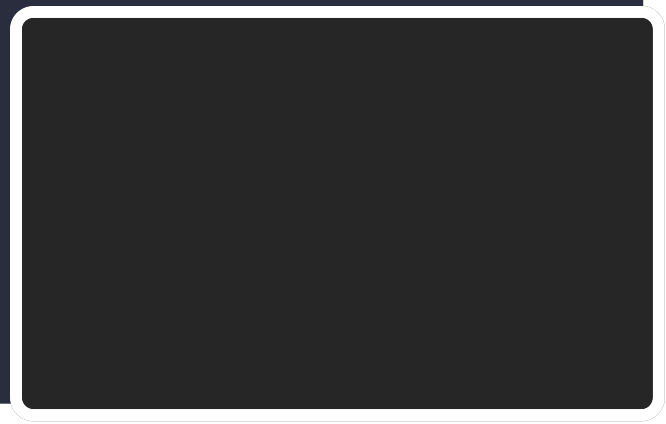

main()
1. Call method2()
2. Call method1()
3. Print “Finished!”

Week-8/Function-Stack/Main.java

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Function Stack

```java
public class Main {
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}
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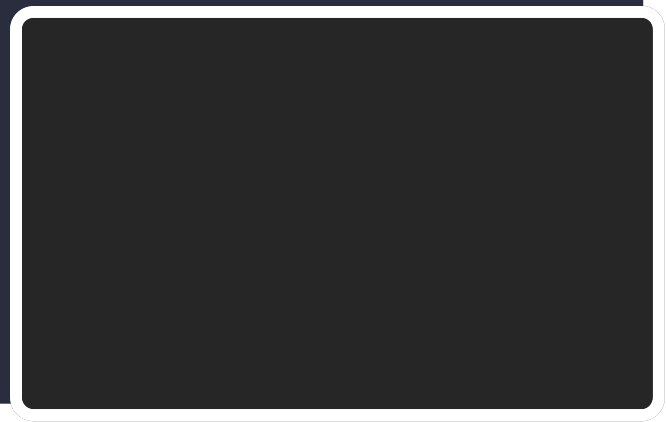

method2()
1. Print “Method 2 was called”

main()
1. Call method2()
2. Call method1()
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Week-8/Function-Stack/Main.java

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Function Stack

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        method2();
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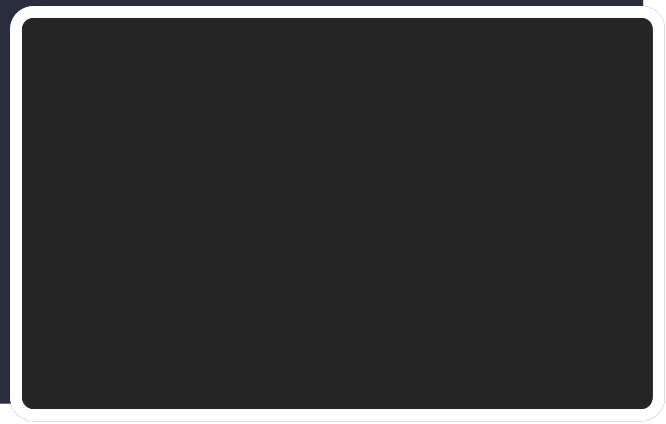

method2()
1. Print “Method 2 was called”

main()
1. Call method2()
2. Call method1()
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Week-8/Function-Stack/Main.java

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Function Stack

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    public static void main(String[] args) {
        method2();
        method1();
        System.out.println("Finished!");
    }
}
```

```
Method 2 was called
```

method2()
1. Print “Method 2 was called”

main()
1. Call method2()
2. Call method1()
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Week-8/Function-Stack/Main.java

Function Stack

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        method2();
        method1();
        System.out.println("Finished!");
    }
}
```

```
Method 2 was called
```

main()
1. Call method1()
2. Print “Finished!”

Week-8/Function-Stack/Main.java

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Function Stack

```java
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    public static void main(String[] args) {
        method2();
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    }
}
```

```
Method 2 was called
```

method1()
1. Print “Method 1 was called”
2. Call method2()
3. Print “Method 1 still alive”

main()
1. Call method1()
2. Print “Finished!”

Week-8/Function-Stack/Main.java

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Function Stack

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```

