# Information, Computation, Communication

# Learning Python

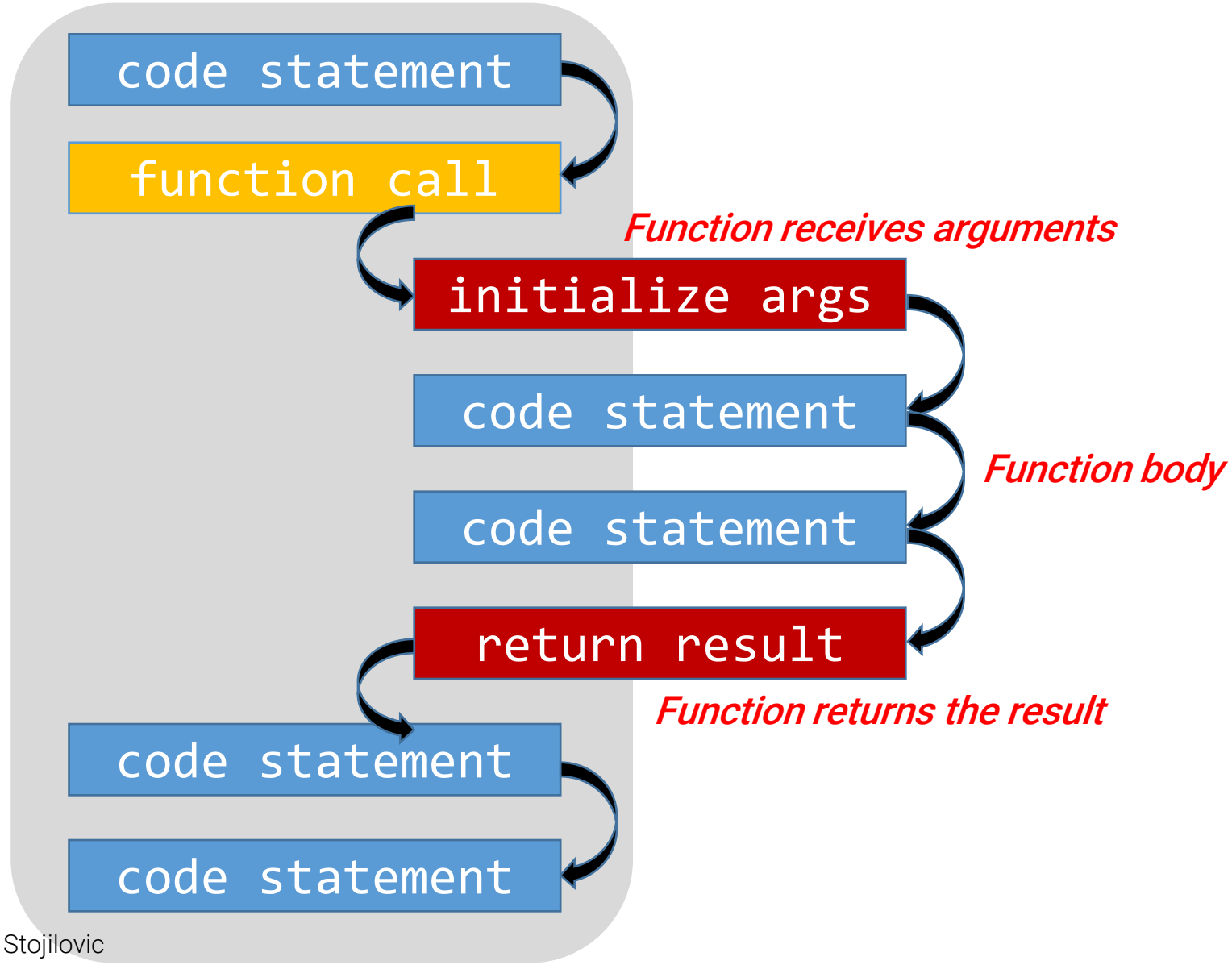
## Functions – Part II

# Quick Reminder: Functions

- Group lines of code in a way that allows reuse without repetition
  - High code reuse
  - High code readability
  - Low code redundancy
  - Low number of error sources
  - High code maintainability

```
def name(arg1, arg2, …, argN):
    code
    return result
```

