Pre-Class Work 10: Recursive Programming

How to Write Recursive Code [Background Reading]

Now that you know how to *read* recursive code, let's talk about how we would go about *writing* recursive code.

Recall that two components of recursive code is the **base case** and the **recursive case**. You may find it easier to think about the **base case** first before thinking about the **recursive case** or, vice versa, think about the **recursive case** before thinking about the **base case**.

This is the beauty of **recursion**! It is largely up to you and how you want to approach the problem.

For this reading, we will be approaching the **base case** first for all of the problems.

1️⃣ Base Case

Let's first consider the **base case**. In the previous reading, we defined the **base case** as the case which ends the **recursion** so it shouldn't make any **recursive** calls. We're going to add onto this definition and say that the **base case** is the solution for the "simplest" case.

Let's revisit the problem which we presented in the previous reading. Given an integer `n`, we want the sum of numbers from 1 all the way to `n` (inclusive). We also made the assumption that `n` is always greater than or equal to 1. What is the simplest case in this problem? In this problem, the simplest case would be if `n` is 1 since all of the numbers between 1 to 1 is just 1!

Therefore, our base case is when `n` is 1 and we should just return 1:

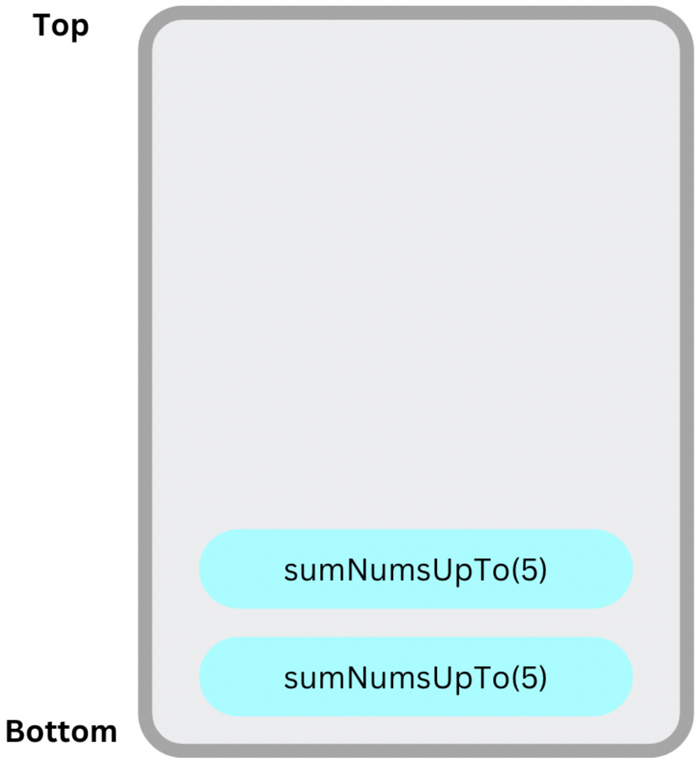
```java
// pre: n >= 1
public static int sumNumsUpTo(int n) {
    if (n == 1) { // Base case
        return 1;
    }
}
```

2️⃣ Recursive Case

Now, let's look at the **recursive case**. We previously defined the **recursive case** as the one calling the method. One cool fact to realize is that if something is not considered a **base case**, then it is automatically a **recursive case**. Thus, every input `n` that is equal to 2 or greater should go into the recursive case!

```java
// pre: n >= 1
public static int sumNumsUpTo(int n) {
    if (n == 1) { // Base case
        return 1;
    } else {      // Recursive case
        return sumNumsUpTo(n);
    }
}
```

