

## Instruction

ADD    R<sub>1</sub>, R<sub>2</sub>  
Oprode    operand

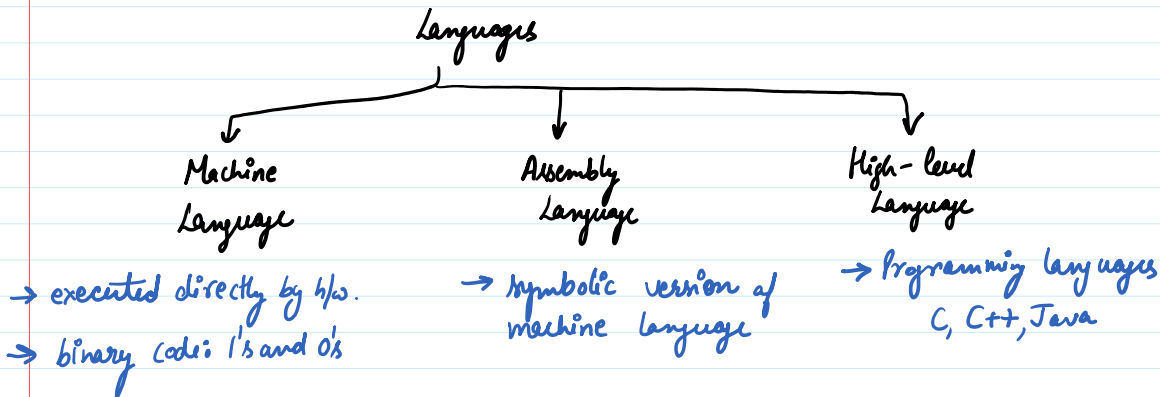
To execute a program, two basic operations are required:

- a) LOAD:        LOAD R1, 2000
- b) STORE:       STORE 2020, R3

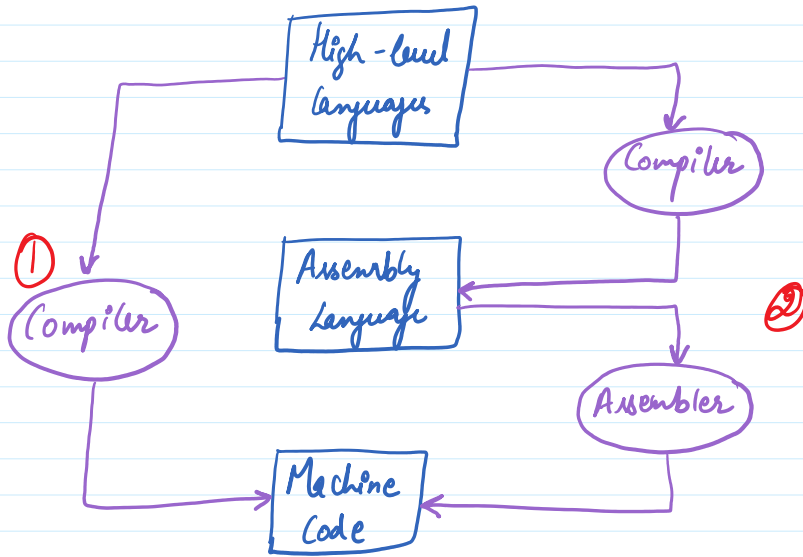
Example instruction:-

$$S = (A+B) - (C-D)$$

```
LOAD R1, A
LOAD R2, B
ADD R3, R1, R2    // R3 = A+B
LOAD R1, C
LOAD R2, D
SUB R4, R1, R2    // R4 = C-D
SUB R3, R3, R4    // R3 = R3 - R4
STORE S, R3
```



Compiler and Assembler



Program / Software :-

Set of instructions.

- simple programs
- compiler
- operating system

### Types of programs

Application  
Software

- Ex:-
- ⇒ Health monitoring app
  - ⇒ Mathematical packages  
MATLAB

System  
Software

- Ex:-
- ⇒ Operating systems
  - ⇒ Compilers and Assemblers
  - ⇒ Editors and debuggers

★ To solve particular user-level problems

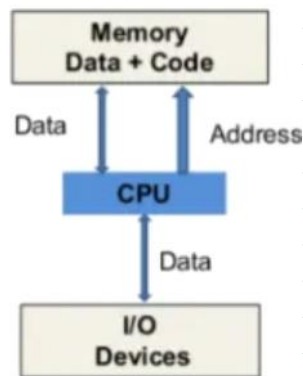
★ Collection of programs, which helps users run other programs

Computer v/a Calculator

# Computer v/s Calculator

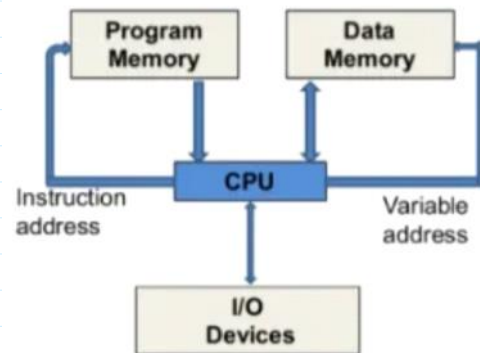
## Classification of Computer Architecture

### Von-Neumann Architecture



Von Neumann Machine

### Harvard Architecture



Harvard Machine

### Von-Neuman Architecture :-

- ① Both instruction and data are stored in the same memory module.
- ② More flexible and easier to implement.
- ③ Suitable for most of the general-purpose processors.

### Harvard Architecture :-

- ① A separate memory module for program and data.
- ② Instructions are stored in program memory.  
Data are stored in data memory.

⑧ Instruction and data access can be done in parallel.

Execution of instructions :-

5 stages of execution of instructions :-

- ① Instruction Fetch (IF)
- ② Instruction Decode (ID)
- ③ ALU operation (EX)
- ④ Memory Access (MEM)
- ⑤ Write back result to register file (WB)

Basic 5-stage pipelining :-

Execution of these 5 instructions in a pipeline.  
(overlapping)

Instr. No.	Pipeline Stage						
	IF	ID	EX	MEM	WB		
1	IF	ID	EX	MEM	WB		
2		IF	ID	EX	MEM	WB	
3			IF	ID	EX	MEM	WB
4				IF	ID	EX	MEM
5					IF	ID	EX
	1	2	3	4	5	6	7

In clock cycle 4, instruction 4 is trying to fetch an instruction (IF), while instruction 1 is trying to access data (MEM)

→ Von-Neumann :- one of these two operations will have to wait - slow.

→ Harvard

Architecture :- the operations can go on without any speed penalty as the instruction and data memories are separate.