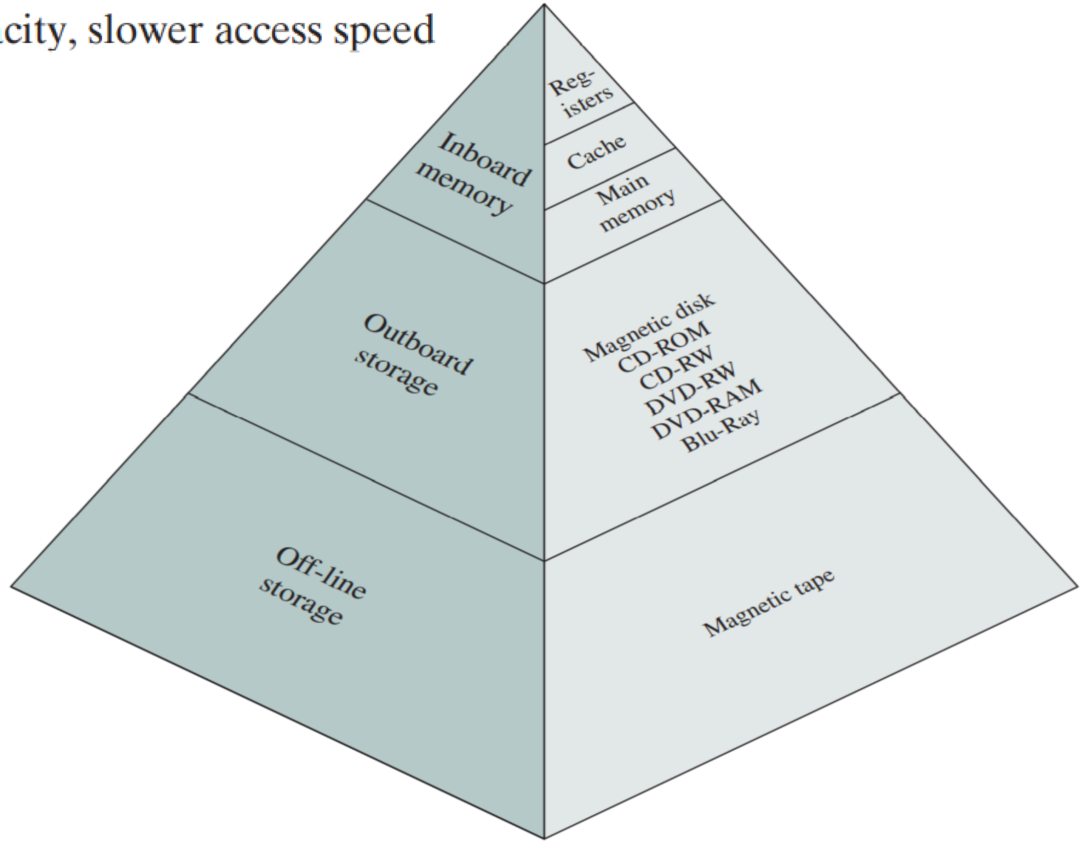
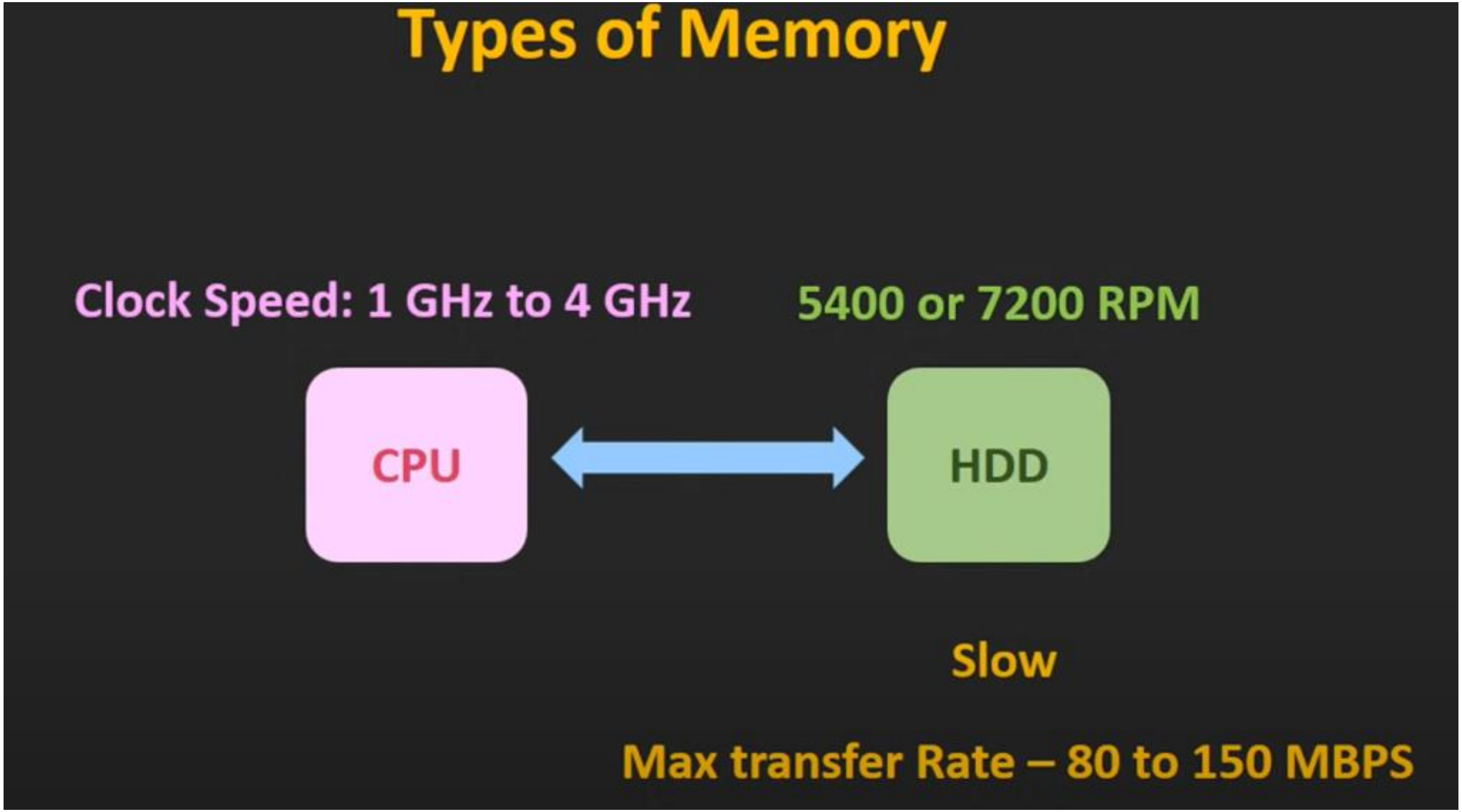
The Memory Hierarchy

- How much?
- How fast?
- How expensive?

