Variable Scope

- What is the difference between the area you receive your **cellular** data signal and your **home wifi** signal?

Global Variable

```
x = 0

def foo_printx():
    print(x)

foo_printx()
print(x)
```

Refers to

- This code will print

```
0
0
```

Global vs Local Variables

```
x = 0

def foo_printx():
    x = 999
    print(x)

foo_printx()
print(x)
```

Because, a new 'x' is born here!

- This code will print

```
999
0
```

- The first '999' makes sense
- But why the second one is '0'?

Global vs Local Variables

A Global 'x'

```
x = 0

def foo_printx():
    x = 999
    print(x)

foo_printx()
print(x)
```

- This code will print

```
999
0
```

Scope of the local 'x'

Scope of the global 'x'

A local 'x' that is created within the function foo_printx() and will 'die' after the function exits

Global vs Local Variables

- A variable which is defined in the main body of a file is called a ***global*** variable. It will be **visible throughout the file**, and also inside any file which imports that file. EXCEPT…
- A variable which is defined inside a function is ***local*** to that function. It is accessible **from the point at which it is defined until the end of the function**, and exists for as long as the function is executing.
- The parameter names in the function definition behave like local variables, but they contain the values that we pass into the function when we call it.

Crossing Boundary

- What if we really want to modify a global variable from inside a function?
- Use the “global” keyword
- (No local variable x is created)

```
x = 0

def foo_printx():
    global x
    x = 999
    print(x)

foo_printx()
print(x)
```

Output:
999
999

How about… this?

```
x = 0

def foo_printx():
    print(x)
    x = 999
    print(x)

foo_printx()
```

- Local or global?
- Error!
- Because the line “x=999” creates a local version of ‘x’
- Then the first print(x) will reference a **local** x that is not assigned with a value
- The line that causes an error

Parameters are LOCAL variables

Scope of x in p1

```
def p1(x):
    print('Entering function p1')
    output = p2(x)
    print('Line before return in p1')
    return output
```

Scope of x in p2

```
def p2(x):
    print('Entering function p2')
    output = p3(x)
    print('Line before return in p2')
    return output
```

Does not refer to

Scope of x in p3

```
def p3(x):
    print('Entering function p3')
    output = x * x
    print('Line before return in p3')
    return output
```

```
print(p1(3))
```

Practices (Convention)

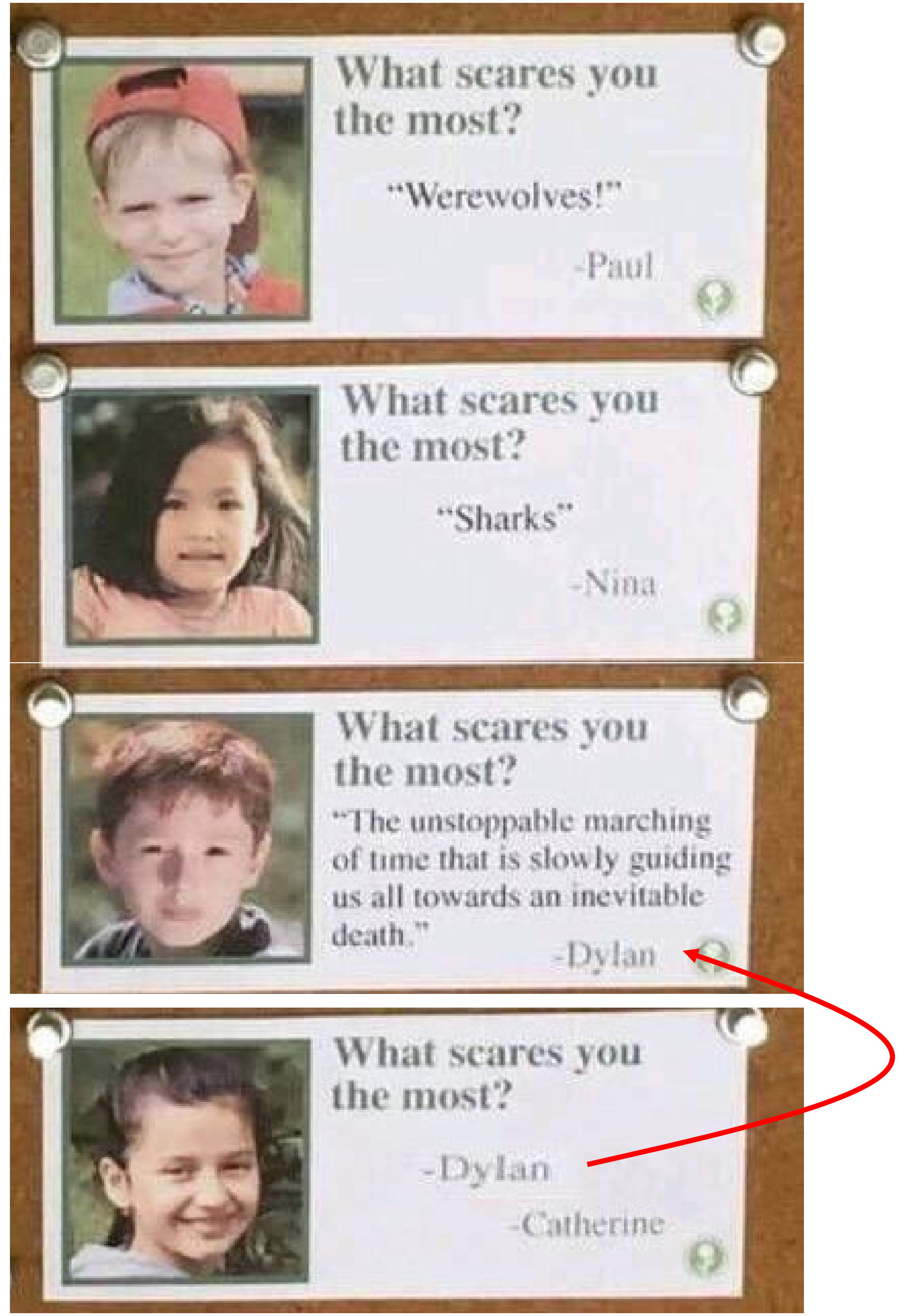
- Global variables are VERY **bad** practices, especially if modification is allowed
- 99% of time, global variables are used as CONSTANTS
  - Variables that every function could access
  - But not expected to be modified

