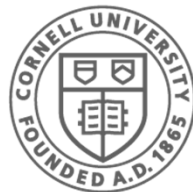


Virtual Memory

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Computer Science
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Cornell CIS
COMPUTING AND INFORMATION SCIENCE

[Weatherspoon, Bala, Bracy, McKee, and Sirer]

Where are we now and where are we going?

- How many programs do you run at once?
 - a) 1
 - b) 2
 - c) 3-5
 - d) 6-10
 - e) 11+

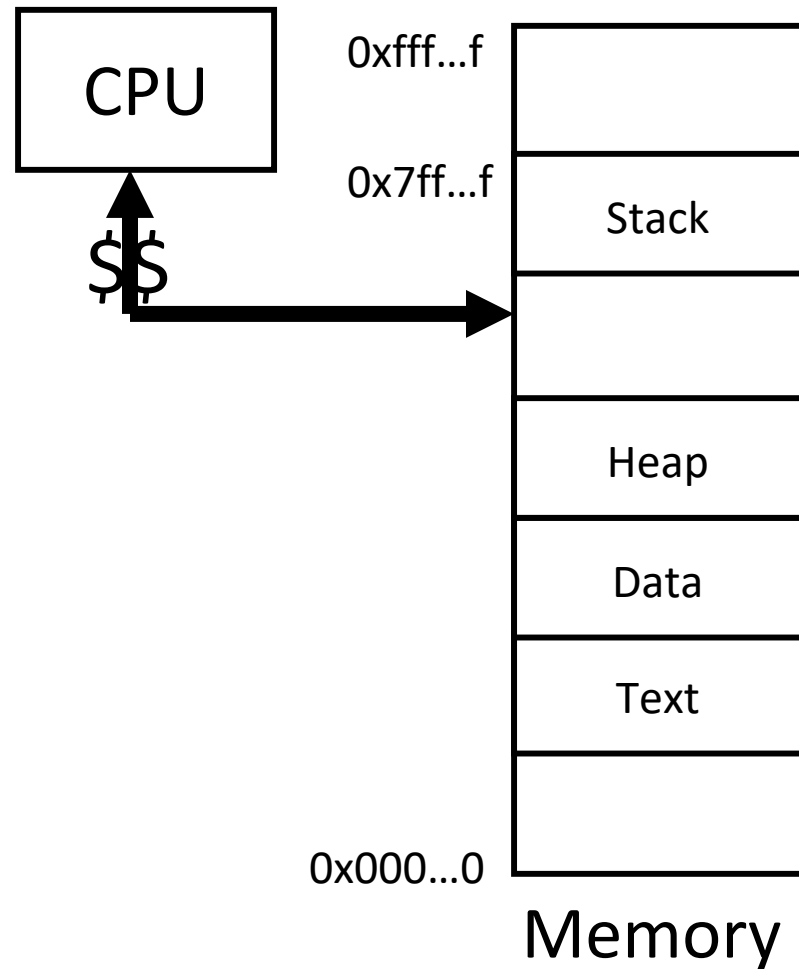
Big Picture: Multiple Processes

How to run multiple processes?

- *Time-multiplex* a single CPU core (multi-tasking)
 - Web browser, skype, office, ... all must co-exist
- Many cores per processor (multi-core)
or many processors (multi-processor)
 - Multiple programs run *simultaneously*

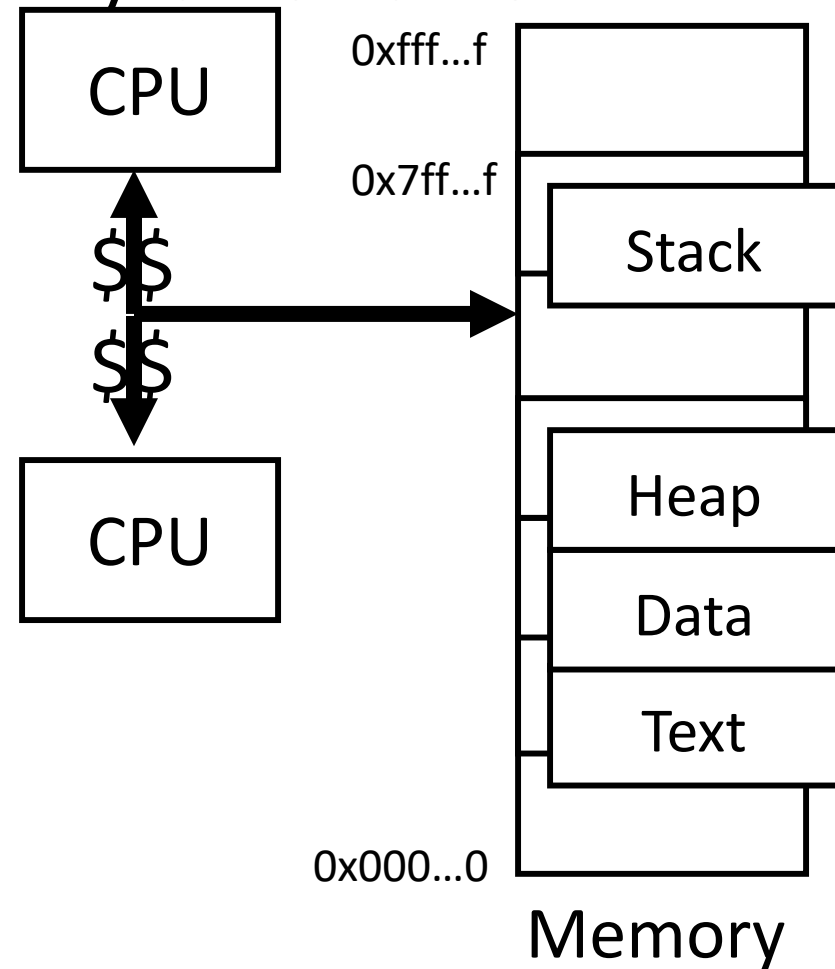
Processor & Memory

- CPU address/data bus...
- ... routed through caches
- ... to main memory
 - Simple, fast, but...