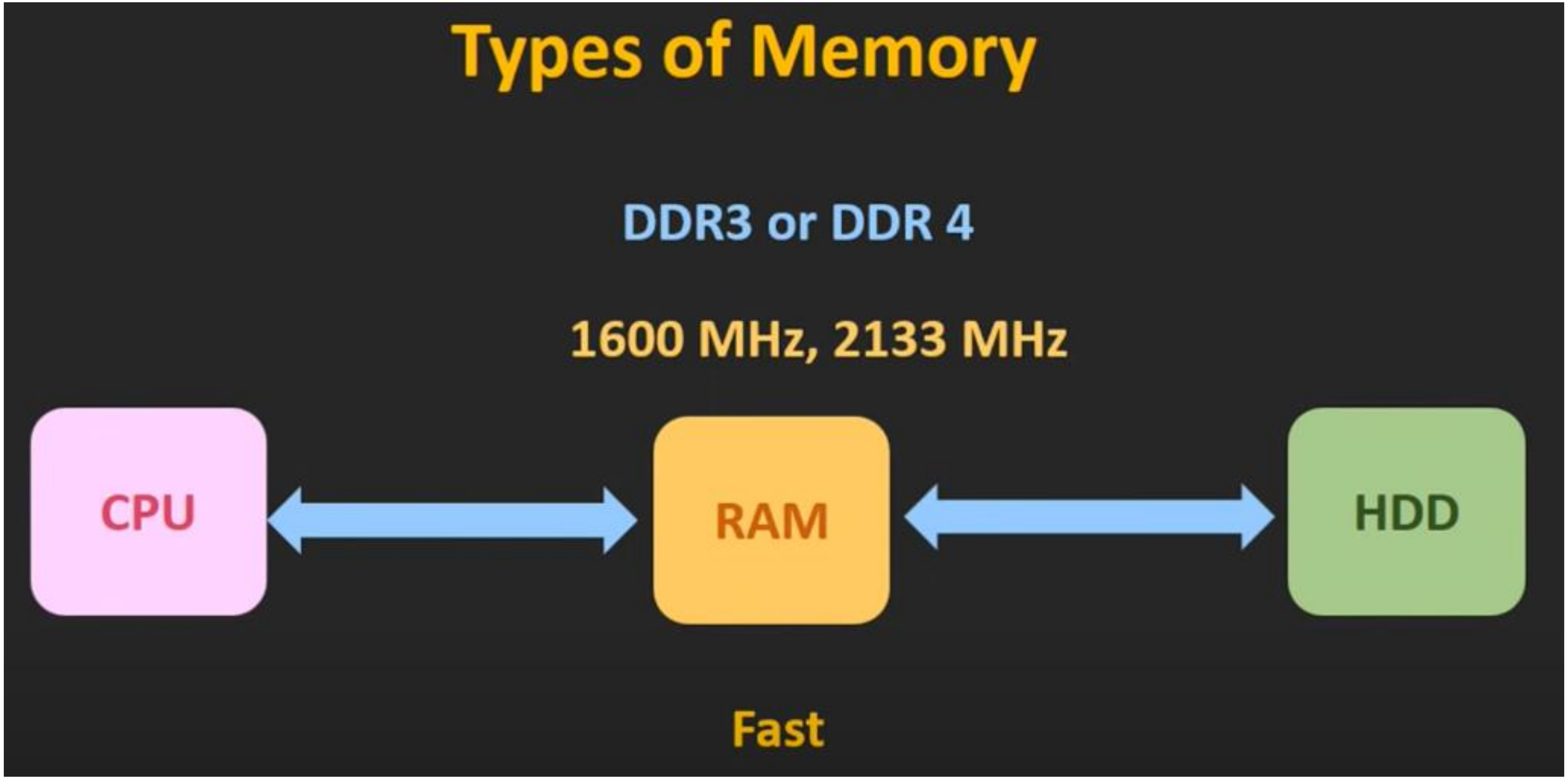
- Faster access time, greater cost per bit
- Greater capacity, smaller cost per bit
- Greater capacity, slower access speed

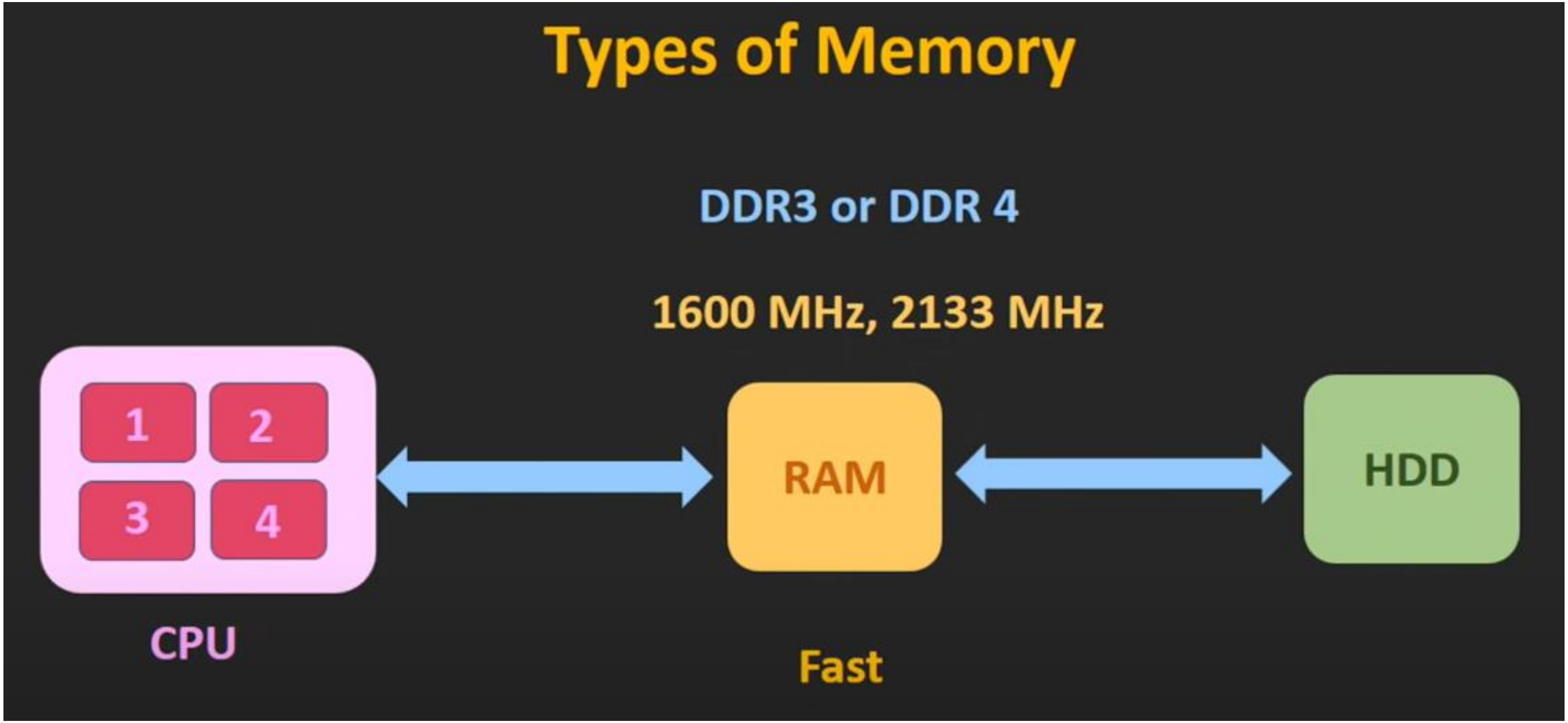


a. Decreasing cost per bit
b. Increasing capacity
c. Increasing access time
d. Decreasing frequency of access to the memory by the processor



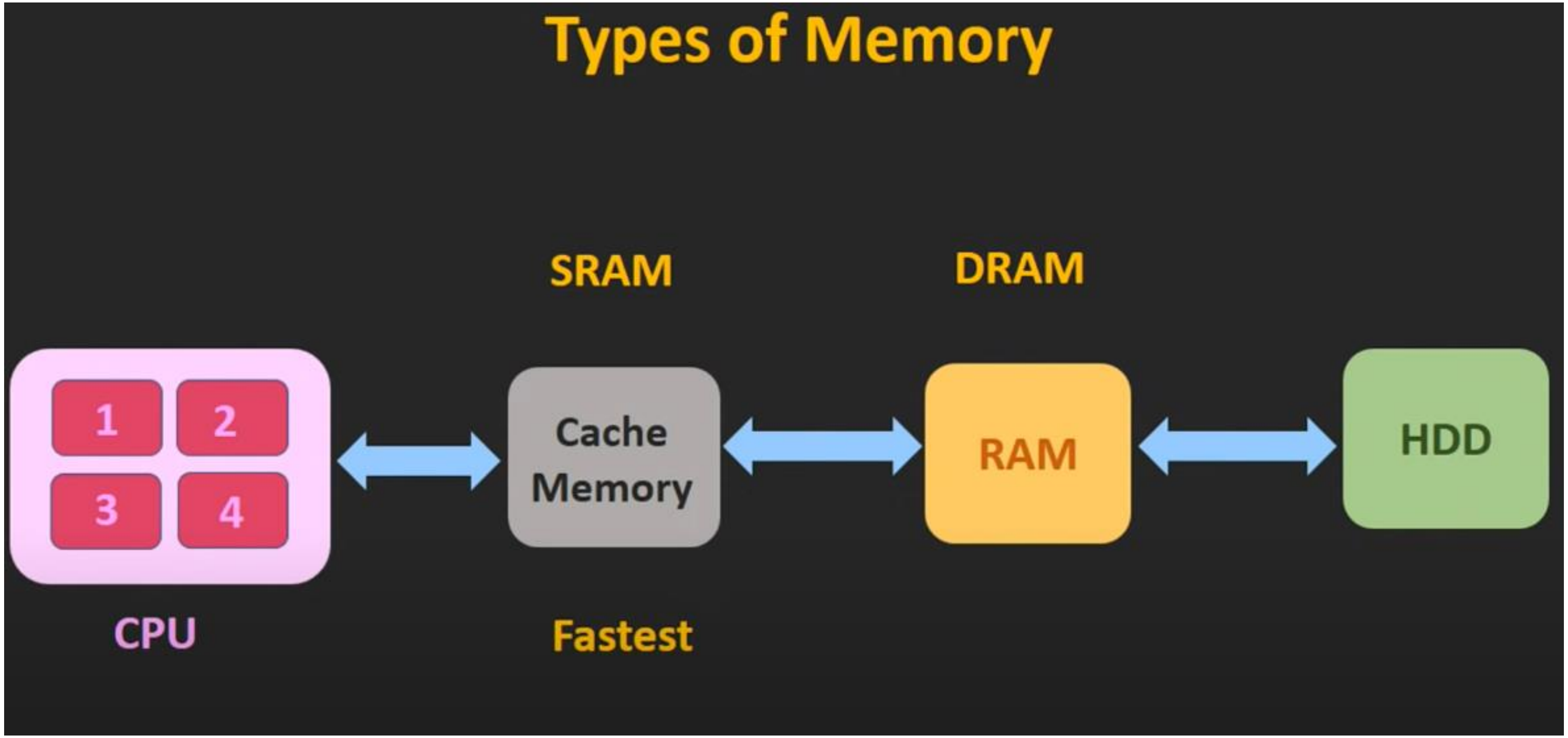
Types of Memory
Clock Speed: 1 GHz to 4 GHz
5400 or 7200 RPM
CPU
HDD
Slow
Max transfer Rate – 80 to 150 MBPS


