Memory management

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(partly based on slides of Le Thanh Van)

Outline

1. Background
2. Swapping
3. Contiguous memory allocation
4. Segmentation
5. Paging
   - Structure of page table

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1 Background

2 Swapping

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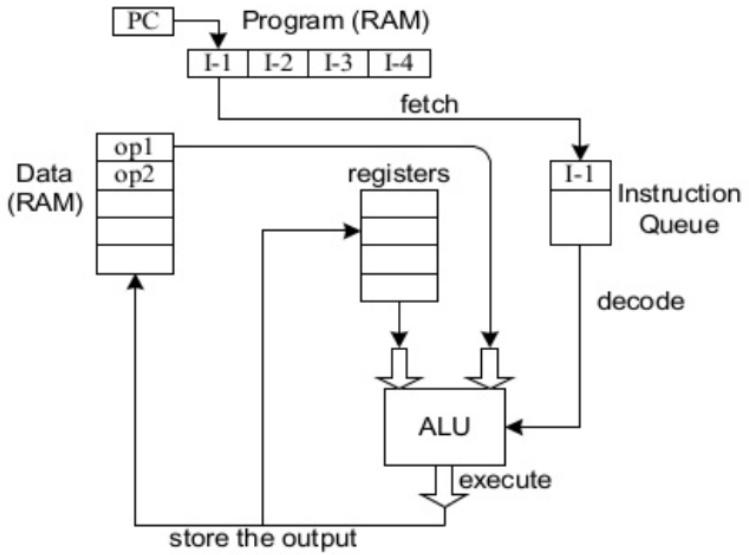
Role of memory



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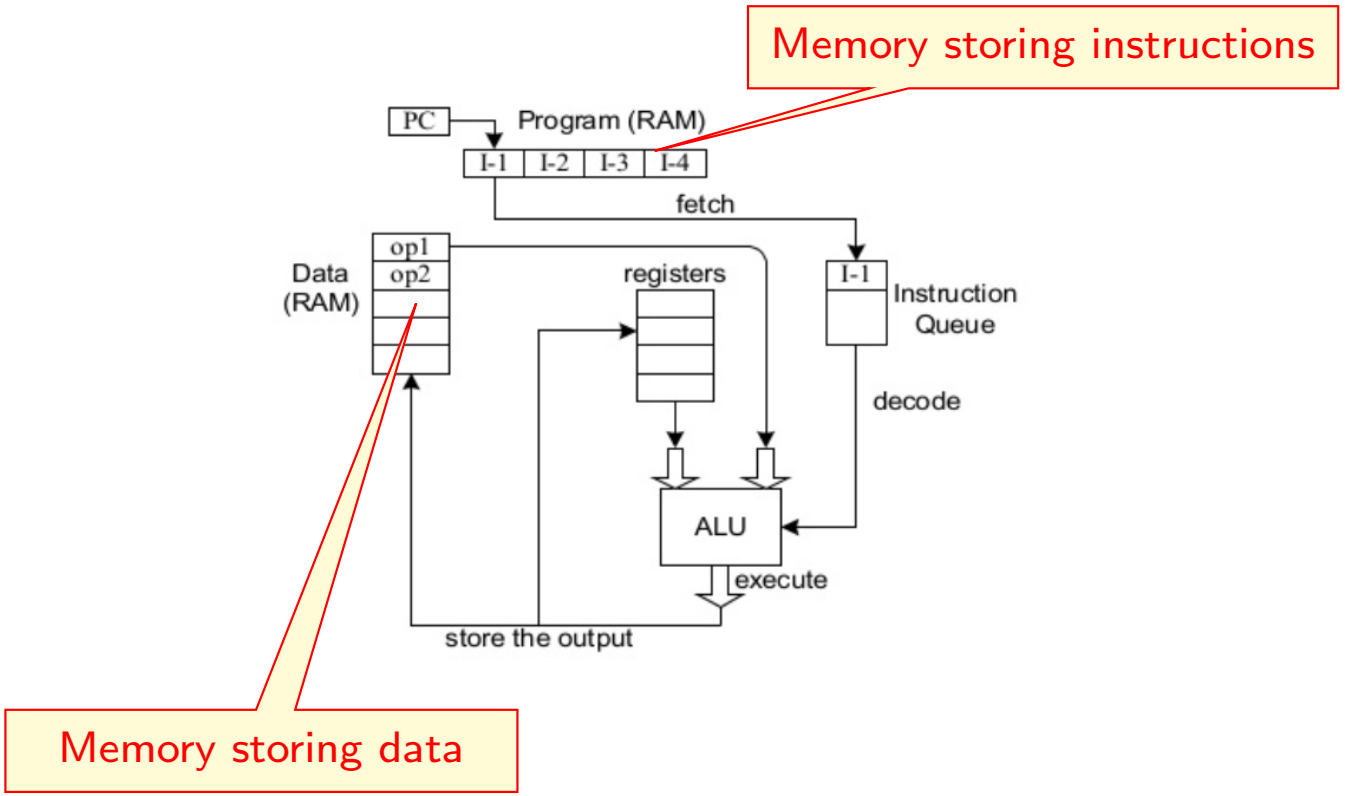

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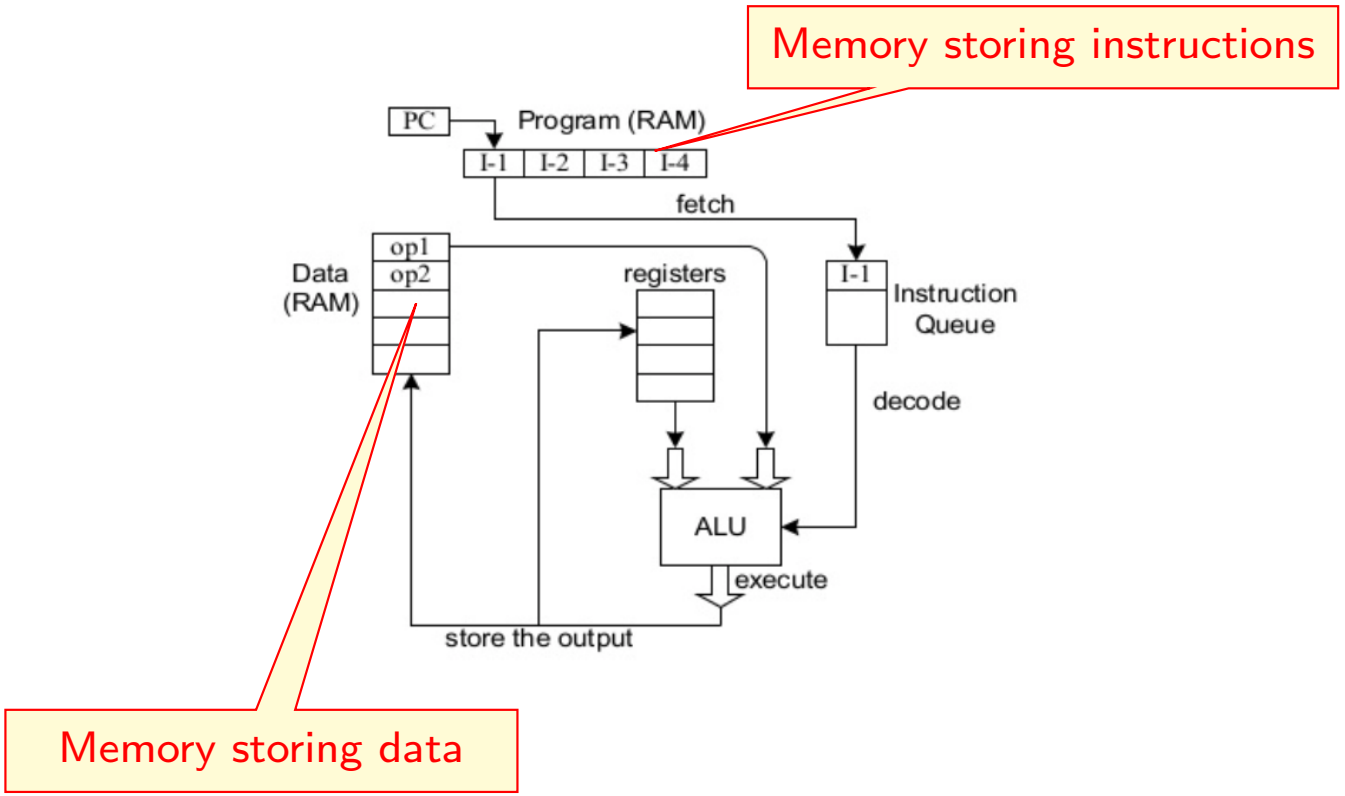
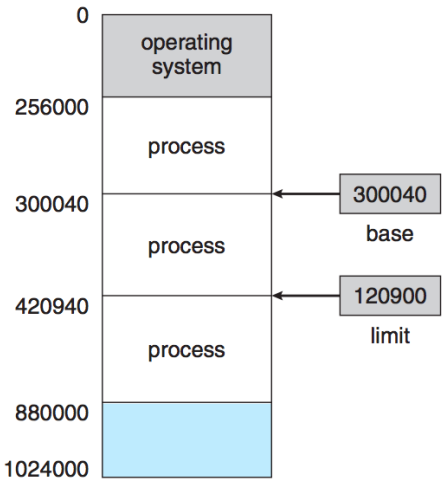
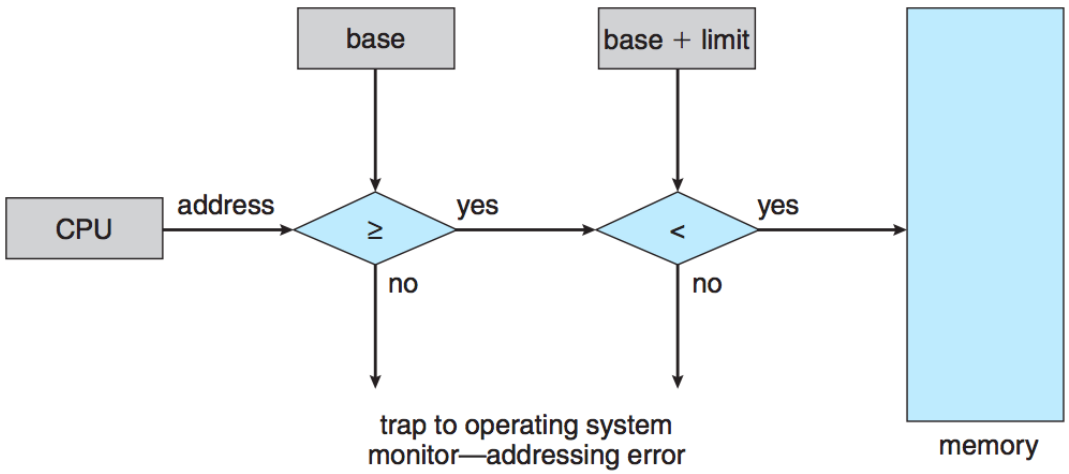


- Instructions of programs are only executed when they are in memory
- Memory management requires some hardware support

Hardware support

- Each user process has a separate memory space
- Base and limit registers give a range of the memory space





