Amirkabir University of Technology
(Tehran Polytechnic)

Operating Systems

Main Memory-Part1

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Chapter 9: Memory Management

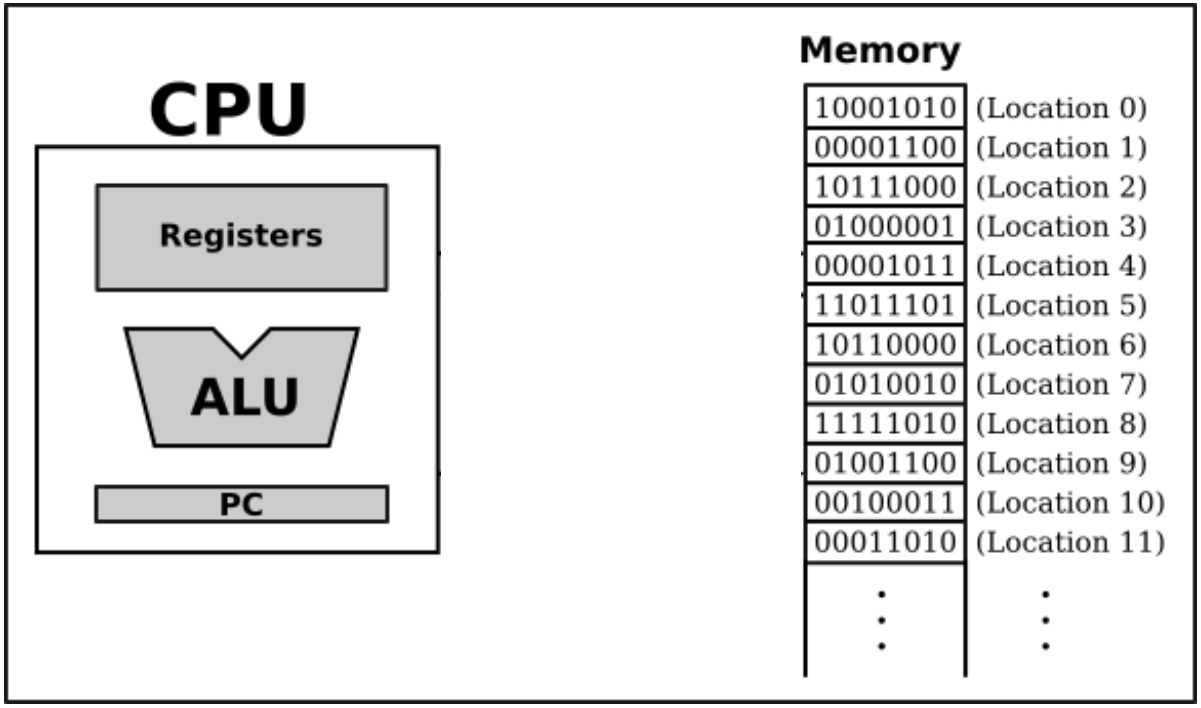
- Background
- Contiguous Memory Allocation
- Paging
- Structure of the Page Table
- Swapping

Objectives

- To provide a detailed description of various ways of organizing memory hardware.
- To discuss various memory-management techniques.
- To provide a detailed description of the Intel Pentium, which supports both pure segmentation and segmentation with paging.

Background

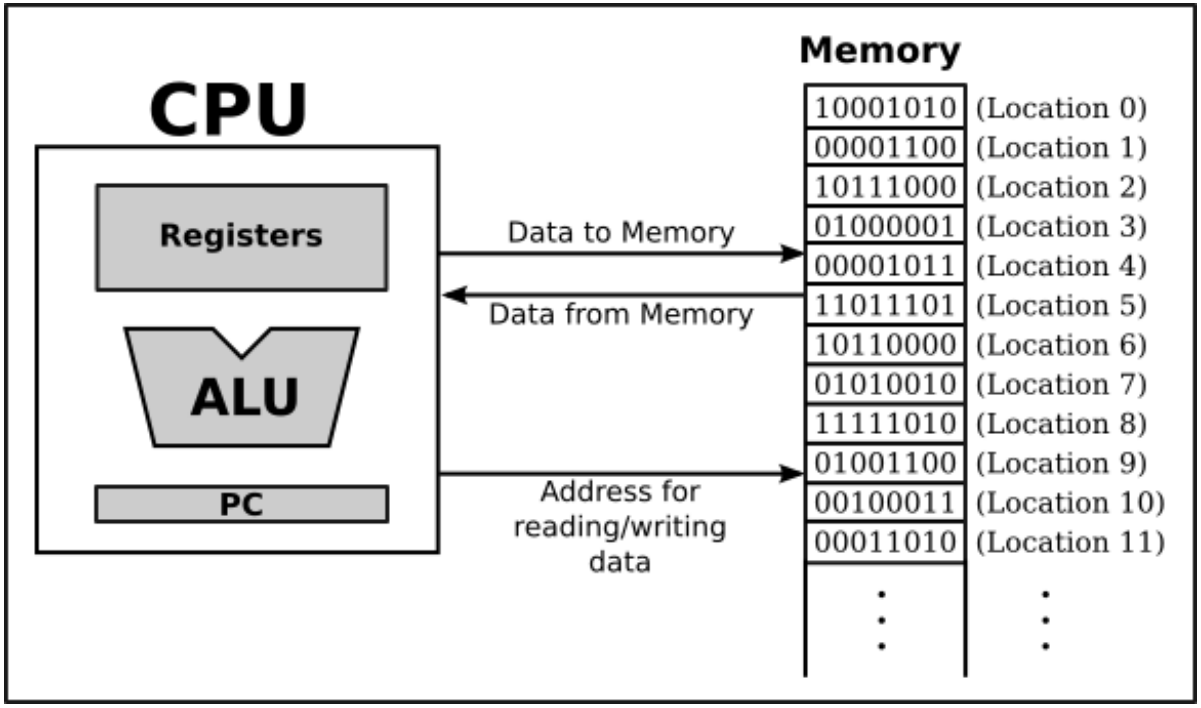
- Program must be brought (from disk) into memory and placed within a process for it to be run.
- Main memory and registers are only storage CPU can access directly.



https://math.hws.edu/javanotes/c1/s1.html

Background (cont.)