Types of Memory
DDR3 or DDR 4
1600 MHz, 2133 MHz
CPU
RAM
HDD
Fast

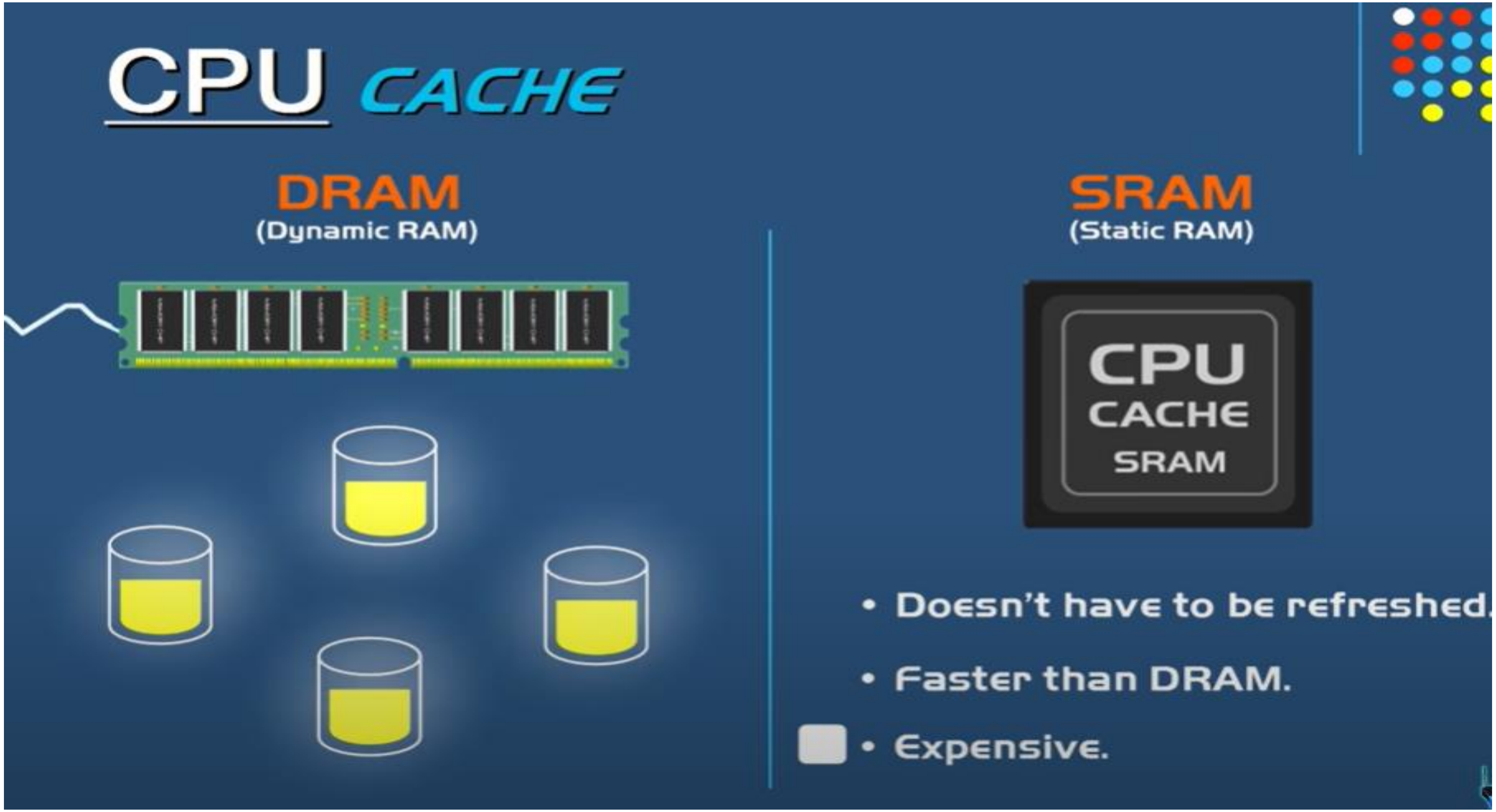

Types of Memory
DDR3 or DDR 4
1600 MHz, 2133 MHz
1
2
3
4
CPU
RAM
Fast
HDD

Special kind of RAM is know as Static RAM

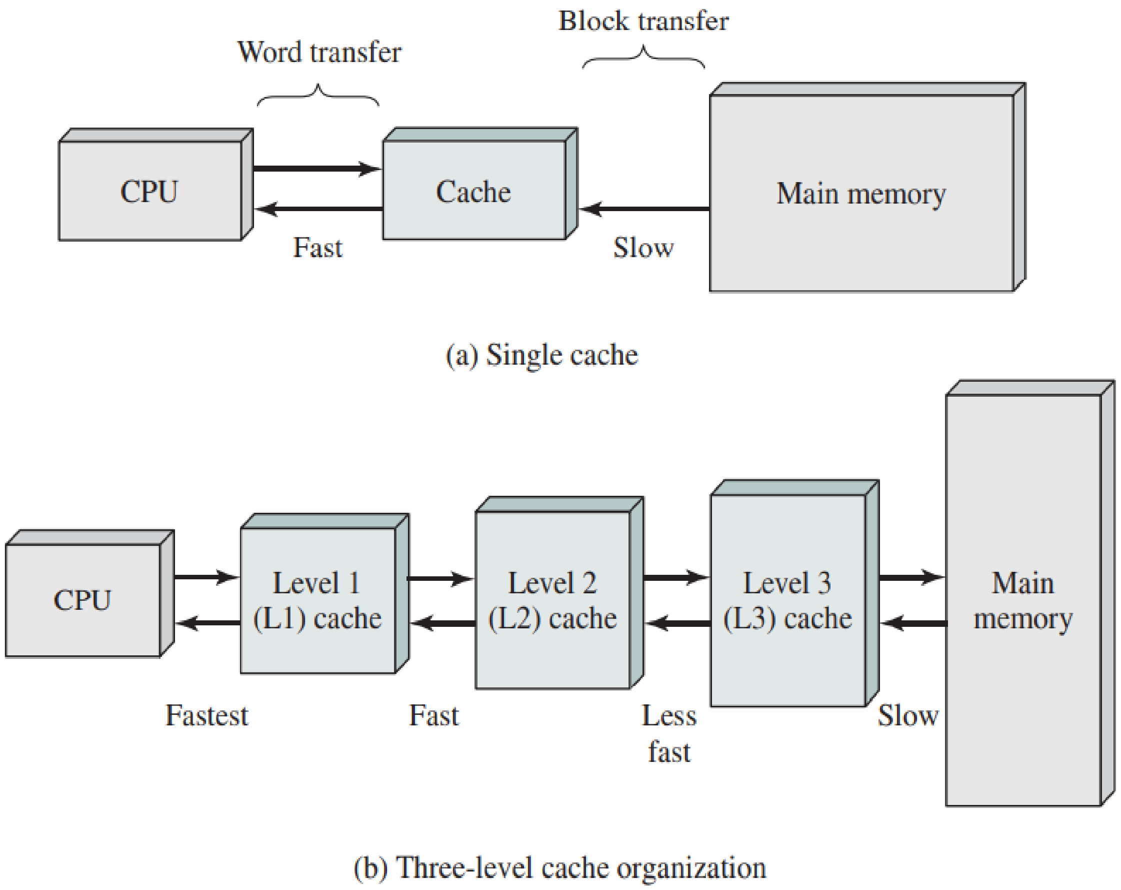
- Size of cach memory is in the range of KiloByte up to Few MB