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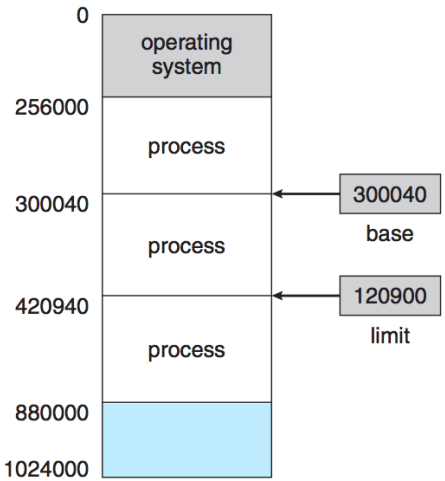
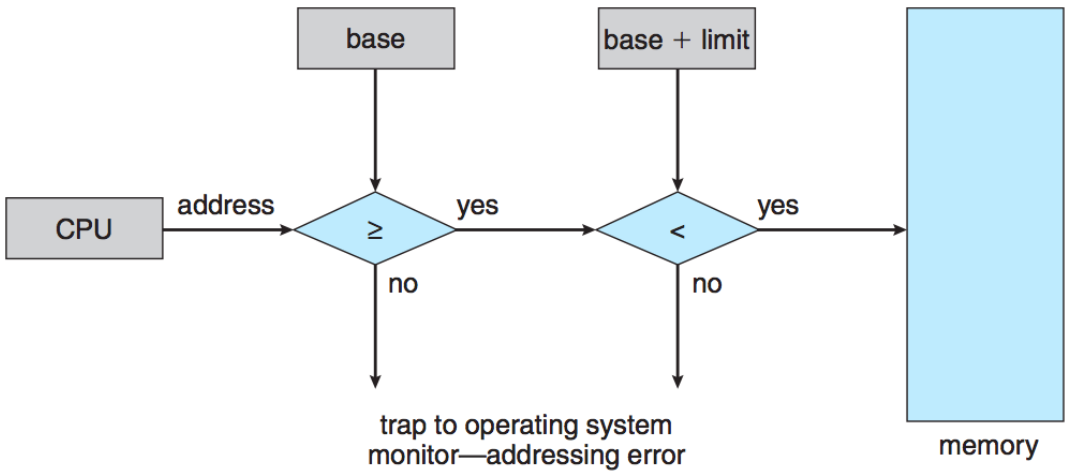
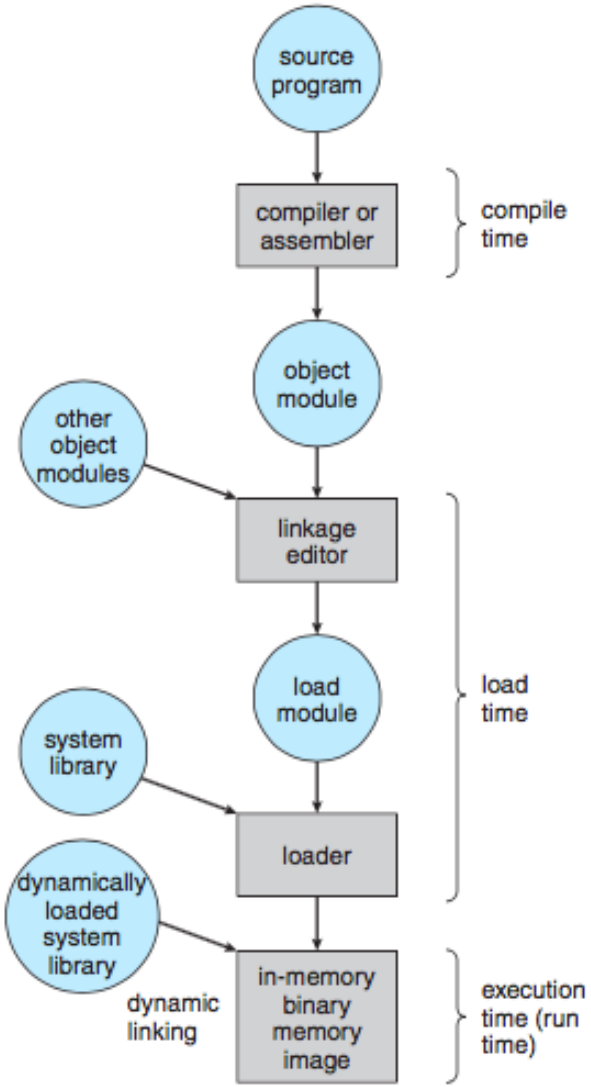




Memory protection mechanism is not applied for operating system executing in kernel mode

Address binding

User program to execution



Address binding

A process to convert one kind of high abstract memory address to low abstract memory address

- a symbolic address to a relocatable address
- a relocatable address to a absolute address

Example:

- a variable "`count`" → a relocatable address "14 bytes from the beginning of this module"
- "14 bytes from the beginning of this module" → an absolute address "74014"

Address binding

When it happens?

Binding is performed in any of following 3 steps

- Compile time: if starting location changes, absolute address must be regenerated (by compile)
- Load time: with relocatable code, only reloading is needed when starting address changes
- Execution time: if a process moved in memory, binding is delayed until its run time. Most general-purpose OSs use this method

Logical address vs. physical address

Logical address

Address generated by CPU

Physical address

Address seen by memory management unit (MMU)

Logical address vs. physical address

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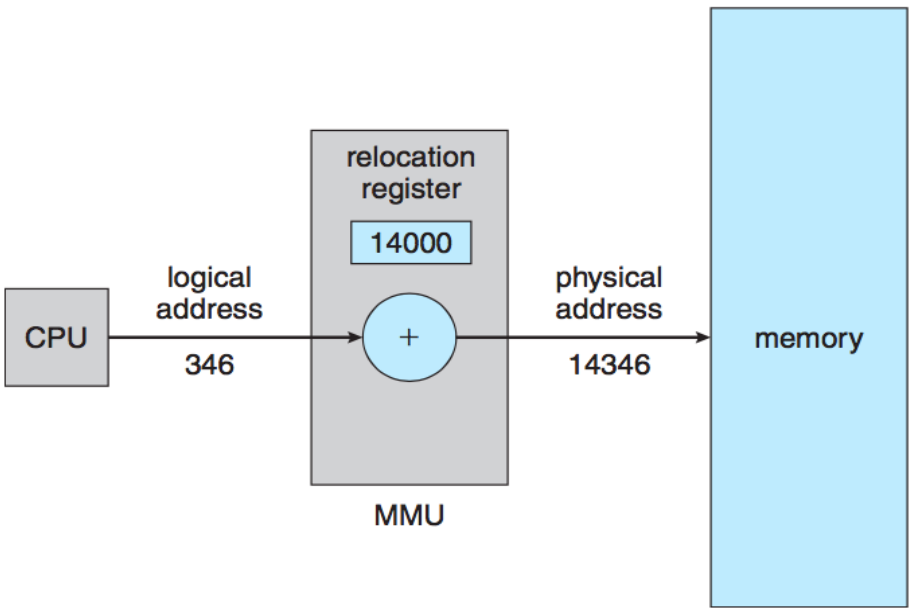

- Compile/load-time binding: logical address = physical address
- Execution-time binding: logical address ≠ physical address
  User program thinks logical (virtual) address range is $[0, max]$, but physical address range is $[R + 0, R + max]$.

Dynamic loading

Dynamic loading

A routine is not loaded until it is called

- Routine must be in relocatable load format
- Relocatable linking loader is responsible to load dynamic loading routing when a caller has not loaded yet
- Better memory=space utilization, useful to handle infrequently occuring cases
- Dynamic loading does not require support from OS

Dynamic linking and shared library

If multiple programs use a same routine, dynamic loading requires duplication of the routine in memory

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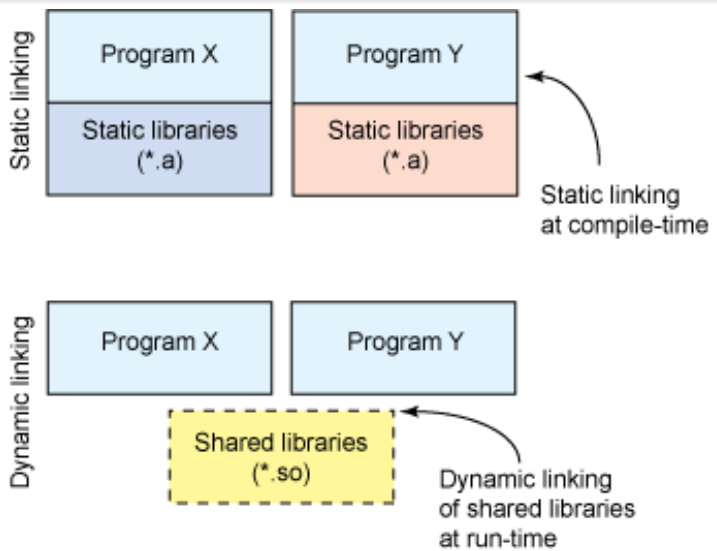
Dynamic linking

A routine is linked to user programs when the programs are run



(source:ibm)

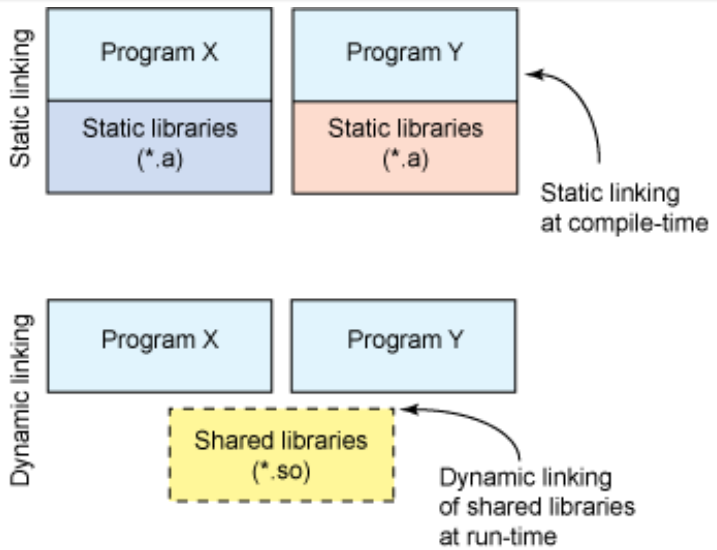
Dynamic linking and shared library

If multiple programs use a same routine, dynamic loading requires duplication of the routine in memory

Dynamic linking

A routine is linked to user programs when the programs are run

- A stub is put in the image of each reference
- The stub is replaced with the address of the needed routine, and then can be referred to by other references without loading



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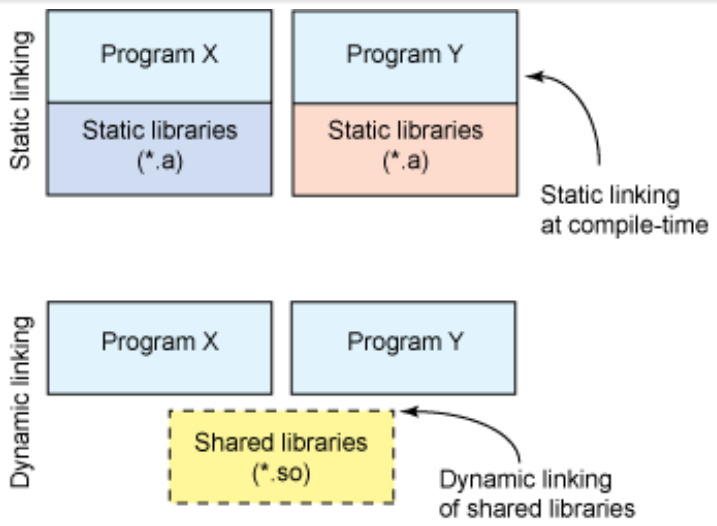

