

Sistemi Operativi I

Corso di Laurea in Informatica
2023-2024



SAPIENZA
UNIVERSITÀ DI ROMA

Gabriele Tolomei

Dipartimento di Informatica

Sapienza Università di Roma

tolomei@di.uniroma1.it

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 - abstract from actual physical (HW) resources
 - ease the interaction between users and HW resources
- Different OS designs depending on how those services are implemented
 - monolithic, layered, microkernel, hybrid, etc.

Part II: Process Management

Program vs. Process

- A **program** is an executable file which resides on the persistent memory (e.g., disk),
 - contains only the set of instructions to accomplish a specific job
 - e.g., the `ls` program is an executable file stored at `/bin/ls` on the disk of a UNIX-like OS

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program → "static/passive" vs. **process** → "dynamic/active"

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Process

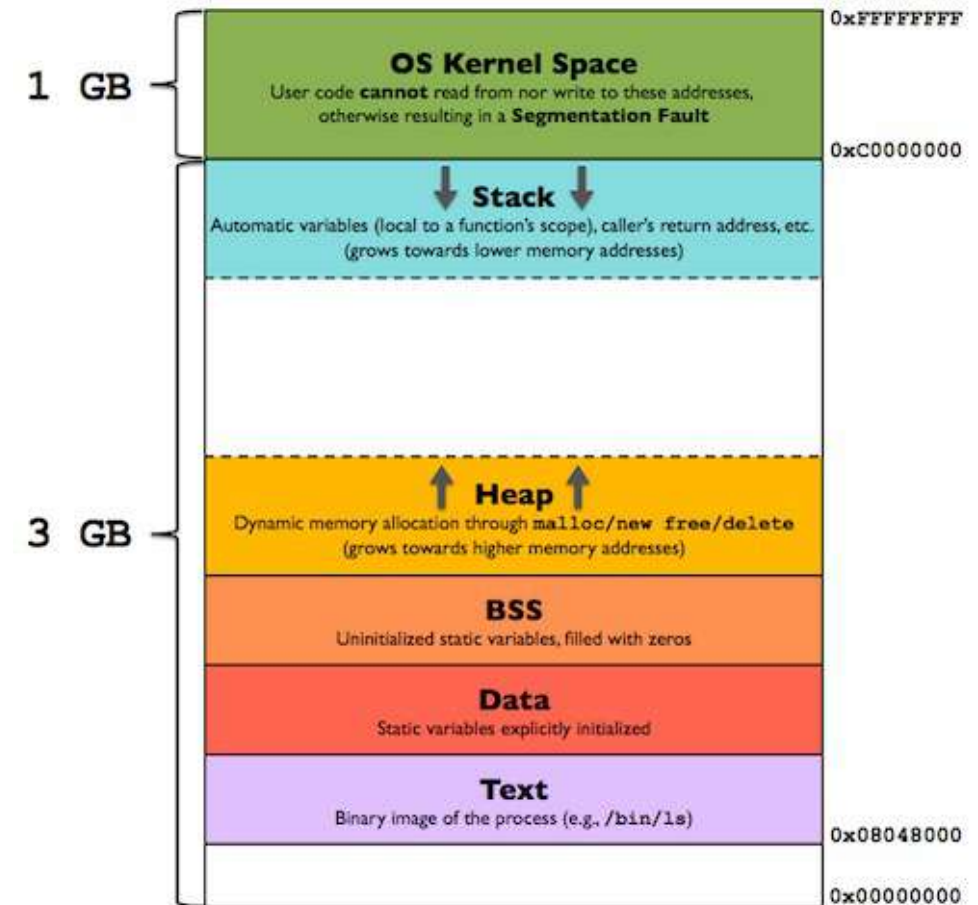
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- Process is dynamic, whilst a program is static (code and data only)
- Several processes may run the same program (e.g., multiple Google Chrome instances) but each has its own state
- A process executes one instruction at a time, sequentially

OS Process Management

- How are processes represented in the OS?
- What are the possible states a process may be in and how the system moves from one state to another?
- How are processes created in the OS?
- How do processes communicate with each other?

Process: Virtual Address Space Layout

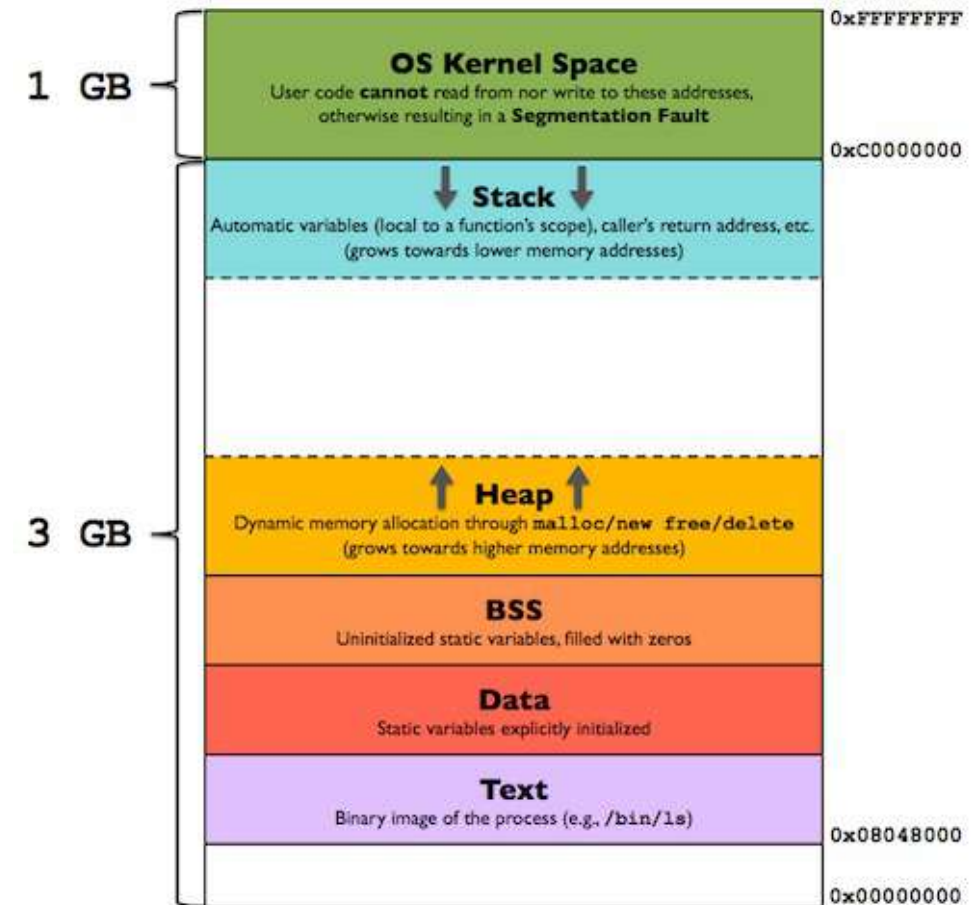
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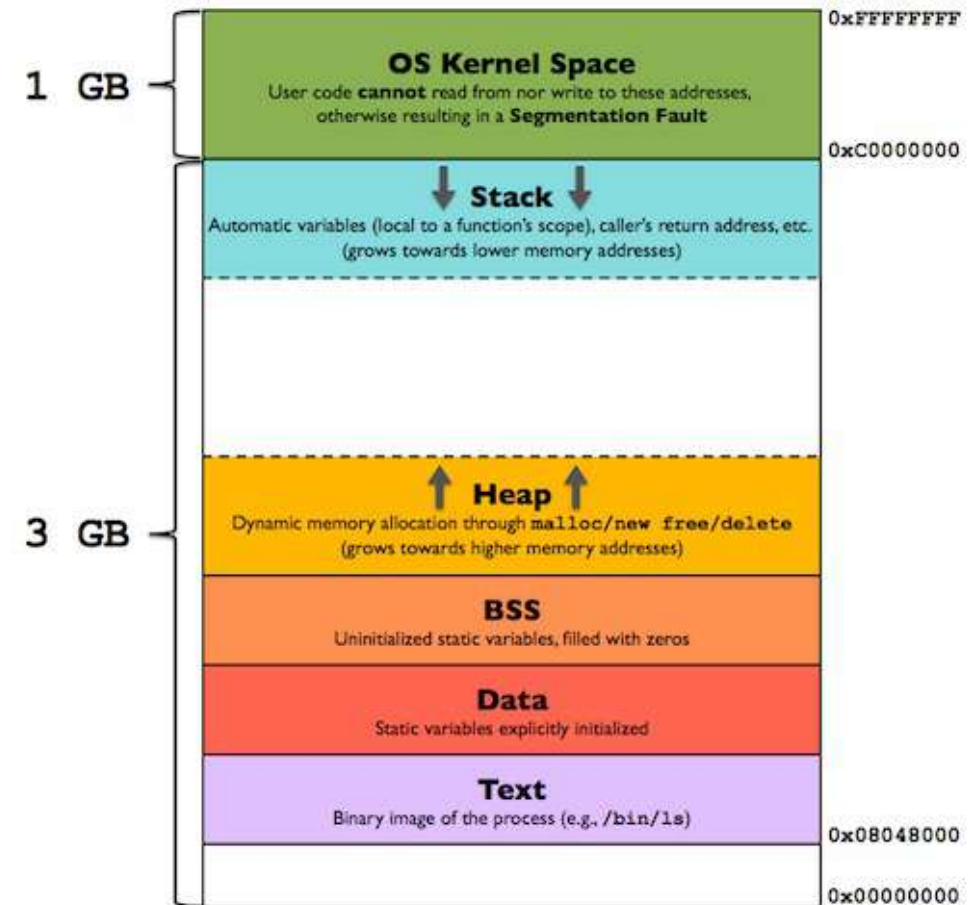


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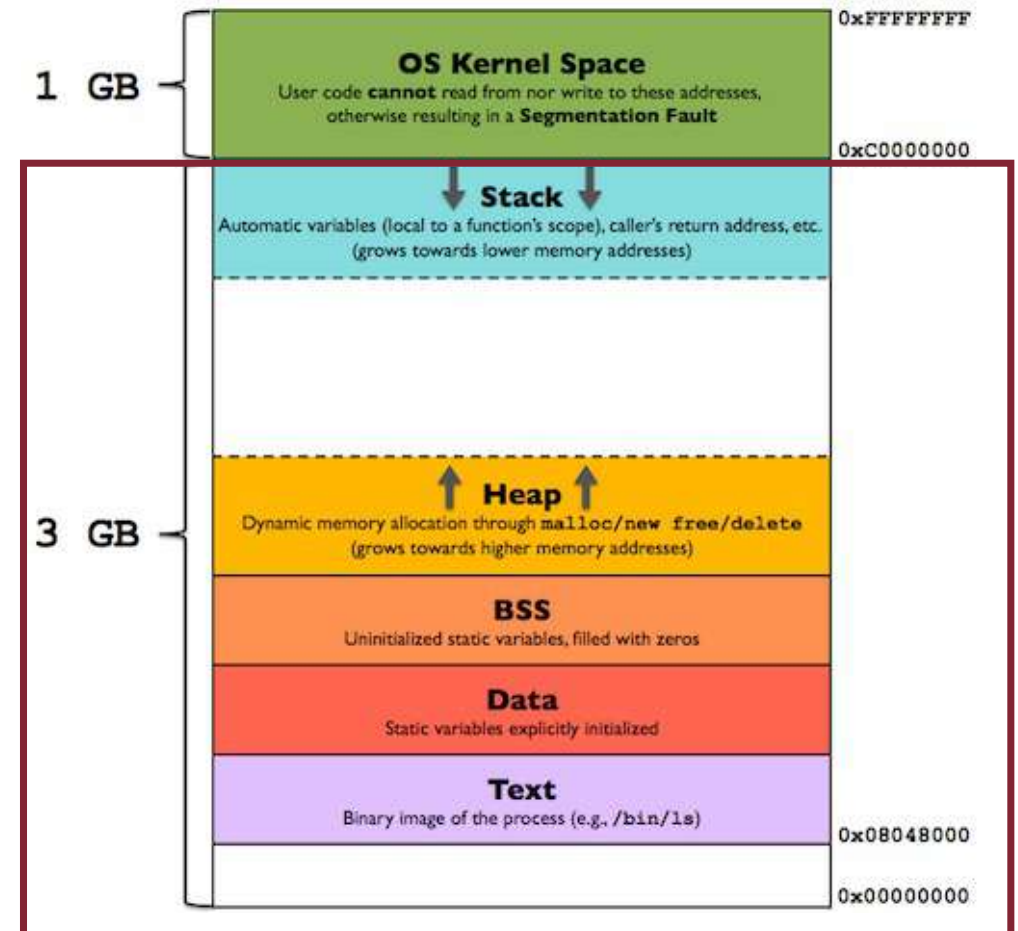
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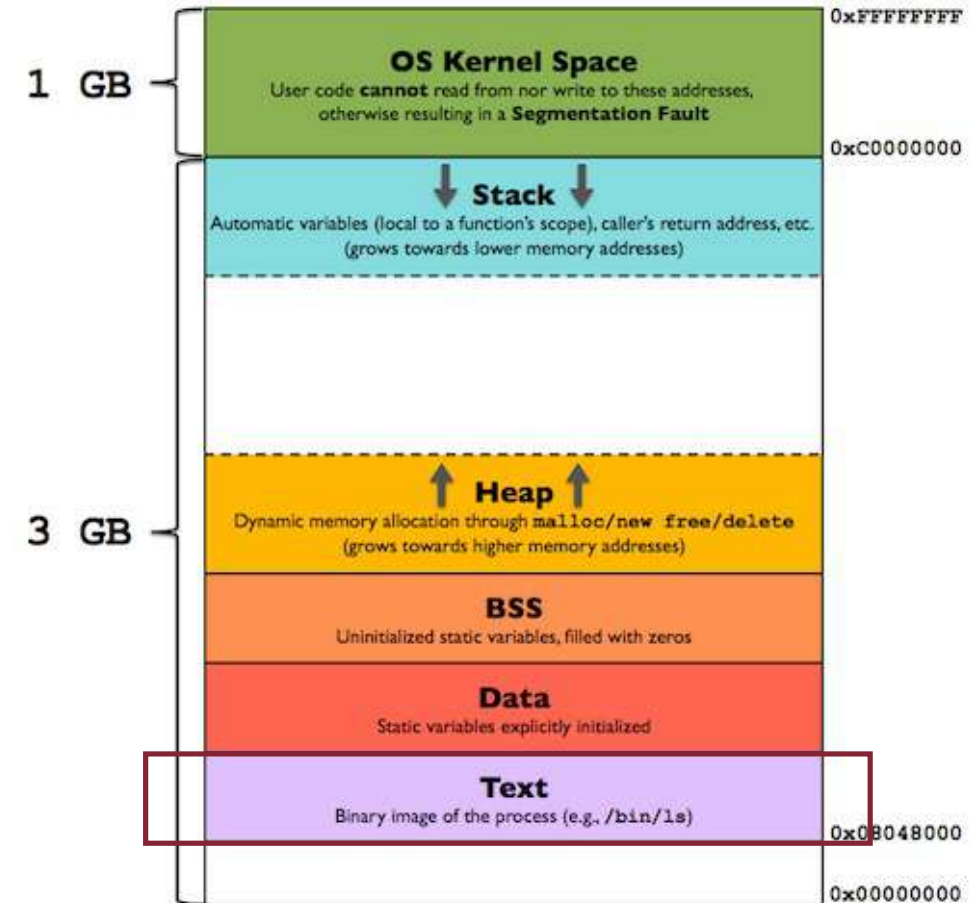
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For example, on a 32-bit architecture, the virtual addresses range from 0 to $2^{32} - 1$
(with the exception of some addresses reserved for the OS kernel)