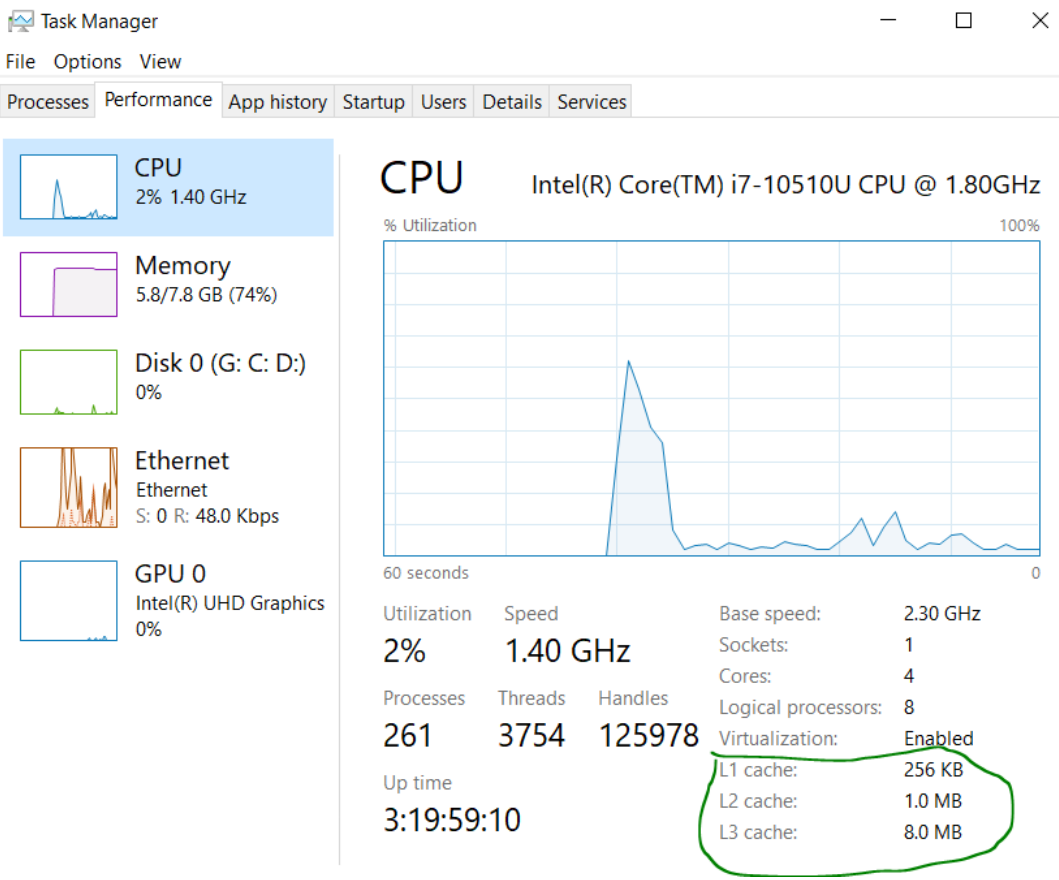


Stored copies of data and instructions from RAM, that's waiting to be used by the CPU

