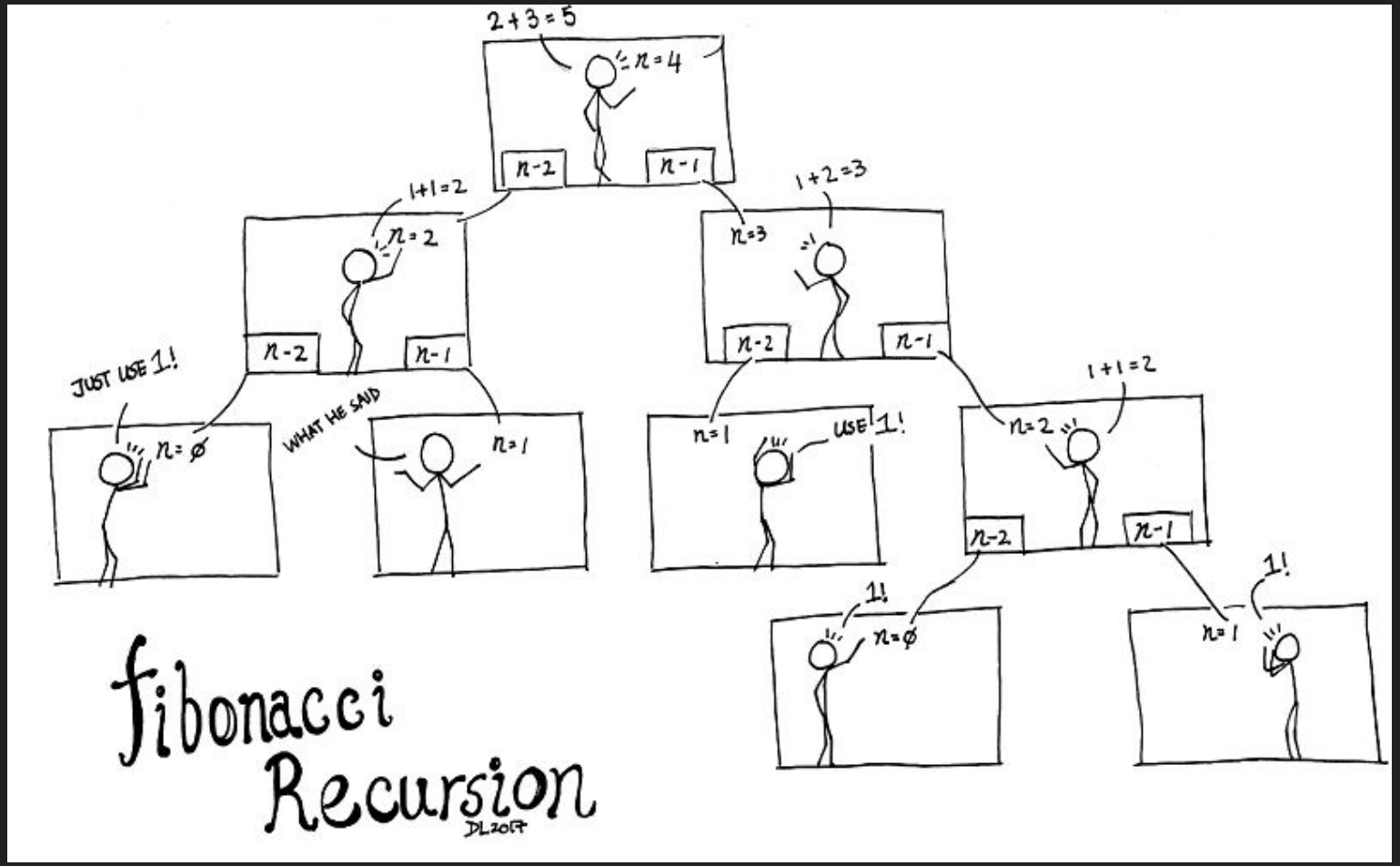
Recursion:

"To loop is human,
to recurse is divine".