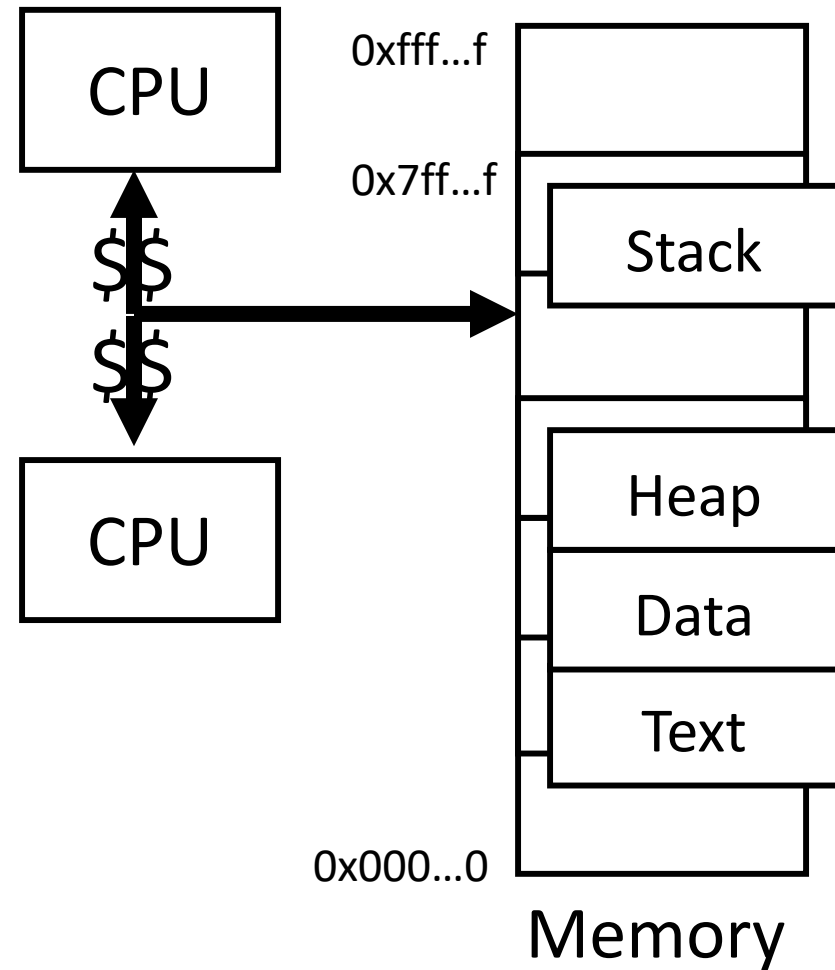
Multiple Processes

- Q: What happens when another program is executed concurrently on another processor?

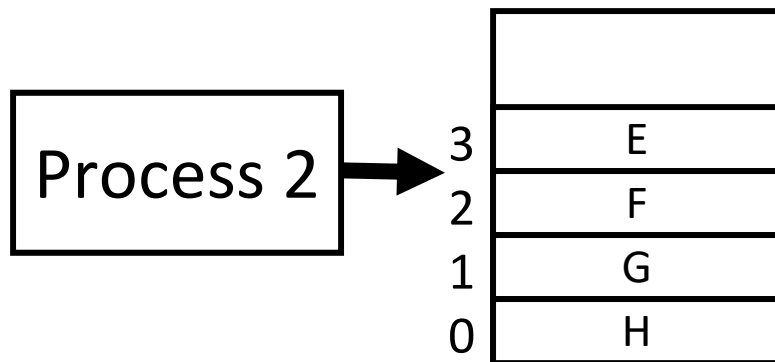
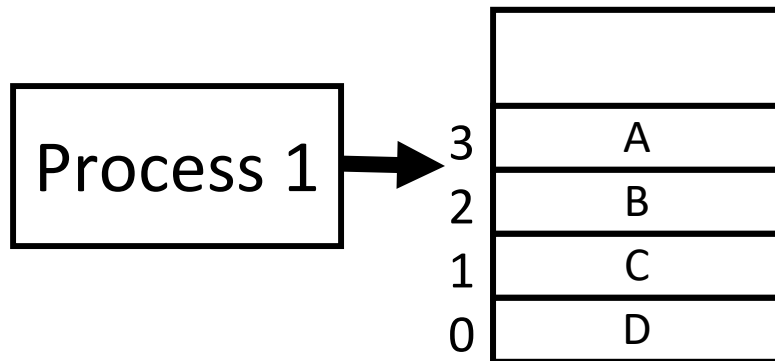


Multiple Processes

- Q: Can we relocate second program?

