LEC 08

CSE 123

Recursion

BEFORE WE START

Talk to your neighbors:

Debrief Quiz 2. How do you feel like it went in comparison to Quiz 1?

Music: 123 24su Lecture Tunes

Instructor: Joe Spaniac

TAs: Andras, Daniel, Eric, Nicole, Sahej, Trien, Zach

Questions during Class?

Raise hand or send here

sli.do #cse123

Lecture Outline

- **Announcements**
- Recursion
  - Definition
  - Call Stack
- Math Examples
- Revisiting Reflections

Announcements

- Quiz 2 Completed! 😮💨
  - Congrats! Expect grades back around next Thursday(hopefully)
  - Practice metacognition: how did that go? What can you learn about your studying process and how can you incorporate it before the next quiz?
- Programming Assignment 2 due in one week (7/24) @ 11:59pm
  - Already said this before – it's hard, start it sooner rather than later
- C2 / R2 grades out after lecture
- Resubmission Period 3 closes this Friday (7/19) @ 11:59pm
  - Available assignments: **C1**, P1, C2
  - Last opportunity to resubmit C1
- Reminder: Grade guarantee calculator

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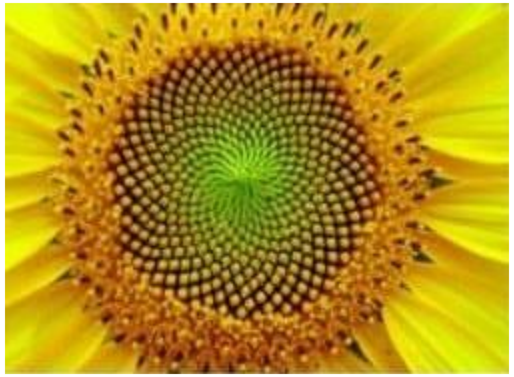
Recursion

"The repeated application of a recursive procedure or definition"

- Oxford Languages

- Real-world definition: defining a problem in terms of itself
  - Case in point: above definition
  - Further natural examples:




Recursion

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Recursion

"The repeated application of a recursive procedure or definition"

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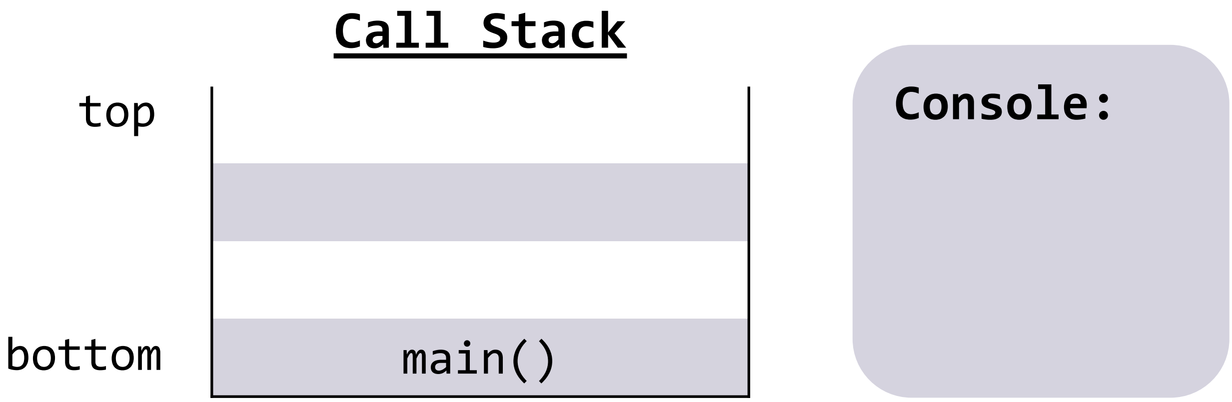
- Real-world definition: defining a problem in terms of itself
  - Case in point: above definition

- Computer science definition: when a method calls itself
  - "Alternative" to iteration (can combine for powerful results)
- 🤔 Wouldn't that just lead to an infinite loop?
  - Yes! If you do things wrong…
  - Let's review *how* method calls work

