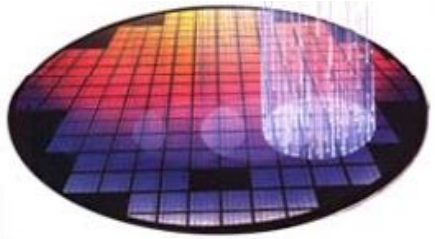
Computer Architecture Intro



The main components of a computer (semiconductor chips) are made out of silicon wafers.

What do you think silicon wafers are made of?

Old School Computer

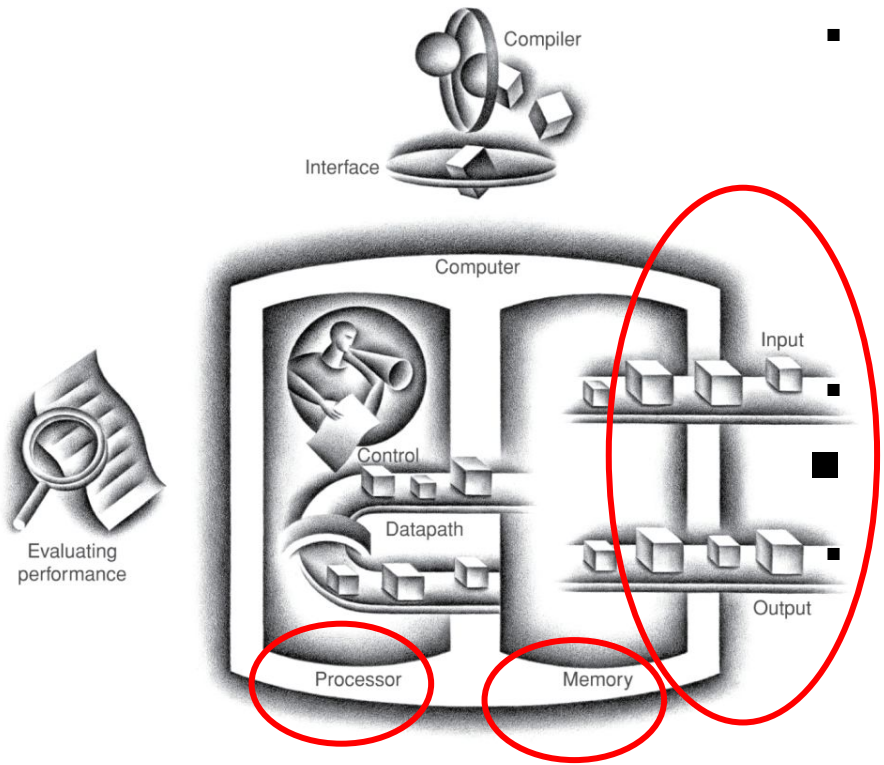
New School Computer

[Parkour Video]