Recursion

A recursive function is a function that calls itself.

Iteration vs. Recursion

In simple terms:

An *iterative* function is one that **loops** to repeat some part of the code.
A *recursive* function is one that **calls itself** again to repeat the code.

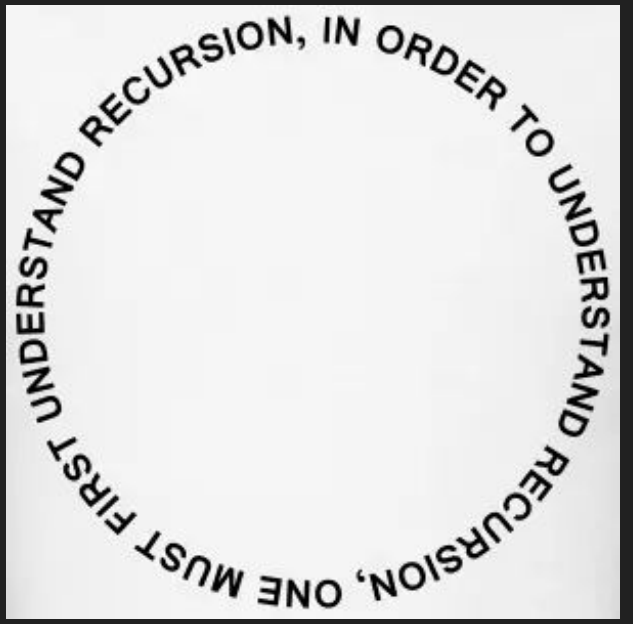
recursion is

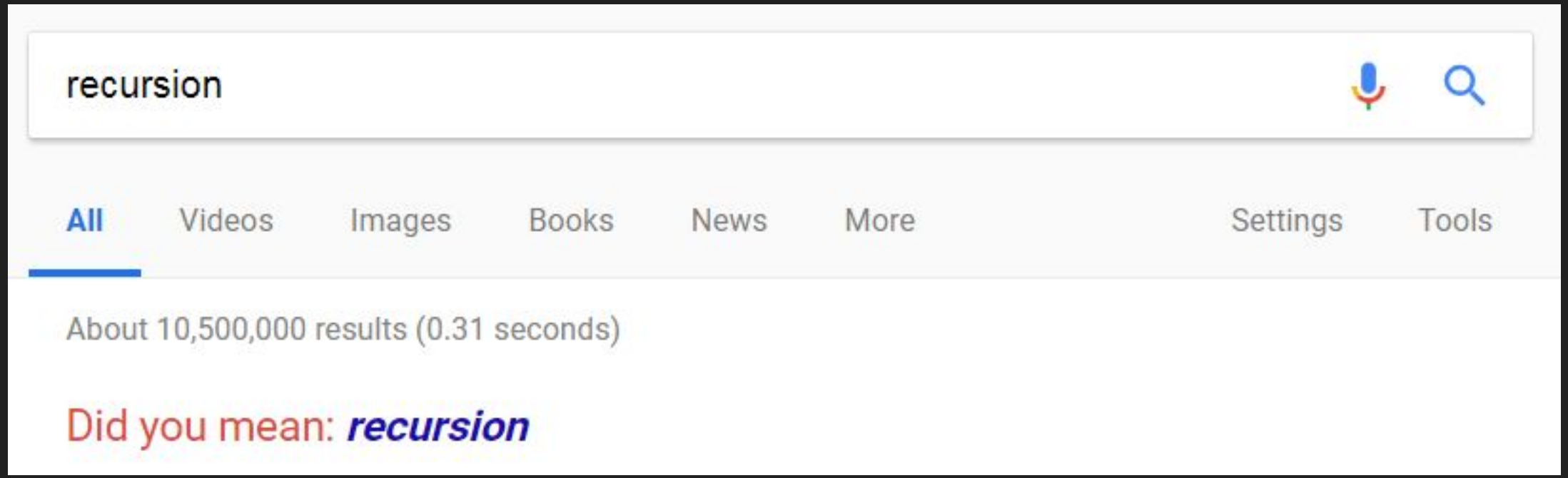
recursion is **memory-intensive because**
recursion is **hard**
recursion is **to the base case as iteration is to what**
recursion is **confusing**
recursion is **bad**
recursion is **magic**
recursion is **slow**
recursion is **a computational technique in which**
recursion is **another name for iteration**
recursion is **similar to which of the following**

