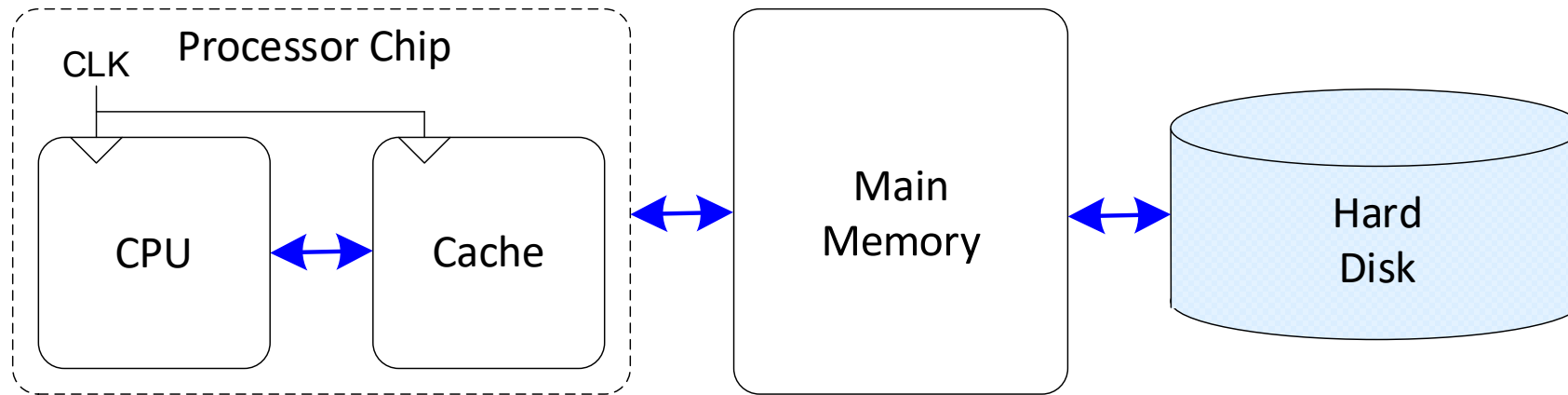


## Chapter 7: Microarchitecture

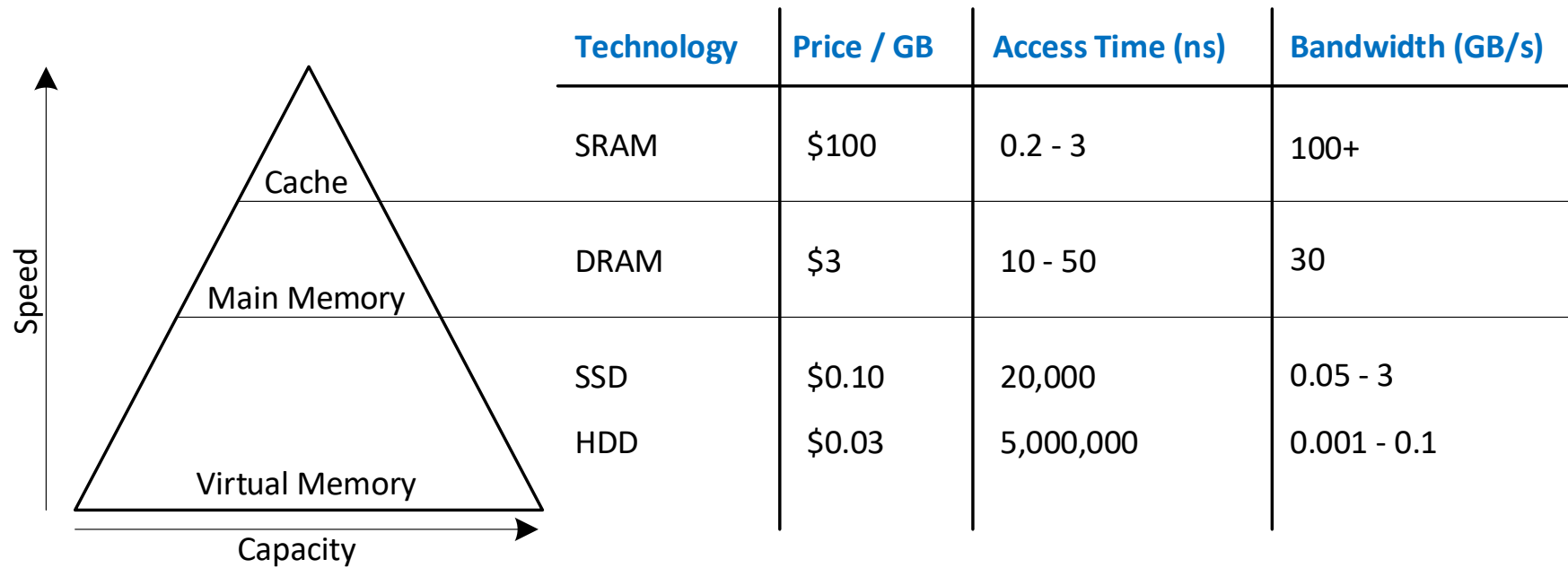
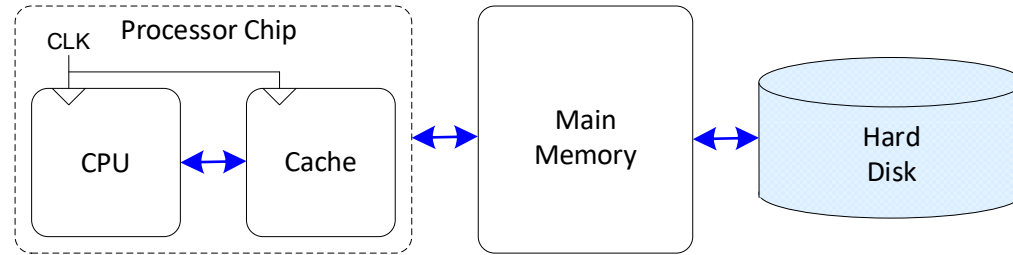
# Virtual Memory

