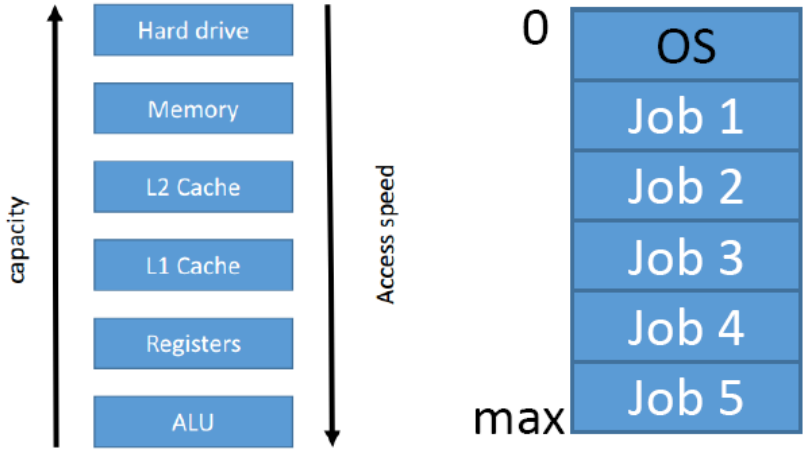
CSCI 509

OPERATING SYSTEMS INTERNALS

MULTIPROGRAMMING

Worksheet Q1

- Q: What sort of stuff could go wrong when running multiple programs?



MULTIPROGRAMMING

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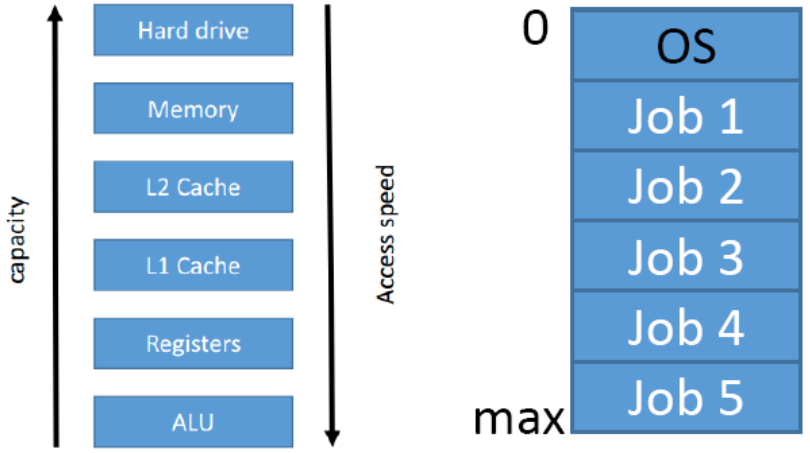
- Performance
  - Not enough memory for all jobs
  - Jobs taking too much or too little share of CPU
  - Multiple Jobs competing for same resource.



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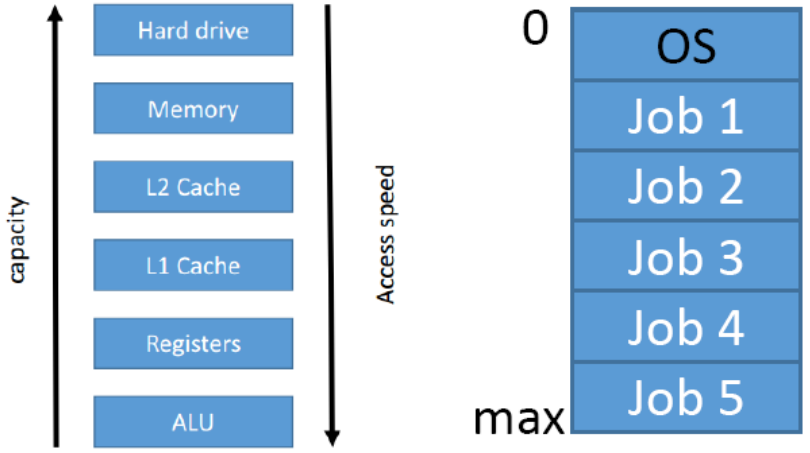

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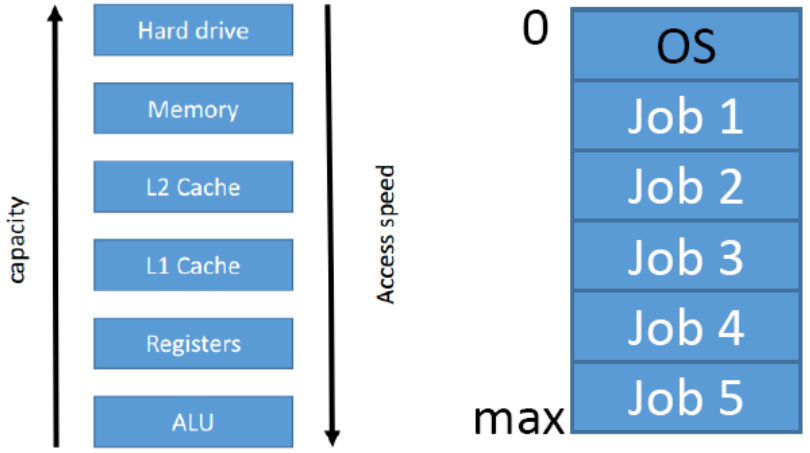
- Kernel / OS must manage all these issues.
- Another name for a 'job' is 'process'.



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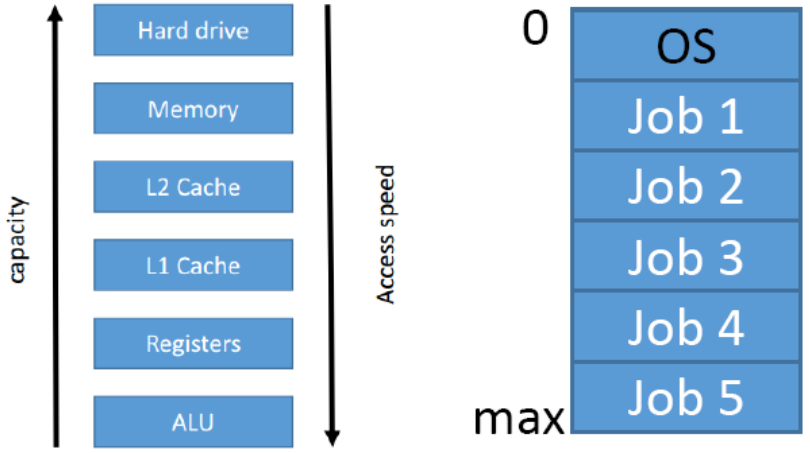
- Another name for a 'job' is 'process'.
- Q:What is the difference between a program and a process?



PROGRAM VS PROCESS

- A process is a program in execution. It is a unit of work within the system.
- Program is a ***passive entity***, process is an ***active entity***.

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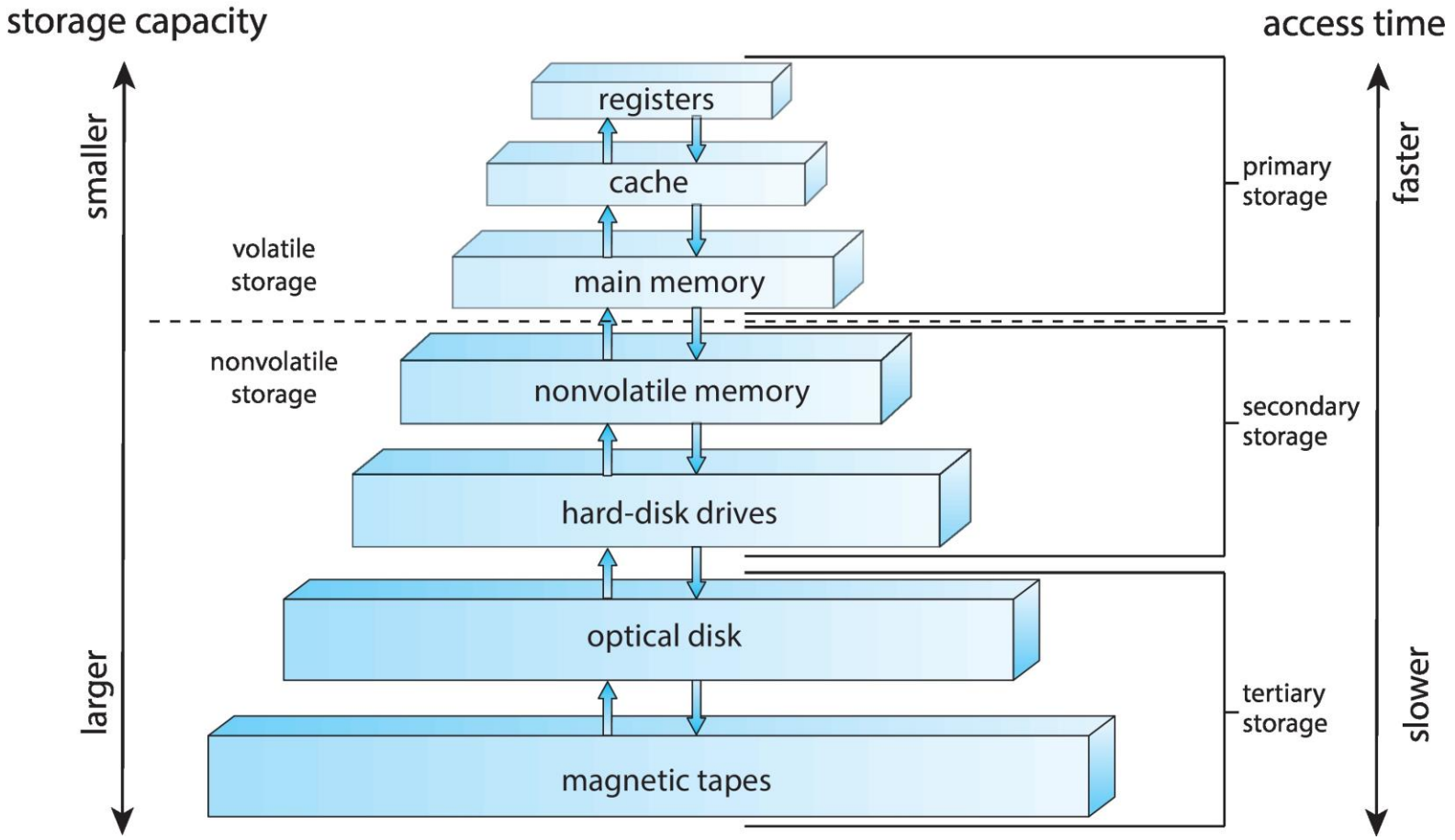
- A process is a program in execution. It is a unit of work within the system.
- Program is a ***passive entity***, process is an ***active entity***.
- Analogy:
  - If a program is the script of a play, the process is the play being performed.
  - You can have multiple processes running the same program.

MEMORY MANAGEMENT: MEMORY HIERARCHY



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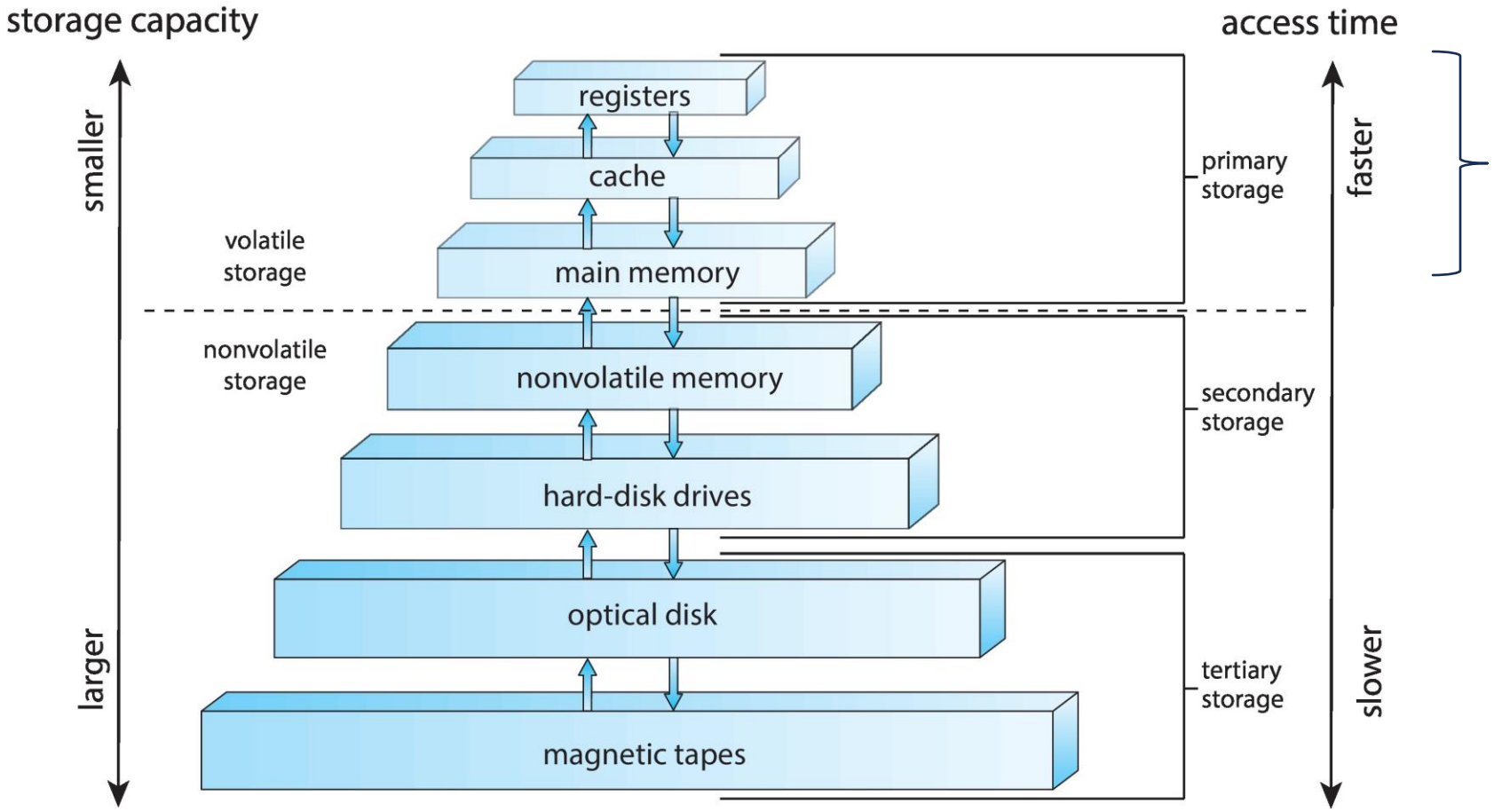

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- Expensive
- Volatile: State is lost on power disconnect.

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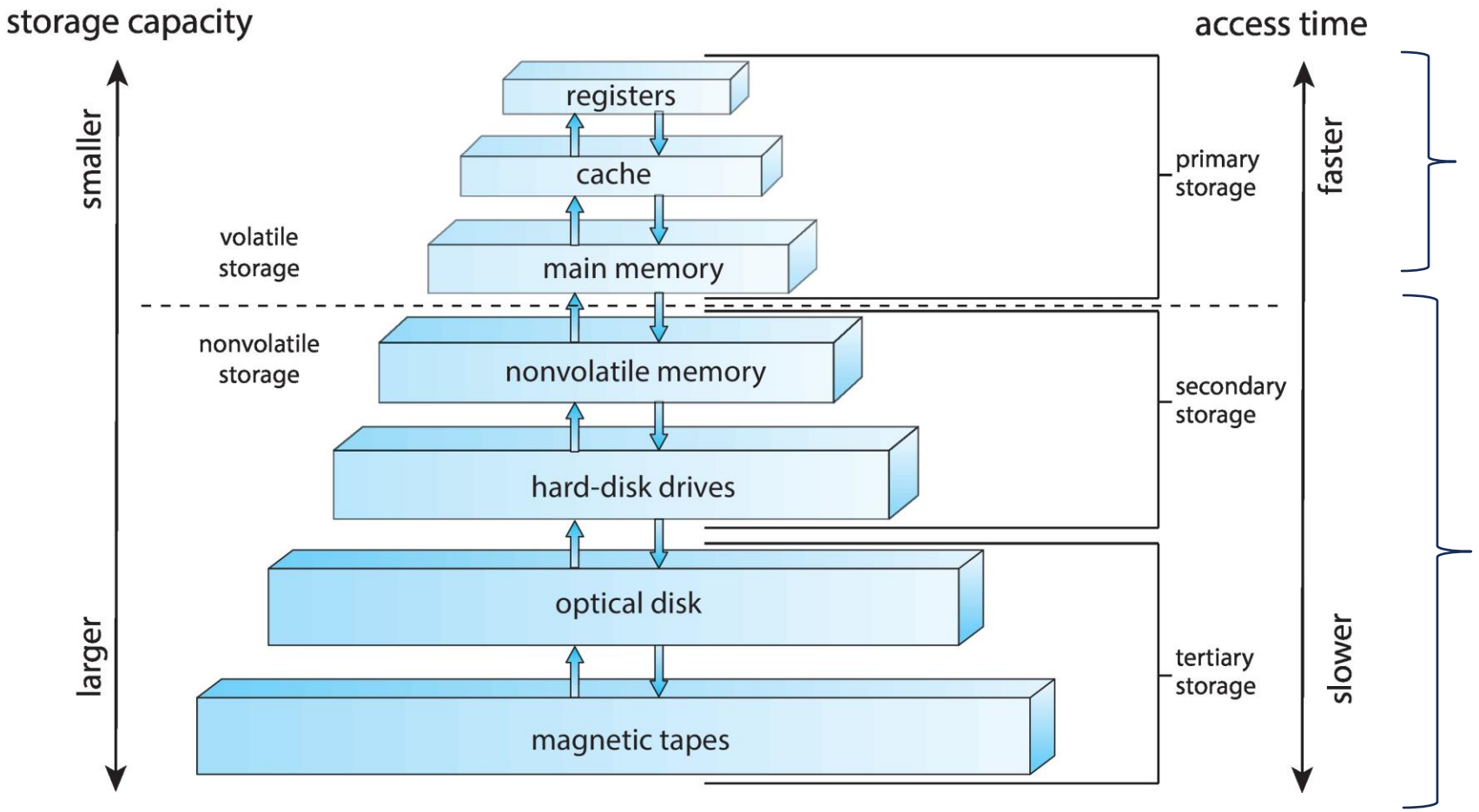
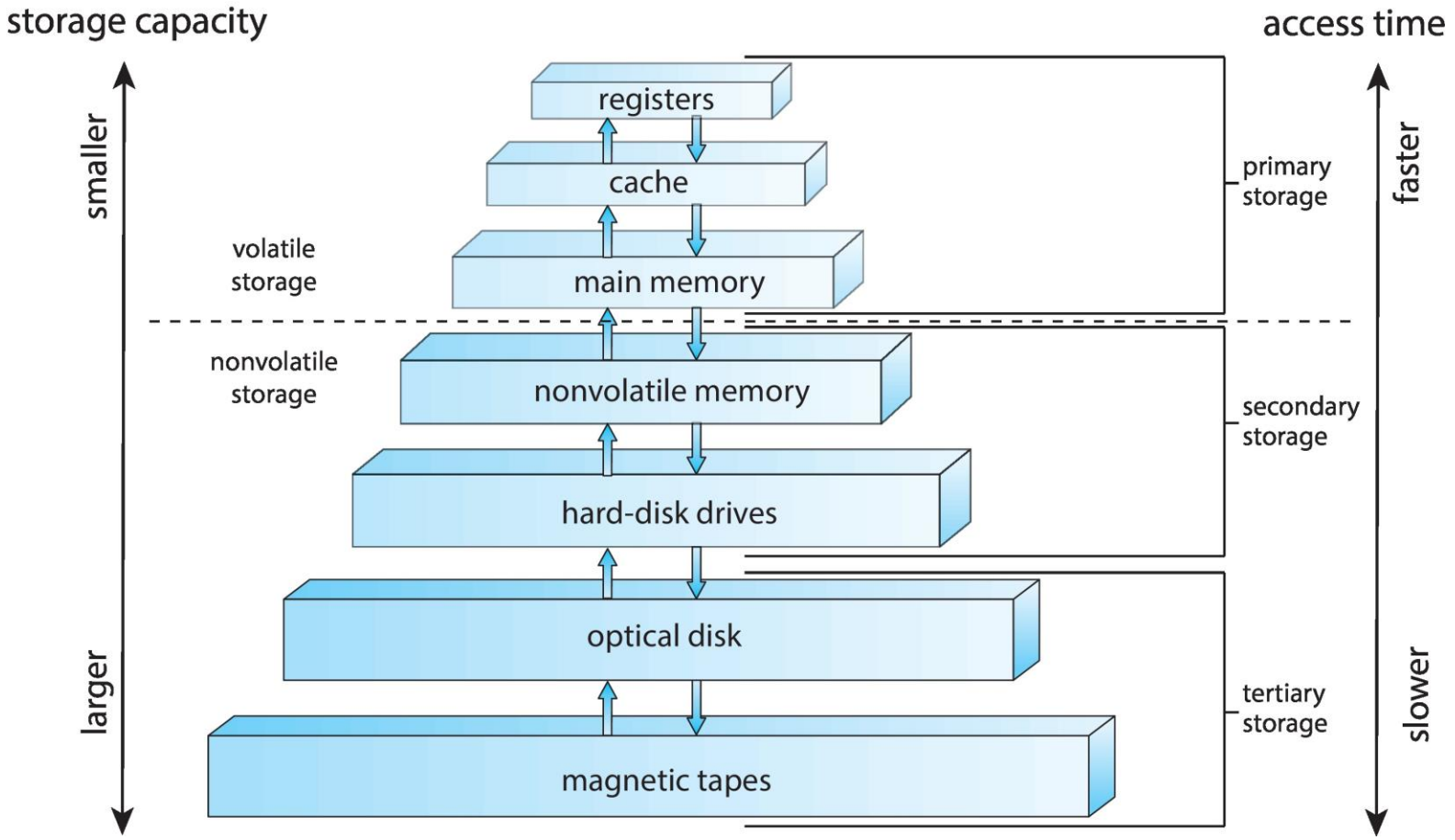


- Fast
- Expensive
- Volatile: State is lost on power disconnect.

- Slow
- Non-volatile
- Cheap

MEMORY MANAGEMENT: MEMORY HIERARCHY



Q: Why does this work?

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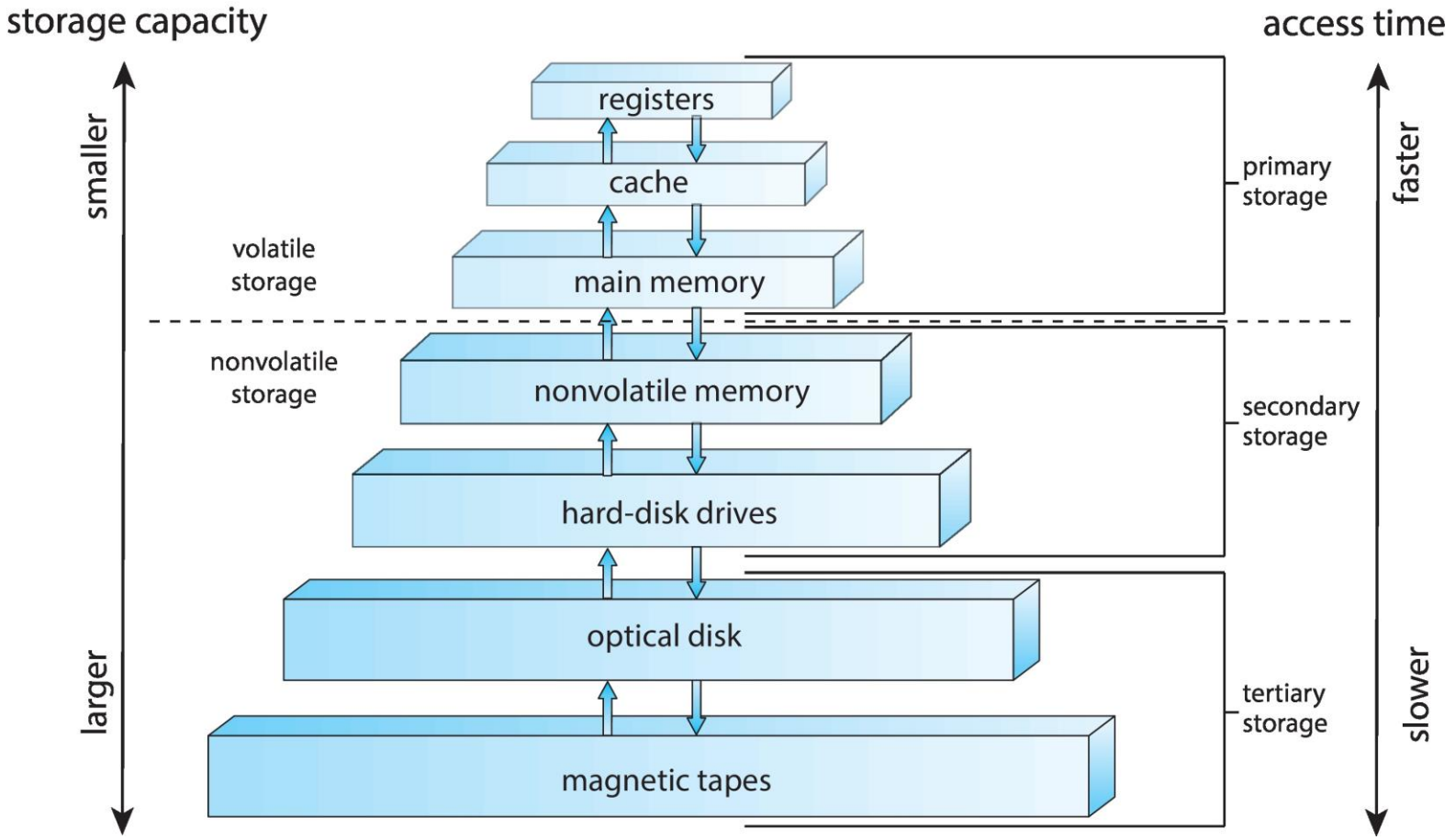
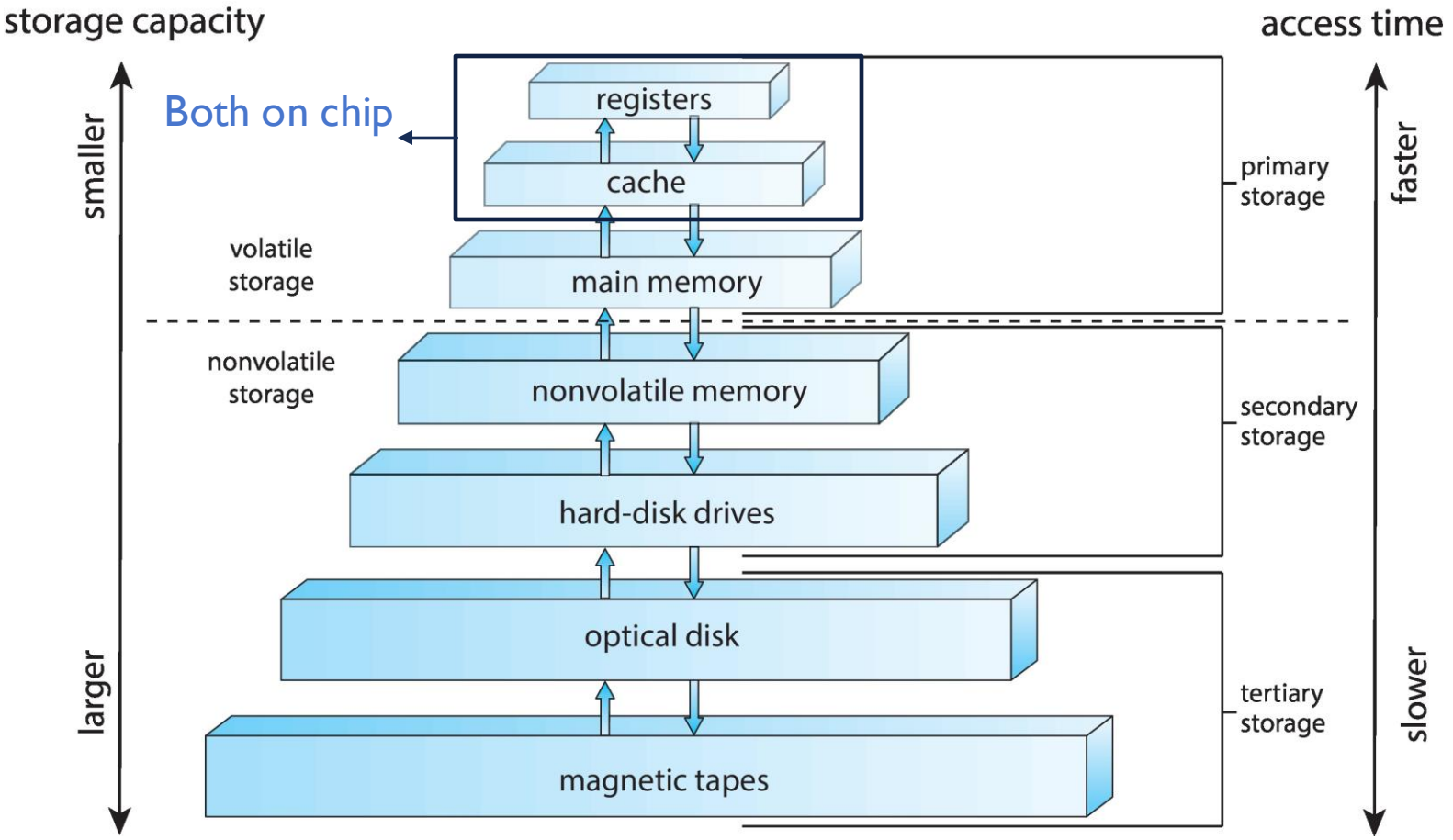


Q: Why does this work?

- CPU only operates on few words at a time …
- It never needs access to the full memory or any significant portion of it.