Data Center is the Computer

Inside the warehouse data center

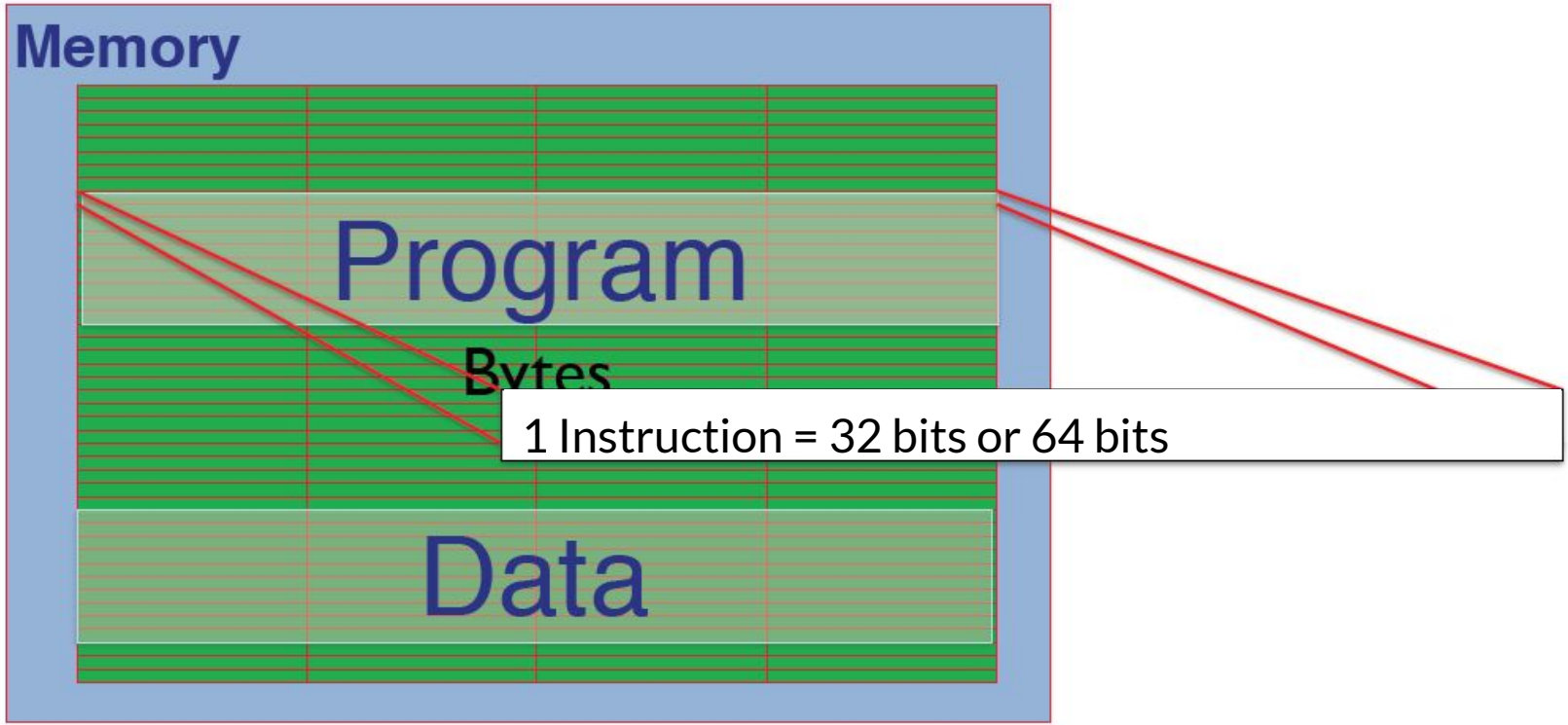
Components of a Computer



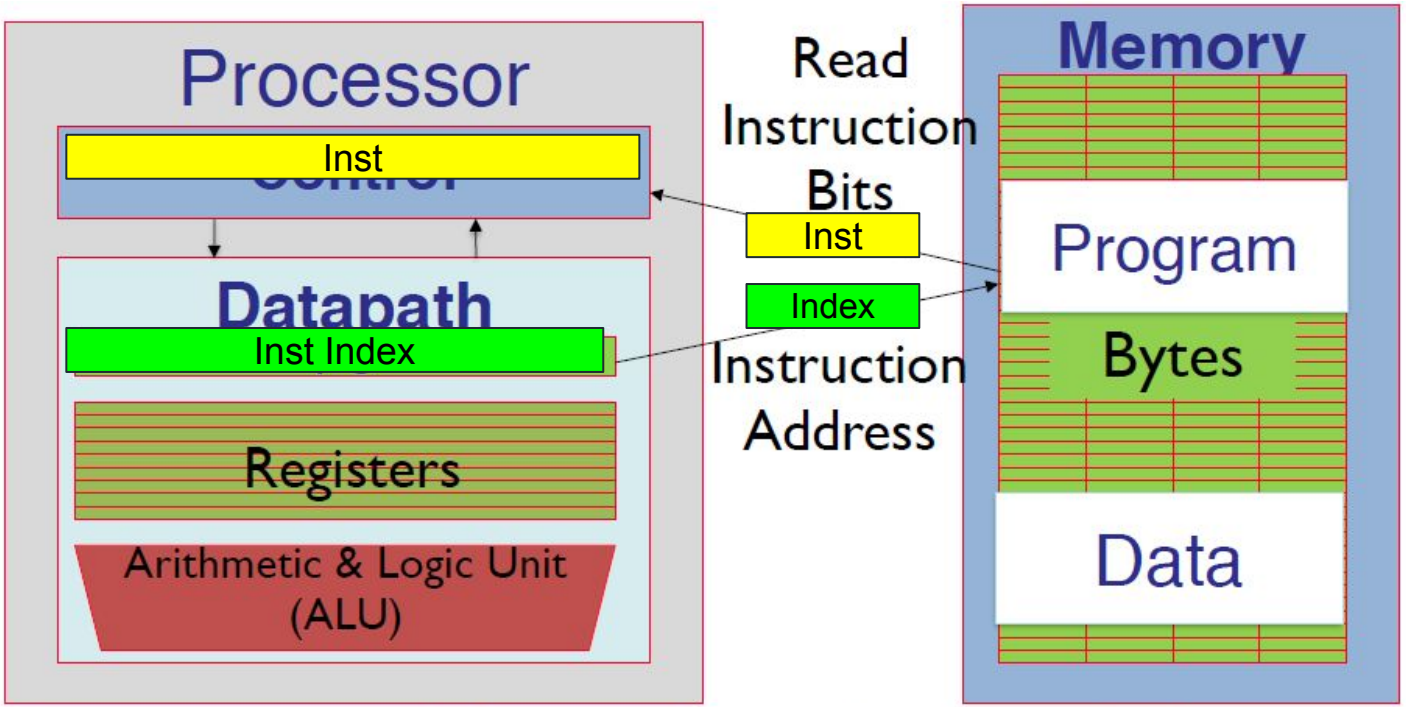
- Same 3 components for all kinds of computers
  - Processor (CPU)
  - Memory
  - I/O
- Processor executes instructions
- Memory holds data (inst)
- I/O transfers data to and from
  - Keyboard, mouse, network
  - Screen, printer, speaker
  - Flash drive, RAM,
-

