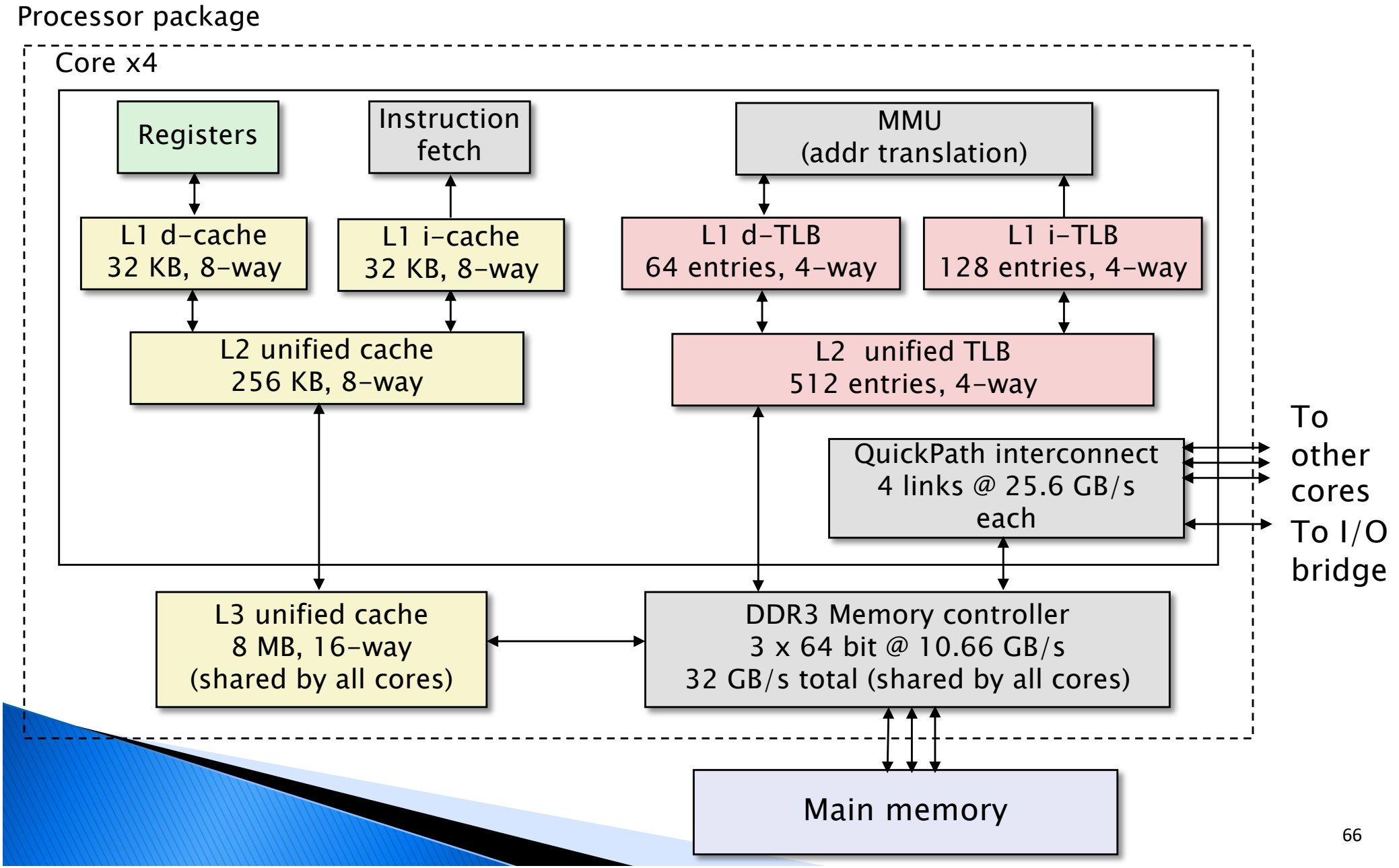
