

# Announcements

- Reading:
  - Today: Chapter 8.4-8.6 (8<sup>th</sup> Ed)
- Midterm:
  - Thursday

# Managing Memory

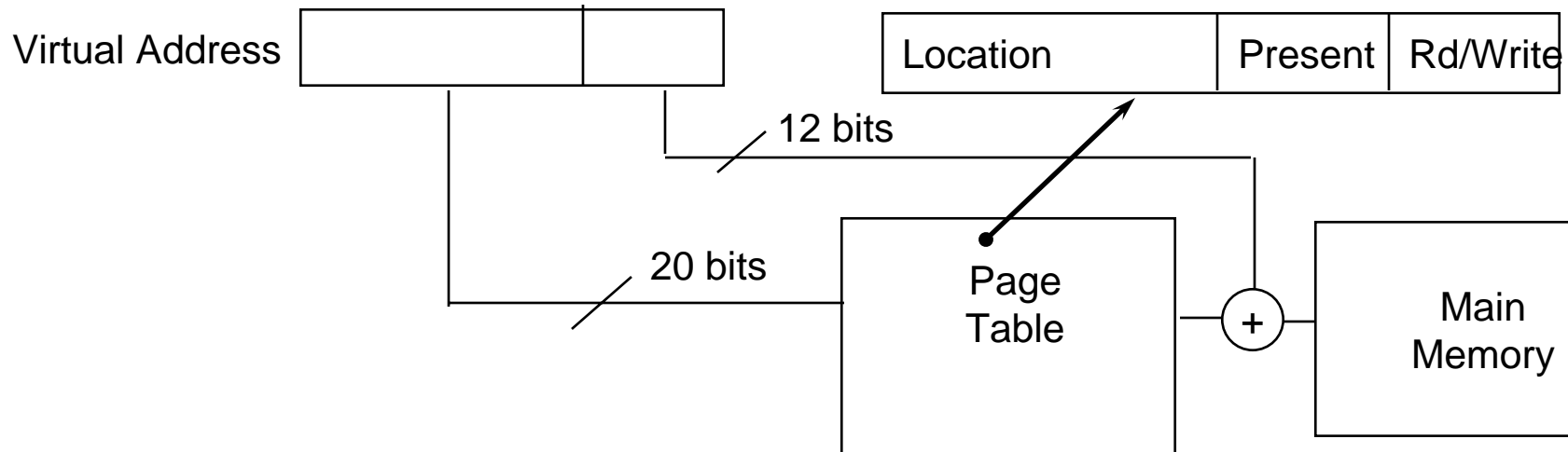
- Main memory is big, but what if we run out
  - use virtual memory
  - keep part of memory on disk
    - bigger than main memory
    - slower than main memory
- Want to have several program in memory at once
  - keeps processor busy while one process waits for I/O
  - need to protect processes from each other
  - have several tasks running at once
    - compiler, editor, debugger
    - word processing, spreadsheet, drawing program
- Use *virtual addresses*
  - look like normal addresses
  - hardware translates them to *physical addresses*

# Advantages of Virtual Addressing

- Can assign non-contiguous regions of physical memory to programs
- A program can only gain access to its mapped pages
- Can have more virtual pages than the size of physical memory
  - pages that are not in memory can be stored on disk
- Every program can start at (virtual) address 0