# Virtual Memory

- Gives the illusion of bigger memory
- Main memory (DRAM) acts as cache for hard disk



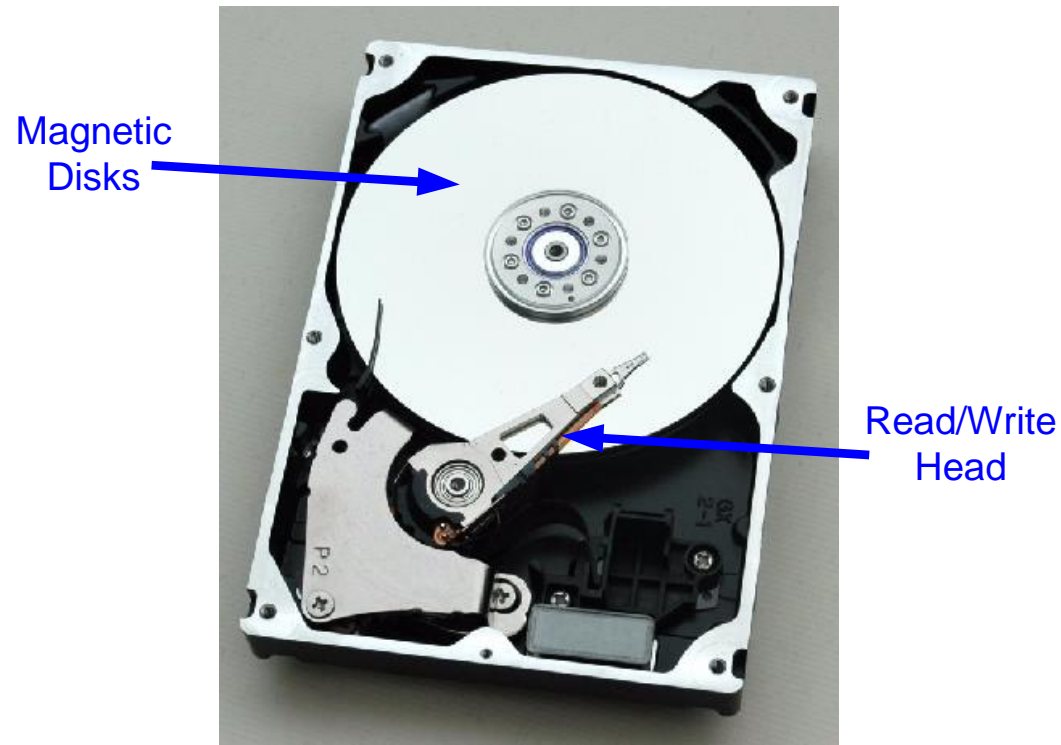
# Memory Hierarchy



- **Physical Memory:** DRAM (Main Memory)
- **Virtual Memory:** Hard drive
  - Slow, Large, Cheap