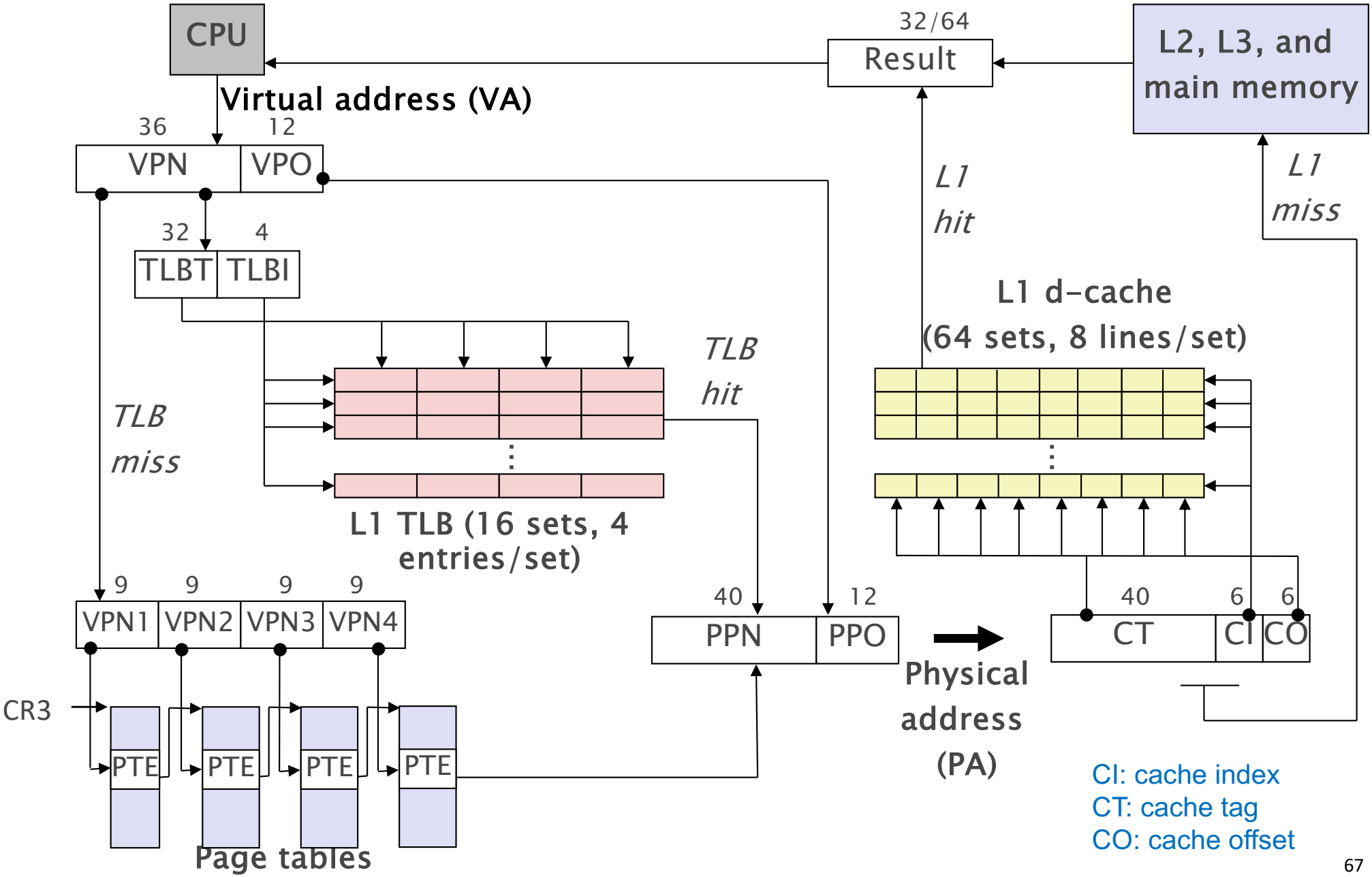
Rest of Chapter 9 slides