Google Search I'm Feeling Lucky

Report inappropriate predictions

To understand recursion,
you must first understand recursion.




recursion
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About 10,500,000 results (0.31 seconds)
Did you mean: recursion

Toothpaste For Dinner.com


I'M SO META, EVEN THIS ACRONYM

I.S.M.E.T.A.

Recursion: A working definition

- Recursion solves a big problem by the solving increasingly smaller examples of the same problem and building up a solution.

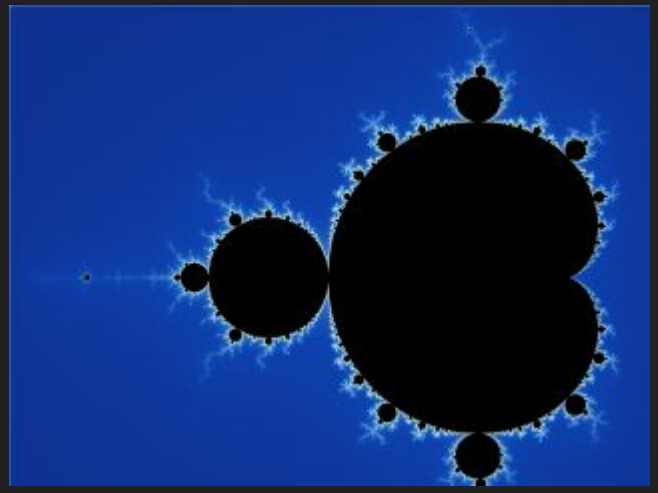
Recursion is All Around Us

- Nature: Cauliflower, ferns, rivers
- Math & Art: Fractals
- Computer Science…

Recursion in Nature: Cauliflower

Recursion in Art: Fractals

Koch Snowflake:
https://upload.wikimedia.org/wikipedia/commons/6/65/Kochsim.gif



Mandelbrot set:
https://en.wikipedia.org/wiki/File:Mandelbrot_sequence_new.gif

Recursion

- A recursive solution must have **base** case
  - A simplest problem where recursion is **not** needed
- A recursive function also has a **recursive** case, which calls same function with reduced version of the problem