Will this work? If you are violently shaking your head from left to right then you are correct! In the **recursive case**, you are making a **recursive** call but notice how you never modify the parameter. Let's apply our **recursive code** tracing knowledge to see what the **call stack** would look like if we inputted 5: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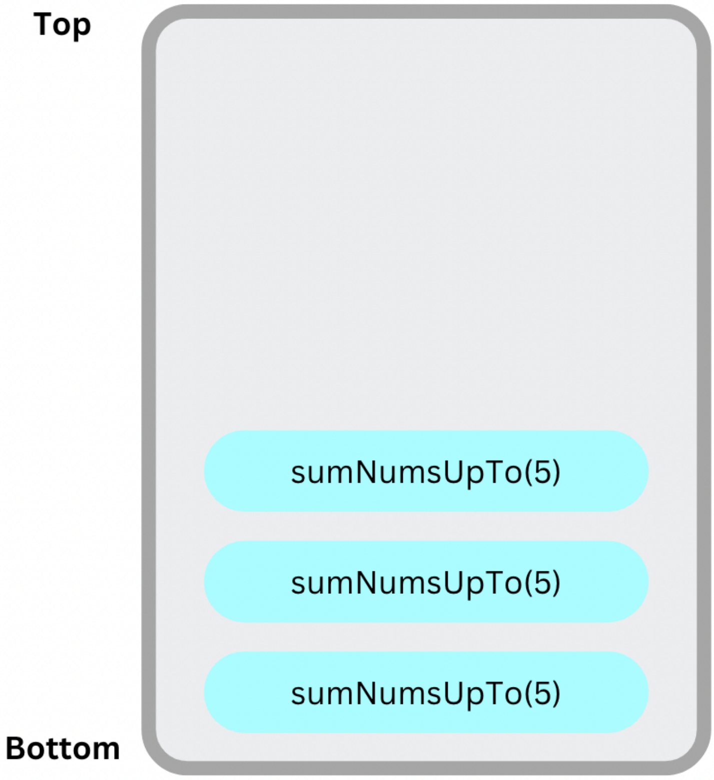
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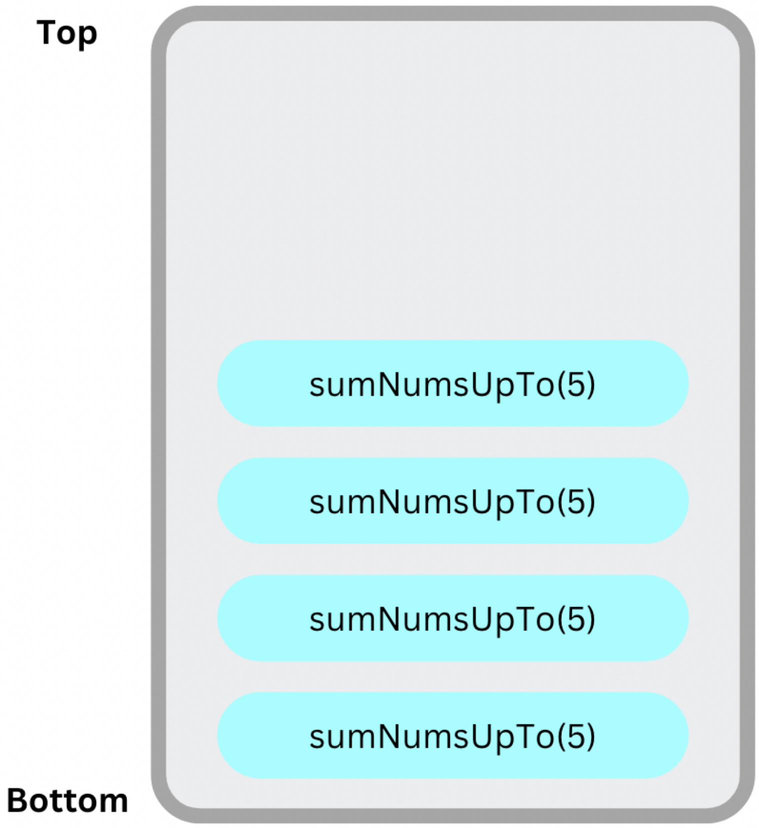