Dynamic linking requires support from OS

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1 Background

2 Swapping

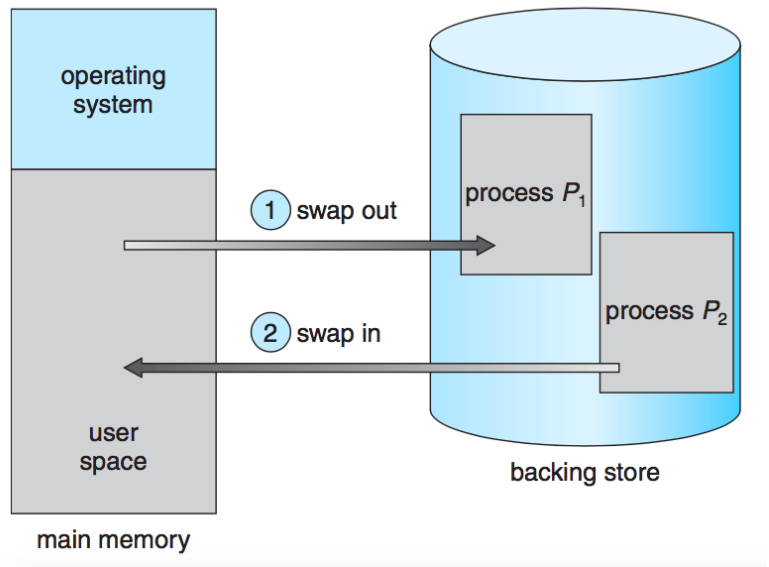
3 Contiguous memory allocation

4 Segmentation

5 Paging
- Structure of page table

Standard swapping

- Backing store must be large enough to accommodate copies of all memory images of all users
- Images of processes in ready queue are in backing store



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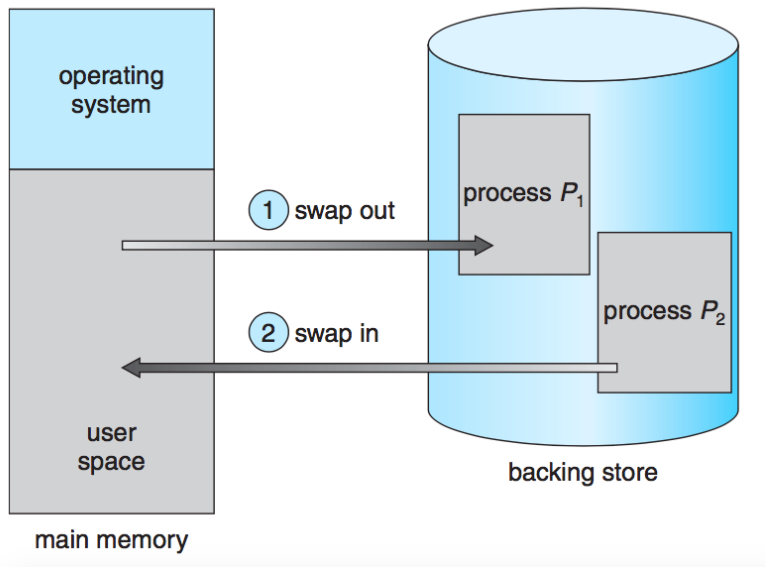

Swapping is influenced by factors

- Transfer time between fast disk and memory
- Informing mechanism to activate swapping
- I/O waiting processes should be swapped out carefully

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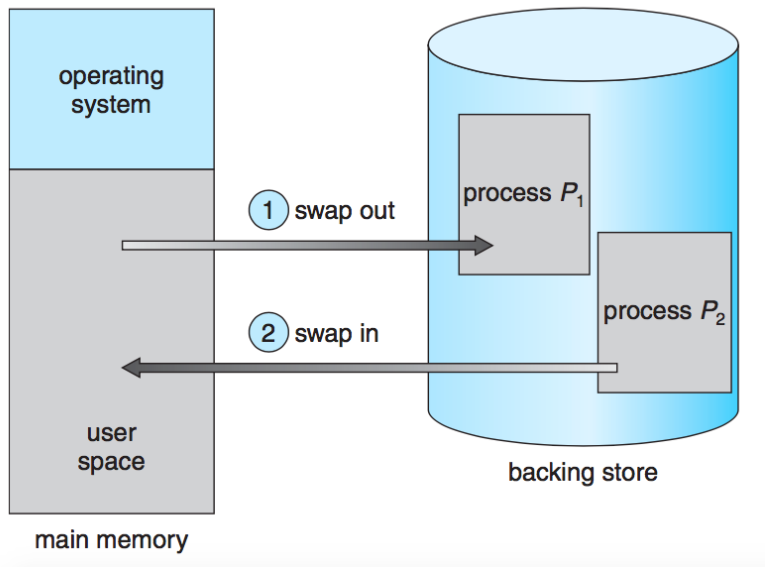

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Standard swapping is not used in modern OSs

Swapping on mobile systems

Flash drives have finite number of write/erase cycles

- Mobile OSs do not support swapping
- OSs may terminate processes if memory is not sufficient
- Developers for mobile systems must carefully allocate and release memory

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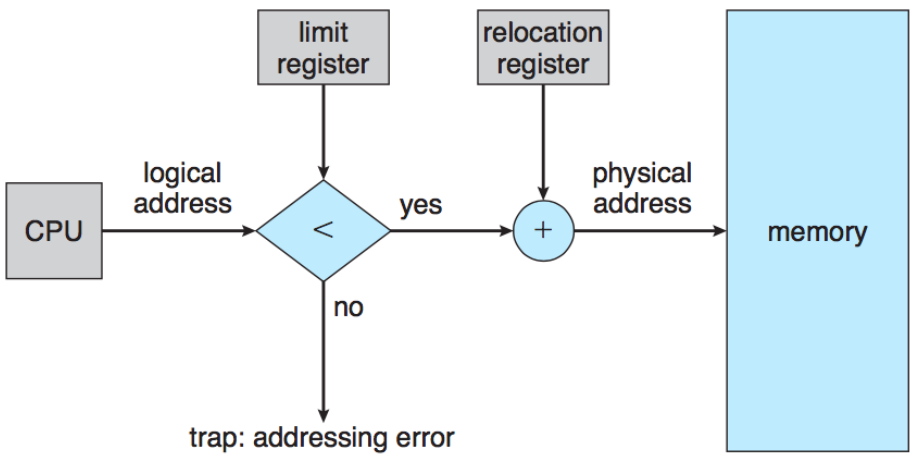
OSs use relocation register for memory protection



Memory allocation

There are 2 ways

- Fixed-partition: memory is divided into several fixed-size partitions. A process is in a single partition
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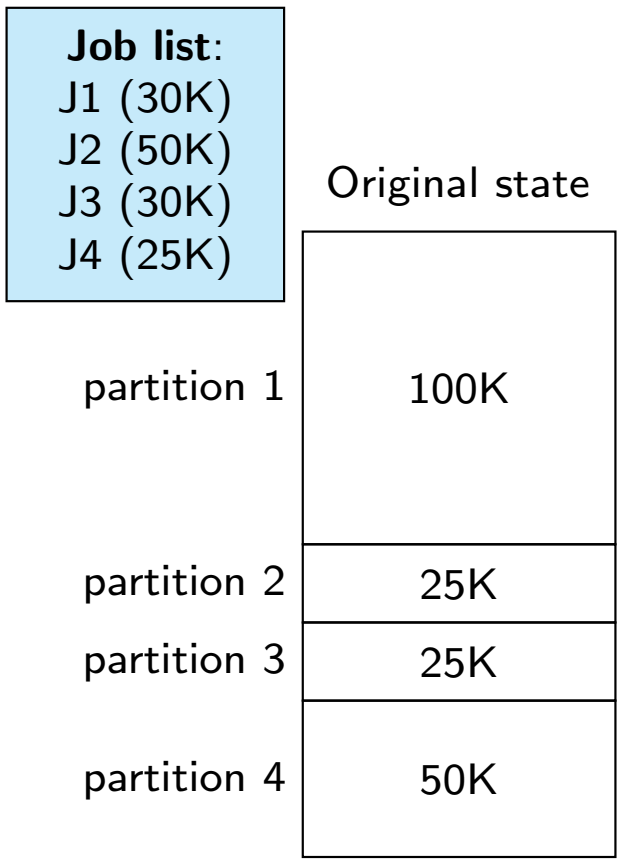

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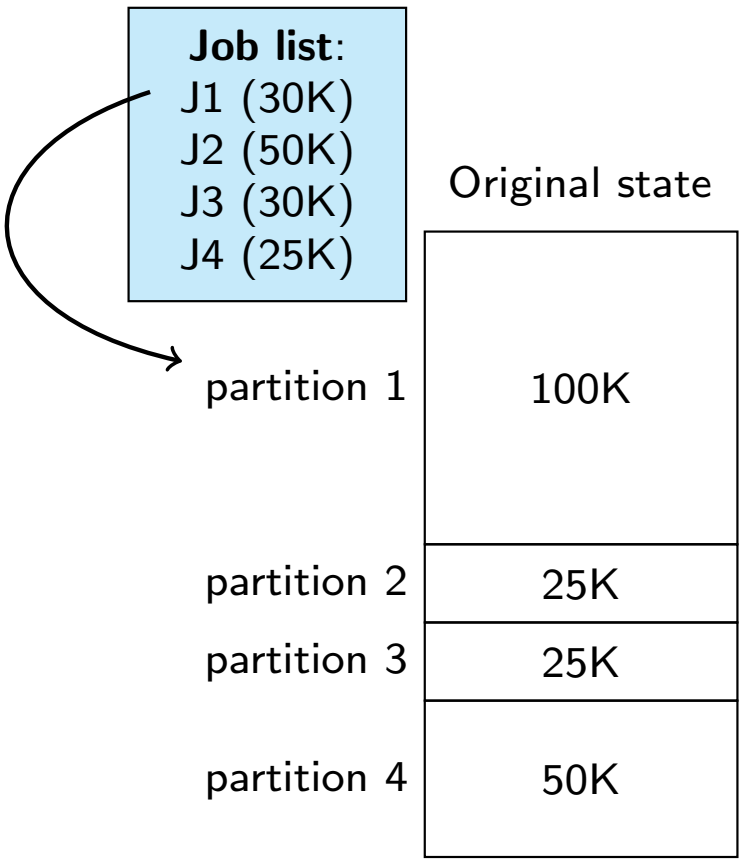

