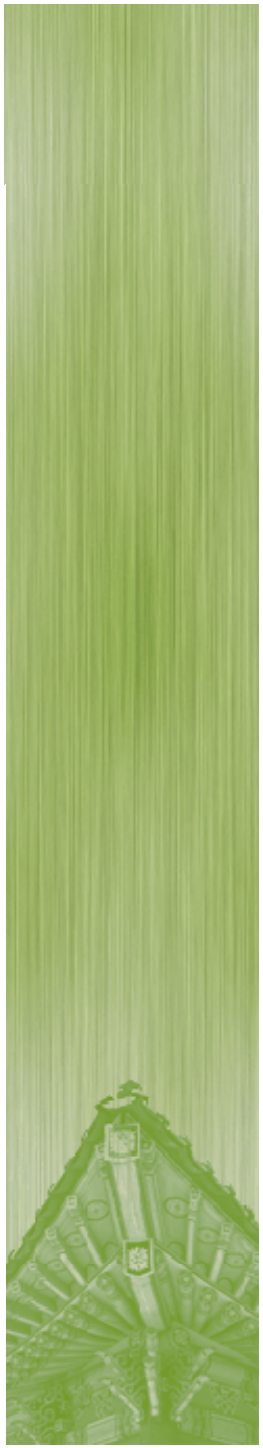

Memory Management

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Today's Topics

- **Why is memory management difficult?**

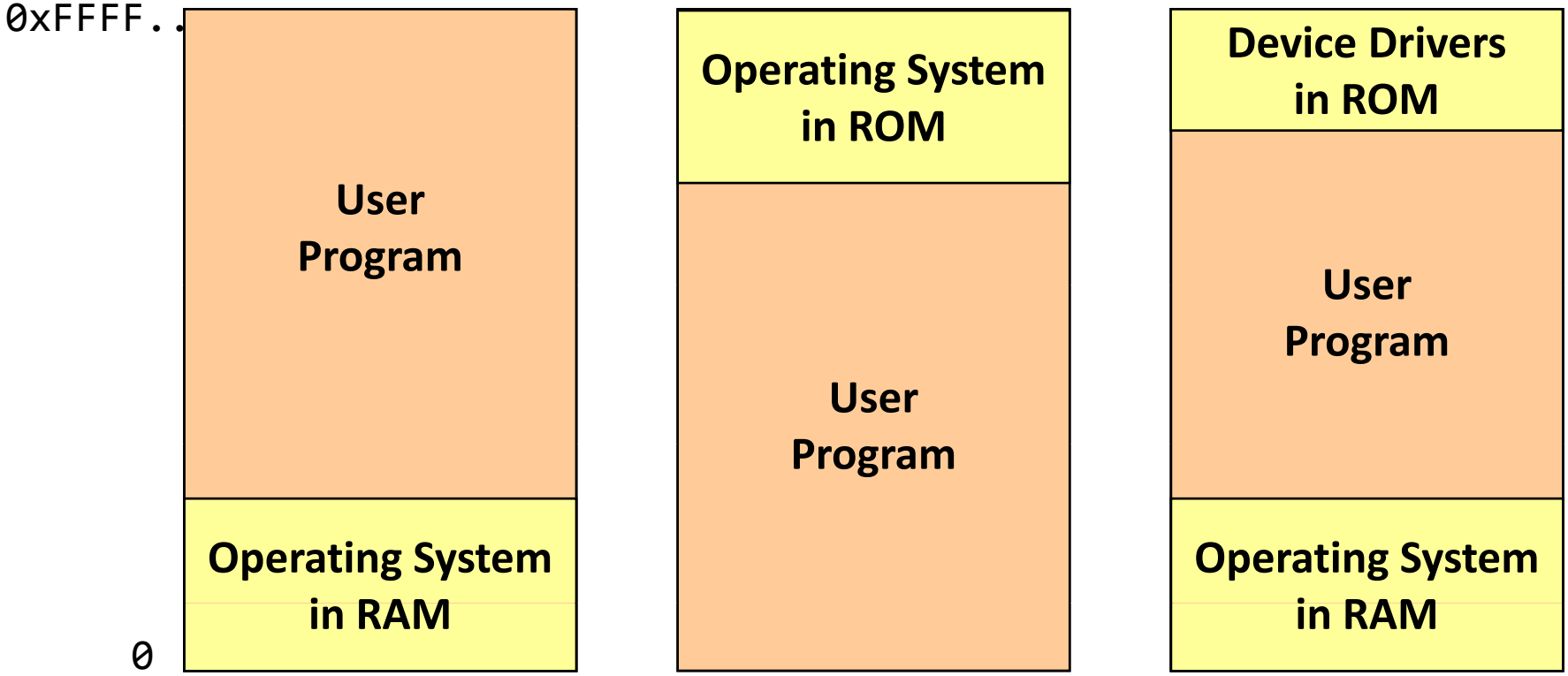
- **Old memory management techniques:**
  - Fixed partitions
  - Variable partitions
  - Overlays
  - Swapping