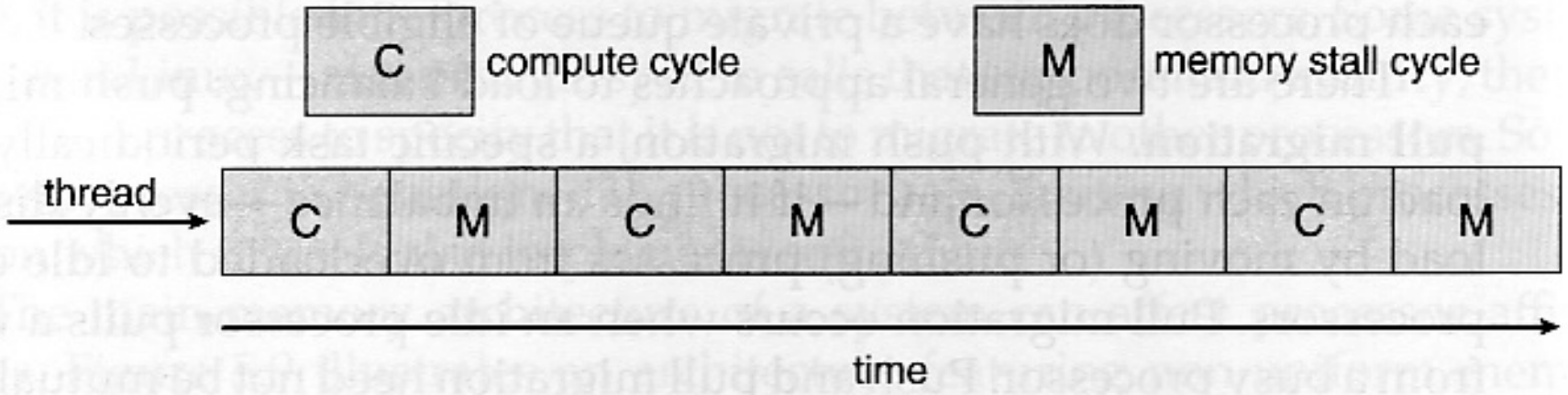
- Memory unit only sees a stream of:
  - addresses + read requests, or
  - address + data and write requests



https://math.hws.edu/javanotes/c1/s1.html

Background (cont.)

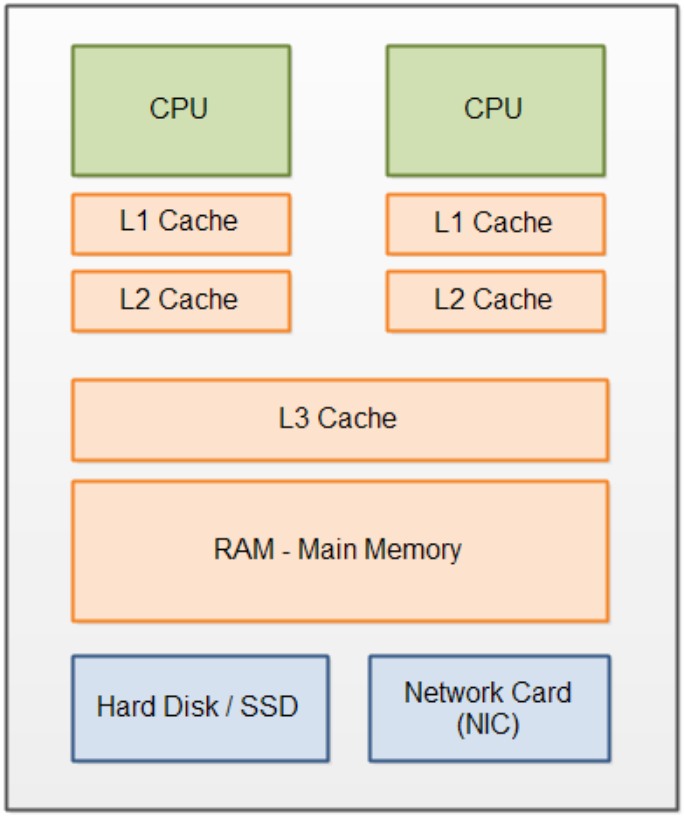
- Register access is done in one CPU clock (or less)
- Main memory can take many cycles, causing a **memory stall**



https://www.cs.uic.edu/~jbell/CourseNotes/OperatingSystems/5_CPU_Scheduling.html

Background (cont.)

- **Cache** sits between main memory and CPU registers
- Protection of memory required to ensure correct operation

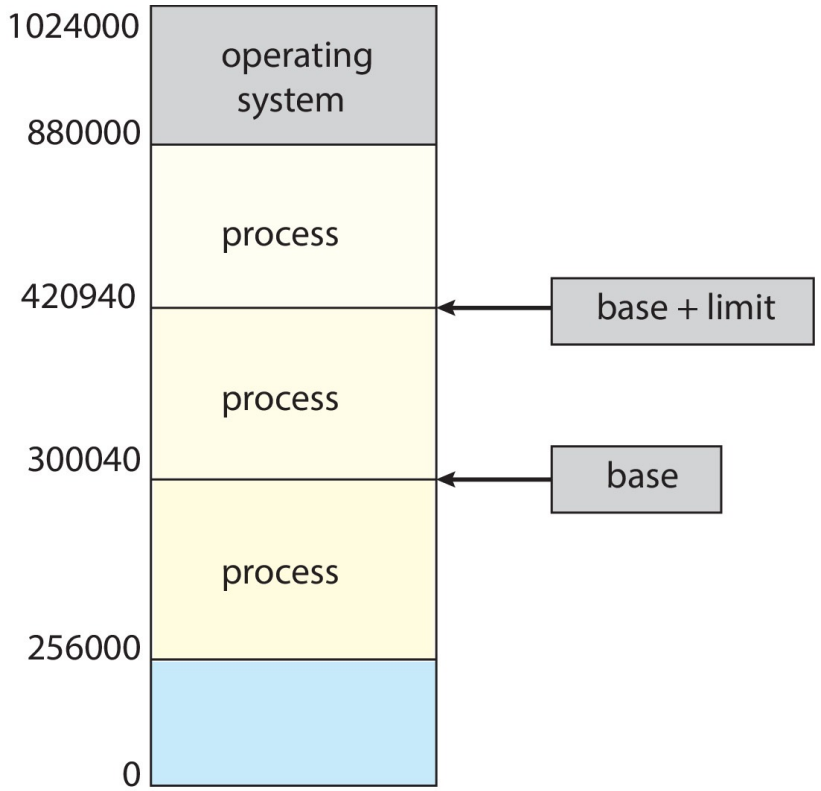


https://software.rajivprab.com/2018/04/29/myths-programmers-believe-about-cpu-caches/