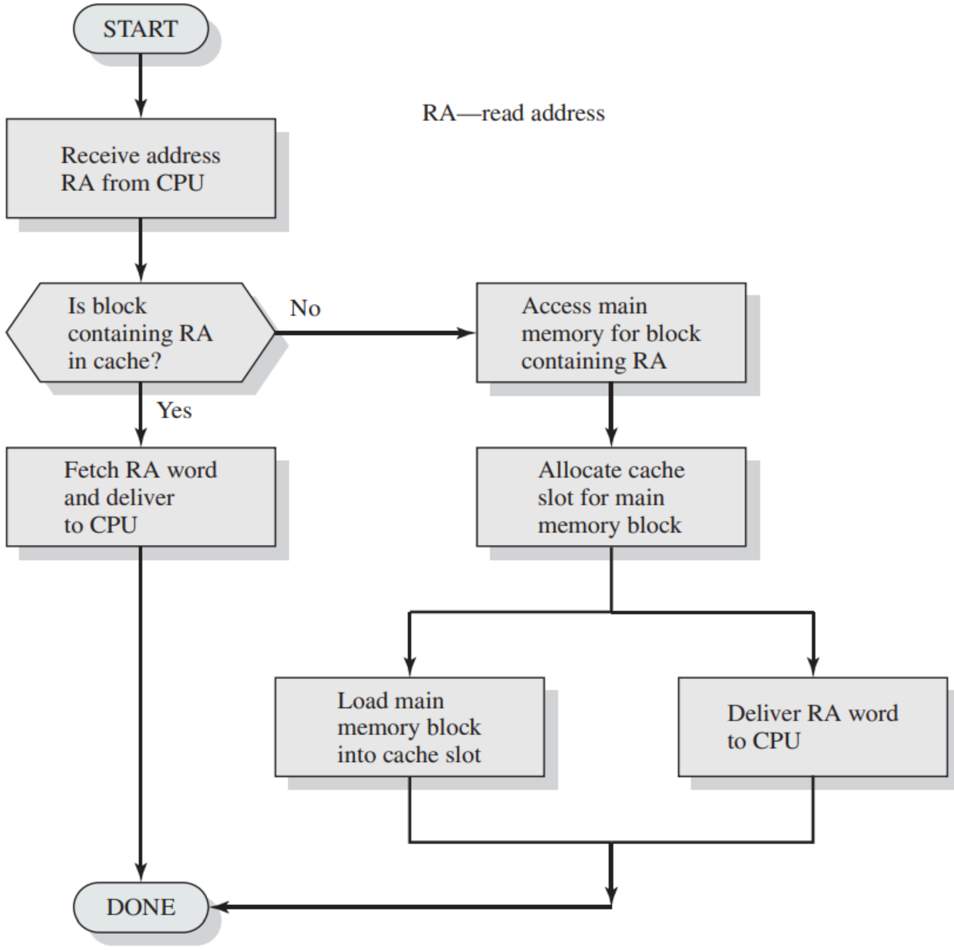


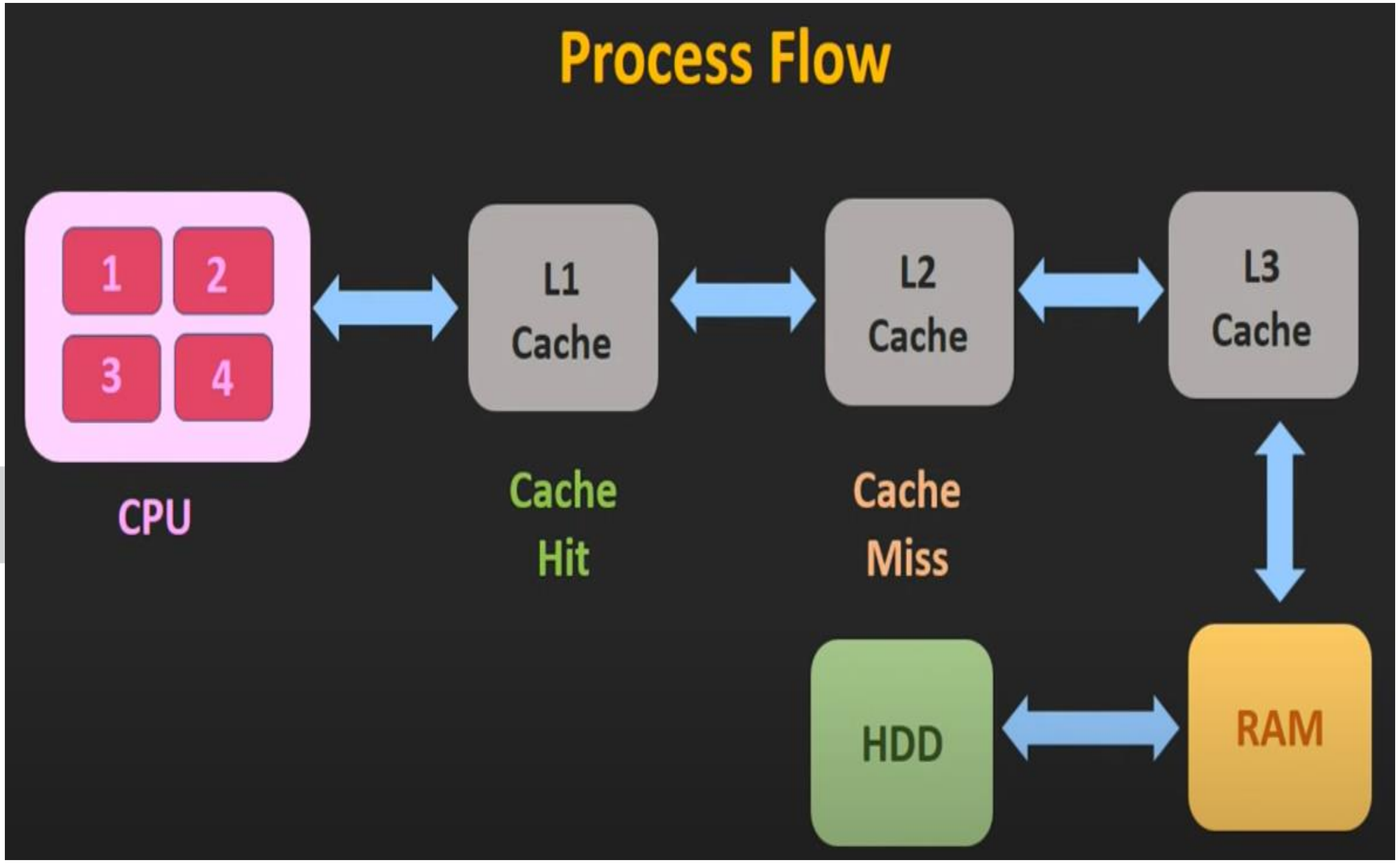
Cache and Main Memory





Process Flow






SAMSUNG
12:45
LG
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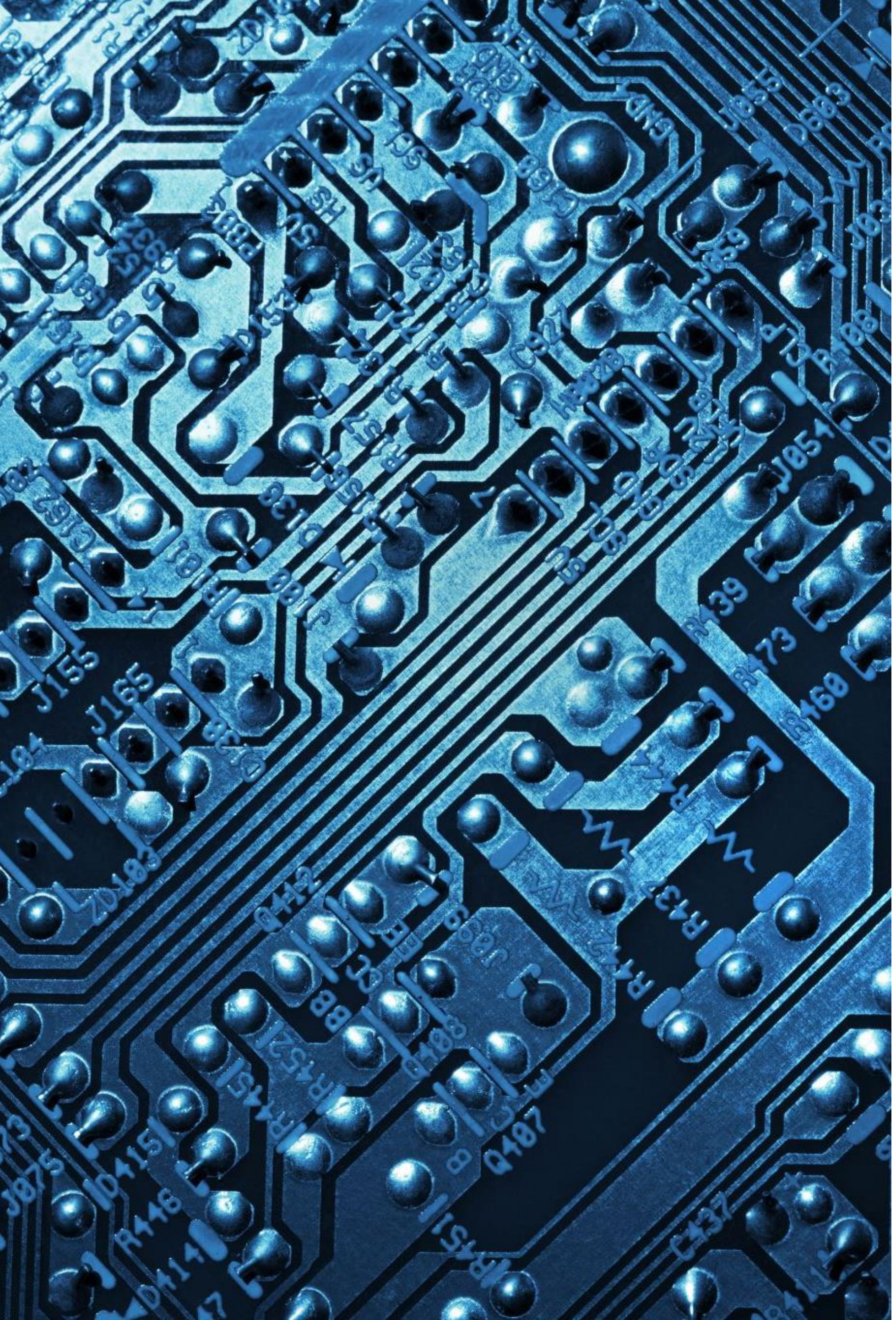
Google
Gallery
Email
Play Store
Phone
Contacts
Camera
Messaging
Apps