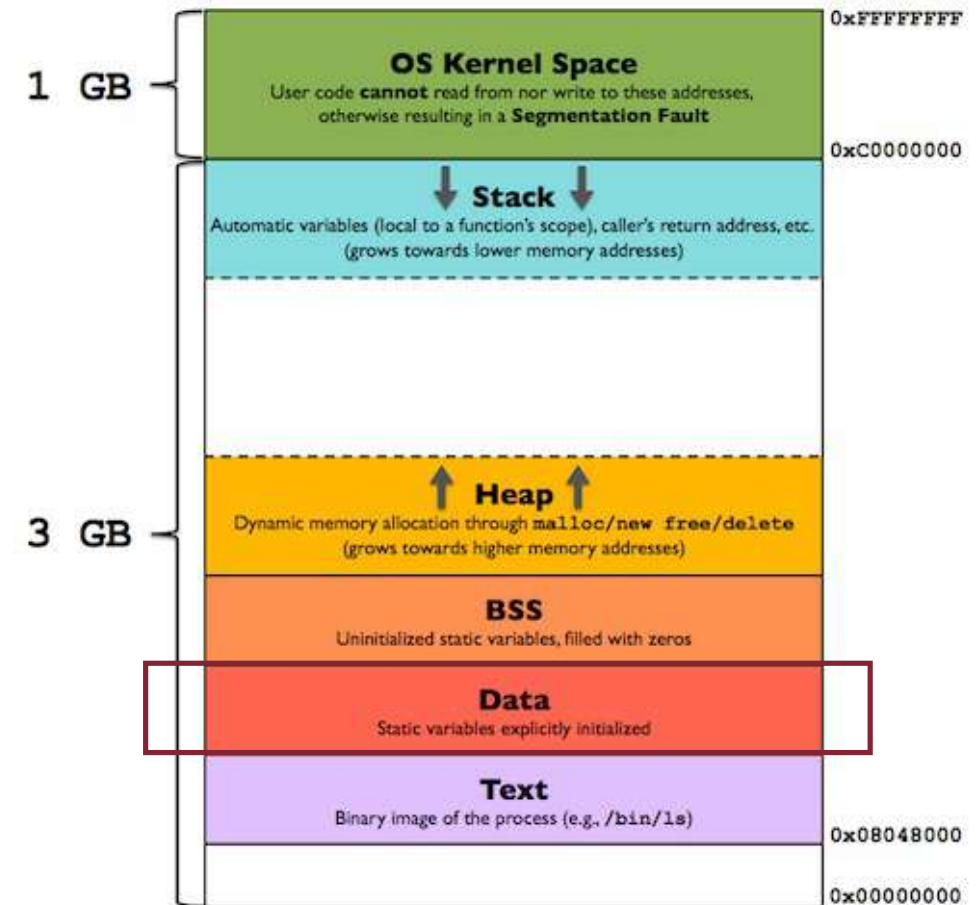
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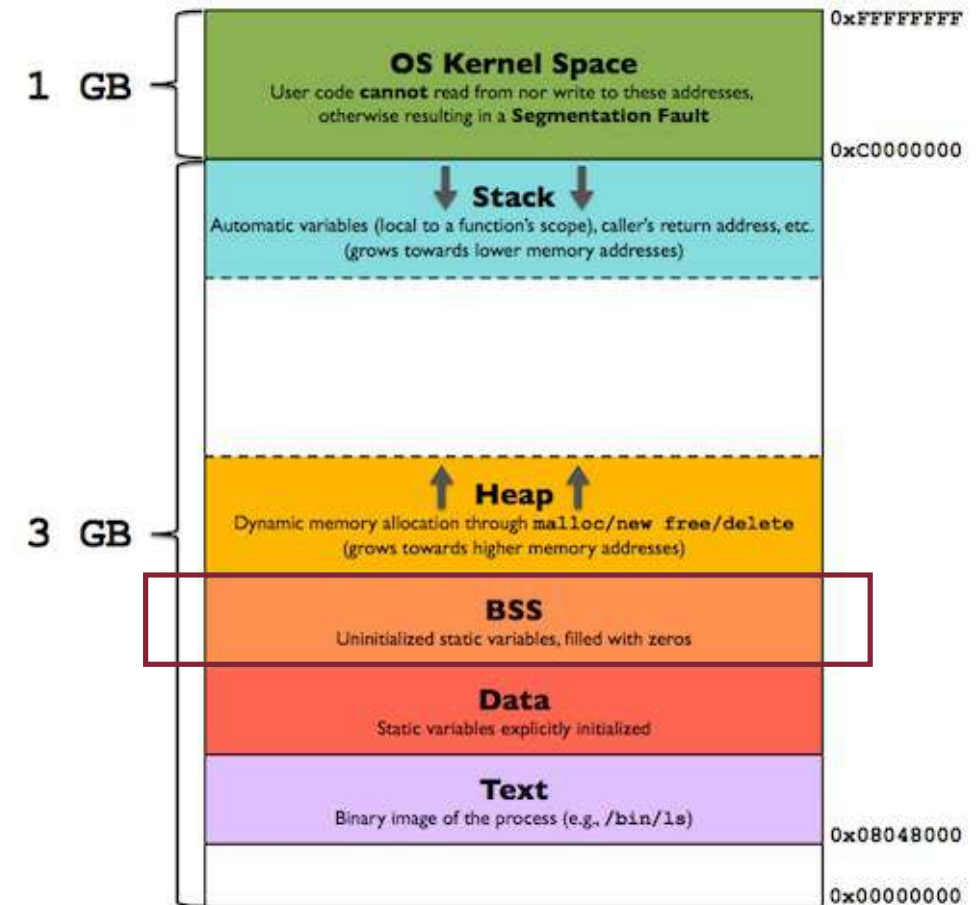
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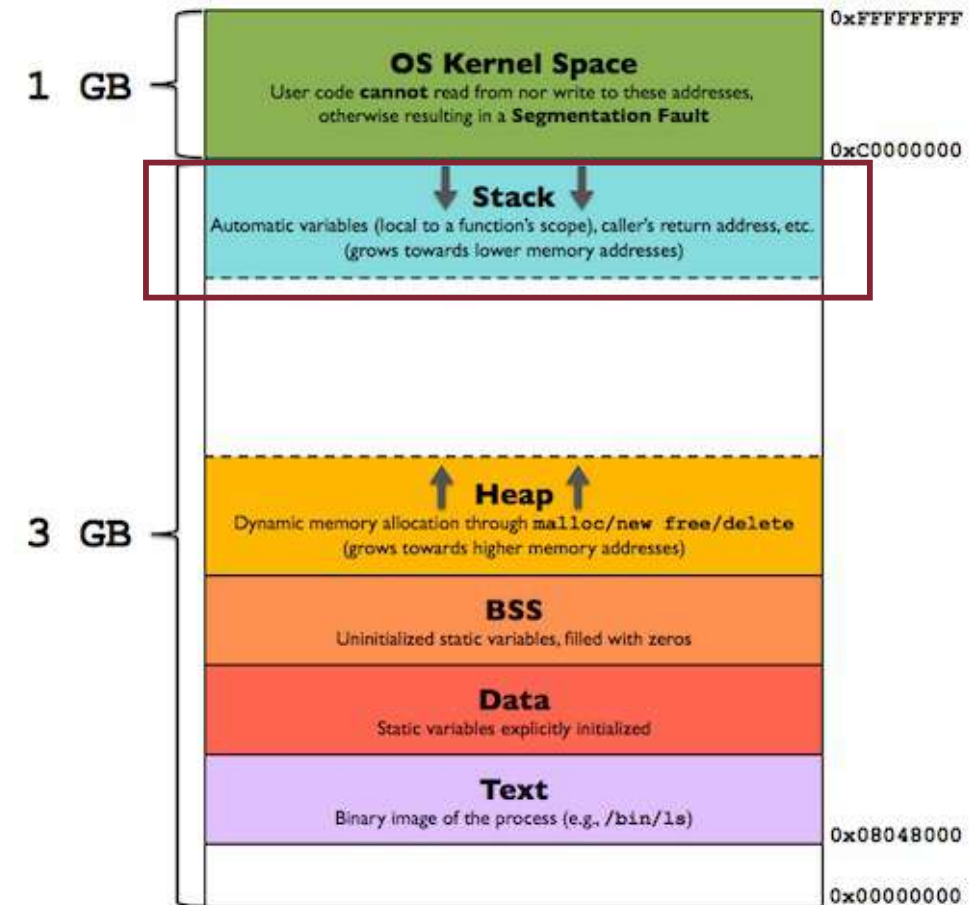
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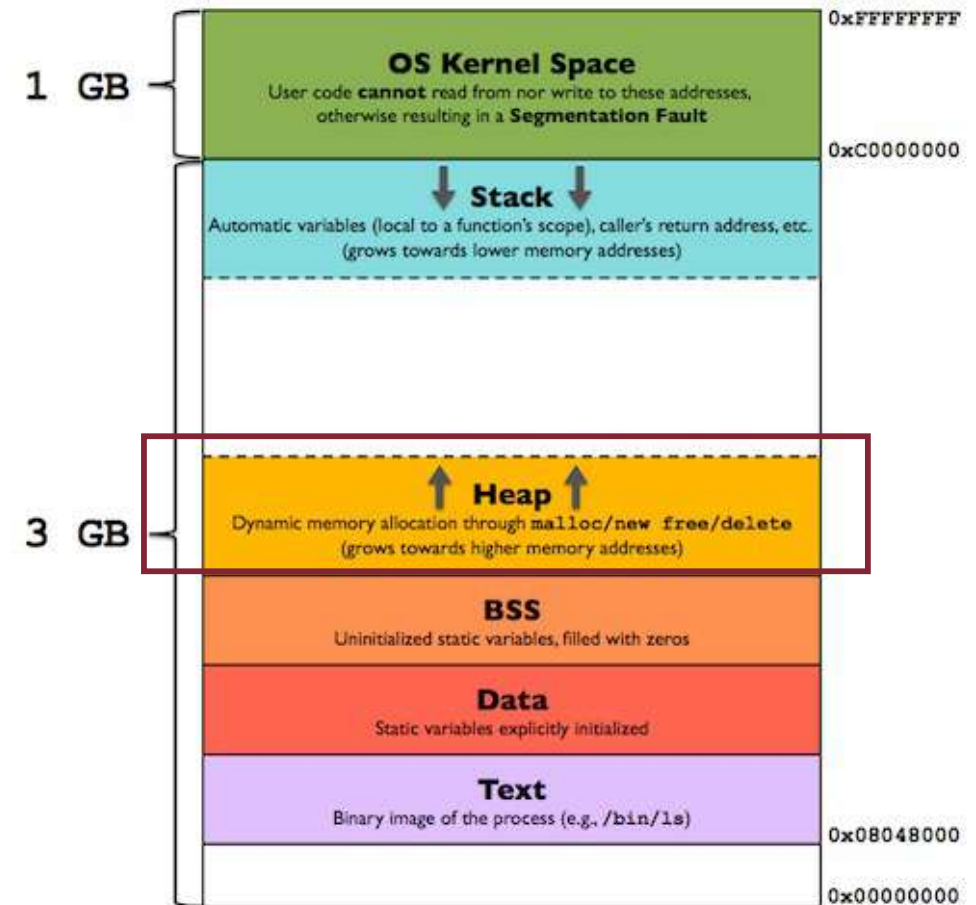
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- Heap → used for dynamic allocation