```
Method 2 was called
```

method1()
1. Print “Method 1 was called”
2. Call method2()
3. Print “Method 1 still alive”

main()
1. Call method1()
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Week-8/Function-Stack/Main.java

Function Stack

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```

```
Method 2 was called
Method 1 was called
```

method1()
1. Print “Method 1 was called”
2. Call method2()
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main()
1. Call method1()
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Week-8/Function-Stack/Main.java

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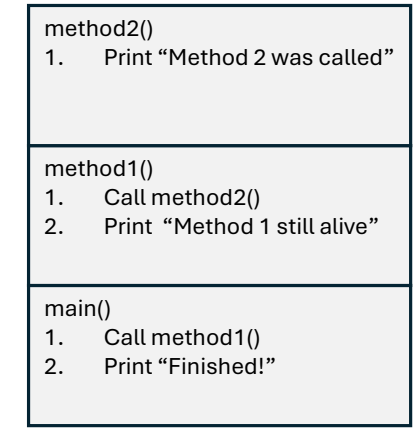
```

```
Method 2 was called
Method 1 was called
```



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Method 2 was called
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method2()
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Week-8/Function-Stack/Main.java

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```
Method 2 was called
Method 1 was called
Method 2 was called
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1. Call method2()
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Week-8/Function-Stack/Main.java

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Method 2 was called
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Method 2 was called
Method 1 still alive
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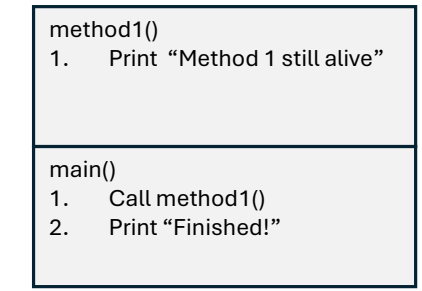

Week-8/Function-Stack/Main.java

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```

```
Method 2 was called
Method 1 was called
Method 2 was called
Method 1 still alive
Finished!
```

main()
1. Print “Finished!”

Week-8/Function-Stack/Main.java

Function Stack

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```
Method 2 was called
Method 1 was called
Method 2 was called
Method 1 still alive
Finished!
```

Program terminated

Week-8/Function-Stack/Main.java

Repetition Structures

- Loops/Iterative:
  - Also called Explicit Repetition.
  - State is maintained by value.
  - Examples:
    - For Loop
    - Foreach Loop
    - While Loop
    - Do While Loop

Repetition Structures

- Recursion or Implicit Repetition:
  - A function calling itself.
  - State is maintained in the call stack.

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Recursion

- Recursion is a programming concept that involves a function calling itself.
- Recursion is used to reduce complex problems into smaller subproblems.
- Code-wise, recursion solutions looks simpler and shorter than its iterative counterpart.

Recursion

- A recursive method consists of two essential components:
- Base Case – We define the stopping point of the recursion.
- Recursive Call – We define the part where the function calls itself.

In-Class Example 1

- Create a Recursive Method that prints a counter.
- It should take in one integer value, which is the starting number for the counter.
- The counter should count down to 0.

Function Stack

```java
public class Counter {
    public static void counter(int number){
        // Base case: Since we count from number to
        // 0, we should stop at -1
        if(number < 0){
            return;
        }
        System.out.println("Counter: " + number);

        // Recursive Call: Since we count from number
        // to 0, each call should decrease number by 1
        counter(number - 1);
    }