# Program Flow When Calling a Function



# Agenda

- Variable scope
  - Local variables
  - Global variables
  - Function arguments of mutable types

Recursive functions

  - Definition
  - Program flow
  - Advantages and disadvantages
  - Example

- Importing functions from files

# Variable Scope

## Local Variables

# Local Variables

- A variable is **local to the function**
  - if it is created **inside its** body or
  - if it is one of its **arguments**

- Local variables are
  - **created** when the function is **called** and
  - **destroyed** when the function **terminates**

# Example 1: Local Variables

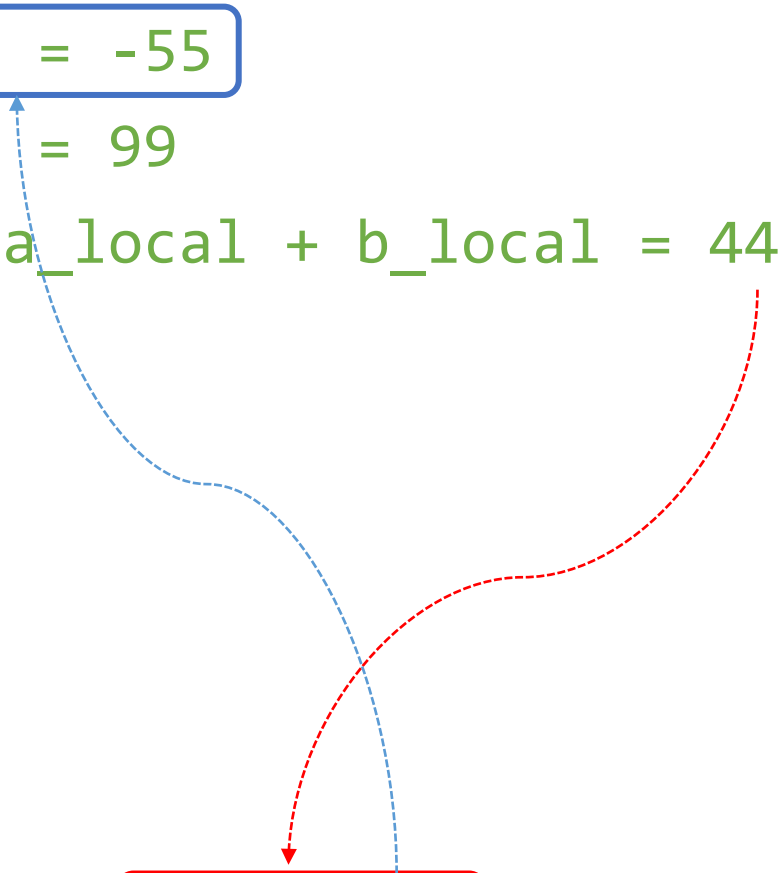
What does this code output?

```
def f_sum(a):
    b = 99
    return a + b

a = 1    # an integer variable
b = 100  # an integer variable
c = -55  # an integer variable

print(a, b, c) # 1 100 -55
print(f_sum(c), a, b, c)  # print(f_sum(-55), 1, 100 -55)
```

# Example 1: Local Variables

What does this code output?

```
def f_sum(a):                  # a_local = -55
    b = 99                     # b_local = 99
    return a + b               # return a_local + b_local = 44


a = 1
b = 100
c = -55

print(a, b, c) # 1 100 -55
print(f_sum(c), a, b, c)  # print(f_sum(-55), 1, 100 -55)
                          # 44 1 100 -55
```