Method Calls

- Regardless how you use them, methods work the same way!
  - Pause execution, finish method, return where you left off
- How does Java keep track of the prior method (LIFO)?
  - Something called the **Call Stack**

Call Stack




```java
public static void main(String[] args) {
    mystery1();
    mystery2();
}

public static void mystery1() {
    System.out.println("One");
}
```

```java
public static void mystery2() {
    System.out.println("Two");
    mystery3();
}

public static void mystery3() {
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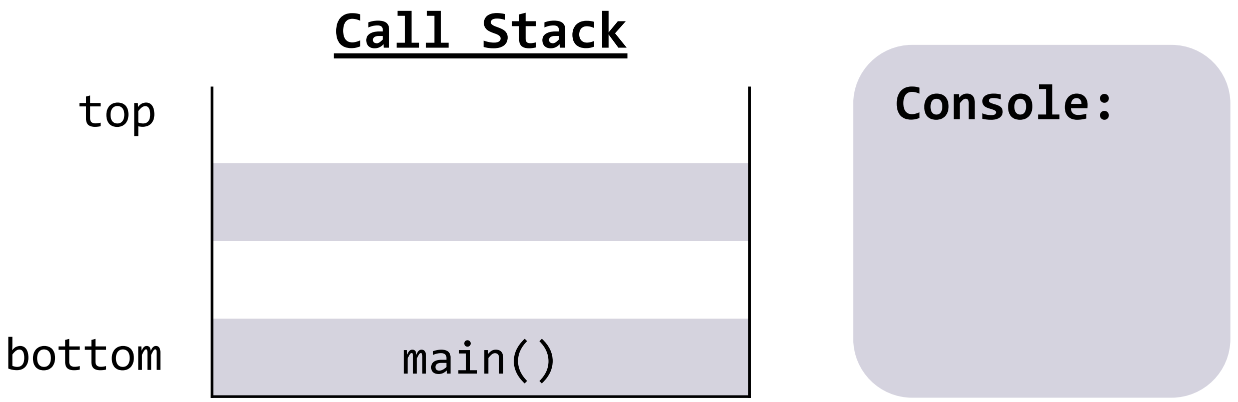
}
```

Call Stack

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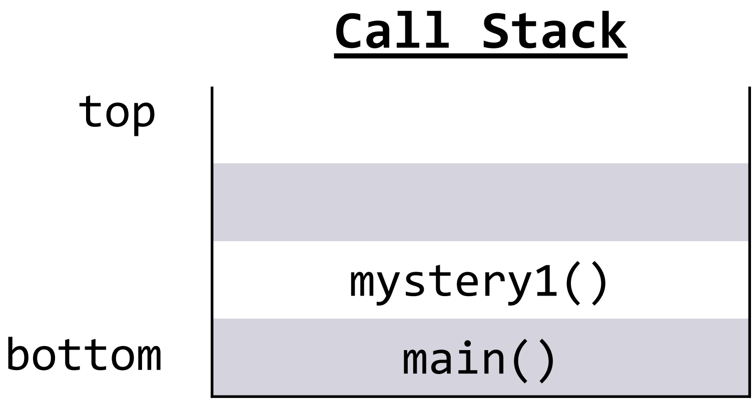
Call Stack



Console:

```
public static void main(String[] args) {
    mystery1();
    mystery2();
}

public static void mystery1() {
    System.out.println("One");
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```
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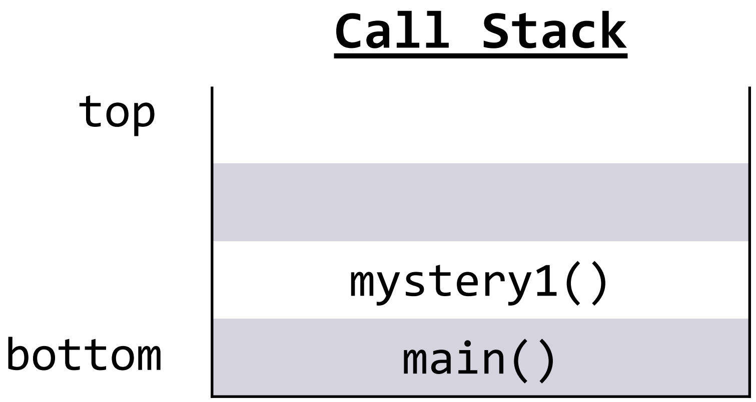
Call Stack



Console:

One