Protection

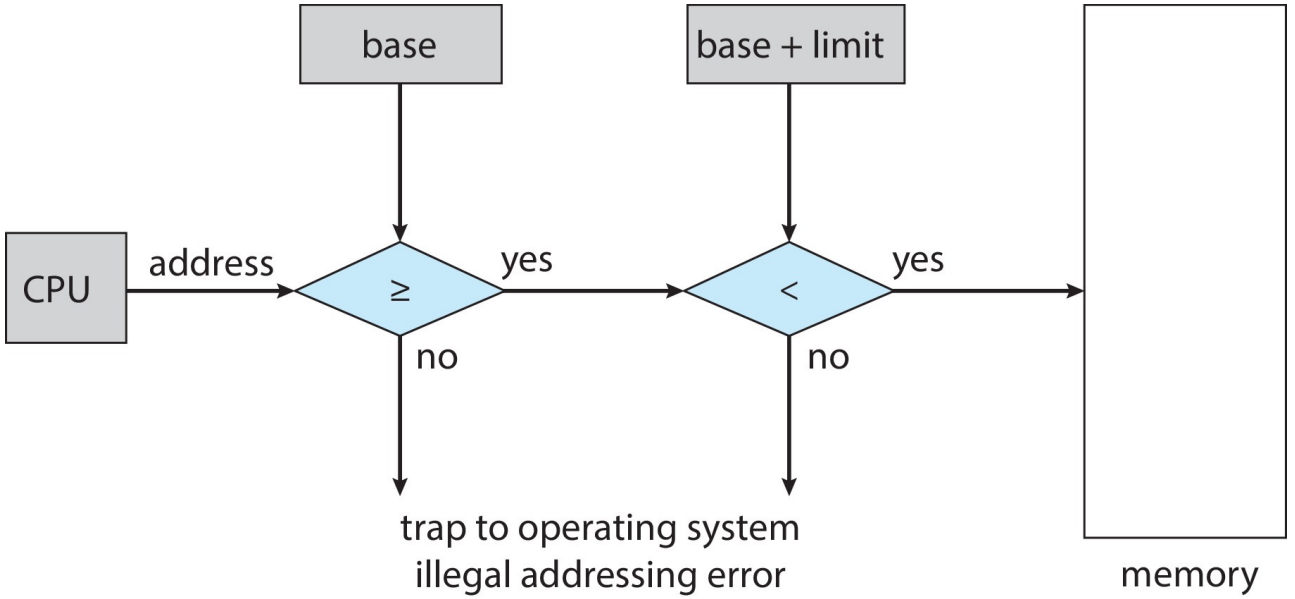
- Need to censure that a process can access only access those addresses in it address space.

- We can provide this protection by using a pair of ***base*** and ***limit registers*** define the logical address space of a process.



Hardware Address Protection

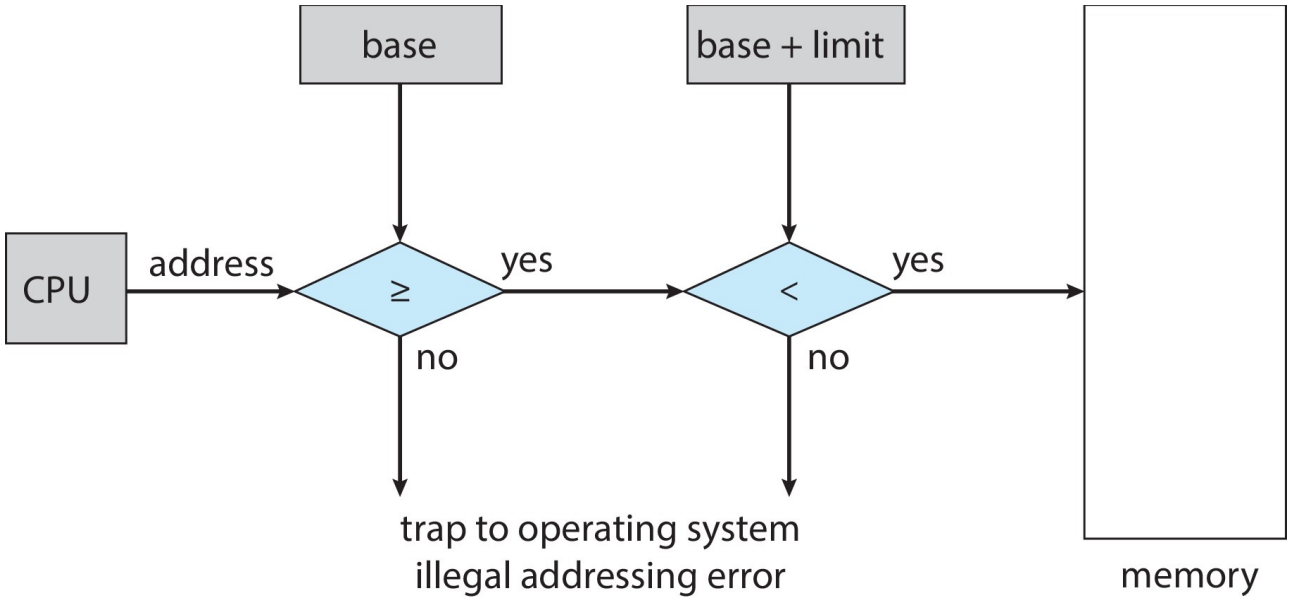
- CPU must check every memory access generated in user mode to be sure it is between base and limit for that user



- The instructions to loading the base and limit registers are **privileged**.

Hardware Address Protection (cont.)