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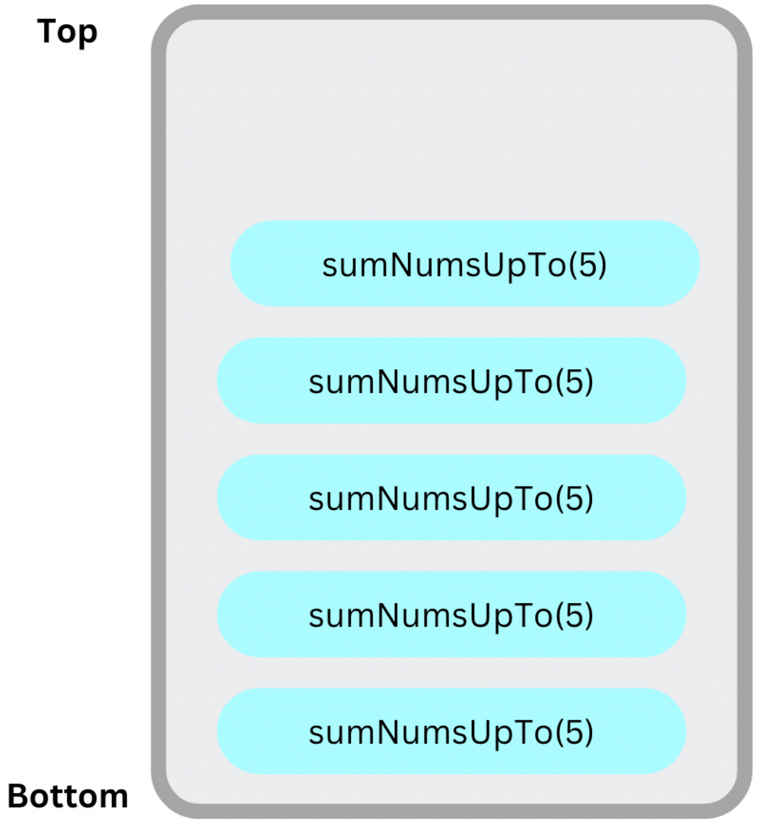
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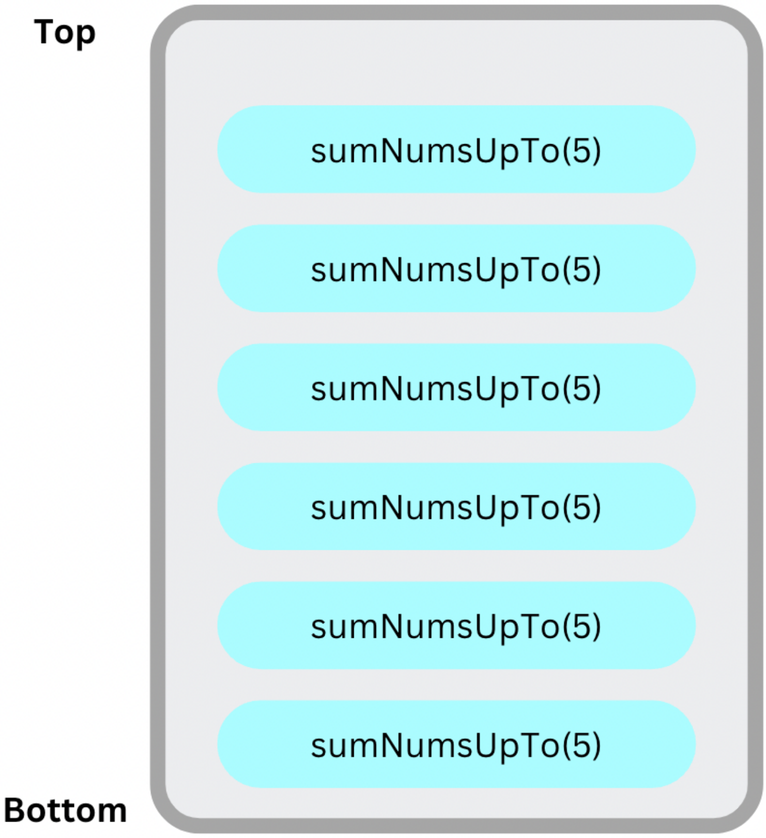
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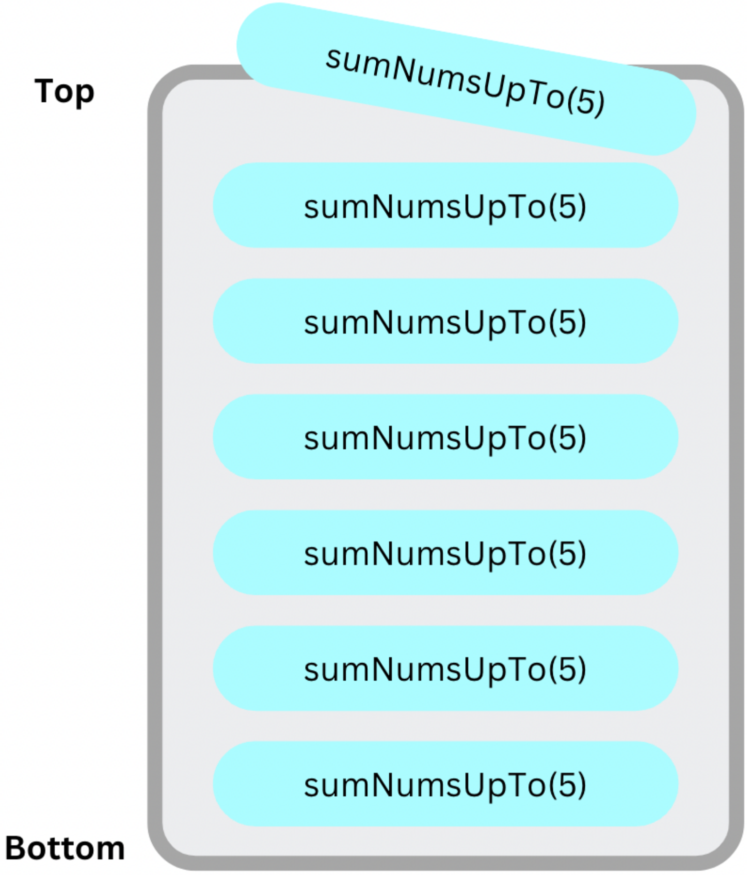