Convention:
Usually in all CAPs

```
POUNDS_IN_ONE_KG = 2.20462

def kg2pound(w):
    return w * POUNDS_IN_ONE_KG

def pound2kg(w):
    return w / POUNDS_IN_ONE_KG
```

Calling Other Functions

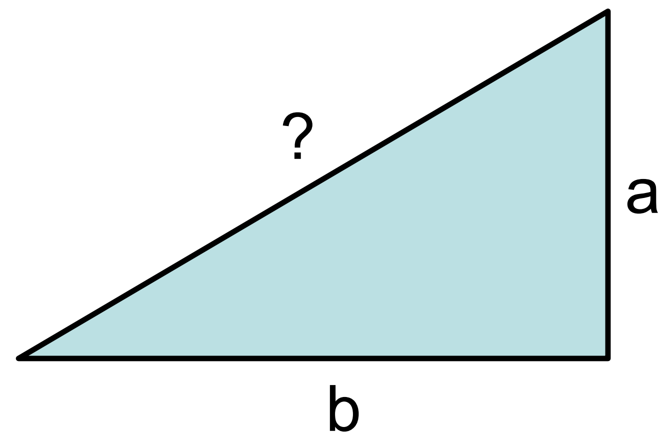
Year Book…



What scares you the most?
"Werewolves!"
-Paul
What scares you the most?
"Sharks"
-Nina
What scares you the most?
"The unstoppable marching of time that is slowly guiding us all towards an inevitable death."
-Dylan
What scares you the most?
-Dylan
-Catherine

Compare:

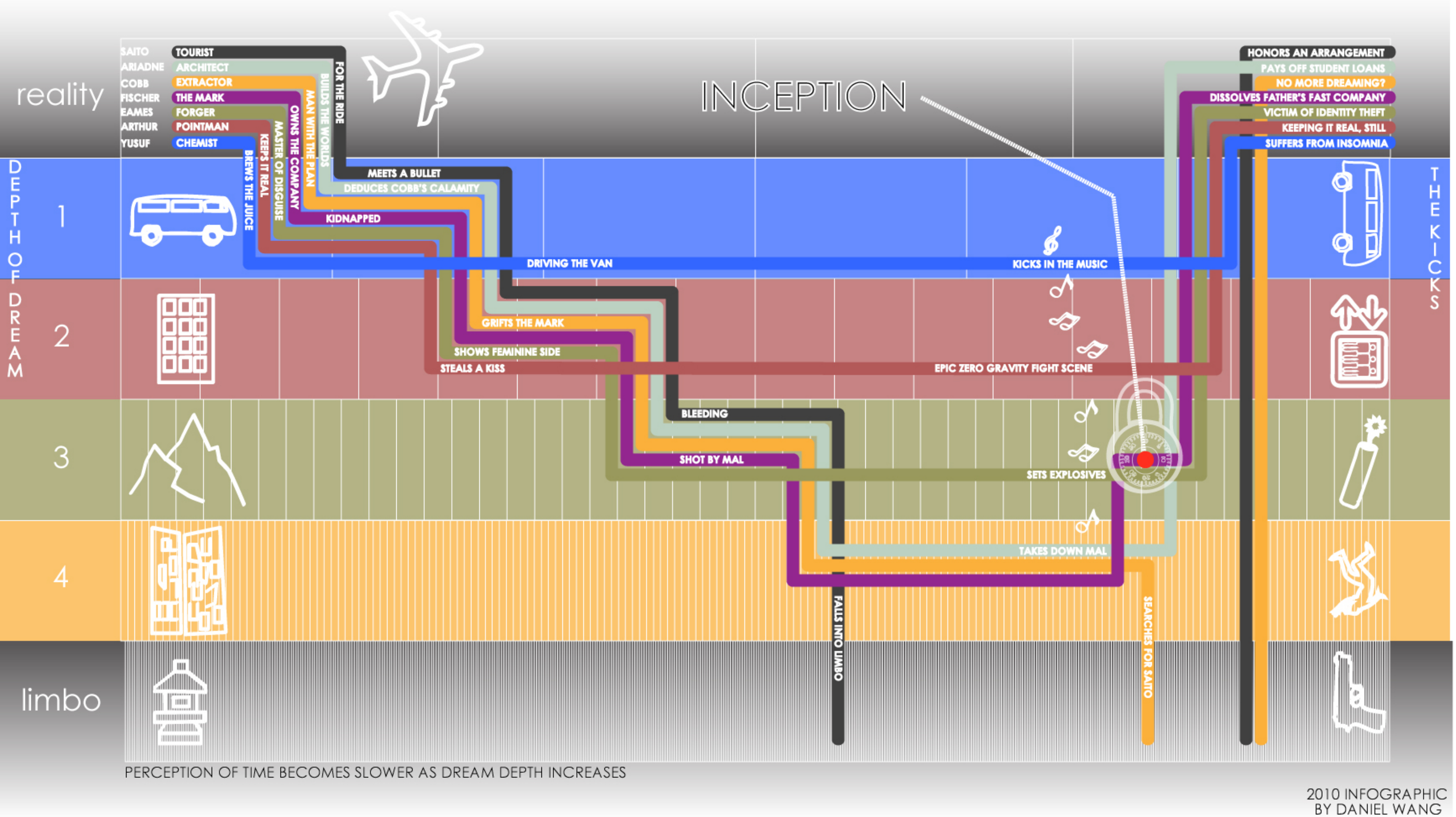
```
def hypotenuse(a, b):
    return sqrt(sum_of_squares(a, b))

def sum_of_squares(x, y):
    return square(x) + square(y)

def square(x):
    return x * x
```