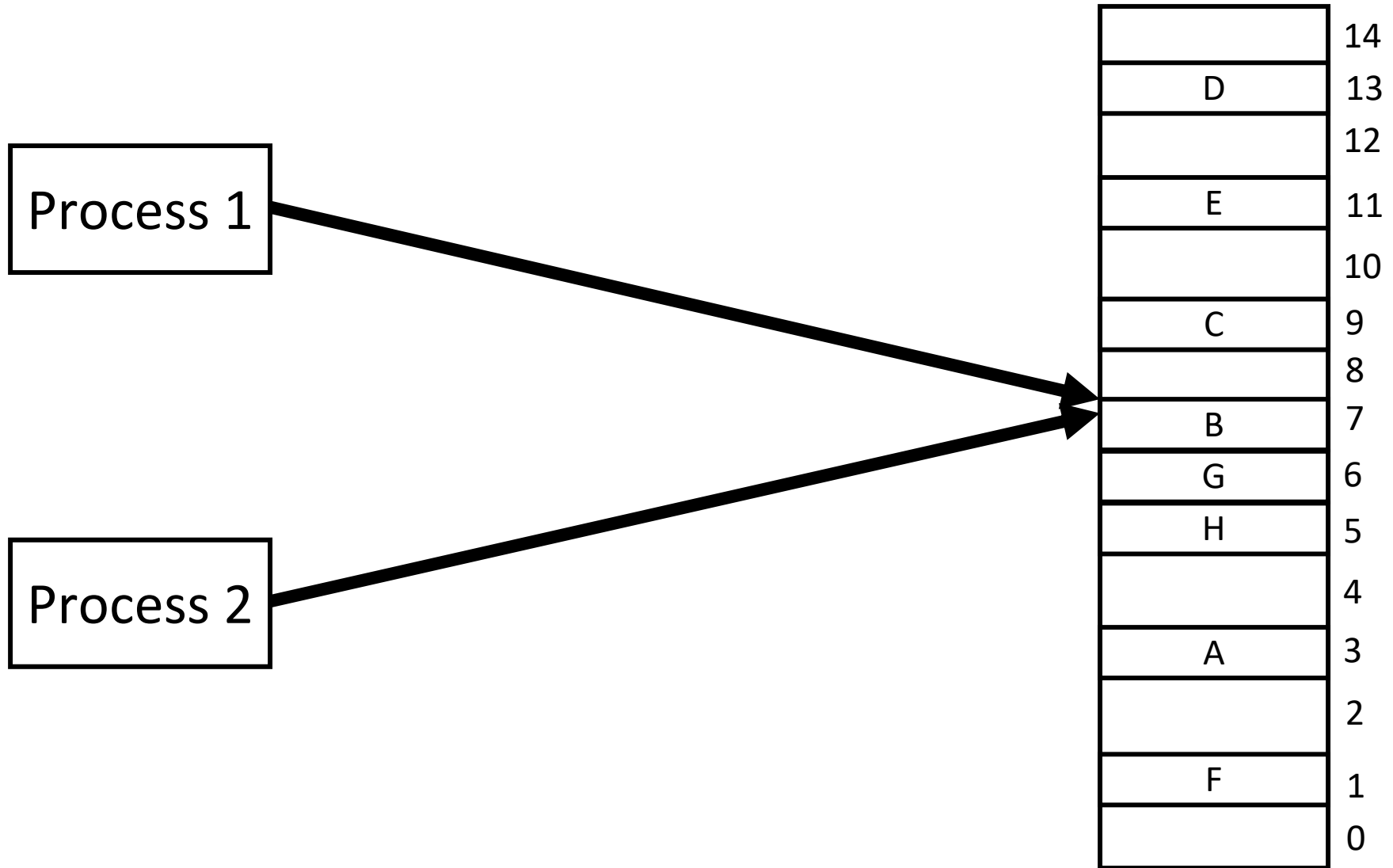


Big Picture: (Virtual) Memory



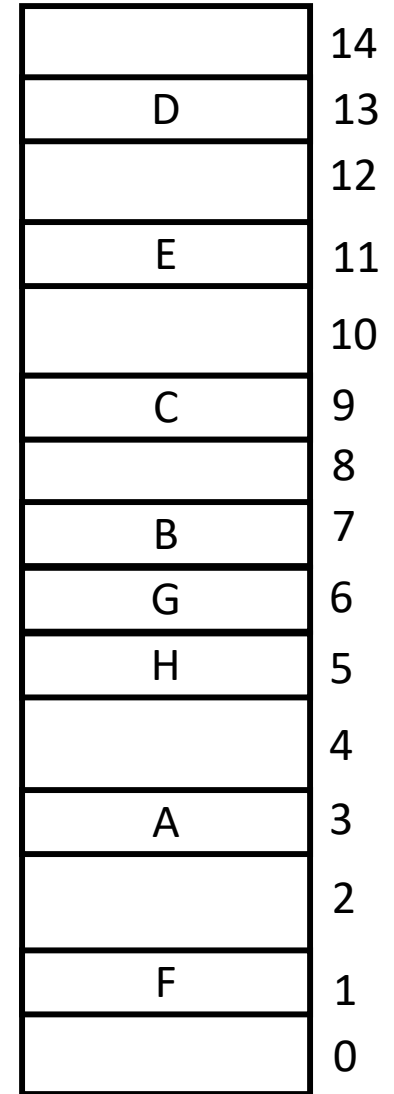
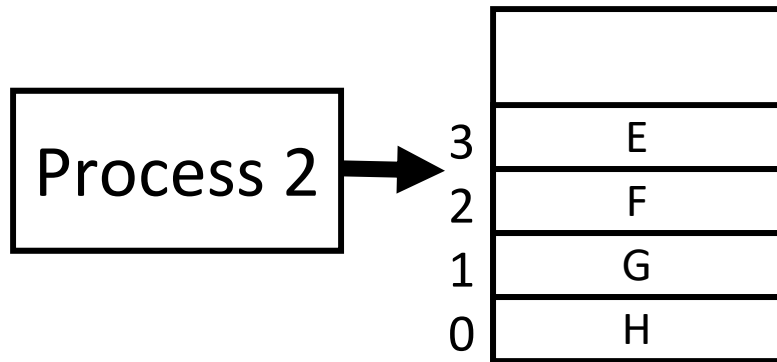
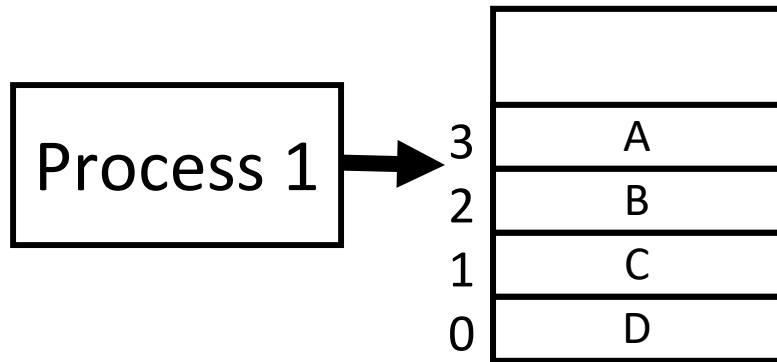
Give each process an illusion that it has exclusive access to entire main memory