- Case study:
  - Core i7/Linux memory system (on your own)

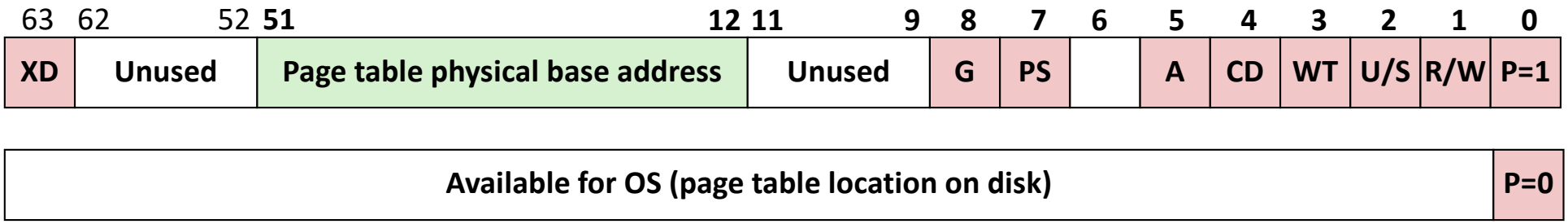
Intel Core i7 Memory System



End-to-end Core i7 Address Translation (fig. 9.22)



Core i7 Level 1-3 Page Table Entries



Each entry references a 4K child page table. Significant fields:

P: Child page table present in physical memory (1) or not (0).

R/W: Read-only or read-write access access permission for all reachable pages.

U/S: user or supervisor (kernel) mode access permission for all reachable pages.

WT: Write-through or write-back cache policy for the child page table.

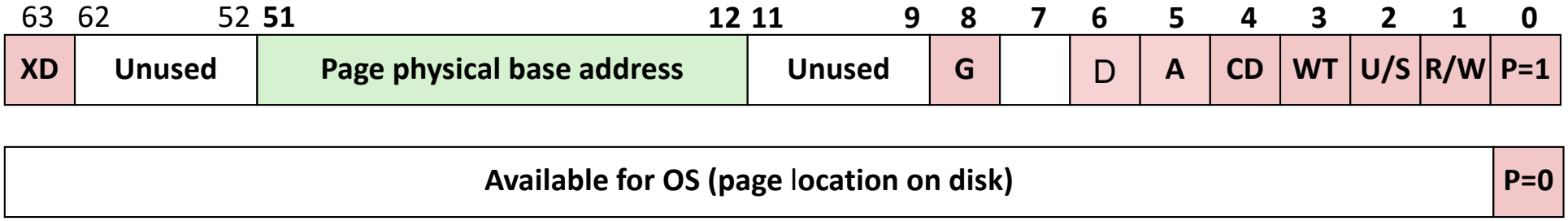
A: Reference bit (set by MMU on reads and writes, cleared by software) (accessed)

PS: Page size either 4 KB or 4 MB (defined for Level 1 PTEs only).

Page table physical base address: 40 most significant bits of physical page table address (forces page tables to be 4KB aligned)

XD: Disable or enable instruction fetches from all pages reachable from this PTE.

Core i7 Level 4 Page Table Entries



Each entry references a 4K child page. Significant fields:

P: Child page is present in memory (1) or not (0)