Versus:

```
def hypotenuse(a, b):
    return sqrt((a*a) + (b*b))
```

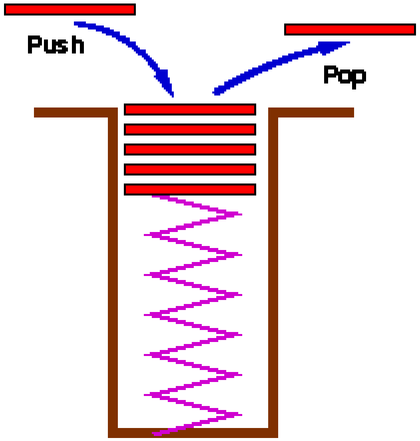
The Call Stack



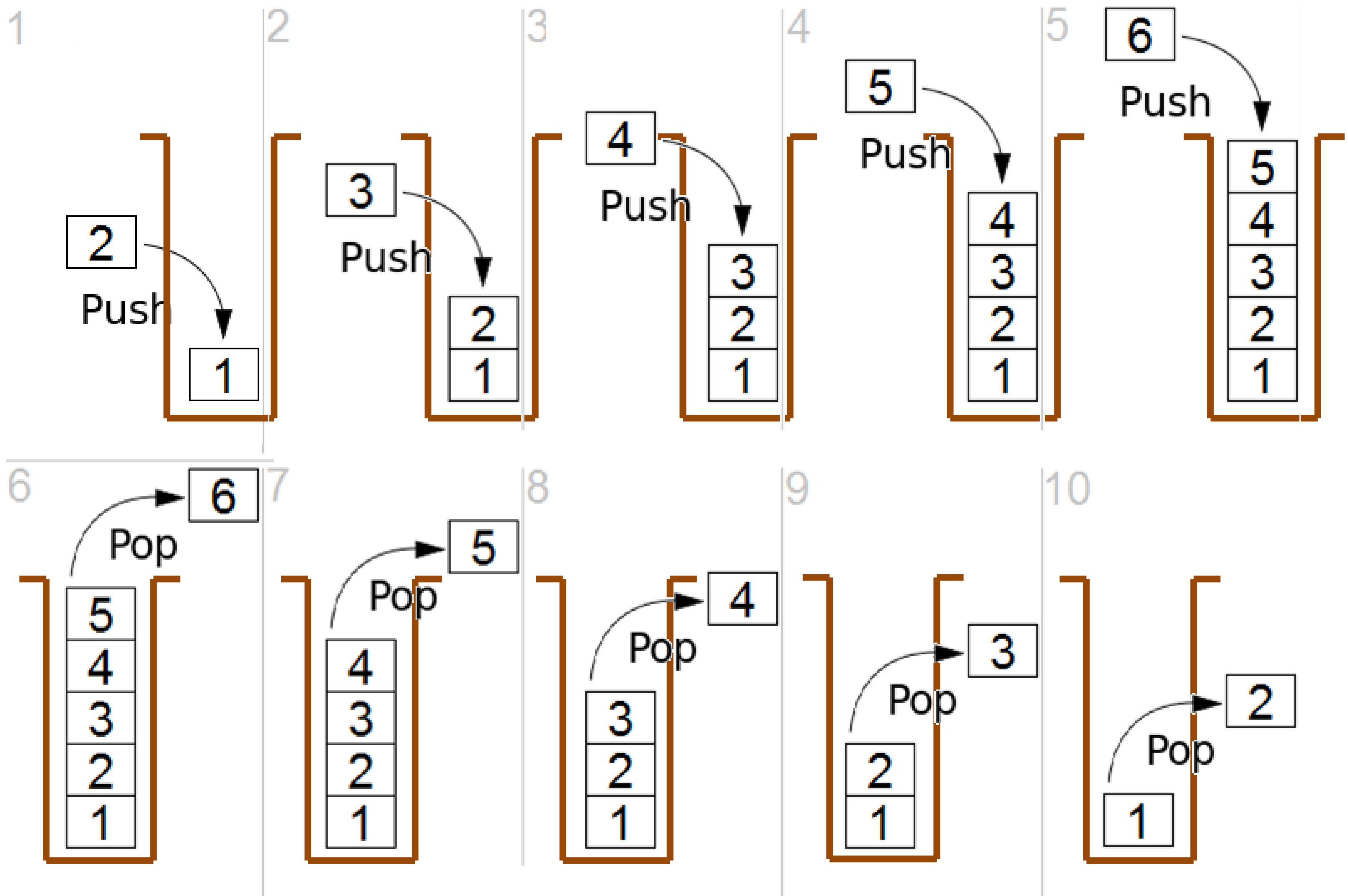
[Michael Caine Just Ended An Eight Year Long Debate Over The Ending Of "Inception"]

Stack

- First in last out order



First in Last Out



The Stack (or the Call Stack)

```python
def p1(x):
    print('Entering function p1')
    output = p2(x)
    print('Line before return in p1')
    return output


def p2(x):
    print('Entering function p2')
    output = p3(x)
    print('Line before return in p2')
    return output

def p3(x):
    print('Entering function p3')
    output = x * x
    print('Line before return in p3')
    return output


print(p1(3))
```

The Stack (or the Call Stack)

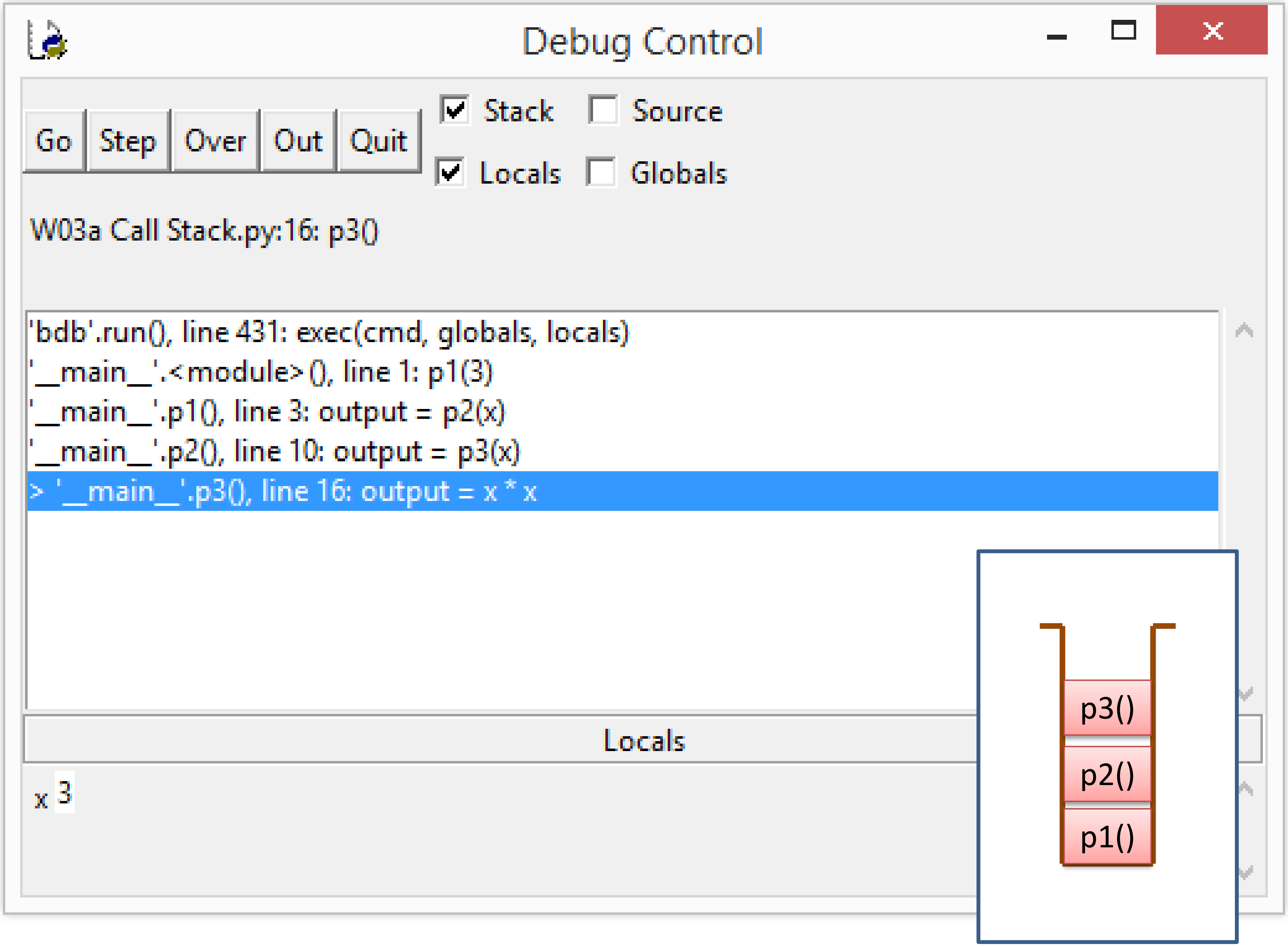
```
>>> p1(3)
Entering function p1
Entering function p2
Entering function p3
Line before return in p3
Line before return in p2
Line before return in p1
9
```