But In Reality...



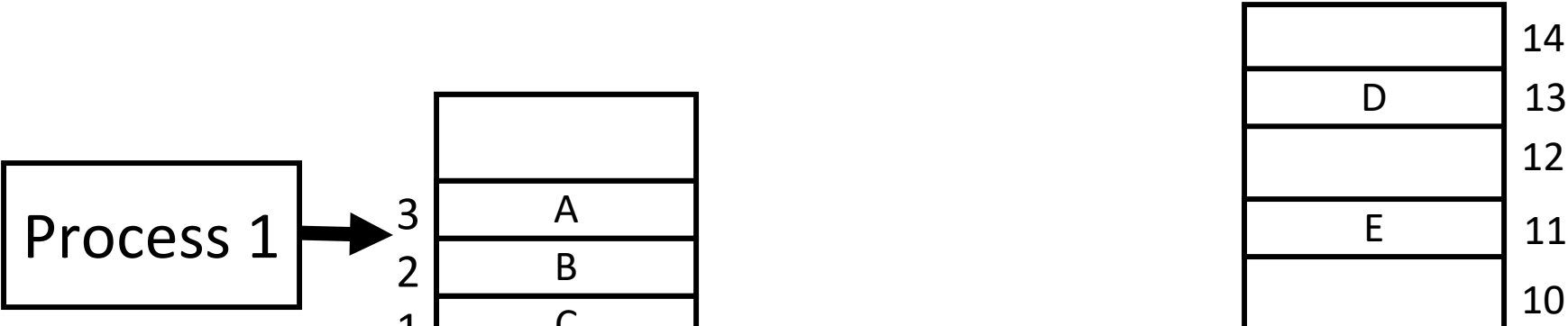
Physical Memory

How do we create the illusion?



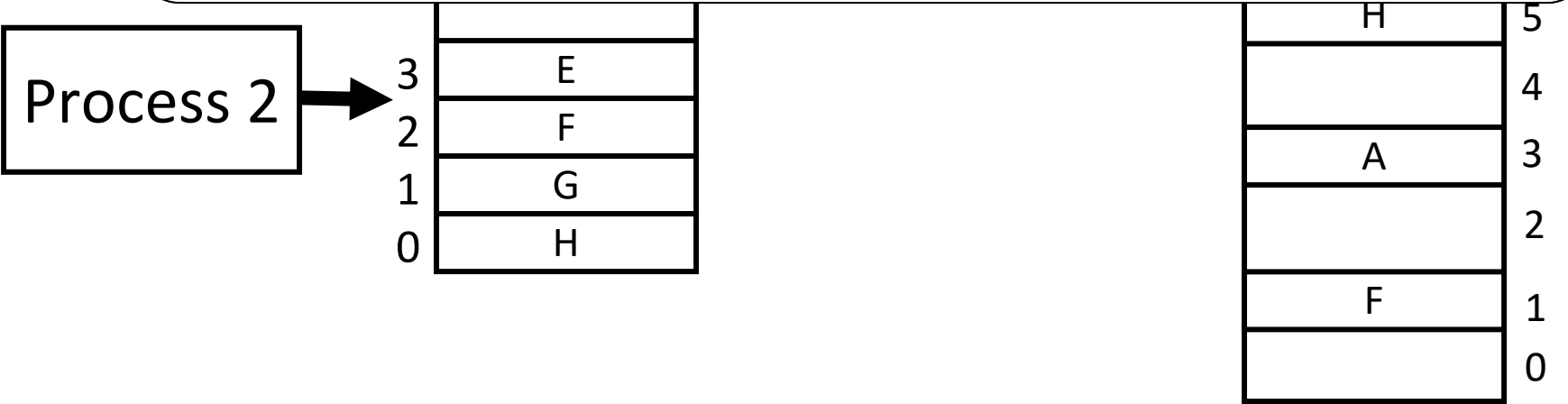
Physical Memory

How do we create the illusion?