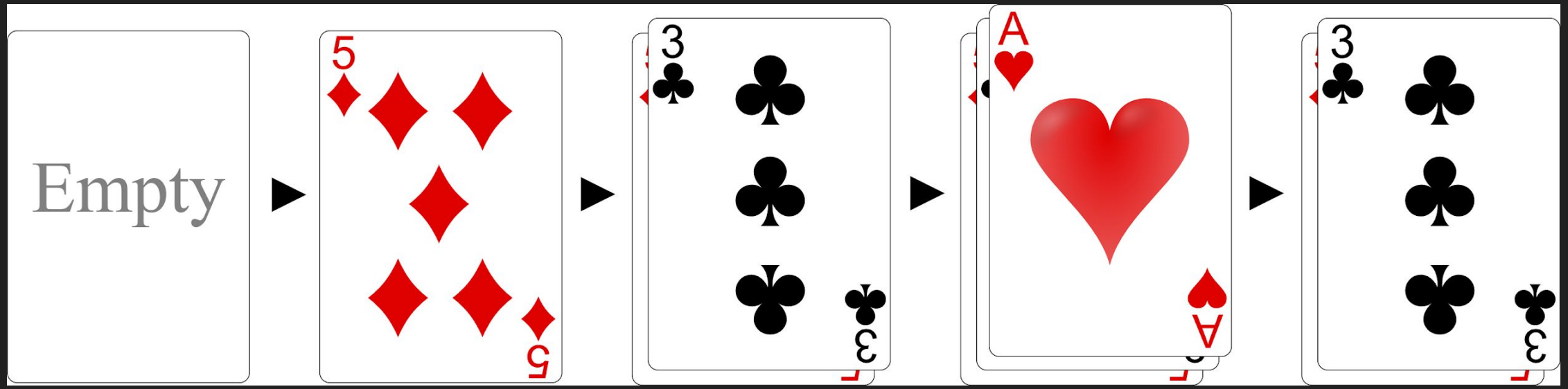
The Three Laws of Recursion

1. A recursive algorithm must have a base case.
2. A recursive algorithm moves toward the base case (recursive case).
3. A recursive algorithm must call itself -> the very definition of recursion.

A simple recursive function

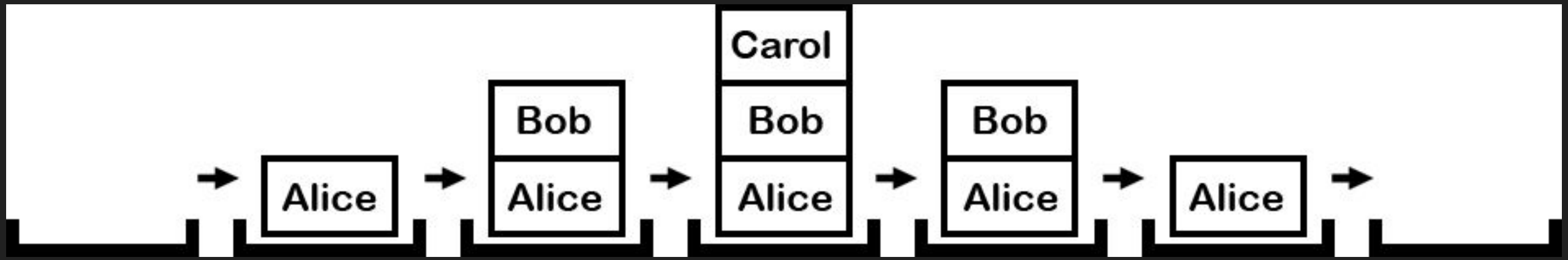
```
def message (times):
   if times==0:
      print('this is the base case ', times)
   else:
      message(times-1)
      print('this is the recursive case ', times)

message(5)
```

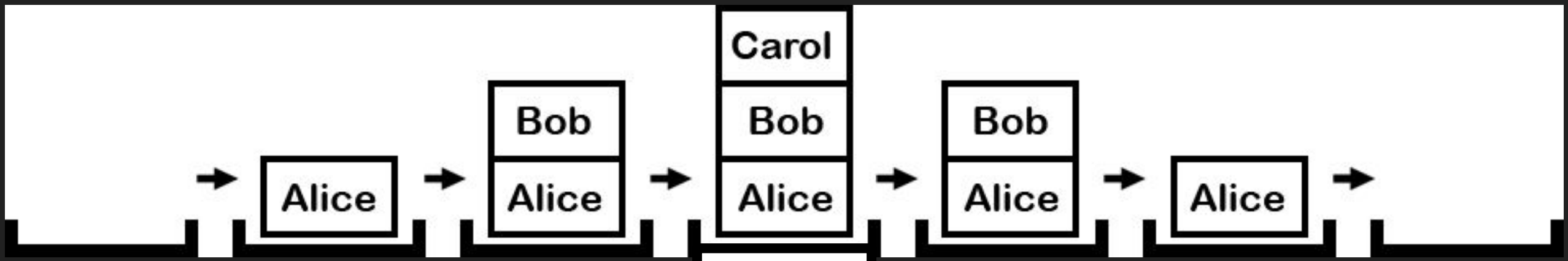
A stack is a data structure that holds a sequence of data and only lets you interact with the topmost item.