MEMORY HIERARCHY



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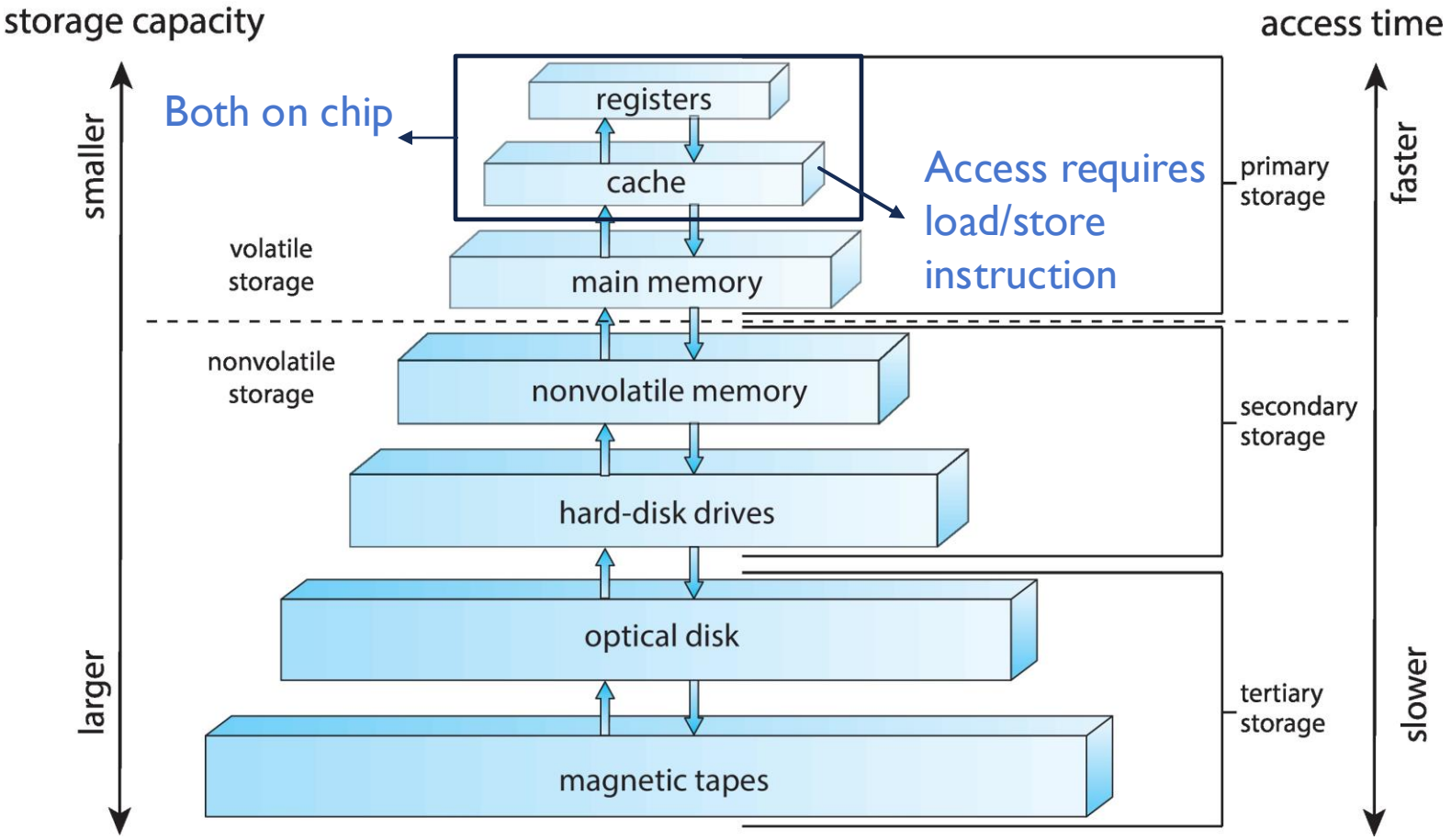

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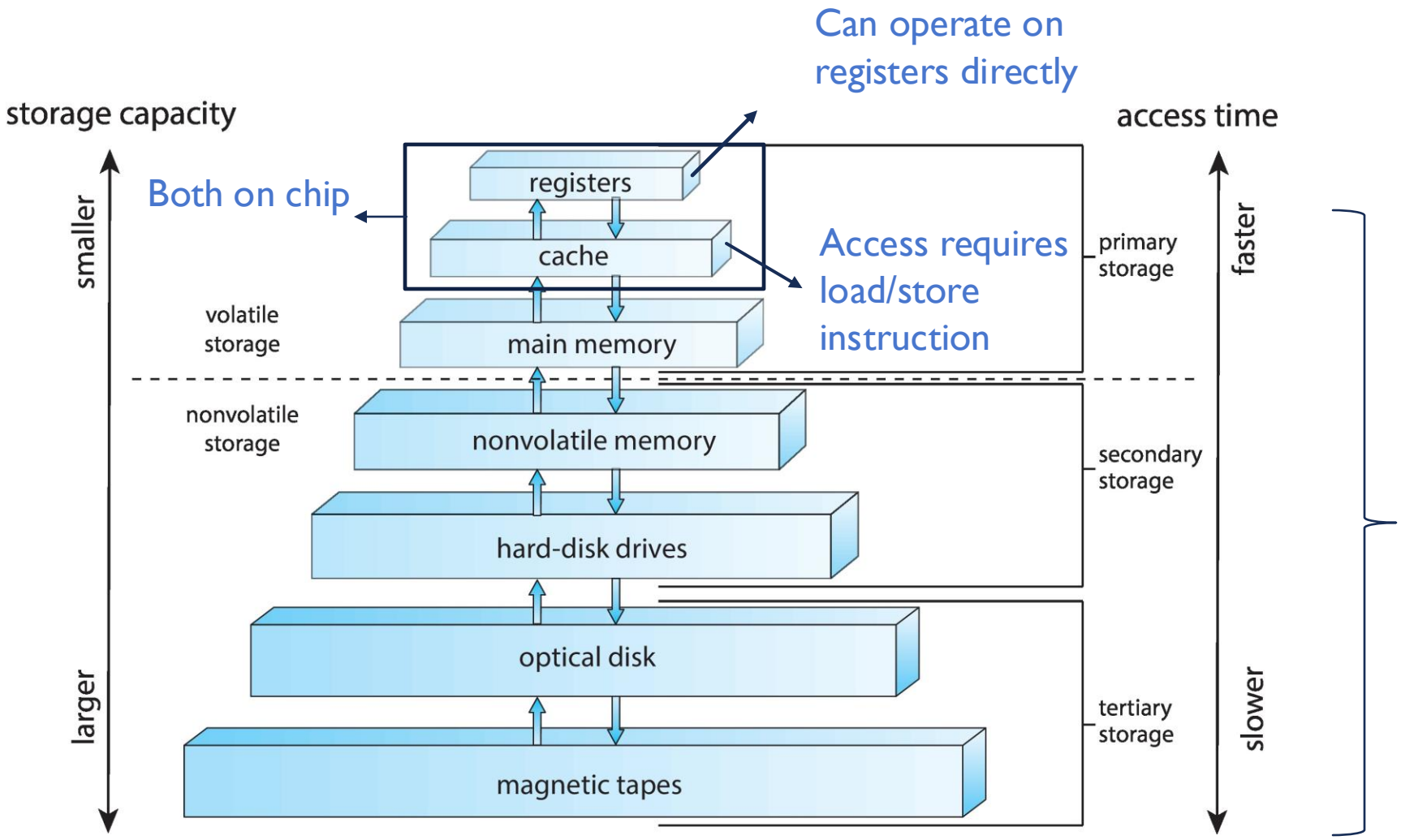
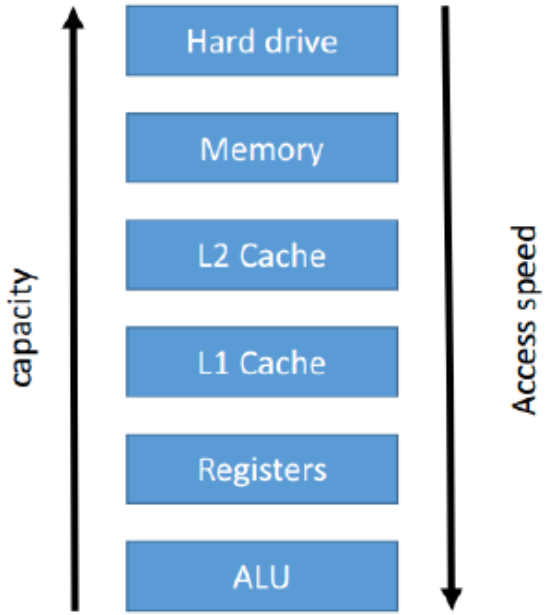
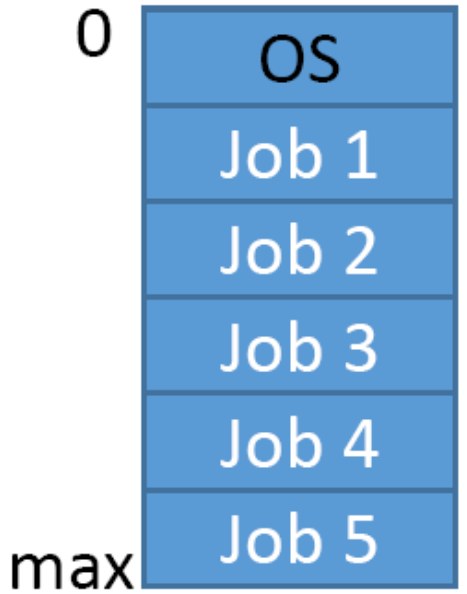


All is handled by the OS
The program doesn't need to worry about registers, cache, …

MEMORY MANAGEMENT

- How to divide limited memory across multiple processes.
- Not enough memory? Swap jobs to storage.





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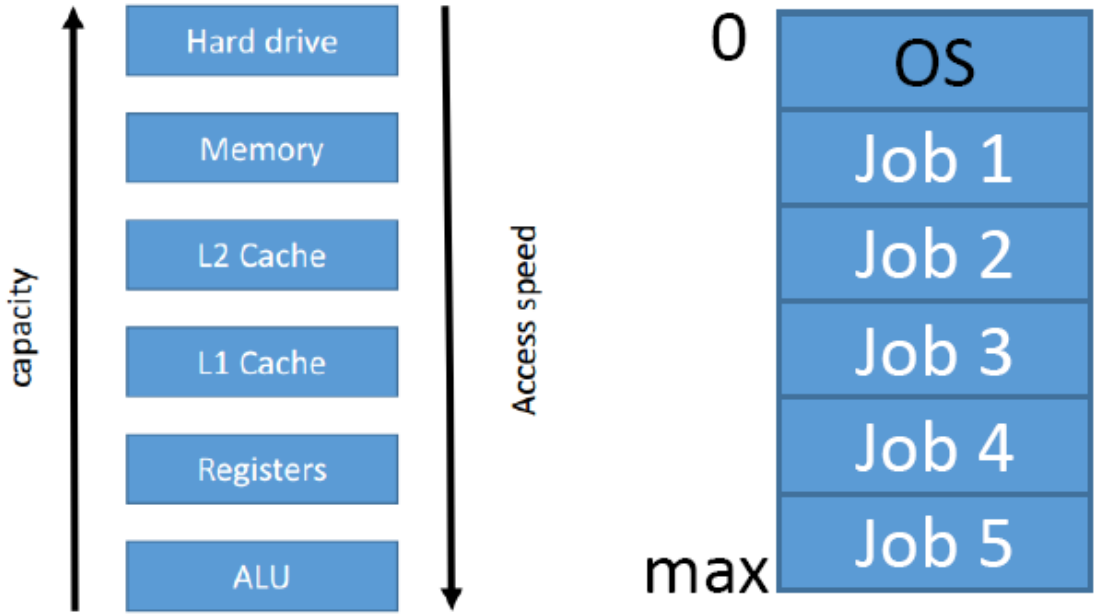

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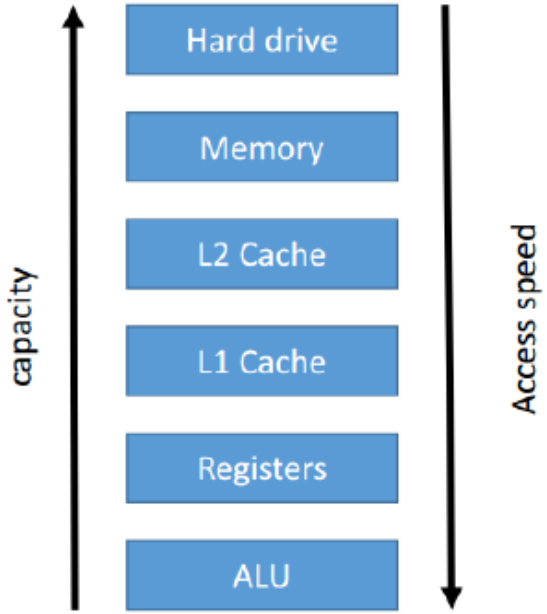
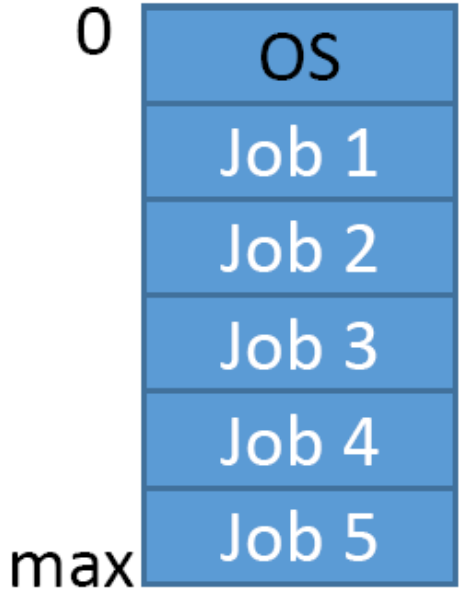
  - **C:** Main Memory
  - **D:** All of the above





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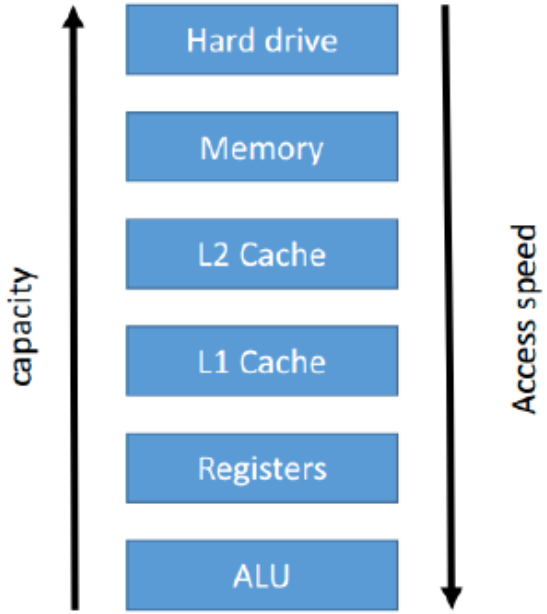
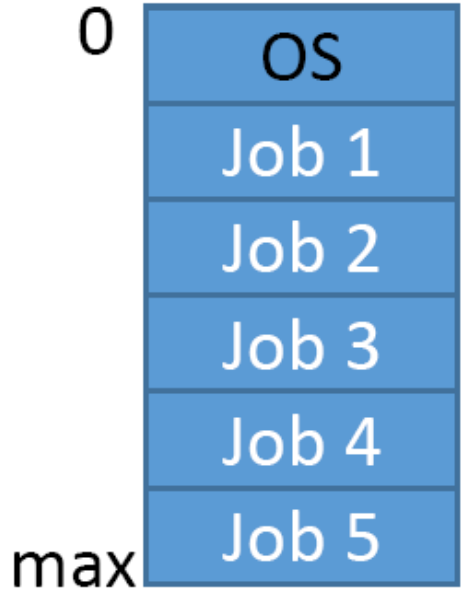
- Only a small portion is loaded in L1 cache.





PROTECTION

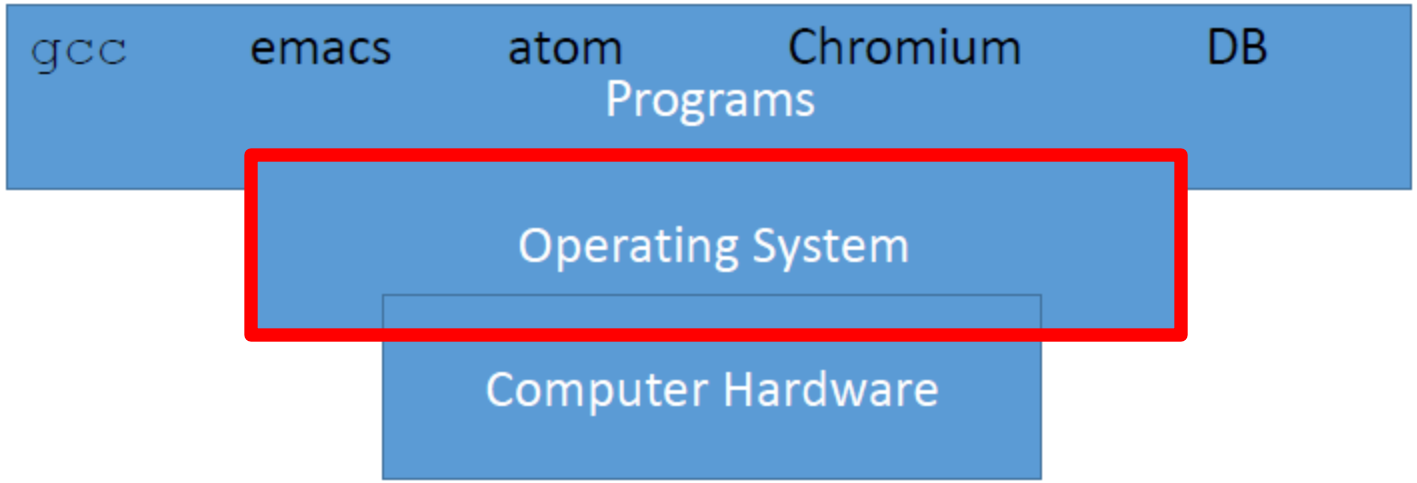
- **Protection** – any mechanism for controlling access of processes or users to resources defined by the OS
  - User identities (**user IDs**, security IDs) include name and associated number, one per user
  - User ID then associated with all files, processes of that user to determine access control
  - Group identifier (**group ID**) allows set of users to be defined and controls managed, then also associated with each process, file
  - **Privilege escalation** allows user to change to effective ID with more rights

SECURITY

- **Security** – defense of the system against internal and external attacks
  - Huge range, including denial-of-service, worms, viruses, identity theft, theft of service
- Can be handled by third party software.
- Protection Vs Security:
  - Protection: Managing access control among authentic users.
  - Security: Protecting the system from malicious software.

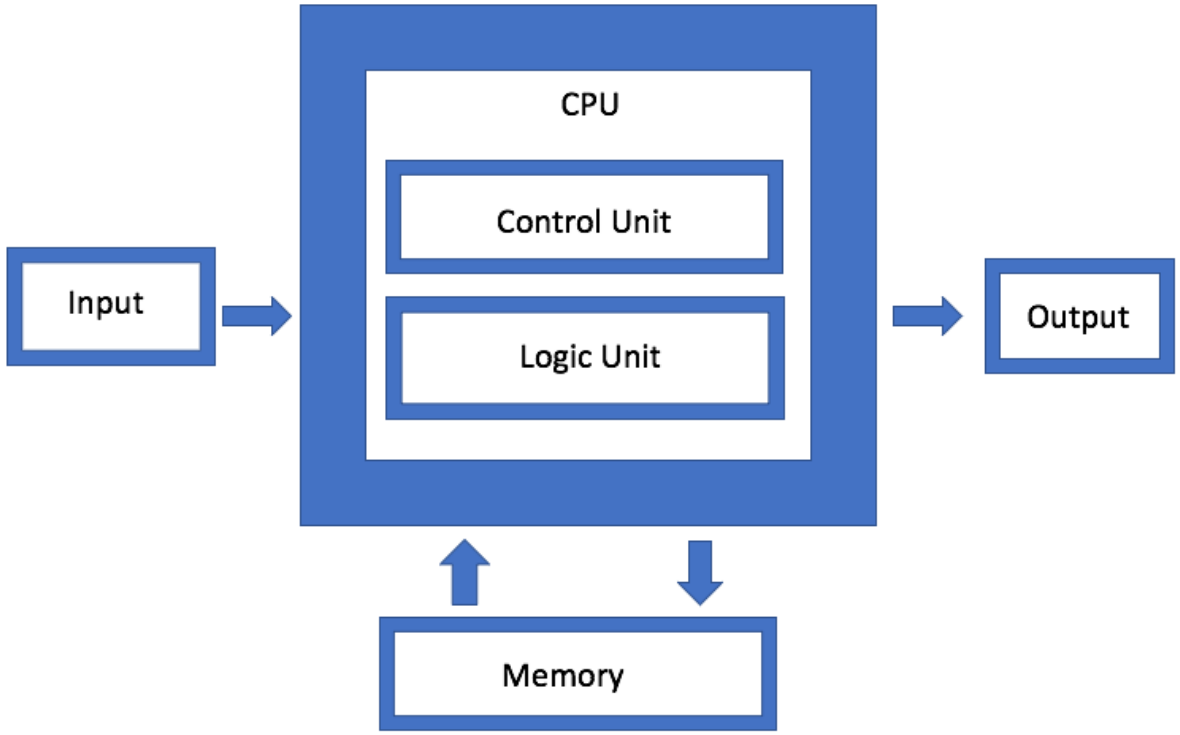
COMPUTER ARCHITECTURE REVIEW

- To understand OS better, we need to understand computer hardware.



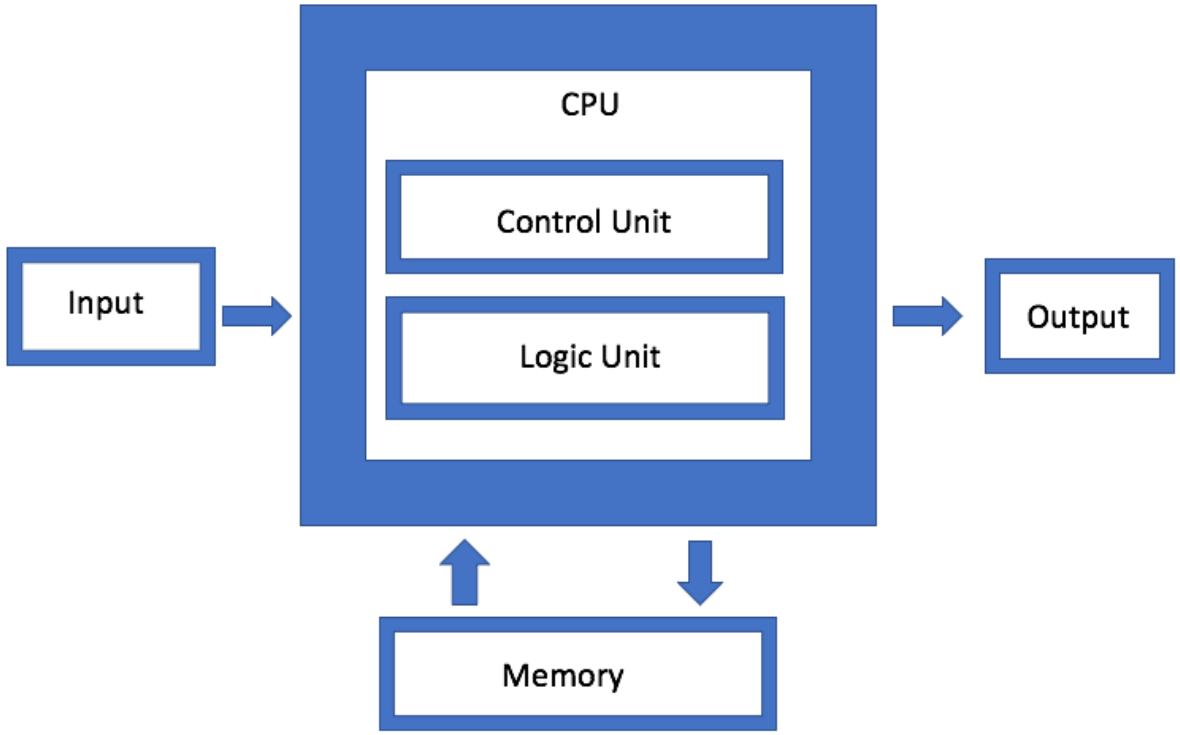
HARDWARE COMPONENTS

- Components:
  - CPU
  - Memory
  - Input
  - Output



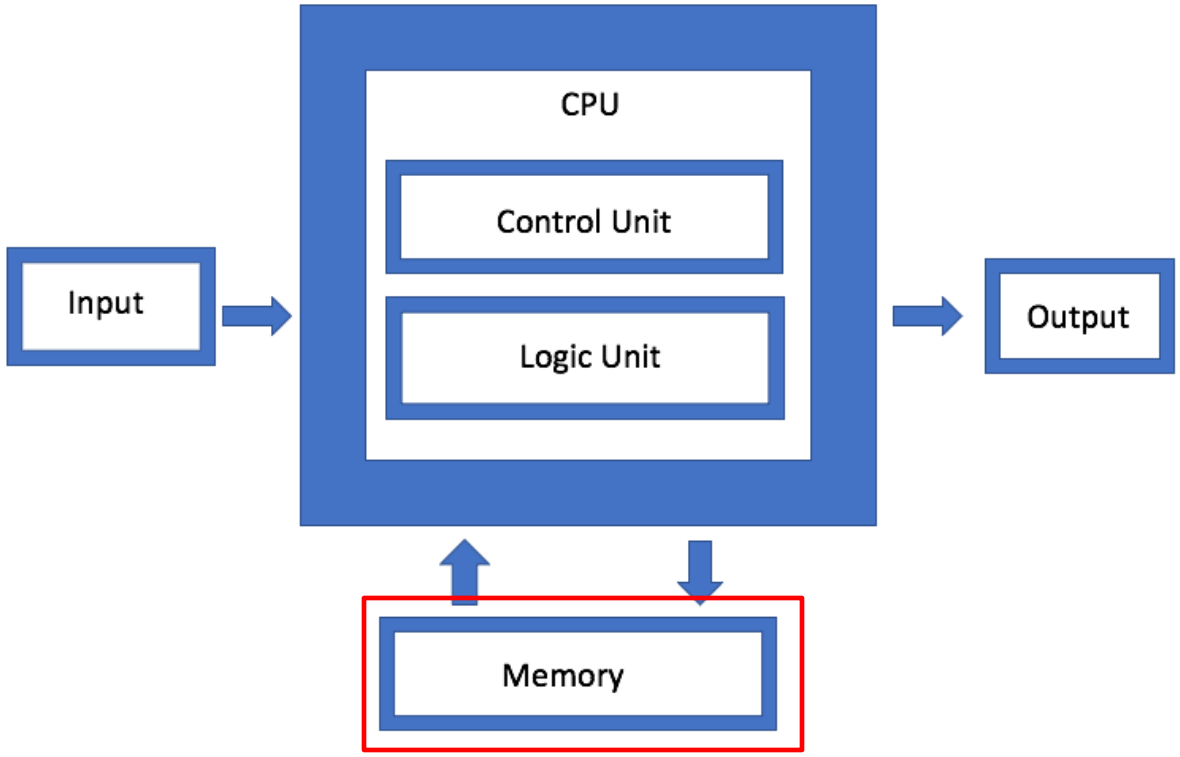
MODERN COMPUTER ARCHITECTURE

- Modern Computer Architecture:
  - Instruction and Data both stored in unified memory.
- At some point, in the early days of computing, program memory and data were separated and each had their own CPU interface.



MEMORY

- Memory has many components:
  - Registers
  - Cache
  - Main Memory
  - Hard Disk
  - …



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  - Registers → Not really considered memory
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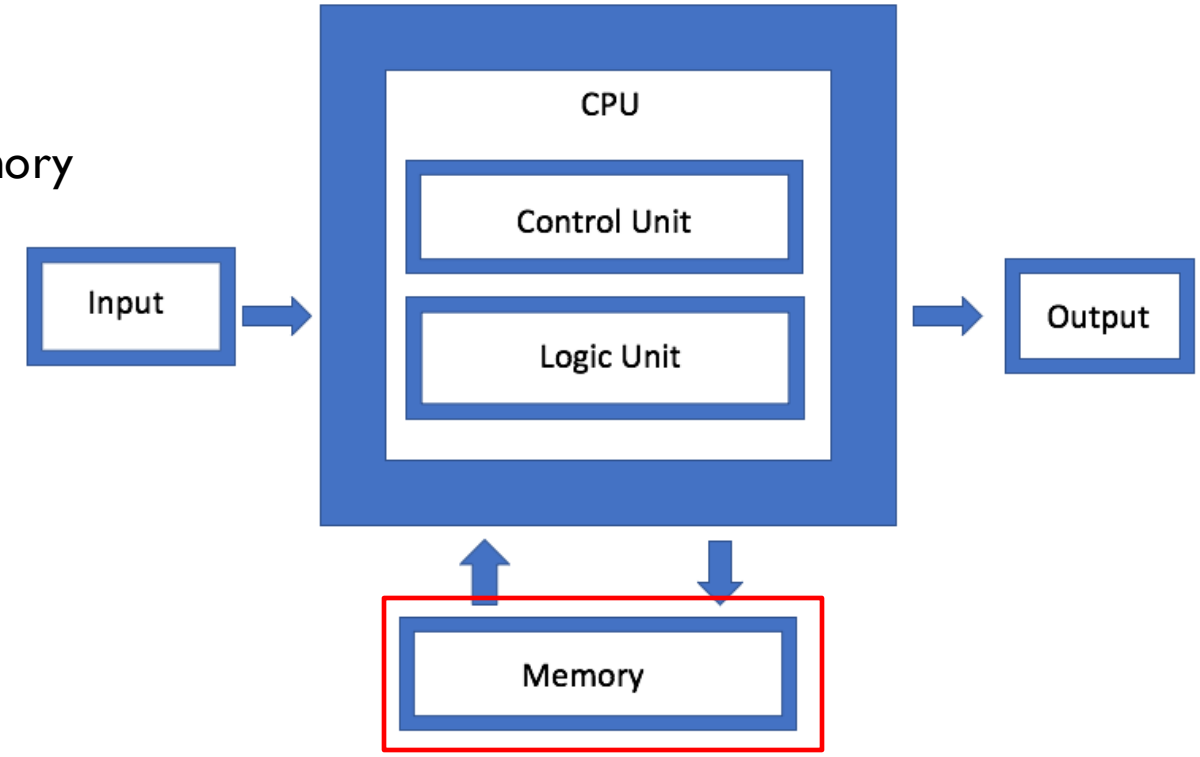

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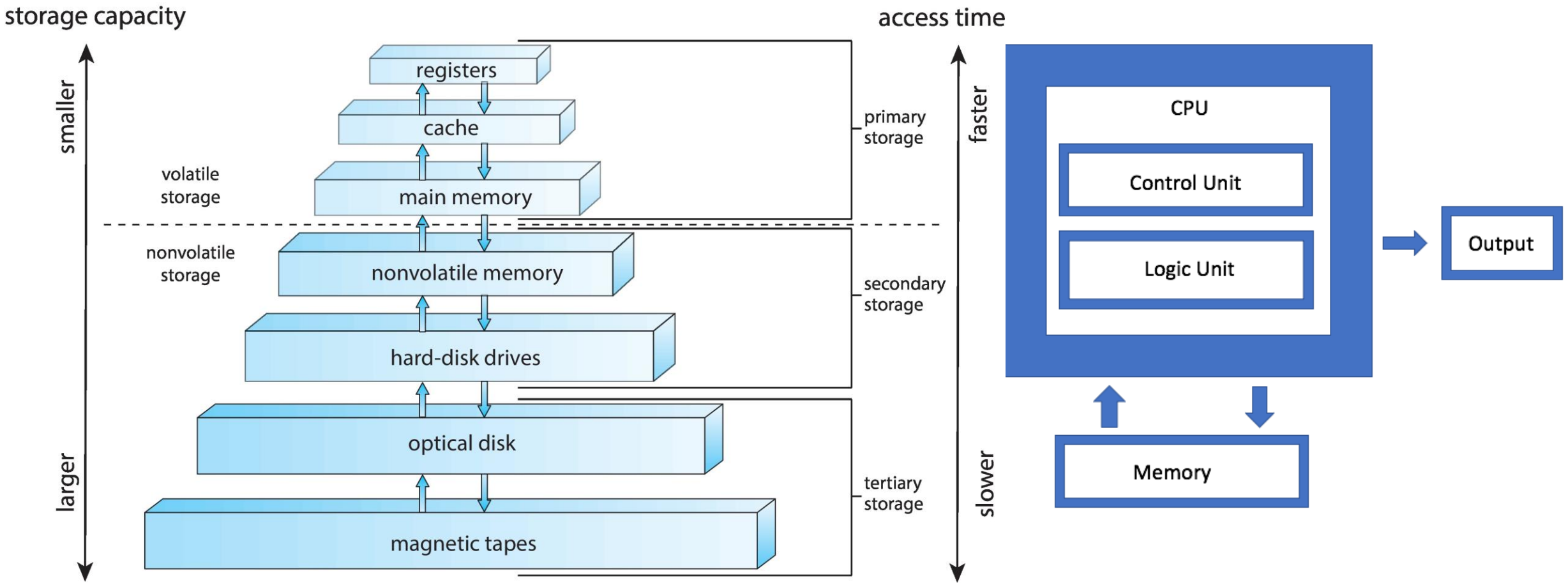

PROGRAMS

Q: What is a program made of?