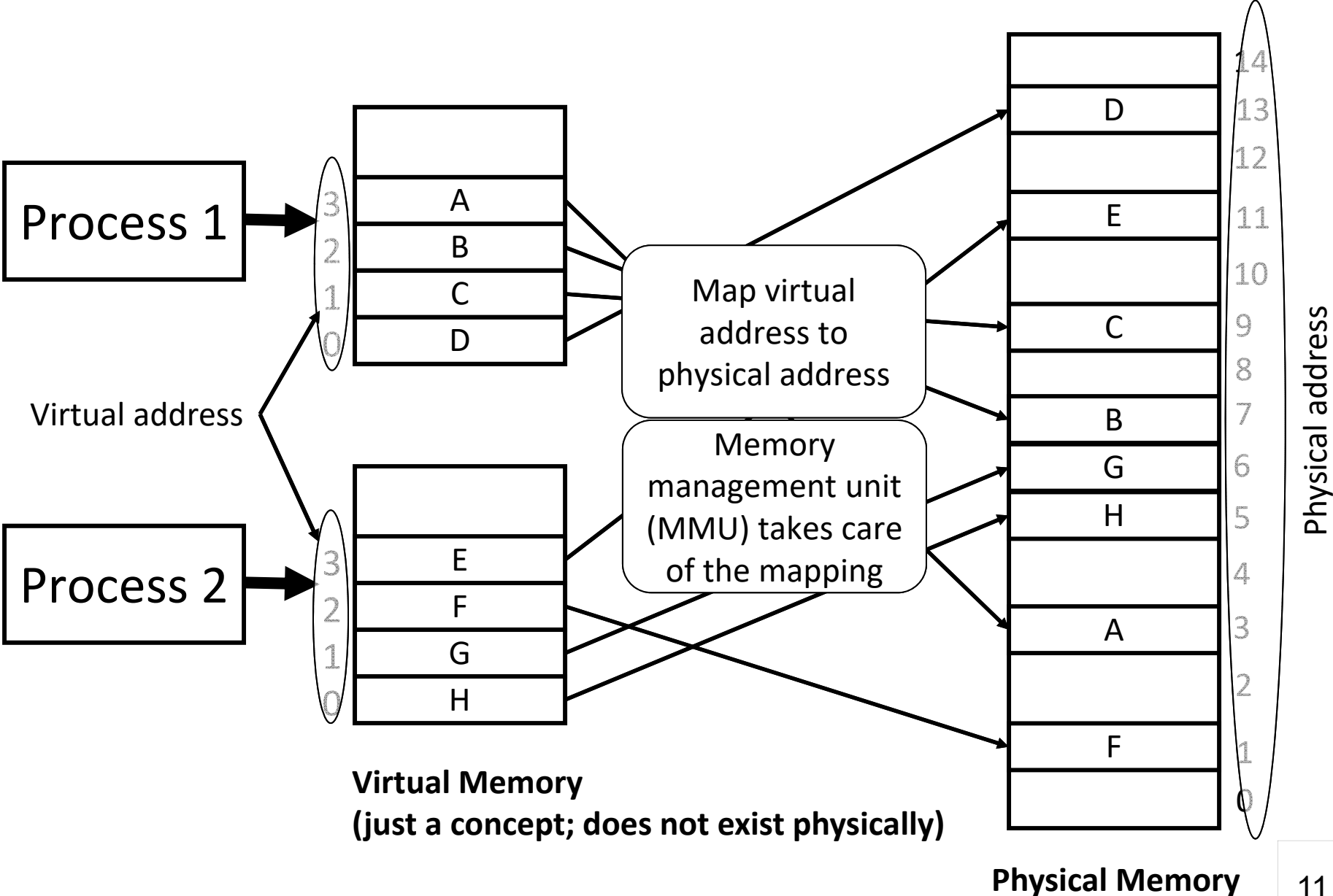
All problems in computer science can be solved by another level of indirection.