```
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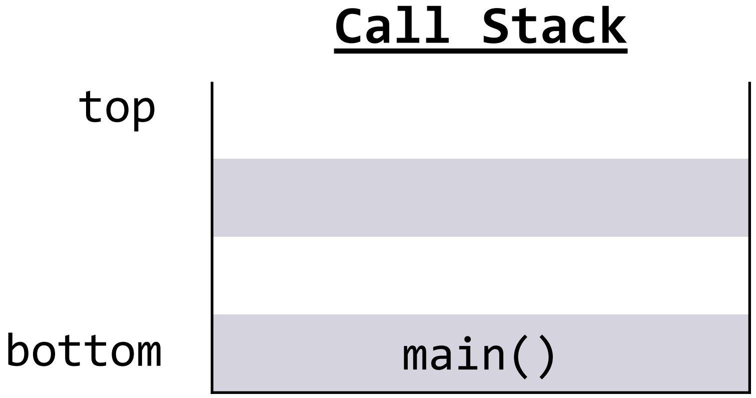
Call Stack



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```
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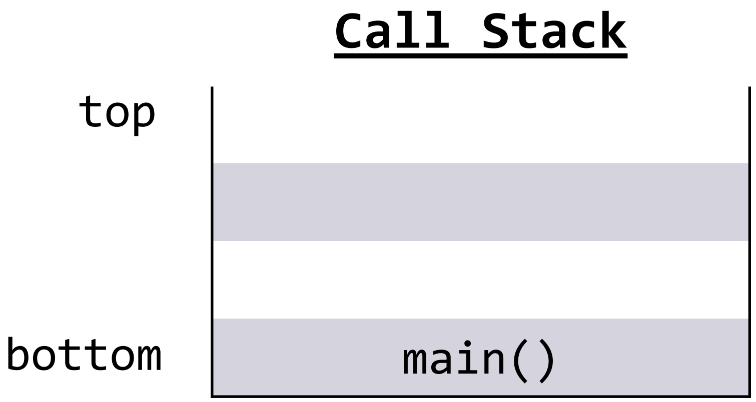
Call Stack



Console:

One

```
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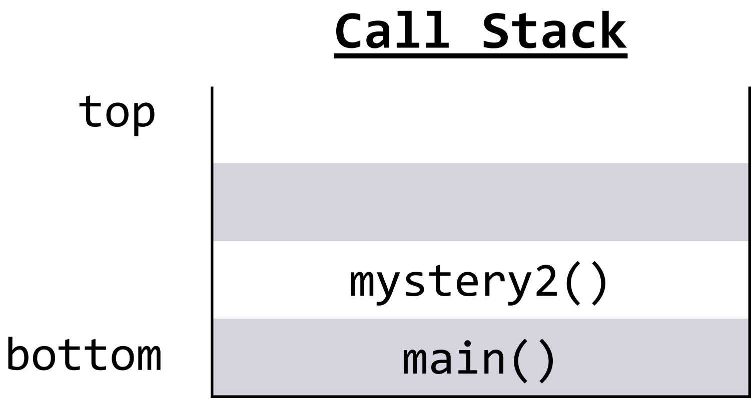
Call Stack



Console:

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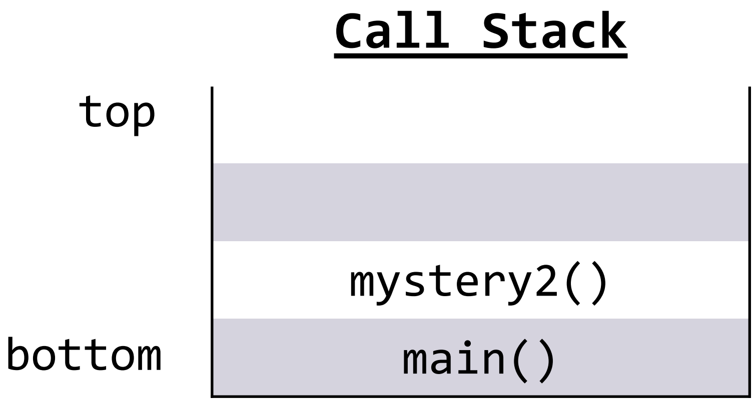
Call Stack



Console:

One
Two