Von Neumann Architecture:

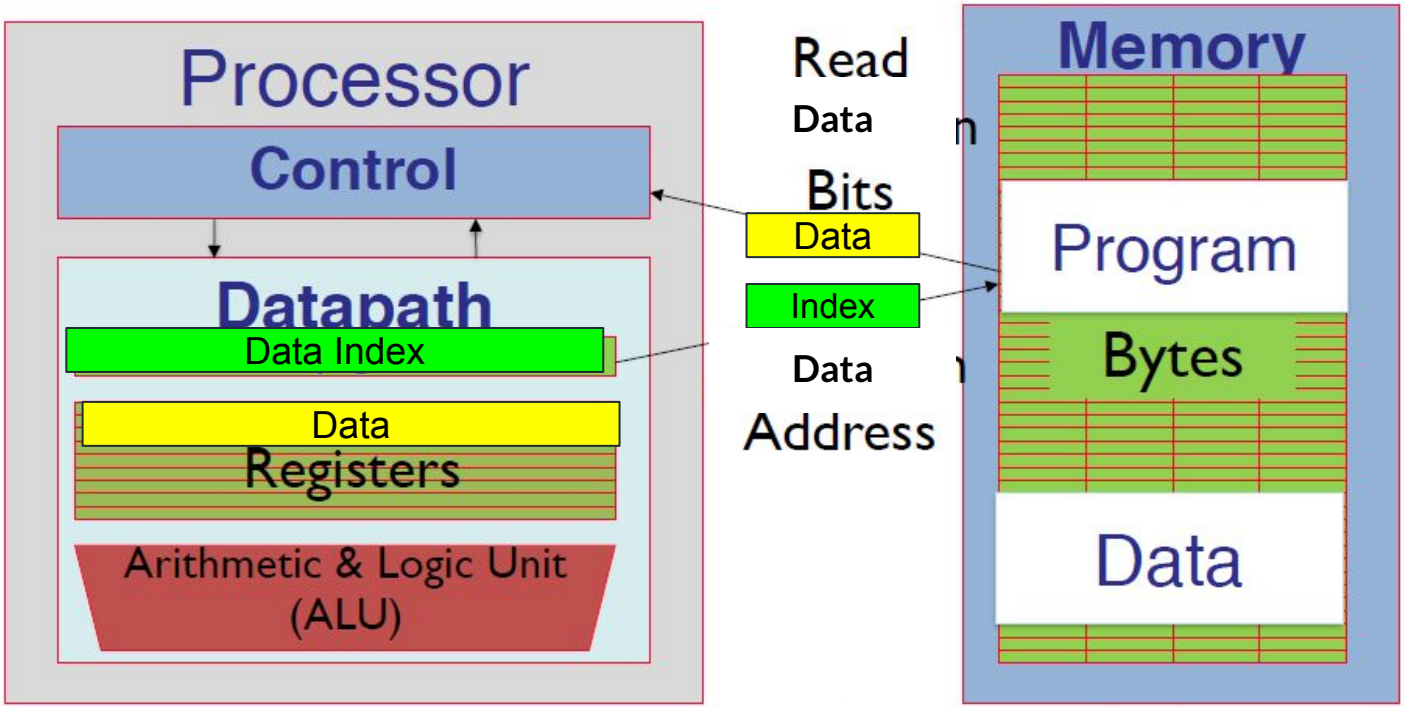
Program is stored in memory - think of memory as a large array