– David Wheeler

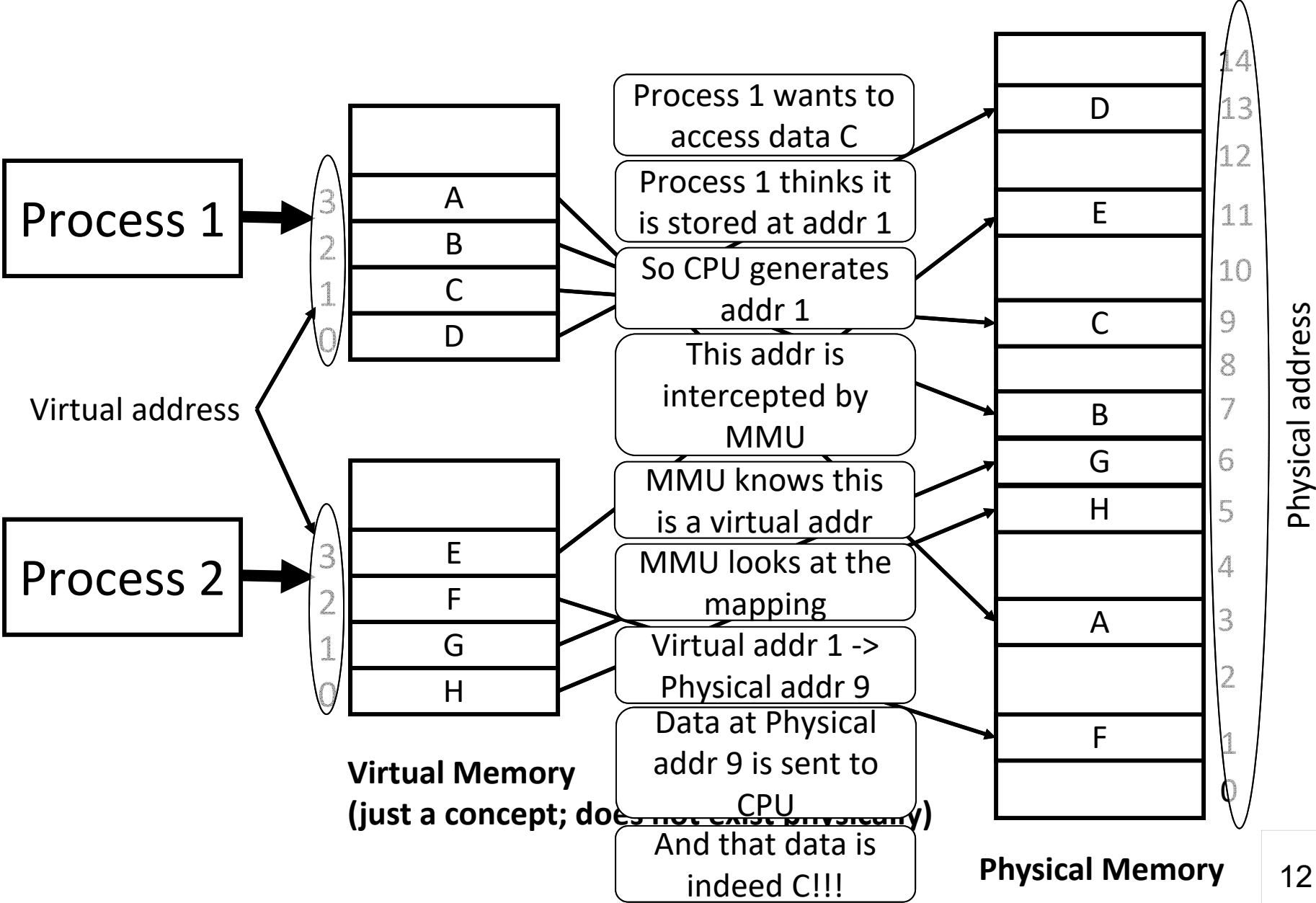


Physical Memory

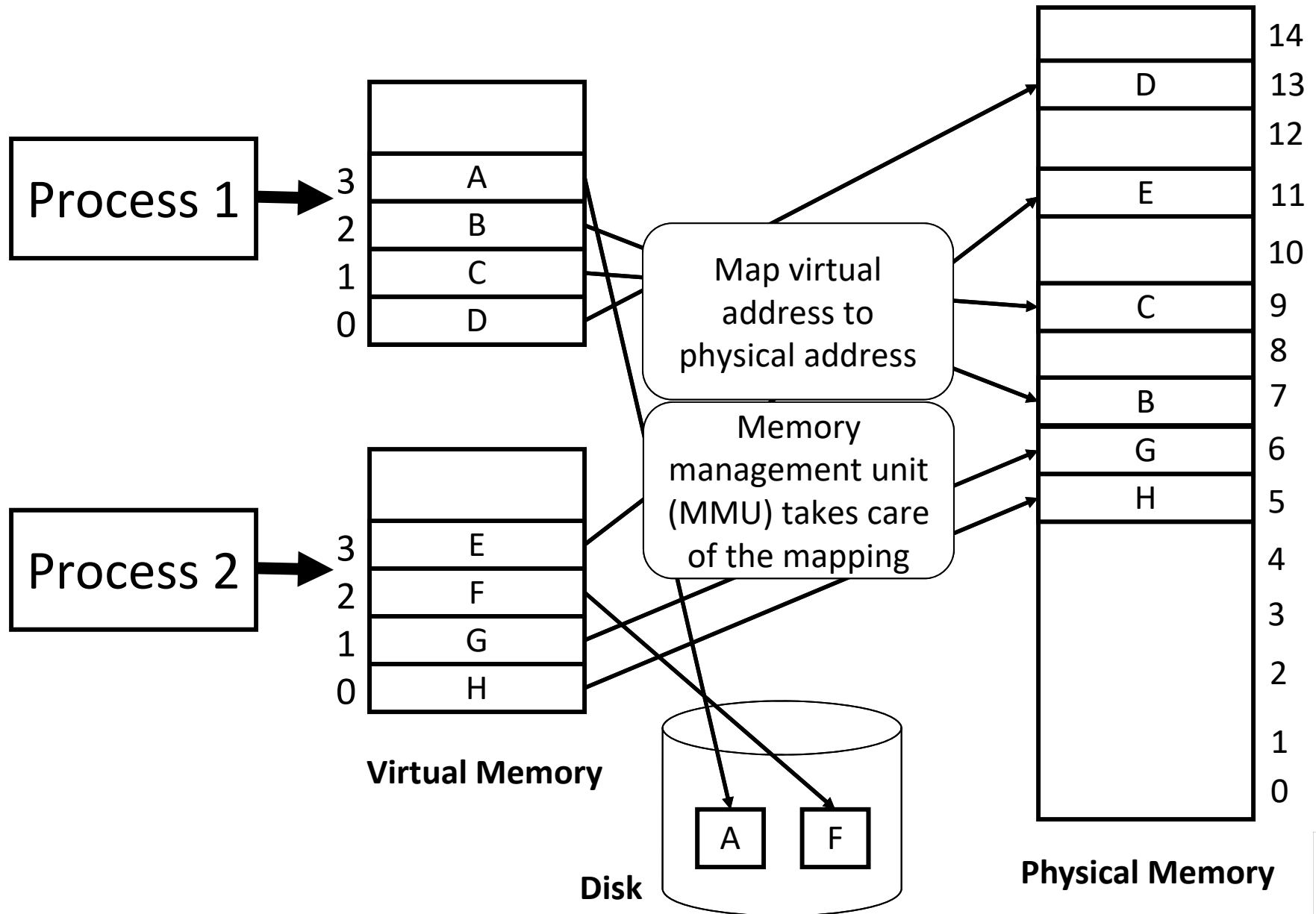
How do we create the illusion?