```
public static void main(String[] args) {
    mystery1();
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}

public static void mystery1() {
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}
```

```
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    System.out.println("Two");
    mystery3();
}

public static void mystery3() {
    System.out.println("Three");
}
```

Call Stack

Call Stack

top	
	mystery2()
bottom	main()

Console:

One
Two

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}

public static void mystery1() {
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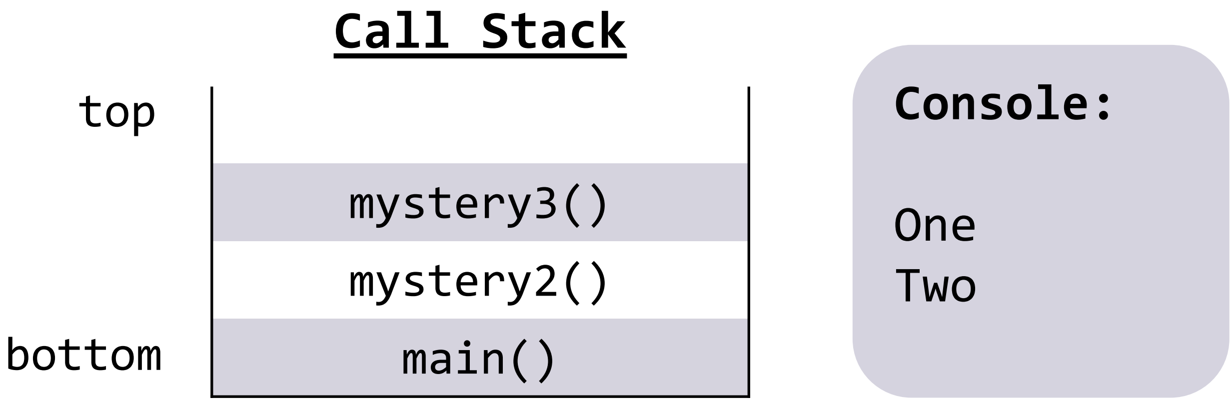
Call Stack

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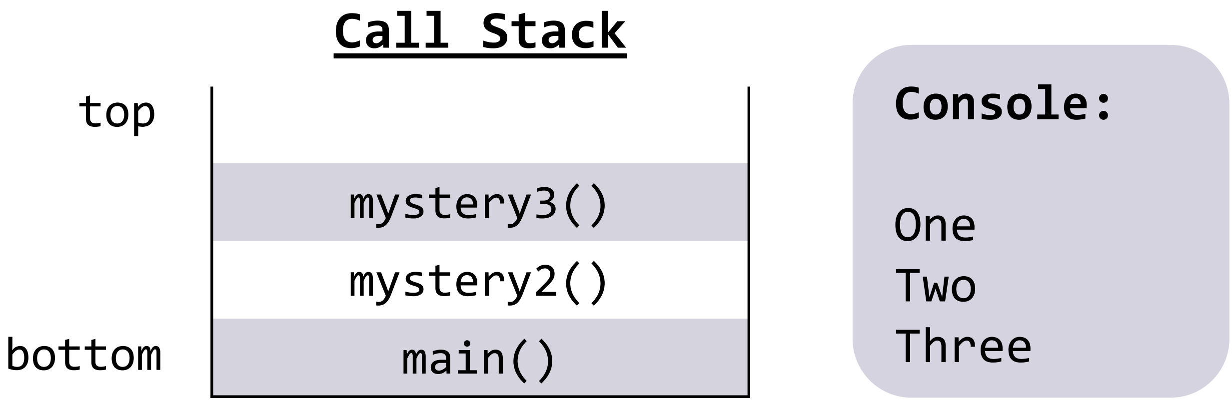
Call Stack