Program vs. Process: Example

Program

```
int w = 42;
int x = 0;
float y;

void doSomething(int f) {
    int z = 37;
    z += f;
    ...
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int main() {
    char* c = malloc(128);
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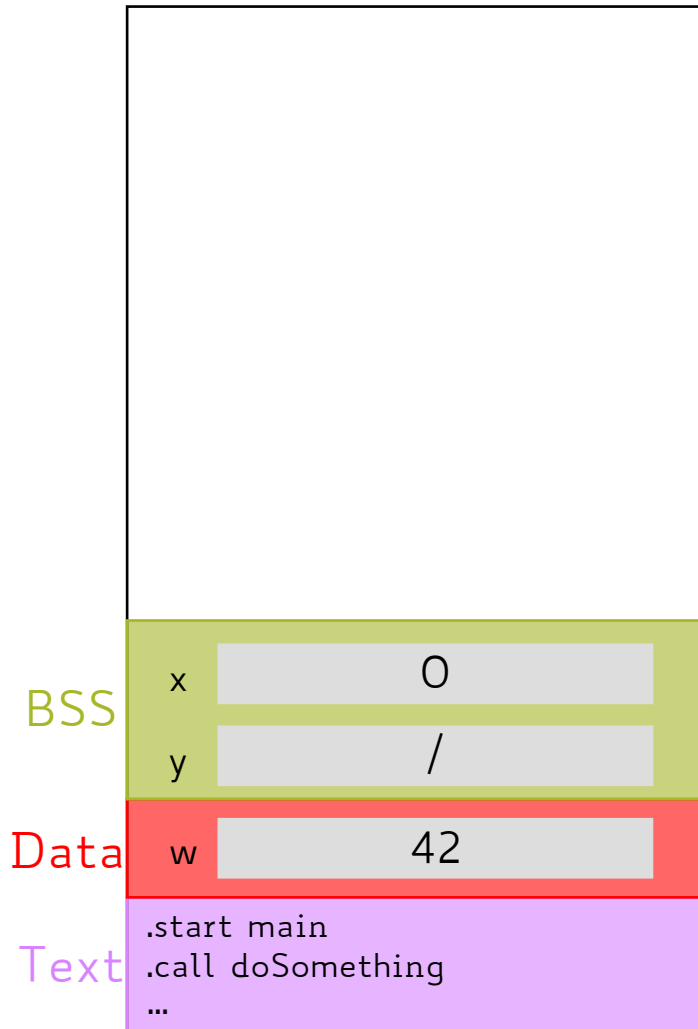
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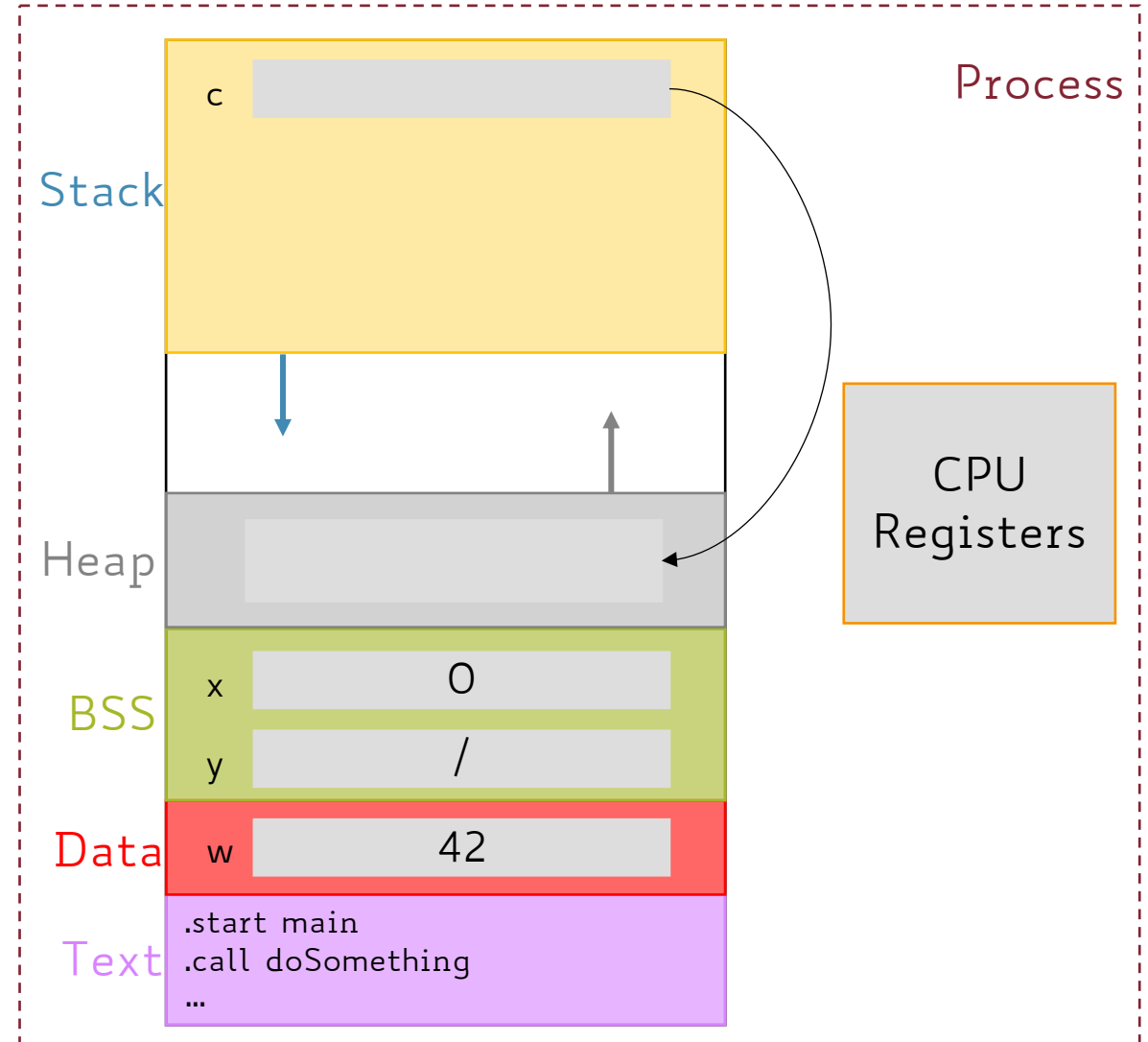
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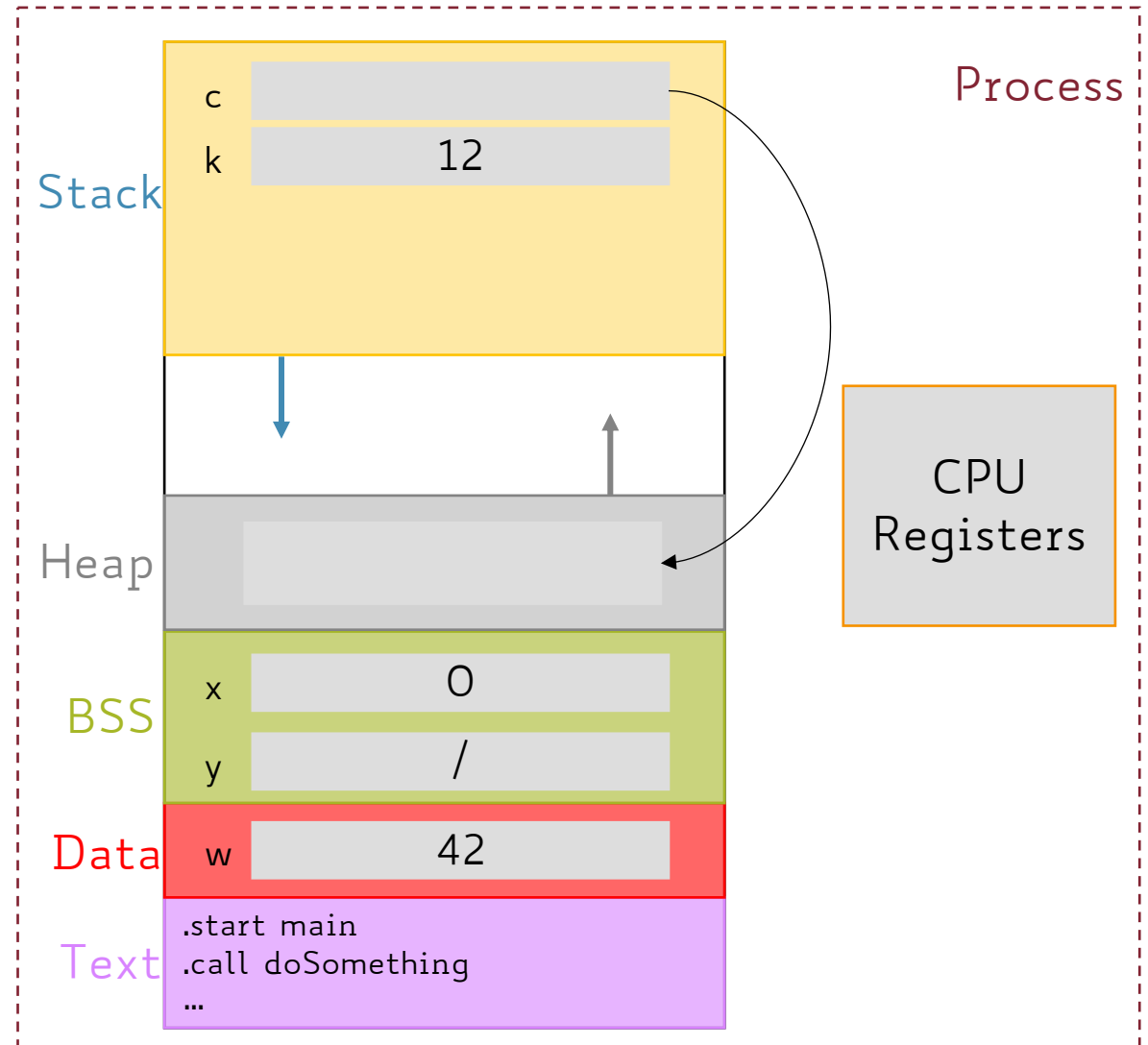
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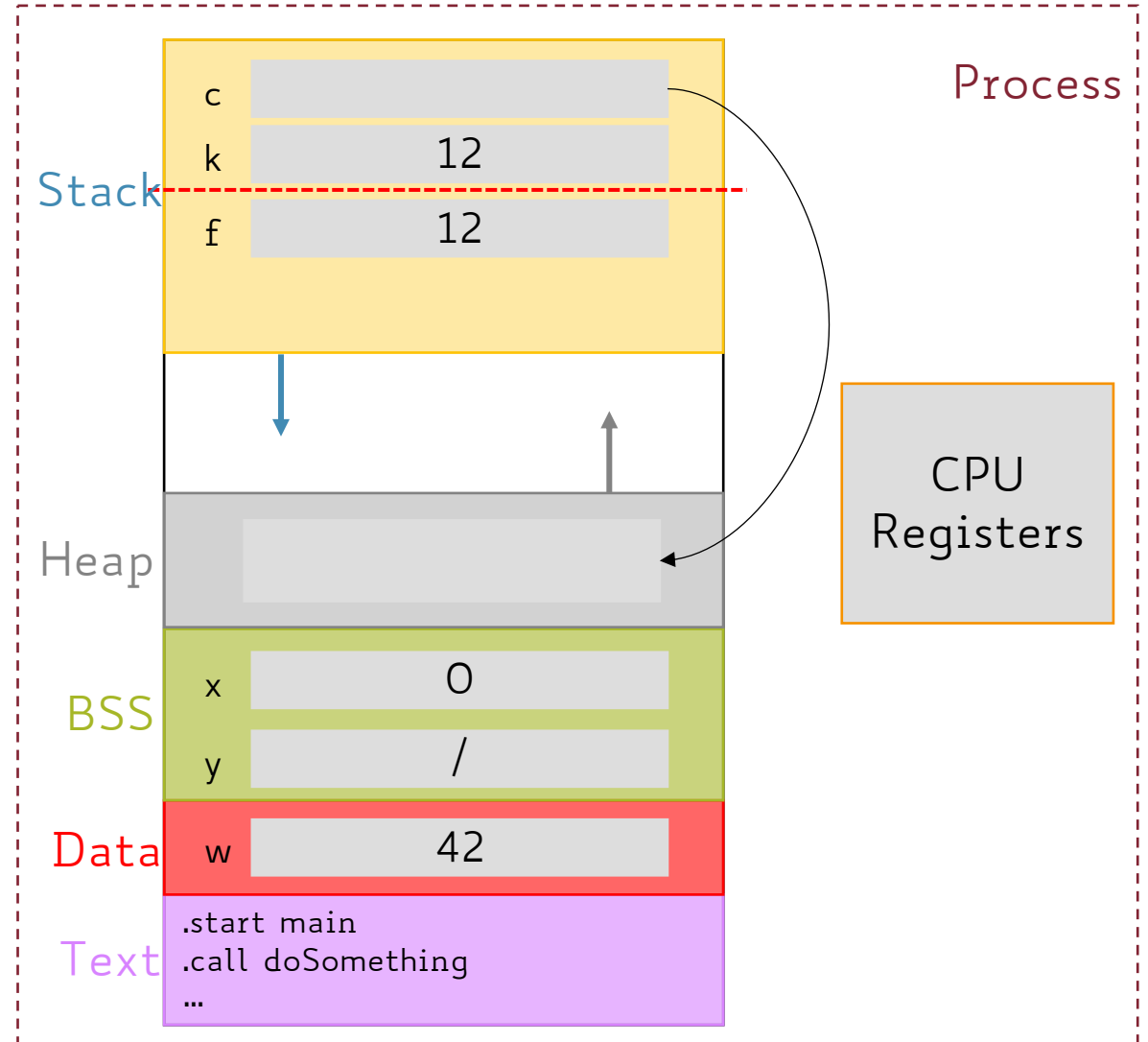
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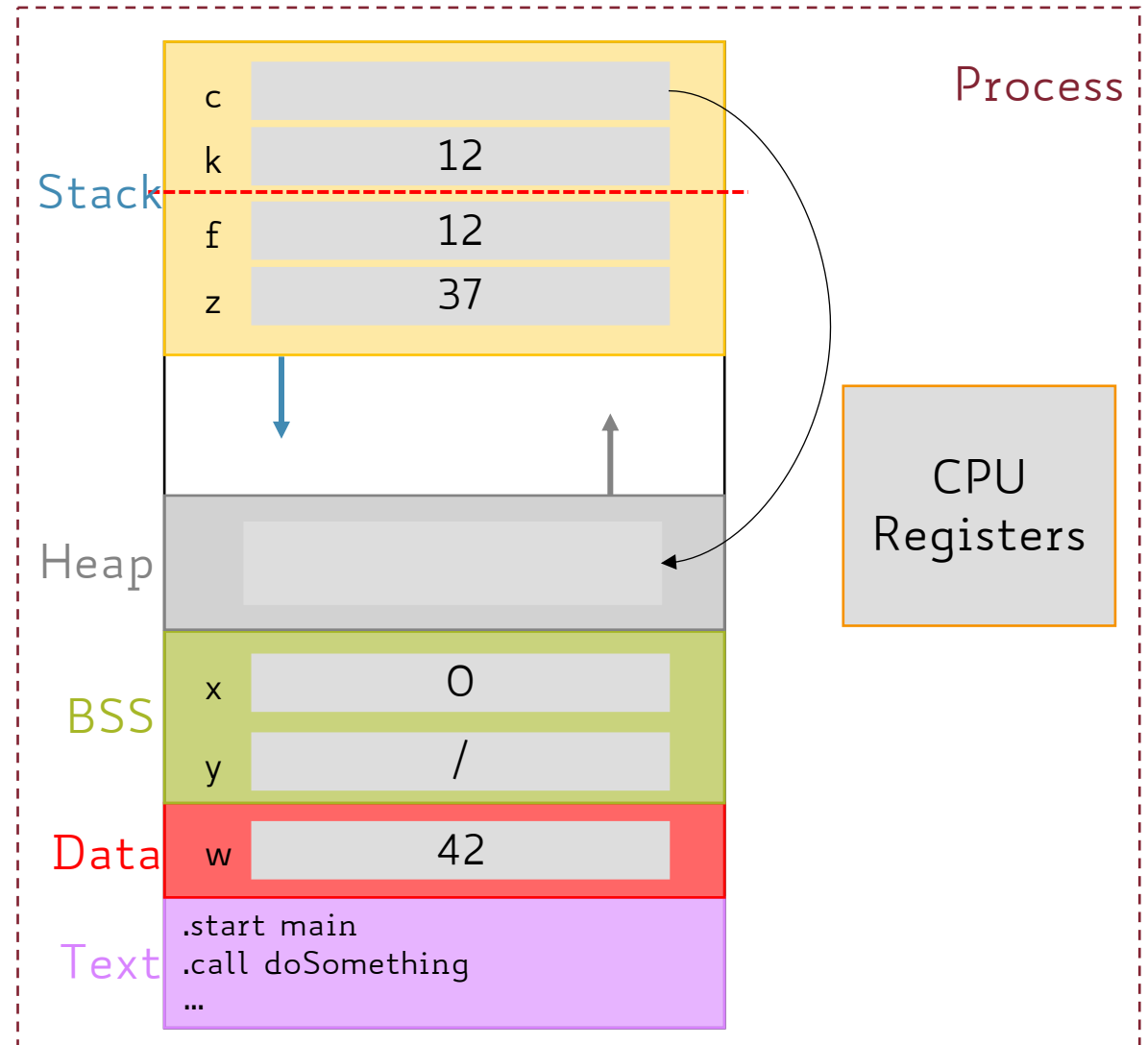
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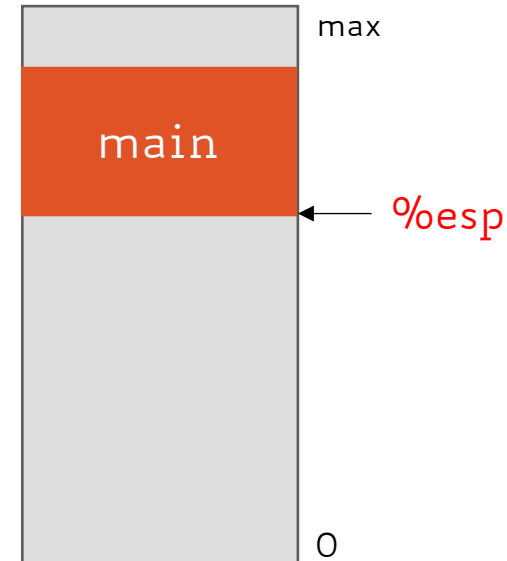
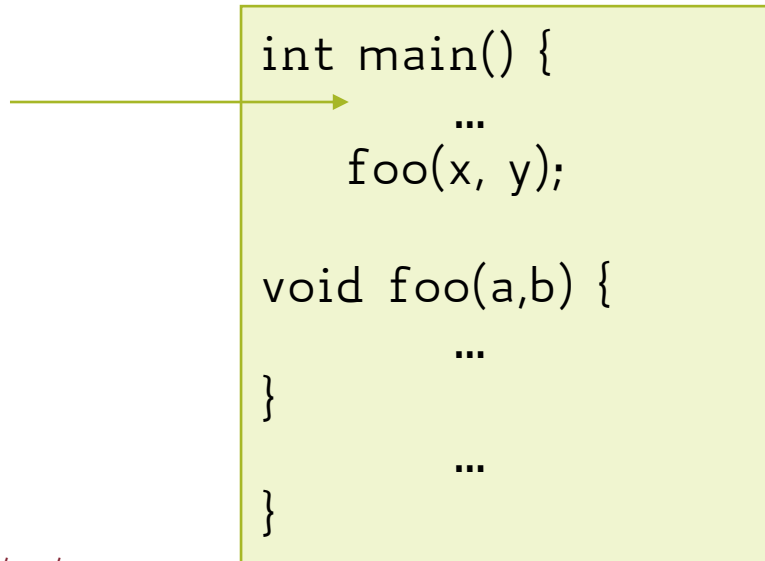
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- Stack memory conventionally grows top-down, i.e., from higher to lower memory addresses

Function Call: Stack Frame

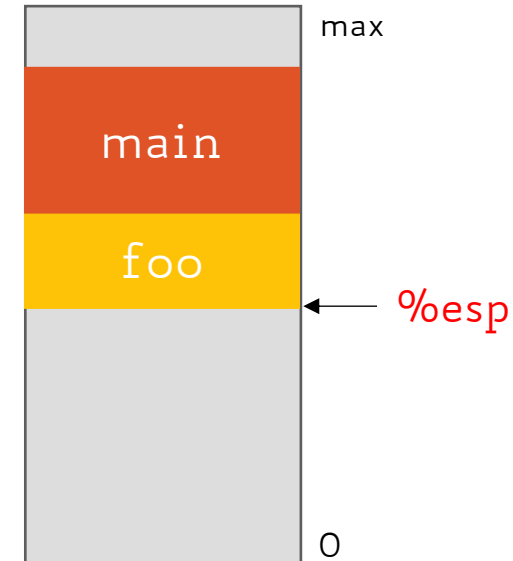
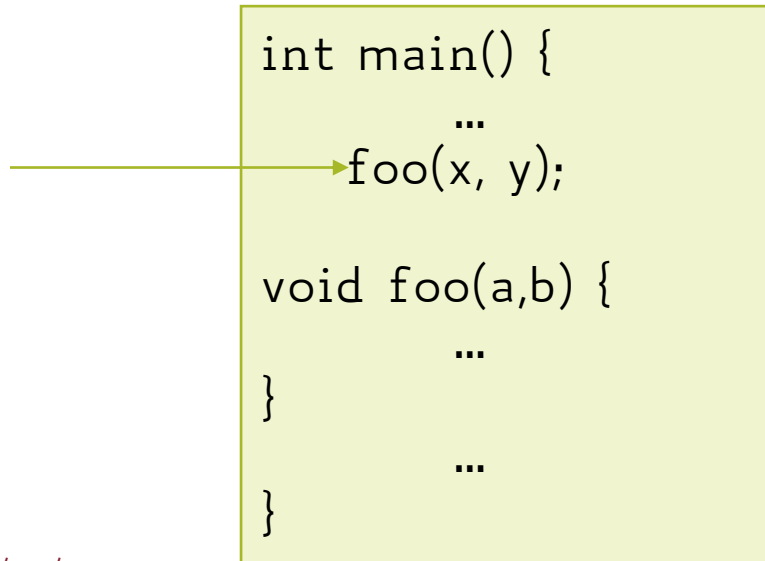
- Each function uses a portion of the stack, called **stack frame**
- At every point in time, multiple stack frames may simultaneously exist, due to several nested function calls, yet only one is **active**