- This scheme prevents a user program from ***modifying the code or data structures*** of either the operating system or other users:
  - Accidentally or deliberately



Address Binding

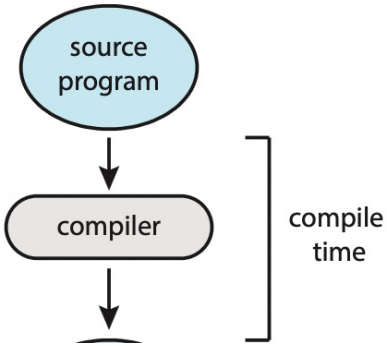
- Most systems allow a user process to reside in any part of the physical memory.

- Thus, although the address space of the computer may start at 00000, the first address of the user process need not be 00000.

- In most cases, a user program goes through several steps.

Compile Time

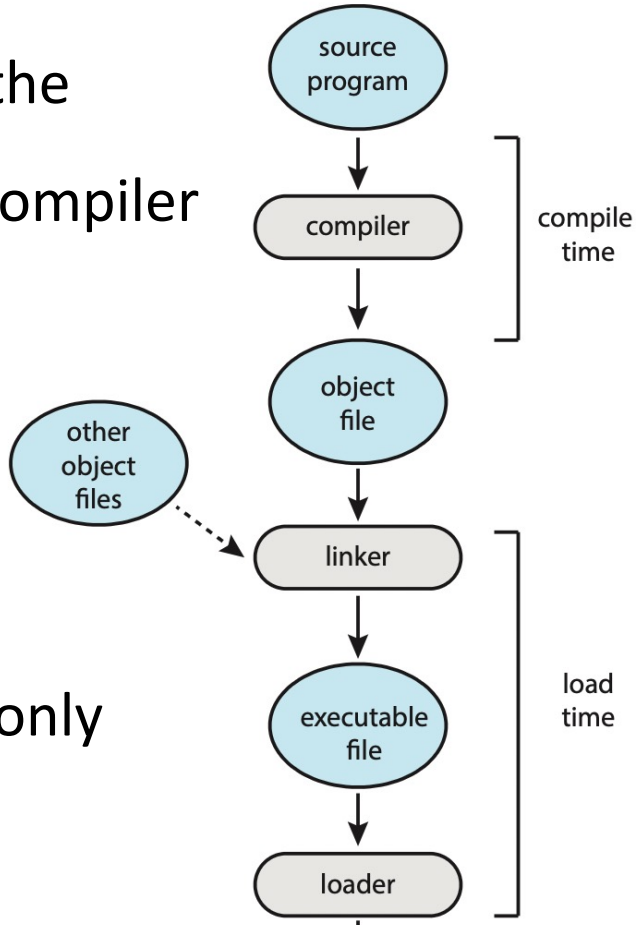
- If you know at compile time where the process will reside in memory, then ***absolute code*** can be generated.



  - E.g., if a user process will reside starting at location ***R***, then the generated compiler code will start at ***R*** and extend up from there.
  - If, at some later time, the starting location changes, then it will be necessary to ***recompile*** this code.

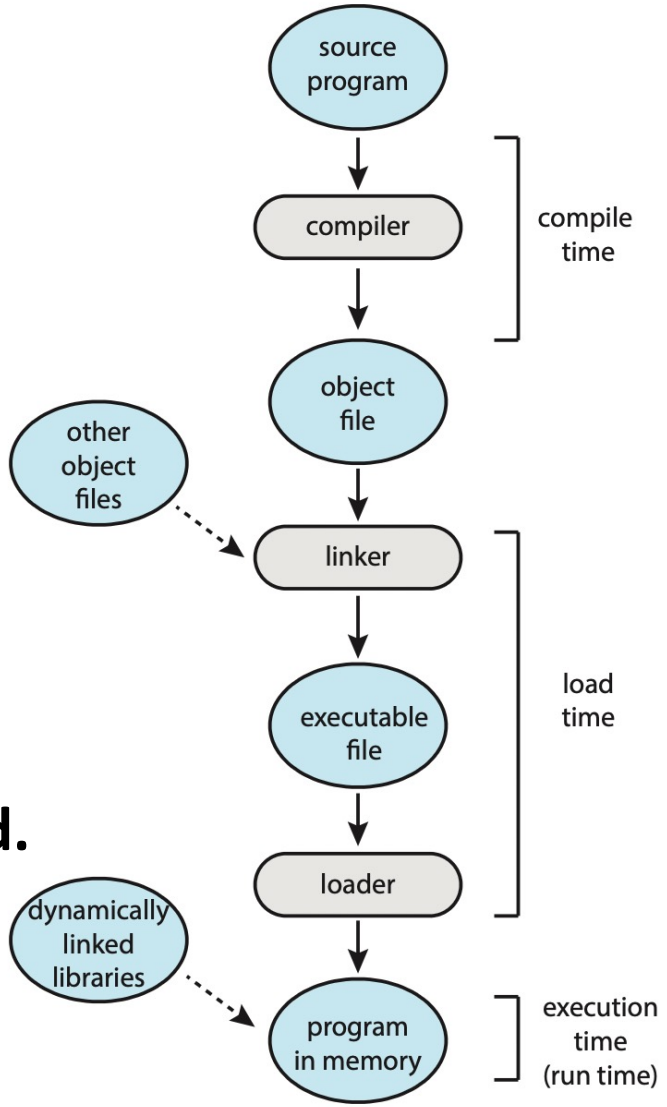
Load Time

- If it is ***not known*** at compile time where the process will reside in memory, then the compiler must generate ***relocatable code.***
- In this case, final binding is delayed until load time.
- If the starting address changes, we need only reload the user code to incorporate this changed value.



Execution Time

- If the process can be ***moved during its execution*** from one memory segment to another, then binding must be delayed until ***run time***.
- Special hardware must be available for this scheme to work.
- **Most operating systems use this method.**



Logical vs. Physical Address Space

- **Logical address**
  - Generated by the CPU
  - Also referred to as **virtual address**
- **Physical address**
  - Address seen by the memory unit

Logical vs. Physical Address Space (cont.)