```
public static void main(String[] args) {
    mystery1();
    mystery2();
}

public static void mystery1() {
    System.out.println(“One”);
}

public static void mystery2() {
    System.out.println(“Two”);
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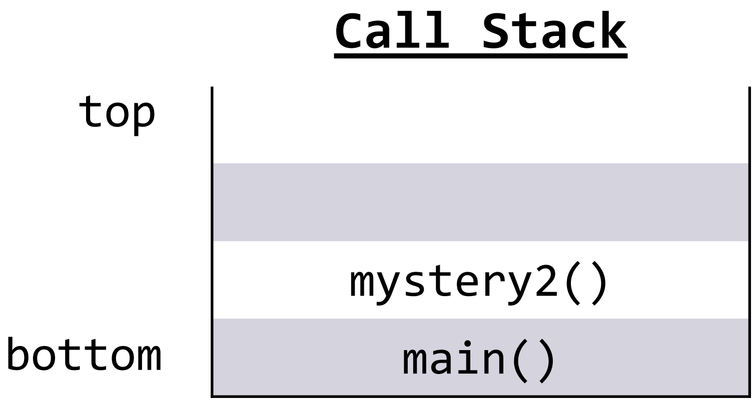
}

public static void mystery3() {
    System.out.println(“Three”);
}
```

Call Stack



Console:

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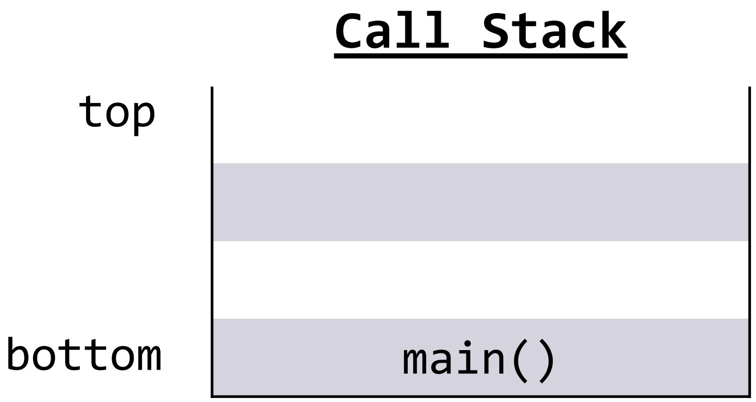

Console:

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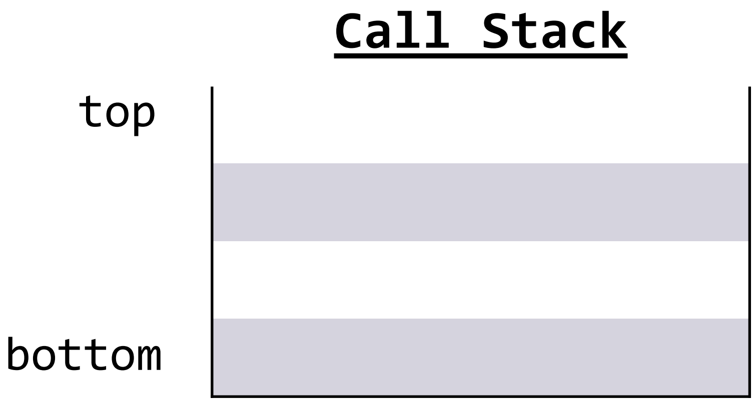
Call Stack



Console:

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Two
Three
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```java
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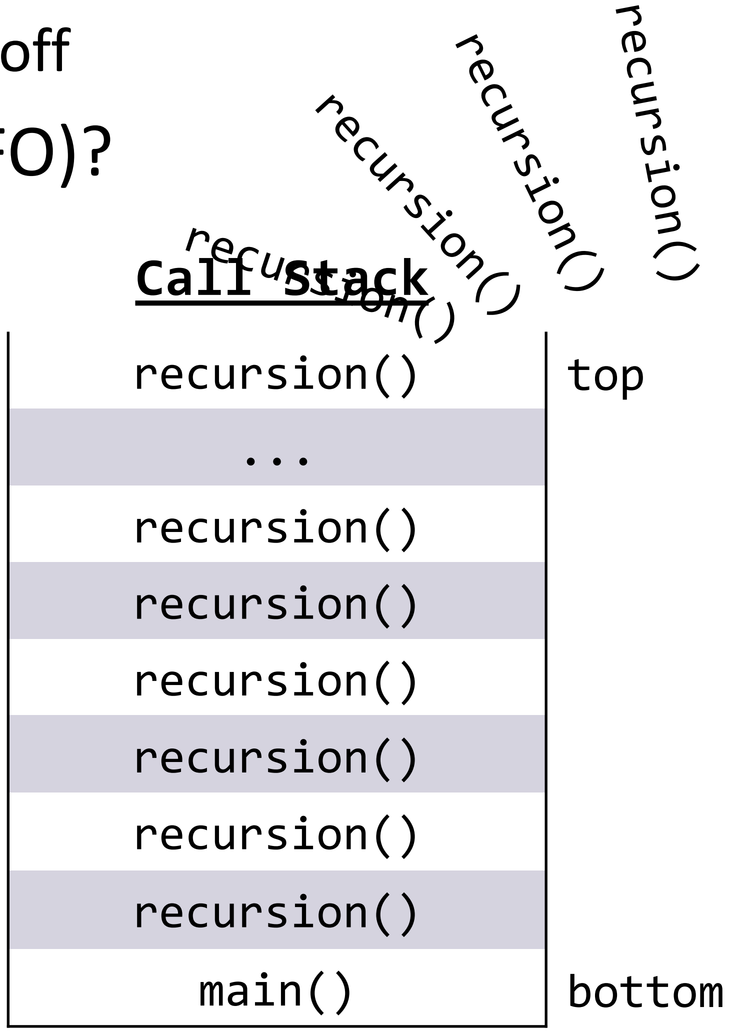
Method Calls

- Regardless how you use them, methods work the same way!
  - Pause execution, finish method, return where you left off
- How does Java keep track of the prior method (LIFO)?
  - Something called the **Call Stack**



🤔 Wouldn't that just lead to an infinite loop?