FILO!

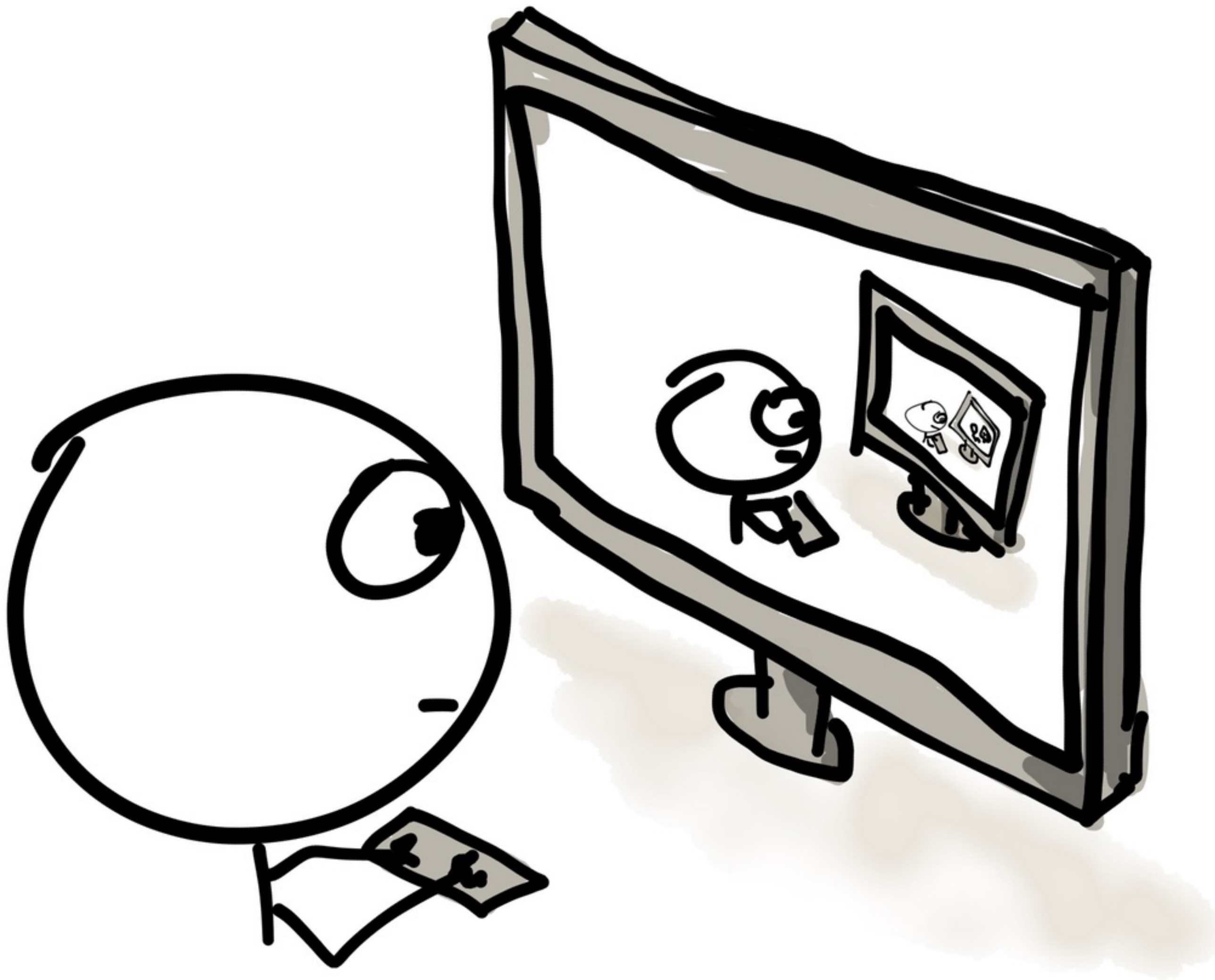
```
print(p1(3))

def p1(x):
    print('Entering function p1')
    output = p2(x)
    print('Line before return in p1')
    return output

def p2(x):
    print('Entering function p2')
    output = p3(x)
    print('Line before return in p2')
    return output

def p3(x):
    print('Entering function p3')
    output = x * x
    print('Line before return in p3'
    return output
```