Memory Management (1)

- **Goals**
  - To provide a convenient abstraction for programming.
  - To allocate scarce memory resources among competing processes to maximize performance with minimal overhead.
  - To provide isolation between processes.
- **Why is it so difficult?**

Single/Batch Programming

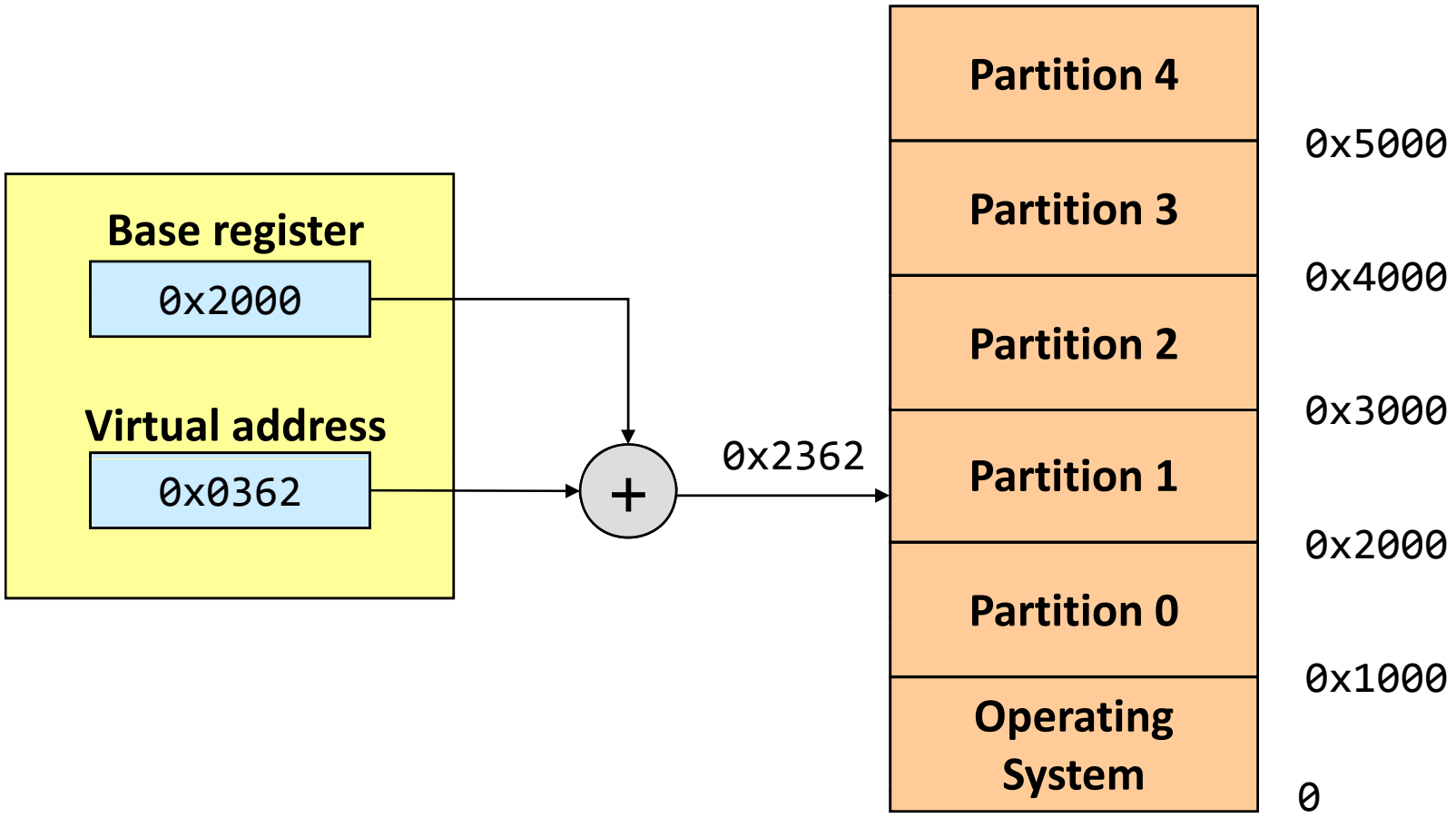
- **An OS with one user process**
  - Programs use physical addresses directly.
  - OS loads job, runs it, unloads it.