- A program is composed of a set of instructions.
- Computer hardware simply executes the instructions, one at a time (for single processor/core systems).

INSTRUCTION CYCLE

- Three steps in instruction cycle:

INSTRUCTION CYCLE

- Three steps in instruction cycle:
  - Fetch Instruction

Fetch the instruction

INSTRUCTION CYCLE

- Three steps in instruction cycle:
  - Fetch Instruction
    - Instruction is retrieved from memory

Fetch the instruction

INSTRUCTION CYCLE

- Three steps in instruction cycle:
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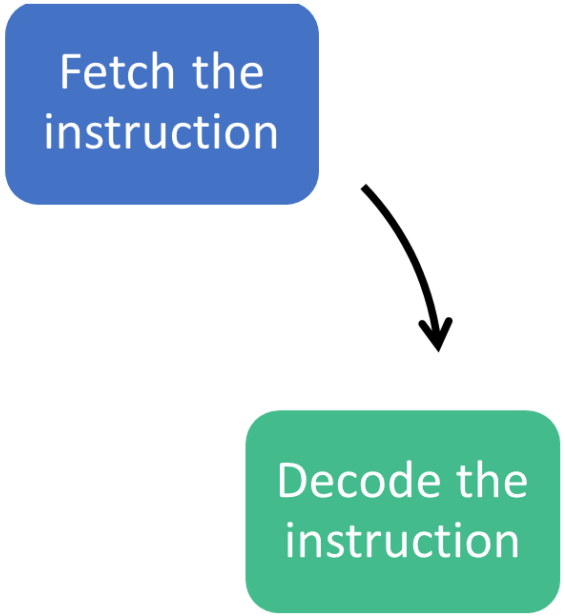
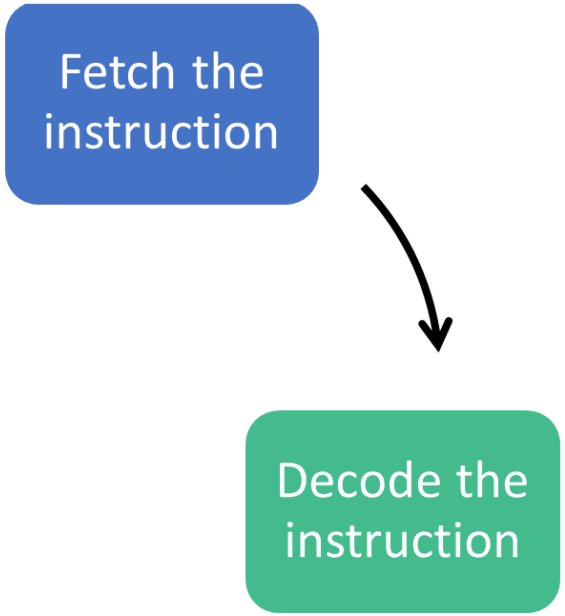
  - Decode Instruction



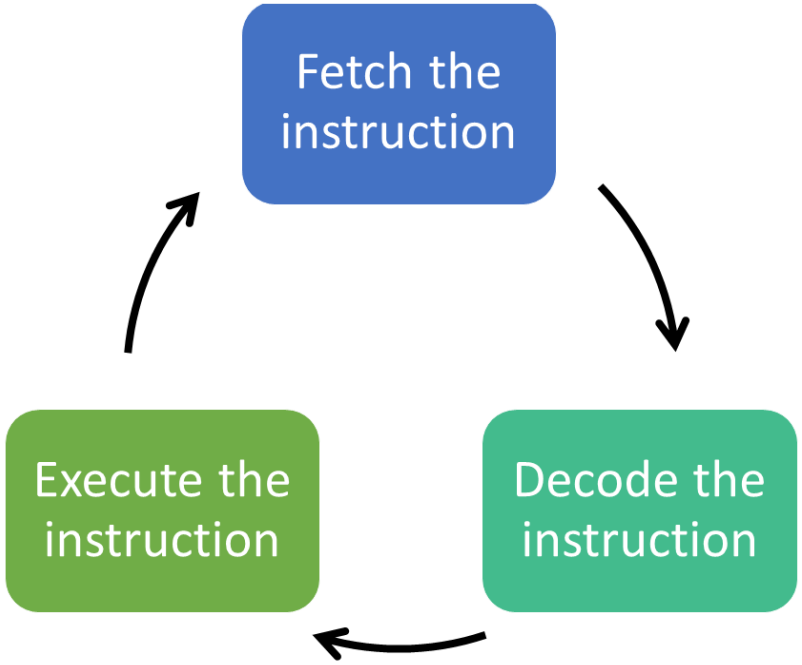
INSTRUCTION CYCLE

- Three steps in instruction
  - Fetch Instruction
  - Decode Instruction
    - Instruction is analyzed.



INSTRUCTION CYCLE

- Three steps in instruction cycle
  - Fetch Instruction
  - Decode Instruction
  - Execute Instruction



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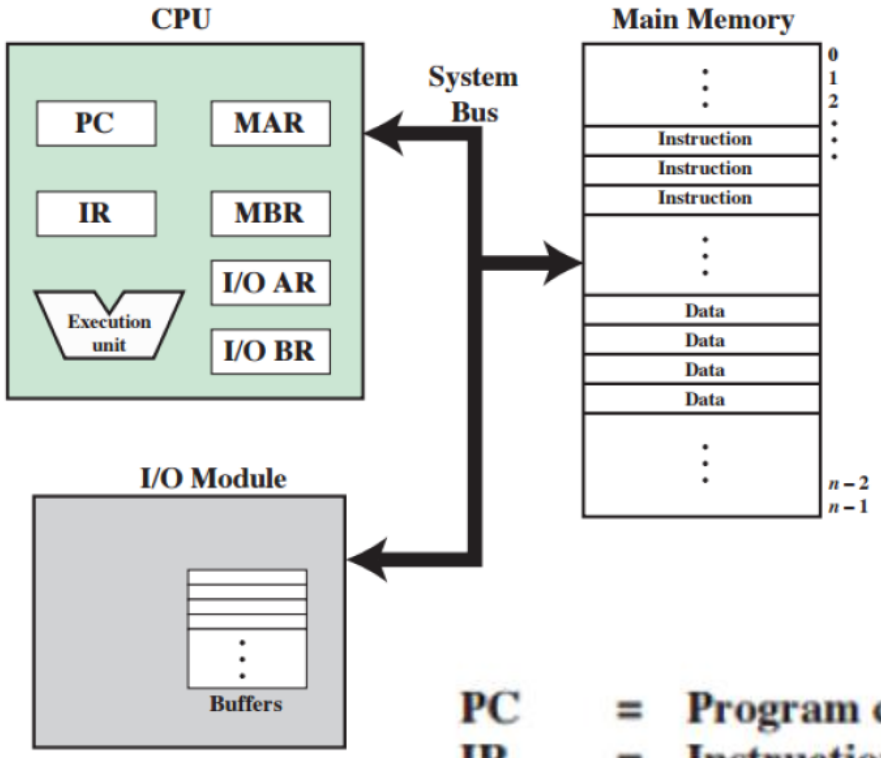

PC = Program counter
IR = Instruction register
MAR = Memory address register
MBR = Memory buffer register
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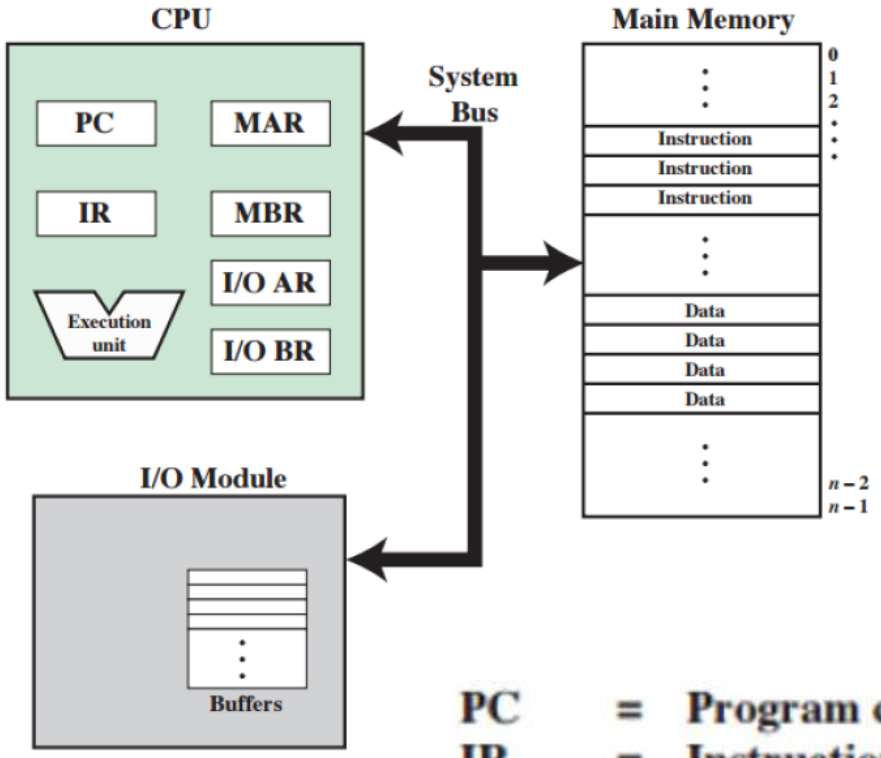

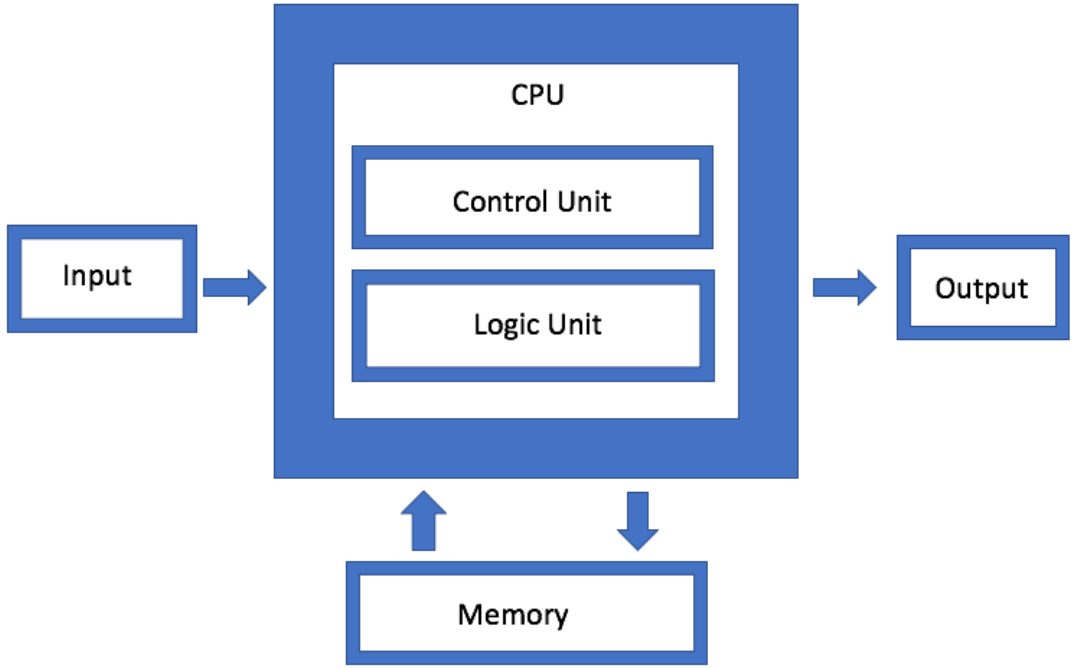

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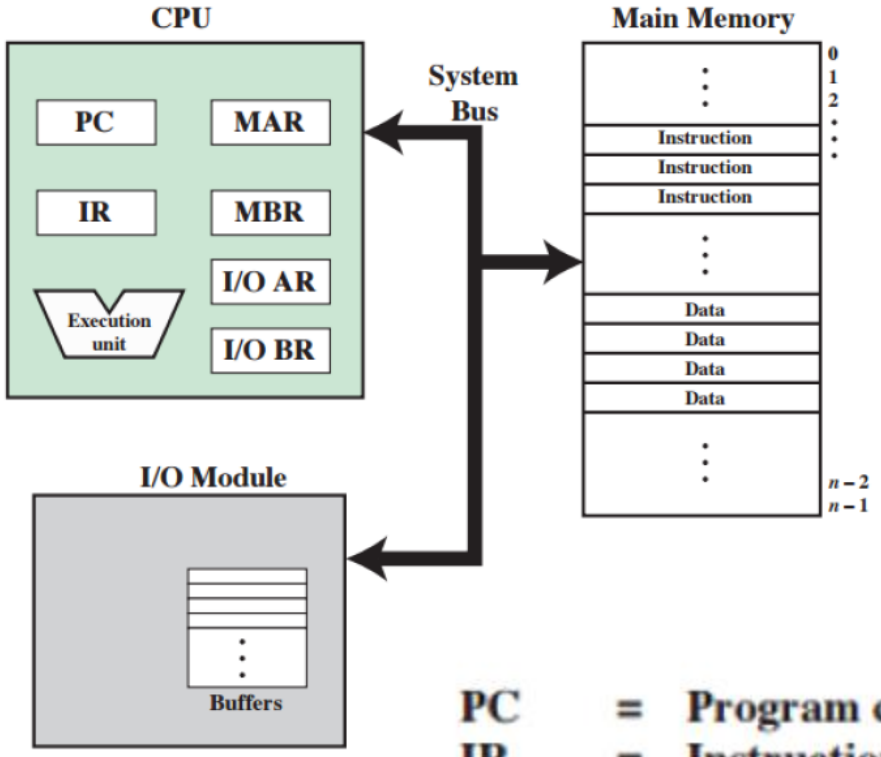

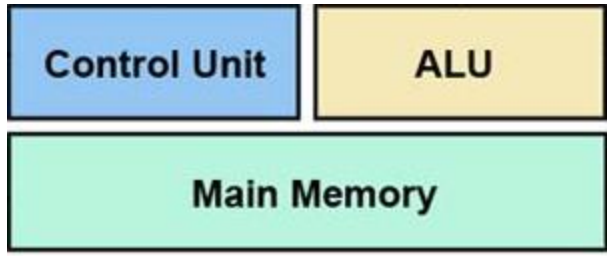

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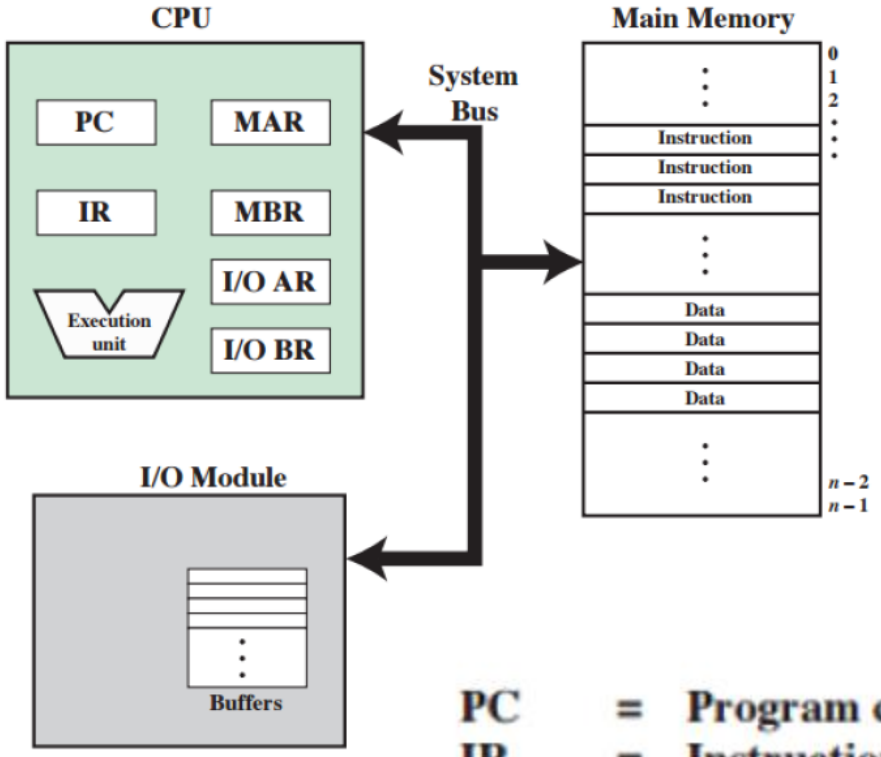

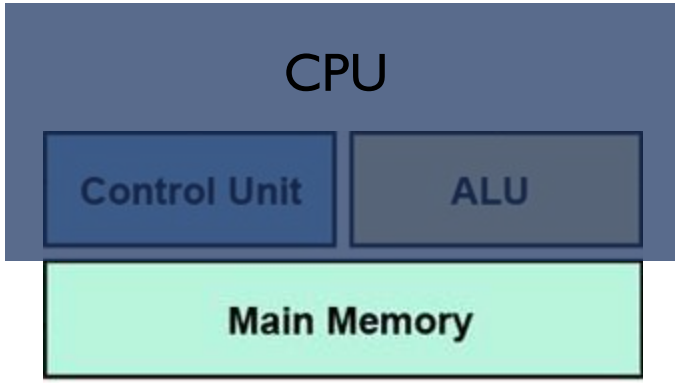

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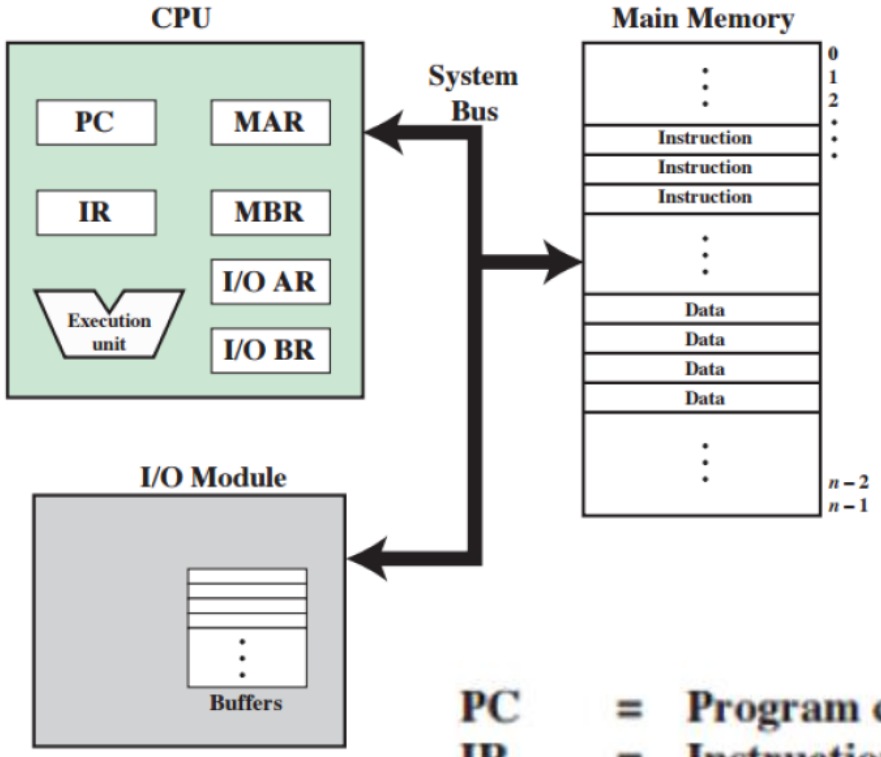

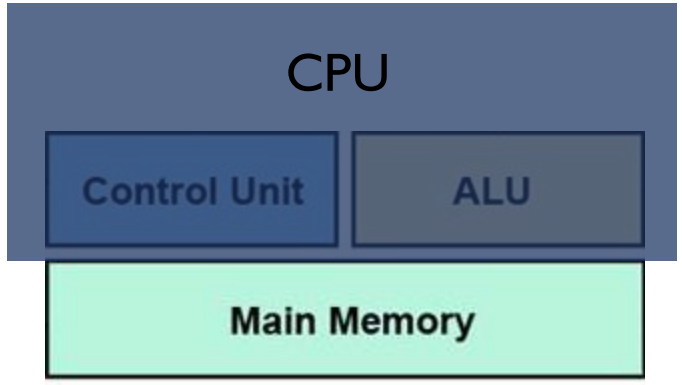

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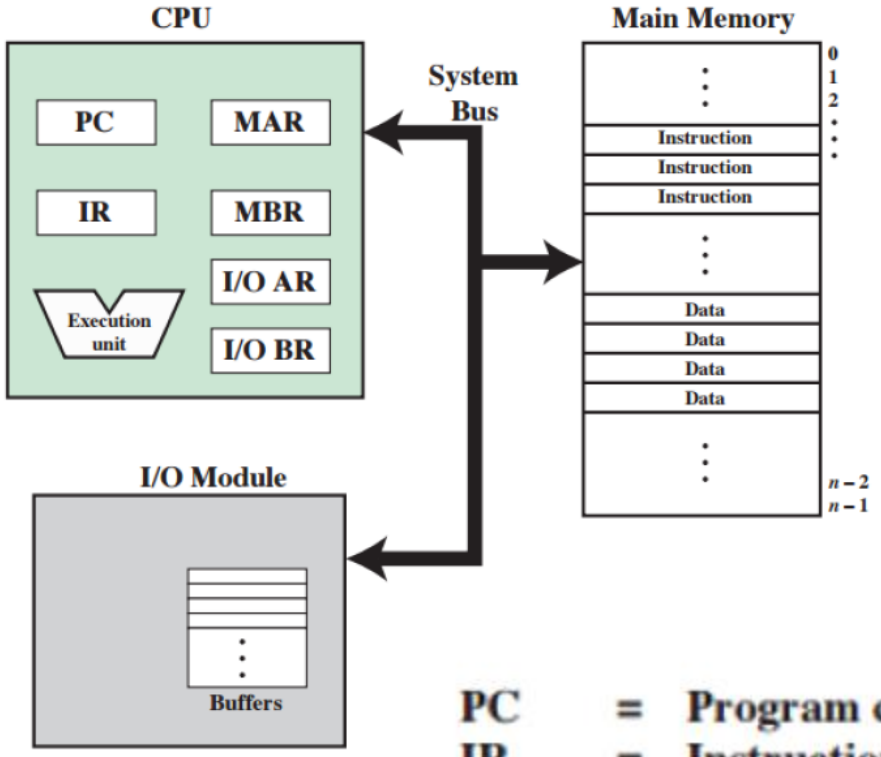
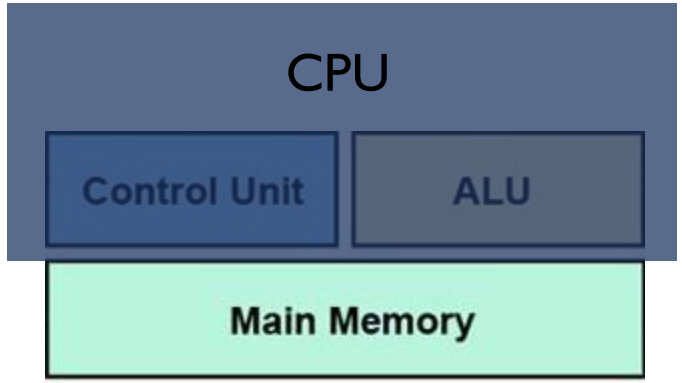
ALU: Execution Unit

Control Unit: Fetches Instructions

INSTRUCTION CYCLE

All execution is performed on registers.