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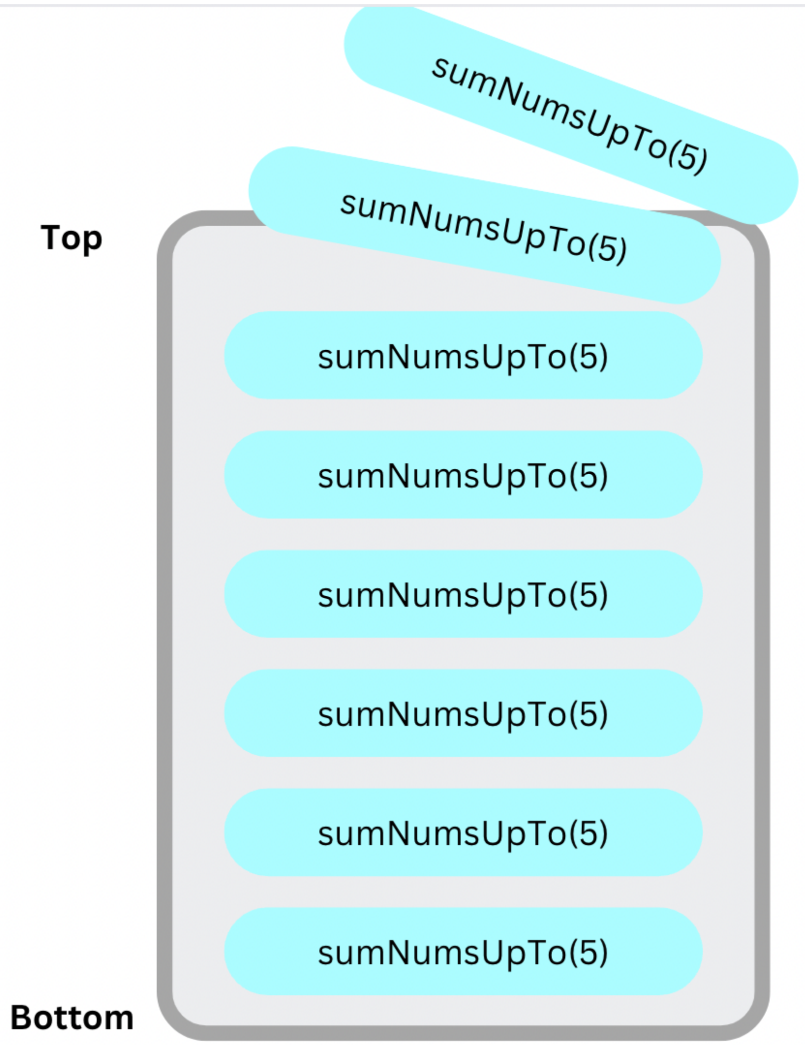
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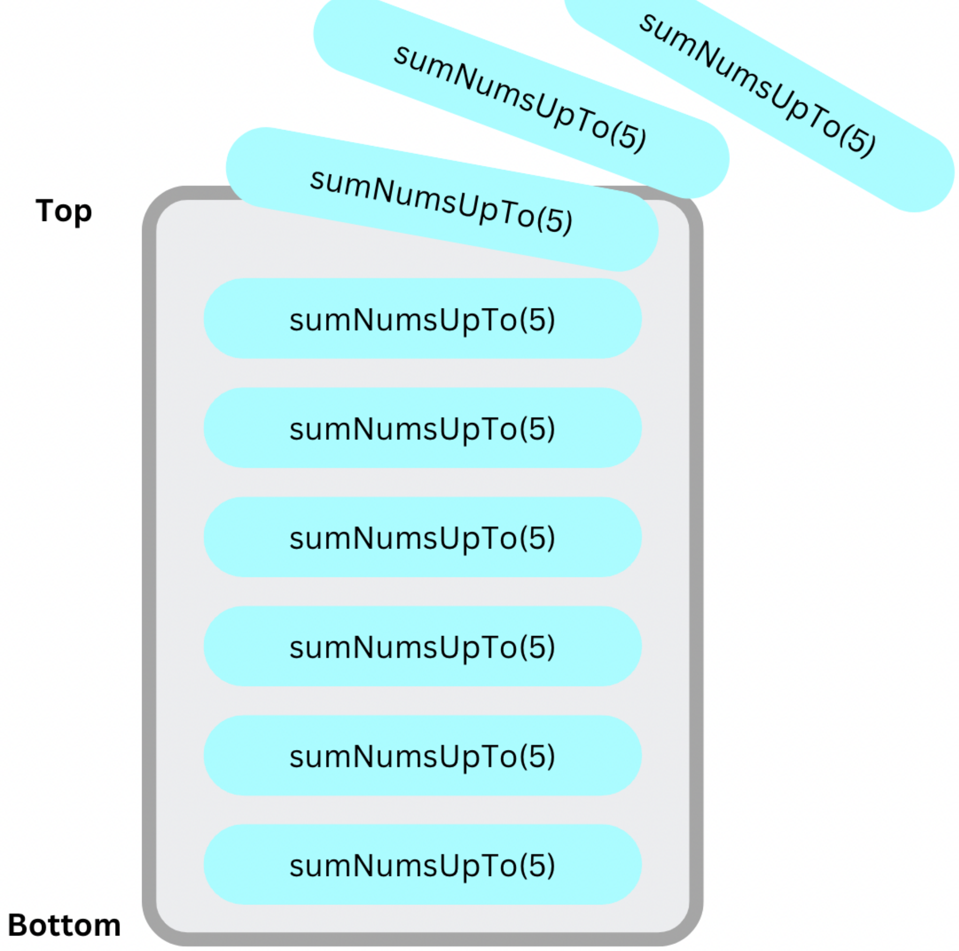
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It never ends! Our **call stack** is overflowing with methods 😱!