Multiprogramming

- **Multiprogramming**
  - Need multiple processes in memory at once.
    - To overlap I/O and CPU of multiple jobs
    - Each process requires variable-sized and contiguous space.
  - Requirements
    - Protection: restrict which addresses processes can use.
    - Fast translation: memory lookups must be fast, in spite of protection scheme.
    - Fast context switching: updating memory hardware (for protection and translation) should be quick.

Fixed Partitions (1)



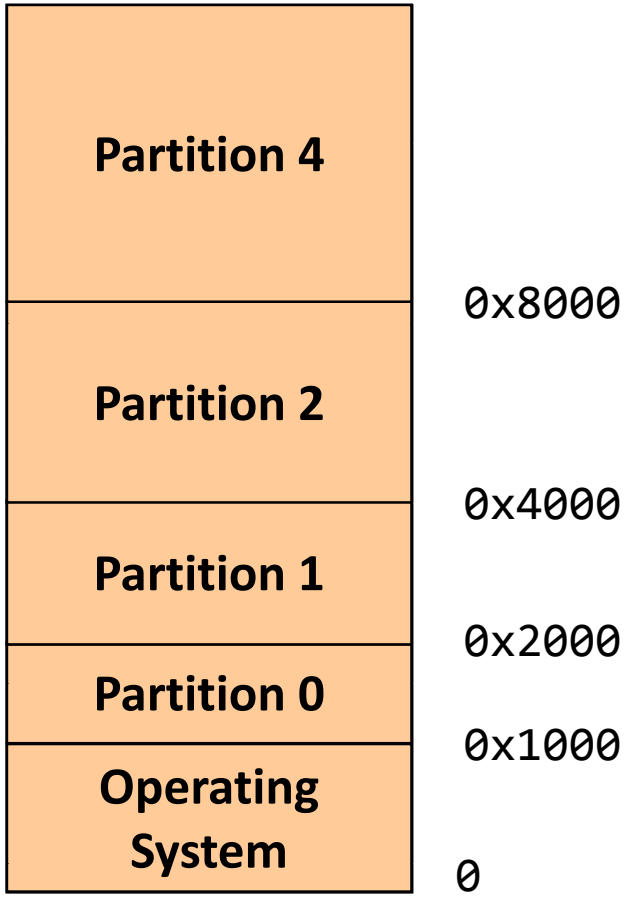
Fixed Partitions (2)

- **Physical memory is broken up into fixed partitions**
  - Size of each partition is the same and fixed
  - the number of partitions = degree of multiprogramming
  - Hardware requirements: base register
    - Physical address = virtual address + base register
    - Base register loaded by OS when it switches to a process
- **Advantages**
  - Easy to implement, fast context switch
- **Problems**
  - Internal fragmentation: memory in a partition not used by a process is not available to other processes
  - Partition size: one size does not fit all
    - Fragmentation vs. fitting large programs