- **Compile time**

Logical Address	(= , !=) ?	Physical address

- **Load time**

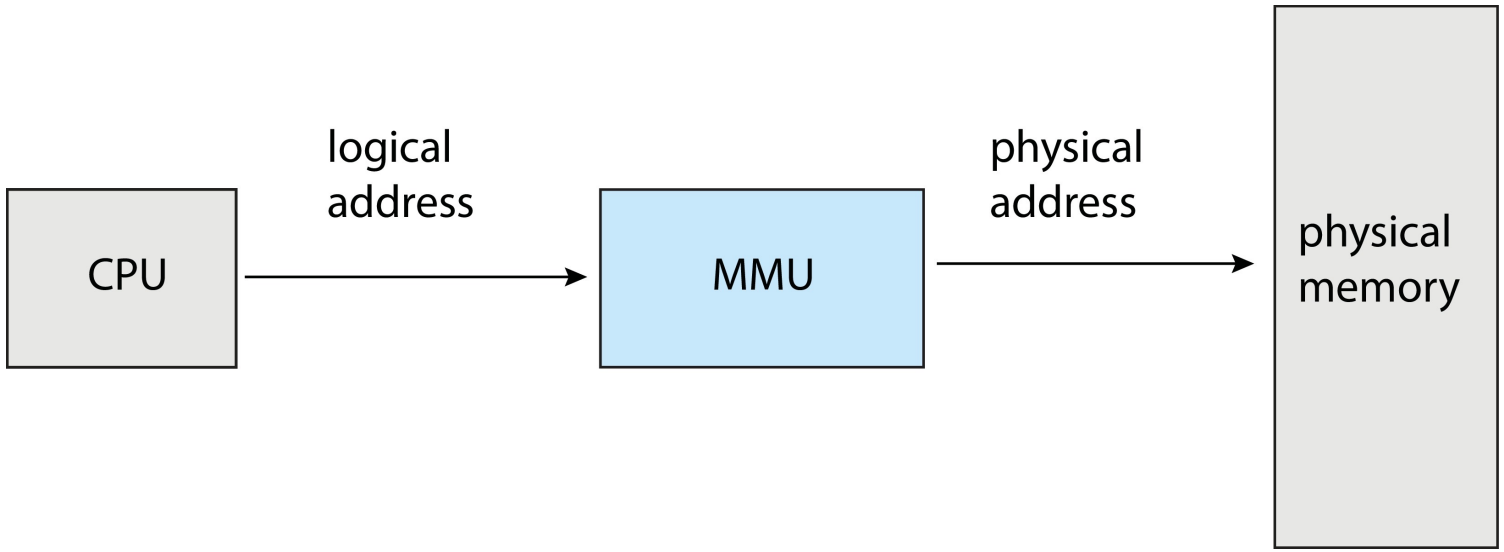
Logical Address	(= , !=) ?	Physical address

- **Execution time**

Logical Address	(= , !=) ?	Physical address

Memory-Management Unit (MMU)

- Hardware device that at run time *maps* virtual to physical address



- Many methods possible, covered in the rest of this chapter

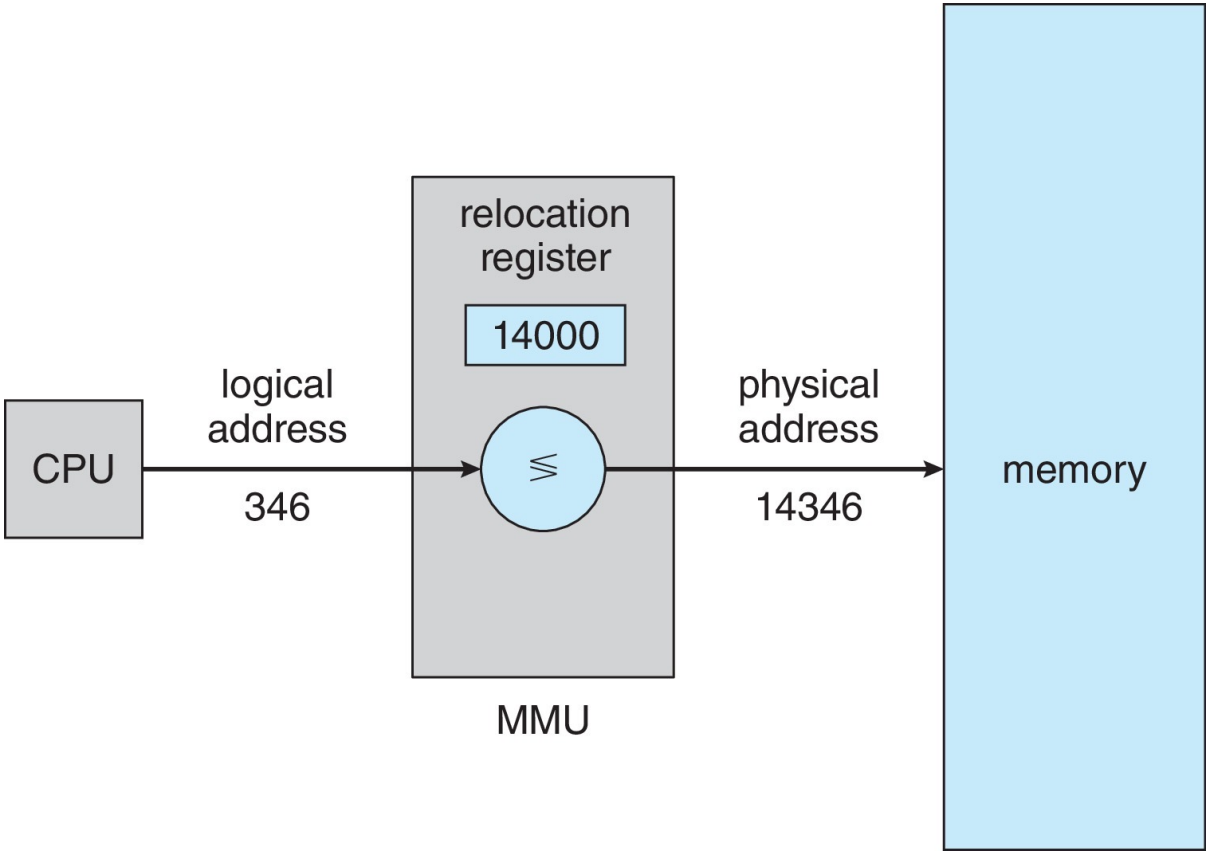
Memory-Management Unit (cont.)