R/W: Read-only or read-write access permission for child page

U/S: User or supervisor mode access

WT: Write-through or write-back cache policy for this page

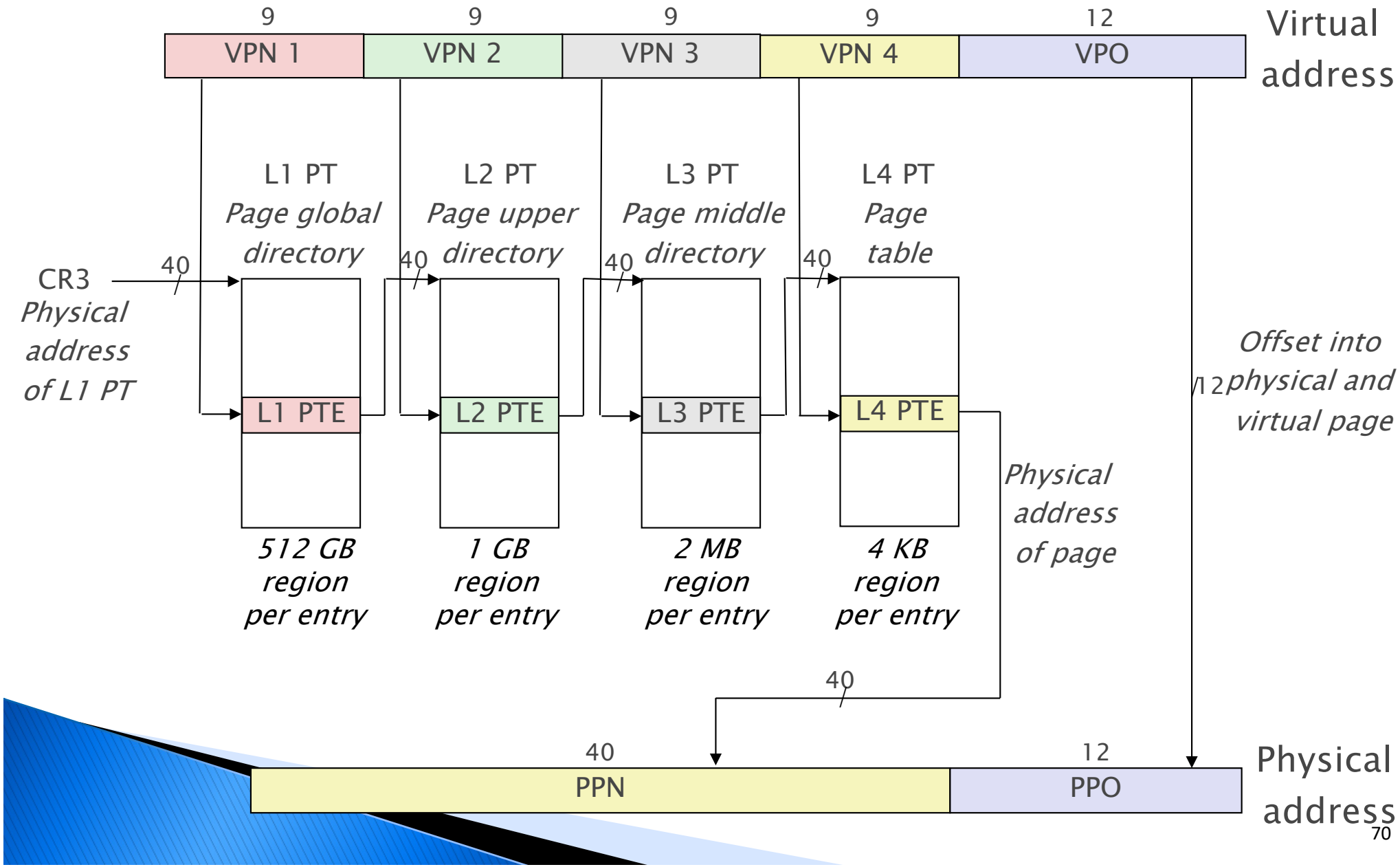
A: Reference bit (set by MMU on reads and writes, cleared by software)

D: Dirty bit (set by MMU on writes, cleared by software)