Going in

Exiting a function

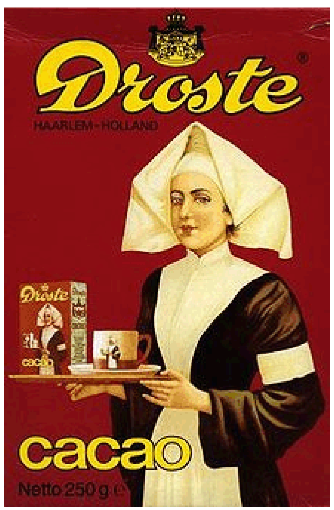

Debug Control
Go
Step
Over
Out
Quit
Stack
Source
Locals
Globals
W03a Call Stack.py:16: p3()
'bdb'.run(), line 431: exec(cmd, globals, locals)
'__main__'.<module>(), line 1: p1(3)
'__main__'.p1(), line 3: output = p2(x)
'__main__'.p2(), line 10: output = p3(x)
> '__main__'.p3(), line 16: output = x * x
Locals
x 3
p3()
p2()
p1()

Recursion

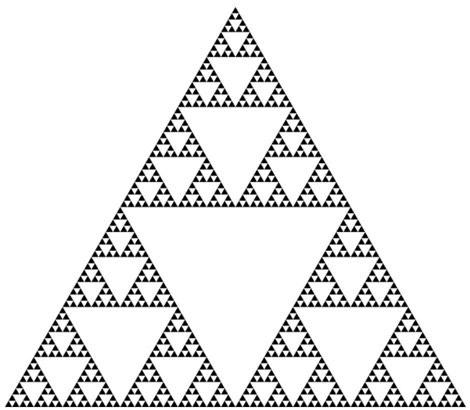


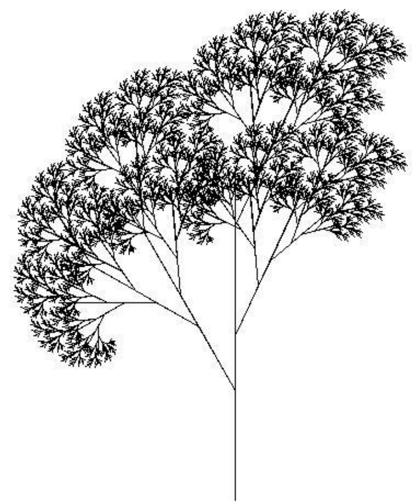
A Central Idea of CS

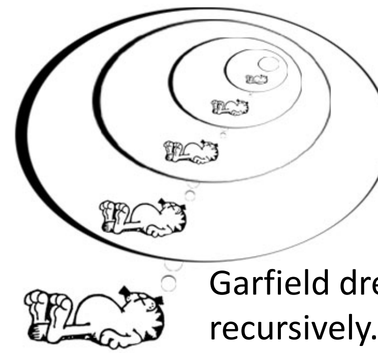
Some examples of recursion (inside and outside CS):



Droste effect


Sierpinksi triangle


Recursive tree


Garfield dreaming recursively.

[Mandelbrot Fractal Endless Zoom]

Recursion

- A function that calls itself
- And extremely powerful technique
- Solve a big problem by solving a smaller version of itself
  - Mini-me

Factorial

- The factorial n! is defined by

$$n! = 1 \times 2 \times 3 \times \cdots \times n$$

- Write a function for factorial?

```
def factorial(n):
    ans = 1
    i = 1
    while i <= n:
        ans = ans * i
        i = i + 1
    print(ans)
```

```
>>> factorial(3)
6
>>> factorial(6)
720
>>>
```

Factorial

$$n! = 1 \times 2 \times 3 \times \cdots \times n$$

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

Factorial

```
def factorial(n):
        ans = 1
        i = 1
        while i <= n:
                ans = ans * i
                i = i + 1
        print(ans)
```

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

Recursion

- Rules of recursion

Must have a **terminal** condition

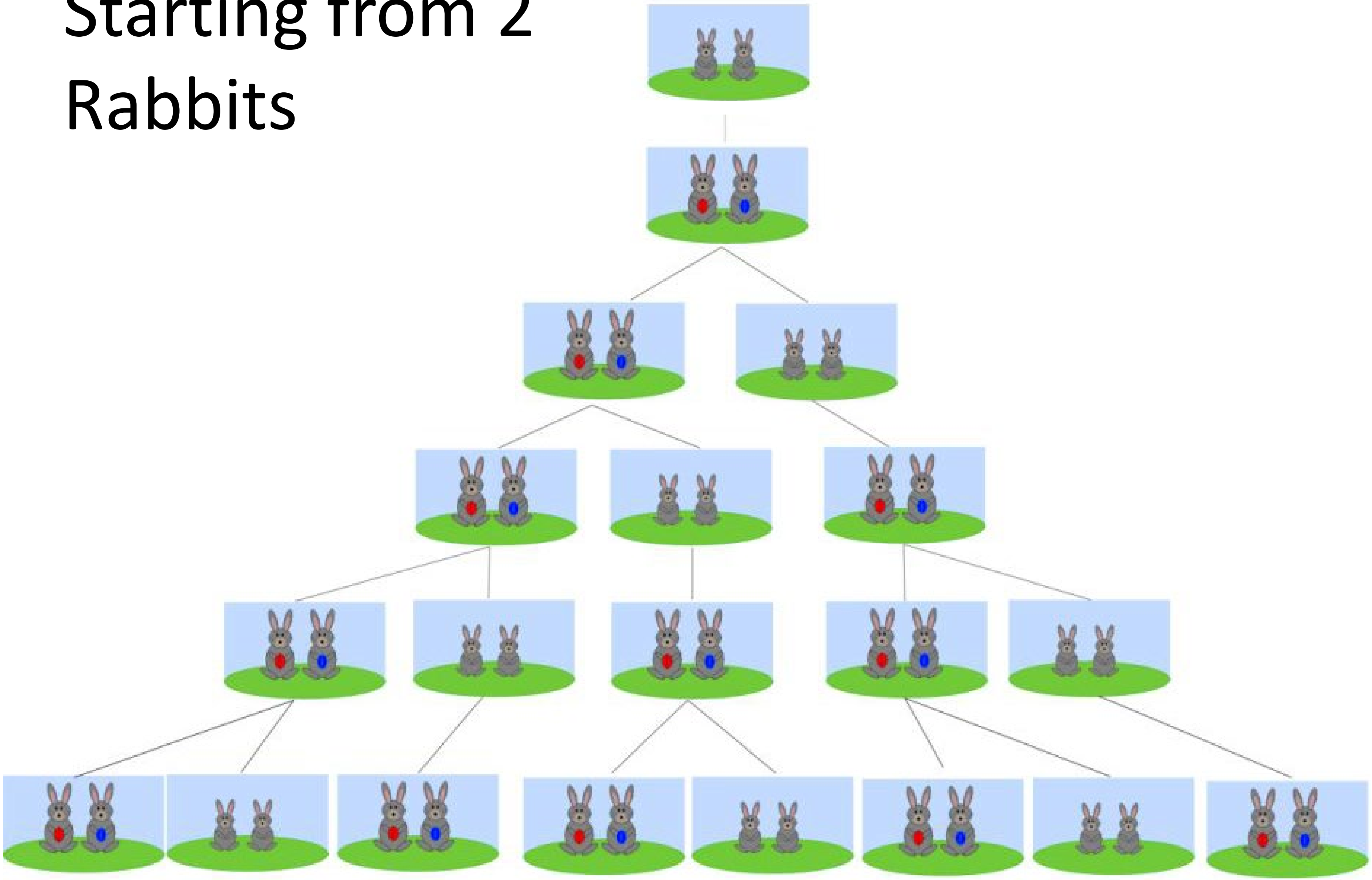
```
def factorialR(n):
    if n == 1:
        return 1
    else:
        return n * factorialR(n-1)
```