- Consider simple scheme.
  - Which is a generalization of the base-register scheme.

- The base register now called **relocation register.**

Memory-Management Unit (cont.)

- The value in the relocation register is added to every address generated by a user process at the time it is sent to memory.



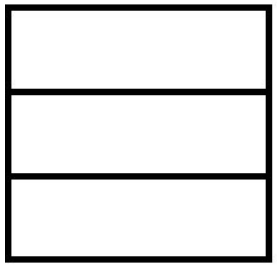
Memory-Management Unit (cont.)

- The user program deals with logical addresses
  - It never sees the real physical addresses
- Execution-time binding occurs when reference is made to location in memory.
  - Logical address bound to physical addresses

Contiguous Allocation

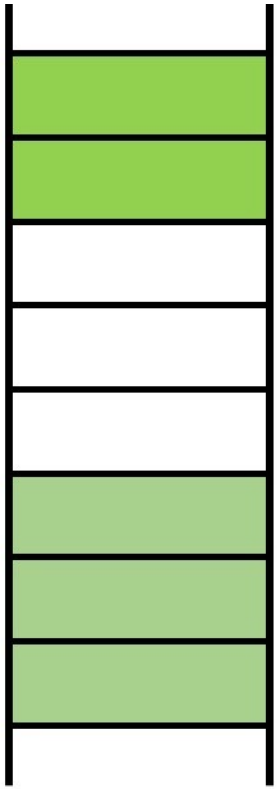
Contiguous Allocation

- Main memory must support both OS and user processes
- Limited resource, must allocate efficiently
- Contiguous allocation is **one early method**



Process

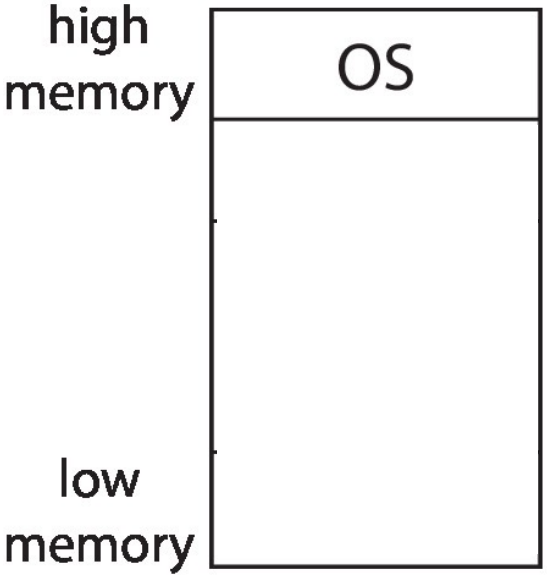
https://www.geeksforgeeks.org/difference-between-contiguous-and-noncontiguous-memory-allocation/



Memory blocks

Contiguous Allocation (cont.)

- Main memory usually into two **partitions**:
  - Resident operating system
  - Each process contained in single contiguous section of memory



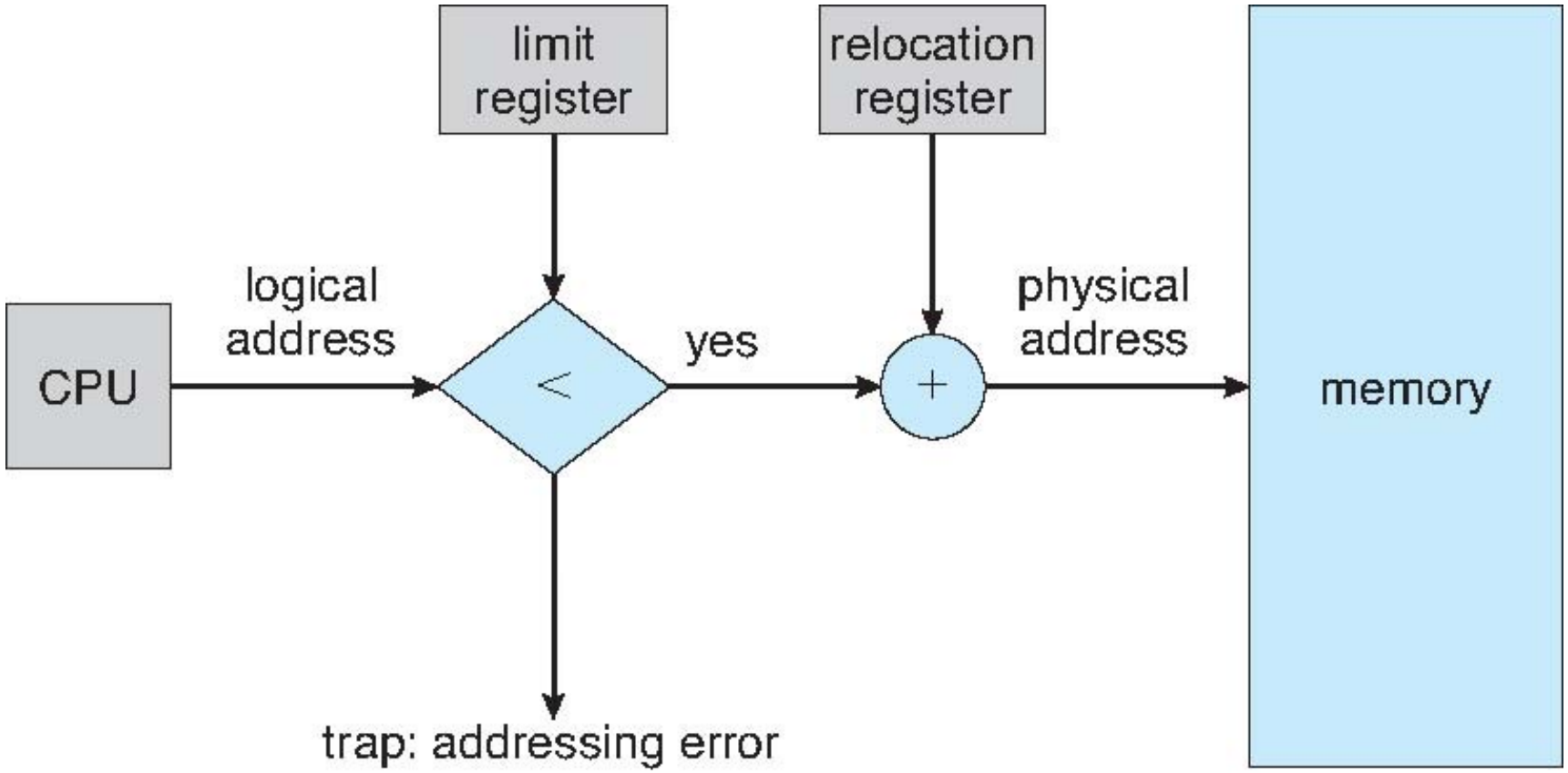
Contiguous Allocation (cont.)