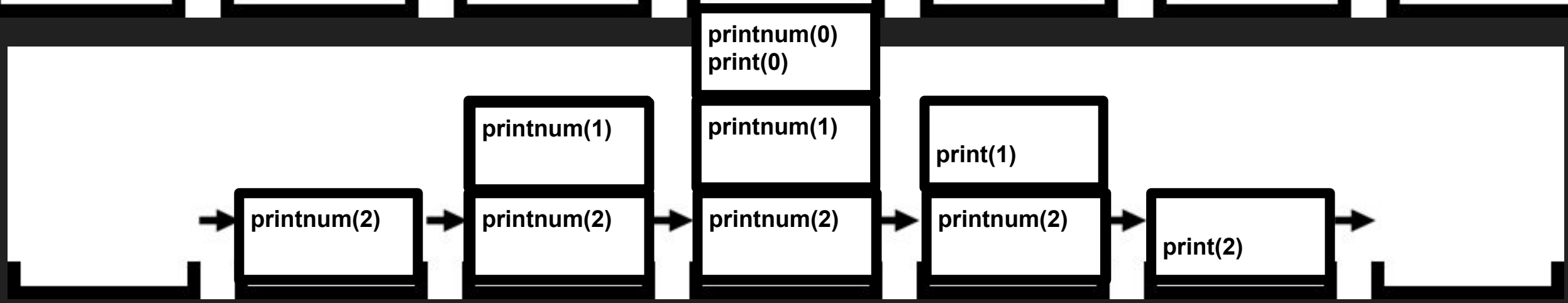


First-In, Last-Out (FILO)

A stack is a data structure that holds a sequence of data and only lets you interact with the topmost item.








```
def printnum(n):
    if n == 0:        # Base case
        print(n)
    else:             # Recursive case
        printnum(n-1)
        print(n)
```

Recursion is a lot easier to understand if you understand stacks and the call stack.

To understand recursion, you must first understand ~~recursion~~.
STACKS (just a bit).

The secret is that the base case starts the first ‘pop’ off the stack

A simple recursive function

```
def message (times):
   if times==0:
      print('this is the base case ', times)
   else:
      message(times-1)
      print('this is the recursive case ', times)

message(5)
```

functions calls in code

```
message(5)
        message(4)
                message(3)
                        message(2)
                                message(1)
                                        message(0)
                                        print(‘this is the base case’, 0 )
                                print(‘this is the recursive case’, 1)
                        print(‘this is the recursive case’, 2)
                print(‘this is the recursive case’, 3)
        print(‘this is the recursive case’, 4)
print(‘this is the recursive case’, 5)
```

A simple recursive function

```
def message (times):
   if times==0:
      print('this is the base case ', times)
   else:
      message(times-1)
      print('this is the recursive case ', times)

message(5)
```

You can try reversing the lines in the recursive case to see what happens.

A simple recursive function

```
def printnum(n):
    if n == 0:    # Base case
        print(n)
    else:         # Recursive case
        printnum(n-1)
        print(n)

def main():
    printnum(4)

main()
```

fucntion calls in code

```
printnum(5)
        printnum(4)
                printnum(3)
                        printnum(2)
                                printnum(1)
                                        printnum(0)
                                        print(0)
                                print(1)
                        print(2)
                print(3)
        print(4)
print(5)
```

function calls in code

```
printnum(5)
        printnum(4)
                printnum(3)
                        printnum(2)
                                printnum(1)
                                        printnum(0)
                                        print(0)
                                print(1)
                        print(2)
                print(3)
        print(4)
```

The Stack of Calls

```
def printnum(n):
    if n == 0:
        print(n)
    else:
        printnum(n-1)
        print(n)

printnum(5)
```

How do you learn recursion?

- Learn the concept.
- Practice the concept with **lots** of coding practice.
- Honestly just keep doing it. You will get/"grok" it at some point.

sum(n) - adds numbers from 1 to n

Let’s try a simple function sum(n) that adds up all numbers from 1 to n.

First create an iterative function sum(n) that uses a *for loop* and returns the sum of all numbers 1 to n.