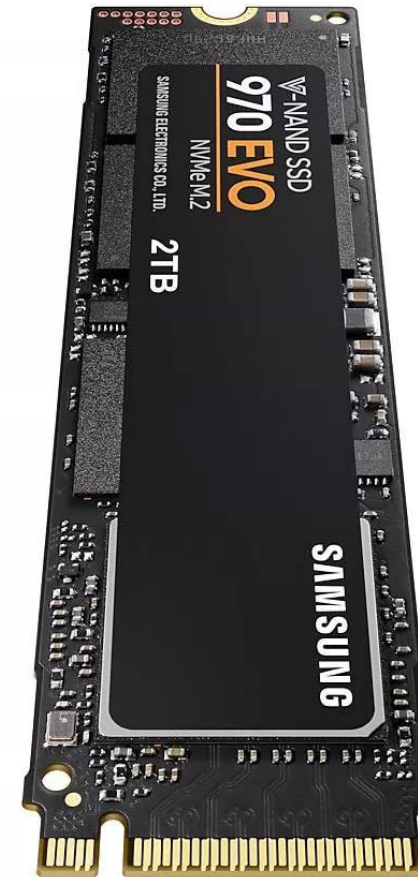
# Memory Hierarchy

## Hard Disk Drive



Takes milliseconds to *seek* correct location on disk

## Solid State Drive



*Arshane88 / CC BY-SA 4.0 / Wikimedia Commons*

# Virtual Memory

- **Virtual addresses**
  - Programs use virtual addresses
  - Entire virtual address space stored on a hard drive
  - Subset of virtual address data in DRAM
  - CPU translates virtual addresses into *physical addresses* (DRAM addresses)
  - Data not in DRAM fetched from hard drive

# Virtual Memory

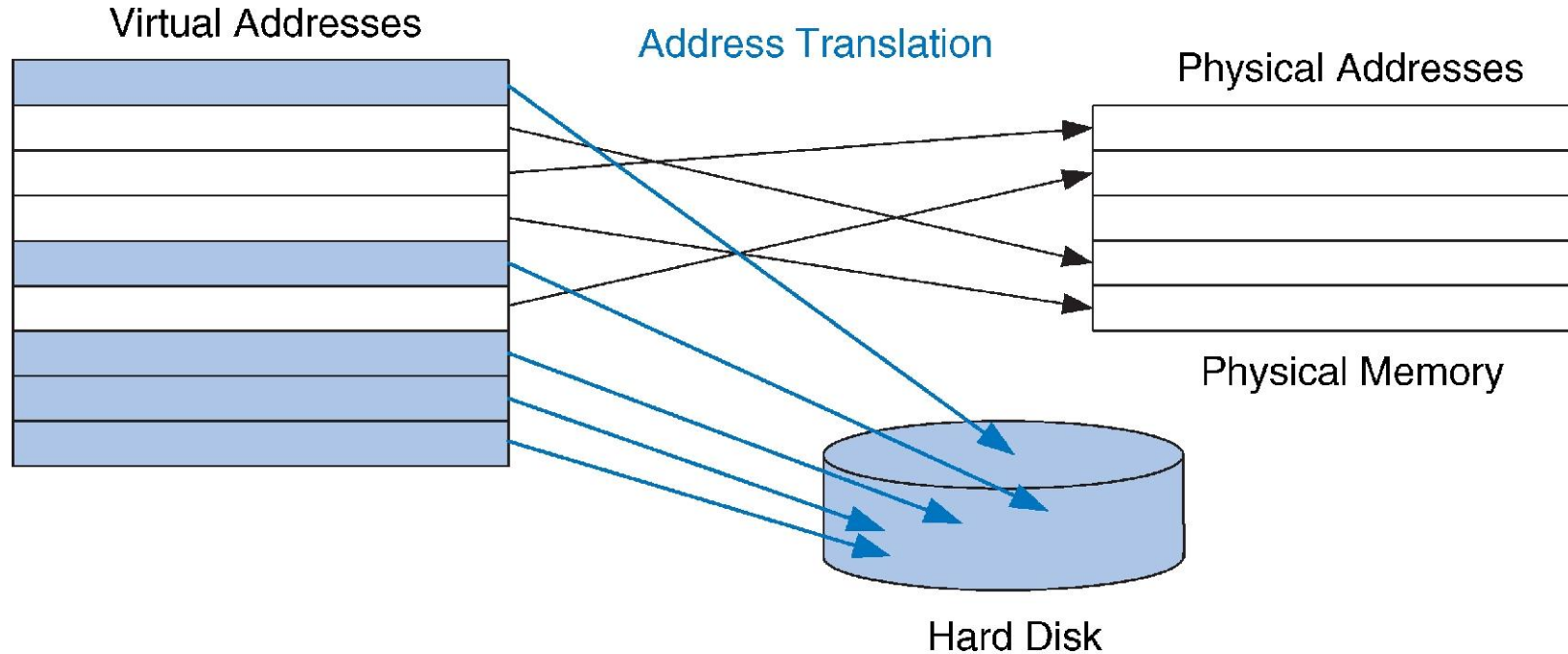
Cache	Virtual Memory
Block	Page
Block Size	Page Size
Block Offset	Page Offset
Miss	Page Fault
Tag	Virtual Page Number