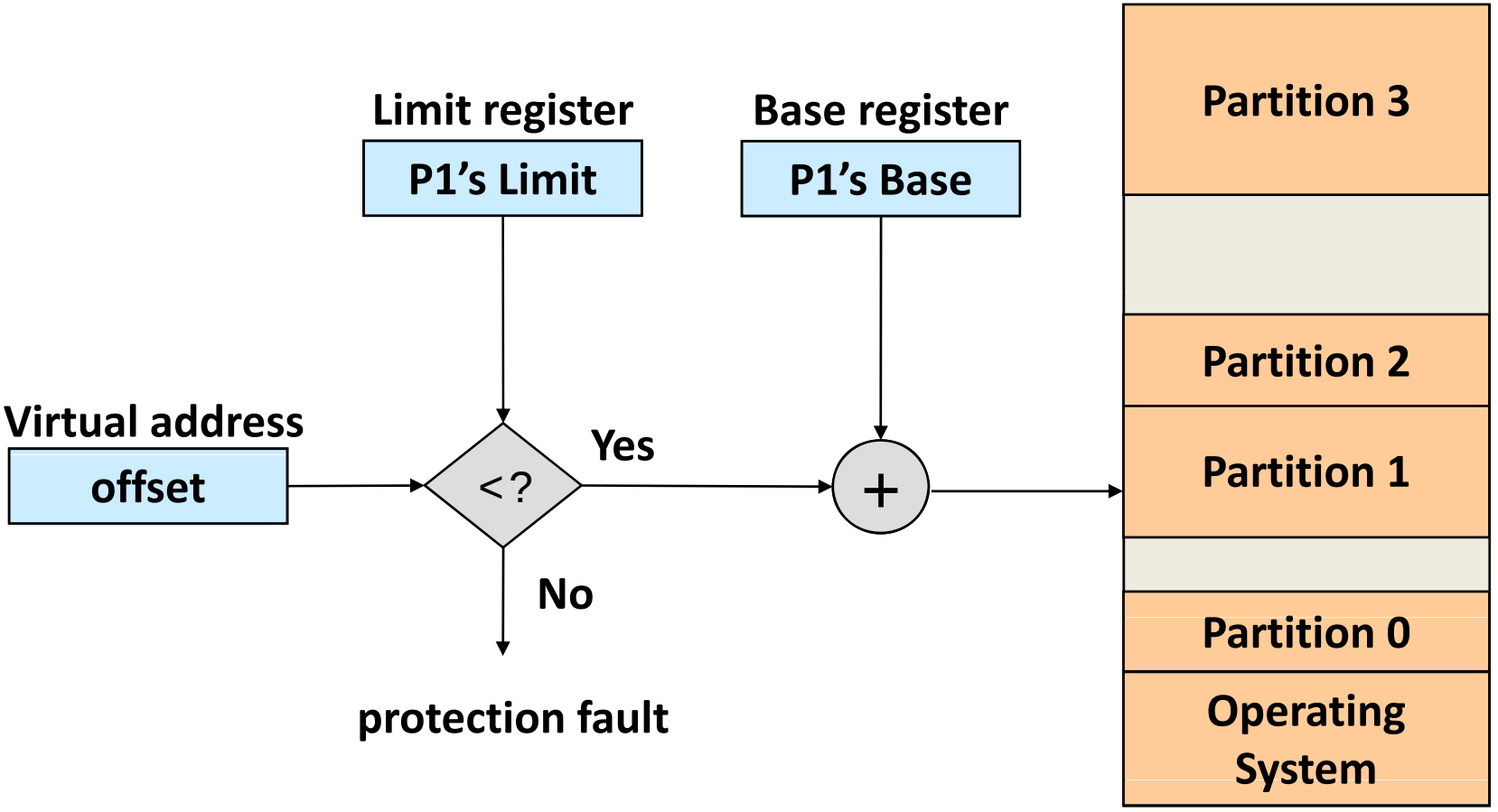
Fixed Partitions (3)

- **Improvement**
  - Partition size need not be equal.
  - Allocation strategies
    - Maintain a separate queue for each partition size
    - Maintain a single queue and allocate to the closest job whose size fits in an empty partition (first fit)
    - Search the whole input queue and pick the largest job that fits in an empty partition (best fit)
  - IBM OS/MFT

    (Multiprogramming with a Fixed number of Tasks)



Variable Partitions (1)



Variable Partitions (2)

- **Physical memory is broken up into variable-sized partitions**
  - IBM OS/MVT
  - Hardware requirements: base register and limit register
    - Physical address = virtual address + base register
    - Base register loaded by OS when it switches to a process
  - The role of limit register: protection
    - If (physical address > base + limit), then raise a protection fault.

- **Allocation strategies**
  - First fit: Allocate the first hole that is big enough
  - Best fit: Allocate the smallest hole that is big enough
  - Worst fit: Allocate the largest hole