```
int main() {  
    ...  
    foo(x, y);  
    void foo(a,b) {  
        ...  
    }  
    ...  
}
```



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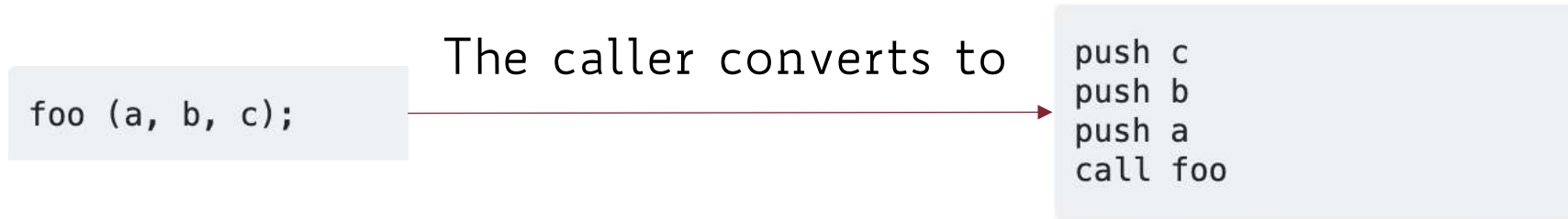
Function Call: Stack Frame

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 - function parameters + return address
 - back-pointer to the previous stack frame
 - local variables
- The first one is set by the caller
- The second and the third ones are set by the **callee**

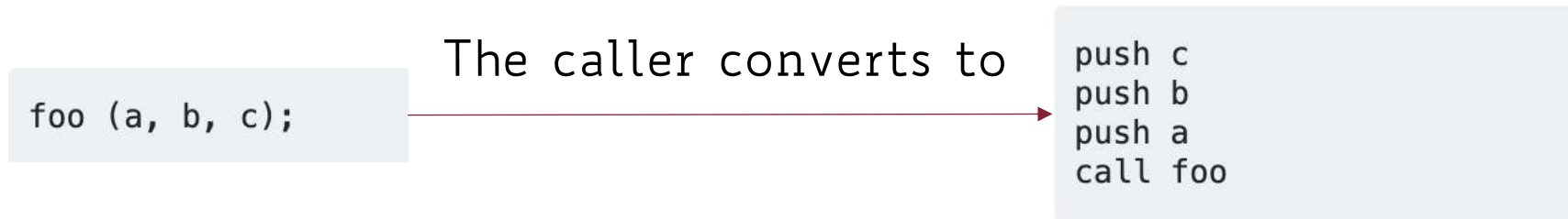
Stack Frame: Parameters + Return