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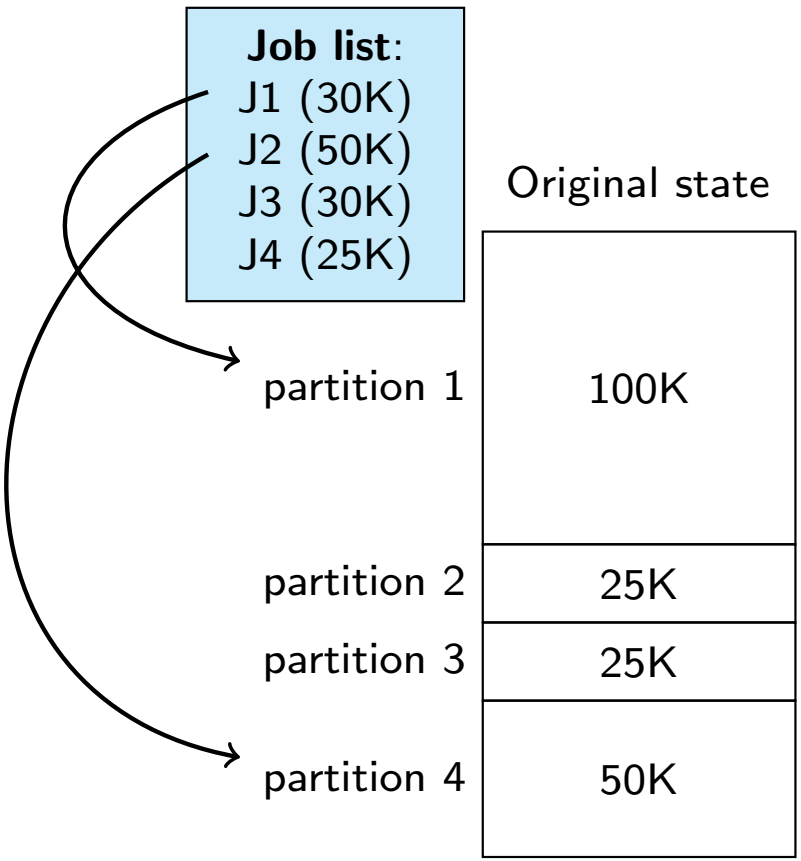

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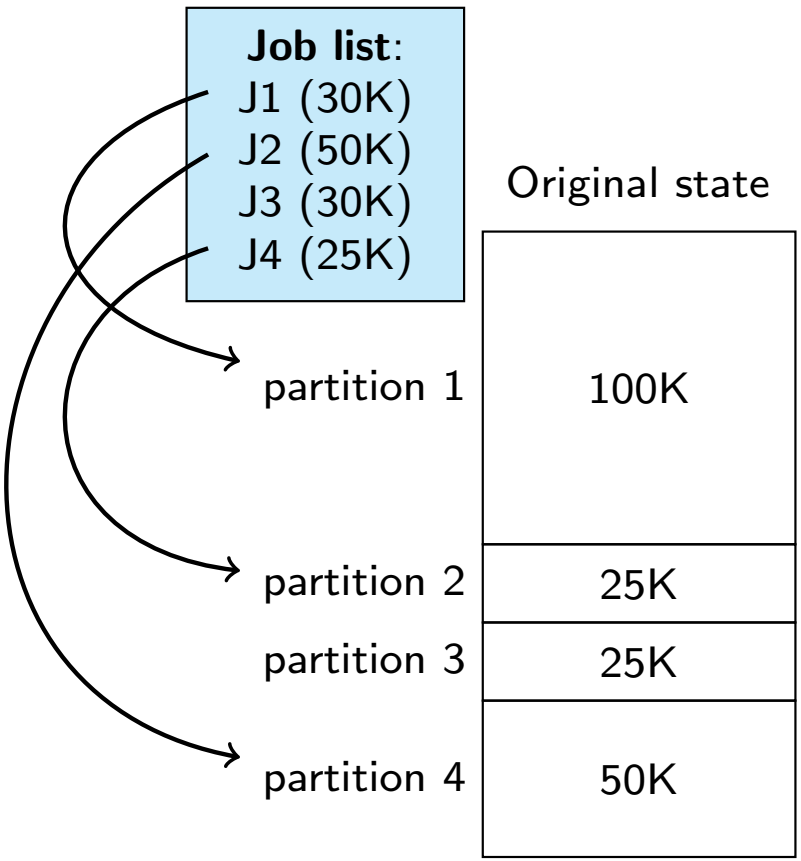

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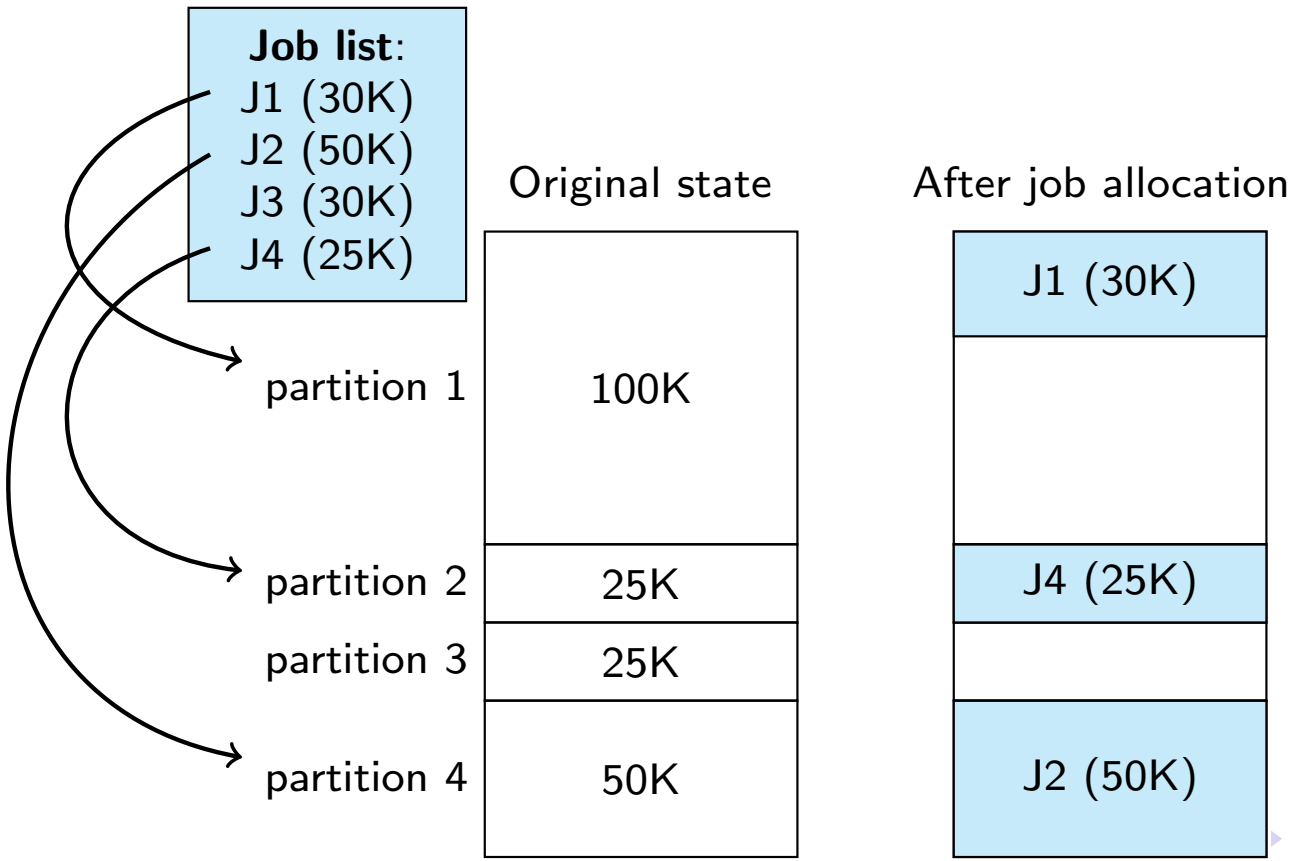
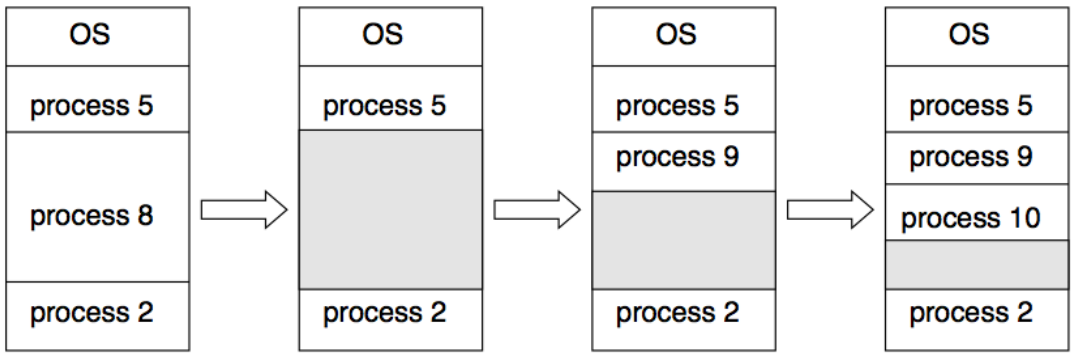


Variable partition

- Fixed-partition scheme limits the level of multiprogramming
- Variable-partition scheme needs a mechanism to deal efficiently with set of holes



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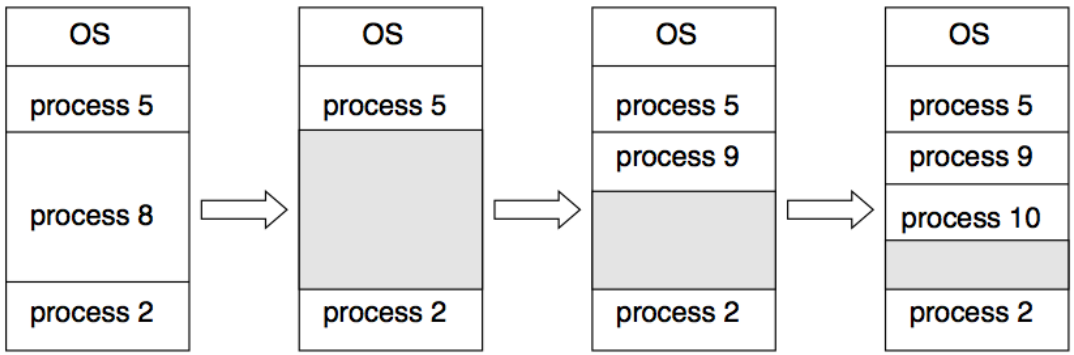
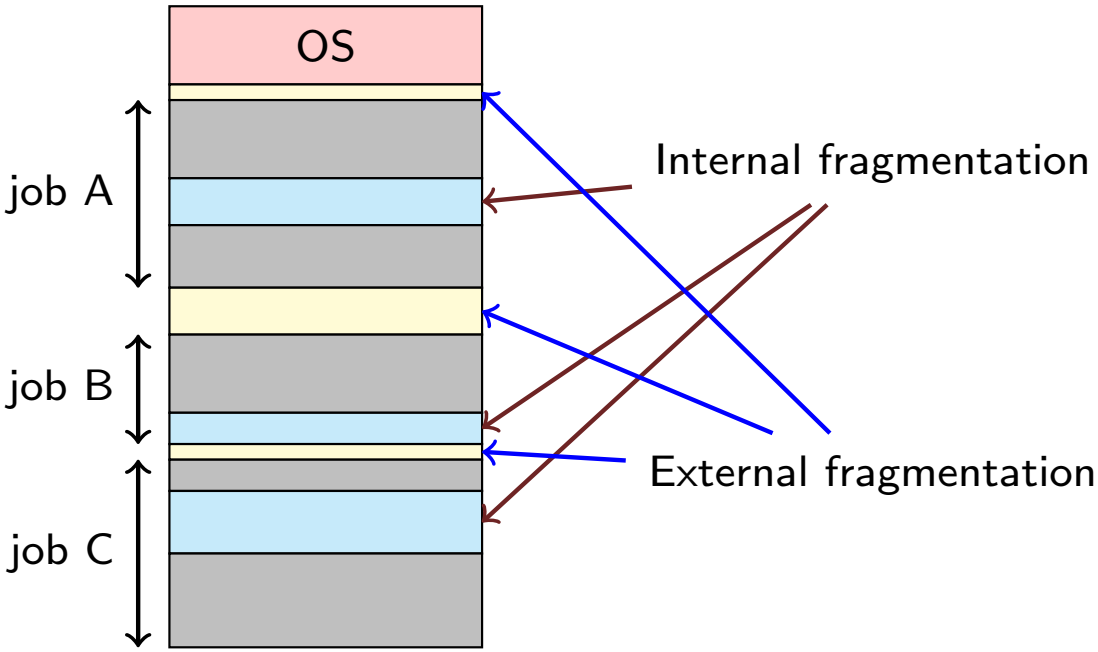