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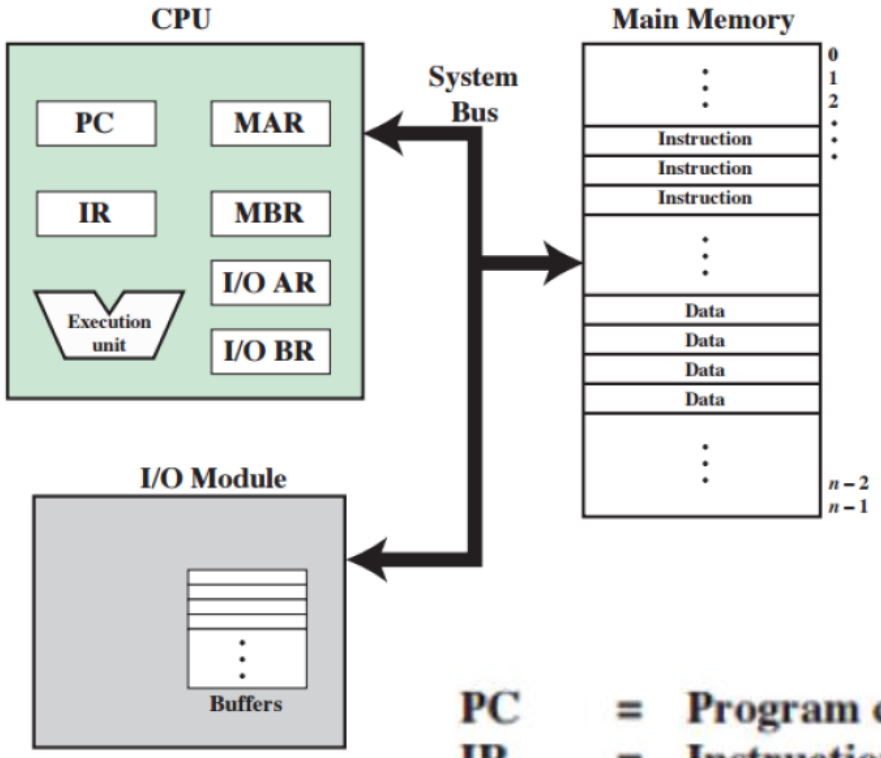

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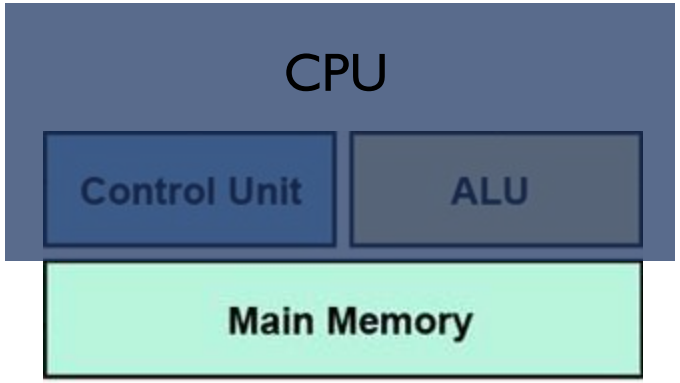
Registered are labeled: r1, r2, r3 …
Floating point registers are separate: f1, f2, f3 …



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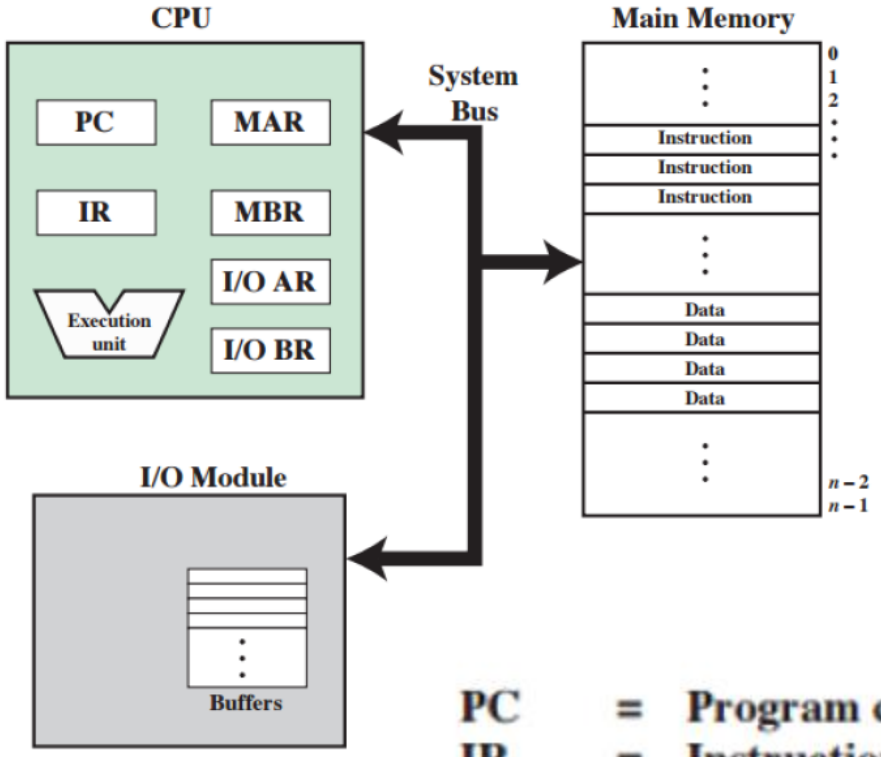

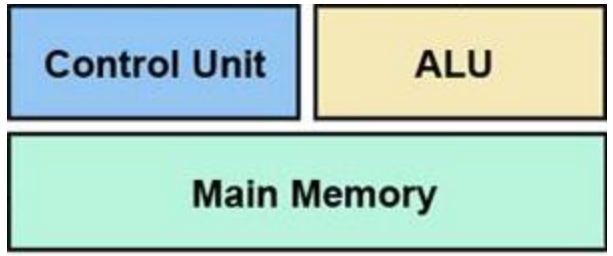

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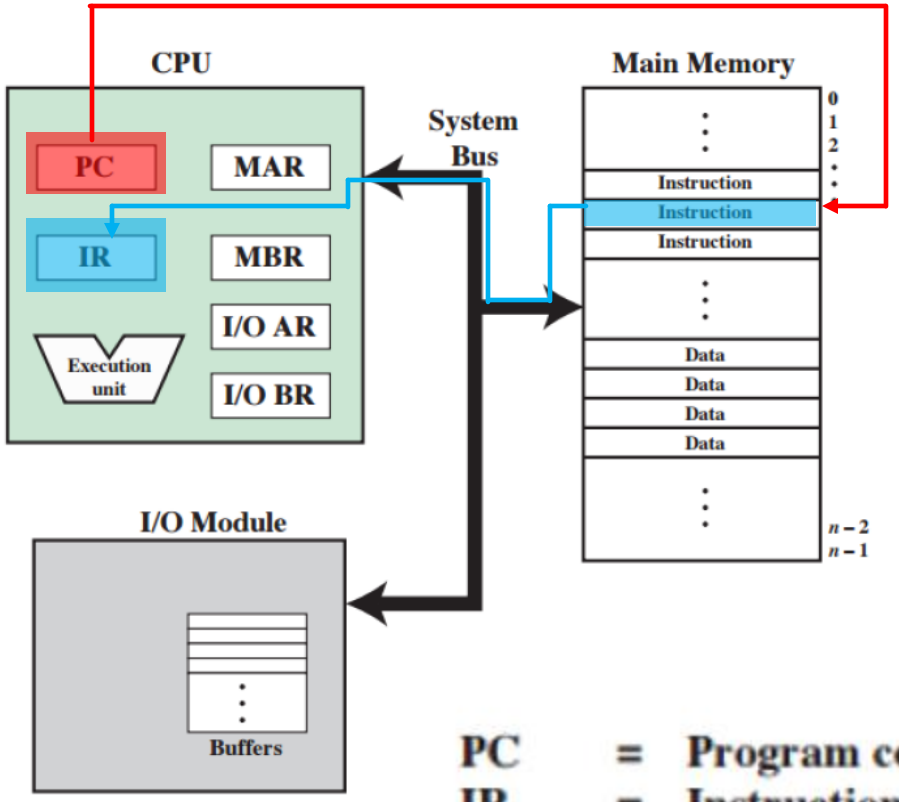
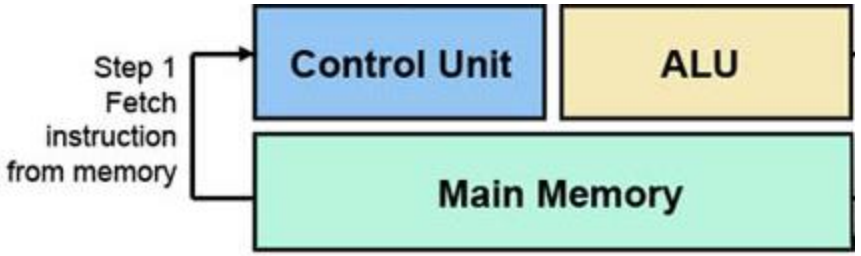
FETCH





PC = Program counter
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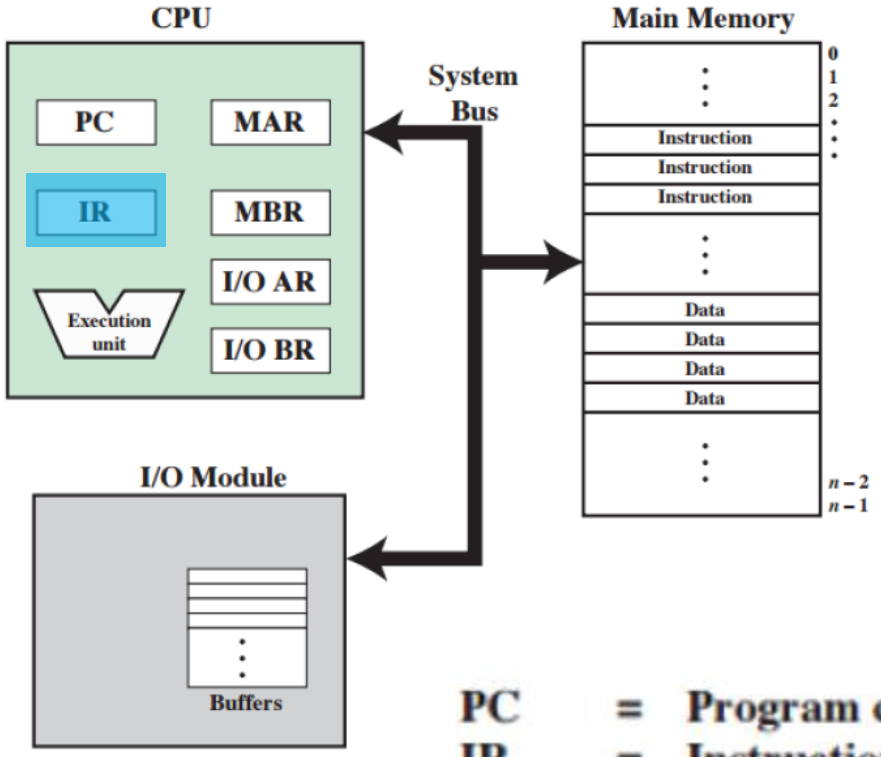
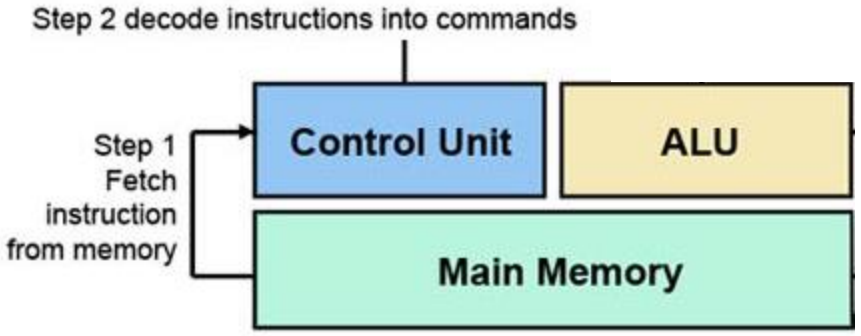
DECODE





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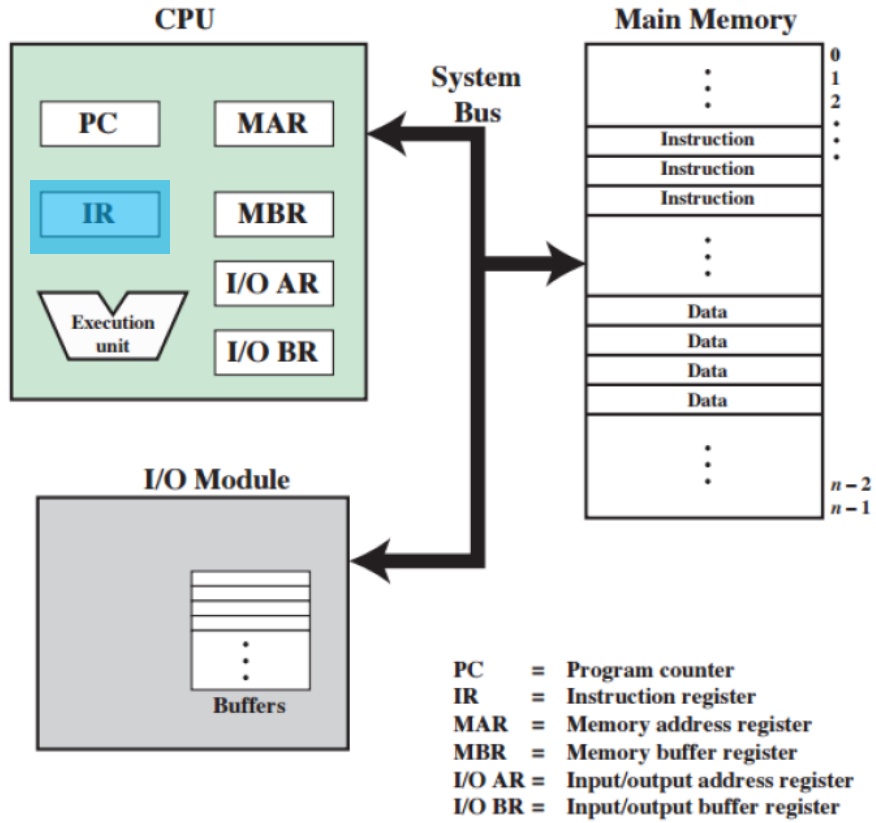
INSTRUCTION FORMAT

- How is an instruction decoded?



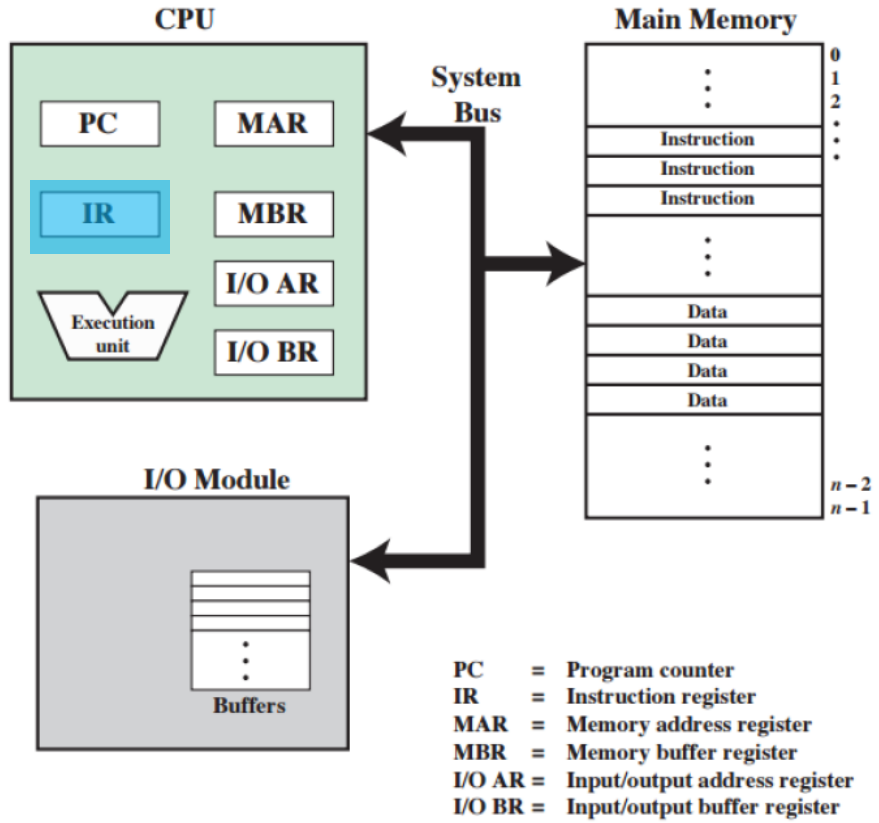
INSTRUCTION FORMAT

- How is an instruction decoded?

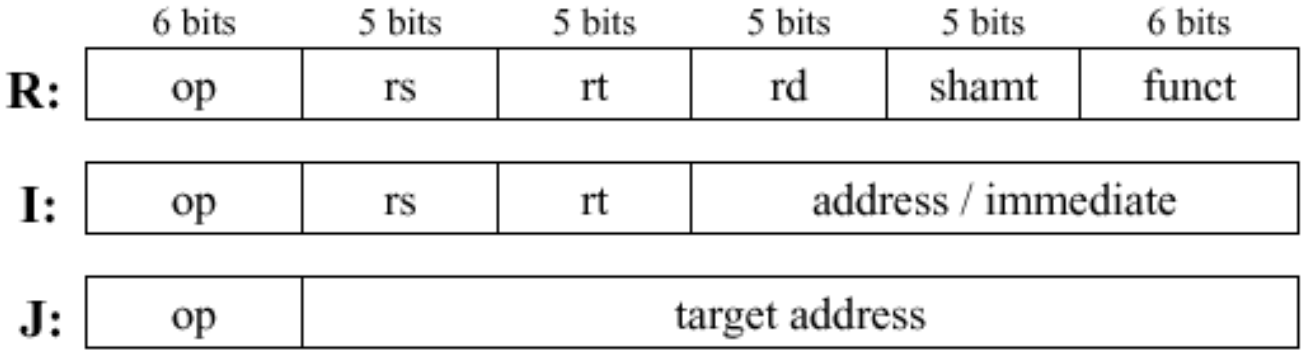
An instruction will look something like this:

001110 01001 01011 01010 00000 000000

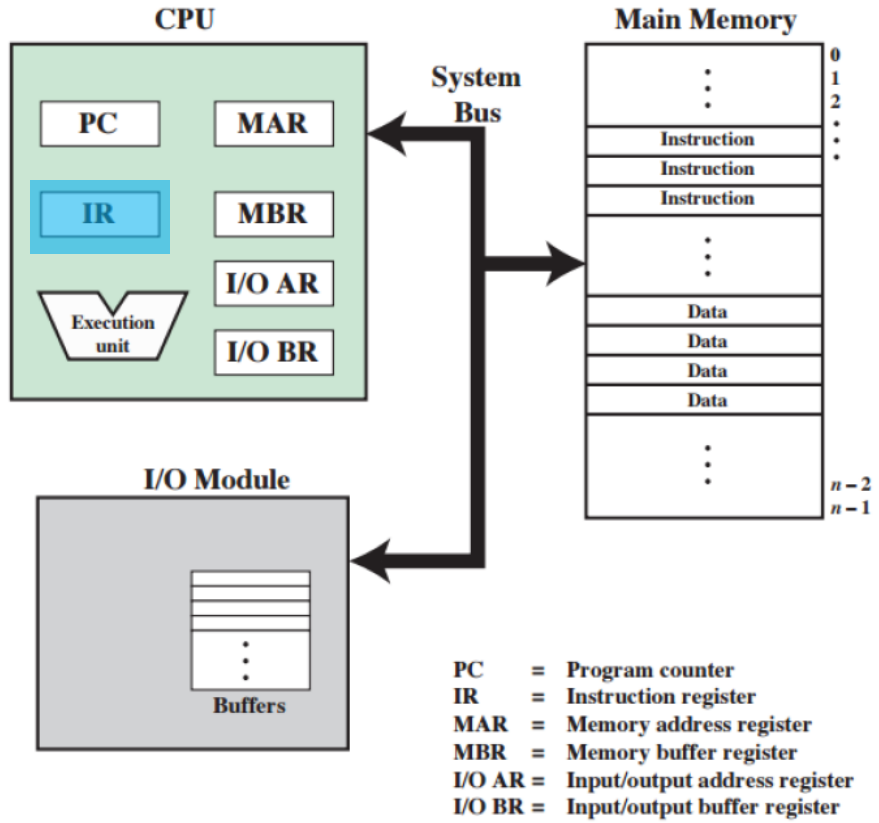
How can we "decode" that into a meaningful CPU operation?



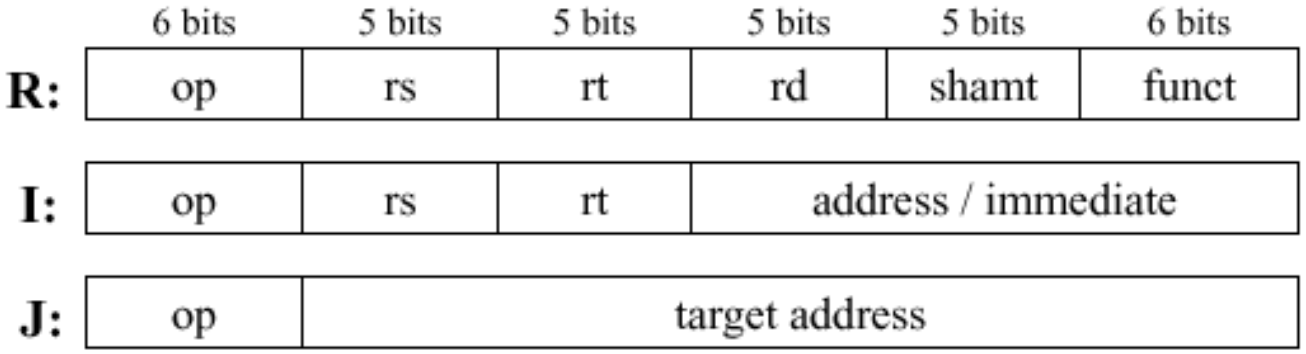
INSTRUCTION FORMAT



MIPS Architecture

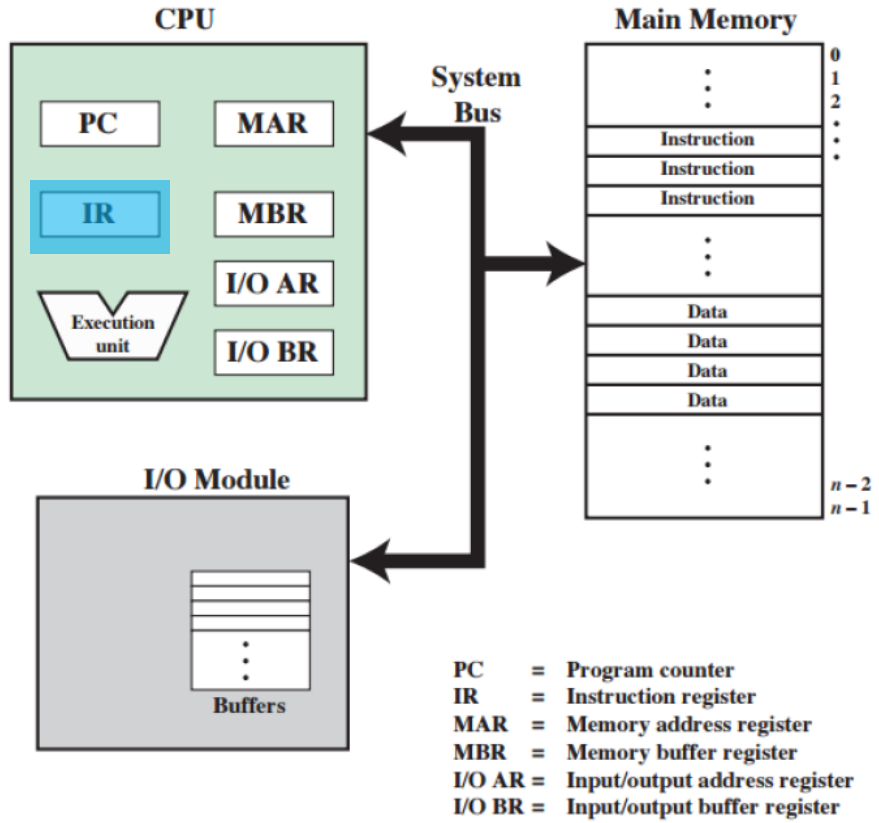


INSTRUCTION FORMAT

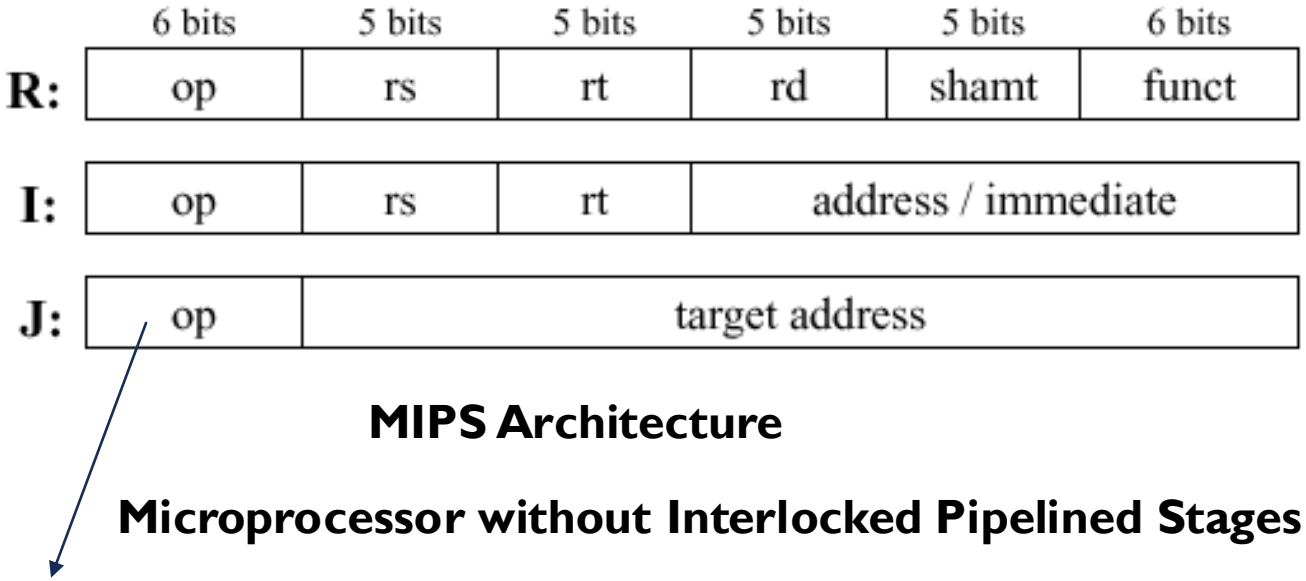


MIPS Architecture

Microprocessor without Interlocked Pipelined Stages



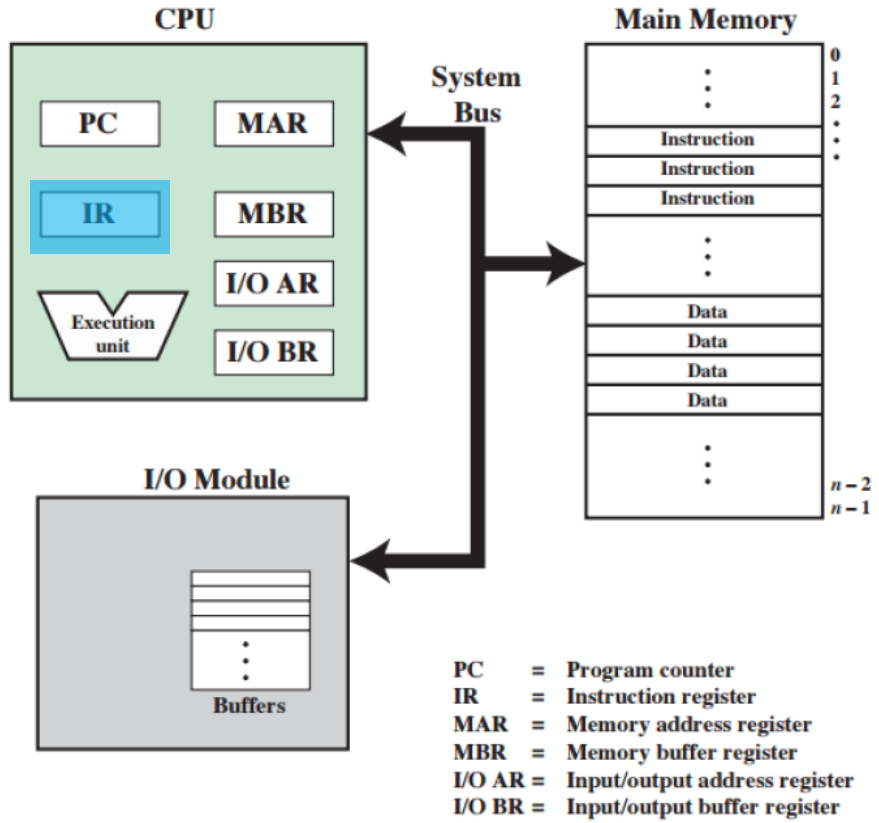
INSTRUCTION FORMAT



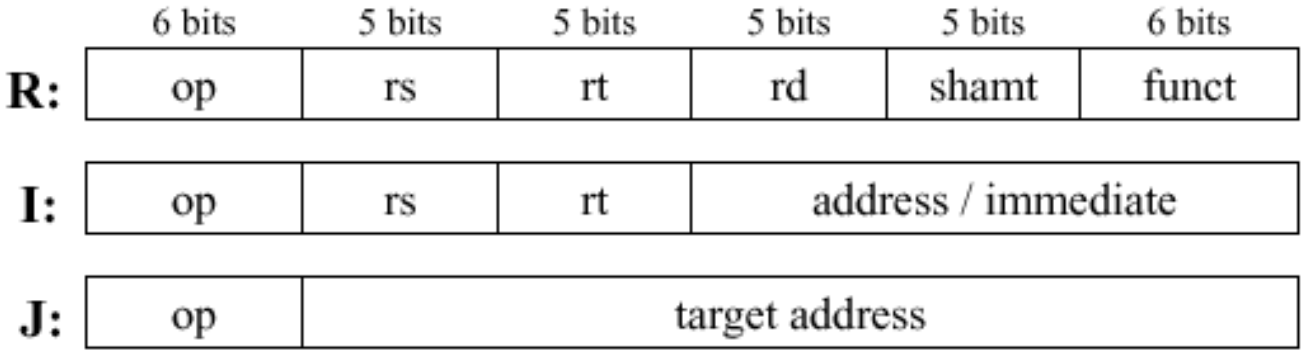
MIPS Architecture

Microprocessor without Interlocked Pipelined Stages

- The op code is the instruction 'ID'
- It indicates both the format and operation of the instruction



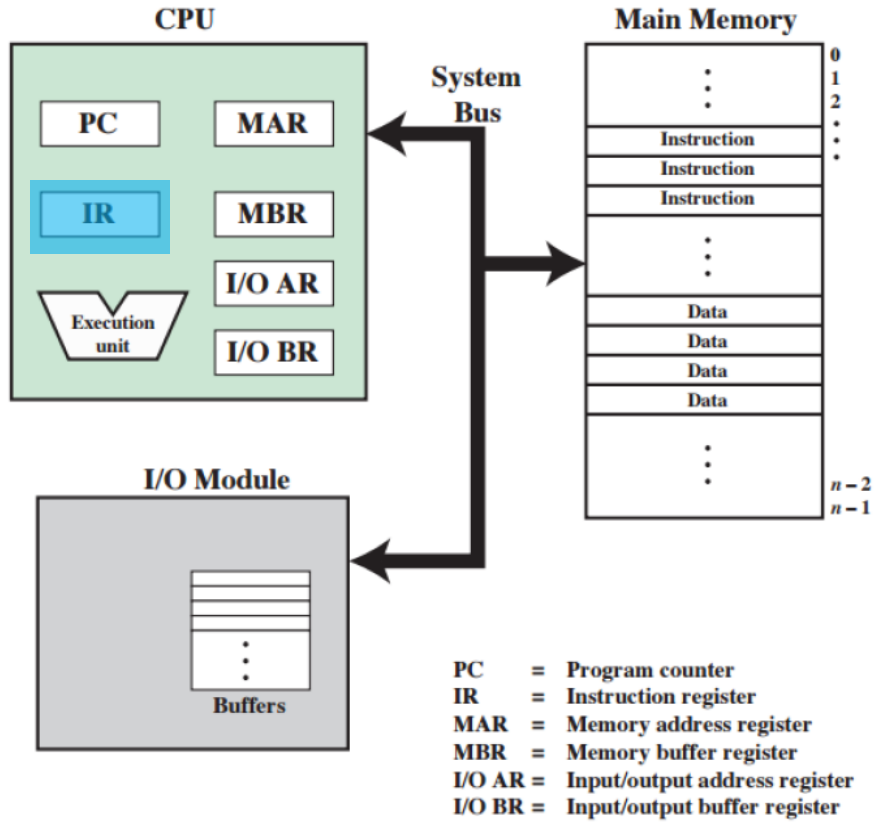
INSTRUCTION FORMAT



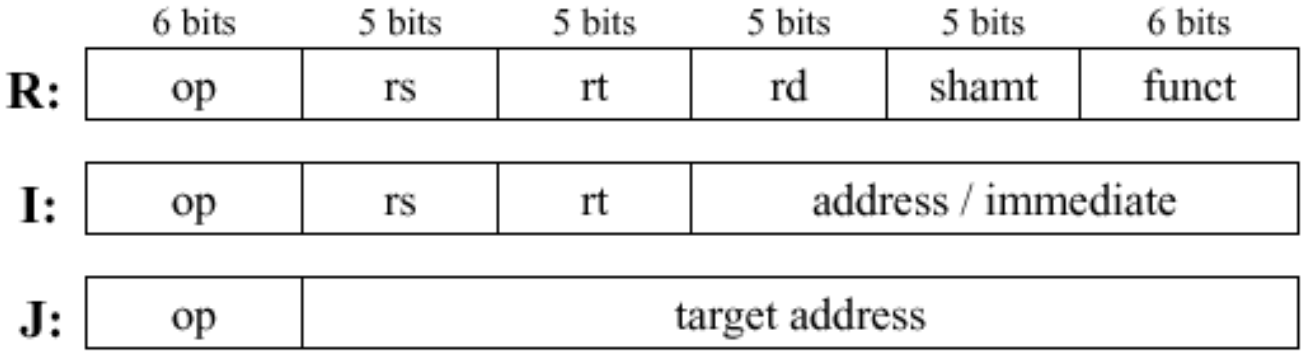
MIPS Architecture

Microprocessor without Interlocked Pipelined Stages

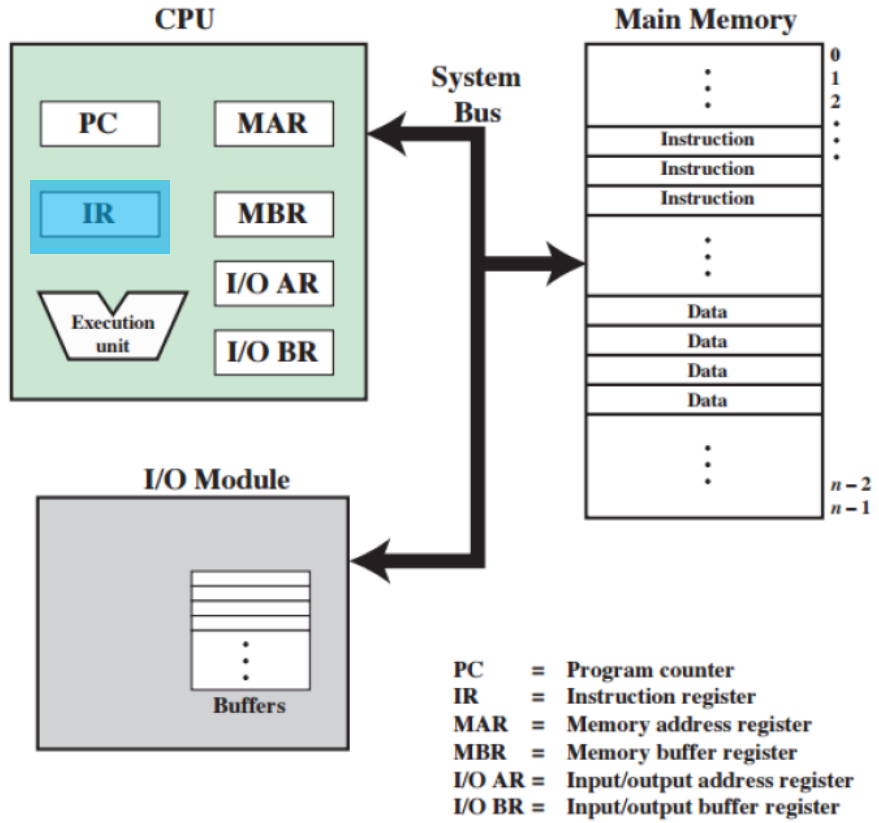
- R: Register type instruction, all operands are registers.
- I: Immediate: Contains immediate values without loading from registers.
- J: Special instruction for jump to new address