```
foo (a, b, c);
```

Stack Frame: Parameters + Return

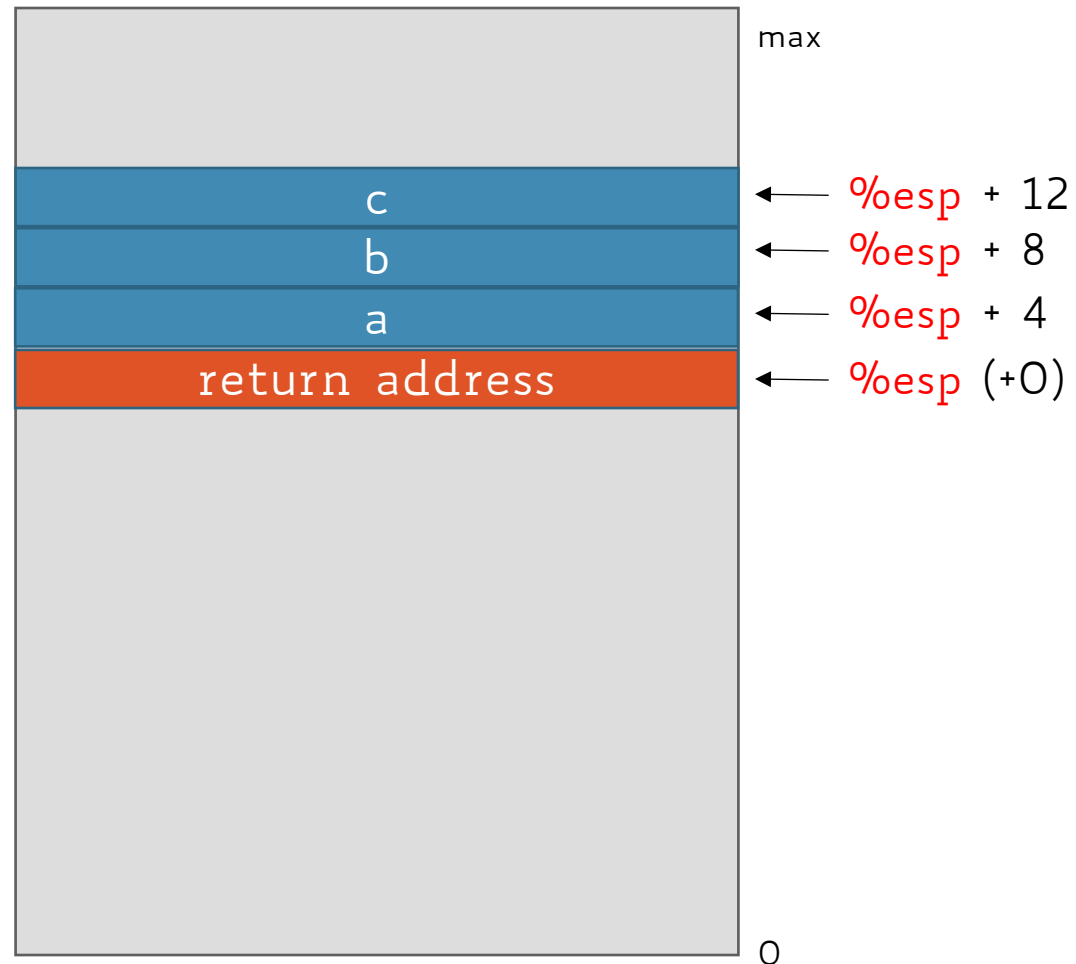


Stack Frame: Parameters + Return



- Each item is pushed onto the stack, the stack grows down
- The value of `esp` register is decremented by, say, 4 bytes (i.e., in 32-bit machines), and the item is copied to the memory location pointed to by it
- The `call` instruction will implicitly push the return address on the stack

Stack Frame: Parameters + Return

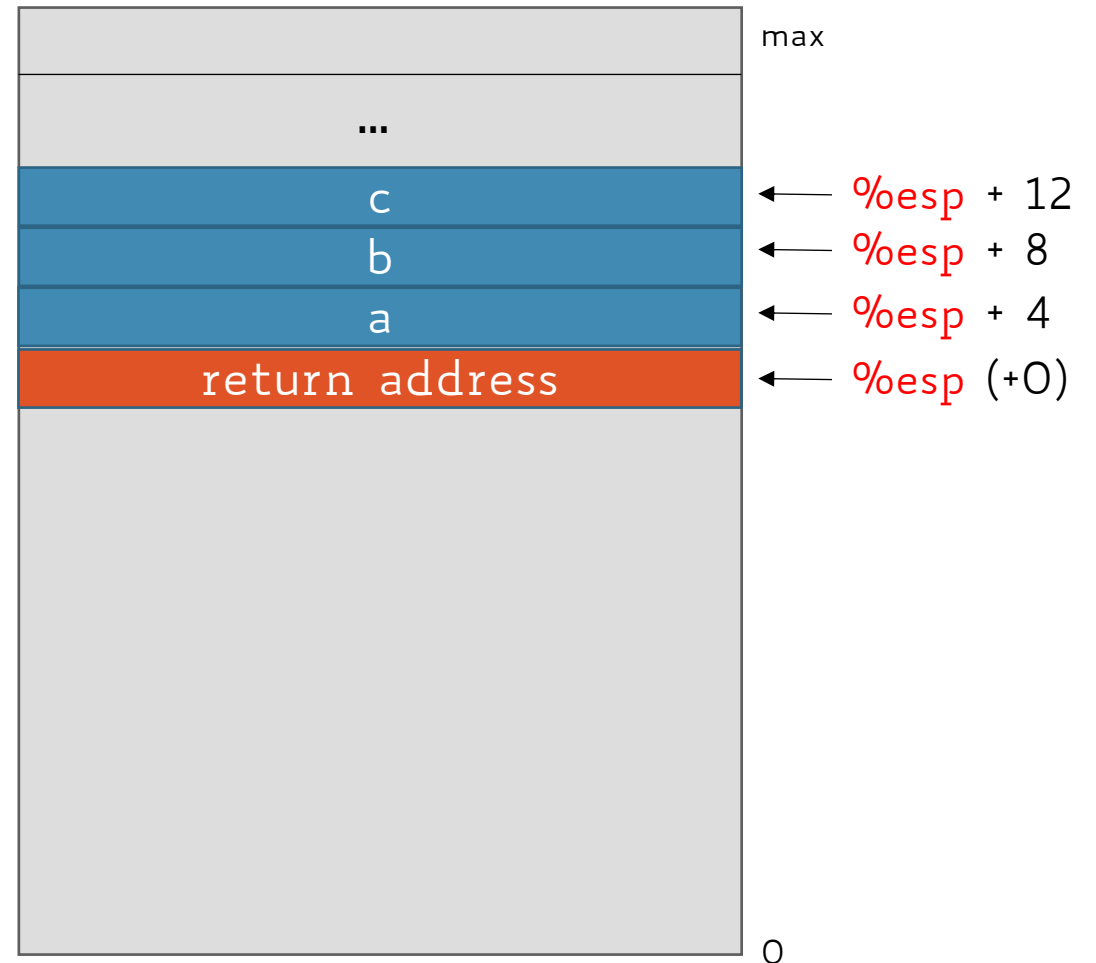


Stack Frame: Parameters + Return

Problem!

The `esp` pointer gets always updated as the stack grows

It is hard for the callee to access the actual parameters without a fixed reference on the stack



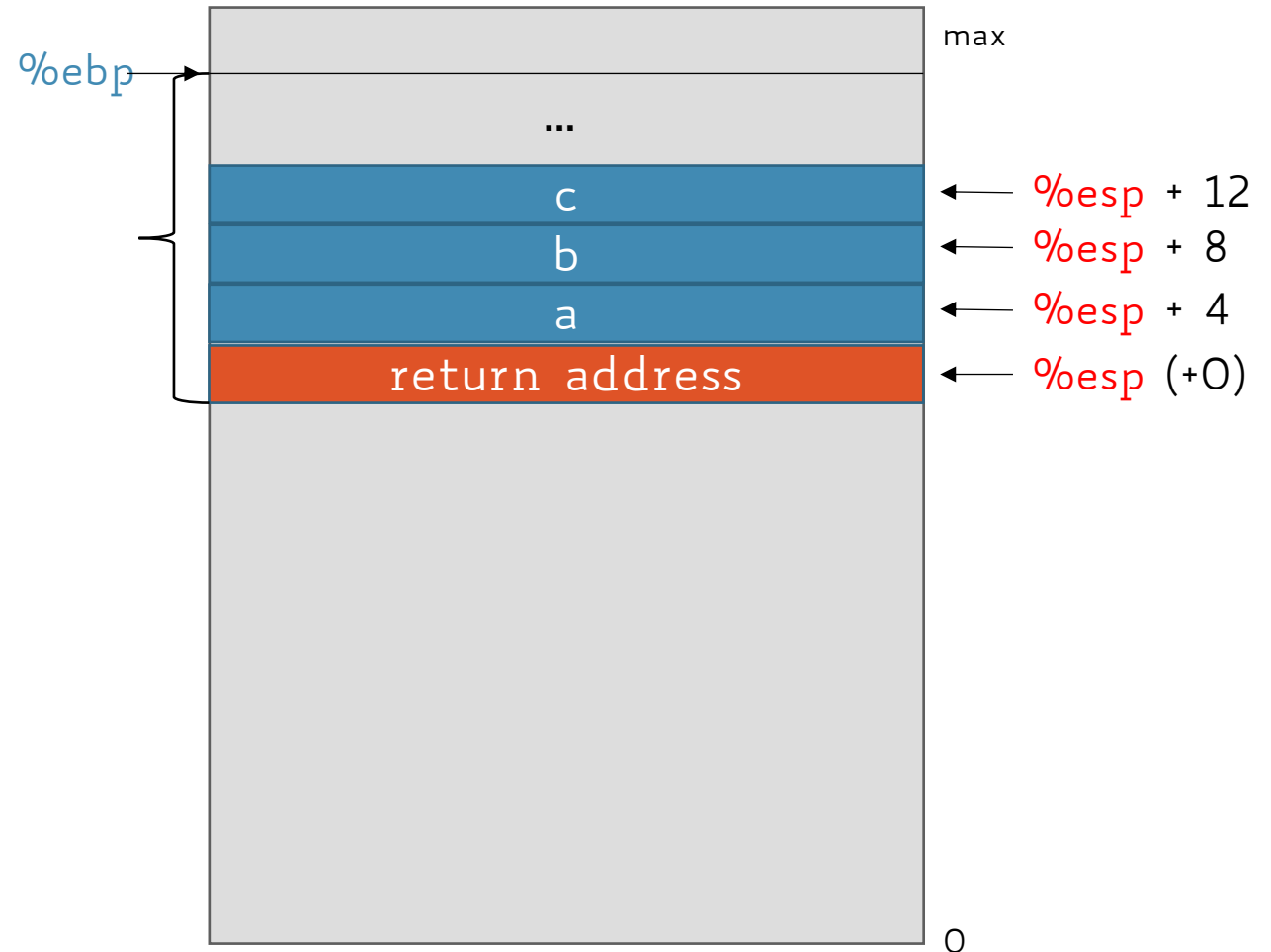
Stack Frame: Parameters + Return

Solution

Instead of using a single pointer to the top of the stack (**esp**)

Use an additional pointer to the bottom (base) of the stack (**ebp**)

Let **esp** be free to change across different function calls, while keep **ebp** fixed within each stack frame

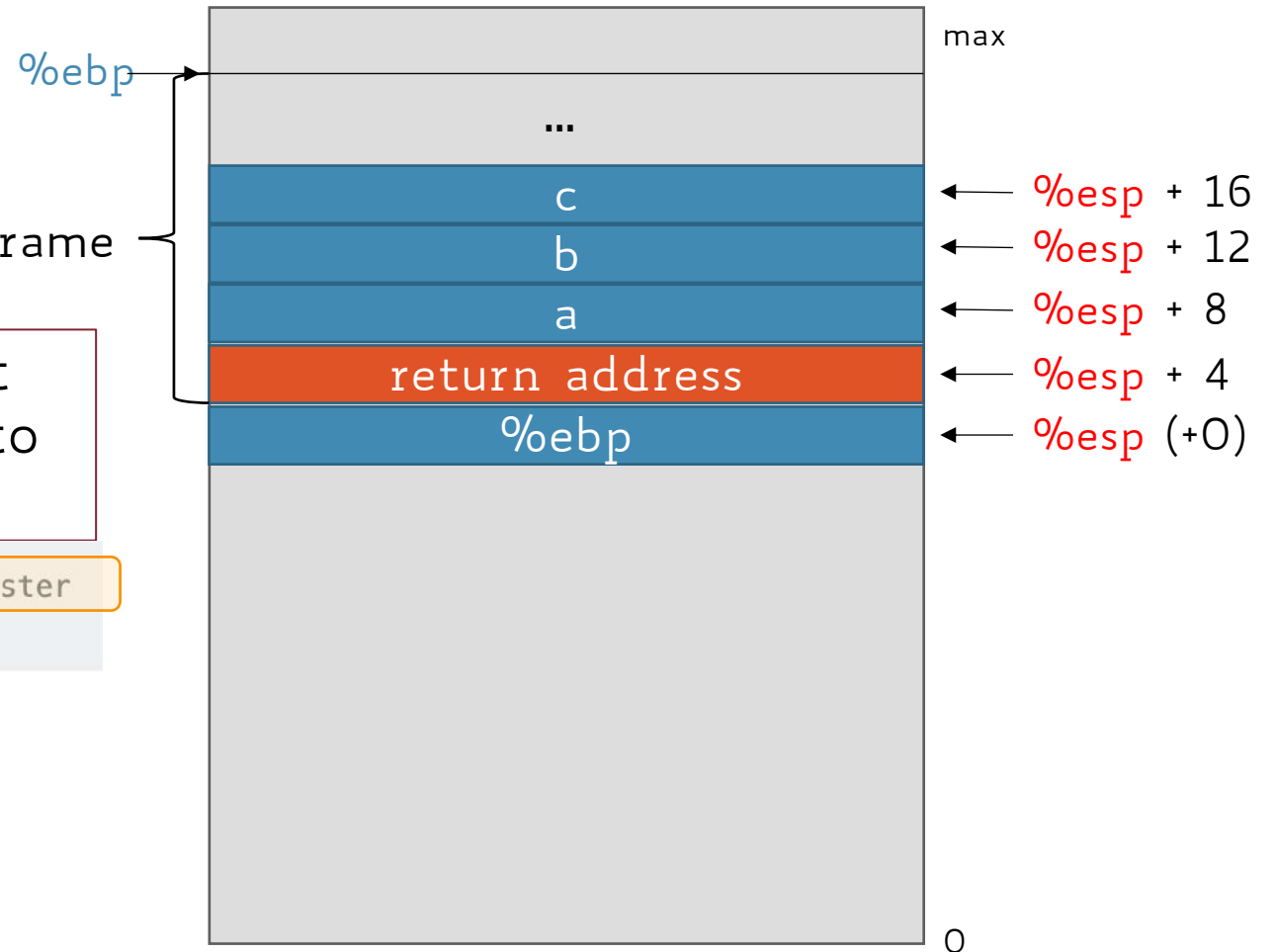


Stack Frame: Saving the Base Frame Pointer

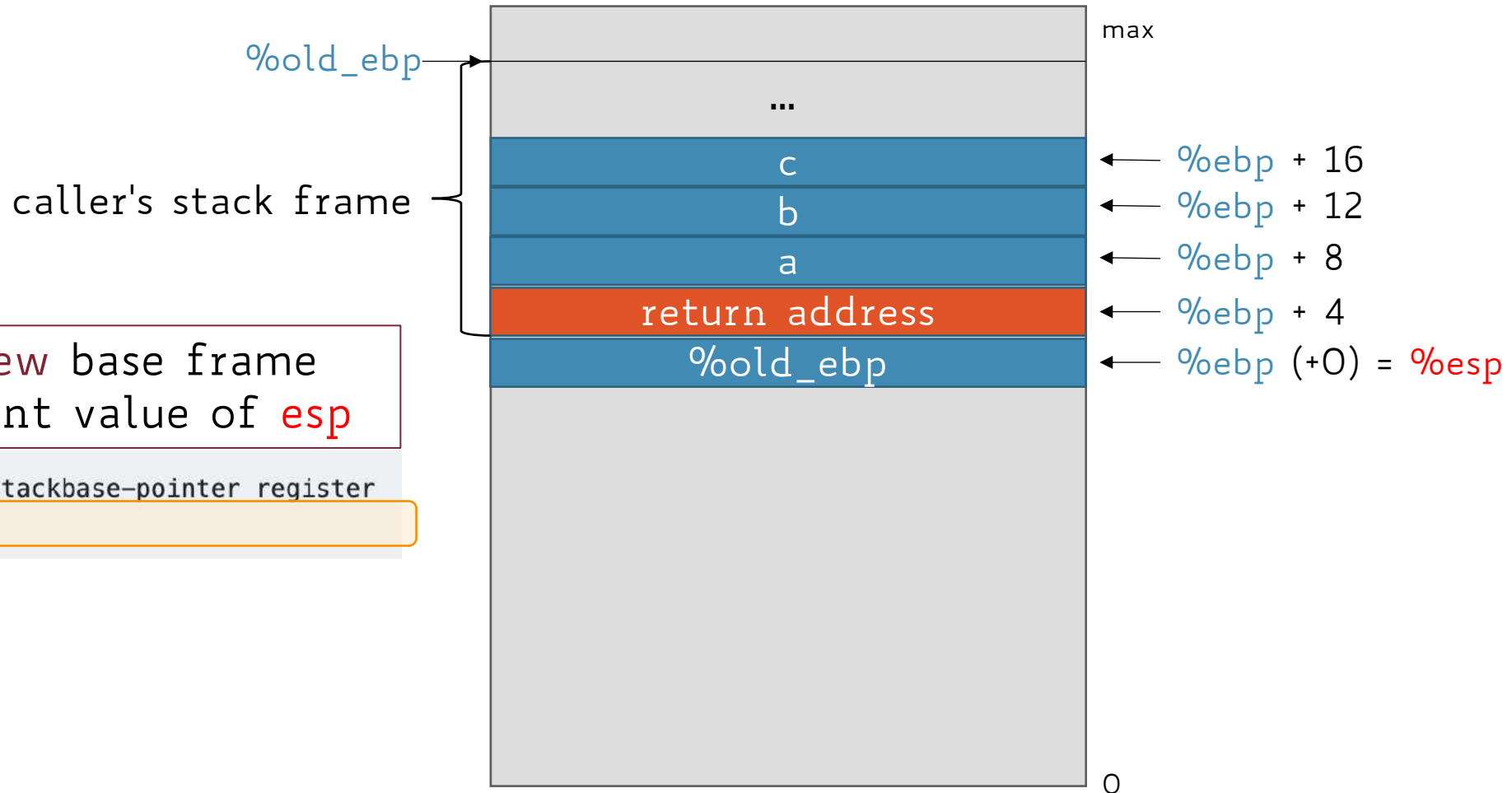
The callee first saves the current stack frame base pointer (`%ebp`) to the stack!