  - State: list of available (free) block sizes, input queue
  - Dynamic storage-allocation problem: how to satisfy a request of size n from a list of free holes
  - Strategies: first-fit, best-fit, worst-fit

Fragmentation

Internal vs. external



- External fragmentation: small holes which cannot satisfy large request
- Internal fragmentation: unused memory which has been allocated for process

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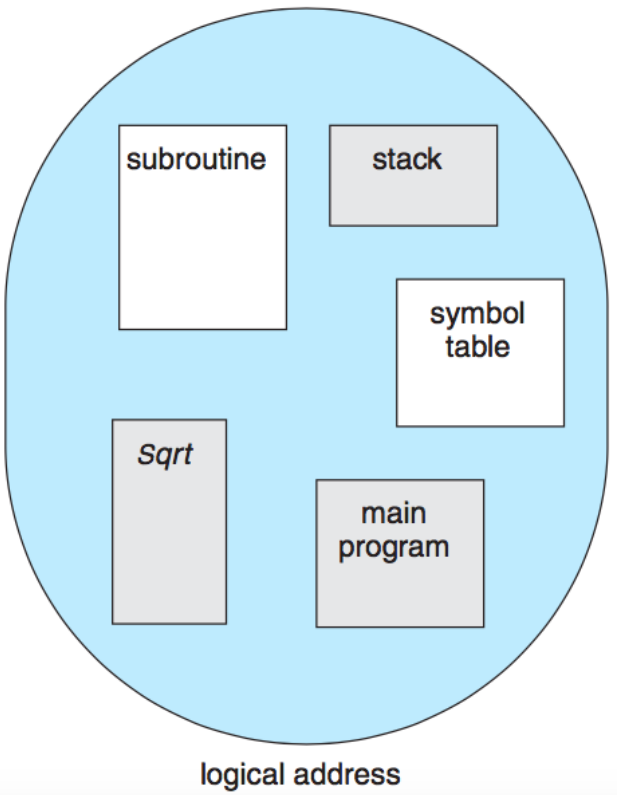
What is segmentation ?

Memory management should be convenient to both OS and programmers



Programmers think of programs as set of data structures and methods. With memory, they need

- Collection of variable-sized memory blocks (segments)
- No neccessary ordering among segments

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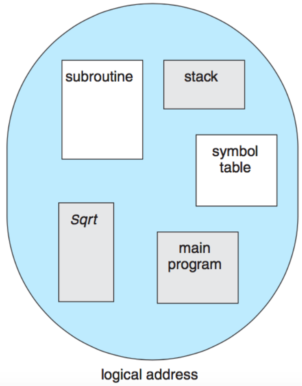

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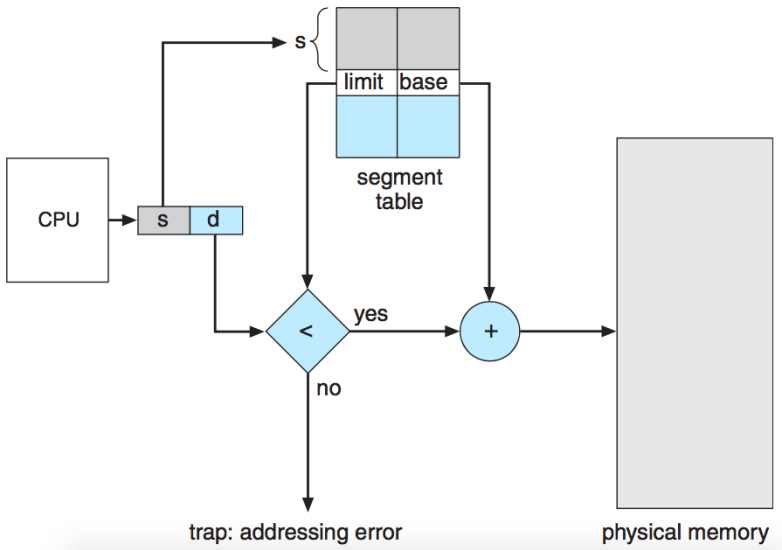
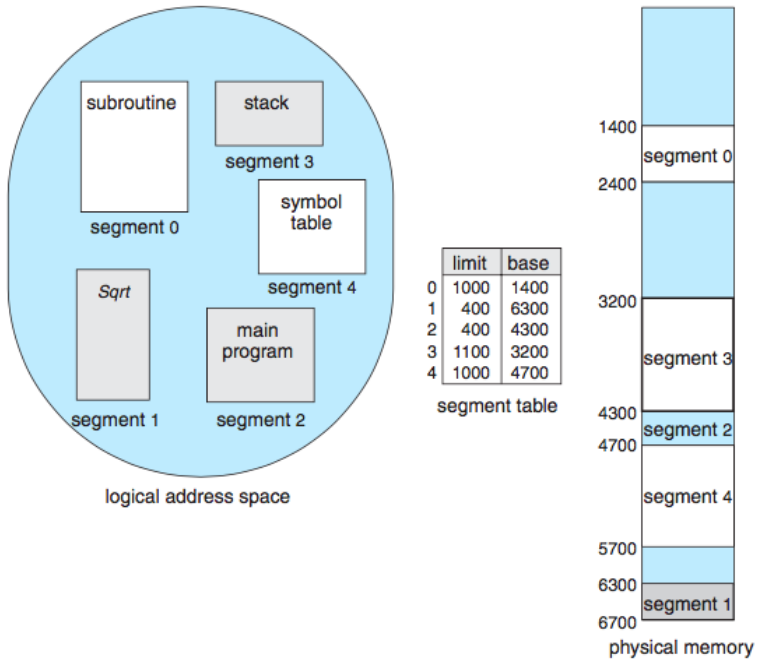
Segment = <segment-number, offset>

Segmentation hardware

Segment address is 2-dimensional, but physical memory address is 1-dimensional





- Segment table is an array of base–limit register pairs

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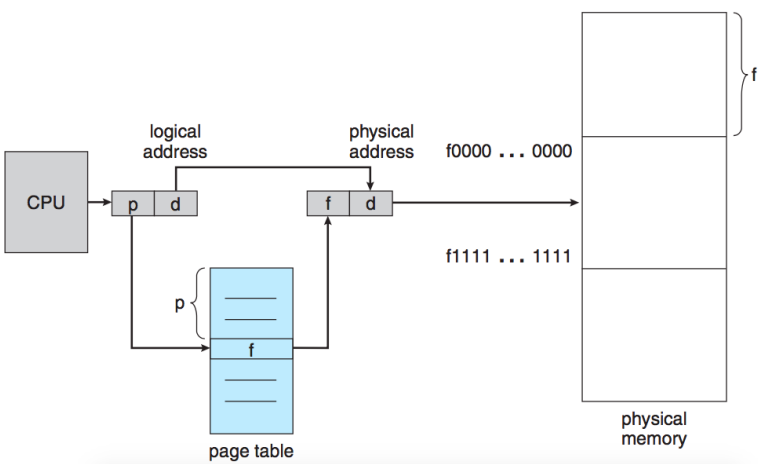
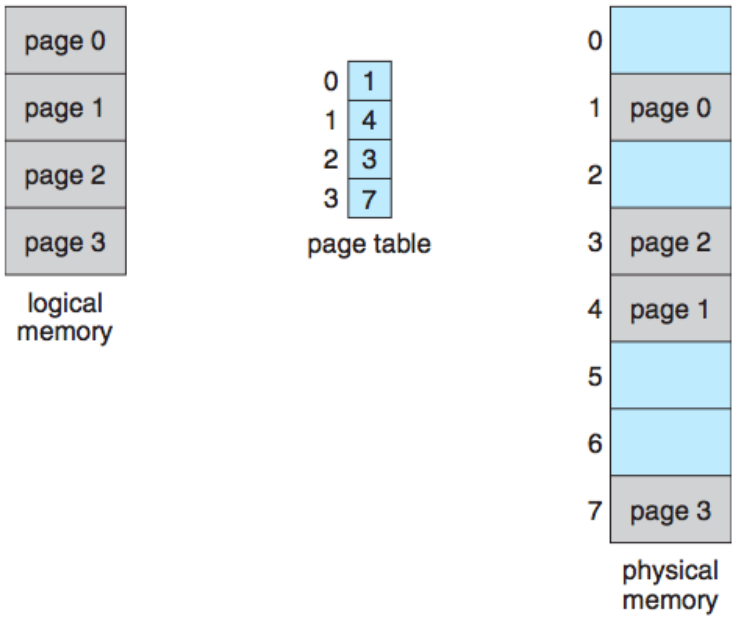
What is paging ?

Segmentation still has external fragmentation, requiring compaction

- Physical memory is divided into fixed-sized blocks (frame)
- Logical memory is divided into same-sized blocks (page)

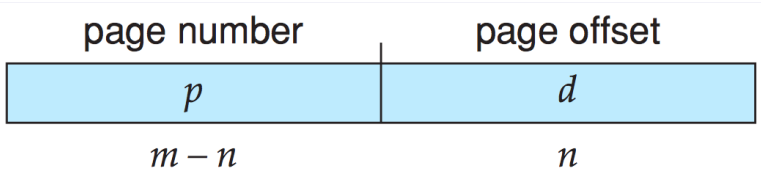




Page address = <page number, page offset>

Paging in practice

Logical address space $= 2^m$
Page size $= 2^n$



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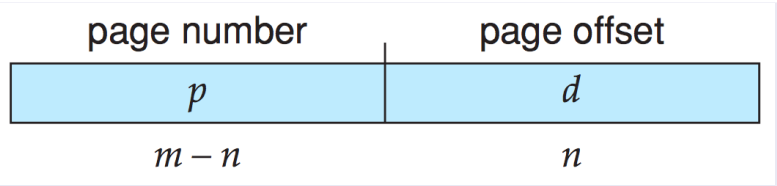