    public static void main(String[] args) {
        counter(5);
    }
}
```

Week-8/Function-Stack/Counter.java

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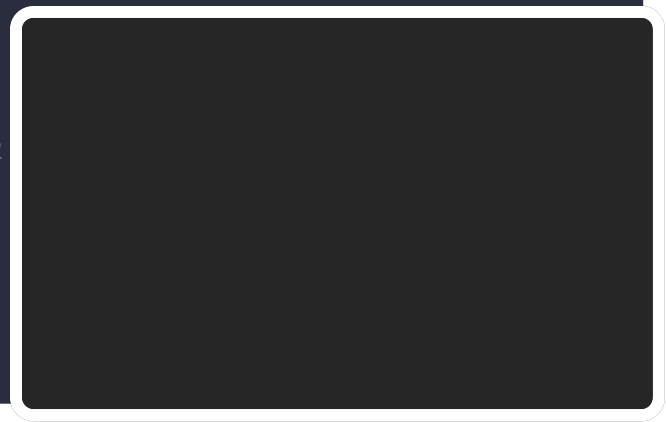

main()
1. Call counter(5)

Week-8/Function-Stack/Counter.java

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Function Stack

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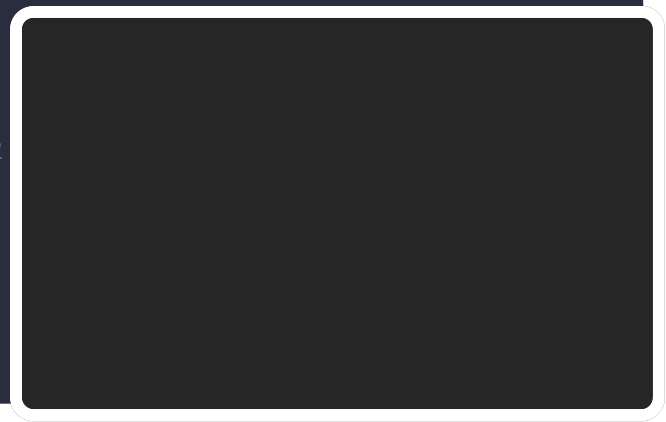

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Week-8/Function-Stack/Counter.java

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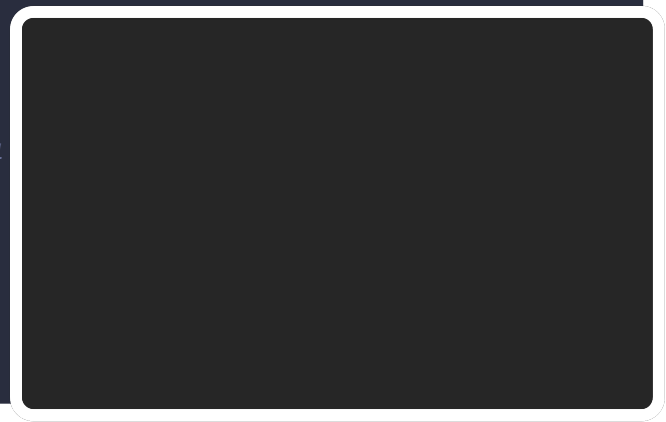

counter(5)
1. Is 5 < 0?
2. Print “Counter: 5”
3. Call counter(4)

main()
1. Call counter(5)

Week-8/Function-Stack/Counter.java

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Function Stack

```java
public class Counter {
    public static void counter(int number){// counter(5)
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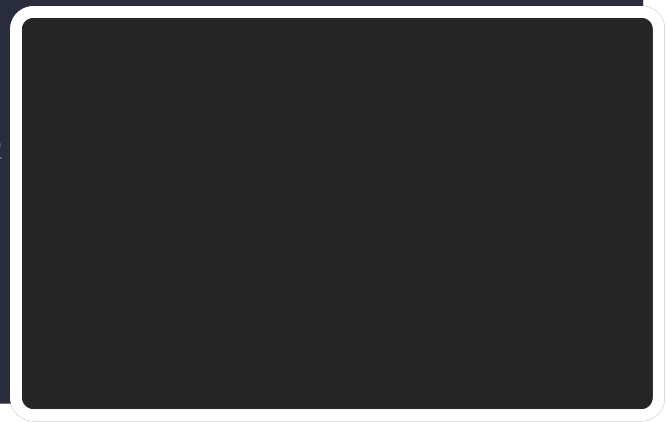

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1. Is 5 < 0?
2. Print “Counter: 5”
3. Call counter(4)

main()
1. Call counter(5)

Week-8/Function-Stack/Counter.java

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    }

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        counter(5);
    }
}
```

```
Counter: 5
```

counter(5)
1. Print “Counter: 5”
2. Call counter(4)

main()
1. Call counter(5)

Week-8/Function-Stack/Counter.java

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Function Stack

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

```
Counter: 5
```

counter(5) 1. Call counter(4)
main() 1. Call counter(5)

Week-8/Function-Stack/Counter.java

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Function Stack

```java
public class Counter {
    public static void counter(int number){// counter(4)
        // Base case: Since we count from number to
        // 0, we should stop at -1
        if(number < 0){
            return;
        }
        System.out.println("Counter: " + number);