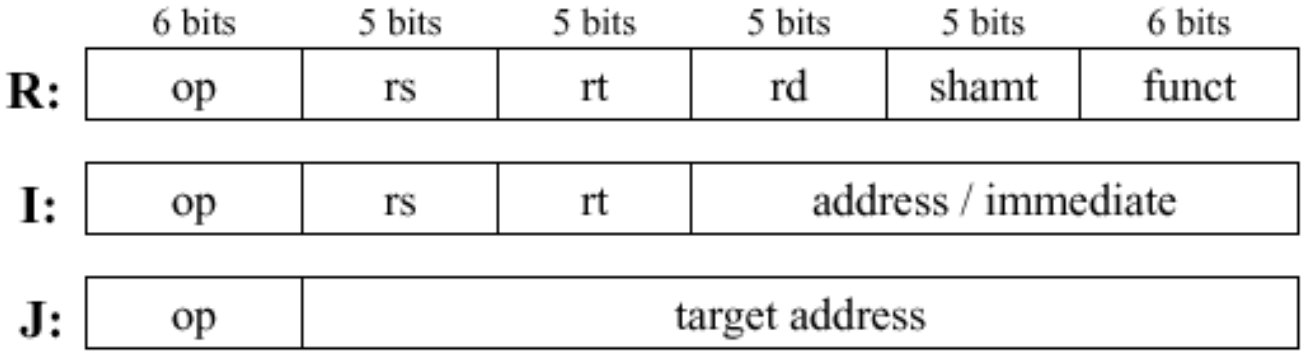
INSTRUCTION DECODE



op: basic operation of the instruction (opcode)
rs: first source operand register
rt: second source operand register
rd: destination operand register
shamt: shift amount
funct: selects the specific variant of the opcode (function code)
address: offset for load/store instructions ($+/-2^{15}$)
immediate: constants for immediate instructions



EXERCISE



- 001110: add R-Type

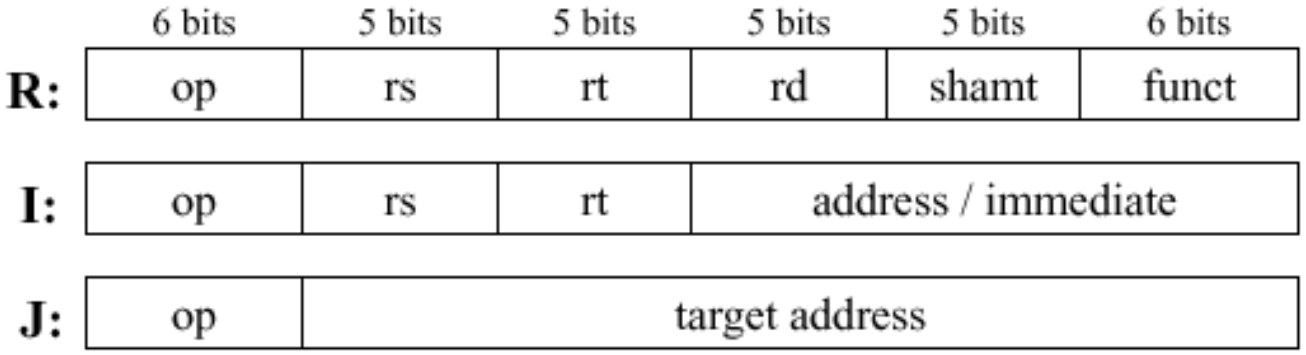
Before Execution

Register	Content
R9	125
R10	56
R11	196
R12	1323

After Execution

Register	Content
R9	???
R10	???
R11	???
R12	???

EXERCISE



- 001110: add R-Type

001110 01010 01100 01010 00000 000000

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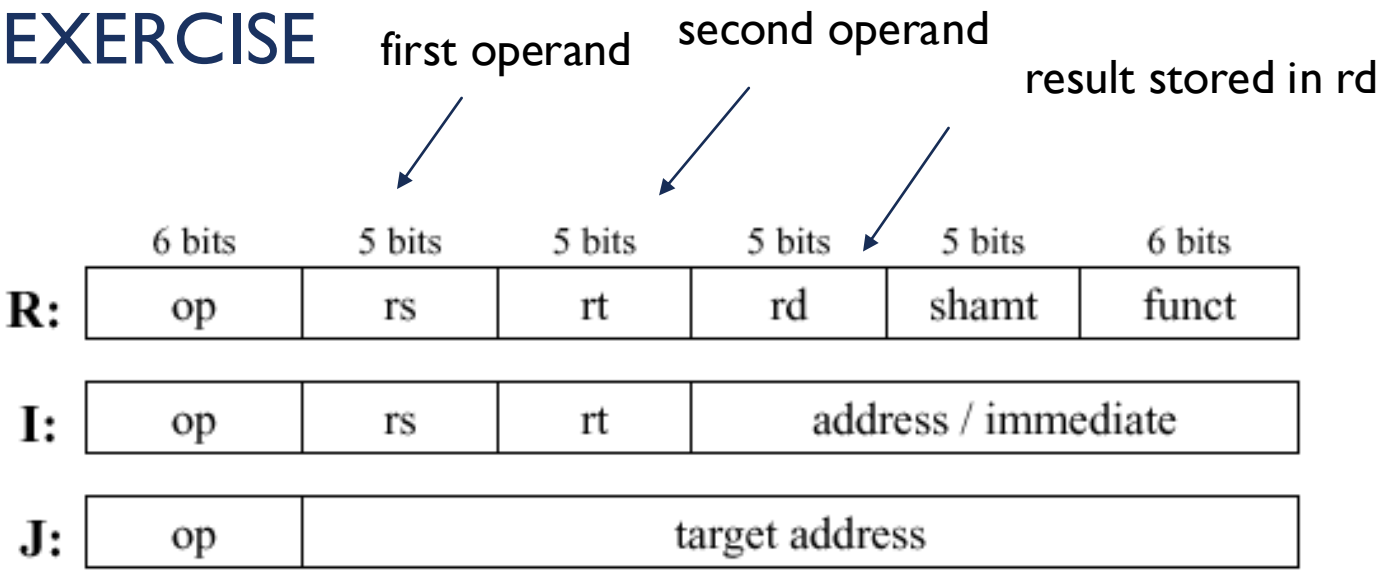

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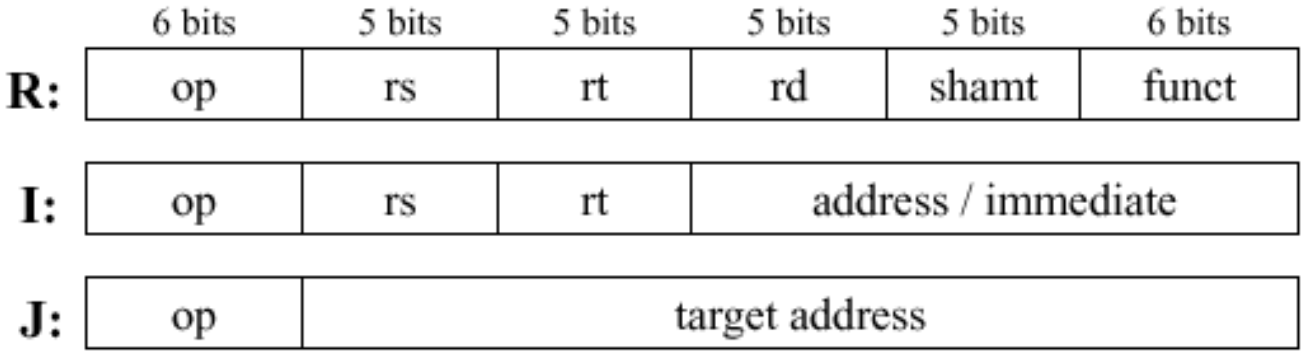

- 001110: add

001110	01010	01100	01010	00000	000000
add	R10	R12	R10	N/A	N/A

Before Execution

Register	Content
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R10	56
R11	196
R12	1323

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Register	Content
R9	???
R10	???
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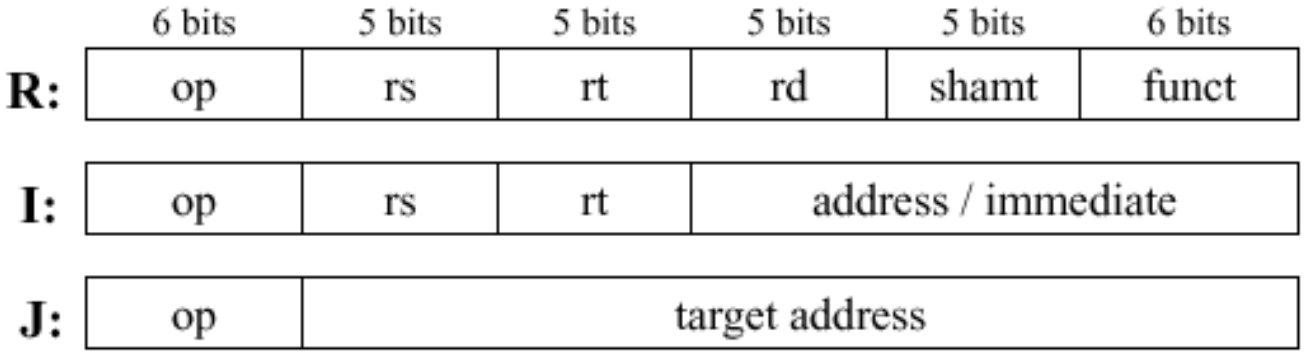
EXERCISE



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Before Execution

Register	Content
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Register	Content
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R10	???
R11	???
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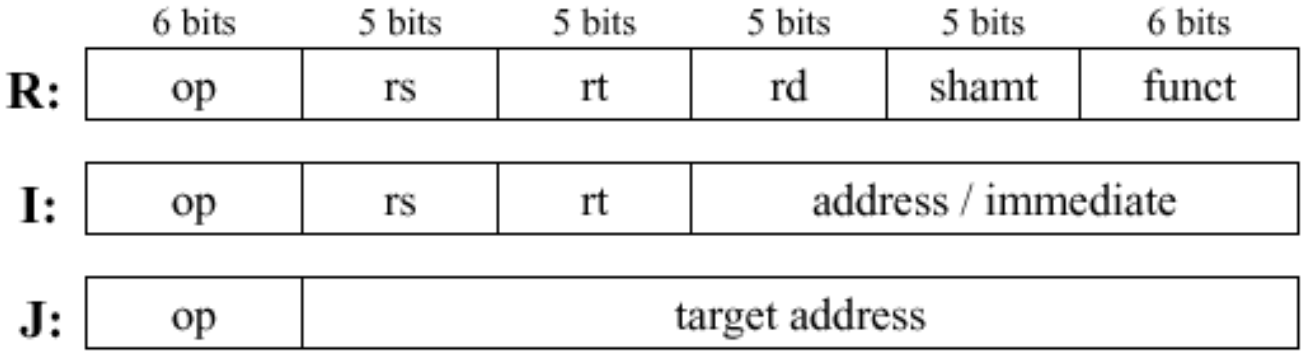
EXERCISE



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001110	01010	01100	01010	00000	000000
add	R10	R12	R10	N/A	N/A

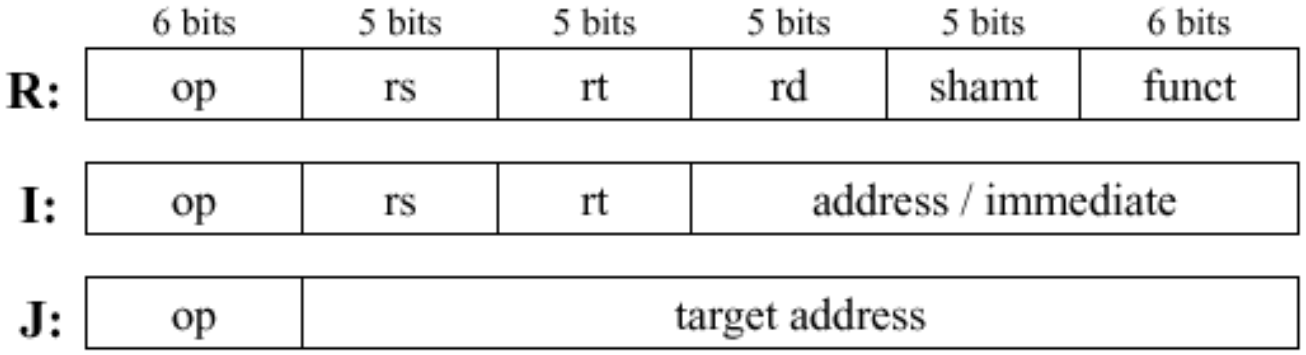
Before Execution

Register	Content
R9	125
R10	56
R11	196
R12	1323

After Execution

Register	Content
R9	125
R10	1379
R11	???
R12	???

EXERCISE



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001110	01010	01100	01010	00000	000000
add	R10	R12	R10	N/A	N/A

Before Execution

Register	Content
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Register	Content
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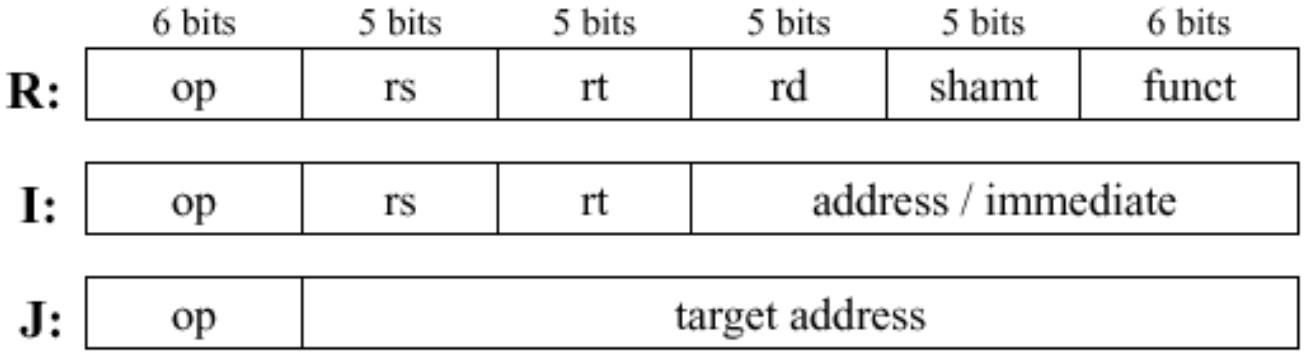
R12	???

EXERCISE



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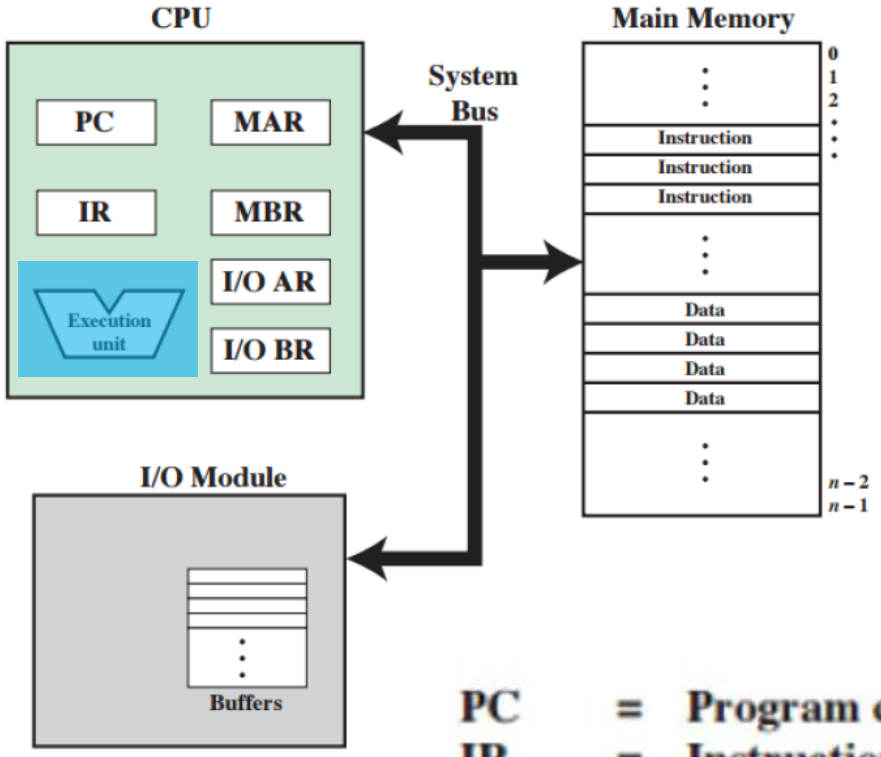
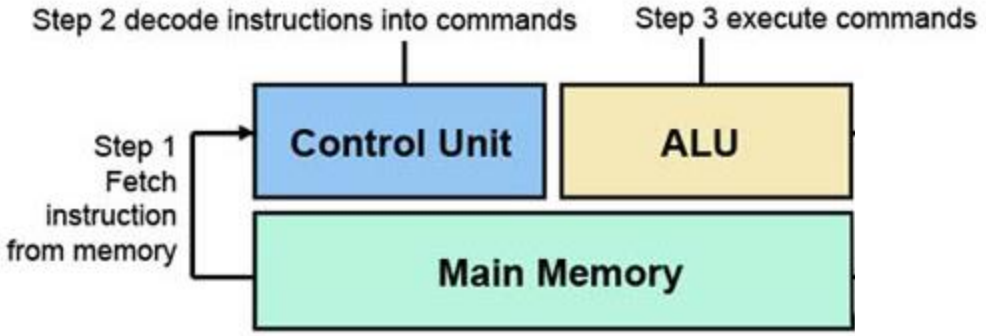
INSTRUCTION CYCLE: EXECUTE





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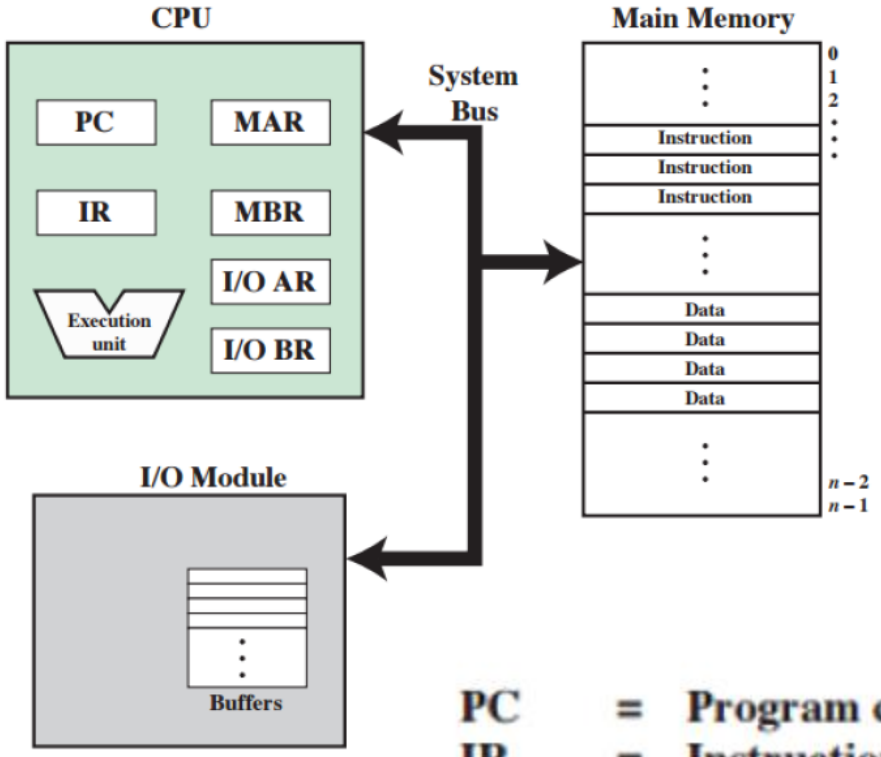
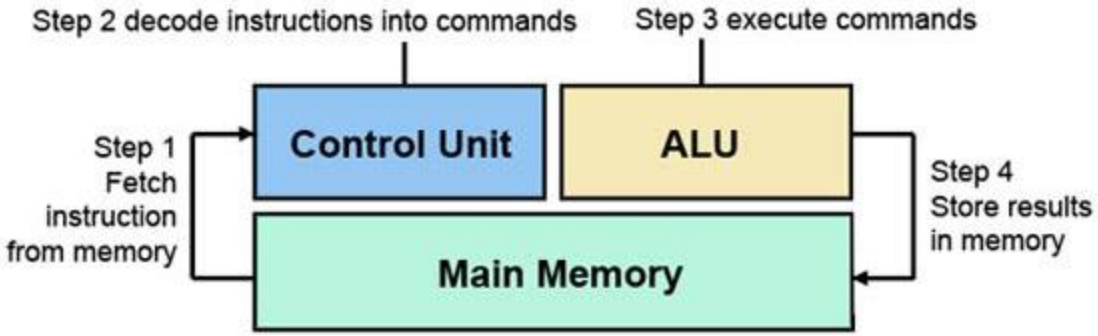
STEP 4: STORE IN MEMORY





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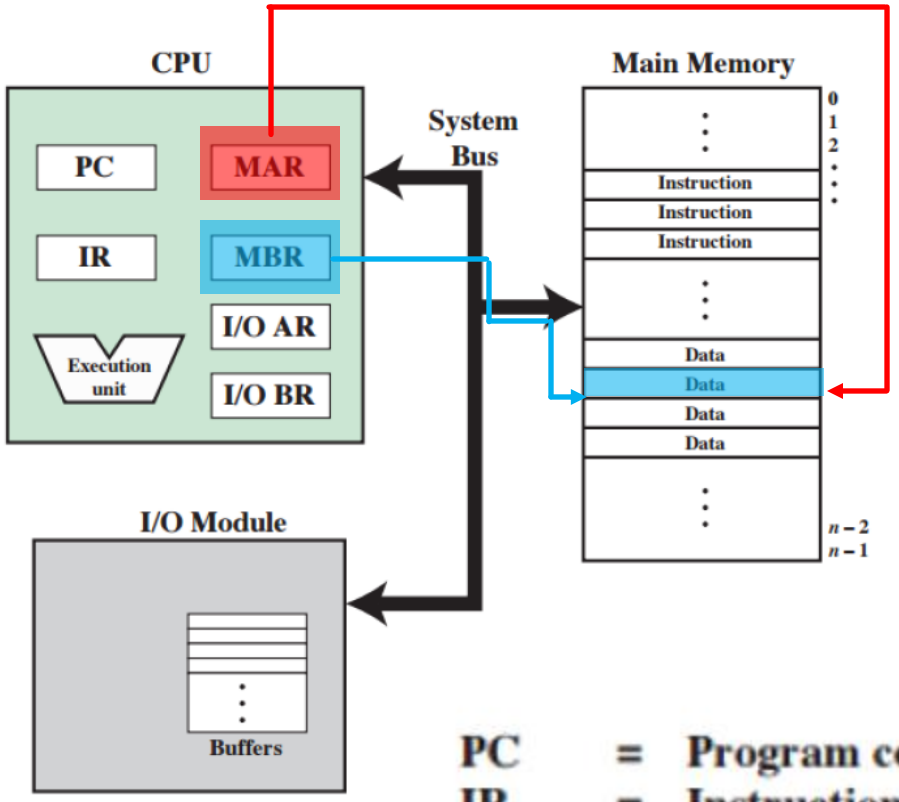

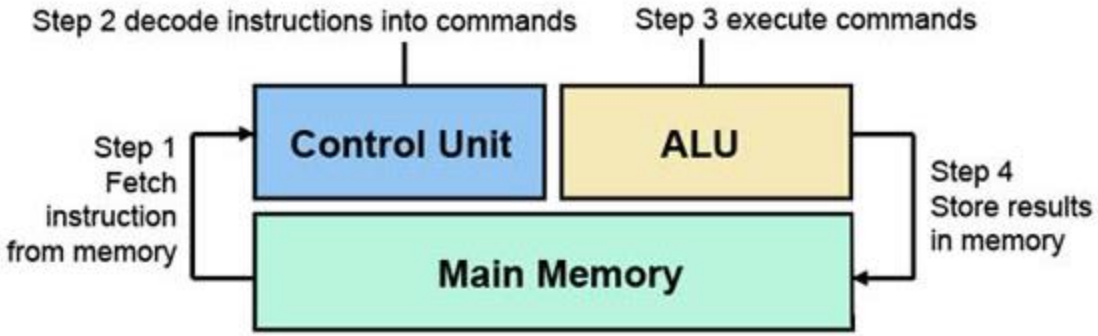

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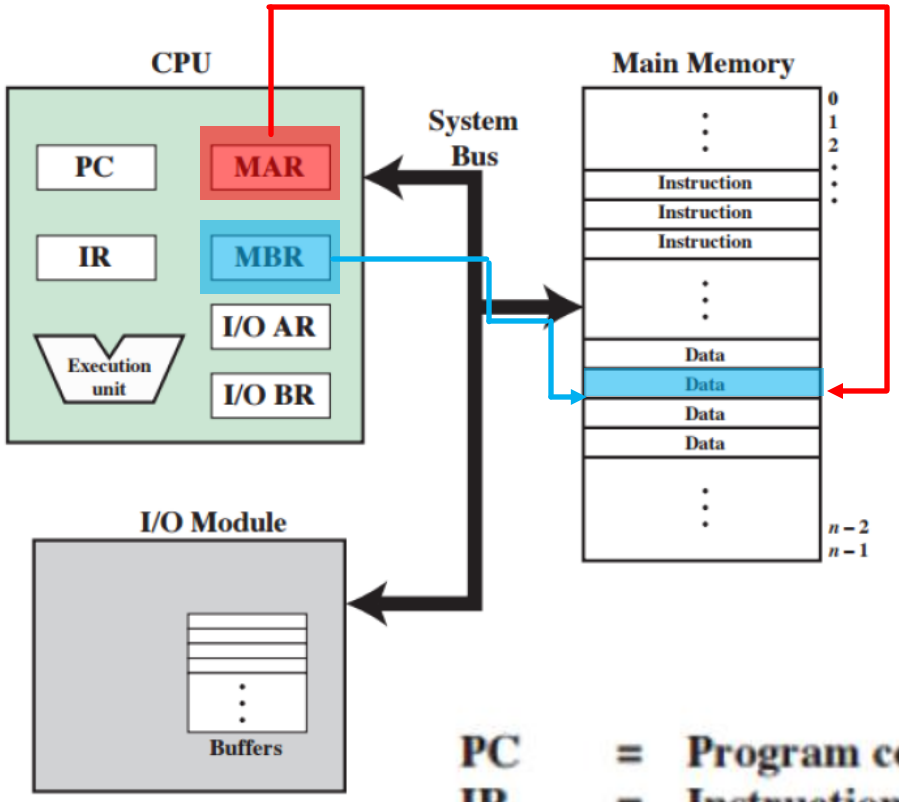
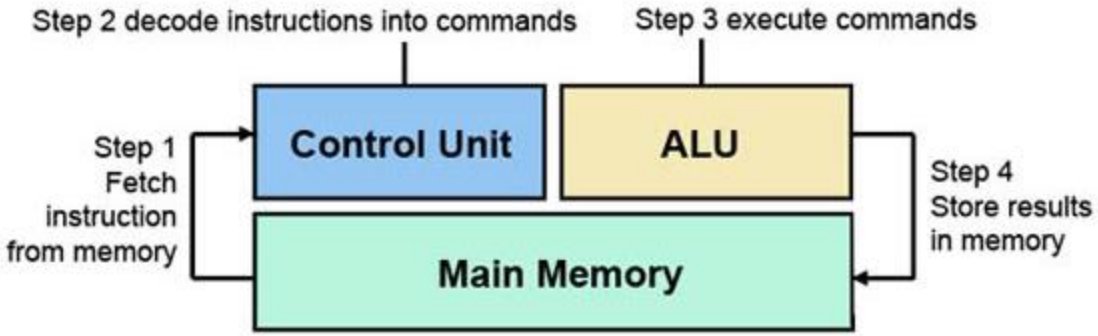


- Step 1 to 3 : Typical Instruction Cycle
- Step 4: Only when we need to store the result.