# Variable Scope

## Global Variables

# Global Variables

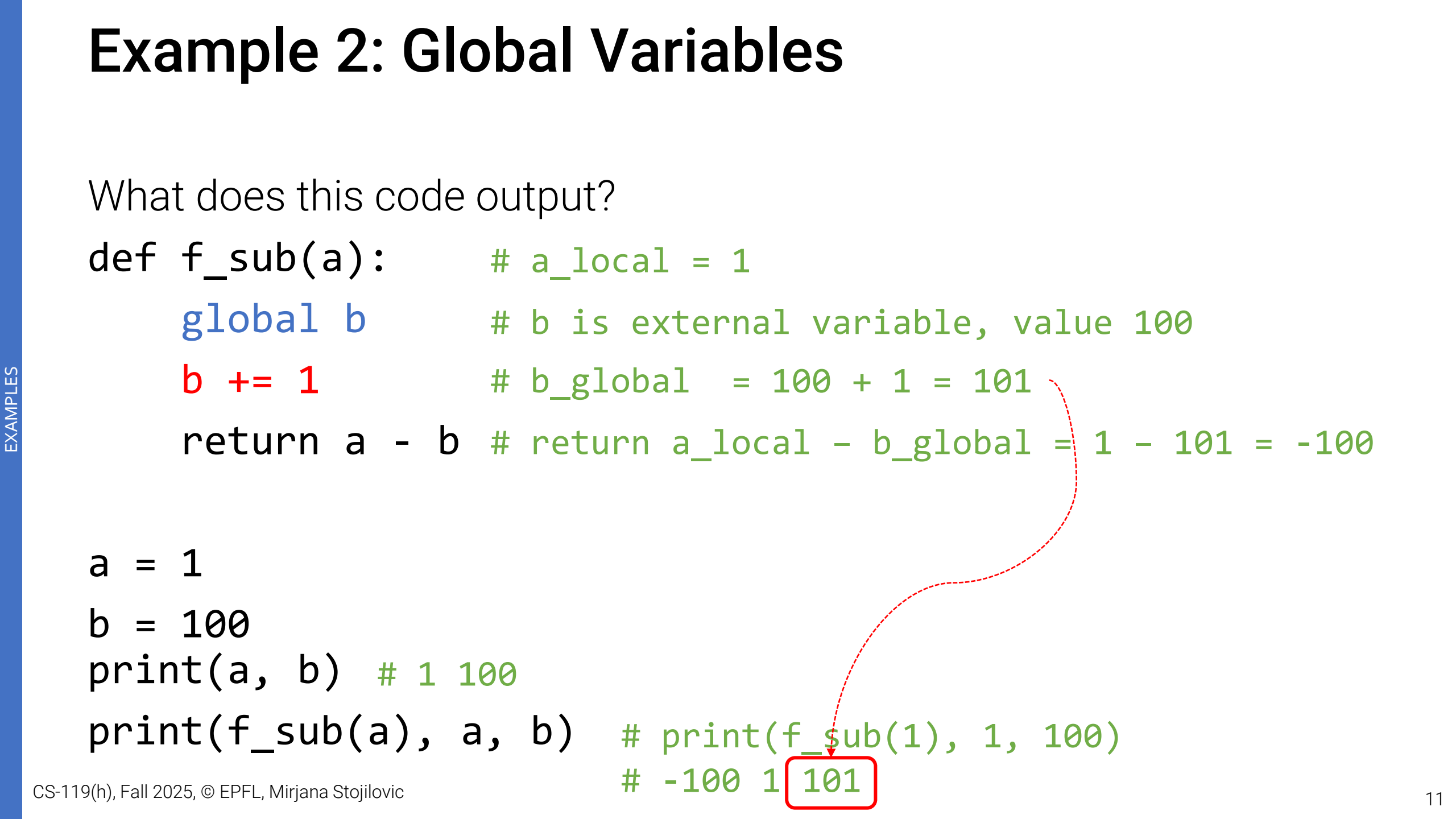
- A variable is **external** with respect to the function if it is created **outside** it and outside any other function body

- Normally, a function cannot modify an external variable
- For a function to gain access to an external variable (and, for example, modify it), the function body must include the keyword **global** alongside the variable name

# Example 2: Global Variables

What does this code output?

```
def f_sub(a):       # a_local = 1
    global b        # b is external variable, value 100
    b += 1          # b_global  = 100 + 1 = 101
    return a - b    # return a_local - b_global = 1 - 101 = -100


a = 1
b = 100
print(a, b)  # 1 100
print(f_sub(a), a, b)   # print(f_sub(1), 1, 100)
                        # -100 1 101
```