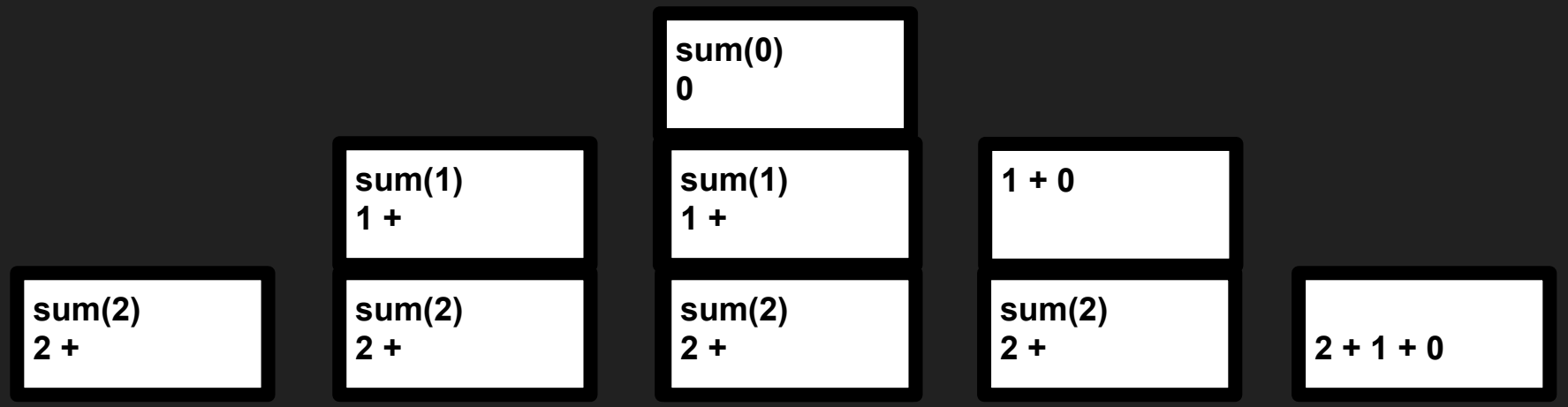
Iterative version of sum(n)

```
def sum_for(n):
   total =0
   for x in range(n+1):
      total+=x
   return total

print(sum_for(5))
```

Recursive sum of numbers from 1 to n

```
def sum(n):
   if n==0:
      return 0
   else:
      return n + sum (n-1)

print(sum(5))
```

```
def sum(n):
    if n==0:
        return 0
    else:
        return n + sum (n-1)

print(sum(2))
```



sum(5)

sum(4)

sum(3)

sum(2)

sum(1)

sum(0)

0

1 + 0

2 + 1 + 0

3 + 2 + 1 + 0

4 + 3 + 2 + 1 + 0

5 + 4 + 3 + 2 + 1 + 0

```
def sum(n):
    if n==0:
        return 0
    else:
        return n + sum (n-1)

print(sum(5))
```

Example: sum of numbers from 1 to n

- What is the base case?
  - When you get to n=0 you return 0 which stops the recursing of the function
- How do we move towards the base case?
  - You start at the highest number and subtract one each time you recurse

Another Example: Factorial

- n! = n x (n-1) x (n-2) x (n-3) … x 1
- 1! = 1 # Base Case
- 2! = 2 x 1! = 2 x 1 = 2
- 3! = 3 x 2! = 3 x (2 x 1!) = 6
- 4! = 4 x 3! = 4 x (3 x 2!) = 24 # Move towards base case
- n! = n x (n -1)!

The Stack of Calls

factorial stack calls

```
factorial(5)
        factorial(4)
                factorial(3)
                        factorial(2)
                                factorial(1)
                                    1
                                2   *  1
                            3   *   2   *   1
                        4   *   3   *   2   *   1
                    5   *   4   *   3   *   2   *   1
```

Note: 0! =1
You will need to account for this in your code

In-Class Exercise: Factorial Functions

- Code it!
  - with ***while*** loop
  - with ***for*** loop
  - with ***recursion***