        // Recursive Call: Since we count from number
        // to 0, each call should decrease number by 1
        counter(number - 1);
    }

    public static void main(String[] args) {
        counter(5);
    }
}
```

```
Counter: 5
```

counter(4)
1. Is 4 < 0?
2. Print “Counter: 4”
3. Call counter(3)

counter(5)
1. Call counter(4)

main()
1. Call counter(5)

Week-8/Function-Stack/Counter.java

Function Stack

```java
public class Counter {
    public static void counter(int number){// counter(4)
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        if(number < 0){
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        counter(number - 1);
    }

    public static void main(String[] args) {
        counter(5);
    }
}
```

```
Counter: 5
```

counter(4)
1. Is 4 < 0?
2. Print “Counter: 4”
3. Call counter(3)

counter(5)
1. Call counter(4)

main()
1. Call counter(5)

Week-8/Function-Stack/Counter.java

Function Stack

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public class Counter {
    public static void counter(int number){// counter(4)
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        System.out.println("Counter: " + number);

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    }

    public static void main(String[] args) {
        counter(5);
    }
}
```

```
Counter: 5
Counter: 4
```

counter(4) 1. Print “Counter: 4” 2. Call counter(3)
counter(5) 1. Call counter(4)
main() 1. Call counter(5)

Week-8/Function-Stack/Counter.java

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Function Stack

```java
public class Counter {
    public static void counter(int number){// counter(4)
        // Base case: Since we count from number to
        // 0, we should stop at -1
        if(number < 0){
            return;
        }
        System.out.println("Counter: " + number);

        // Recursive Call: Since we count from number
        // to 0, each call should decrease number by 1
        counter(number - 1);
    }

    public static void main(String[] args) {
        counter(5);
    }
}
```

```
Counter: 5
Counter: 4
```

counter(4) 1. Call counter(3)
counter(5) 1. Call counter(4)
main() 1. Call counter(5)

Week-8/Function-Stack/Counter.java

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Function Stack

```java
public class Counter {
    public static void counter(int number){// counter(3)
        // Base case: Since we count from number to
        // 0, we should stop at -1
        if(number < 0){
            return;
        }
        System.out.println("Counter: " + number);

        // Recursive Call: Since we count from number
        // to 0, each call should decrease number by 1
        counter(number - 1);
    }

    public static void main(String[] args) {
        counter(5);
    }
}
```

```
Counter: 5
Counter: 4
Counter: 3
```

counter(3) 1. Call counter(2)
counter(4) 1. Call counter(3)
counter(5) 1. Call counter(4)
main() 1. Call counter(5)

Week-8/Function-Stack/Counter.java

Function Stack

```java
public class Counter {
    public static void counter(int number){// counter(2)
        // Base case: Since we count from number to
        // 0, we should stop at -1
        if(number < 0){
            return;
        }
        System.out.println("Counter: " + number);

        // Recursive Call: Since we count from number
        // to 0, each call should decrease number by 1
        counter(number - 1);
    }

    public static void main(String[] args) {
        counter(5);
    }
}
```

```
Counter: 5
Counter: 4
Counter: 3
Counter: 2
```

counter(2) 1. Call counter(1)
counter(3) 1. Call counter(2)
counter(4) 1. Call counter(3)
counter(5) 1. Call counter(4)
main() 1. Call counter(5)

Week-8/Function-Stack/Counter.java

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Function Stack

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        }
        System.out.println("Counter: " + number);

        // Recursive Call: Since we count from number
        // to 0, each call should decrease number by 1
        counter(number - 1);
    }

    public static void main(String[] args) {
        counter(5);
    }
}
```

```
Counter: 5
Counter: 4
Counter: 3
Counter: 2
Counter: 1
```

counter(1) 1. Call counter(0)
counter(2) 1. Call counter(1)
counter(3) 1. Call counter(2)
counter(4) 1. Call counter(3)
counter(5) 1. Call counter(4)
main() 1. Call counter(5)

Week-8/Function-Stack/Counter.java

Function Stack

```java
public class Counter {
    public static void counter(int number){// counter(0)
        // Base case: Since we count from number to
        // 0, we should stop at -1
        if(number < 0){
            return;
        }
        System.out.println("Counter: " + number);

        // Recursive Call: Since we count from number
        // to 0, each call should decrease number by 1
        counter(number - 1);
    }

    public static void main(String[] args) {
        counter(5);
    }
}
```

```
Counter: 5
Counter: 4
Counter: 3
Counter: 2
Counter: 1
```

counter(0) 1. Is 0 < 0? 2. Print “Counter: 0” 3. Call counter(-1)
counter(1) 1. Call counter(0)
counter(2) 1. Call counter(1)
counter(3) 1. Call counter(2)
counter(4) 1. Call counter(3)
counter(5) 1. Call counter(4)
main() 1. Call counter(5)

Week-8/Function-Stack/Counter.java

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Function Stack