Must **reduce** the **size** of the problem for every layer

Fibonacci Number

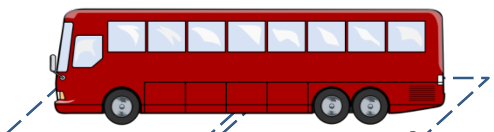
(Recursion)

Starting from 2 Rabbits



How many ways to arrange cars?

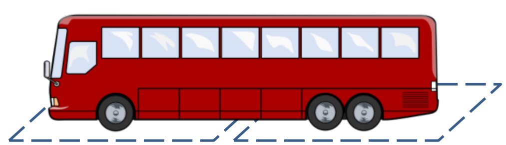
- Let's say we have two types of vehicles, cars and buses



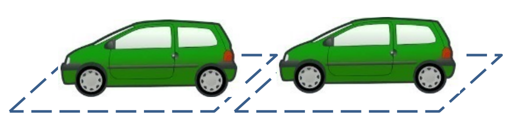
- And each car can park into one parking space, but a bus needs two consecutive ones
- If we have 1 parking space, I can only park a car

1 way

- But if there are 2 parking spaces, we can either park a bus or two cars

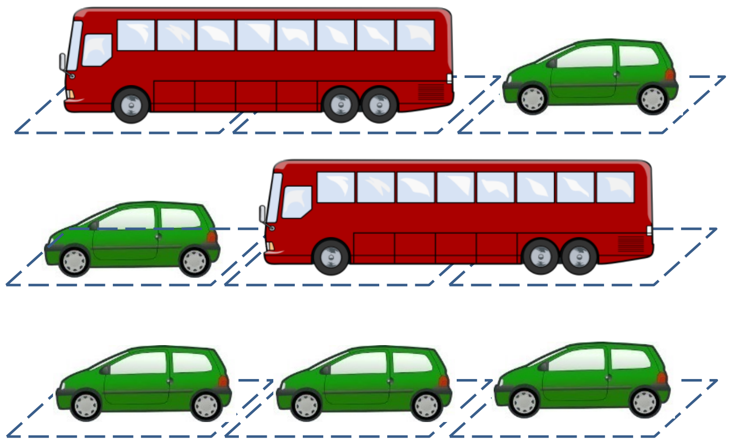


2 ways



How many ways to arrange cars?

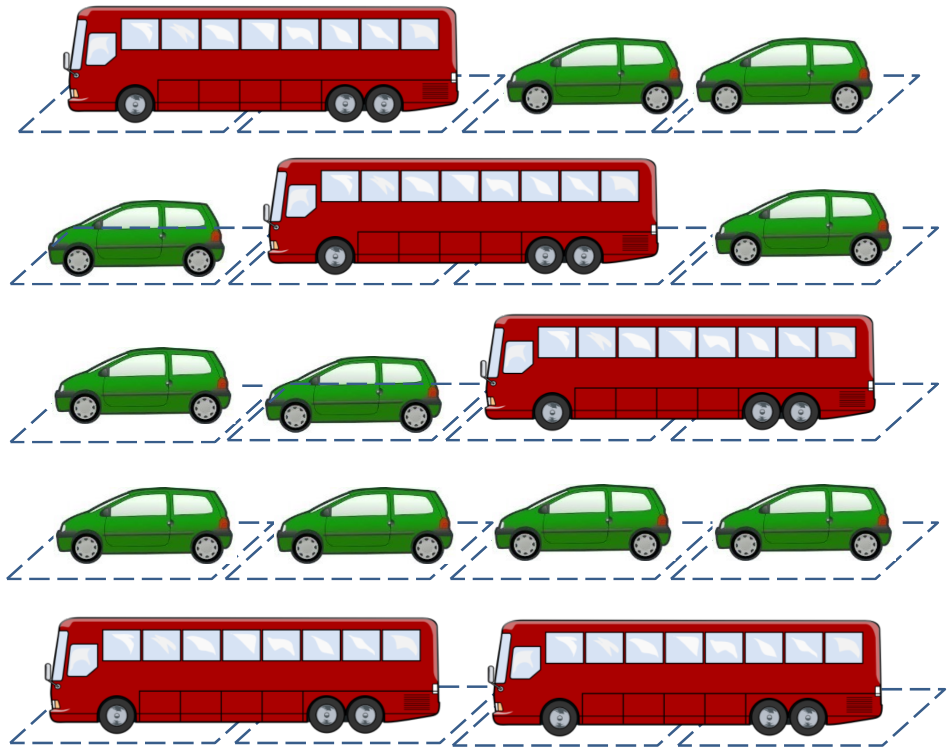
- So if we have 3 parking spaces, how many different ways can we park cars and buses?



3 ways

How many ways to arrange cars?

- So if we have 4 parking spaces, how many different ways can we park cars and buses?



5 ways

How many ways to arrange cars?