```
push ebp      ; save previous stackbase-pointer register
mov  ebp, esp ; ebp = esp
```

caller's stack frame



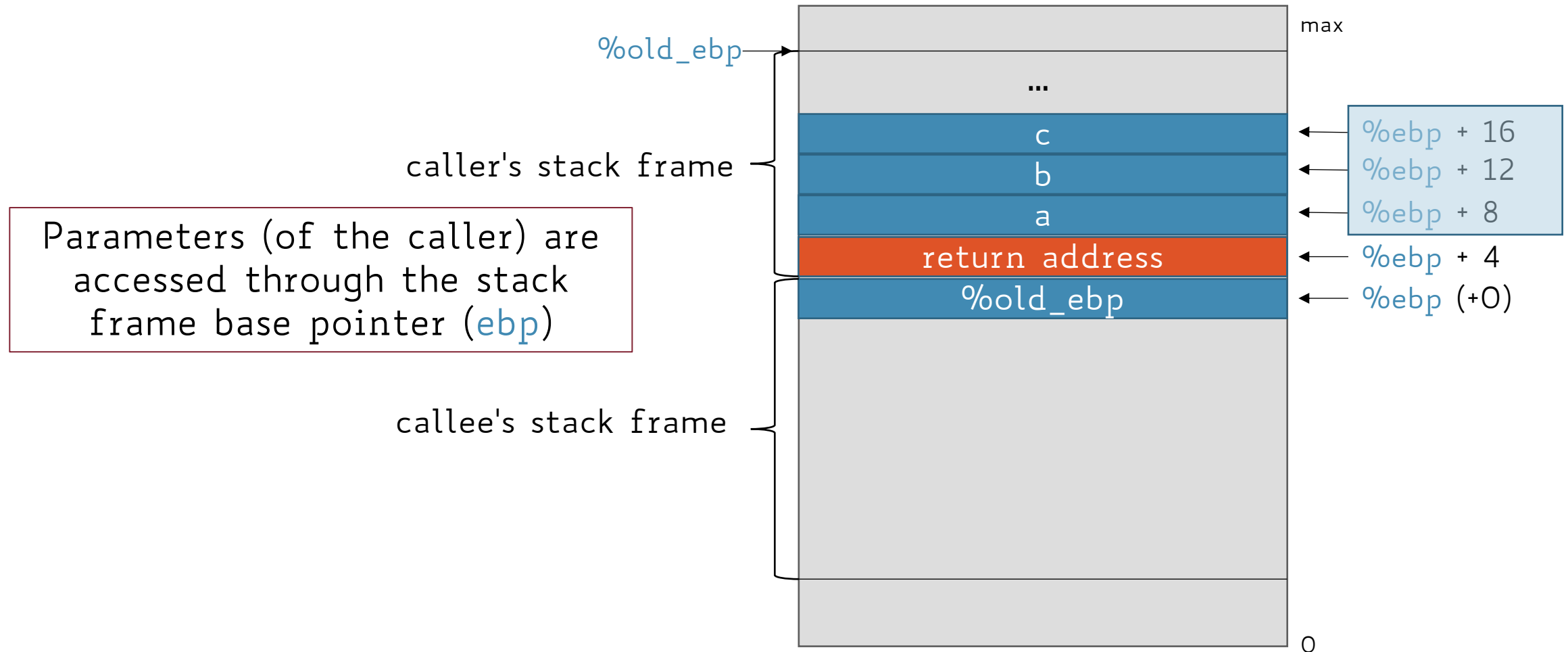
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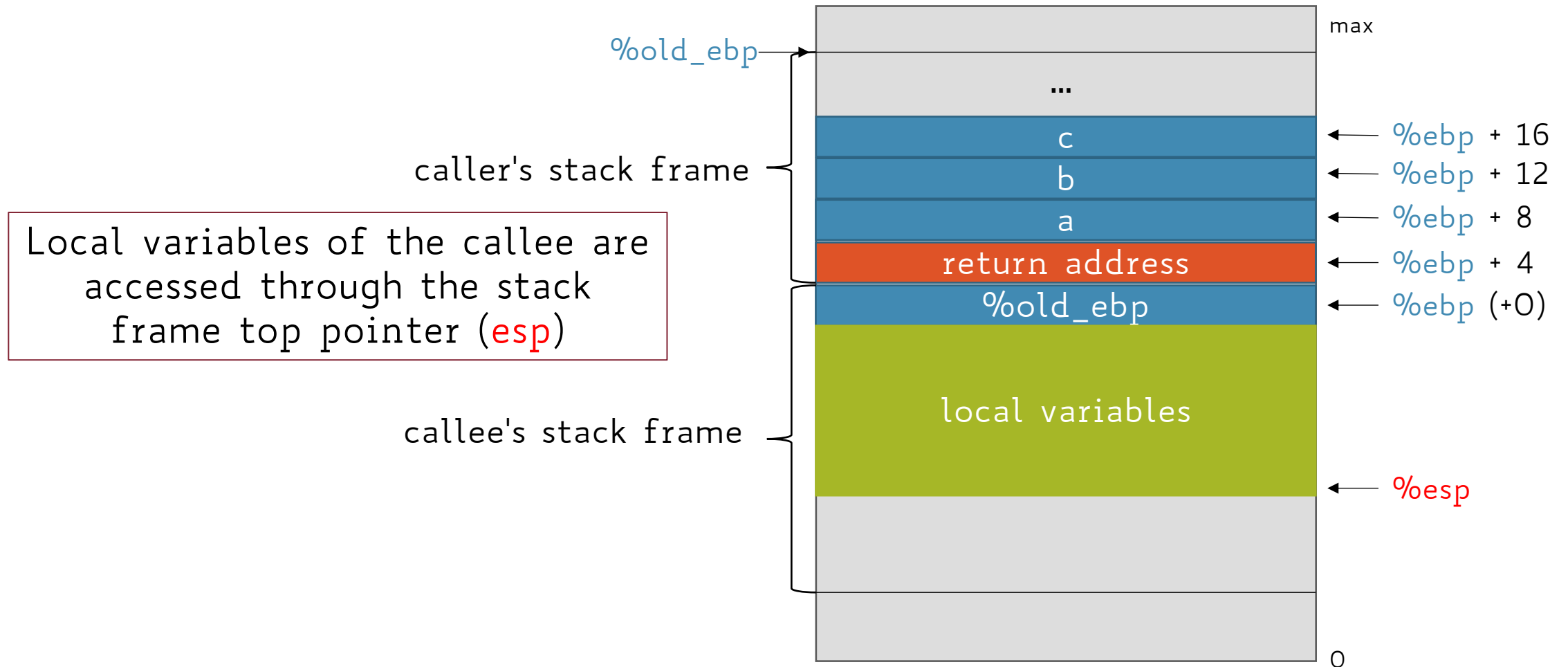
Then it sets the **new** base frame pointer to the current value of **esp**

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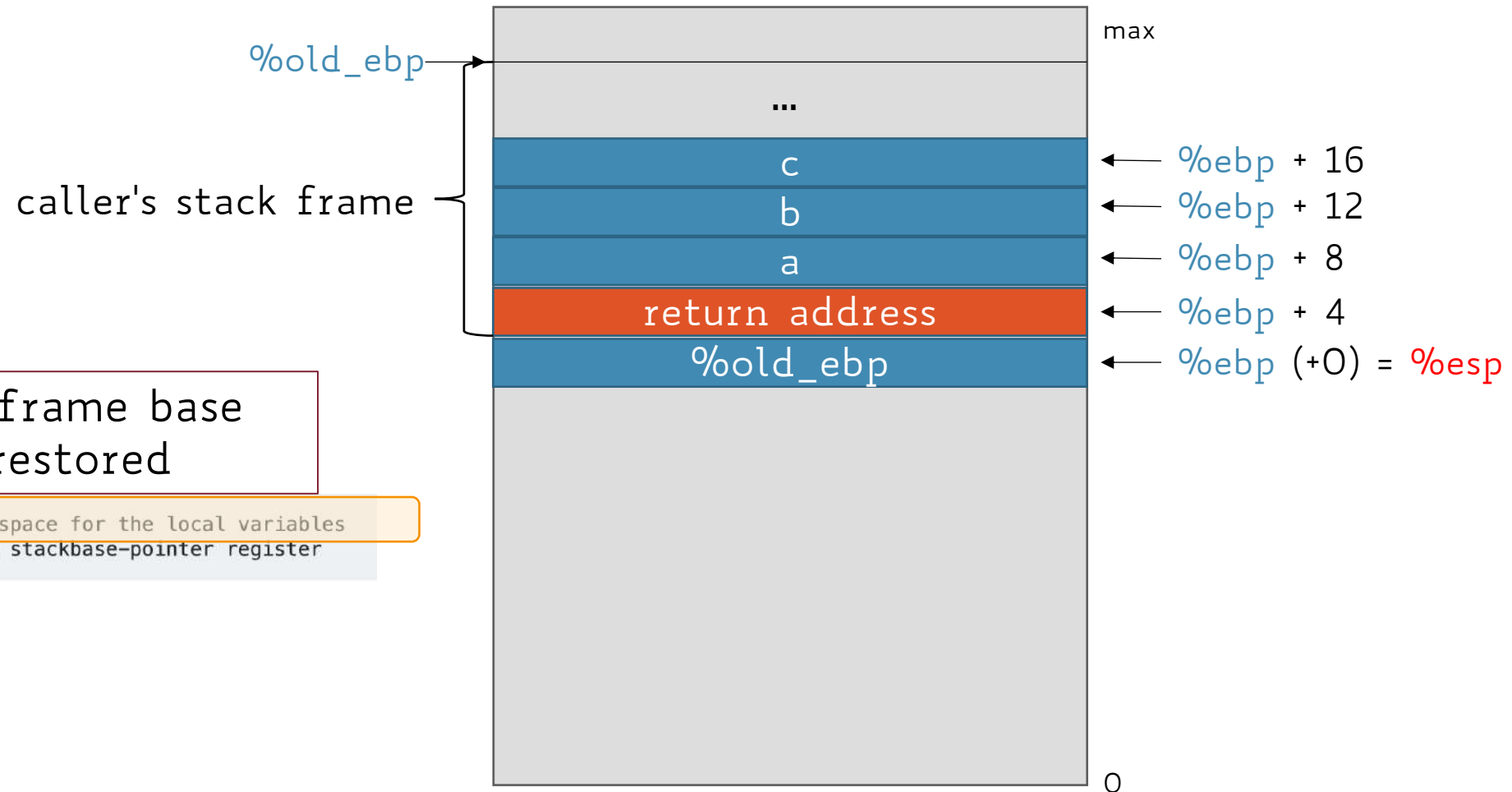
Parameters: Offset from the Base Frame Pointer



Local Variables: Offset from Stack Pointer



Stack Frame: Cleanup and Return



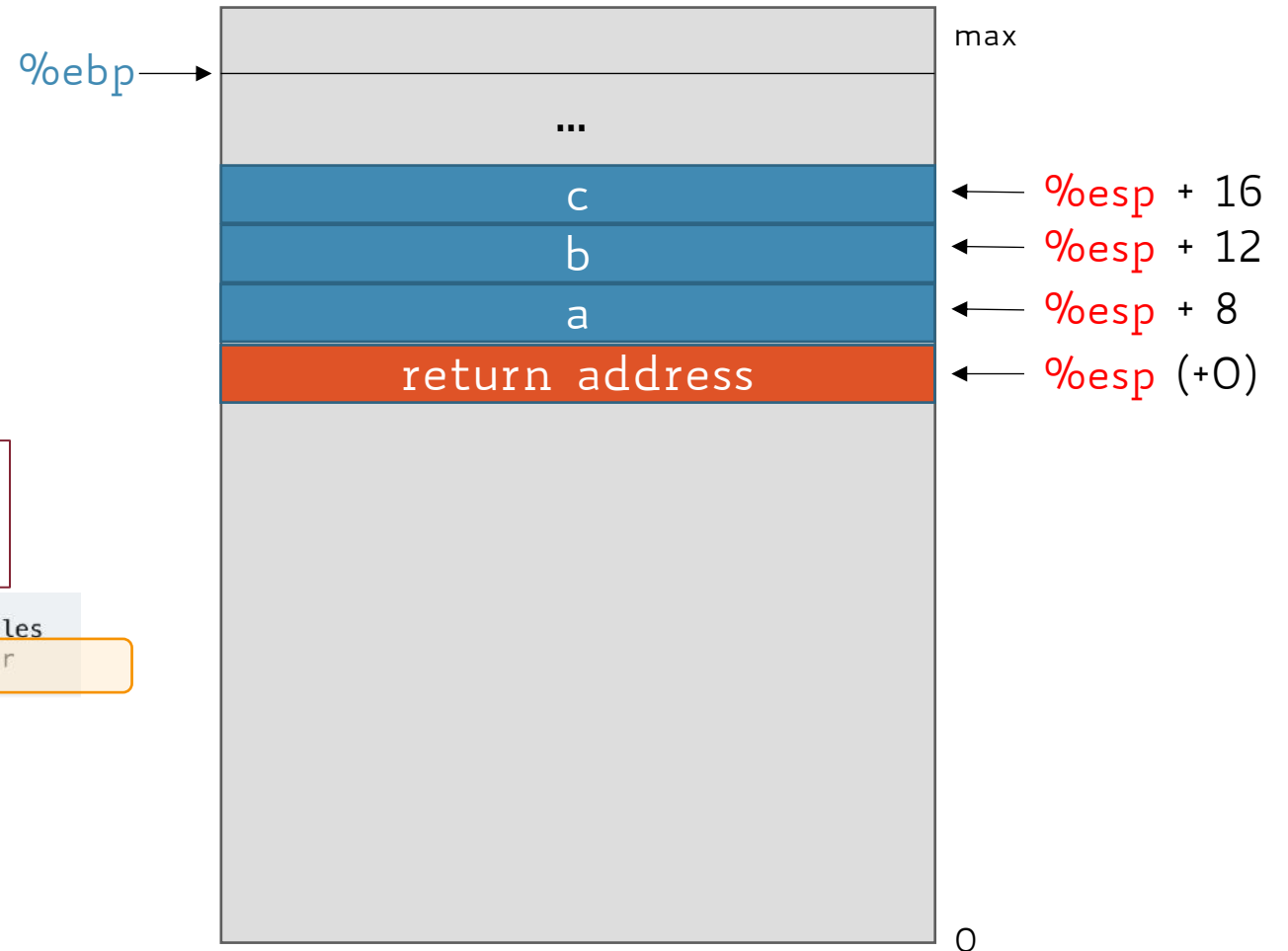
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mov esp, ebp ; undo the carving of space for the local variables
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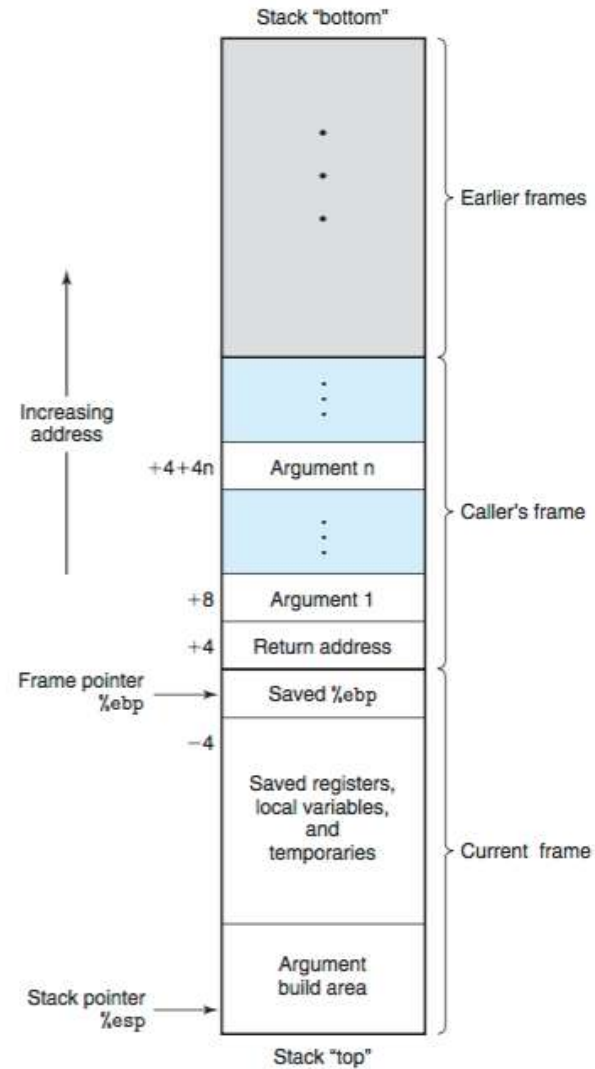

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Stack: Outline



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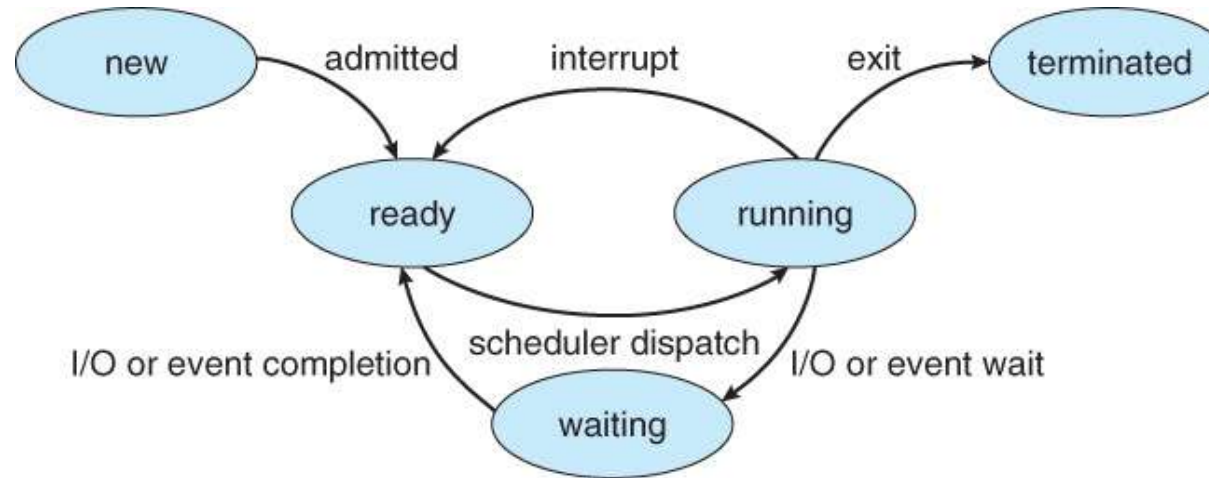
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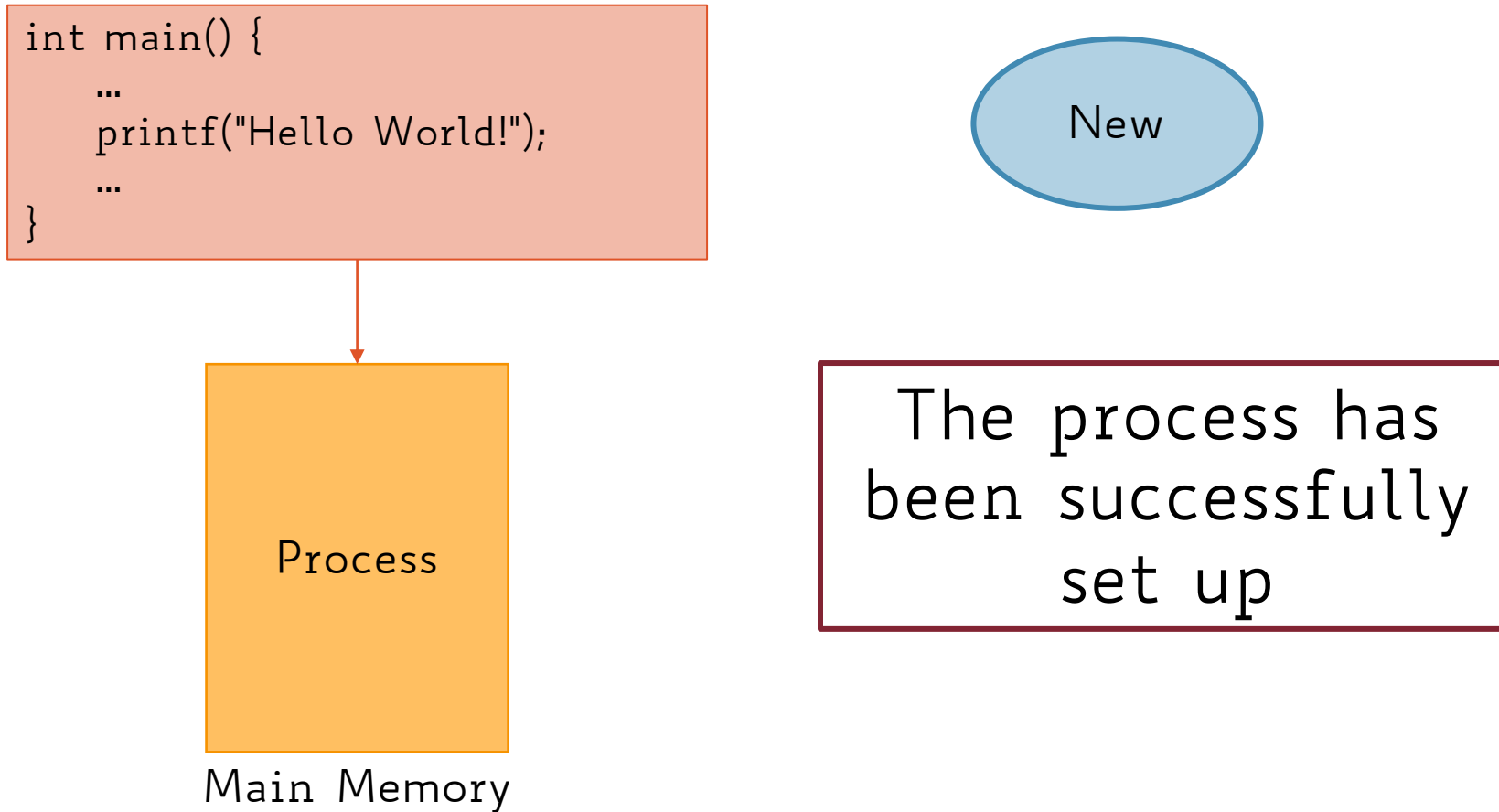
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 - **Terminated** → The process is finished and the OS can destroy it