```java
public class Counter {
    public static void counter(int number){// counter(0)
        // Base case: Since we count from number to
        // 0, we should stop at -1
        if(number < 0){
            return;
        }
        System.out.println("Counter: " + number);

        // Recursive Call: Since we count from number
        // to 0, each call should decrease number by 1
        counter(number - 1);
    }

    public static void main(String[] args) {
        counter(5);
    }
}
```

```
Counter: 5
Counter: 4
Counter: 3
Counter: 2
Counter: 1
```

counter(0)
1. Is 0 < 0?
2. Print “Counter: 0”
3. Call counter(-1)

counter(1)
1. Call counter(0)

counter(2)
1. Call counter(1)

counter(3)
1. Call counter(2)

counter(4)
1. Call counter(3)

counter(5)
1. Call counter(4)

main()
1. Call counter(5)

Week-8/Function-Stack/Counter.java

Function Stack

```java
public class Counter {
    public static void counter(int number){// counter(0)
        // Base case: Since we count from number to
        // 0, we should stop at -1
        if(number < 0){
            return;
        }
        System.out.println("Counter: " + number);

        // Recursive Call: Since we count from number
        // to 0, each call should decrease number by 1
        counter(number - 1);
    }

    public static void main(String[] args) {
        counter(5);
    }
}
```

```
Counter: 5
Counter: 4
Counter: 3
Counter: 2
Counter: 1
Counter: 0
```

counter(0)
1. Print “Counter: 0”
2. Call counter(-1)

counter(1)
1. Call counter(0)

counter(2)
1. Call counter(1)

counter(3)
1. Call counter(2)

counter(4)
1. Call counter(3)

counter(5)
1. Call counter(4)

main()
1. Call counter(5)

Week-8/Function-Stack/Counter.java

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Function Stack

```java
public class Counter {
    public static void counter(int number){// counter(0)
        // Base case: Since we count from number to
        // 0, we should stop at -1
        if(number < 0){
            return;
        }
        System.out.println("Counter: " + number);

        // Recursive Call: Since we count from number
        // to 0, each call should decrease number by 1
        counter(number - 1);
    }

    public static void main(String[] args) {
        counter(5);
    }
}
```

```
Counter: 5
Counter: 4
Counter: 3
Counter: 2
Counter: 1
Counter: 0
```

counter(0) 1. Call counter(-1)
counter(1) 1. Call counter(0)
counter(2) 1. Call counter(1)
counter(3) 1. Call counter(2)
counter(4) 1. Call counter(3)
counter(5) 1. Call counter(4)
main() 1. Call counter(5)

Week-8/Function-Stack/Counter.java

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Function Stack

```java
public class Counter {
    public static void counter(int number){// counter(-1)
        // Base case: Since we count from number to
        // 0, we should stop at -1
        if(number < 0){
            return;
        }
        System.out.println("Counter: " + number);

        // Recursive Call: Since we count from number
        // to 0, each call should decrease number by 1
        counter(number - 1);
    }

    public static void main(String[] args) {
        counter(5);
    }
}
```

```
Counter: 5
Counter: 4
Counter: 3
Counter: 2
Counter: 1
Counter: 0
```

counter(-1) 1. Is -1 < 0? 2. Print “Counter: -1” 3. Call counter(-2)
counter(0) 1. Call counter(-1)
counter(1) 1. Call counter(0)
counter(2) 1. Call counter(1)
counter(3) 1. Call counter(2)
counter(4) 1. Call counter(3)
counter(5) 1. Call counter(4)
main() 1. Call counter(5)

Week-8/Function-Stack/Counter.java

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Function Stack

```java
public class Counter {
    public static void counter(int number){// counter(-1)
        // Base case: Since we count from number to
        // 0, we should stop at -1
        if(number < 0){
            return;
        }
        System.out.println("Counter: " + number);