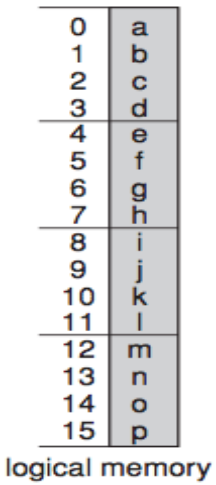

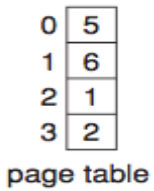

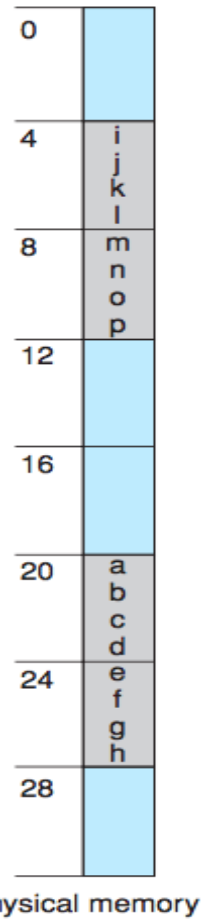

$n = 2, m = 4$

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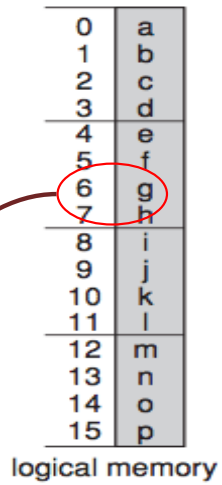
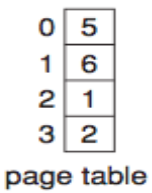
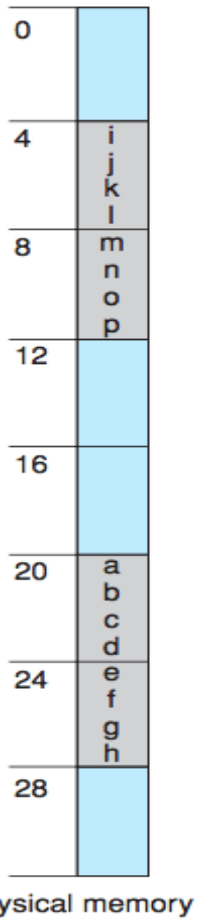
page number	page offset
p	d
$m-n$	n







$6 = 0110_2$

page=01_2
offset=10_2

$n = 2, m = 4$

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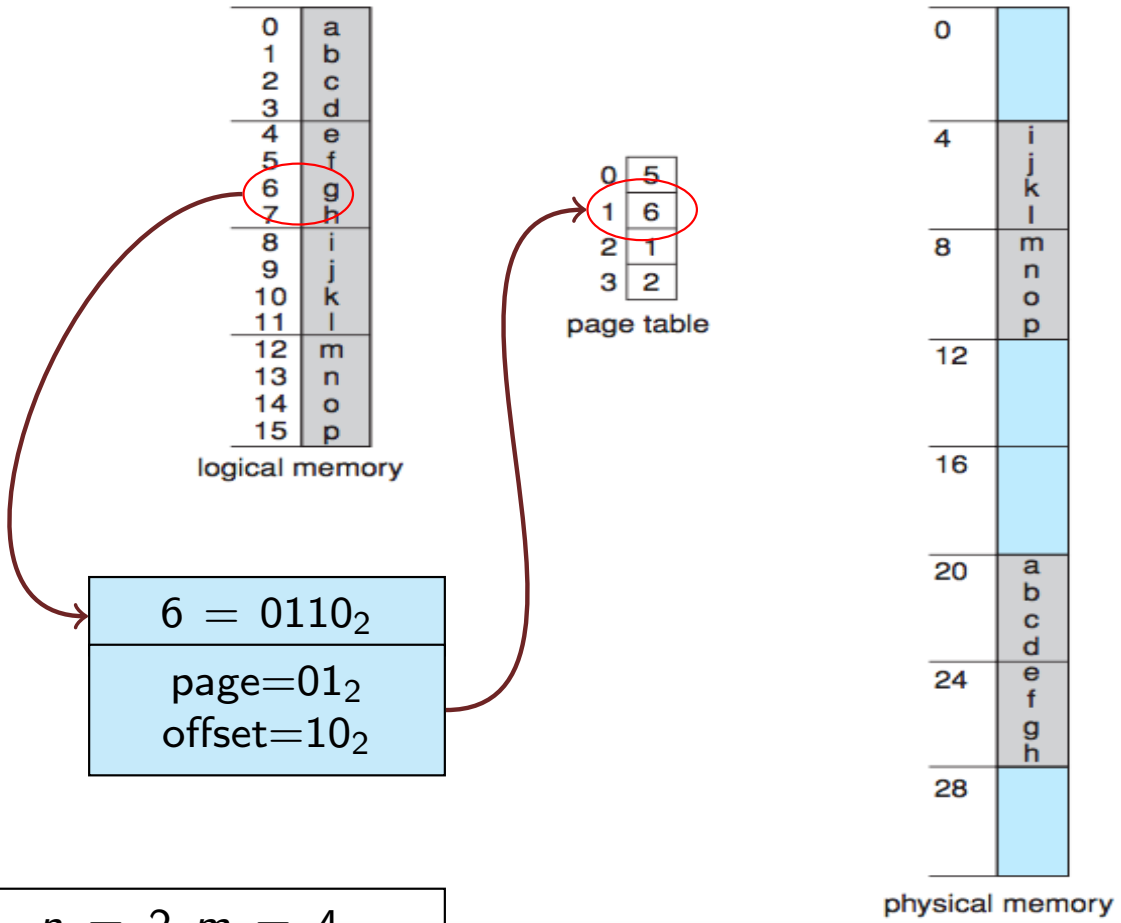

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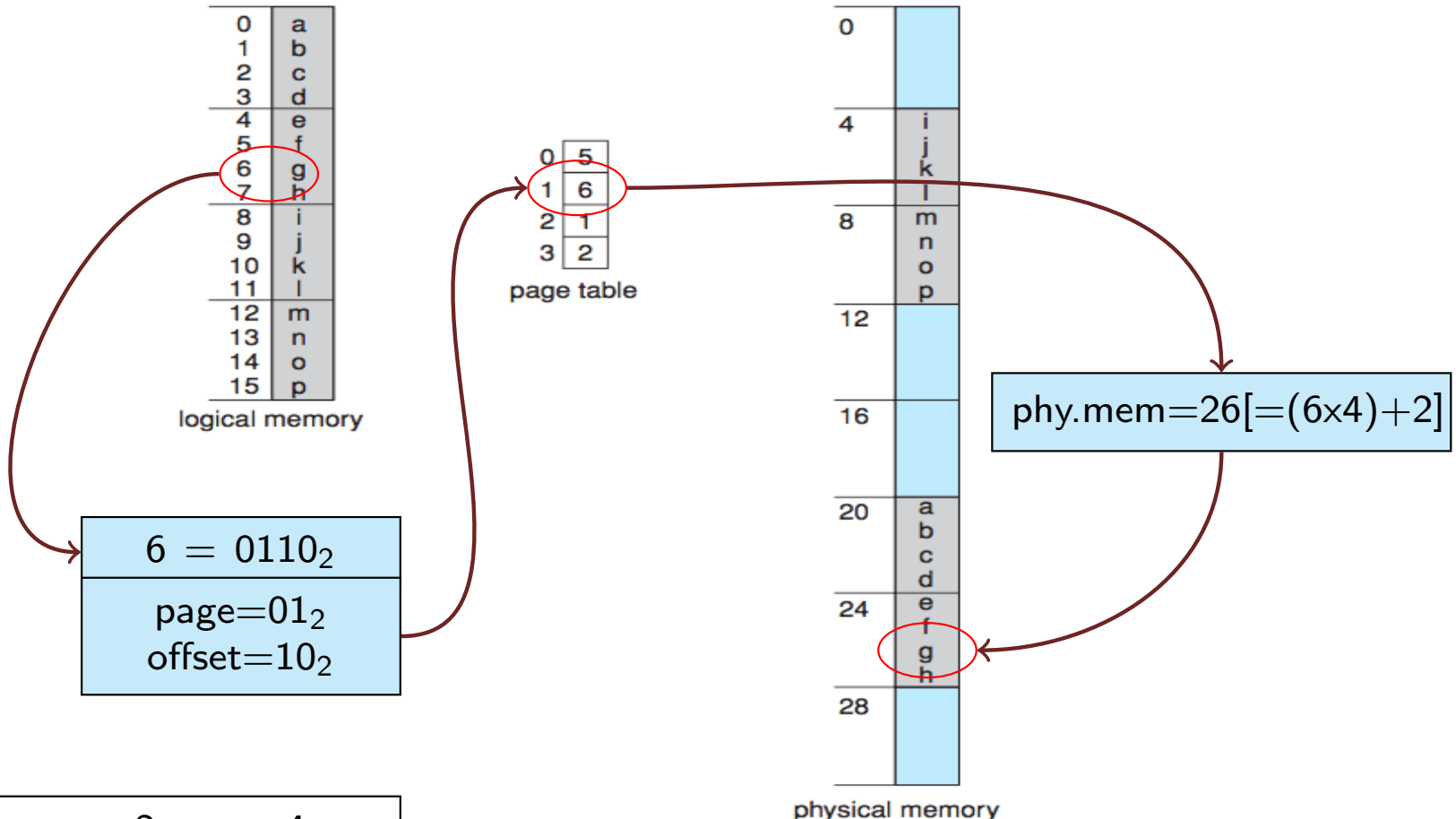

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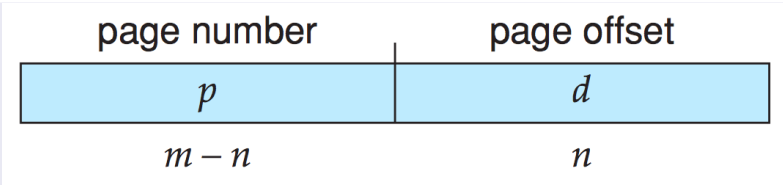
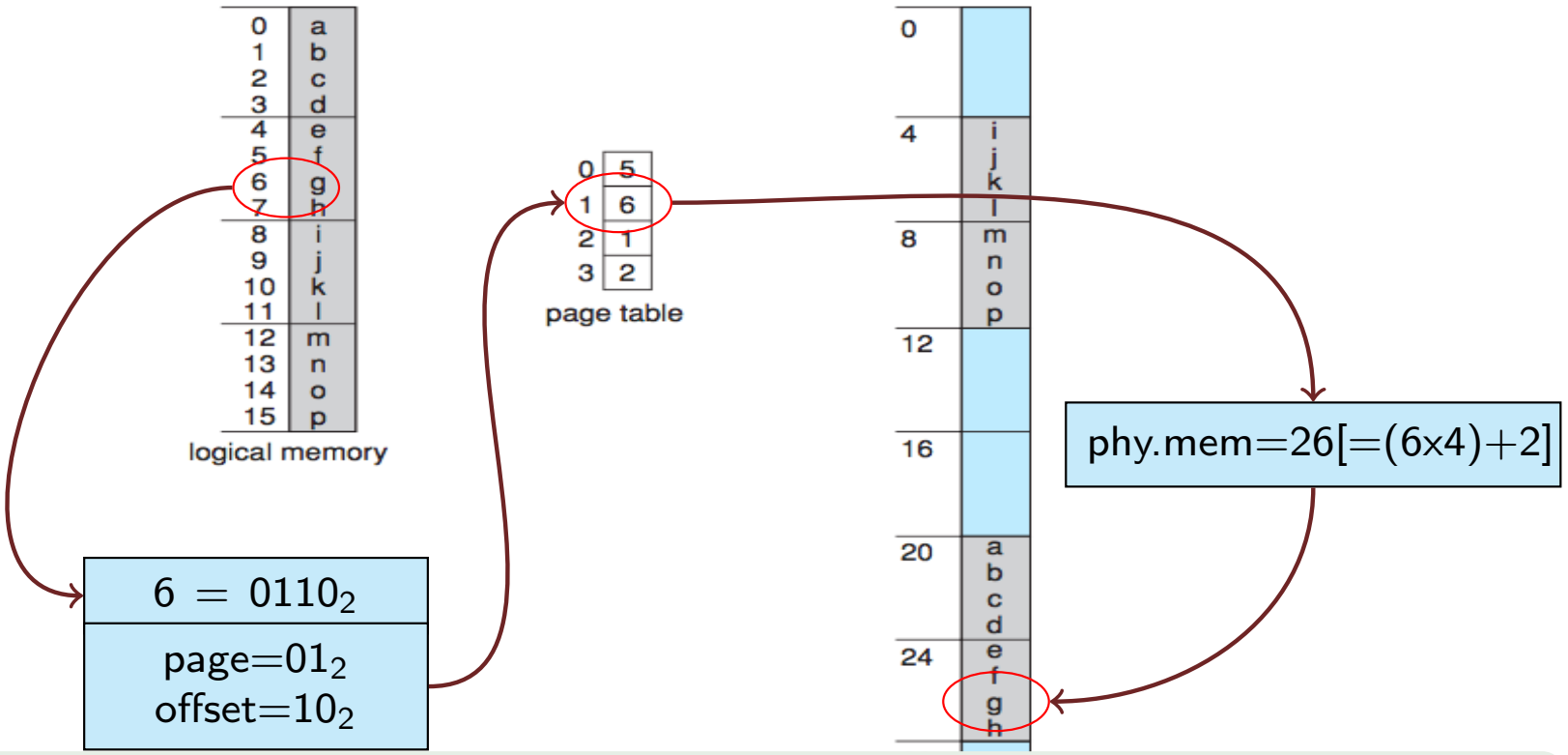