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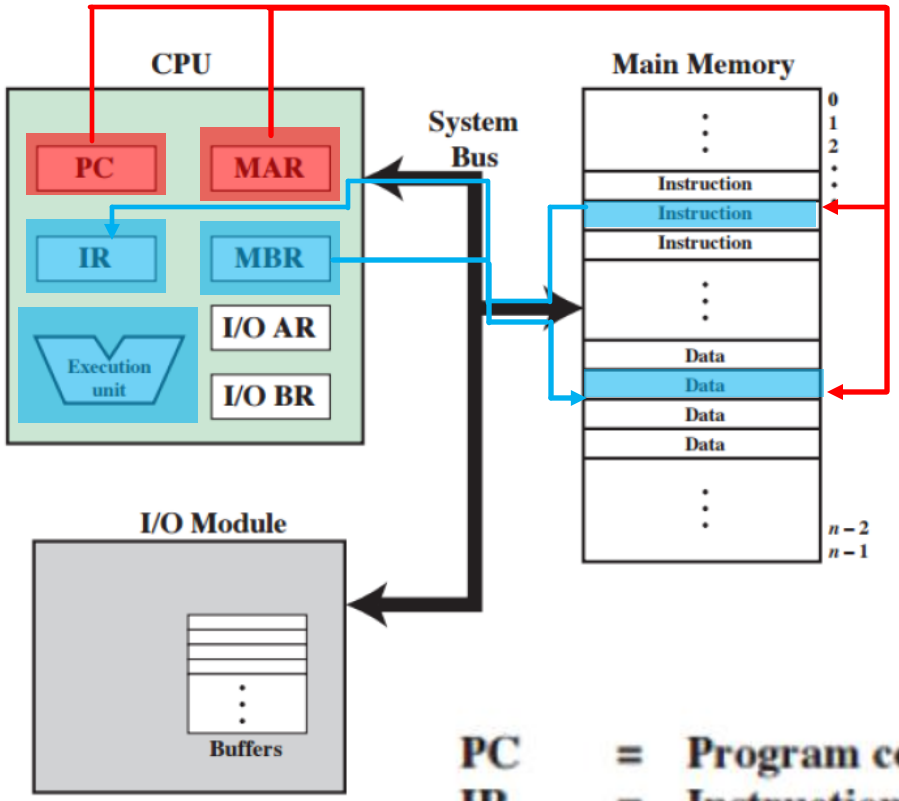
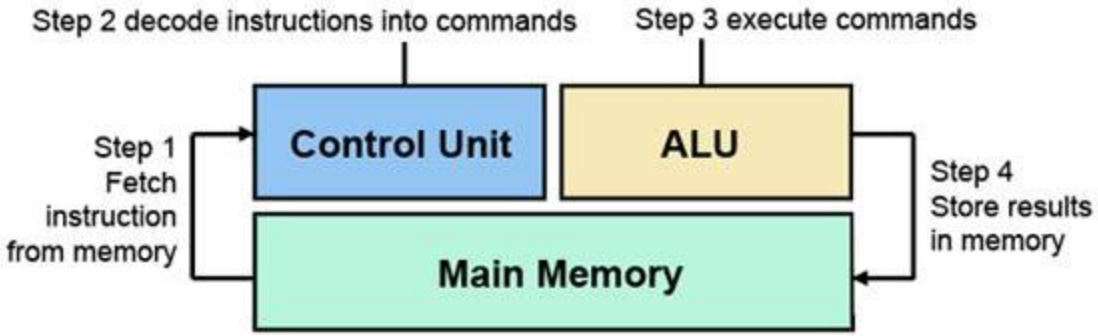
OPERATING SYSTEM



- So where is the Operating System?



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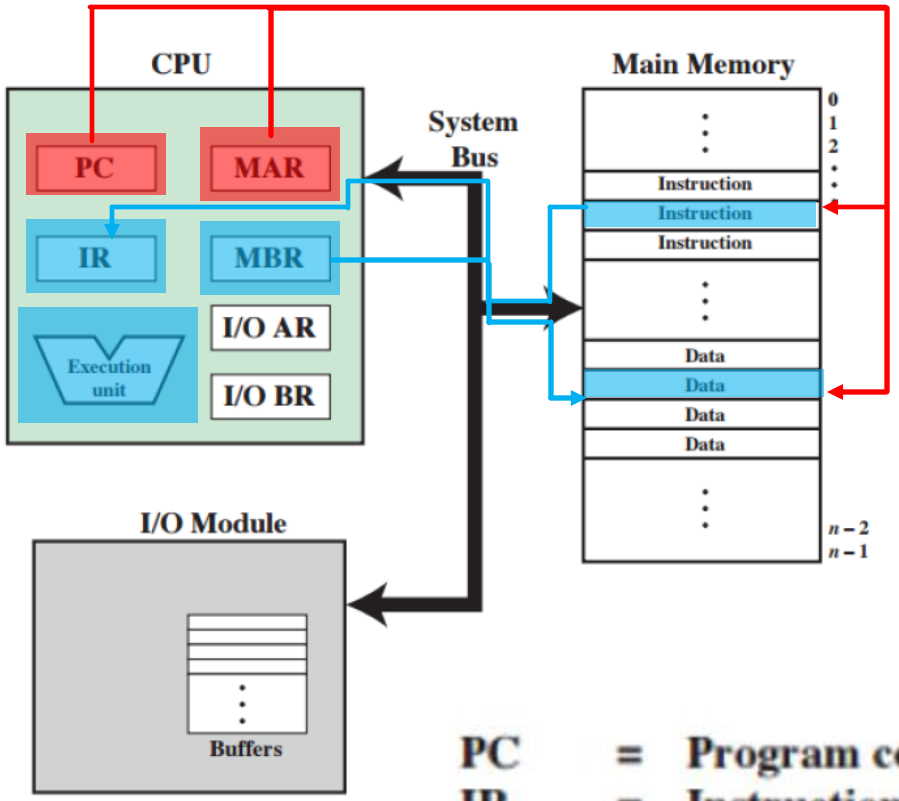
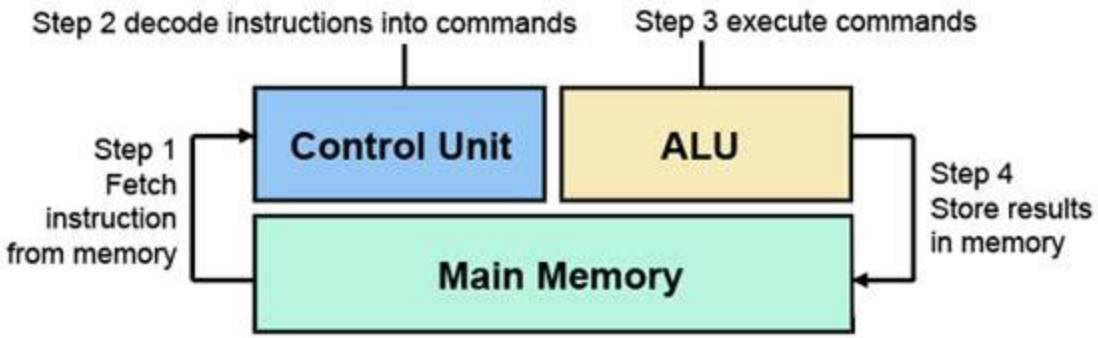


- What could cause the OS to step in?



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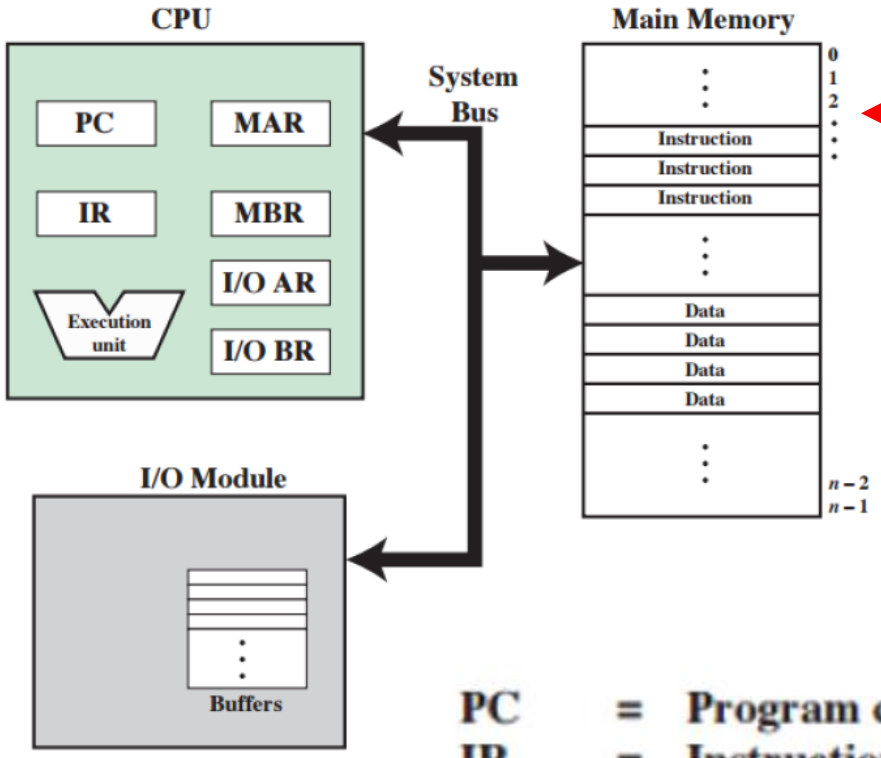
OPERATING SYSTEM FUNCTIONS



- Data/Instruction not in memory! Need to be retrieved from disk.

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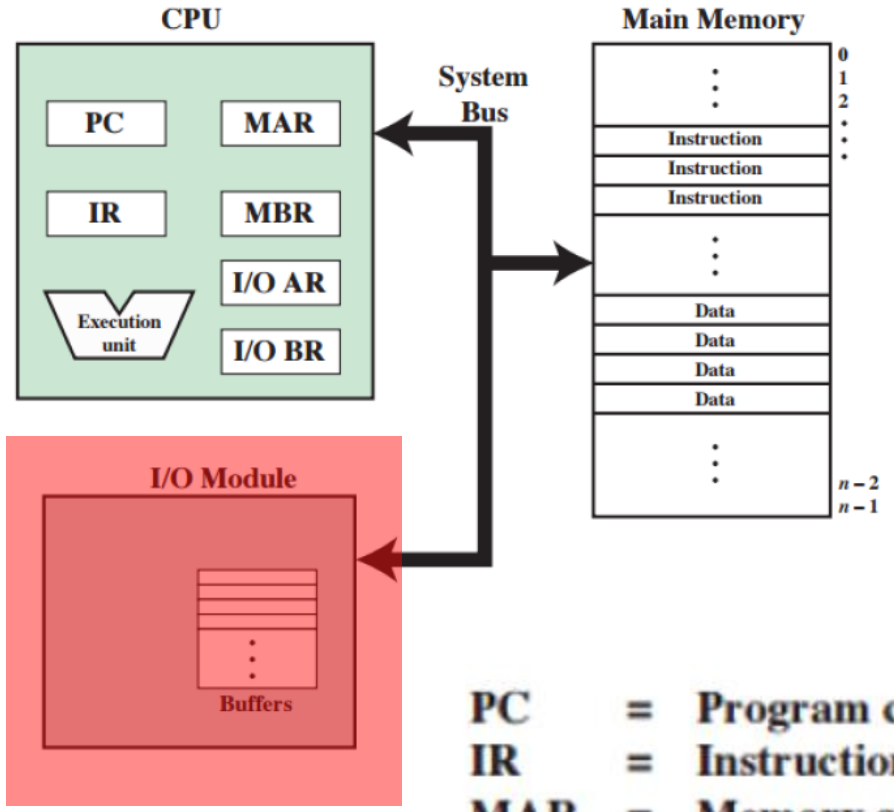
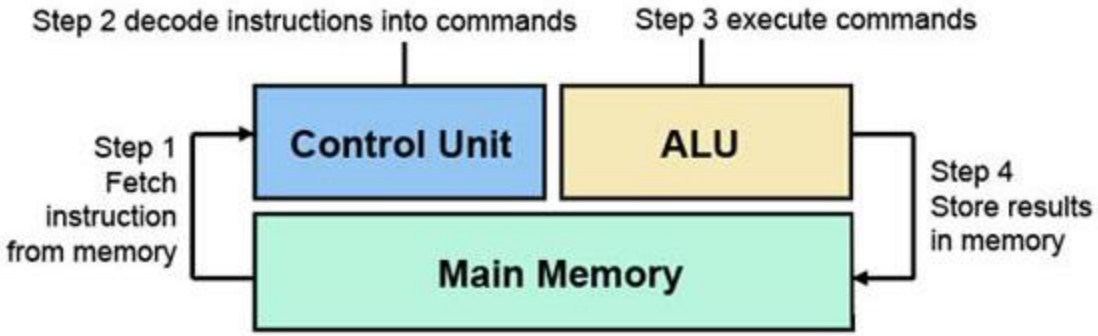
OPERATING SYSTEM FUNCTIONS



- What about I/O?
- System calls for I/O are made, and execution is handed to OS.



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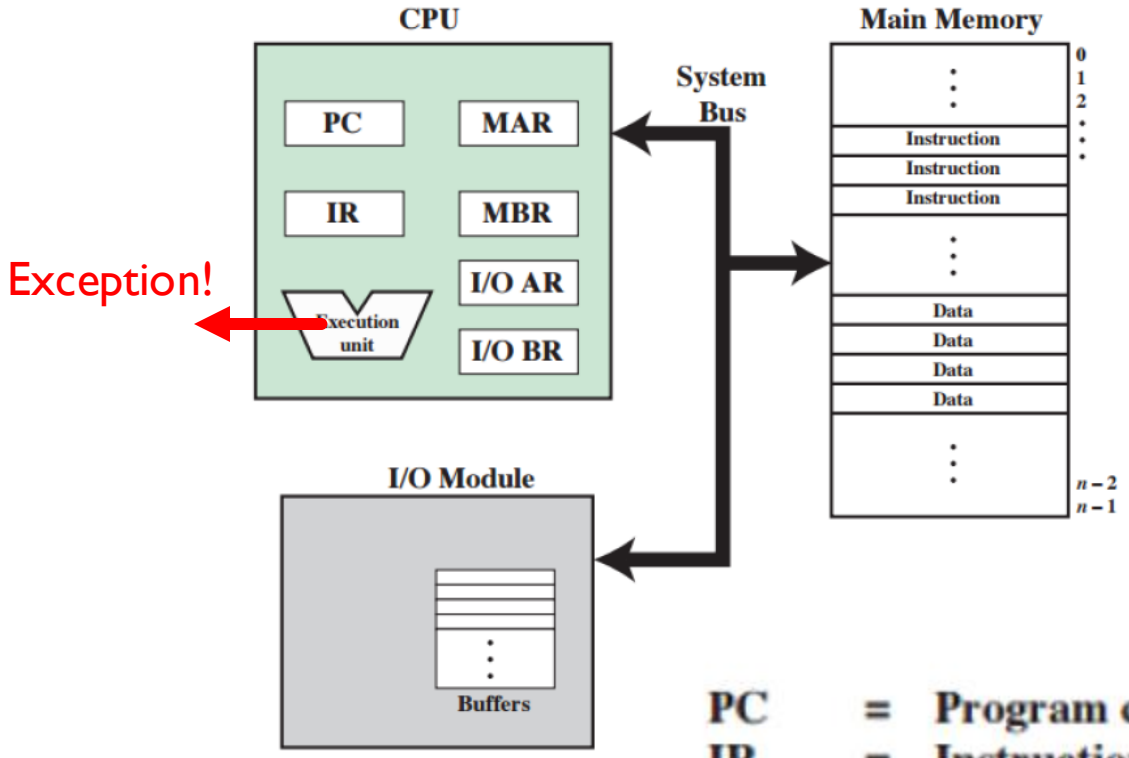
OPERATING SYSTEM FUNCTIONS



- Exceptions can be triggered by the execution unit.
- Ex. Division by zero.

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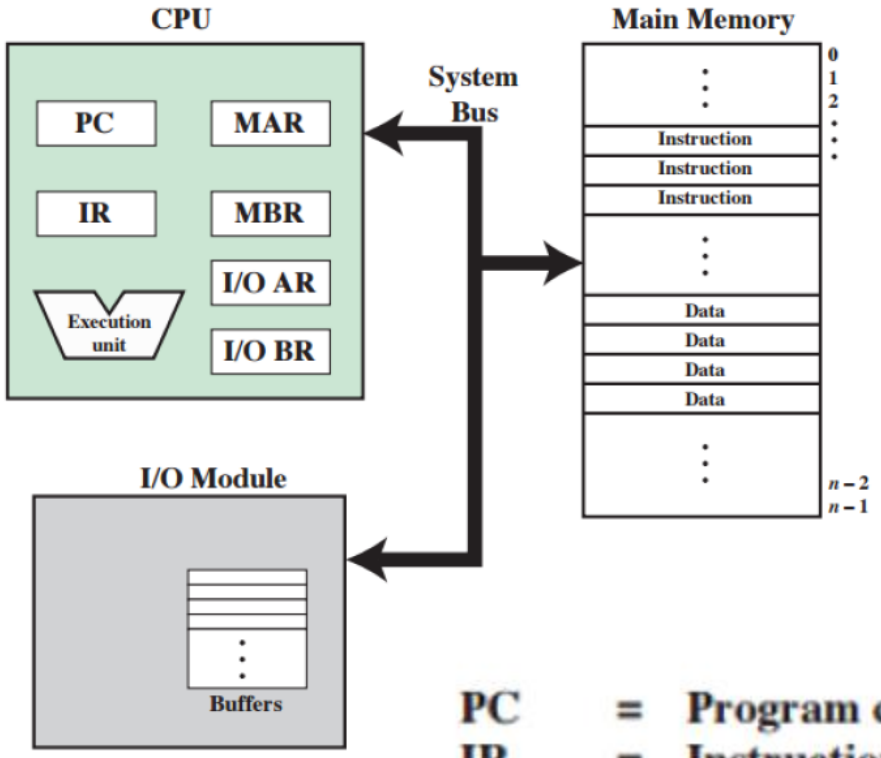
OPERATING SYSTEM FUNCTIONS



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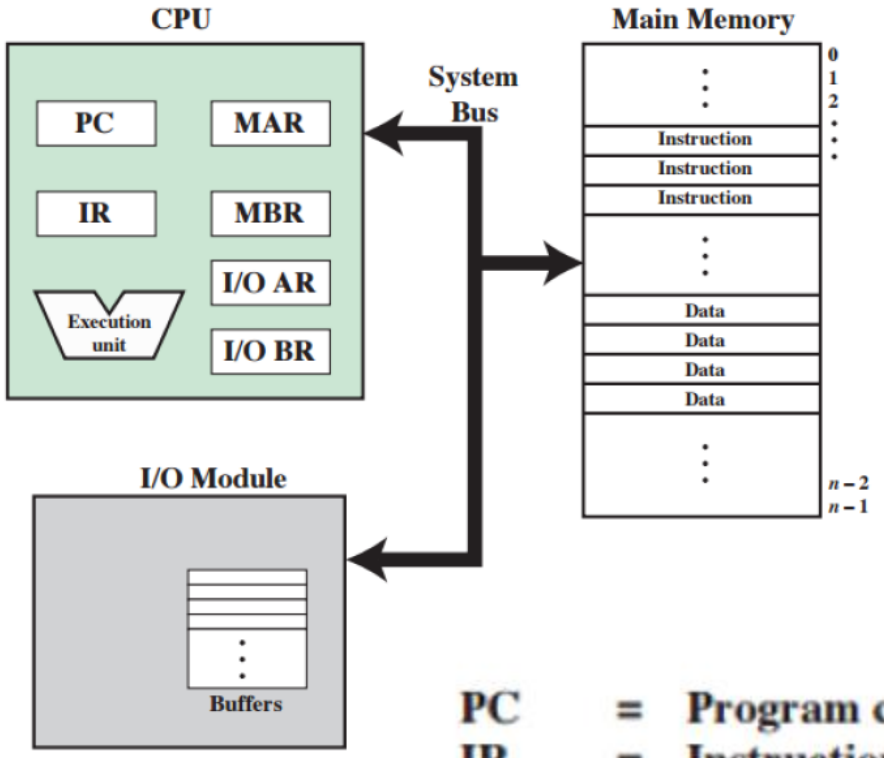
- Hardware events:
  - User pressed keyboard key or moved mouse.
  - Network event has occurred.
  - A new device got connected.

OPERATING SYSTEM FUNCTIONS



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- Exception/Trap: internal event, caused by the process that is currently executing
- Interrupts: external events.
- Once triggered, control is handed to the **'kernel',** which is the core program running the operating system and running all system calls.

KERNEL MODE

KERNEL MODE

mode bit: 0 / 1

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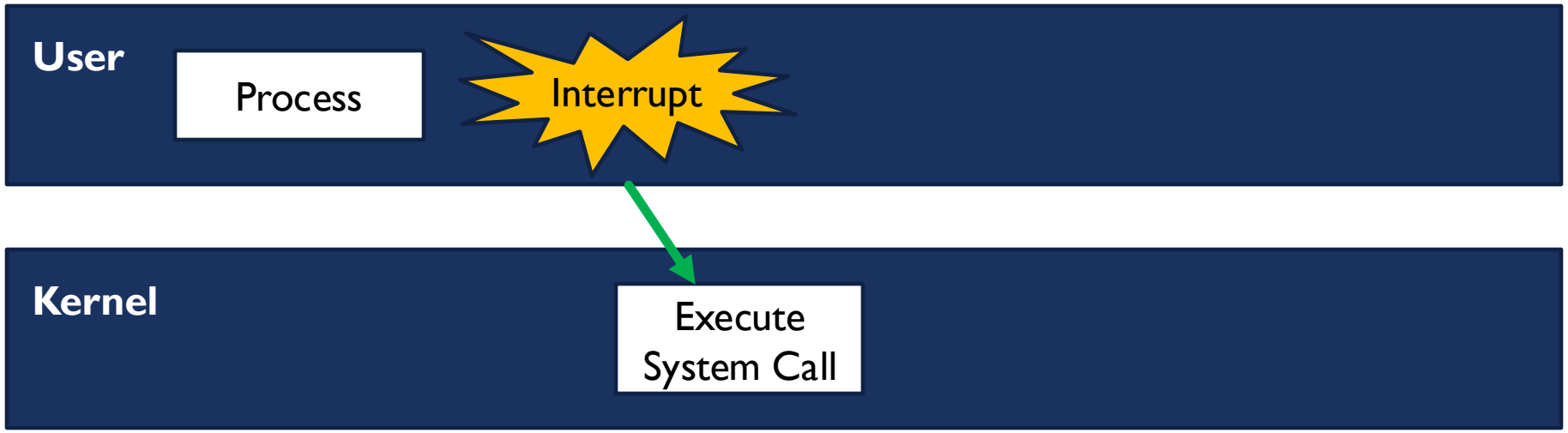
KERNEL MODE



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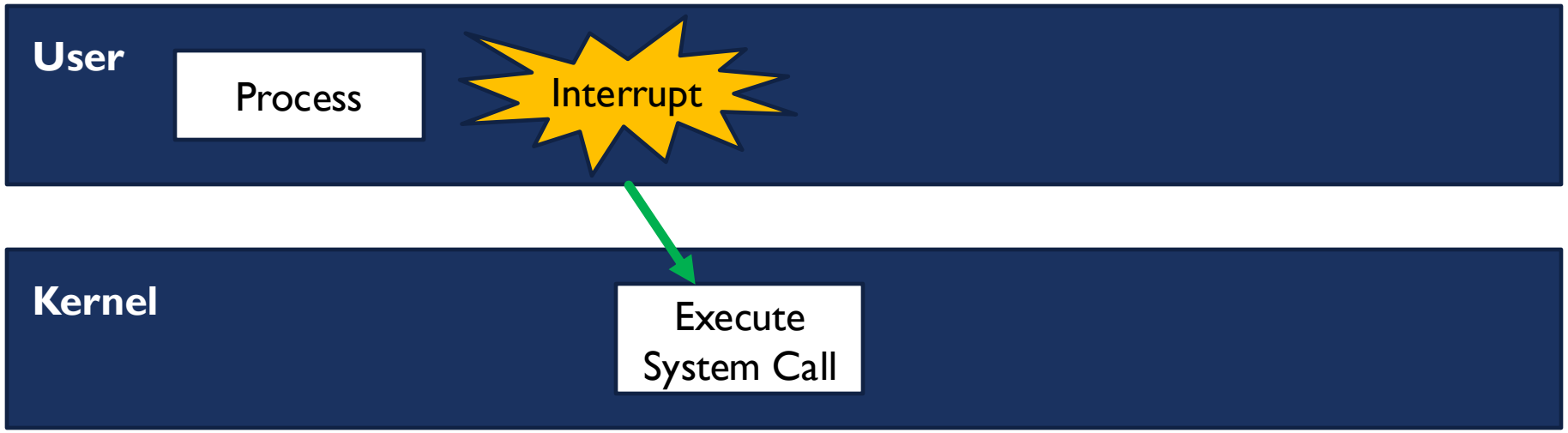
KERNEL MODE



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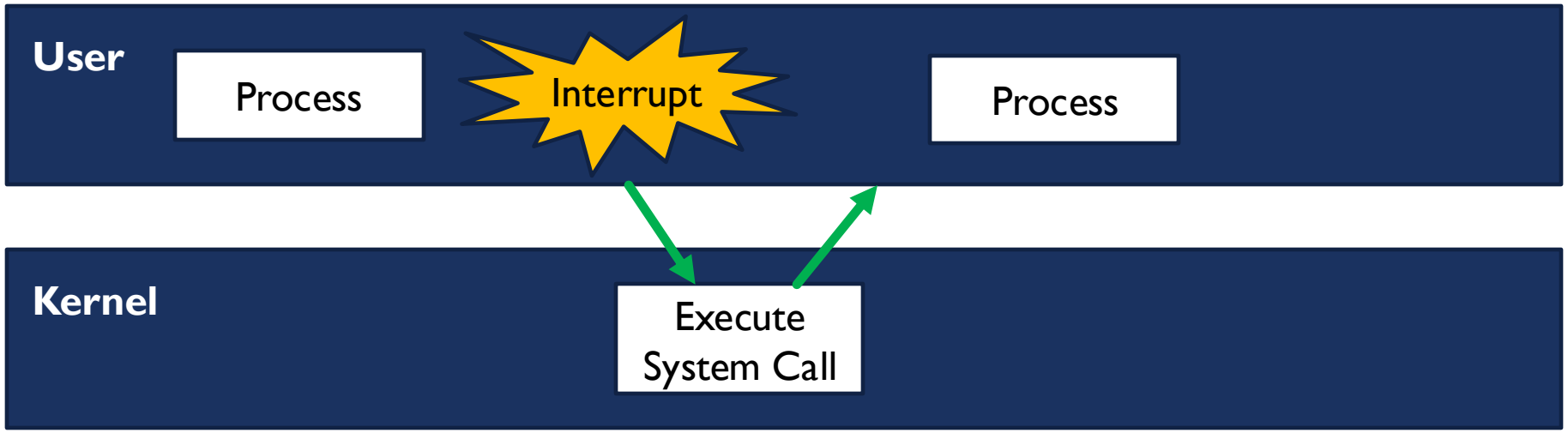

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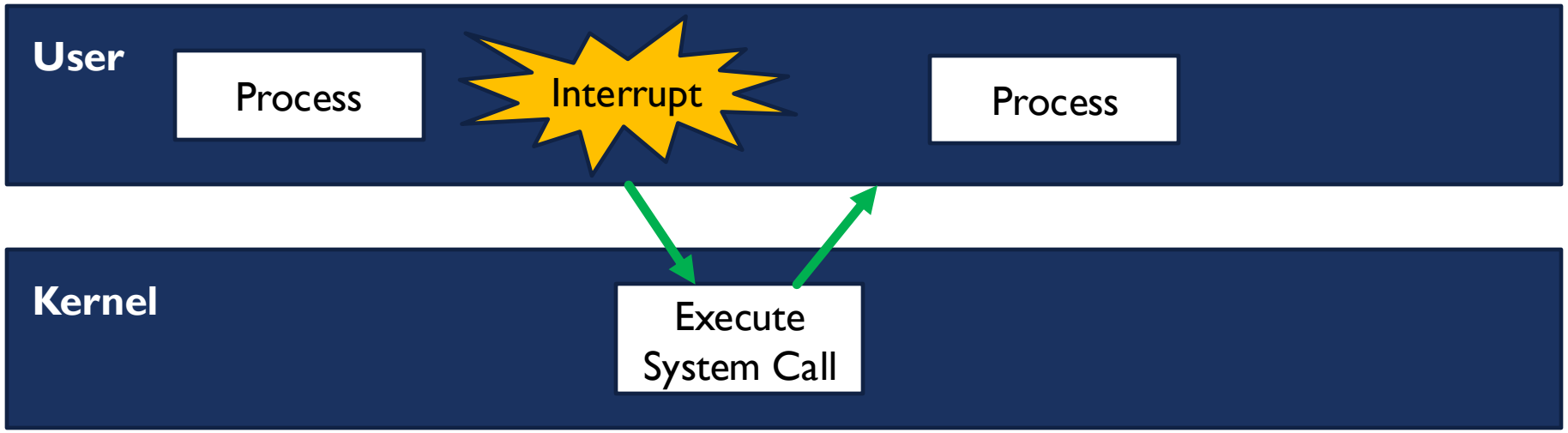
KERNEL MODE