        // Recursive Call: Since we count from number
        // to 0, each call should decrease number by 1
        counter(number - 1);
    }

    public static void main(String[] args) {
        counter(5);
    }
}
```

```
Counter: 5
Counter: 4
Counter: 3
Counter: 2
Counter: 1
Counter: 0
```

counter(-1) 1. Is -1 < 0? 2. Print “Counter: -1” 3. Call counter(-2)
counter(0) 1. Call counter(-1)
counter(1) 1. Call counter(0)
counter(2) 1. Call counter(1)
counter(3) 1. Call counter(2)
counter(4) 1. Call counter(3)
counter(5) 1. Call counter(4)
main() 1. Call counter(5)

Week-8/Function-Stack/Counter.java

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Function Stack

```java
public class Counter {
    public static void counter(int number){// counter(-1)
        // Base case: Since we count from number to
        // 0, we should stop at -1
        if(number < 0){
            return;
        }
        System.out.println("Counter: " + number);

        // Recursive Call: Since we count from number
        // to 0, each call should decrease number by 1
        counter(number - 1);
    }

    public static void main(String[] args) {
        counter(5);
    }
}
```

```
Counter: 5
Counter: 4
Counter: 3
Counter: 2
Counter: 1
Counter: 0
```

counter(-1) 1. Is -1 < 0? 2. **Print "Counter: -1"** 3. **Call counter(-2)**
counter(0) 1. Call counter(-1)
counter(1) 1. Call counter(0)
counter(2) 1. Call counter(1)
counter(3) 1. Call counter(2)
counter(4) 1. Call counter(3)
counter(5) 1. Call counter(4)
main() 1. Call counter(5)

Week-8/Function-Stack/Counter.java

KENNESAW STATE UNIVERSITY

Function Stack

```java
public class Counter {
    public static void counter(int number){// counter(-1)
        // Base case: Since we count from number to
        // 0, we should stop at -1
        if(number < 0){
            return;
        }
        System.out.println("Counter: " + number);

        // Recursive Call: Since we count from number
        // to 0, each call should decrease number by 1
        counter(number - 1);
    }

    public static void main(String[] args) {
        counter(5);
    }
}
```

```
Counter: 5
Counter: 4
Counter: 3
Counter: 2
Counter: 1
Counter: 0
```

counter(-1)
1. Is -1 < 0?
2. return

counter(0)
1. Call counter(-1)

counter(1)
1. Call counter(0)

counter(2)
1. Call counter(1)

counter(3)
1. Call counter(2)

counter(4)
1. Call counter(3)

counter(5)
1. Call counter(4)

main()
1. Call counter(5)

Week-8/Function-Stack/Counter.java

Function Stack

```java
public class Counter {
    public static void counter(int number){// counter(0)
        // Base case: Since we count from number to
        // 0, we should stop at -1
        if(number < 0){
            return;
        }
        System.out.println("Counter: " + number);

        // Recursive Call: Since we count from number
        // to 0, each call should decrease number by 1
        counter(number - 1);
    }

    public static void main(String[] args) {
        counter(5);
    }
}
```

```
Counter: 5
Counter: 4
Counter: 3
Counter: 2
Counter: 1
Counter: 0
```

counter(0) 1. Call counter(-1)
counter(1) 1. Call counter(0)
counter(2) 1. Call counter(1)
counter(3) 1. Call counter(2)
counter(4) 1. Call counter(3)
counter(5) 1. Call counter(4)
main() 1. Call counter(5)

Week-8/Function-Stack/Counter.java

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Function Stack

```java
public class Counter {
    public static void counter(int number){// counter(1)
        // Base case: Since we count from number to
        // 0, we should stop at -1
        if(number < 0){
            return;
        }
        System.out.println("Counter: " + number);

        // Recursive Call: Since we count from number
        // to 0, each call should decrease number by 1
        counter(number - 1);
    }

    public static void main(String[] args) {
        counter(5);
    }
}
```

```
Counter: 5
Counter: 4
Counter: 3
Counter: 2
Counter: 1
Counter: 0
```

counter(1) 1. Call counter(0)
counter(2) 1. Call counter(1)
counter(3) 1. Call counter(2)
counter(4) 1. Call counter(3)
counter(5) 1. Call counter(4)
main() 1. Call counter(5)

Week-8/Function-Stack/Counter.java

Function Stack

```java
public class Counter {
    public static void counter(int number){// counter(2)
        // Base case: Since we count from number to
        // 0, we should stop at -1
        if(number < 0){
            return;
        }
        System.out.println("Counter: " + number);