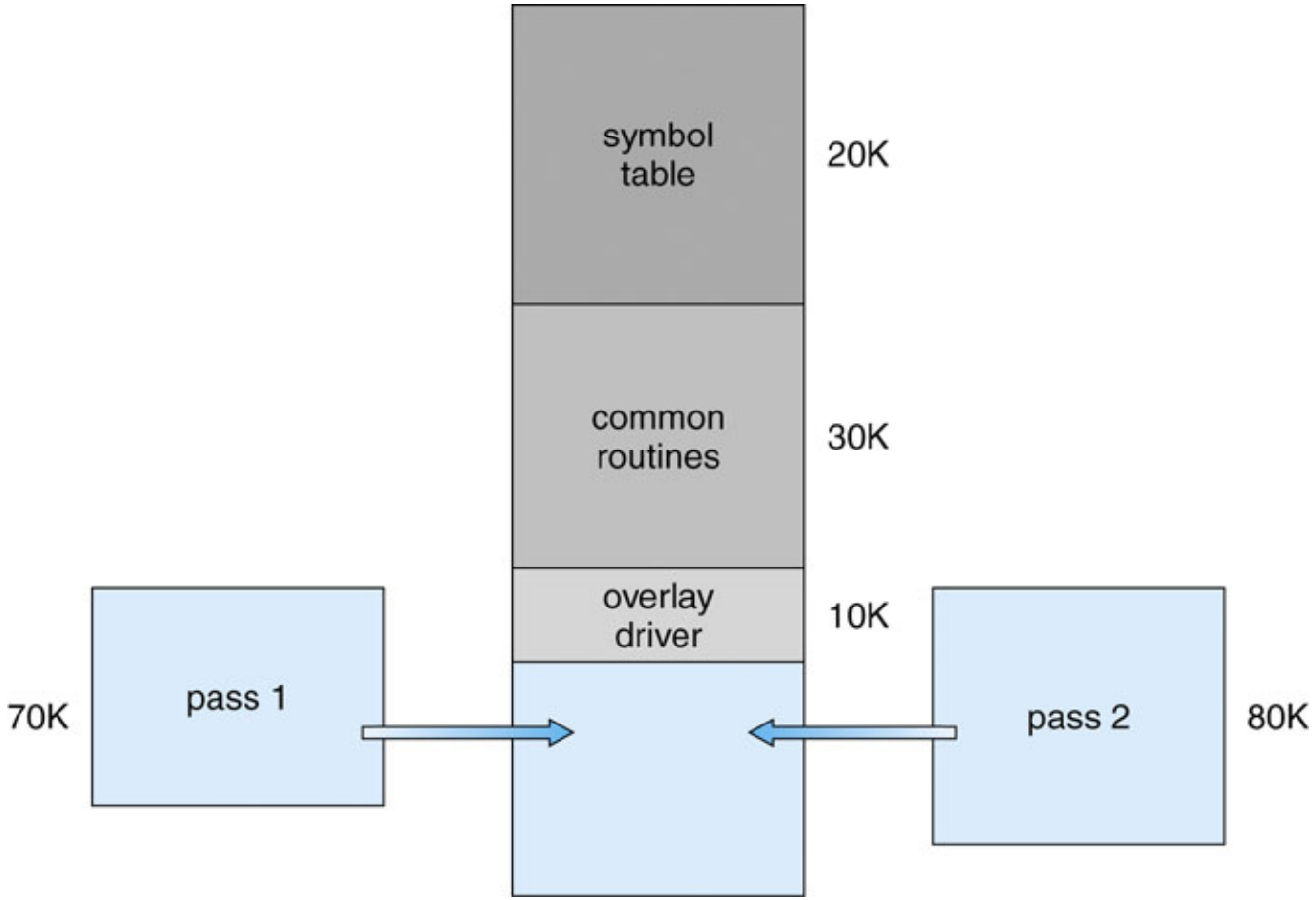
Variable Partitions (3)

- **Advantages**
  - No internal fragmentation
    - Simply allocate partition size to be just big enough for process
    - But, if we break the physical memory into fixed-sized blocks and allocate memory in unit of block sizes (in order to reduce bookkeeping), we have internal fragmentation.

- **Problems**
  - External fragmentation
    - As we load and unload jobs, holes are left scattered throughout physical memory
  - Solutions to external fragmentation:
    - Compaction
    - Paging and segmentation

Overlays (1)