How do we create the illusion?

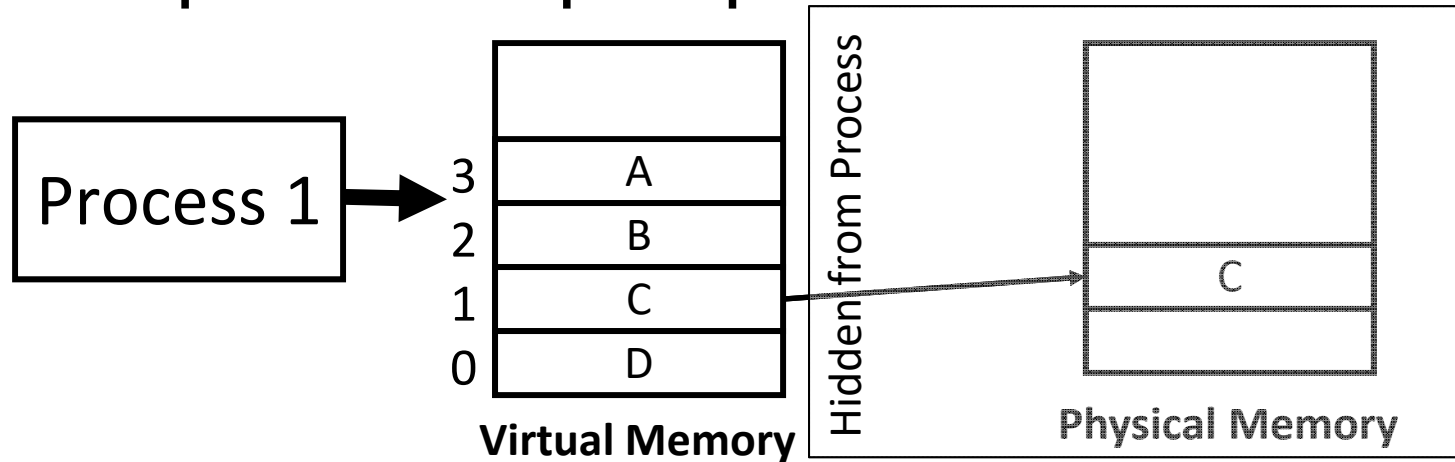


How do we create the illusion?