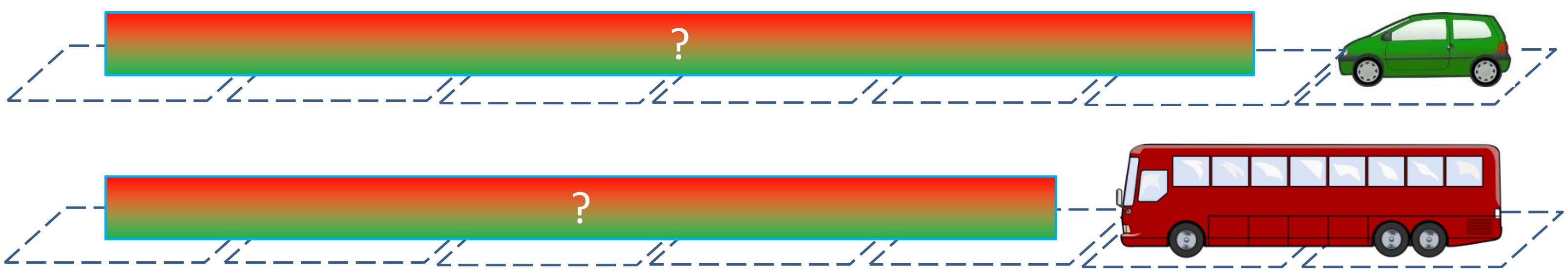
- 5 parking spaces?
- 6 parking spaces?

#parking spaces	#ways
0	1
1	1
2	2
3	3
4	5
5	8
6	13

- Can you figured out THE pattern?
  - 1, 1, 2, 3, 5, 8, 13, …
  - What is the next number?

How many ways to arrange cars?

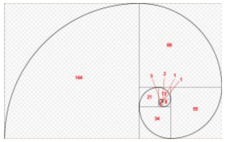
- In general, if we have n parking spaces, how many ways can we park the vehicles?
- You can think backward, the last parking space can be either a car or a bus



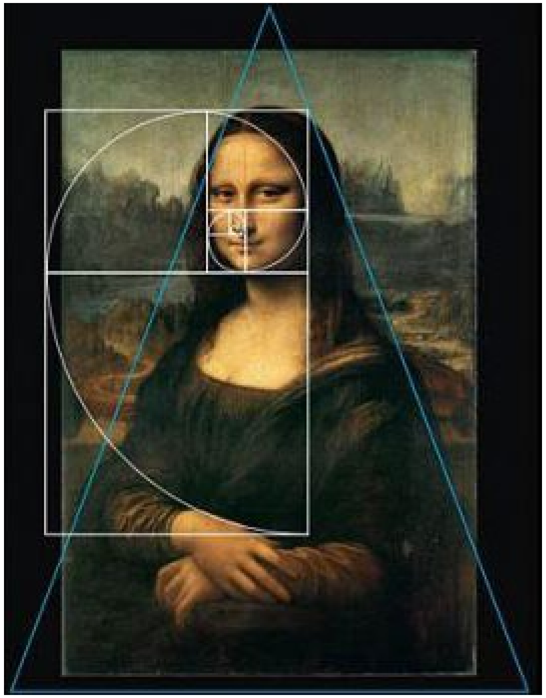
- If it's a car, there are n - 1 spaces left, you can have the number of way for n - 1 spaces
  - Otherwise, it's the number of way for n - 2 spaces
- So

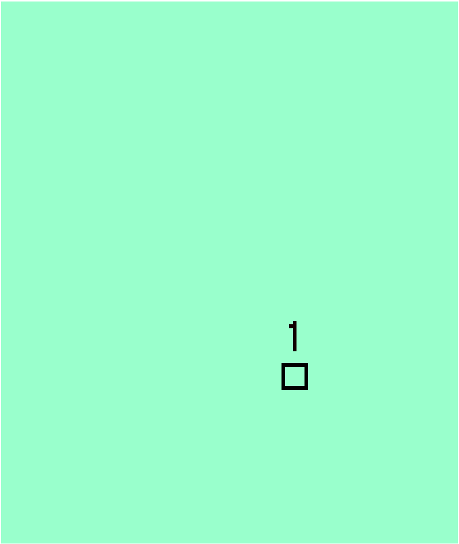
$$f(n) = f(n-1) + f(n-2) \quad \text{for } f(0) = f(1) = 1$$

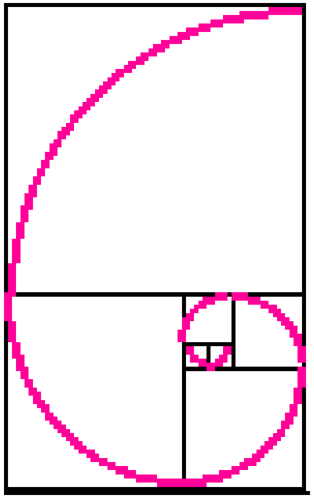
Fibonacci Numbers

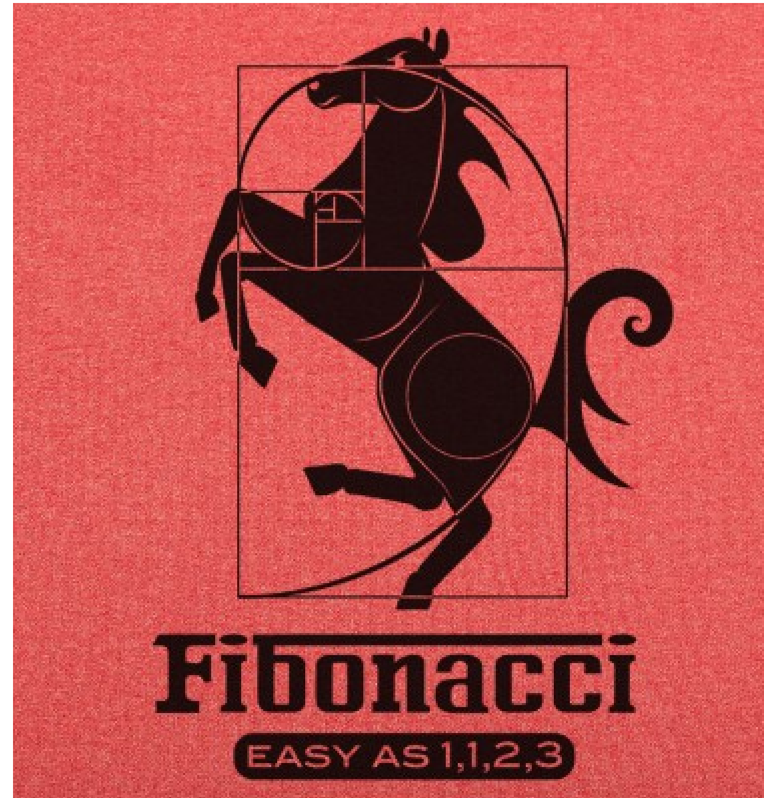


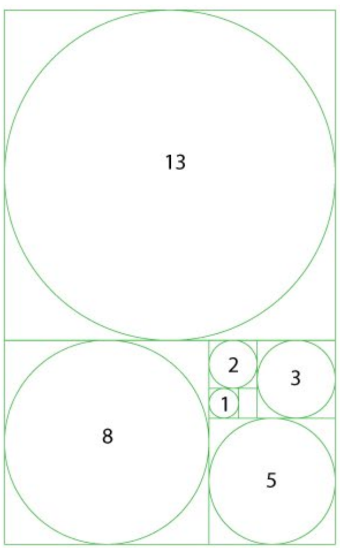
- Fibonacci numbers are found in nature (sea-shells, sunflowers, etc)
- http://www.maths.surrey.ac.uk/hosted-sites/R.Knott/Fibonacci/fibnat.html