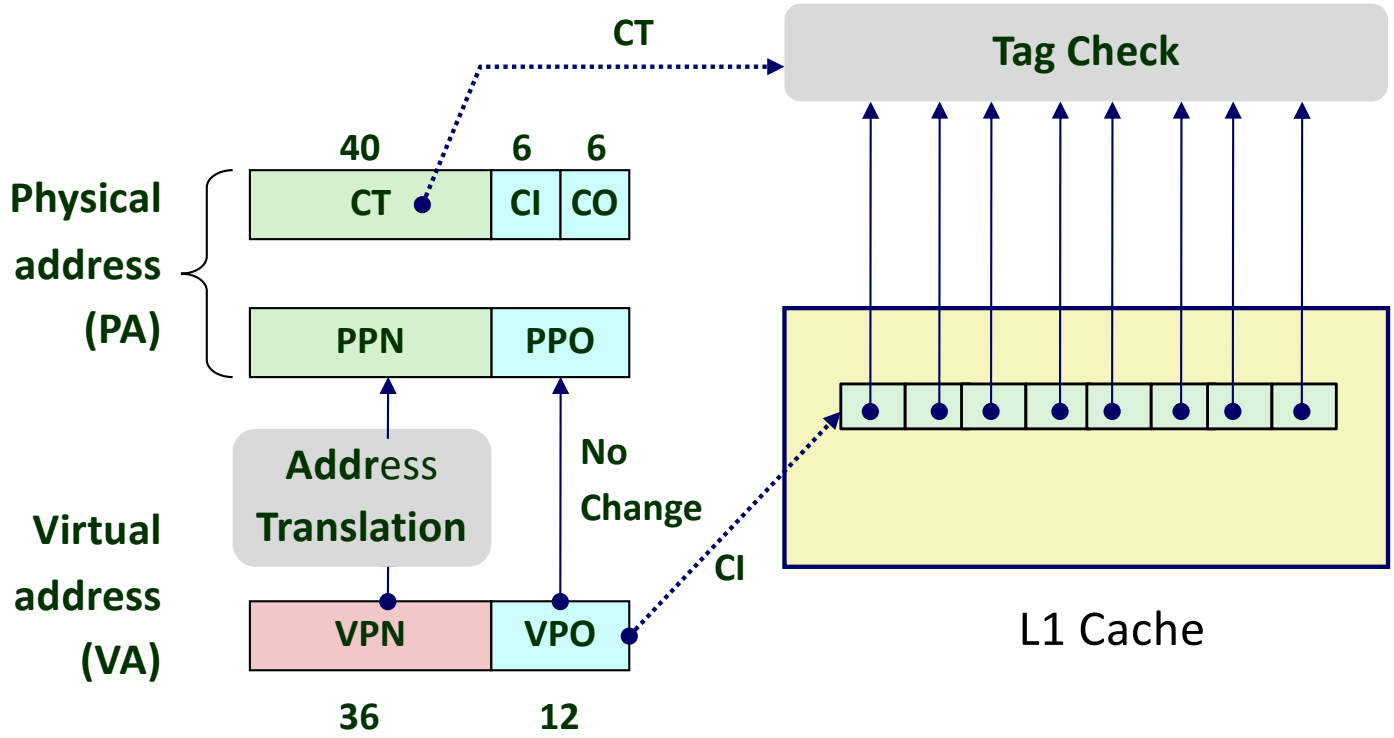
Page physical base address: 40 most significant bits of physical page address (forces pages to be 4KB aligned)

XD: Disable or enable instruction fetches from this page.