Program Execution:
Load instruction into processor (internal registers)



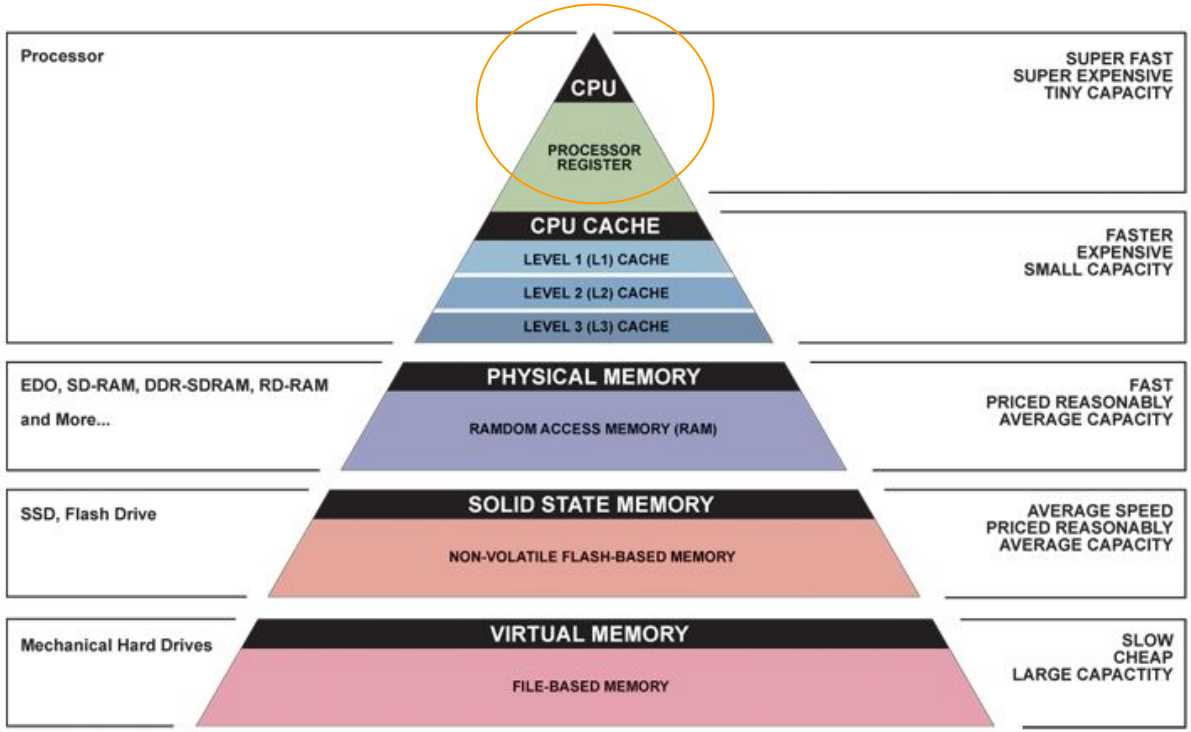
Program Execution:
Load data into registers



Typically, we only have 32 - 64 registers. You can think of these as hardware variables!