# Example 3: Global Variables

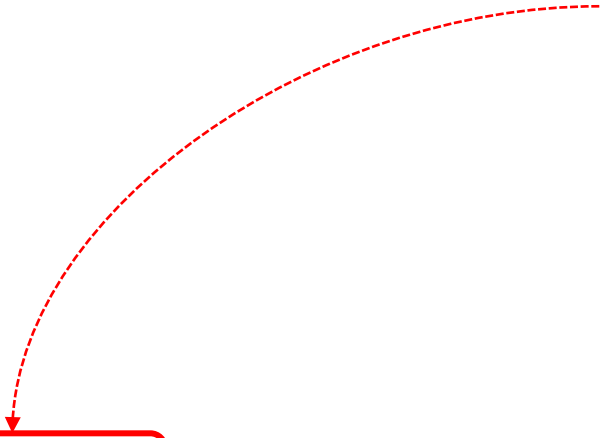
What does this code output?

```
def f_sub(a):
    global b
    a += 1
    return a - b


a = 1
b = 100
print(a, b)  # 1 100
print(f_sub(a), a, b)  # print(f_sub(1), 1, 100)
```

# Example 3: Global Variables

What does this code output?

```
def f_sub(a):       # a_local = 1
    global b        # b is external variable, value 100
    a += 1          # a_local = 1 + 1 = 2
    return a - b    # return a_local - b = 2 - 100 = -98


a = 1
b = 100
print(a, b)  # 1 100
print(f_sub(a), a, b)   # print(f_sub(1), 1, 100)
                        # -98 1 100
```



# Variable Scope

## Function Arguments of Mutable Types (i.e., lists, sets, dictionaries)

# What if Arguments are Lists/Sets/Dictionaries?

## Mutable Types

If arguments are of mutable type, functions **can** modify the external variables they correspond to

```
def f_extender(my_list, factor):
    my_list *= factor       # external list gets modified
```

# What if Arguments are Lists/Sets/Dictionaries?

## Mutable Types

EXAMPLES

If arguments are of mutable type, functions can modify the external variables they correspond to

```
def f_extender(my_list, factor):
    my_list *= factor       # external list gets modified

numbers = ['N', 0, 'v']

f_extender(numbers, 2)
# numbers = ['N', 0, 'v', 'N', 0, 'v']

f_extender(numbers, 2)
# numbers = ['N',0,'v','N',0,'v','N',0,'v','N',0,'v']
```

# Variable Scope

## Summary

If function **arguments** have the following types

- **Immutable: Boolean, integer, string, floating-point numbers**
  - All changes made inside the function remain local to the function (i.e., last until the function returns/terminates and do not affect any external variable)
- **Mutable: Lists, dictionaries, sets**
  - All changes made inside the function are persistent (i.e., last even after the function returns/terminates and affect external variables)

## Global variables

- Functions can use (read, modify) a variable created outside this and any other function, provided the keyword **global** precedes it