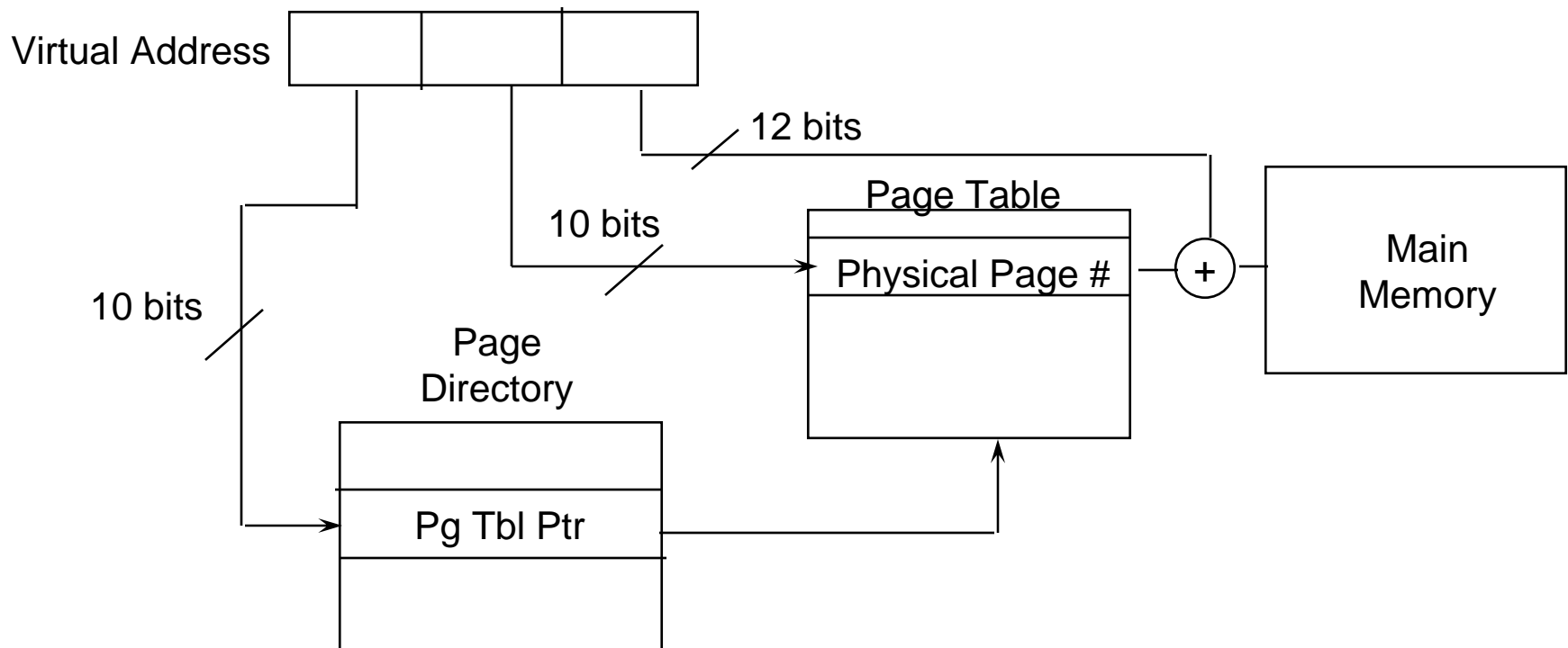
# Paging

- Divide physical memory into fixed sized chunks called *pages*
  - typical pages are 512 bytes to 64KB bytes
  - When a process is to be executed, load the pages that *are actually used* into memory
- Have a table to map virtual pages to physical pages
- Consider a 32 bit addresses
  - 4096 byte pages (12 bits for the page)
  - 20 bits for the page number



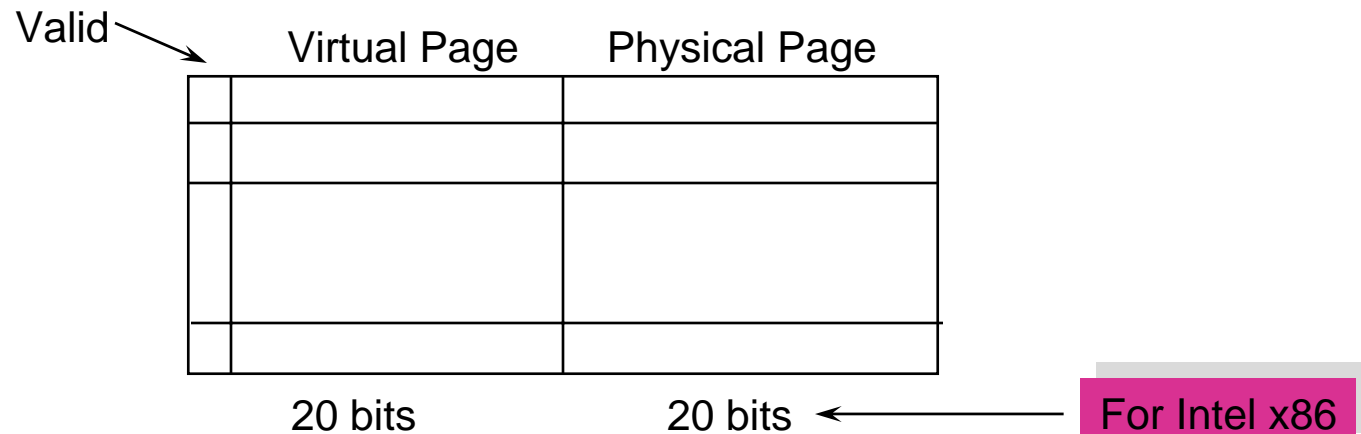
# Problems with Page Tables

- One page table can get very big
  - $2^{20}$  entries (for most programs, most items are empty)
- solution1: use a hierarchy of page tables



# Faster Mapping from Virtual to Physical Addresses

- need hardware to map between physical and virtual addresses
  - can require multiple memory references
  - this can be slow
- answer: build a cache of these mappings
  - called a translation look-aside buffer (TLB)
  - associative table of virtual to physical mappings
  - typically 16- 64 entries



# Super Pages

- TLB Entries
  - Tend to be limited in number
  - Can only refer to one page
- Idea
  - Create bigger pages
  - 4MB instead of 4KB
  - One TLB entry covers more memory