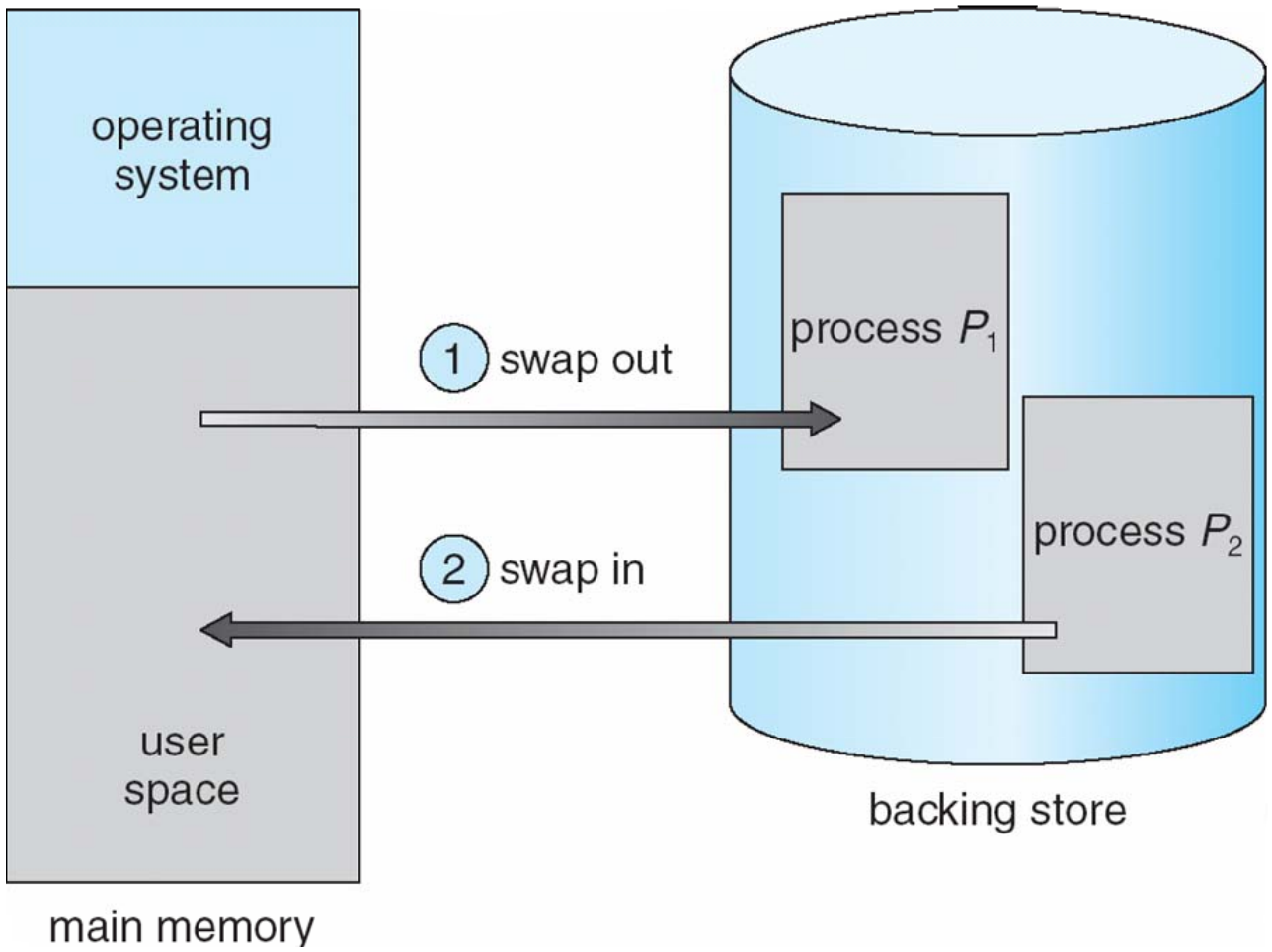
- Overlays for a two-pass assembler



Overlays (2)

- **Overlays**
  - Keep in memory only those instructions and data that are needed at any given time.
  - Normally implemented by user
- **Advantages**
  - Needed when a process is larger than the amount of memory allocated to it.
  - No special support needed from operating system.
- **Problems**
  - Programming design of overlay structure is complex.

Swapping (1)


operating system
process P_1
1 swap out
process P_2
2 swap in
user space
backing store
main memory

Swapping (2)

- **Swapping**
  - A process can be swapped temporarily out of memory to a backing store and then brought back into memory later for continued execution.
  - Backing store
    - Fast disk large enough to accommodate copies of all memory images for all users
    - Must provide direct access to these memory images
  - Major part of swap time is transfer time.
    - Directly proportional to the amount of memory swapped.
  - Swapping a process with a pending I/O
    - Do not swap a process with pending I/O
    - Execute I/O operations only into OS buffers