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A: True
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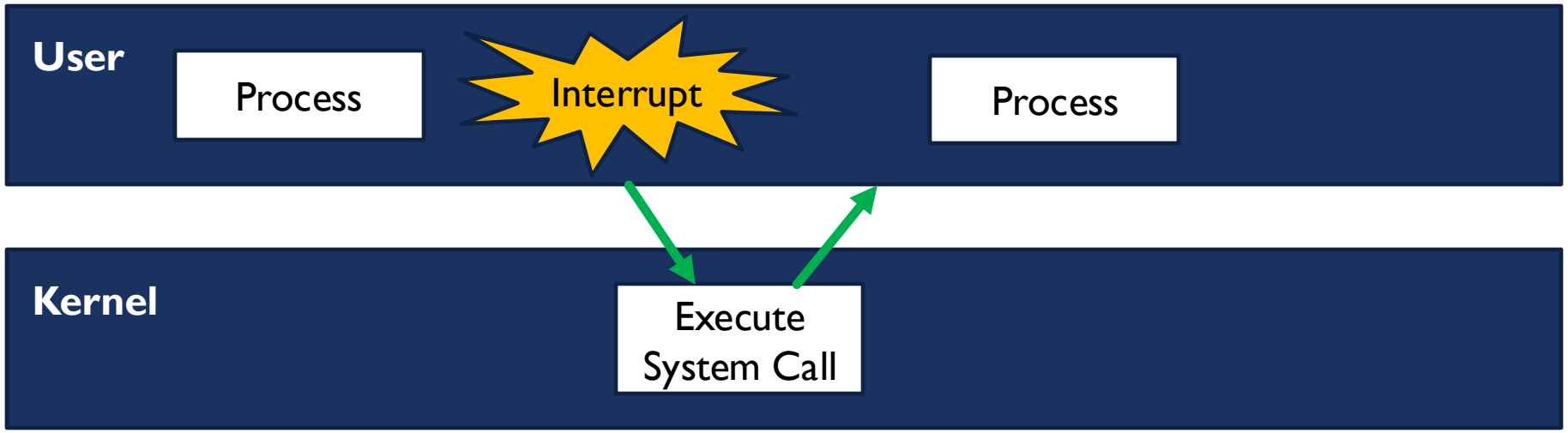

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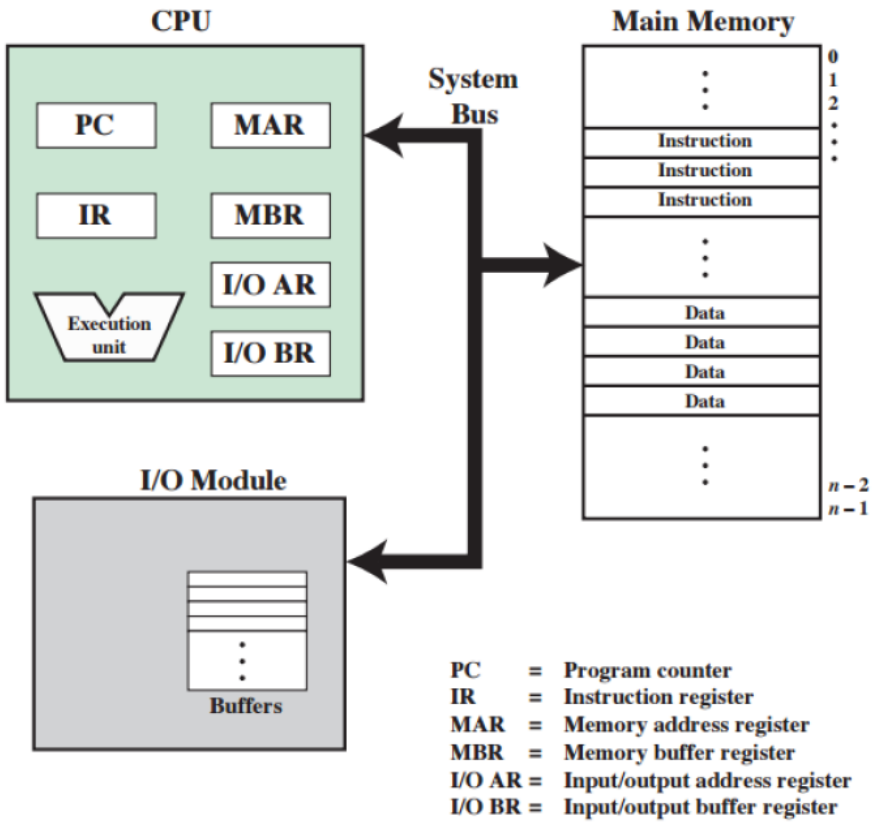
- Privileged instructions, with unique OP code can be performed.
- Examples of Privileged Instructions

KR



KERNEL INSTRUCTIONS

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- Access to Kernel Registers
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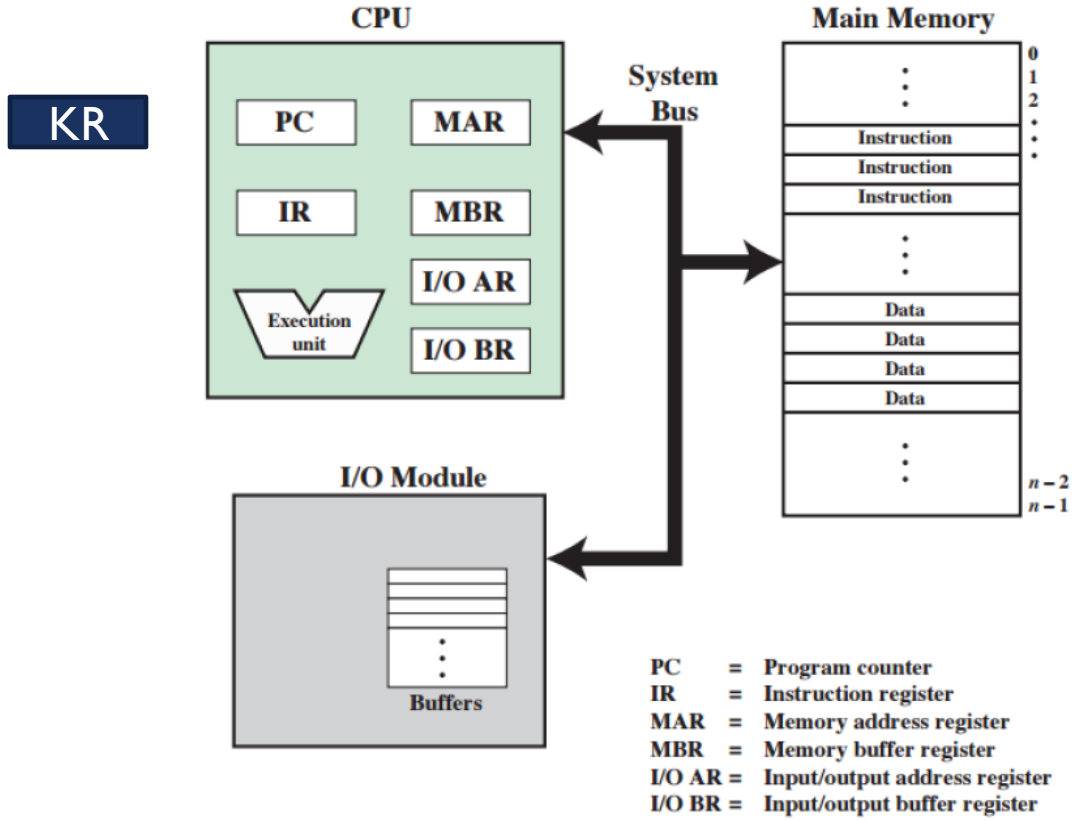
- Examples of Privileged Instructions
  - I/O instructions and Halt instructions
  - Turn off all Interrupts
  - Set the Timer
  - Context Switching
  - Clear the Memory
  - Remove a process from the Memory
  - Modify entries in Device-status table



REVIEW EXERCISES

- What are the four major components of a computing system?
- What are the three core steps in an instruction cycle?
- What is difference between Interrupts and Exceptions/Traps?
- What does the kernel mode allow access to?
- Can we have multiple processes executing the same program?

REVIEW EXERCISES

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LOADING THE OPERATING SYSTEM

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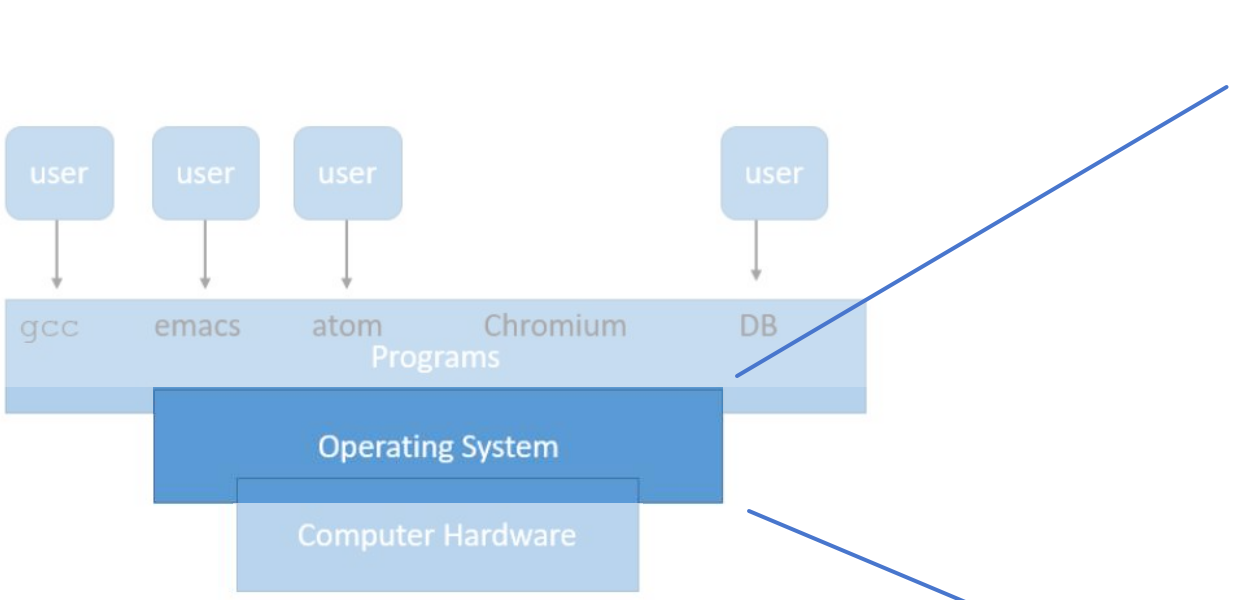
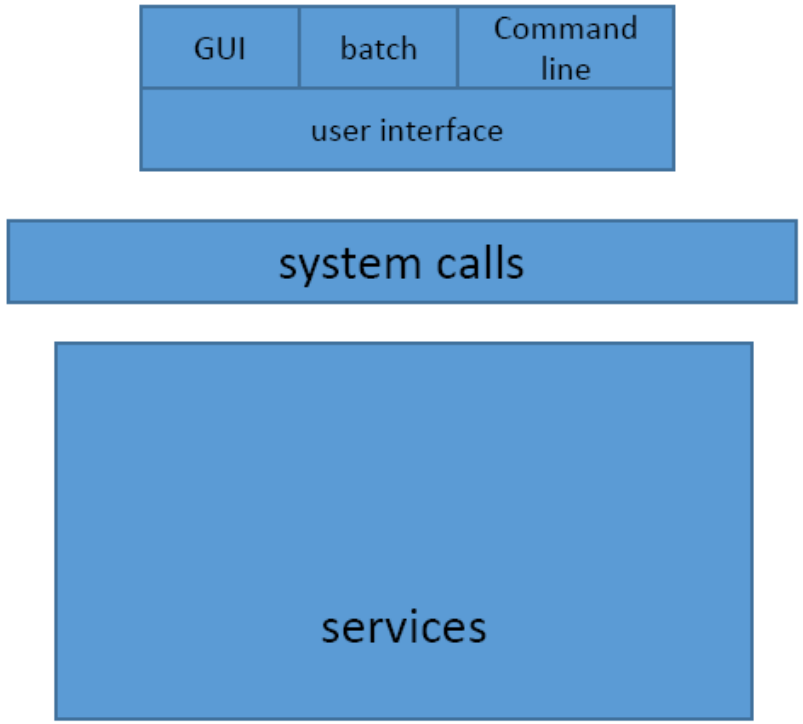
  - **Basic Instructions Operating System (BIOS)** or its modern replacement **Unified Extensible Firmware Interface** (**UEFI**).

OPERATING SYSTEM SERVICES





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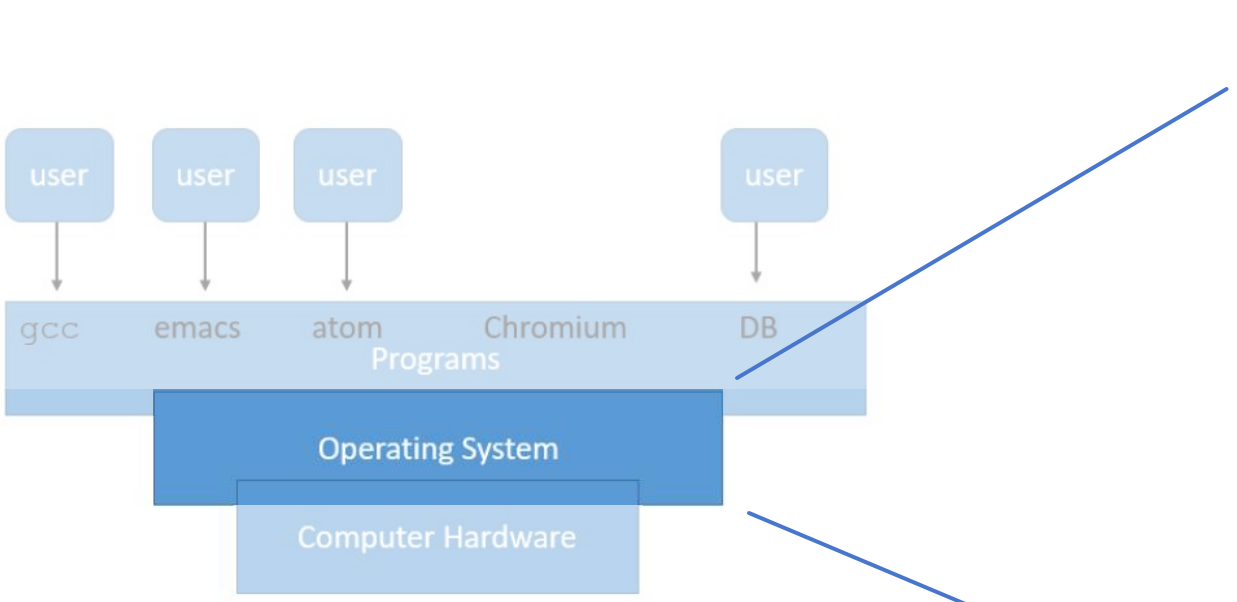
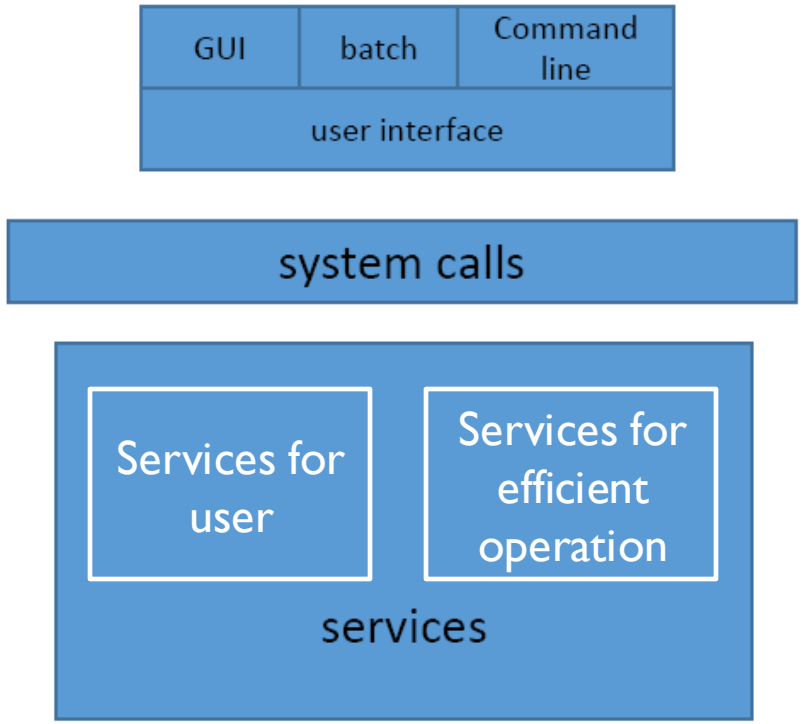
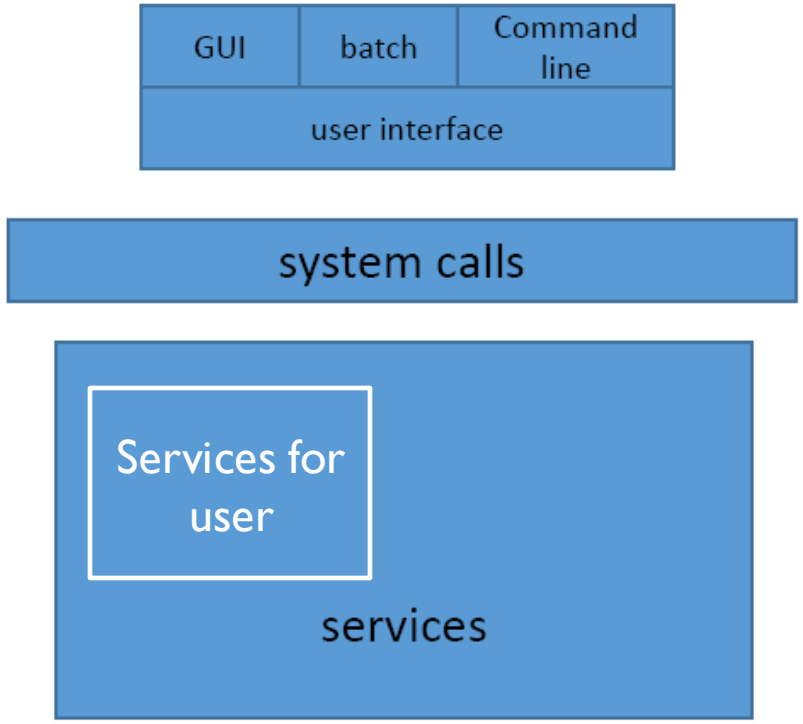




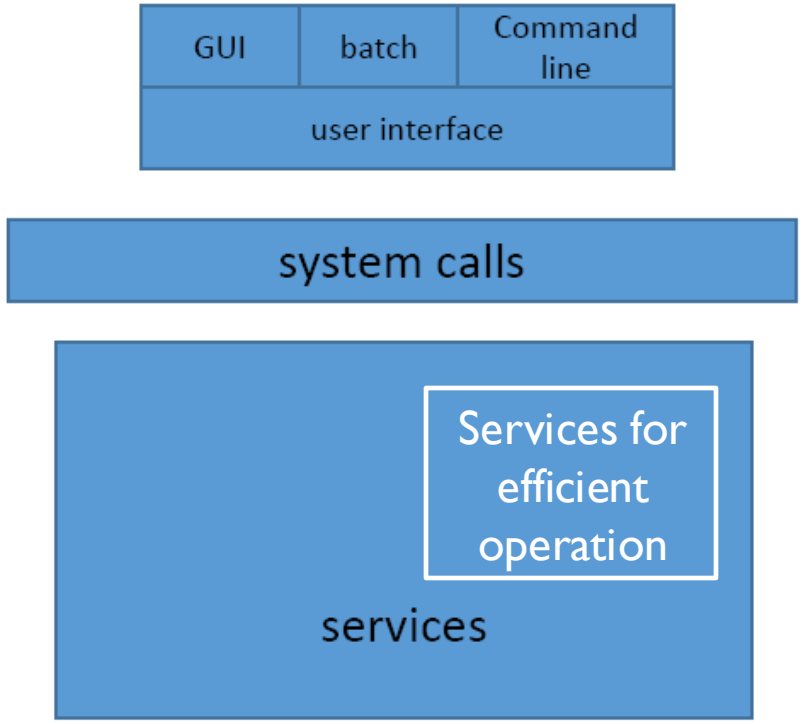
OPERATING SYSTEM SERVICES FOR USERS

- Program Execution: load the program and run it.
- I/O: Programs rarely communicate with I/O devices directly.
- Protection and Security.
  - Protection: User privileges
  - Security: Anti-malware systems
- Error detection.
- User Interface: CLI, GUI, touch



SERVICES FOR EFFICIENT SYSTEM OPERATION

- Resource Allocation
  - Scheduling Algorithms
  - Memory Allocation Algorithms
- Accounting
  - Which user/process uses how much of a specific resource.
  - Storage space, Memory, CPU access …
- Protection and Security



GUI HISTORY

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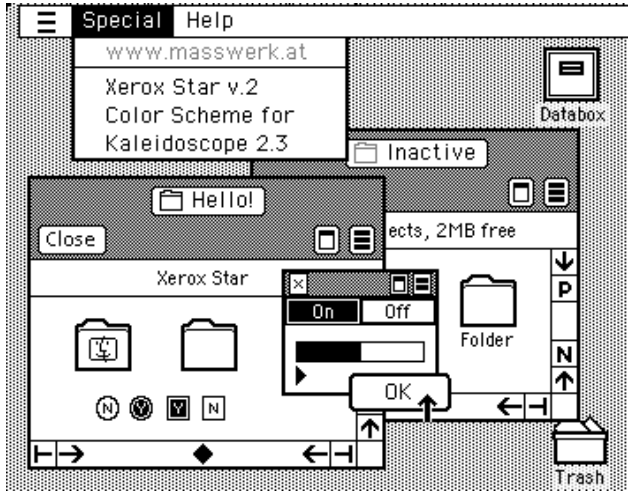

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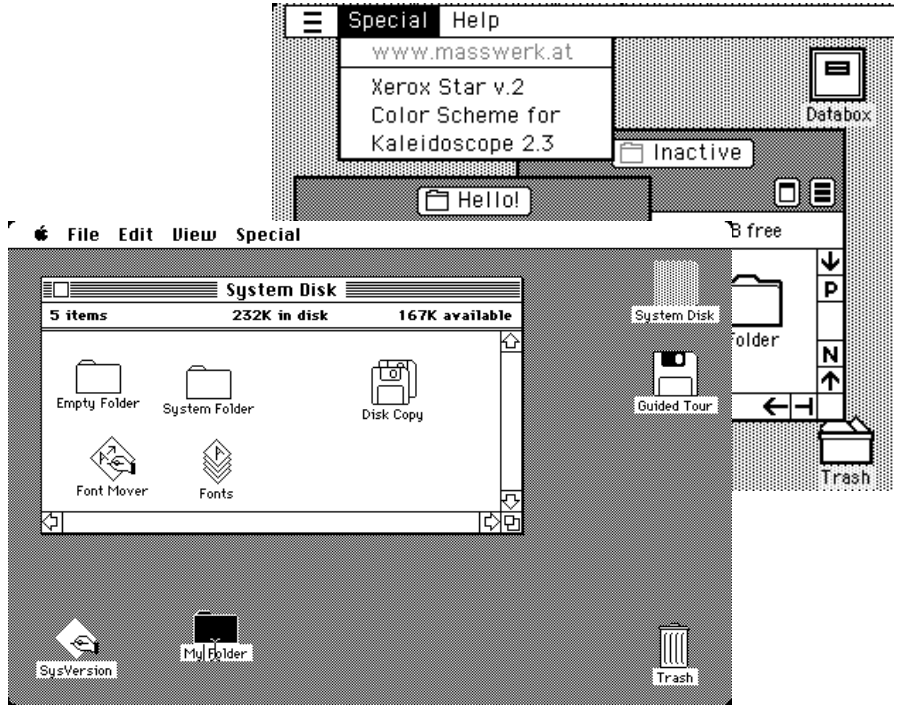

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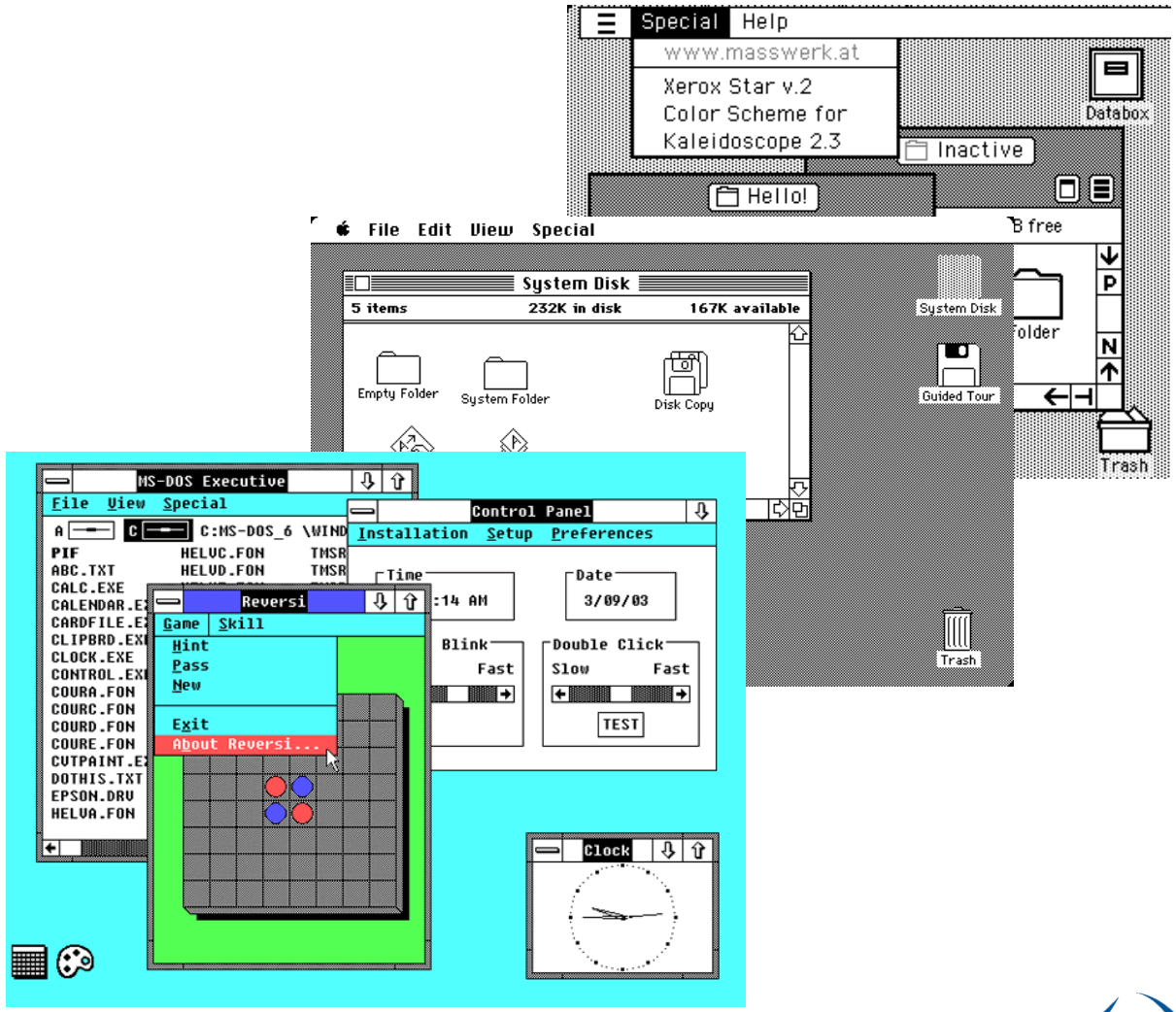

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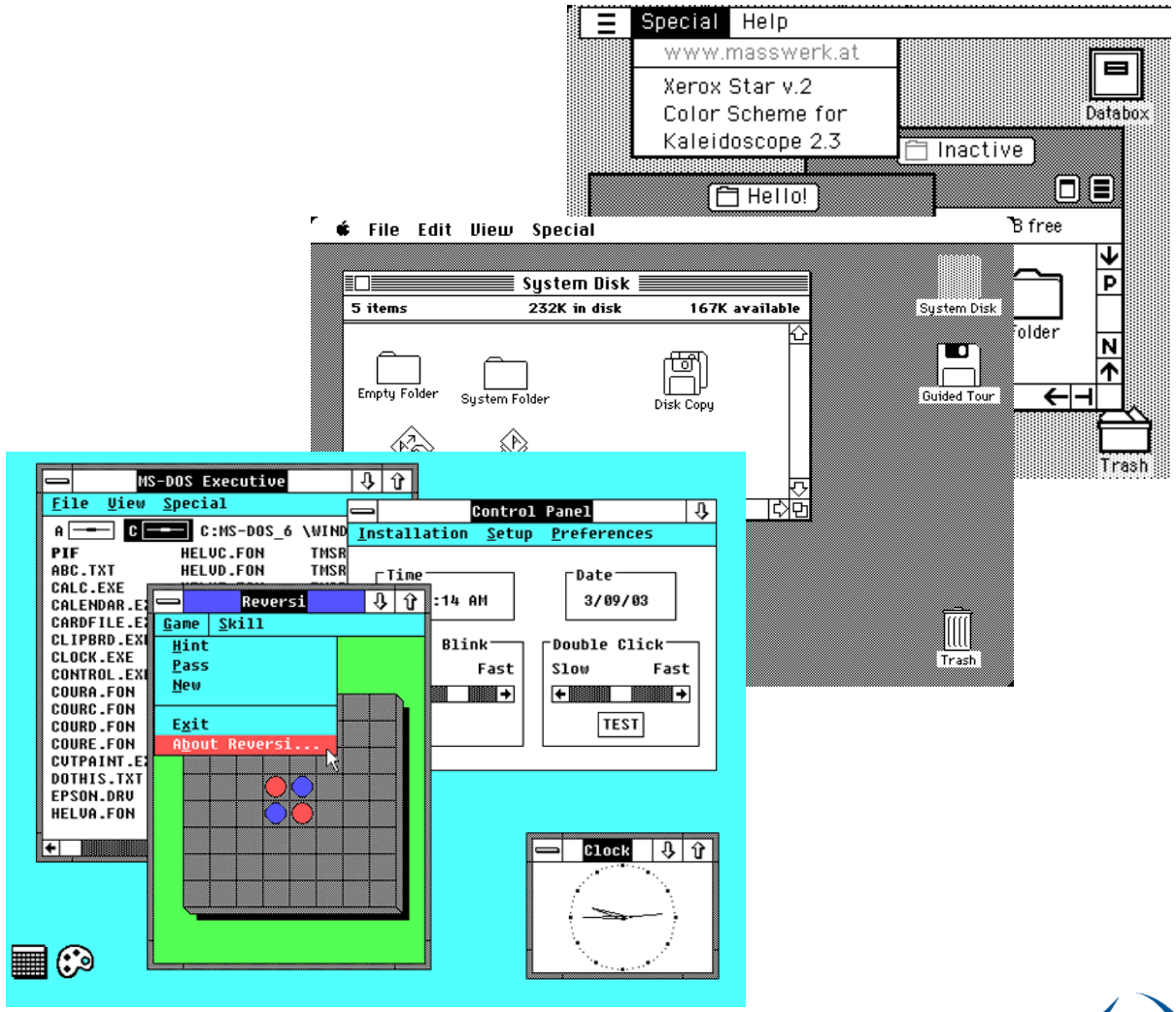
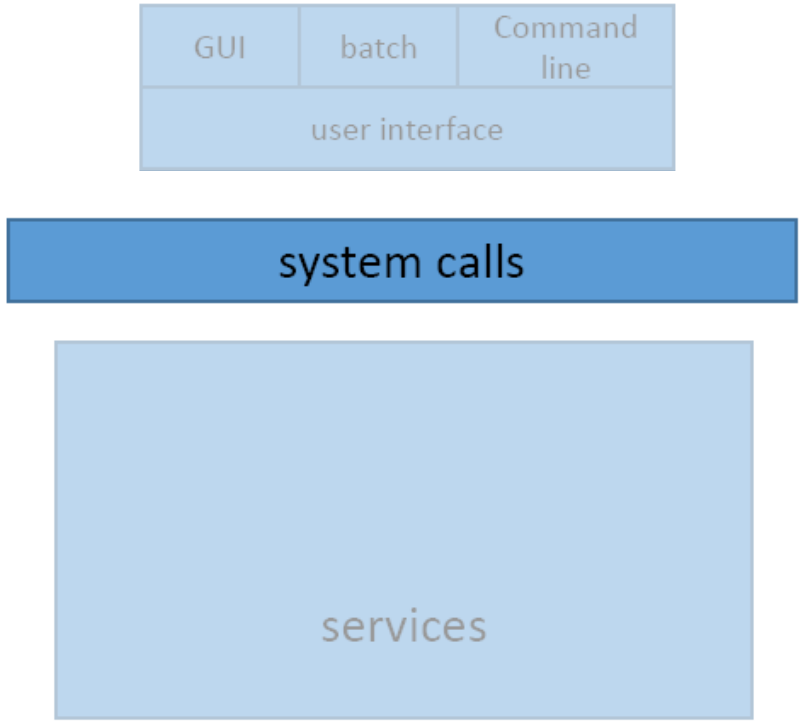
- Interesting fact: Apple sued Microsoft in 1988 for copying the “look and feel” of Mac. Apple lost the case.