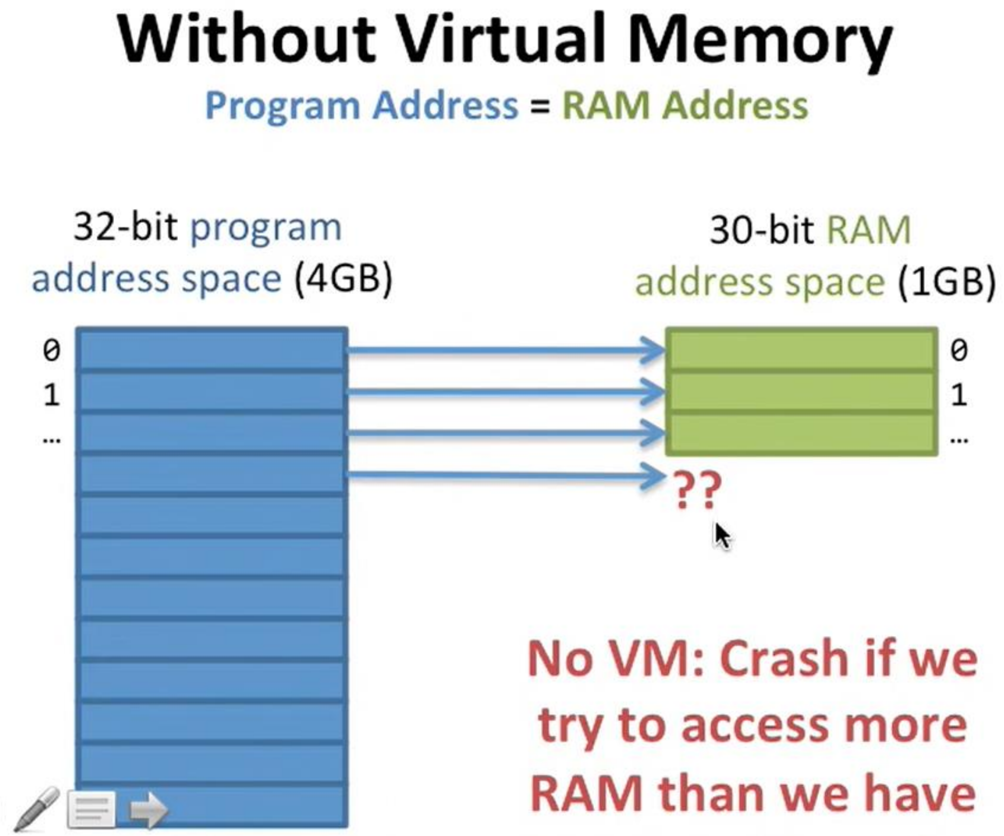
VIRTUAL MEMORY

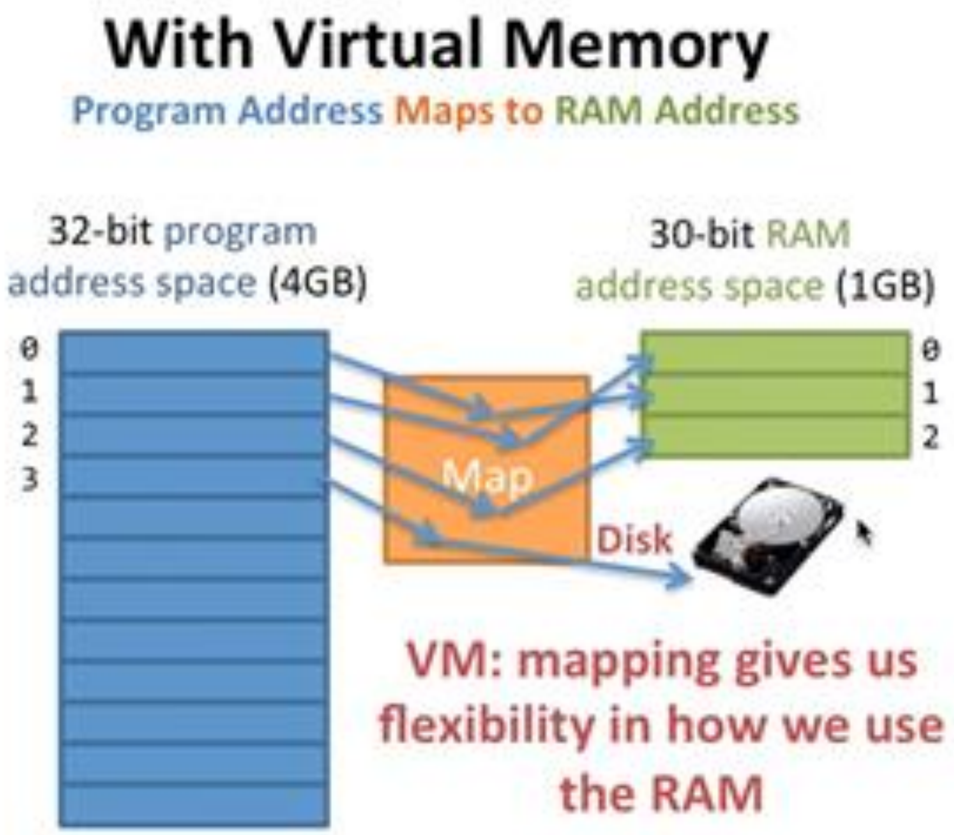
- **Thre memory problems:**
  - Not enough RAM
  - Holes in our address space
  - Programs writing over each other
- **What is virtual memory?**
  - Indrection
  - How does it solve the problems?
  - Page Table and Translation
- **Implementing virtula memory**
  - Where do we store the page tables?
  - Making translation fast
- **Virtual memory and caches**

Virtula memory is a layer of indirection

"Any problem in computer science can be solved by adding indrection"

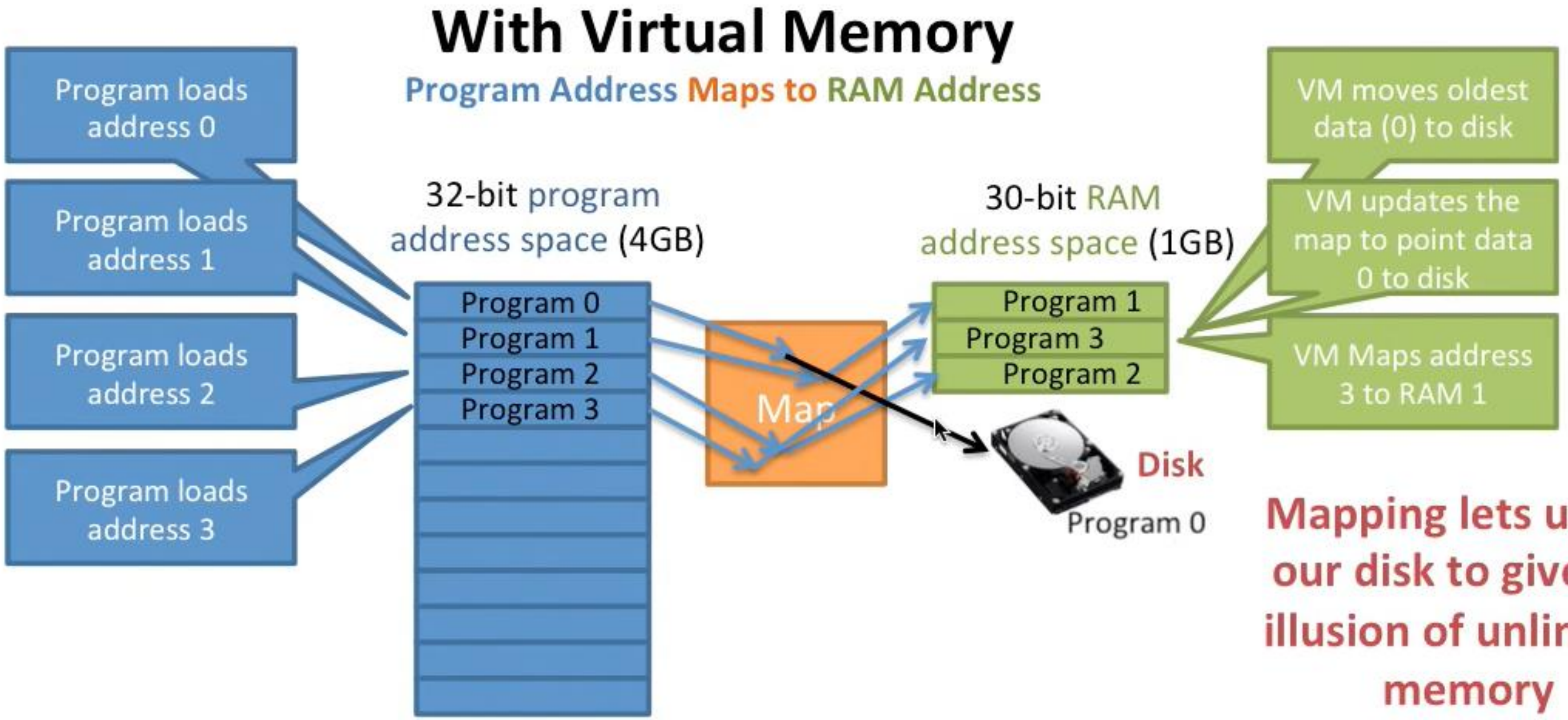
Virtual memory takes program address and maps them to RAM address





Solving the problems: #1 not enough memory

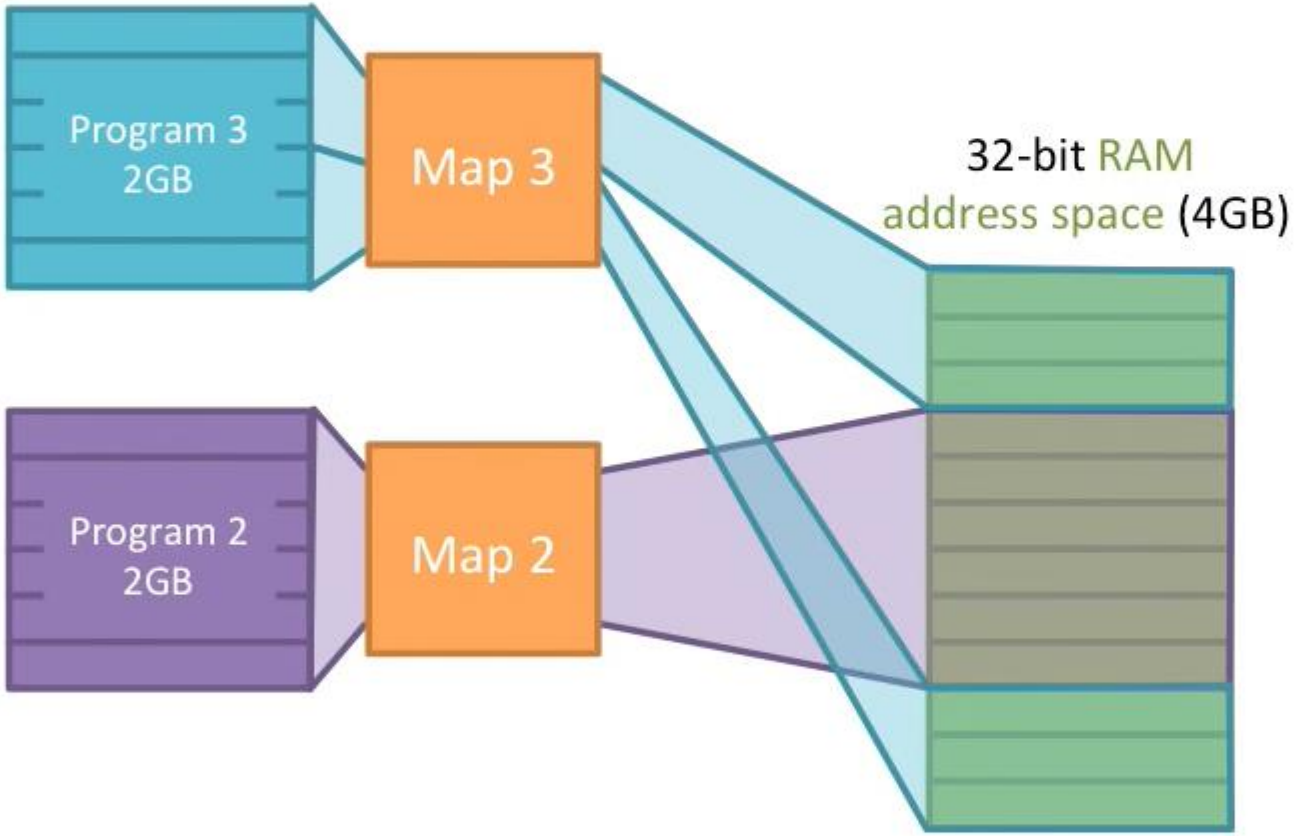
- **Map** some of the **program's address space** to the **disk**
- When we need it, we bring it into memory



Mapping lets us use our disk to give the illusion of unlimited memory

Solving the problems: #2 holes in the address space

- How do we use the holes left when programs quit?
- We can **map** a program's addresses to RAM addresses however we like



With Virtual Memory

Program Address Maps to RAM Address

Each program has its own mapping.