Process Execution State Diagram



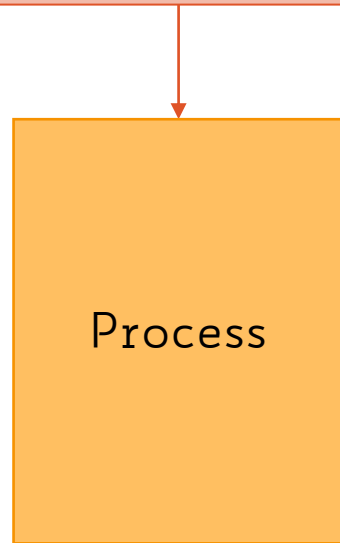
- As the process executes, it moves from state to state depending on:
 - program actions (e.g., system calls)
 - OS actions (e.g., scheduling)
 - external actions (e.g., interrupts)

Process Execution State: Example



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```
int main() {  
    ...  
    printf("Hello World!");  
    ...  
}
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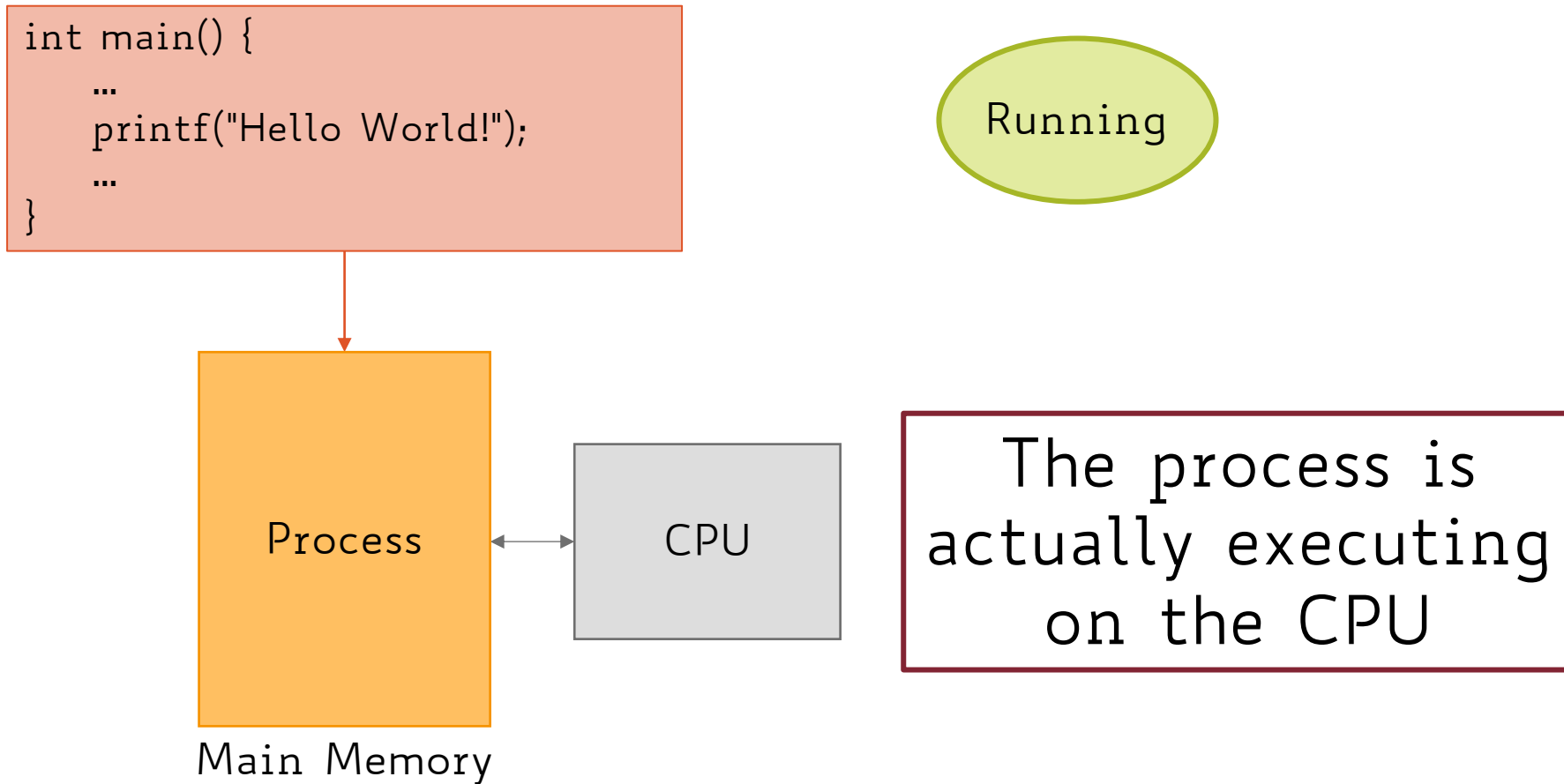


Main Memory

Ready

The process is
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Waiting



Main Memory

`printf` delegates off to a **blocking** I/O system call:
The current process is suspended in order for the OS to schedule another process which is ready to run

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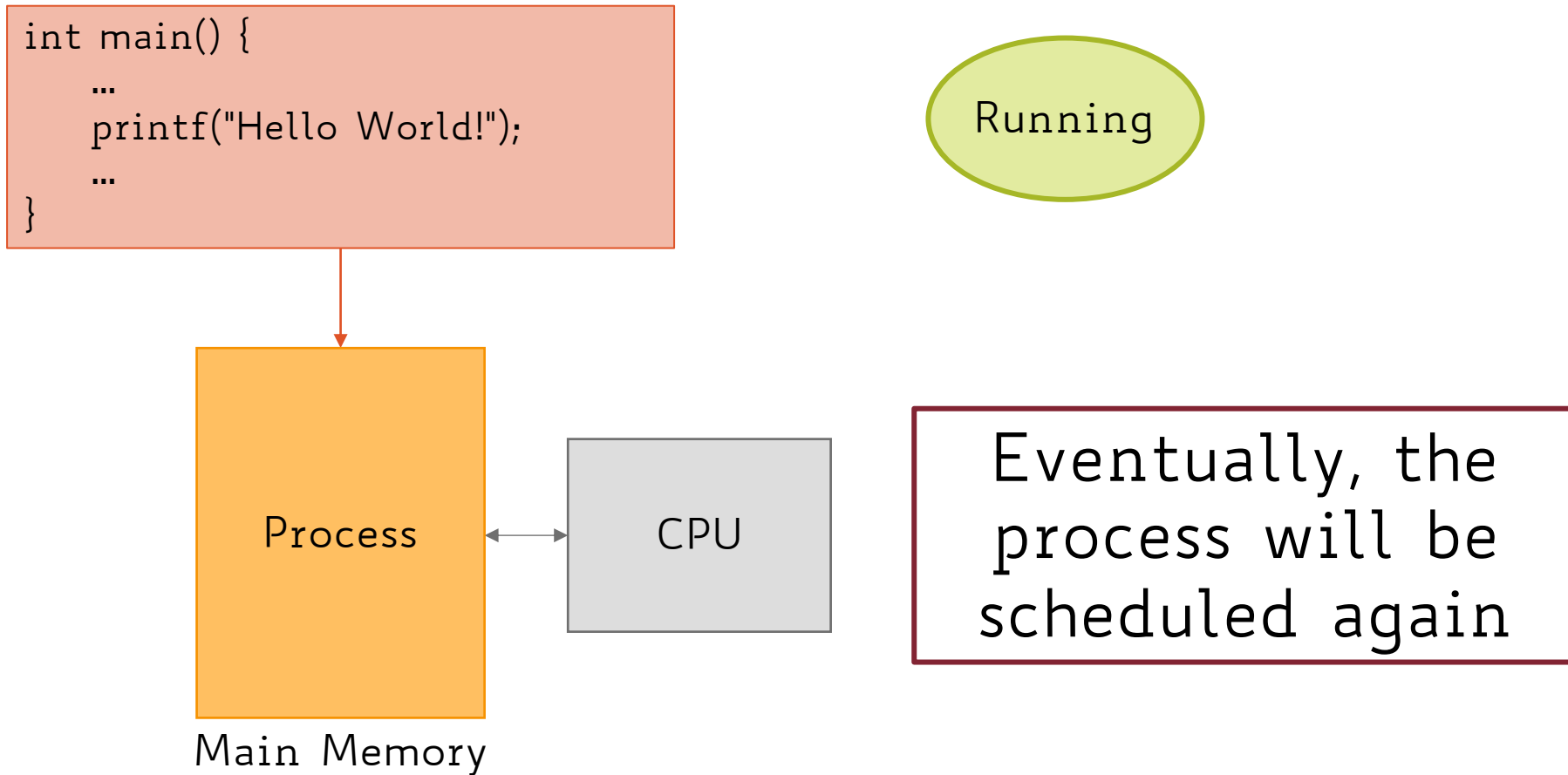
Ready

Process

Main Memory


Once `printf` is done (e.g., HW interrupt) the process goes back to ready status yet it is not resumed directly!
(i.e., it is up to the OS to decide which process to schedule next)

Process Execution State: Example



Process Execution State: Example