▯ StackOverflowError

In Java, this is known as a `StackOverflowError`. Even well-versed recursive programmers will encounter this error so do not feel bad if you encounter this error!

While it is true that the **recursive case** should be the one calling the method, we're going to add onto this definition and say that the goal of the **recursive case** is to get closer to the **base case**. If we never make progress closer to the **base case**, then we'll just keep recursing forever and eventually hit a `StackOverflowError`!

Remember that the purpose of recursion is to take a large task and break it down into smaller tasks. Since we want to sum all the numbers from 1 to `n` (inclusive), this is our large task. Now, let's think critically on how to properly sub-task the large task. If we are summing all numbers from 1 to `n` (inclusive) as our large task, what is smaller version of this?

What sub-task will help us get closer to the **base case** (i.e. when `n` is 1)? If we are `sumNumsUpTo(5)`, we know that `n` is currently 5. Thus, the numbers summing up to 5 is just 5 plus the numbers summing up to 4 (i.e. `sumNumsUpTo(4)`)! On each recursive call, if we subtract one each time, we will eventually reach our base case which stops the recursion!

```java
// pre: n >= 1
public static int sumNumsUpTo(int n) {
    if (n == 1) { // Base case
        return 1;
    } else {      // Recursive case
        return n + sumNumsUpTo(n - 1);
    }
}
```

The main takeaway you should get from this is that the **base case** stops the recursion and the **recursive case** works towards the **base case**.

If the **recursive case** doesn't properly update the parameter on each **recursive call**, or if it goes in the opposite direction of the **base case** (like if the **recursive case** was `n + sumNumsUpTo(n + 1)`, then you'll get a `StackOverflowError` which means your **recursion** never ended!

▯ Main Points

- With **recursion**, we want to break down a larger task into smaller sub-tasks. Each recursive call we make should progress towards the **base case**, otherwise we may get infinite recursion.

- The **base case** is the condition that stops **recursion.**
  - It's the simplest/smallest case that we know the solution of.
  - When we want to sum up numbers from 1 to n, then our **base case** would be when `n = 1`, since we know that the sum of all numbers from 1 to 1 is `1`.
- The **recursive case** is where the method calls itself with <u>modified</u> parameters so we can make further progress towards the **base case.**
- If we don't properly update the arguments of our **recursive case**, or if we don't eventually end up at the **base case**, we may get a `StackOverflowError`, which happens when our call stack is too deep because of infinite recursion.

Parenthesize [Programming Question]

Write a recursive method called `parenthesize` that takes a String and an integer n as parameters and that returns the string inside n sets of parentheses.

For example, this code:

```
System.out.println(parenthesize("Brett Wortzman", 2));
System.out.println(parenthesize("The University of Washington", 6));
System.out.println(parenthesize("cats", 1));
```

should produce these 3 lines of output:

```
((Brett Wortzman))
((((((The University of Washington))))))
(cats)
```

Your method should throw an `IllegalArgumentException` if passed a negative number.

It could be passed 0, as in: `parenthesize("CSE122, Winter 2022", 0`);

In this case the returned String would have no (i.e., 0) parentheses:

```
CSE122, Winter 2022
```

For this question, we will provide you with the **recursive call**:

```
return "(" + parenthesize(str, n - 1) + ")";
```

Write Chars [Programming Question]

Write a recursive method `writeChars` that accepts an integer parameter `n` and returns `n` characters as follows. The middle character of the output should always be an asterisk ("*"). If you are asked to write out an even number of characters, then there will be two asterisks in the middle ("**").

Before the asterisk(s) you should write out less-than characters ("<"). After the asterisk(s) you should write out greater-than characters (">").

For example, the following calls produce the following output:

- `writeChars(1)` returns `*`
- `writeChars(2)` returns `**`
- `writeChars(3)` returns `<*>`
- `writeChars(4)` returns `<**>`
- `writeChars(5)` returns `<<*>>`
- `writeChars(6)` returns `<<**>>`
- `writeChars(7)` returns `<<<*>>>`
- `writeChars(8)` returns `<<<**>>>`

Your method should throw an `IllegalArgumentException` if passed a value less than 1. Note that the output does not advance to the next line.

For this question, we will provide you with the **base cases:**

```
if (n == 1) {
    return "*";
} else if (n == 2) {
    return "**";
}
```