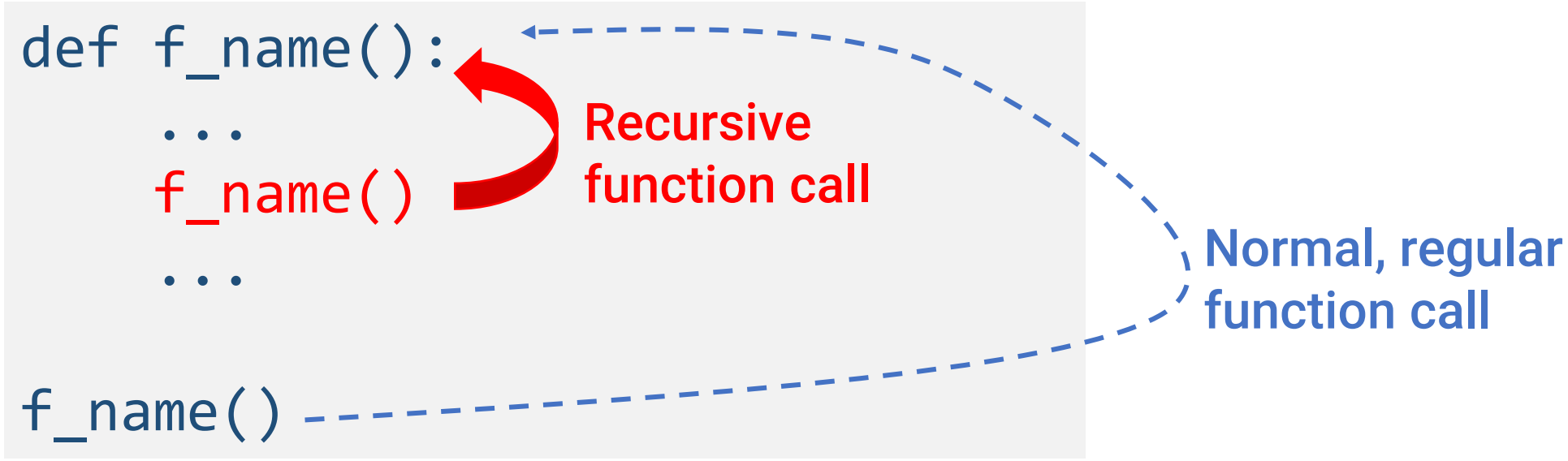
## Local variables

- Variables created inside the function; they can only be used by the function and last (we also say **live**) until the function returns/terminates

# Recursive Functions

# Recursive Functions

- Recursive functions are the functions that call themselves



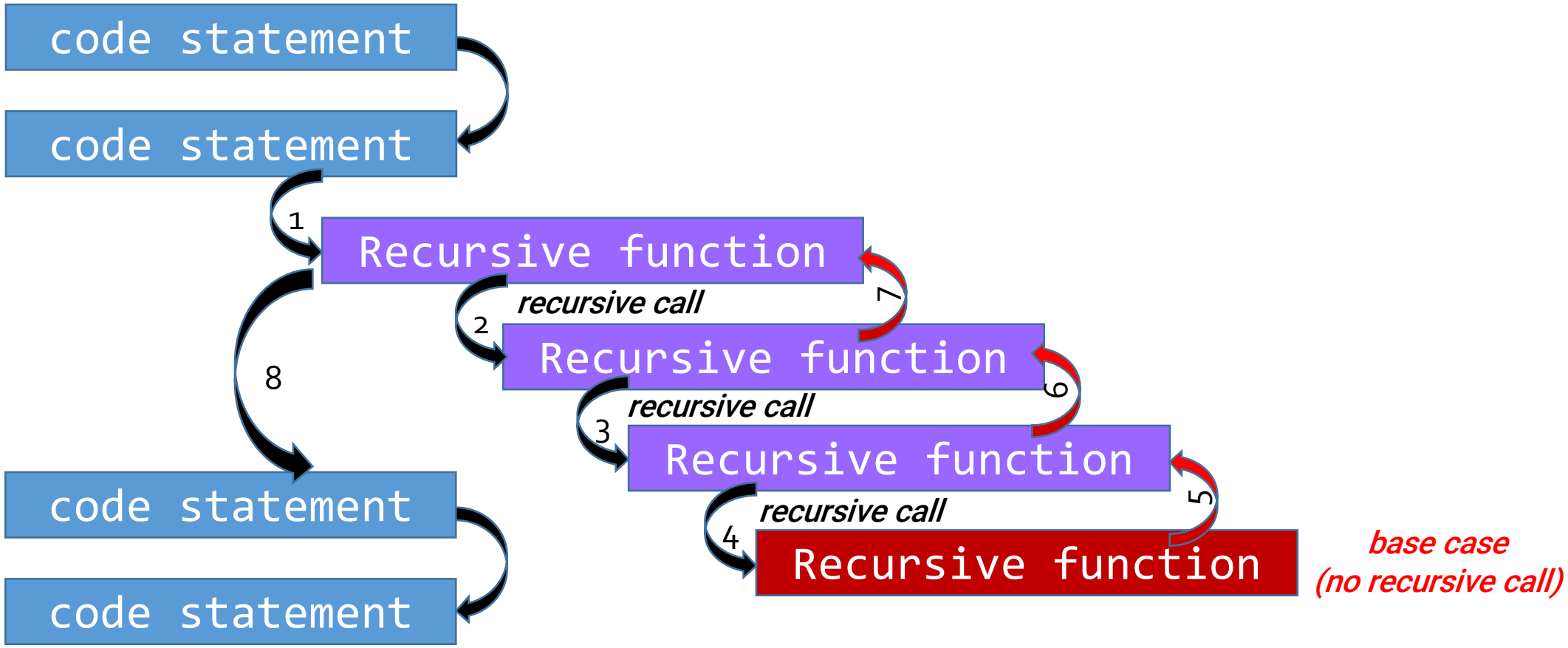
# Recursive Functions

- Recursive functions are the functions that call themselves
- Every recursive function must have a **base condition** that stops recursion, or else the function calls itself indefinitely
  - *Analogous to preventing infinite loops*
- In Python, by default, max recursive calls is limited to 1000; past that number, **RecursionError** occurs