```
int main() {  
    ...  
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```



Terminated

A gray oval with a black border containing the word "Terminated".

Finally, the
process
terminates

Blocking vs. Non-Blocking Calls (Again!)

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NOTE:

the whole system is **not** blocked, only the process which has requested the blocked call is!

Process State

- At least, process state consists of the following:
 - the code of the running program
 - the static data of the running program
 - the program counter (PC) indicating the next instruction to execute
 - CPU registers
 - the program's call chain (stack) along with frame and stack pointers
 - the space for dynamic memory allocation (heap) along with the heap pointer
 - the set of resources in use (e.g., open files)
 - the process execution state (ready, running, etc.)

Process Control Block (PCB)

- The main data structure used by the OS to keep track of any process
- The PCB keeps track of the execution state and location of a process
- The OS allocates a new PCB upon the creation of a process and places it into a state queue
- The OS deallocates a PCB as soon as the associated process terminates

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 - Accounting information → user and kernel CPU time consumed, owner

Process Control Block (PCB)

- At least, the PCB contains the following:
 - Process state → ready, waiting, running, etc.
 - Process number (i.e., unique identifier)
 - Program Counter (PC) + Stack Pointer (SP) + general purpose registers
 - CPU scheduling information → priority and pointers to state queues
 - Memory management information → page tables
 - Accounting information → user and kernel CPU time consumed, owner
 - I/O status → list of open files

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- OS gives every process the illusion of having a contiguous sequence of memory addresses that they can refer (**virtual address space**)
- OS keeps track of process-related information using an ad hoc data structure called **Process Control Block (PCB)**
- Process can be in one of **5 possible states**: **new**, **ready**, **waiting**, **running**, or **terminated**