        // Recursive Call: Since we count from number
        // to 0, each call should decrease number by 1
        counter(number - 1);
    }

    public static void main(String[] args) {
        counter(5);
    }
}
```

```
Counter: 5
Counter: 4
Counter: 3
Counter: 2
Counter: 1
Counter: 0
```

counter(2) 1. Call counter(1)
counter(3) 1. Call counter(2)
counter(4) 1. Call counter(3)
counter(5) 1. Call counter(4)
main() 1. Call counter(5)

Week-8/Function-Stack/Counter.java

Function Stack

```java
public class Counter {
    public static void counter(int number){// counter(3)
        // Base case: Since we count from number to
        // 0, we should stop at -1
        if(number < 0){
            return;
        }
        System.out.println("Counter: " + number);

        // Recursive Call: Since we count from number
        // to 0, each call should decrease number by 1
        counter(number - 1);
    }

    public static void main(String[] args) {
        counter(5);
    }
}
```

```
Counter: 5
Counter: 4
Counter: 3
Counter: 2
Counter: 1
Counter: 0
```

counter(3) 1. Call counter(2)
counter(4) 1. Call counter(3)
counter(5) 1. Call counter(4)
main() 1. Call counter(5)

Week-8/Function-Stack/Counter.java

Function Stack

```java
public class Counter {
    public static void counter(int number){// counter(4)
        // Base case: Since we count from number to
        // 0, we should stop at -1
        if(number < 0){
            return;
        }
        System.out.println("Counter: " + number);

        // Recursive Call: Since we count from number
        // to 0, each call should decrease number by 1
        counter(number - 1);
    }

    public static void main(String[] args) {
        counter(5);
    }
}
```

```
Counter: 5
Counter: 4
Counter: 3
Counter: 2
Counter: 1
Counter: 0
```

counter(4) 1. Call counter(3)
counter(5) 1. Call counter(4)
main() 1. Call counter(5)

Week-8/Function-Stack/Counter.java

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Function Stack

```java
public class Counter {
    public static void counter(int number){// counter(5)
        // Base case: Since we count from number to
        // 0, we should stop at -1
        if(number < 0){
            return;
        }
        System.out.println("Counter: " + number);

        // Recursive Call: Since we count from number
        // to 0, each call should decrease number by 1
        counter(number - 1);
    }

    public static void main(String[] args) {
        counter(5);
    }
}
```

```
Counter: 5
Counter: 4
Counter: 3
Counter: 2
Counter: 1
Counter: 0
```

counter(5) 1. Call counter(4)
main() 1. Call counter(5)

Week-8/Function-Stack/Counter.java

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Function Stack

```java
public class Counter {
    public static void counter(int number){
        // Base case: Since we count from number to
        // 0, we should stop at -1
        if(number < 0){
            return;
        }
        System.out.println("Counter: " + number);

        // Recursive Call: Since we count from number
        // to 0, each call should decrease number by 1
        counter(number - 1);
    }

    public static void main(String[] args) {
        counter(5);
    }
}
```

```
Counter: 5
Counter: 4
Counter: 3
Counter: 2
Counter: 1
Counter: 0
```

main()
1. Call counter(5)

Week-8/Function-Stack/Counter.java

Function Stack

```java
public class Counter {
    public static void counter(int number){
        // Base case: Since we count from number to
        // 0, we should stop at -1
        if(number < 0){
            return;
        }
        System.out.println("Counter: " + number);

        // Recursive Call: Since we count from number
        // to 0, each call should decrease number by 1
        counter(number - 1);
    }

    public static void main(String[] args) {
        counter(5);
    }
}
```

```
Counter: 5
Counter: 4
Counter: 3
Counter: 2
Counter: 1
Counter: 0
```

Week-8/Function-Stack/Counter.java

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Function Stack

```java
public class Counter {
    public static void counter(int number){
        // Base case: Since we count from number to
        // 0, we should stop at -1
        if(number < 0){
            return;
        }
        System.out.println("Counter: " + number);

        // Recursive Call: Since we count from number
        // to 0, each call should decrease number by 1
        counter(number - 1);
    }

    public static void main(String[] args) {
        counter(5);
    }
}
```

```
Counter: 5
Counter: 4
Counter: 3
Counter: 2
Counter: 1
Counter: 0
```

Program terminated

Week-8/Function-Stack/Counter.java

In-Class Example 2

- Let’s try the opposite, the method should now count up, starting from 0 until we reach the input number.