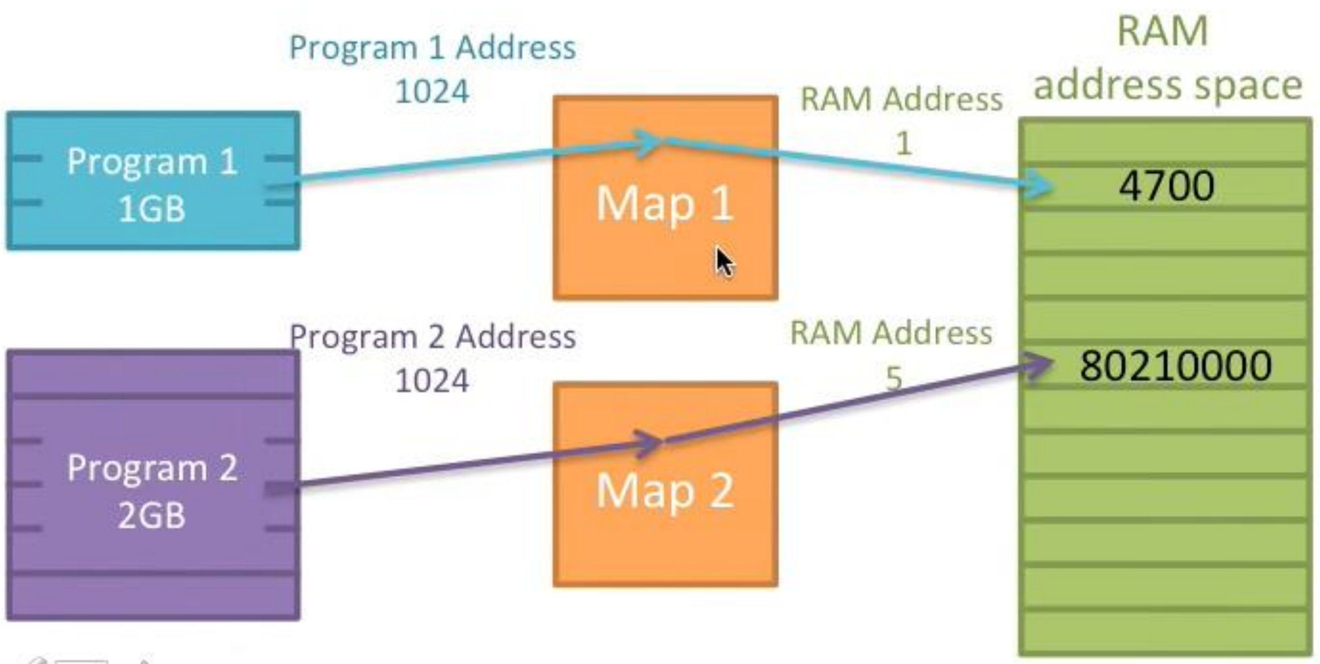
Mappings lets us put our program data wherever we want in the RAM.

Solving the problems: #3 keeping programs secure

- **Program 1's** and **Program 2's** addresses **map to** different **RAM addresses**
- Because each program has its own address space, they cannot access each other's data: security and reliability!

With Virtual Memory

Program Address Maps to RAM Address

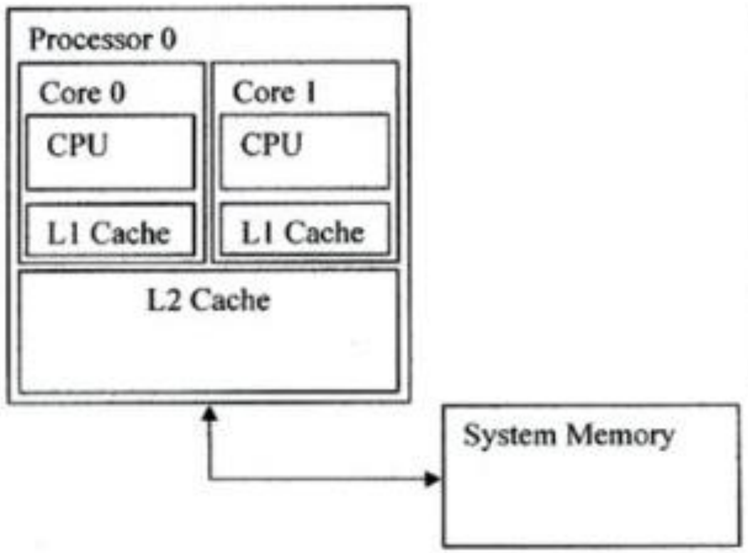


1. **Program 1** stores your bank balance at address 1024
1B. **VM maps** it to **RAM address 1**

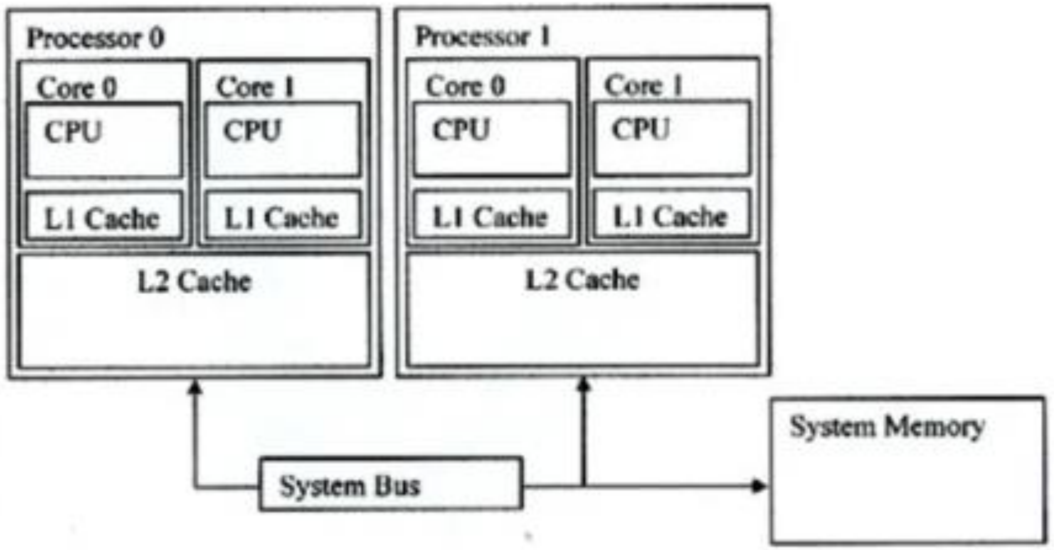
2. **Program 2** stores your video game score at address 1204
2B. **VM maps** it to **RAM address 5**