Core i7 Page Table Translation

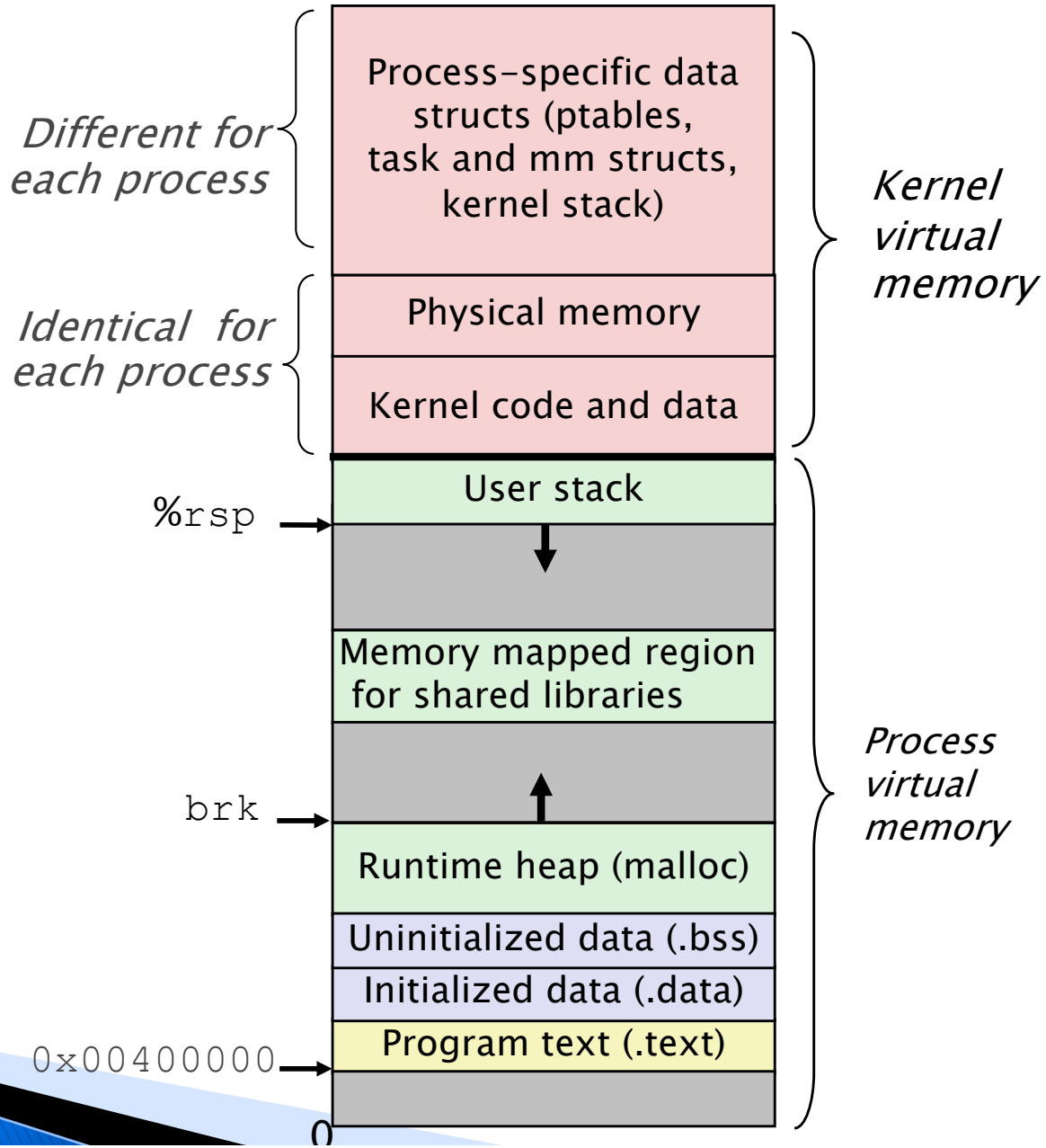


Cute Trick for Speeding Up L1 Access

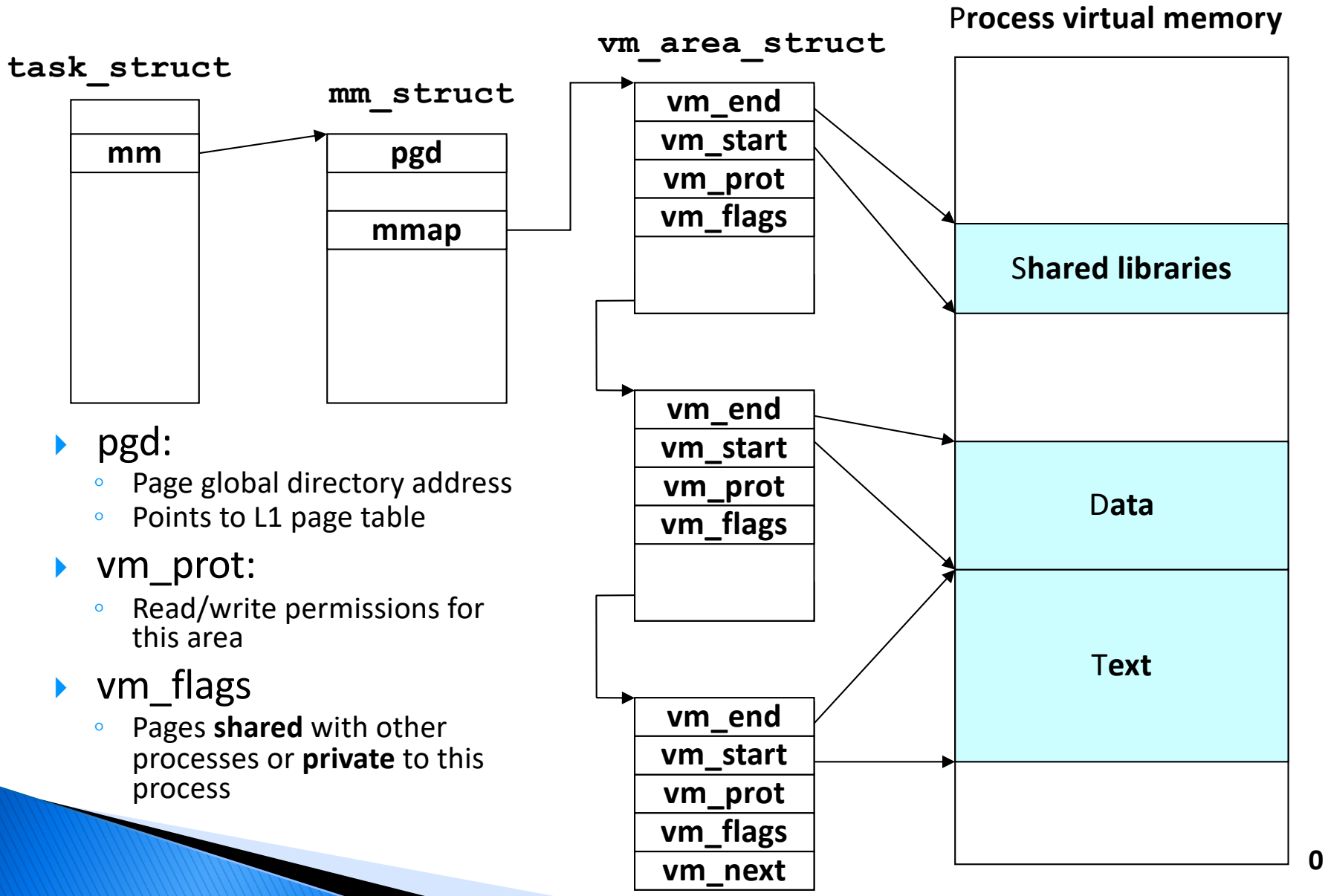


- Observation
  - Bits that determine CI identical in virtual and physical address
  - Can index into cache while address translation taking place
  - Generally we hit in TLB, so PPN bits (CT bits) available next
  - “Virtually indexed, physically tagged”
  - Cache carefully sized to make this possible