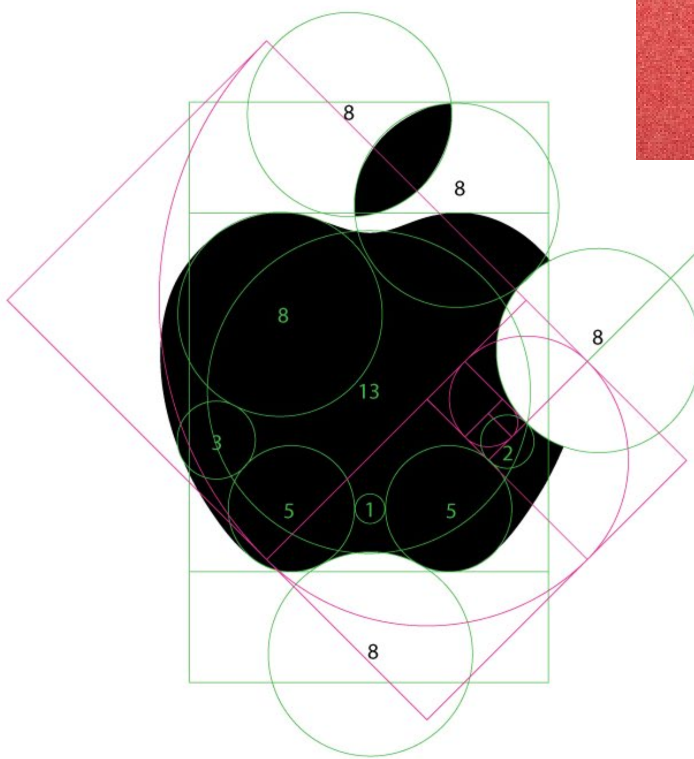







Fibonacci
EASY AS 1,1,2,3


13
2
3
1
8
5


8
8
8
8
13
3
2
5
1
5
8

```python
def fibonacci(n):
    if n == 1 or n == 0:
            return 1
    else:
            return fibonacci(n-1) + fibonacci(n-2)
```

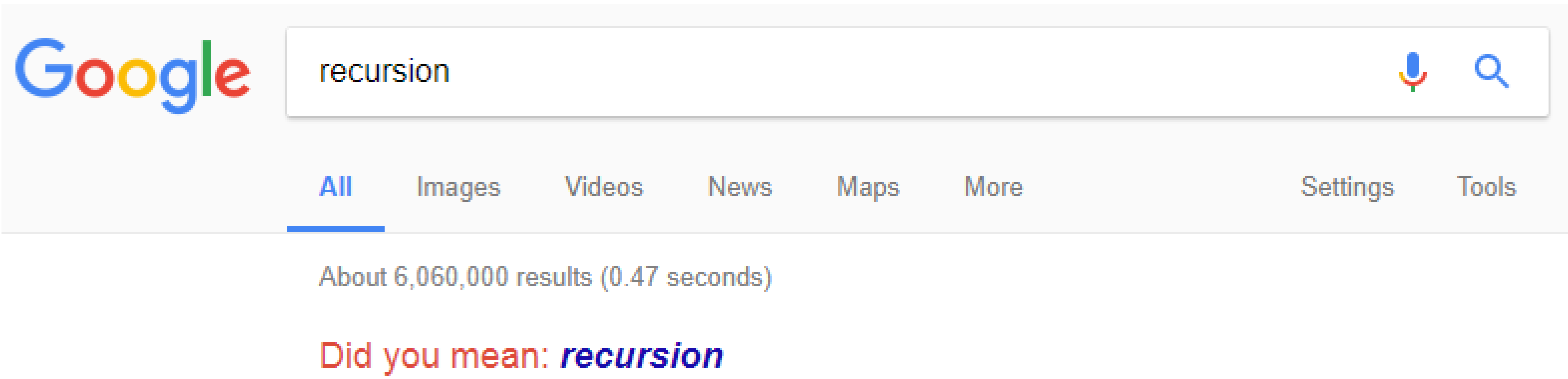
```
>>> fibonacci(10)
89
>>> fibonacci(20)
10946
>>> fibonacci(994)
Traceback (most recent call last):
  File "<pyshell#16>", line 1, in <module>
    fibonacci(994)
  File "<pyshell#5>", line 5, in fibonacci
    return fibonacci(n-1) + fibonacci(n-2)
  File "<pyshell#5>", line 5, in fibonacci
    return fibonacci(n-1) + fibonacci(n-2)
  File "<pyshell#5>", line 5, in fibonacci
    return fibonacci(n-1) + fibonacci(n-2)
  [Previous line repeated 989 more times]
  File "<pyshell#5>", line 2, in fibonacci
    if n == 1 or n == 0:
RecursionError: maximum recursion depth exceeded in comparison
>>> fibonacci(50)
```

Challenge

- Write a fibonacci function that can compute f(n) for n > 1000

```
>>> fibonacci(1000)
703303677114228158218352548771835497701812698363587327426049050871545371181969335797422494945626117334877504492417659910881863632654502236471060120533741212738673391111981393731255987676900919022452453234035
01
>>> fibonacci(2000)
683570225957580664704539654917058010705540802936552456540755336779808245440805401495453431895311380272660372676952344747823819219271452667793994333830610140510541481970566409090181363729645376709552810486826470491443352935557914873104468563413548773589795462984251694710149425357586969989340097653954574021481981915195208508953842295456514672038375212197211572576114175911499044897894137003091240157341822149659282262
6
```

Google about Recursion



- Try to search these in Google:
  - Do a barrel roll
  - Askew
  - Anagram
  - Google in 1998
  - Zerg rush
- More in Google Easter Eggs