```
public static void recursion() {
    System.out.println("Woah");
    recursion();
}
```

Method Calls

- Regardless how you use them, methods work the same way!
  - Pause execution, finish method, return where you left off
- How does Java keep track of the prior method (LIFO)?
  - Something called the **Call Stack**

🤔 Wouldn’t that just lead to an infinite loop?
  - Yes! We get something called a **StackOverflowException**

- How do we avoid infinite recursion?

Recursive Methods

- 2 components of every recursive method:

- Recursive case
  - Decompose problem into subproblem
  - Make the actual recursive call
  - Combine results meaningfully
- Base case
  - Simplest version of the problem
  - No subproblems to break into
  - Return known answer

Recursive Methods

- 2 components of every recursive method:
- Recursive case
  - Decompose problem into subproblem
  - Make the actual recursive call
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- Base case
  - Simplest version of the problem
  - No subproblems to break into
  - Return known answer

If decomposing moves you closer to the base, no infinite recursion!

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  - Call Stack
- **Math Examples**
- Revisiting Reflections

Math Examples

n! / factorial(n) = product of all positive integers <= n

- Two ways of viewing this idea:

- $n! = n * (n-1) * (n-2) * \cdots * 2 * 1$
  - Iterative approach - loop through all values and multiply together

- $n! = n * (n-1)!$
  - Recursive approach – decompose into subproblem and combine
  - What would our base case / simplest input (n) be?

Math Examples

n! / factorial(n) = product of all positive integers <= n

- Reminder, recursive approach: $n! = n * (n-1)!$
  - Let's trace through with a simple example 3!

$4! = 4 * 3!$ $3! = 3 * 2!$ $2! = 2 * 1!$ $1! = 1 * 0!$ $0! = 1$

Math Examples

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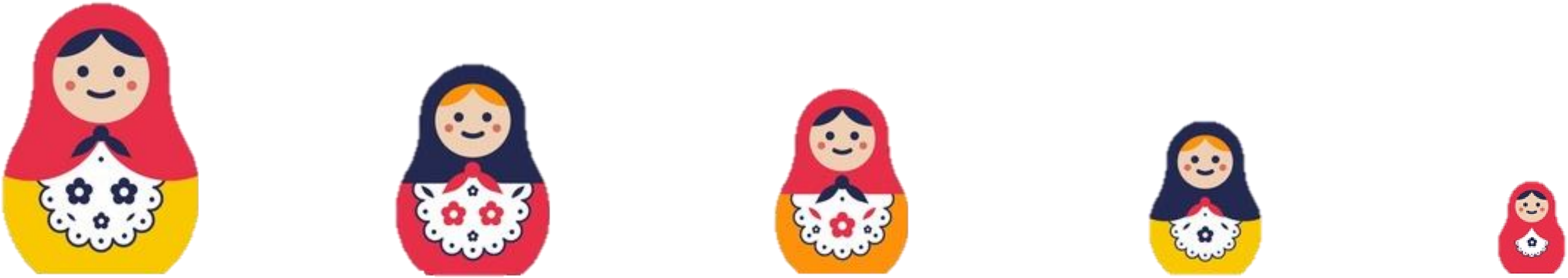

$4! = 4 * 3!$ $\quad$ $3! = 3 * 2!$ $\quad$ $2! = 2 * 1!$ $\quad$ $1! = 1 * 0!$ $\quad$ $0! = 1$

Math Examples

n! / factorial(n) = product of all positive integers <= n

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$4! = 4 * 3!$

$3! = 3 * 2!$

$2! = 2 * 1!$

$1! = 1 * 1$

Math Examples

n! / factorial(n) = product of all positive integers <= n

- Reminder, recursive approach: $n! = n * (n-1)!$
  - Let's trace through with a simple example 3!

$4! = 4 * 3!$

$3! = 3 * 2!$

$2! = 2 * 1!$

$1! = 1$

Math Examples

n! / factorial(n) = product of all positive integers <= n