SYSTEM CALLS

- How are OS services performed?
- Services are performed through system calls.



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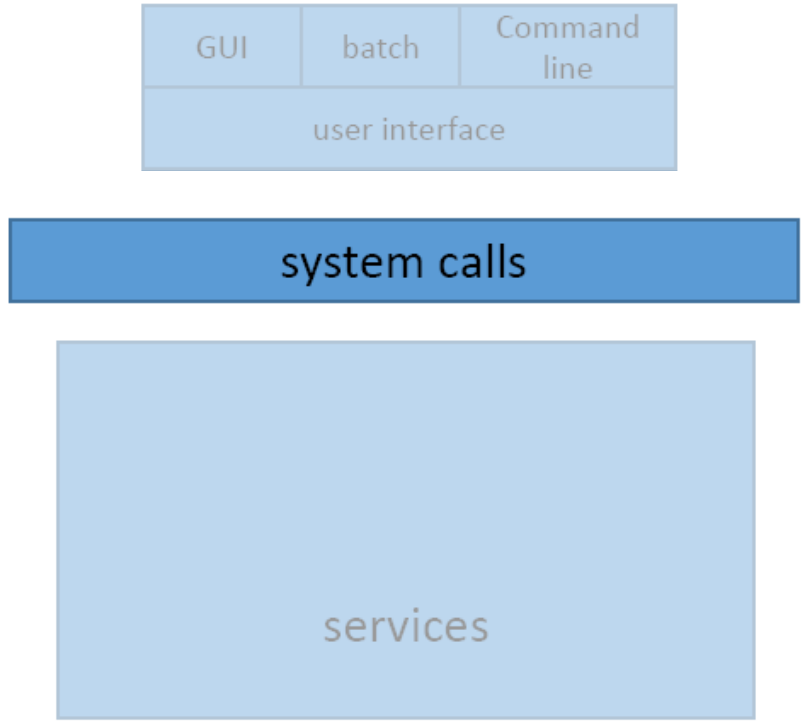

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EXAMPLES OF WINDOWS AND UNIX SYSTEM CALLS

The following illustrates various equivalent system calls for Windows and UNIX operating systems.

	Windows	Unix

Process control	`CreateProcess()`
	`ExitProcess()`
	`WaitForSingleObject()`
		`fork()`
		`exit()`
		`wait()`

File management	`CreateFile()`
	`ReadFile()`
	`WriteFile()`
	`CloseHandle()`
		`open()`
		`read()`
		`write()`
		`close()`

Device management	`SetConsoleMode()`
	`ReadConsole()`
	`WriteConsole()`
		`ioctl()`
		`read()`
		`write()`

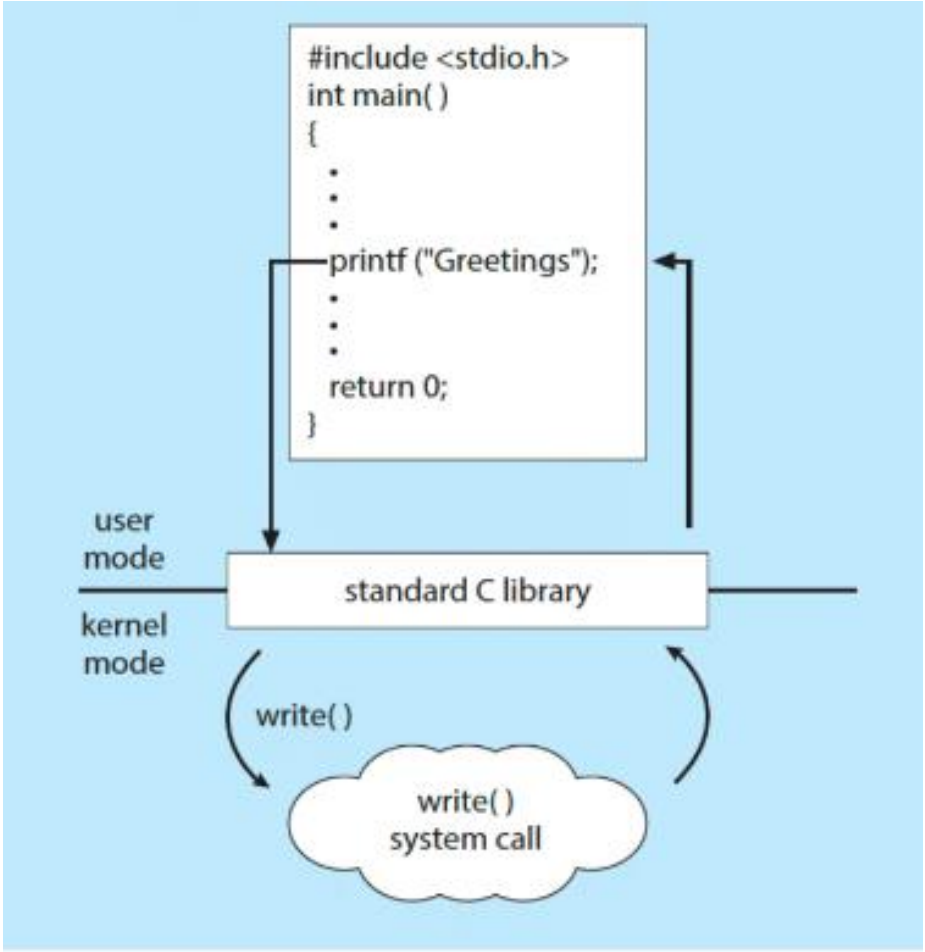
Information maintenance	`GetCurrentProcessID()`
	`SetTimer()`
	`Sleep()`
		`getpid()`
		`alarm()`
		`sleep()`

Communications	`CreatePipe()`
	`CreateFileMapping()`
	`MapViewOfFile()`
		`pipe()`
		`shm_open()`
		`mmap()`

Protection	`SetFileSecurity()`
	`InitlializeSecurityDescriptor()`
	`SetSecurityDescriptorGroup()`
		`chmod()`
		`umask()`
		`chown()`

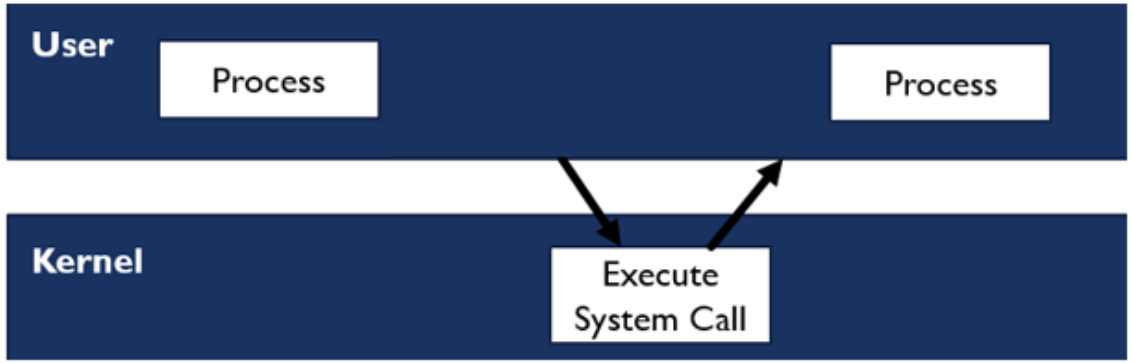
EXAMPLE OF IMPLICIT SYSTEM CALL

- Standard C library would call appropriate system call functions when needed.



SYSTEM CALLS: PARAMETER PASSING

- Example: program initiates a system call to print text on screen.
- It has to pass the "text" to the kernel to do the printing.



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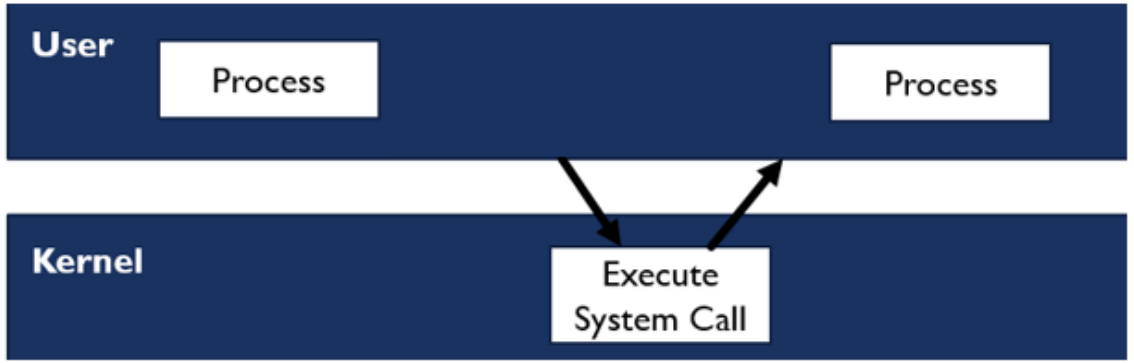

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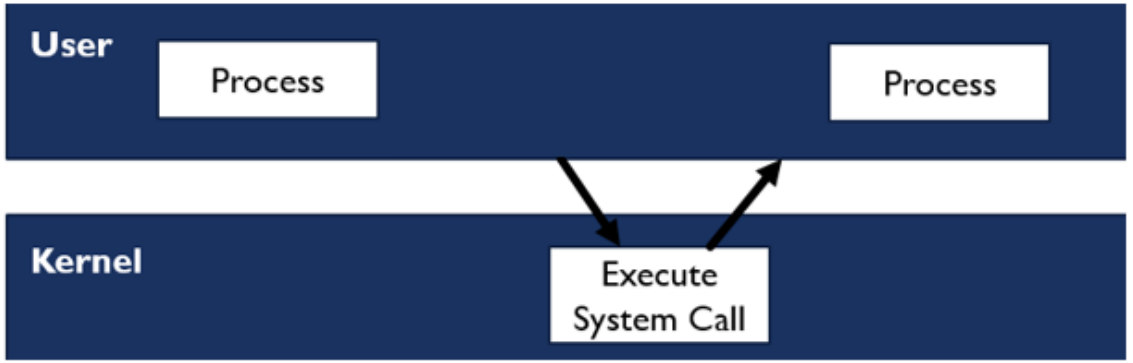


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72      newProc* node = (newProc*) malloc(sizeof(proc));
73      node->proc = procNum;
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From a programmer perspective, "arguments" are passed very easily.

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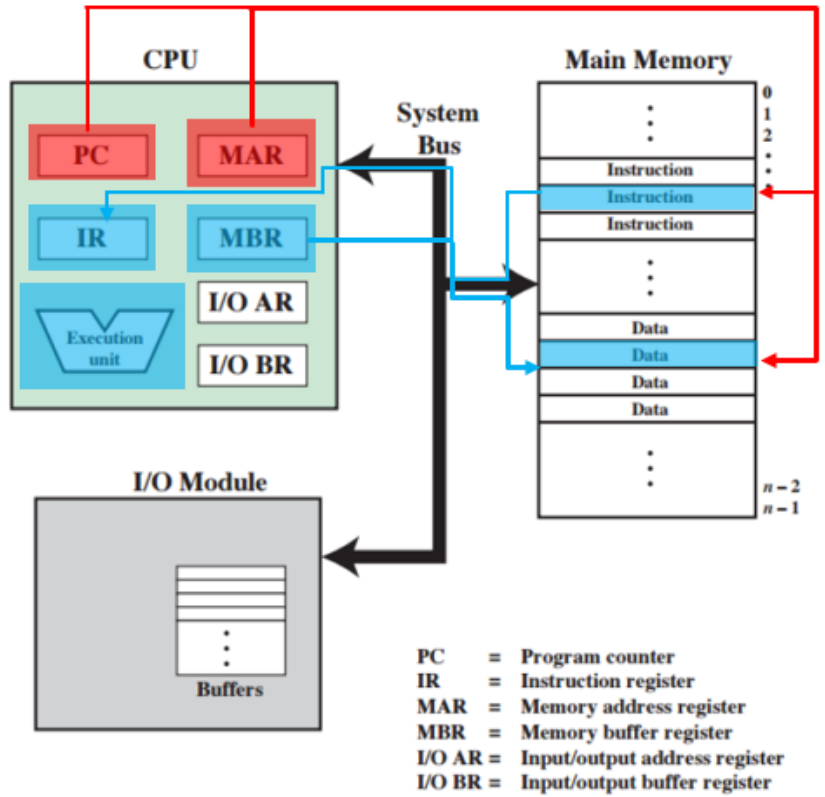
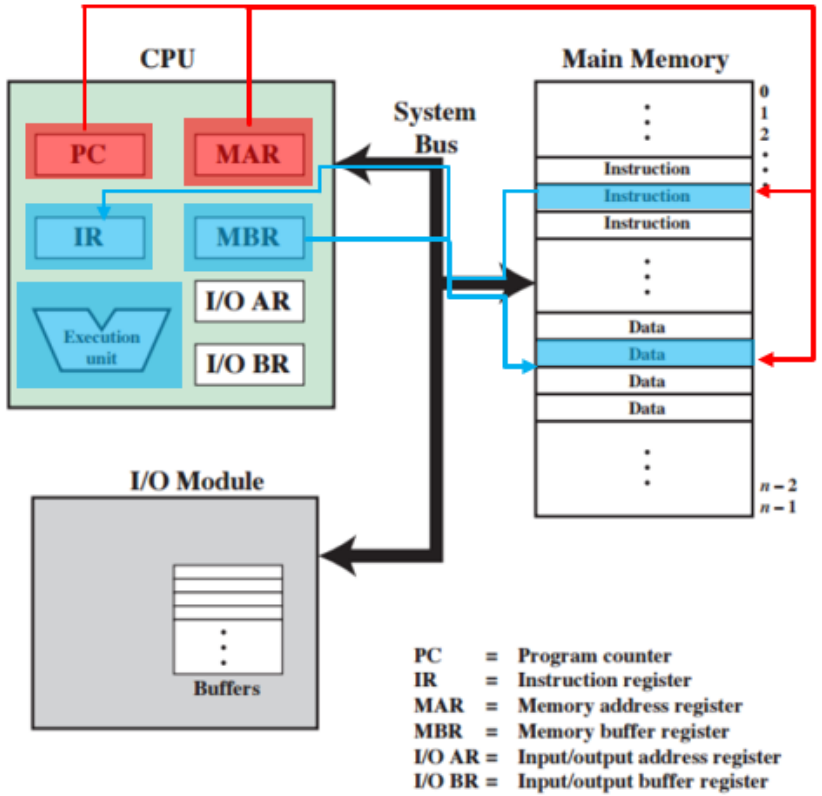


From a hardware perspective, things are a bit more complicated.

SYSTEM CALLS: PARAMETER PASSING

- Actual computer hardware: bunch of registers with access to memory … not enough "fields" for passing all parameters.
- Instructions are performed one at a time



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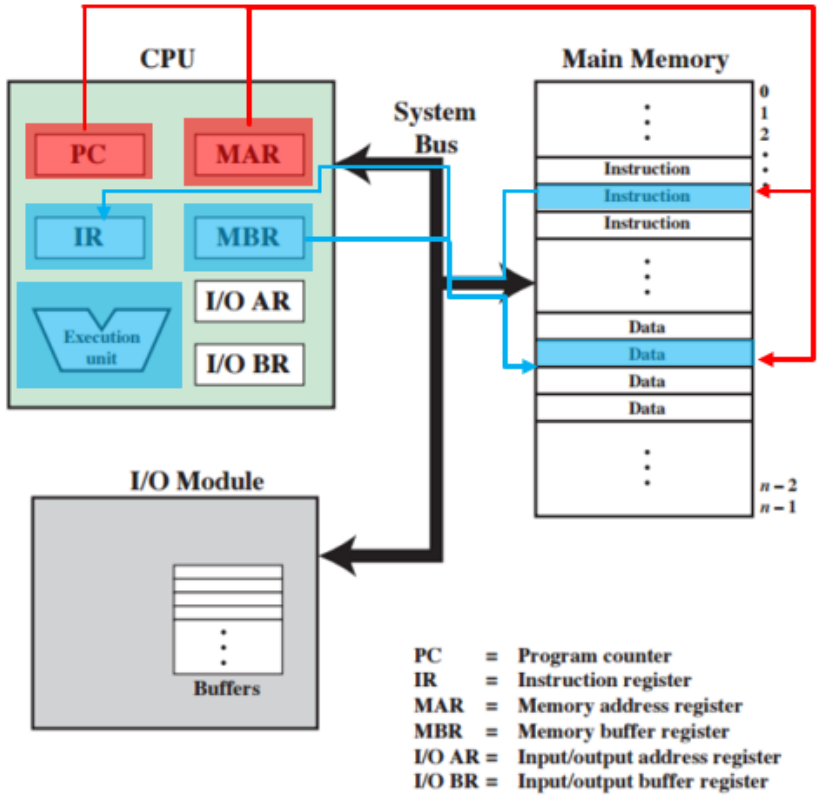
- Calling a "function" or doing a system call is simply "jumping" to different PC.



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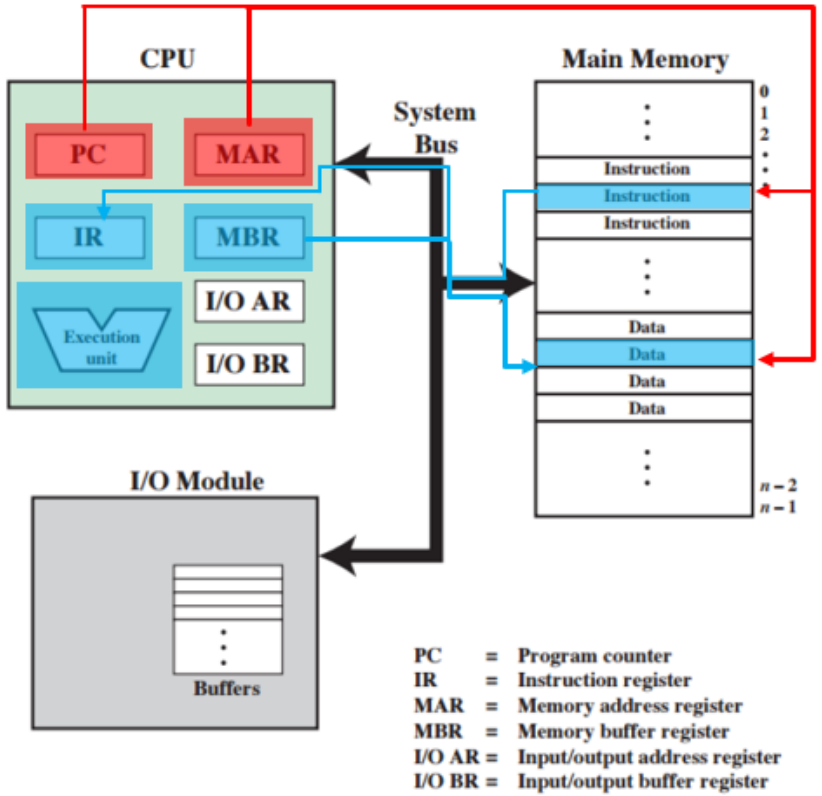
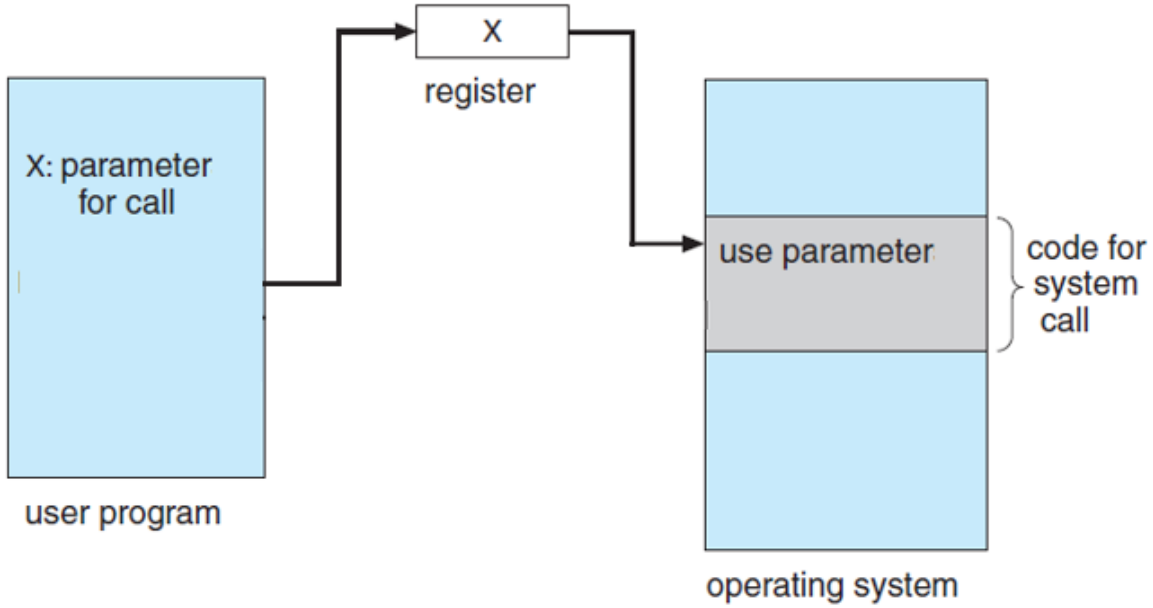


- Worksheet Q1:
- Think and list a couple of approaches that we can use to pass parameters from program to kernel.

SYSTEM CALLS: PARAMETER PASSING

- Three methods for passing parameters:
- Saved into registers.



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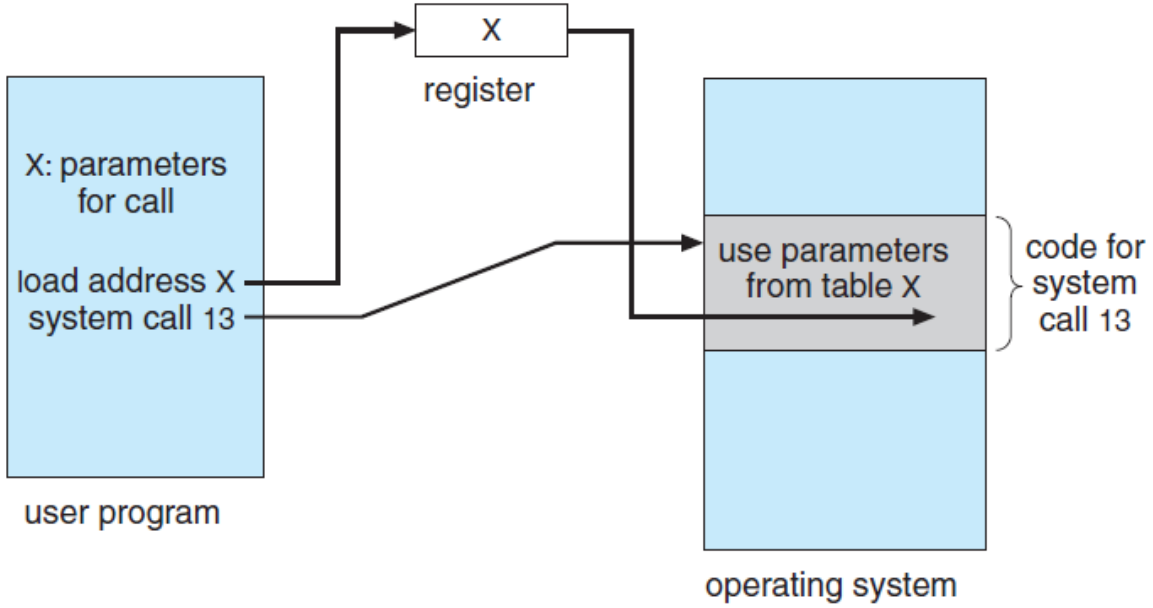

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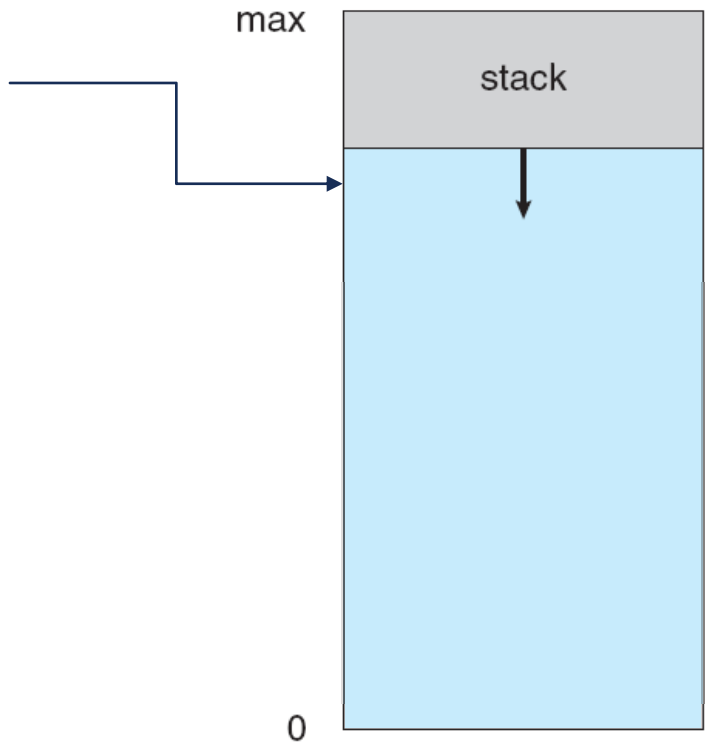
- Pushed onto the stack where it is popped by the called function.



SYSTEM CALLS: PARAMETER PASSING

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  - A: The program performing the system call.
  - B: The system call.

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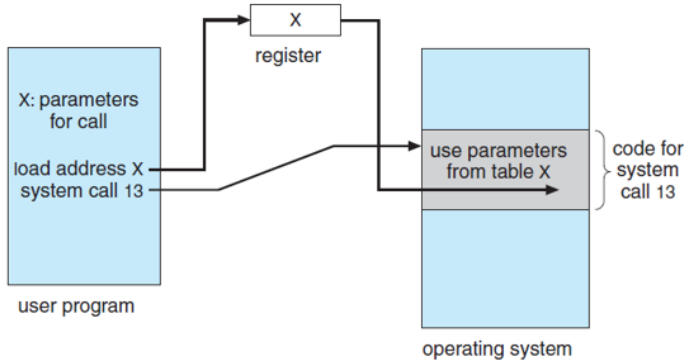

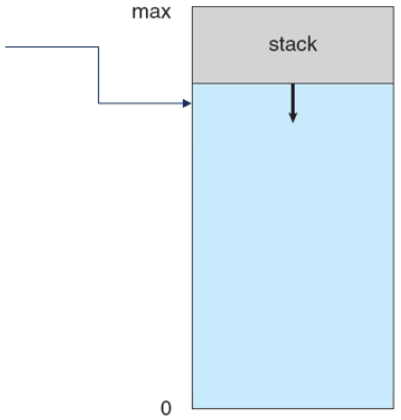

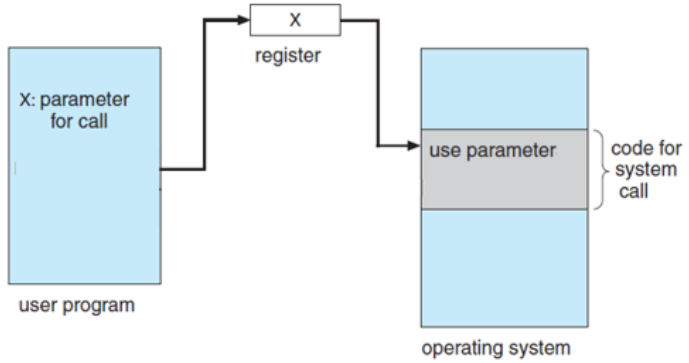

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