Physical memory acts as cache for virtual memory

# Virtual Memory Definitions

- **Page size:** amount of memory transferred from hard disk to DRAM at once
- **Address translation:** determining physical address from virtual address
- **Page table:** lookup table used to translate virtual addresses to physical addresses
  - It also indicates that there is a page fault.
  - Note that the physical address acts as a fully associative cache to the hard disk.
  - The table is basically substituting Tags and comparators.

# Virtual Memory Definitions



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Most accesses **hit** in physical memory

But programs have the **large capacity** of virtual memory



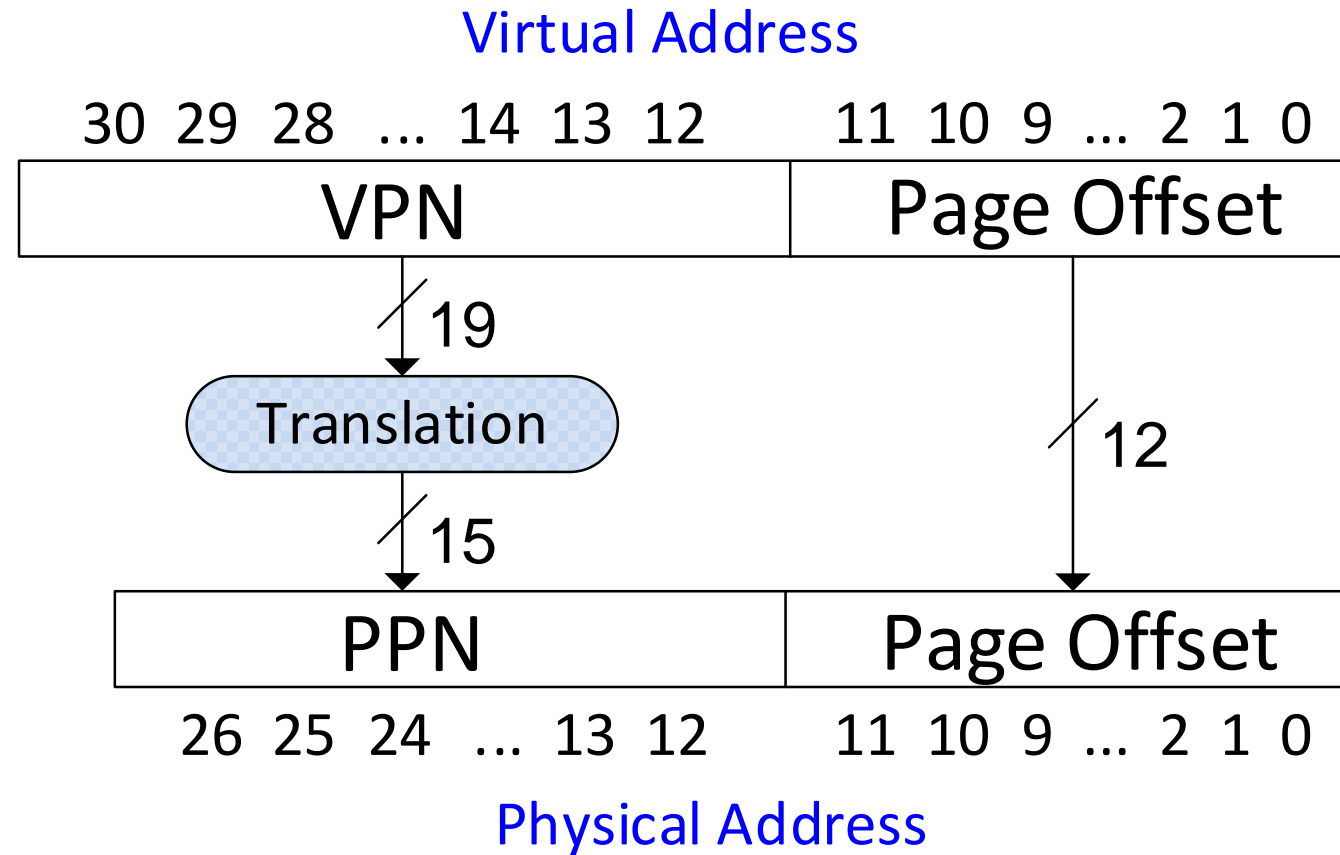
## Chapter 7: Microarchitecture

# Address Translation

# Virtual Memory Example

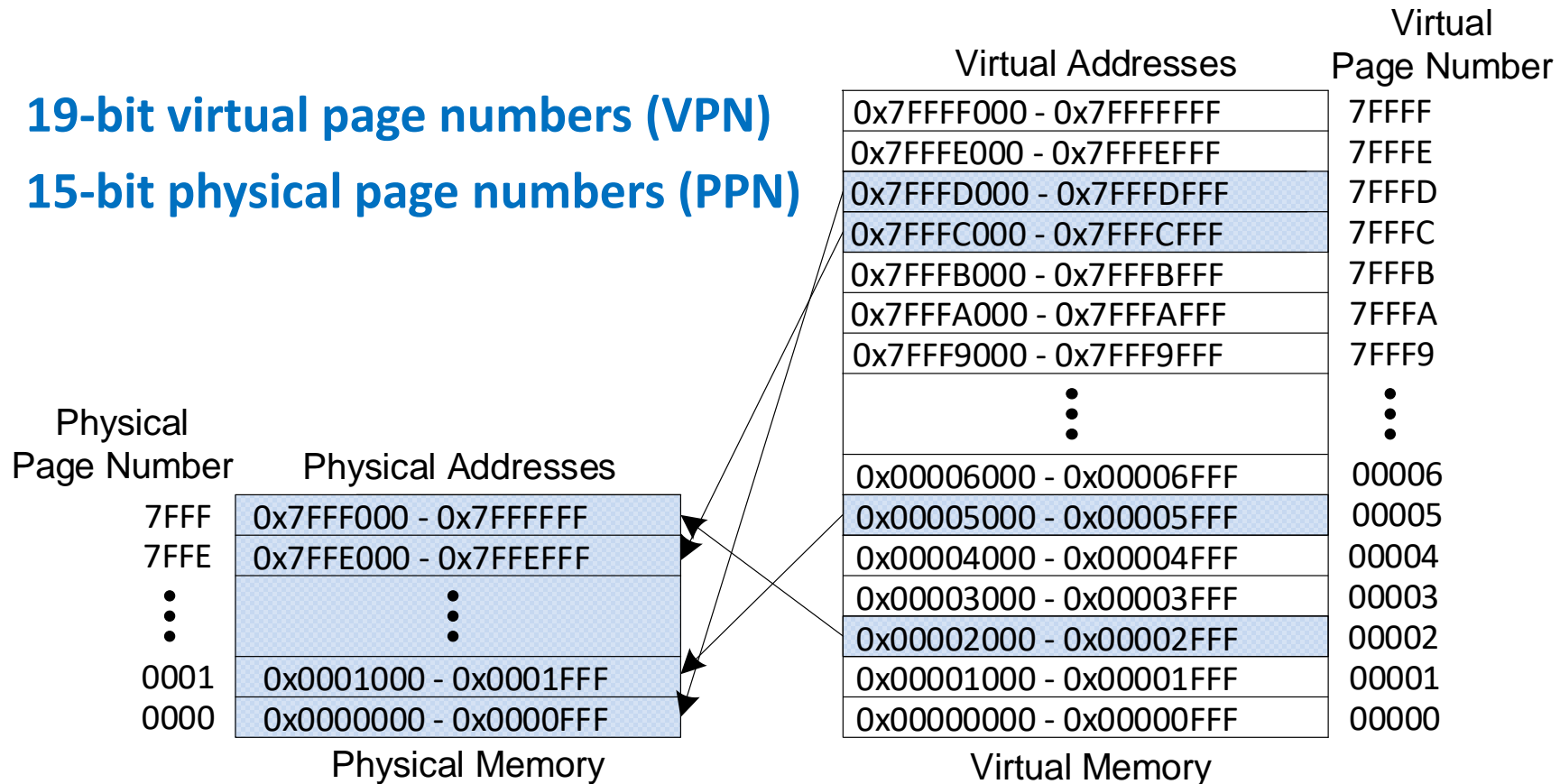
- **System:**
  - Virtual memory size: 2 GB =  $2^{31}$  bytes
  - Physical memory size: 128 MB =  $2^{27}$  bytes
  - Page size: 4 KB =  $2^{12}$  bytes

# Address Translation



# Virtual Memory Example

- 19-bit virtual page numbers (VPN)
- 15-bit physical page numbers (PPN)



# Virtual Memory Example

What is the physical address of virtual address **0x247C**?