#3 – Principle of Locality – aka Memory Hierarchy

More Memory

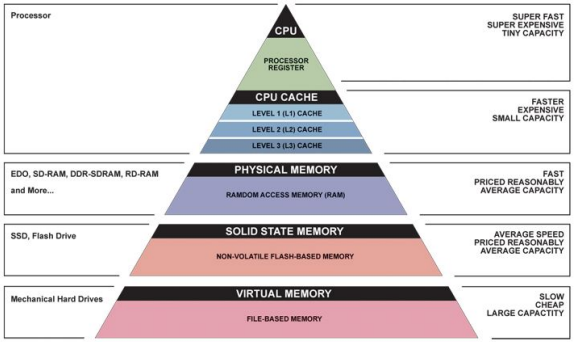


Faster Memory

All data in layers above resides in the layer below
What should we store closer to CPU? Farther from CPU?

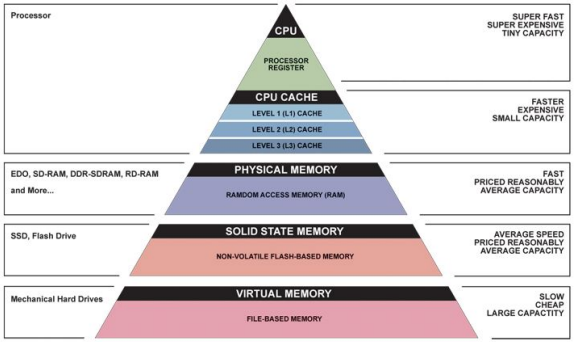
Key: Mem closest to CPU is fast, expensive, and scarce. Mem farthest is slow, cheap, plenty.

Registers



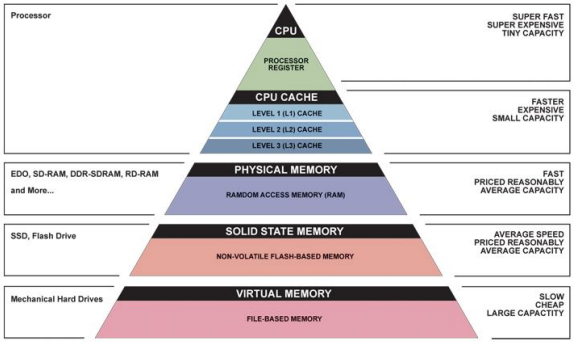
- Fastest, most expensive, tiny capacity
  - How fast is fast?
    - Registers operate at the same speed as a CPU's clock
      - A 3.33 GHz CPU has a clock period of 0.3ns
      - Access to registers are usually single cycle (0.3ns)
      - **C (speed of light) is $3*10^8$ m/s = 0.3 m/ns = 30 cm/ns = 10 cm/0.3 ns**
        - **Light can travel only 10cm in the span of of a clock period 0.3ns**
- 32 - 64 registers per processor core
- Each holds 32 - 64 bits of data

Cache



- Faster, expensive, small capacity
- Slower than registers, but faster than main memory
  - 10 - 100 cycles
- Typically, 1-3 levels (L1, L2, L3, etc.)
- 32-64 KB for L1, 128 - 512 KB for L2, 1MB+ for L3

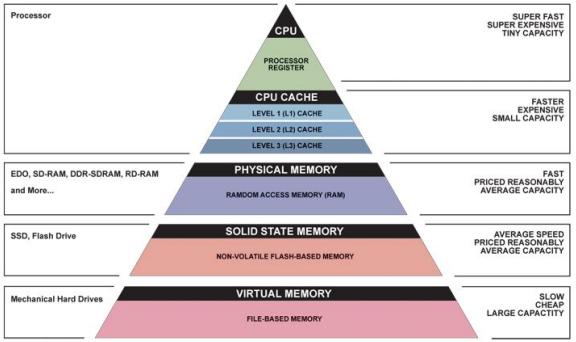
Main memory (RAM)
Physical memory



- Fast, reasonably priced, average capacity
- Much slower than registers, but faster than disk
- 8 - 32 GB
- All programs and data must fit in memory
    - Use virtual memory when we need memory > physical memory
    - Virtual memory gives each program the illusion of having all memory space
    - Utilize disk to store data that do not fit into physical memory

External memory (disk)

- Slow, cheap, large capacity
- Recent computers use solid state drives (SSDs)
- Hundred of GB to a few TB



Assignment 5: On-disk merge sort