Virtual Address Space of a Linux Process

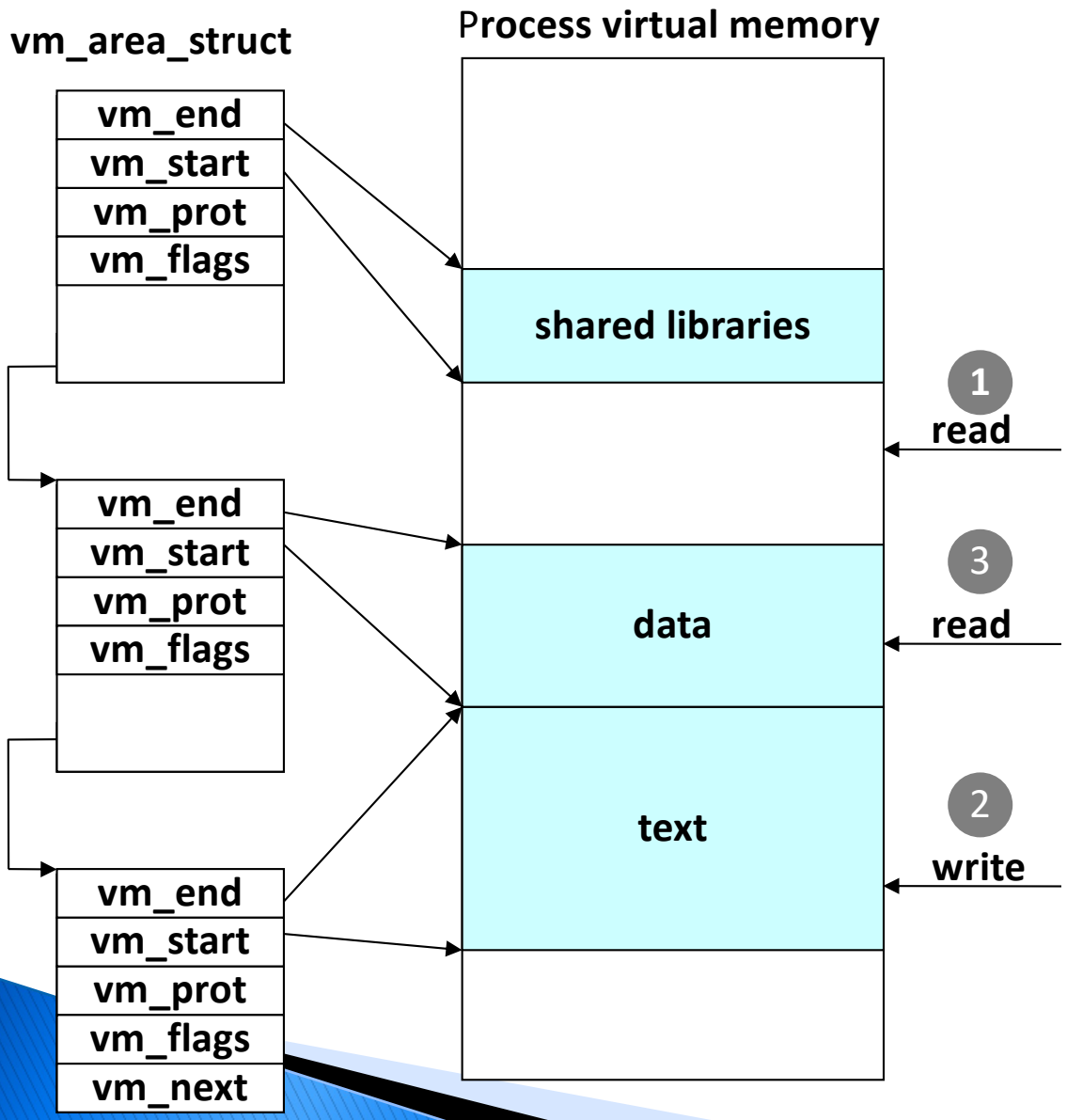


Linux Organizes VM as Collection of "Areas" (p.830)



- pgd:
  - Page global directory address
  - Points to L1 page table
- vm_prot:
  - Read/write permissions for this area
- vm_flags
  - Pages **shared** with other processes or **private** to this process

Linux Page Fault Handling



Segmentation fault:
accessing a non-existing page

Normal page fault (miss)

Protection exception:
e.g., violating permission by writing to a read-only page (Linux reports as Segmentation fault)