- Reminder, recursive approach: $n! = n * (n - 1)!$
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$4! = 4 * 3!$

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Math Examples

n! / factorial(n) = product of all positive integers <= n

- Reminder, recursive approach: $n! = n * (n-1)!$
  - Let's trace through with a simple example 3!

$4! = 4 * 3!$

$3! = 3 * 2!$

$2! = 2$

Math Examples

n! / factorial(n) = product of all positive integers <= n

- Reminder, recursive approach: $n! = n * (n-1)!$
  - Let's trace through with a simple example 3!

$4! = 4 * 3!$

$3! = 3 * 2$

Math Examples

n! / factorial(n) = product of all positive integers <= n

- Reminder, recursive approach: $n! = n * (n-1)!$
  - Let's trace through with a simple example 3!

$4! = 4 * 3!$

$3! = 6$

Math Examples

n! / factorial(n) = product of all positive integers <= n

- Reminder, recursive approach: $n! = n * (n-1)!$
  - Let's trace through with a simple example 3!

$4! = 4 * 6$

Math Examples

n! / factorial(n) = product of all positive integers <= n

- Reminder, recursive approach: $n! = n * (n - 1)!$
  - Let's trace through with a simple example 3!

$4! = 24$

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- **Revisiting Reflections**

Revisiting Reflections

- Throughout this course, we'll ask you to form opinions on topics
  - Provide exposure to issues so you can decide for yourself
- Opinions aren't formed in a vacuum
  - Exposure to various viewpoints reinforces/challenges perspectives
  - Shouldn't be making arbitrary decisions
    - Rationalization is often important! (Not always necessary, but helps in communication)

- Integrating reflections to in-class components
  - Discuss opinions, challenge assumptions, potentially change minds
  - Please be respectful of other people's opinions
    - There are no "right" or "wrong" answers to these questions
    - Everyone has different experiences with the world that informs their decisions

P1 / C2 Reflections

- P1 - Video: *End to End Encryption (E2EE)*
  - Q6: Do you believe it's necessary to sacrifice privacy for the "greater good" / safety of modern society? Why or why not?

- C2 - Behavioral Mapping Study
  - Describe what game you implemented / define rules if necessary
  - Q7: If you were to make one change to your implementation centered around **usability**, what would it be?
  - Bonus: How could you make your game more **accessible** for users? No formal definition, just how you interpret the question.