Big Picture: (Virtual) Memory

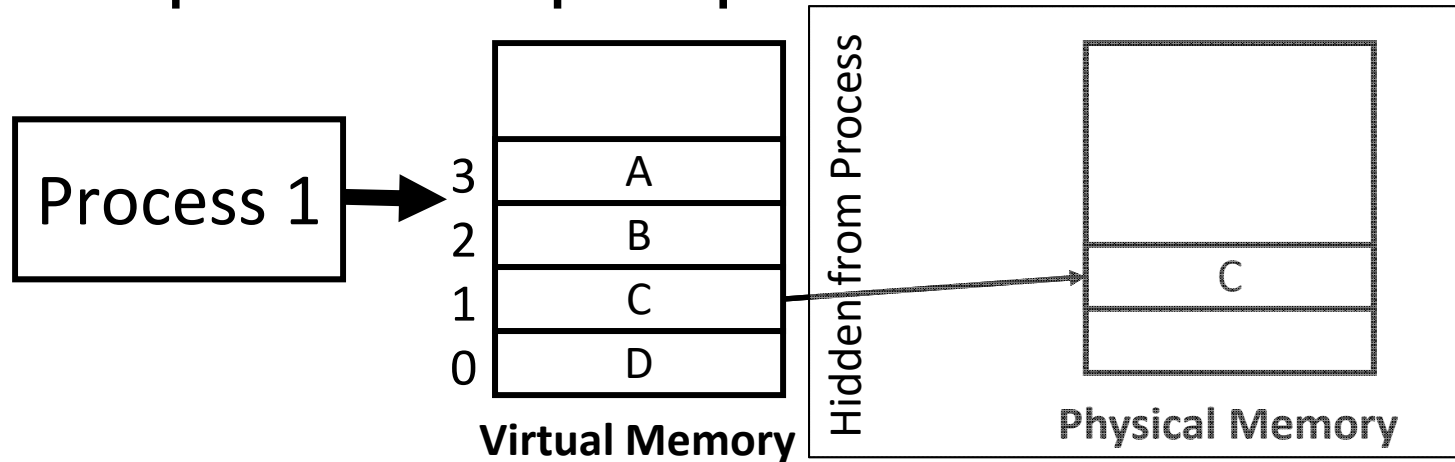
- From a process's perspective –



- Process only sees the virtual memory
 - ✓ Contiguous memory

Big Picture: (Virtual) Memory

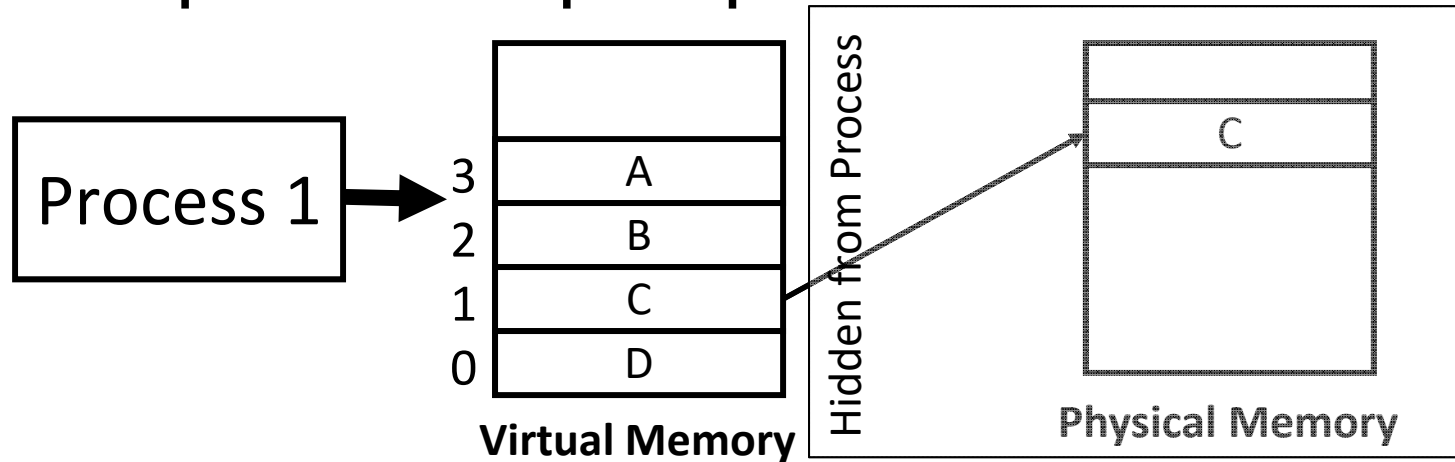
- From a process's perspective –



- Process only sees the virtual memory
 - ✓ Contiguous memory
 - ✓ No need to recompile - only mappings need to be updated

Big Picture: (Virtual) Memory

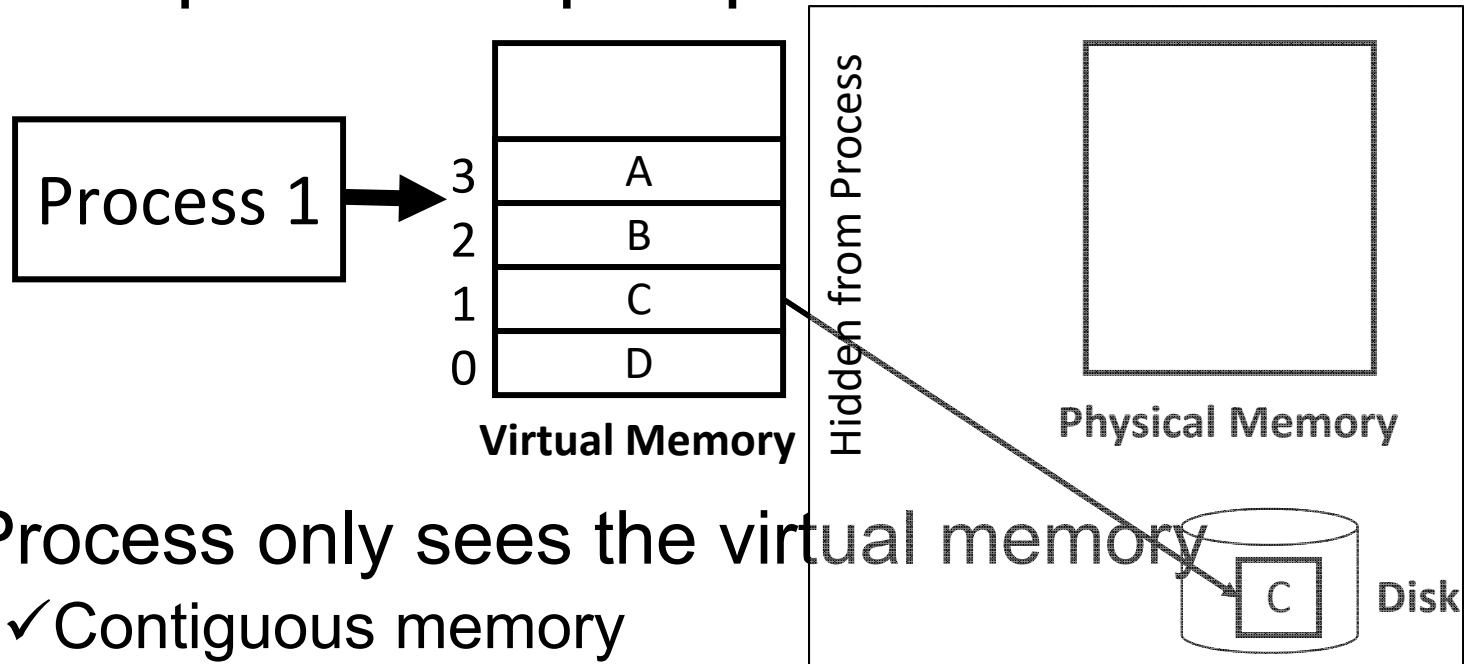
- From a process's perspective –



- Process only sees the virtual memory
 - ✓ Contiguous memory
 - ✓ No need to recompile - only mappings need to be updated

Big Picture: (Virtual) Memory

- From a process's perspective –



- Process only sees the virtual memory
 - ✓ Contiguous memory
 - ✓ No need to recompile - only mappings need to be updated
 - ✓ When run out of memory, MMU maps data on disk in a transparent manner

Next Goal

- How does Virtual Memory work?
- i.e. How do we create the “map” that maps a virtual address generated by the CPU to a physical address used by main memory?



Next Goal (after spring break!)

- How does Virtual Memory work?
- i.e. How do we create the “map” that maps a virtual address generated by the CPU to a physical address used by main memory?



Virtual Memory Agenda

What is Virtual Memory?

How does Virtual memory Work?

- Address Translation
- Overhead
- Paging
- Performance