# Pros and Cons of Recursive Functions

- Advantages
  - Code is clean and elegant
  - Complex task is broken into simpler repetitive subproblems
- Disadvantages
  - Sometimes, the logic behind recursion is hard to follow
  - Recursive calls are expensive: they take up memory and run time
  - Hard to debug

# Recursive Functions: Program Flow



# Example: Recursion


**f(a, b)** is a recursive function to calculate the sum of elements in list **a,** from index **b** down to index 3. What does this code output?

```
def f(a, b):
    # Base case
    if b < 3:           # if b < 3, stop the recursion and return 0
        return 0        # 2nd return: 0 is a neutral value for the sum
    # Recursive step: add the list element at index b to
    # the sum of all elements from index b-1 down to …
    res = a[b] + f(a, b - 1)
    return res          # 1st return

s = [2, 7, 1, 4, 6, 9, 4, 3, 0, 0]
# Call the function f starting from index 8 and print the result
print(f(s, 8))
```

# Recursion: Solution

**All function calls (six recursive, one base)**


**s = [2, 7, 1, 4, 6, 9, 4, 3, 0, 0]**

1) f(s, 8) = s[8] + f(s, 7)
2) f(s, 7) = s[7] + f(s, 6)
3) f(s, 6) = s[6] + f(s, 5)
4) f(s, 5) = s[5] + f(s, 4)
5) f(s, 4) = s[4] + f(s, 3)
6) f(s, 3) = s[3] + f(s, 2)
7) f(s, 2) = 0

```
def f(a, b):
    if b < 3:
        return 0
    res = a[b] + f(a, b - 1)
    return res

s = [2, 7, 1, 4, 6, 9, 4, 3, 0, 0]
print(f(s, 8))
```

*Once we have reached the end of the recursion, we can start computing the intermediate values*

# Recursion: Solution

## Computing the result


**s = [2, 7, 1, 4, 6, 9, 4, 3, 0, 0]**

1) f(s, 8) = s[8] + f(s, 7)
2) f(s, 7) = s[7] + f(s, 6)
3) f(s, 6) = s[6] + f(s, 5)
4) f(s, 5) = s[5] + f(s, 4)
5) f(s, 4) = s[4] + f(s, 3)
6) f(s, 3) = s[3] + f(s, 2)
7) f(s, 2) = 0

1) f(s, 8) = s[8] + f(s, 7) **= 0 + 26 = 26**
2) f(s, 7) = s[7] + f(s, 6) **= 3 + 23 = 26**
3) f(s, 6) = s[6] + f(s, 5) **= 4 + 19 = 23**
4) f(s, 5) = s[5] + f(s, 4) **= 9 + 10 = 19**
5) f(s, 4) = s[4] + f(s, 3) **= 6 + 4 = 10**
6) f(s, 3) = s[3] + f(s, 2) **= 4 + 0 = 4**
7) f(s, 2) **= 0**

*Once we have reached the end of the recursion, we can start computing the intermediate values, one by one*

# Importing Functions

Python allows us to write functions in separate files and then use/import them in our scripts

# Importing Functions from Files

- Importing **one** function from a file

```
from file_name import func_name
```

- Importing **several** functions from a file

```
from file_name import func_name_1, func_name_2
```

- Importing **all** functions from a file

```
from file_name import *
```

*Important: The file containing function definitions should reside in the same directory as your script that is using those functions*

# Importing Functions from Files

```
def multiply (what, times):
    return what * times
```

funcMultiply.py

```
# How to link this function call and
# the correct function definition?
x = multiply(3, 4) # x = 12
x = multiply(2, 3) # x = 6
```

myScript.py

EXAMPLES

# Importing Functions from Files

```
def multiply (what, times):
    return what * times
```

funcMultiply.py

```
from funcMultiply import multiply

x = multiply(3, 4) # x = 12
x = multiply(2, 3) # x = 6
```

myScript.py

# Next topic:
# Tuples and Sets