3. Neither can touch the other's data!

Multicore and Multiprocessor processor

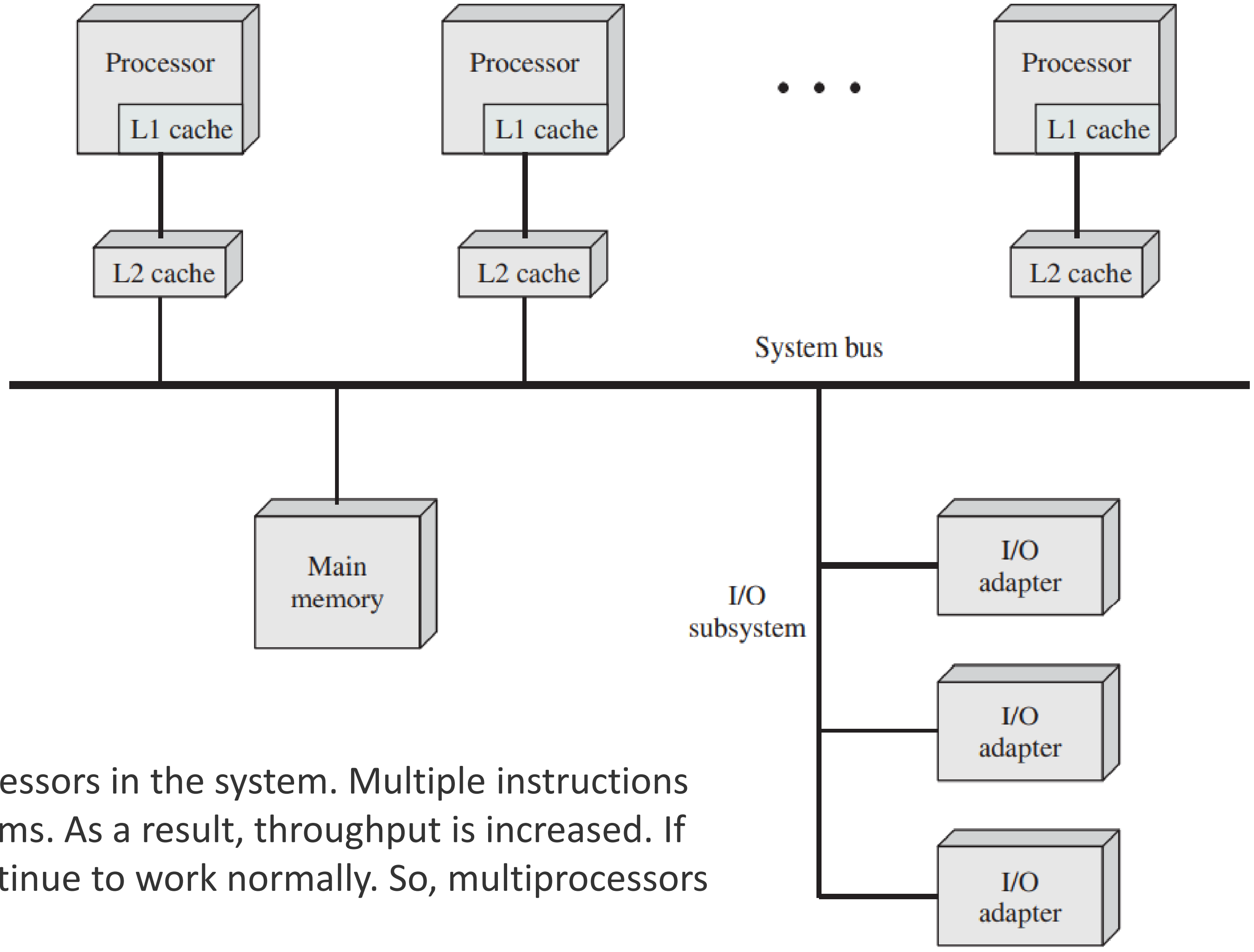


Multi-Core Processor with Shared L2 Cache



Multi-Processor System with Cores that share L2 Cache

Symmetric Multiprocessor Organization



A multiprocessor has multiple CPUs or processors in the system. Multiple instructions are executed simultaneously by these systems. As a result, throughput is increased. If one CPU fails, the other processors will continue to work normally. So, multiprocessors are more reliable.

Symmetric Multiprocessor Organization

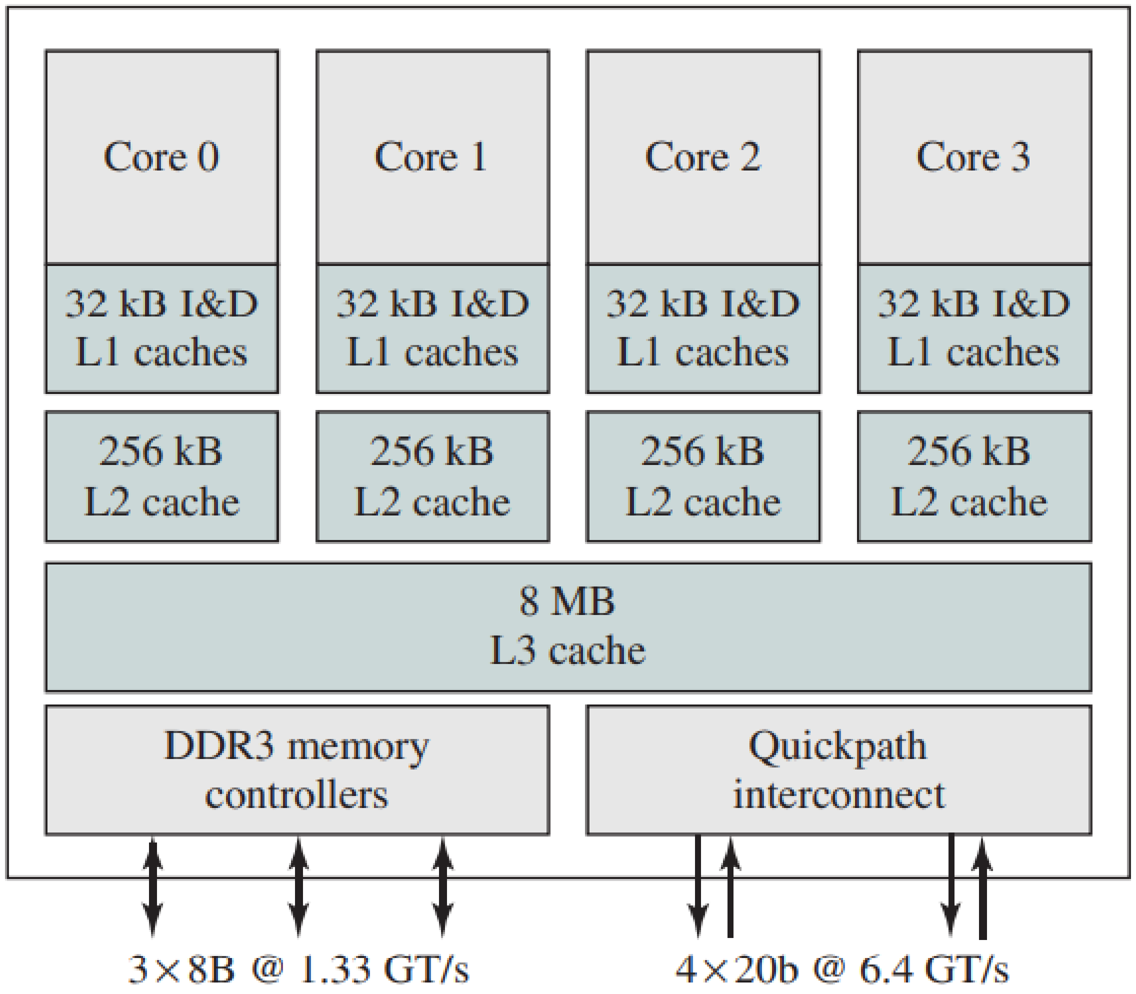
There are various advantages and disadvantages of the multiprocessor system

Advantages	Disadvantages
It is a very reliable system because multiple processors may share their work between the systems, and the work is completed with collaboration.	Multiprocessors work with different systems, so processors require memory space.
It requires complex configuration.	If one of the processors fails, the work is shared among the remaining processors.
Parallel processing is achieved via multiprocessing.	These types of systems are very expensive.
If multiple processors work at the same time, the throughput may increase.	If any processor is already utilizing an I/O device, additional processors may not utilize the same I/O device that creates deadlock.
Multiple processors execute the multiple processes a few times.	The operating system implementation is complicated because multiple processors communicate with each other.

COMPUTER SYSTEM OVERVIEW

MultiCore Processor

A processor that has more than one core is called Multicore Processor while one with single core is called Unicore Processor or Uniprocessor. Nowadays, most of systems have four cores (Quad-core) or eight cores (Octa-core).



Intel Core i7 Block Diagram

Comparison between the Multiprocessors and Multicore Systems

Features	Multiprocessors	Multicore
Definition	It is a system with multiple CPUs that allows processing programs simultaneously.	A multicore processor is a single processor that contains multiple independent processing units known as cores that may read and execute program instructions.
Execution	Multiprocessors run multiple programs faster than a multicore system.	The multicore executes a single program faster.
Reliability	It is more reliable than the multicore system. If one of any processors fails in the system, the other processors will not be affected.	It is not much reliable than the multiprocessors.
Traffic	It has high traffic than the multicore system.	It has less traffic than the multiprocessors.
Cost	It is more expensive as compared to a multicore system.	These are cheaper than the multiprocessors system.
Configuration	It requires complex configuration.	It doesn't need to be configured.