- Operating system placement
  - Low memory addresses
  - High memory addresses
- This decision depends on many factors
  - Such as the location of the interrupt vector.
- Many operating systems (including Linux and Windows) place the operating system in high memory.

Contiguous Allocation (cont.)

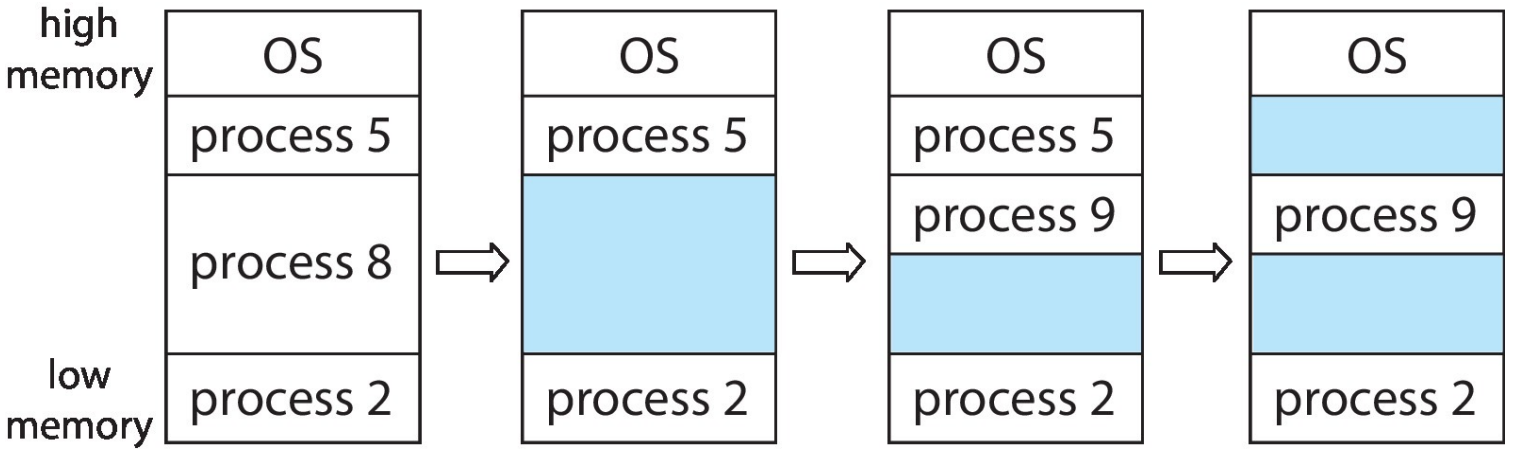
- **Relocation registers** used to protect user processes from each other, and from changing operating-system code and data
  - **Base register** contains value of smallest physical address
  - **Limit register** contains range of logical addresses – each logical address must be less than the limit register
  - **MMU** maps logical address ***dynamically***

Hardware Support for Relocation and Limit Registers



Multiple-partition Allocation

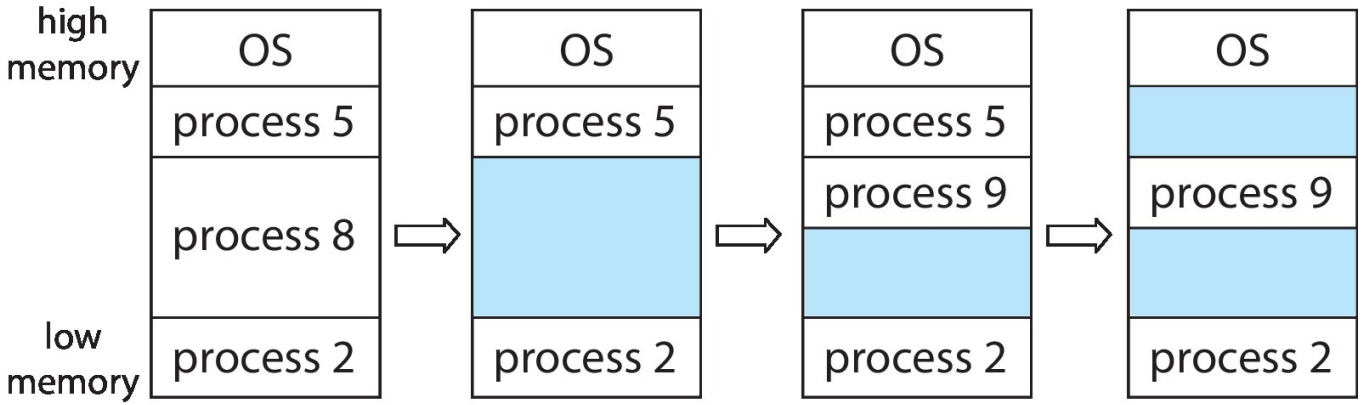
- Degree of multiprogramming limited by number of partitions
- **Variable-partition** sizes for efficiency (sized to a given process' needs)
- **Hole:** block of available memory
  - Holes of various size are scattered throughout memory



Multiple-partition Allocation (cont.)

- When a process arrives, it is allocated memory from a hole large enough to accommodate it.
- Process exiting frees its partition, adjacent free partitions combined
- Operating system maintains information about:

  a) allocated partitions b) free partitions (hole)



Dynamic Storage-Allocation Problem

How to satisfy a request of size ***n*** from a list of free holes?