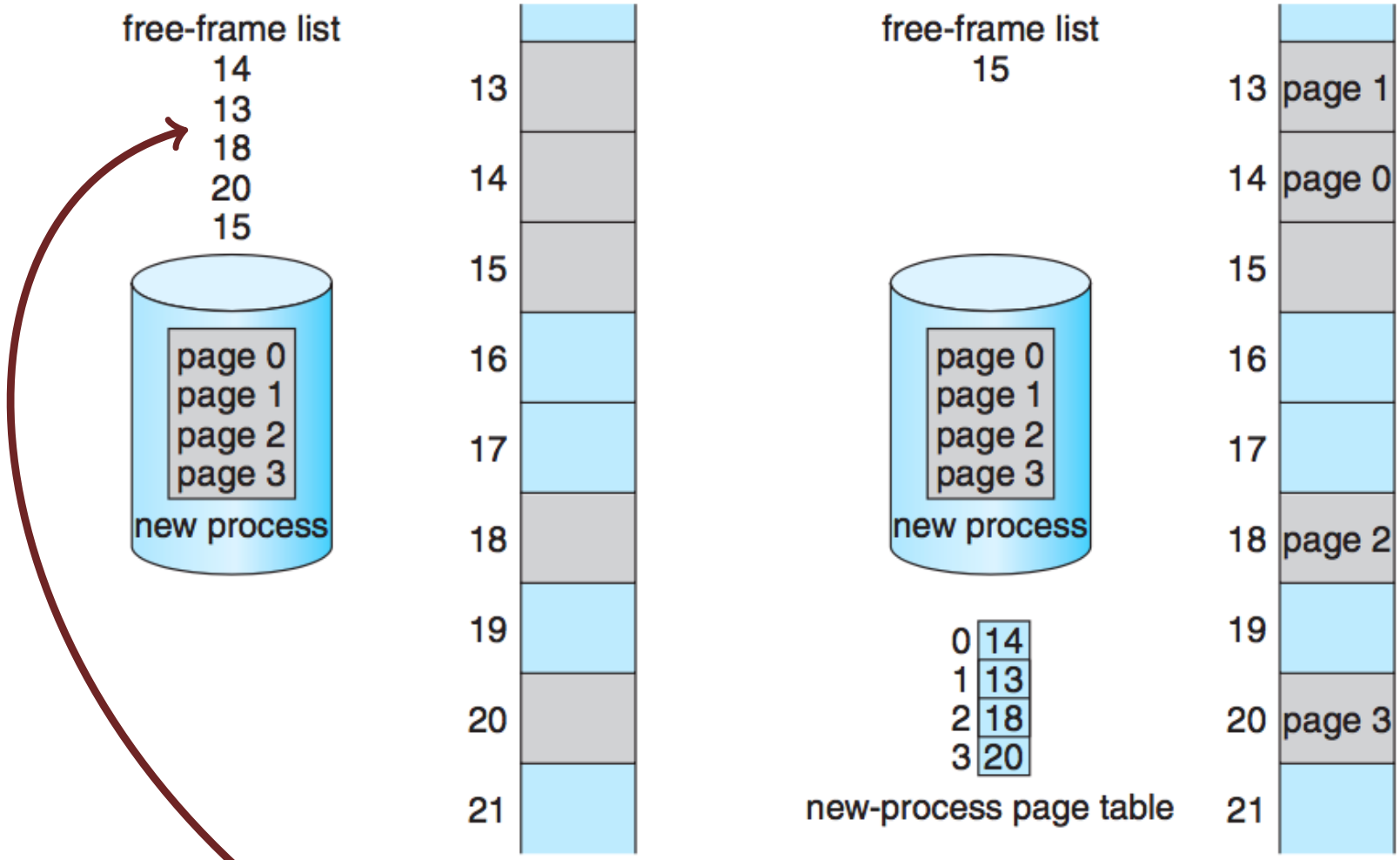


Paging has no external fragmentation, but has internal fragmentation.

Frame allocation

A process can be given a non-contiguous set of frames

Frame allocation



A process can be given a non contiguous set

A data structure (frame-table) is needed to manage frames.

Hardware support

- Page table stored in main memory,
  - A page table for each process, pointer to it in PCB
  - Few page tables for all processes

Hardware support

- Page table stored in main memory,
  - A page table for each process, pointer to it in PCB
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- Page-address translation overhead $\Rightarrow$ hardware support
  - Page-table base register (PTBR): point to page table
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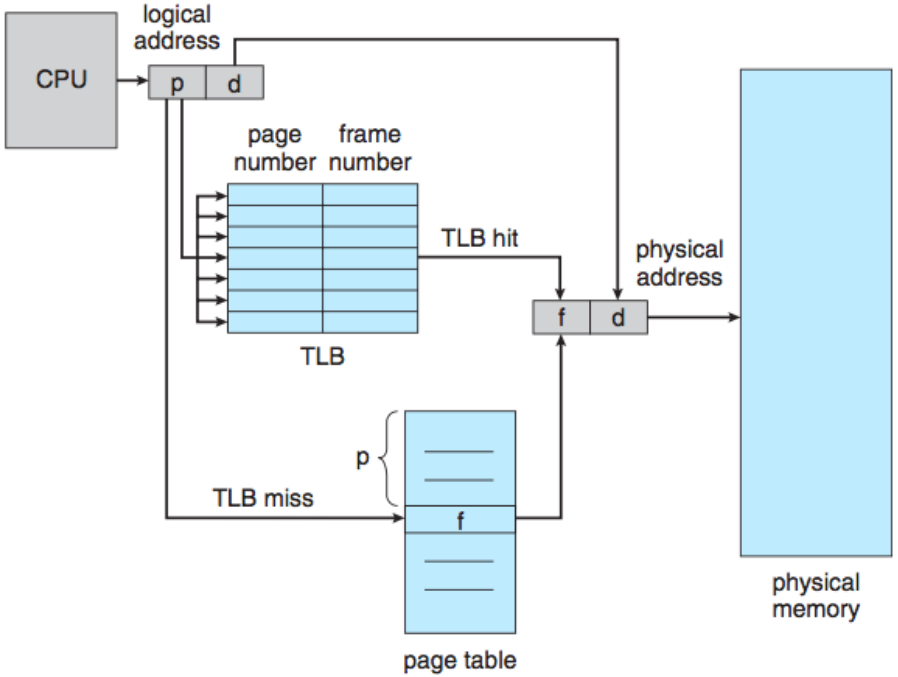
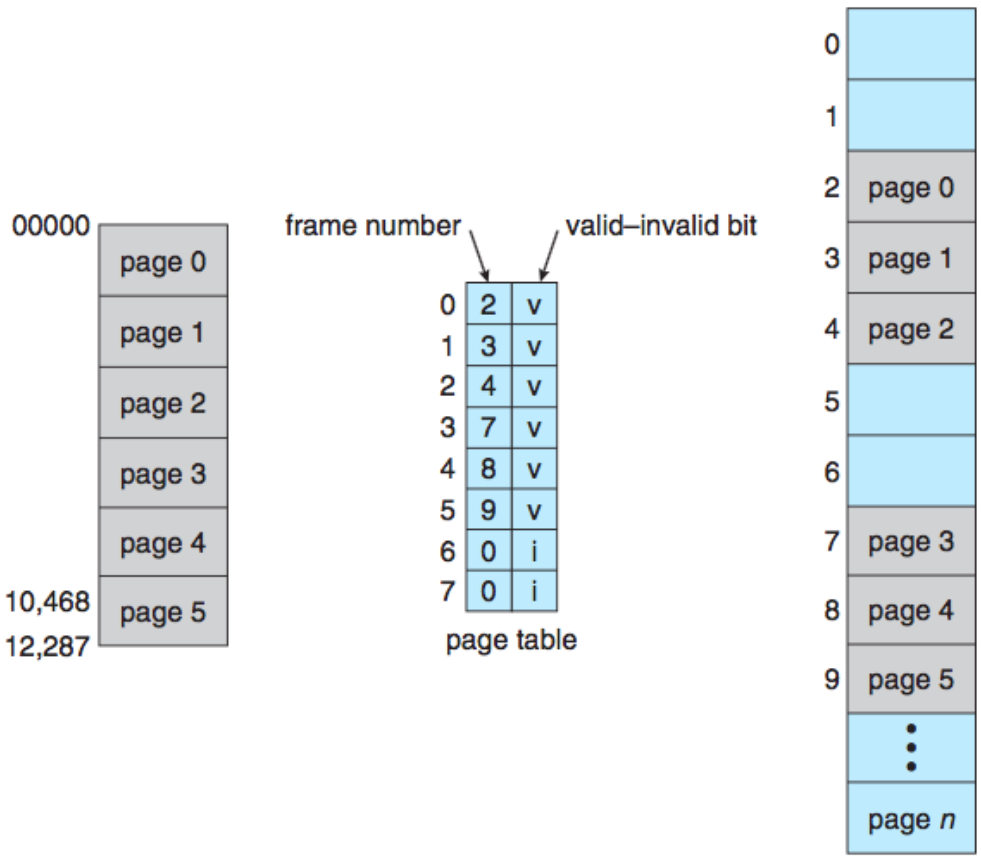


