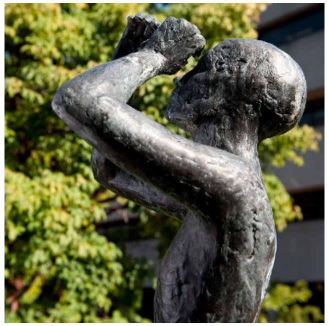

CS1117 – Introduction to Programming

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School of Computer Science and Information Technology

A TRADITION OF INDEPENDENT THINKING

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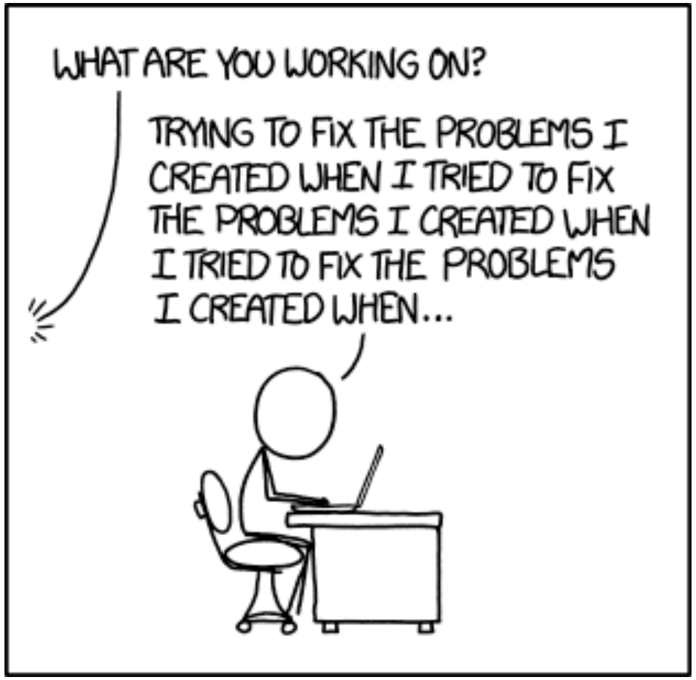
Problems, problems, problems…



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Recursion

- **Recursion**: The definition of an operation in terms of itself.
  - Solving a problem using recursion depends on solving smaller occurrences of the same problem.

- **Recursive Programming**:
  - Writing functions that **call themselves** to solve problems.
  - We already know that in Python functions can call other functions.
  - Now it's also possible for a function to call/invoke itself?

Recursion

- Many functional programming languages (e.g. Haskell) use recursion only (no loops).

- A different way of thinking about problems

- + Leads to elegant, simplistic and short code (when used well)
- + Can solve certain types of problems better than iteration
- - Can be slower, performance isn't always as efficient as an iterative solution.

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Recursion

- **Question: How many students in total are behind you in your "column" of the classroom?**

- Assume you have poor eyesight and can't simply turn around and count them all.
- You can however see the person behind you.
- How do we solve the problem recursively?

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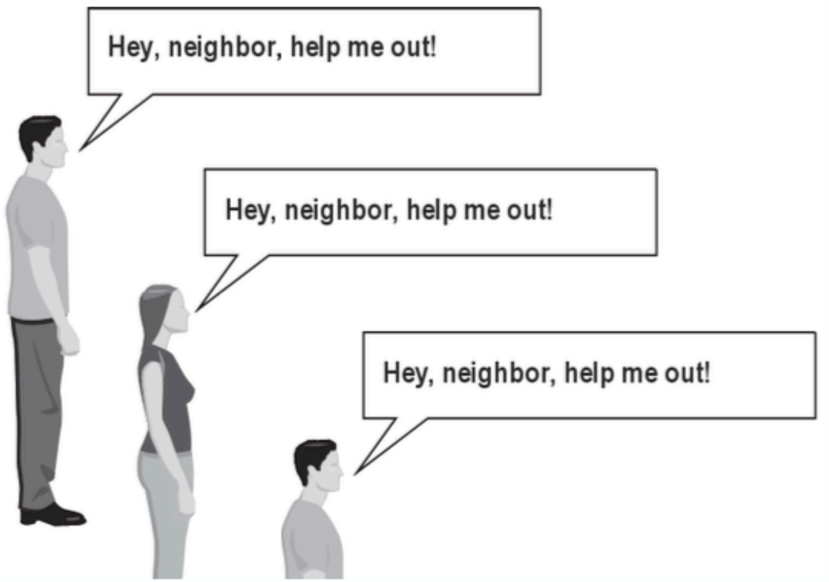
Recursion

- **Recursion breaks a bigger problem into smaller occurrences of the same problem**
- Each person solves a small part of the problem
- What's the smallest version of the problem that's easy to answer?
- What info rom a neighbour would help me?