- **First-fit**: Allocate the first hole that is big enough
- **Best-fit**: Allocate the smallest hole that is big enough; must search entire list, unless ordered by size
  - Produces the smallest leftover hole
- **Worst-fit**: Allocate the largest hole; must also search entire list
  - Produces the largest leftover hole

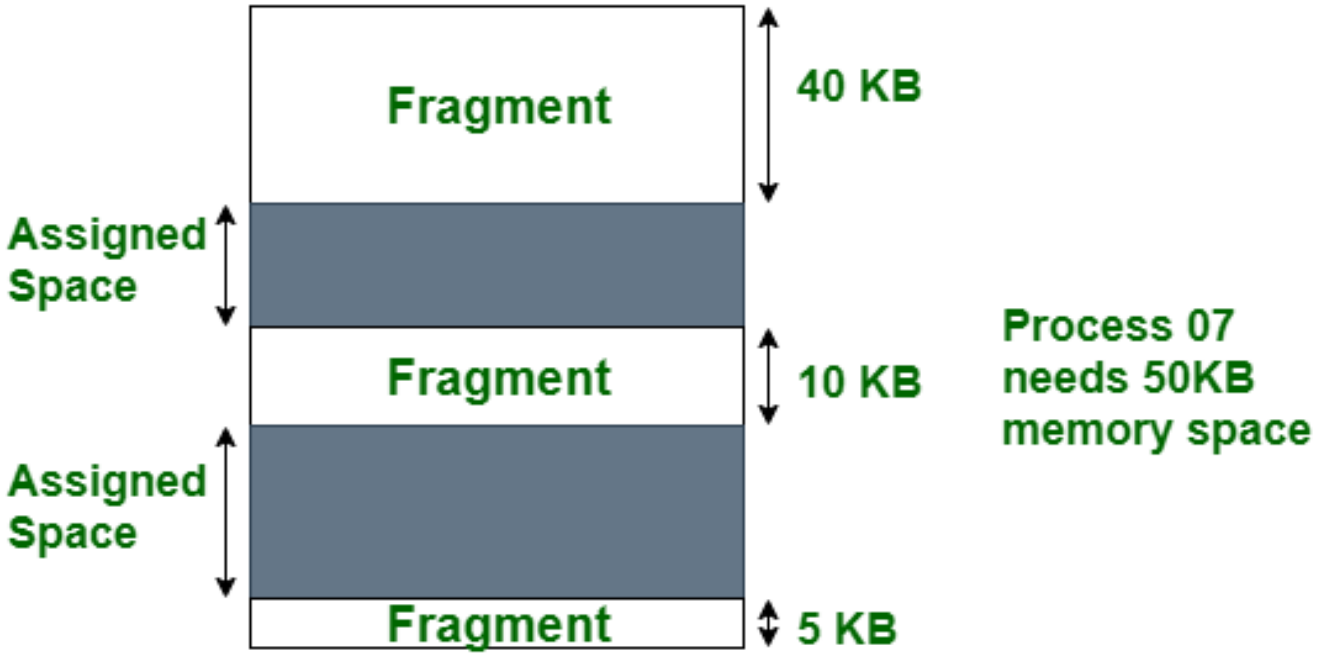
Dynamic Storage-Allocation Problem

First-fit and best-fit better than worst-fit in terms of speed and storage utilization

Simulations have shown that both first fit and best fit are better than worst fit in terms of decreasing time and storage utilization. Neither first fit nor best fit is clearly better than the other in terms of storage utilization, but first fit is generally faster.

Fragmentation

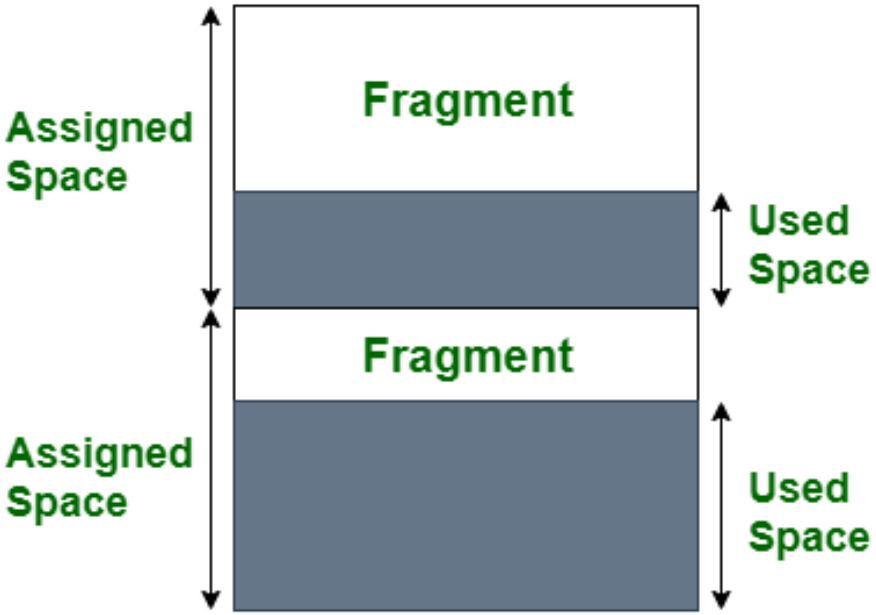
- **External Fragmentation**
  - Total memory space exists to satisfy a request, but it is not contiguous.



https://www.geeksforgeeks.org/difference-between-internal-and-external-fragmentation/

Fragmentation (cont.)

- **Internal Fragmentation**
  - Allocated memory may be slightly larger than requested memory.
  - This size difference is memory internal to a partition, but not being used.



https://www.geeksforgeeks.org/difference-between-internal-and-external-fragmentation/

Fragmentation (cont.)

- First fit analysis reveals that given N blocks allocated, another 0.5*N blocks lost to fragmentation
  - 1/3 may be unusable -> **50-percent rule**

Fragmentation (cont.)

- Reduce external fragmentation by ***compaction***
  - Shuffle memory contents to place all free memory together in one large block.
  - Compaction is possible *only* if relocation is dynamic, and is done at execution time.

Fragmentation (cont.)

- The simplest compaction algorithm is to move all processes toward one end of memory.
- All holes move in the other direction, producing one large hole of available memory.
- This scheme can be expensive.

- Now consider that backing store has same fragmentation problems.