hit ratio

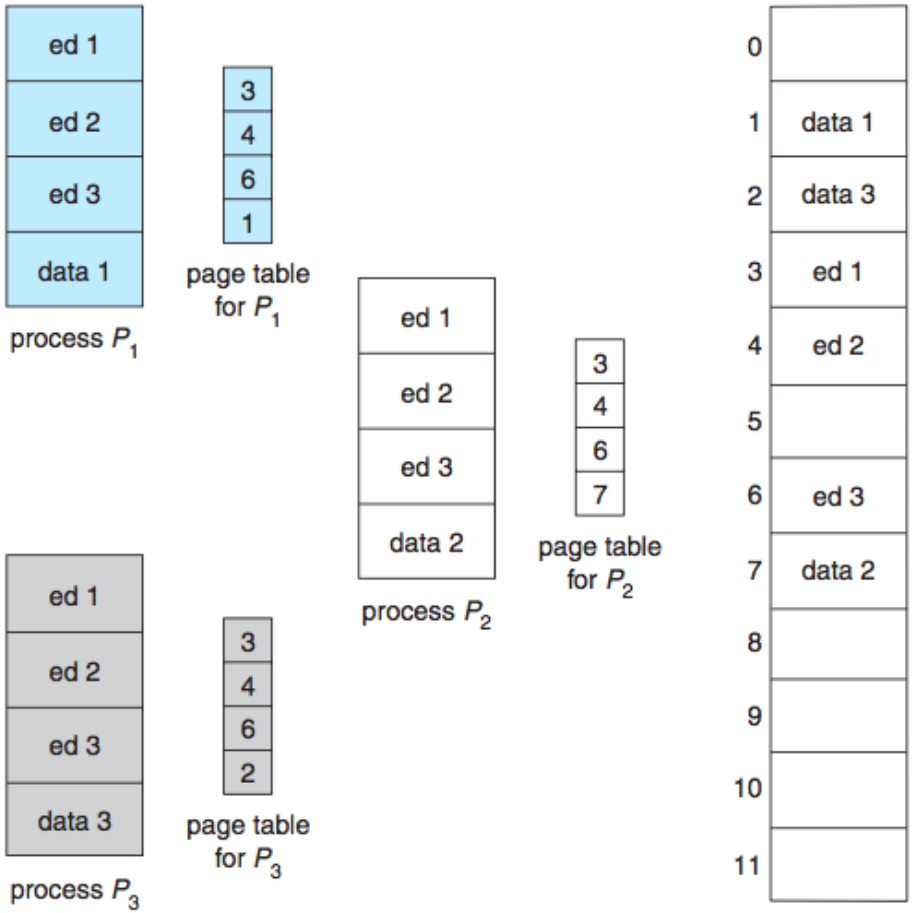
- 80%
  effective access time =
  $80\% \times 100(ns) + 20\% \times 200(ns) = 120(\text{ns})$
- 99%
  effective access time =
  $99\% \times 100(ns) + 1\% \times 200(ns) = 101(\text{ns})$

Protection

- From access permission: read-write/read-only bit
- From out-of-range access: valid-invalid bit
  - Just keep a small range of pages ⇒ page-table length register (PTLR)



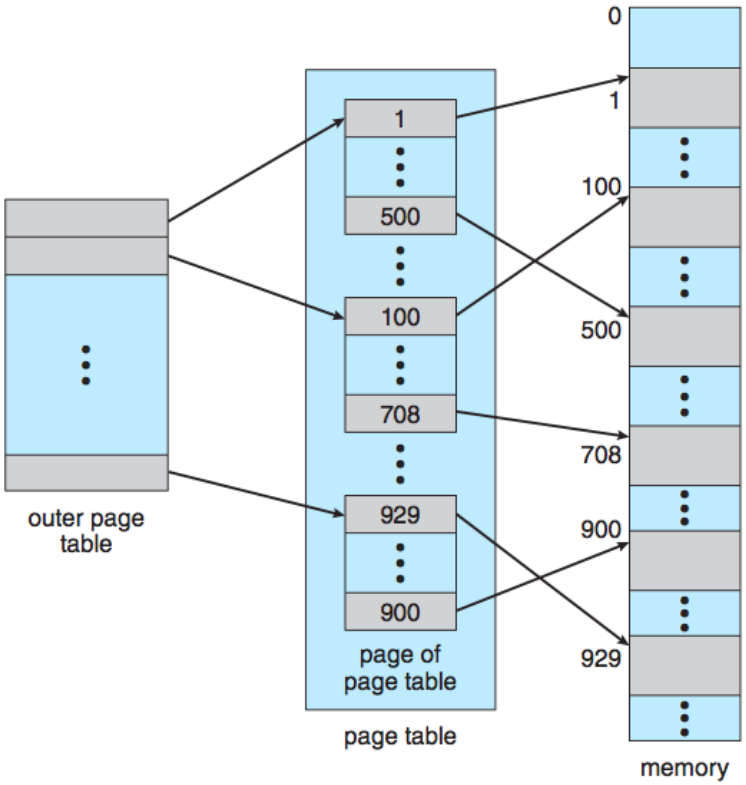
Shared pages

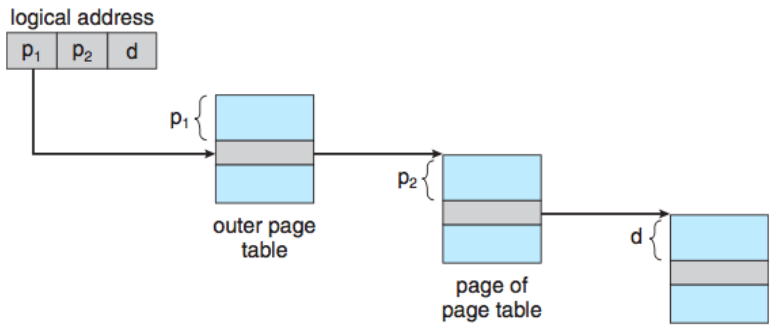


An advantage of paging is possibility of sharing common code

Hierarchical paging

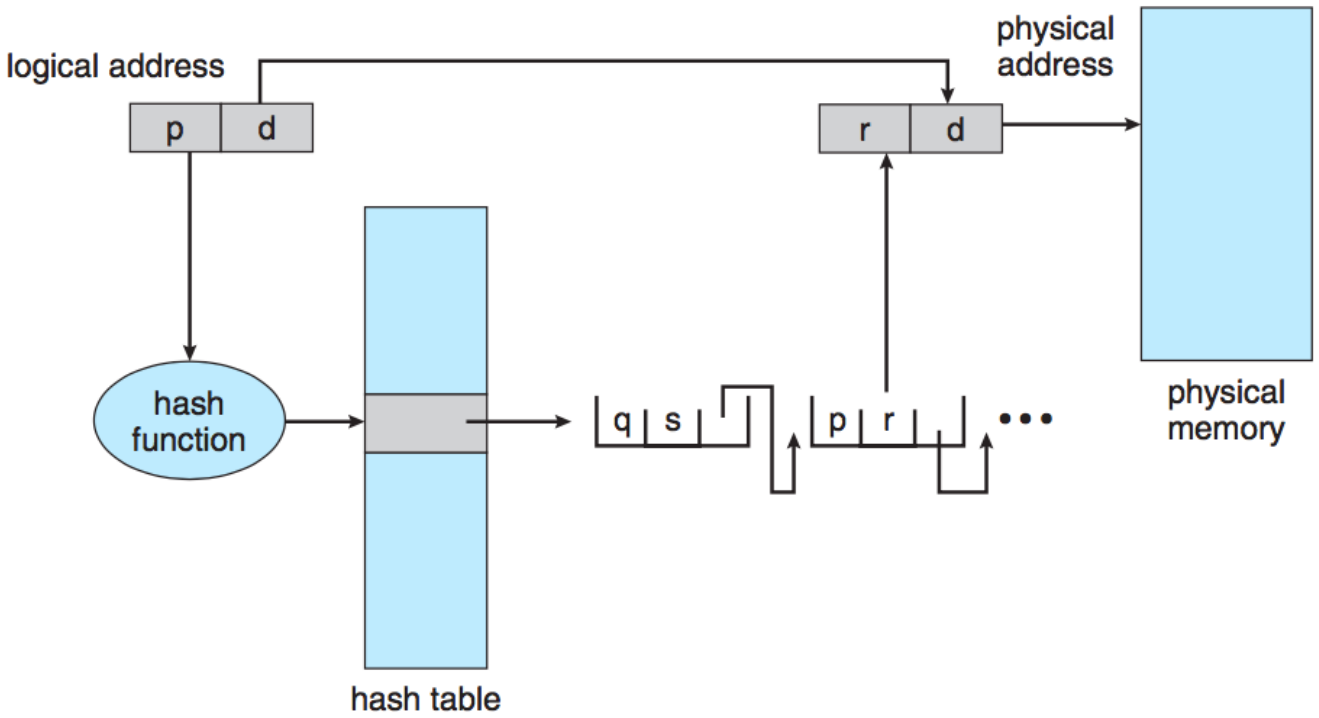
2-level paging scheme





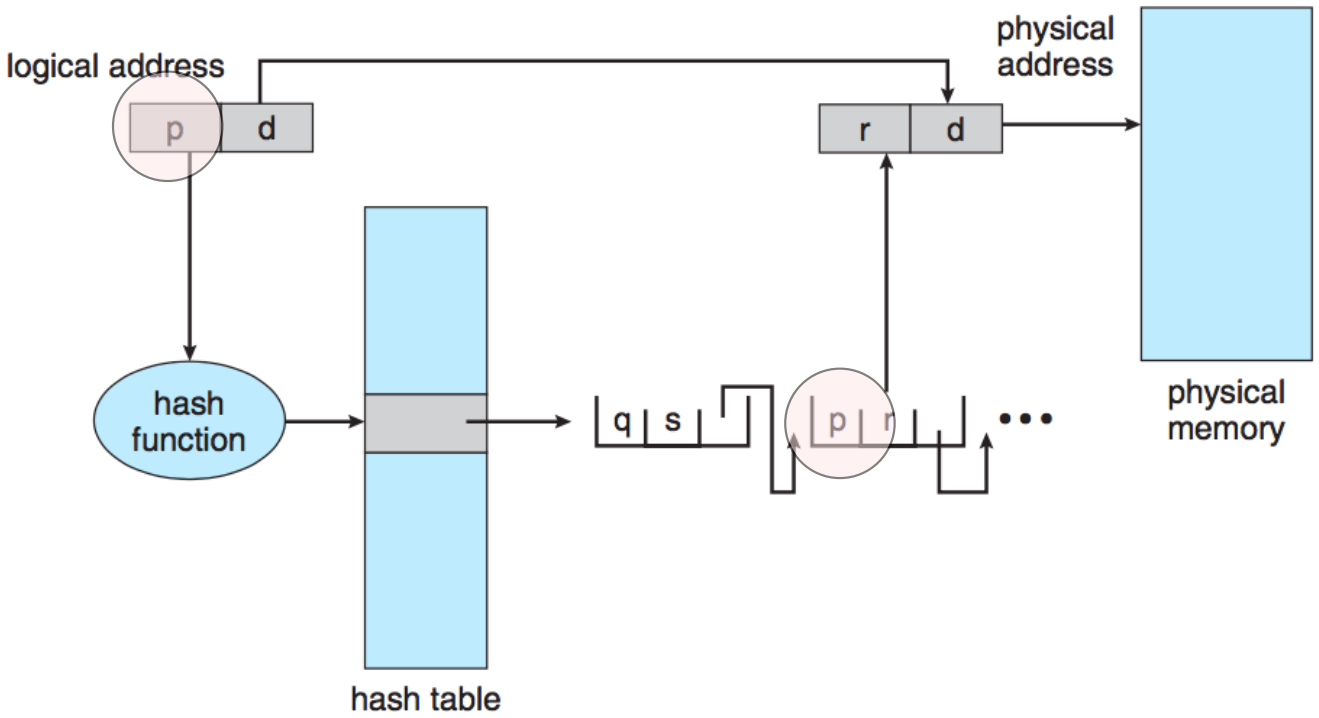
- It is often applied for 32(or less)-bit address space

Hashed paging



- It is often applied for 32(or more)-bit address space

Hashed paging



- It is often applied for 32(or more)-bit address space

Inverted paging

Just keep a page table for all processes. PID is needed to search for an address-space identifier