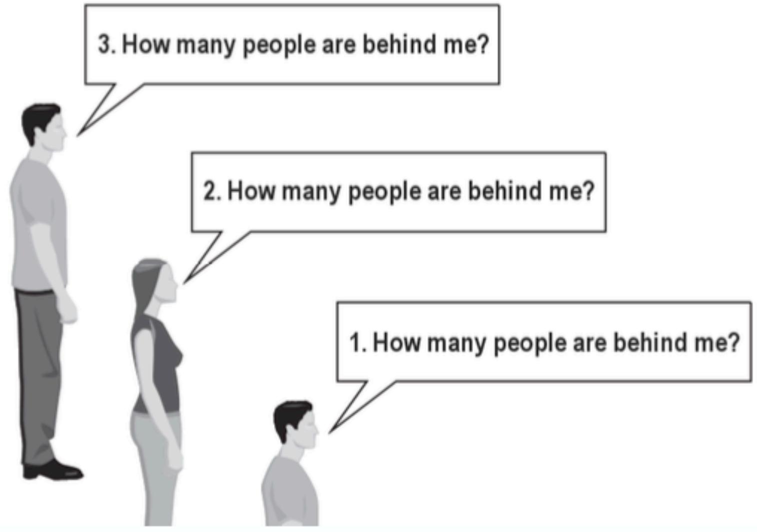


Recursion

- If there is someone behind me, ask him/her how many people behind him/her
  - When they respond with a value **N**, I will answer the person in front of me with **N + 1**

  -> Recursive Case

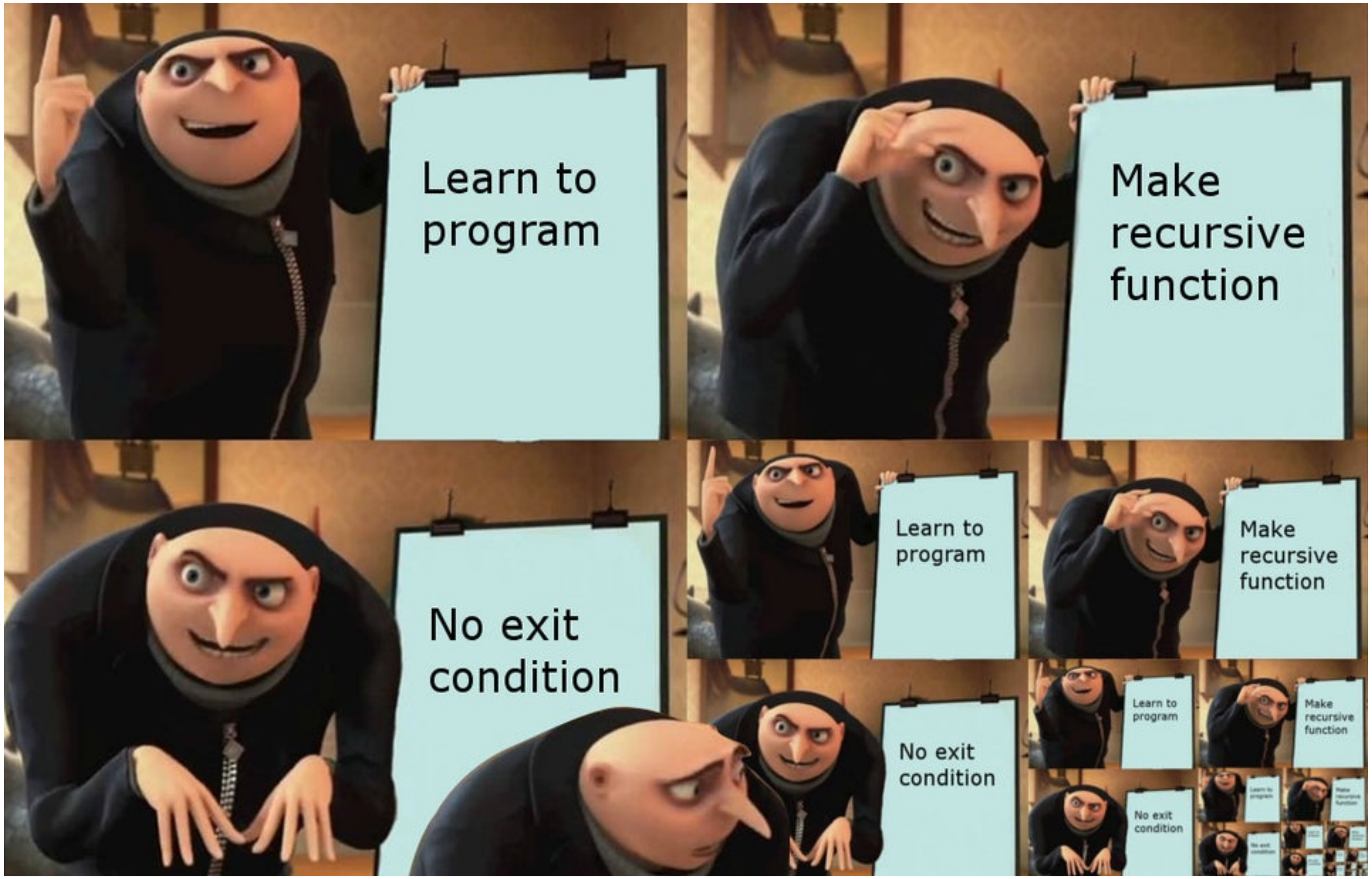
- If there's nobody behind me I will answer 0. -> Base Case



Recursion

- Every recursive algorithm involves at least 2 cases:
  - **Base Case**: A simple occurrence that can be answered directly.
  - **Recursive Case**: A more complex occurrence of the problem that cannot be directly answered, but can instead be described in terms of smaller occurrences of the same problem

Recursion



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Recursion

- **To solve a problem recursively:**
  1. Break into smaller problems
  2. Solve smaller sub-problems recursively ⟵ **Divide and Conquer**
  3. Assemble the sub-solutions

```
recursive-algorithm(input) {
    //base-case
    if  (isSmallEnough(input))
        compute the solution and return it
    else
        //recursive case
        break input into simpler instances input1, input 2,...
        solution1 = recursive-algorithm(input1)
        solution2 = recursive-algorithm(input2)
        ...
        figure out solution to this problem from solution1, solution2,...
        return solution
}
```

Recursion

- **To solve a problem recursively:**
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```

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Recursion

$\sum 5 = 5 + 4 + 3 + 2 + 1$ **OR** $\sum 5 = 5 + \sum 4$

$\sum 8 = 8 + 7 + 6 + 5 + 4 + 3 + 2 + 1$ **OR** $\sum 8 = 8 + \sum 7$

What's the formal definition?

Recursion

```
def summationI (n):
    sum = 0
    for count in range (1, n, 1):
        sum = sum + count
    return sum
```

n+1 not n

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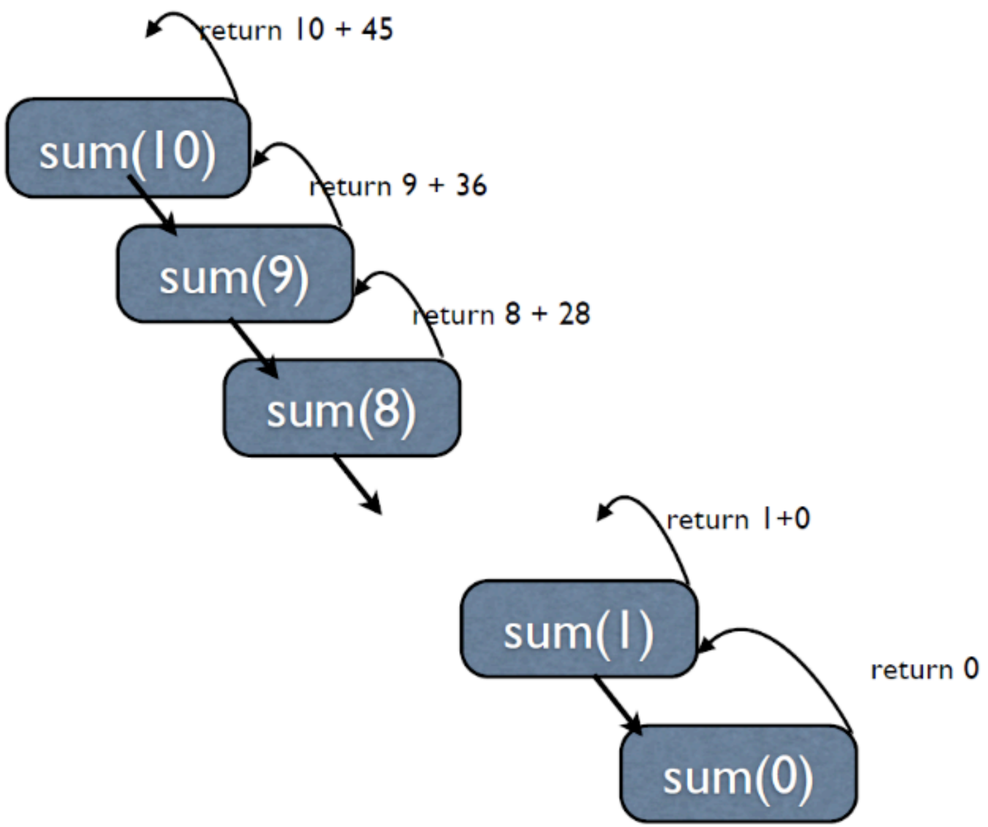
Recursion

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

Recursion



The system keeps track of the sequence of method calls that have been started but not finished yet (active calls)

Recursion

```
5! = 5 * 4 * 3 * 2 * 1        OR       5! = 5 * 4!
8! = 8 * 7 * 6 * 5 * 4 * 3 * 2 * 1    OR   8! = 8 * 7!
```

$$n! = \begin{cases} 1 & \text{if } n = 0, \\ (n-1)! \times n & \text{if } n > 0 \end{cases}$$

Base Line

Recursive Case

Recursion

```
def factorialI (n):
      fact = 1
      for count in range (2, n+1, 1):
            fact = fact * count
      return fact
```

Recursion

```
def factorialR (n):
    if n == 1:
        return 1
    else:
        return n * factorialR(n-1)

def factorialI (n):
    fact = 1
    for count in range (2, n+1, 1):
        fact = fact * count
    return fact
```

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Recursion

Let's look at some code…

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