Operating System Principles

操作系统原理

Memory Management

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Objectives

- No Memory Abstraction
- Basic Memory Management
- ~~*Virtual Memory Management*~~

Parkinson's law

Programs expand to fill the memory available to hold them!

Memory Management

- Memory is an important resource that must be carefully managed

While the average home computer nowadays has a thousand times as much memory as the IBM 7094, the largest computer in the world in the early 1960's

- Memory hierarchy
  - *Volatile* cache memory

a small amount,very fast,expensive

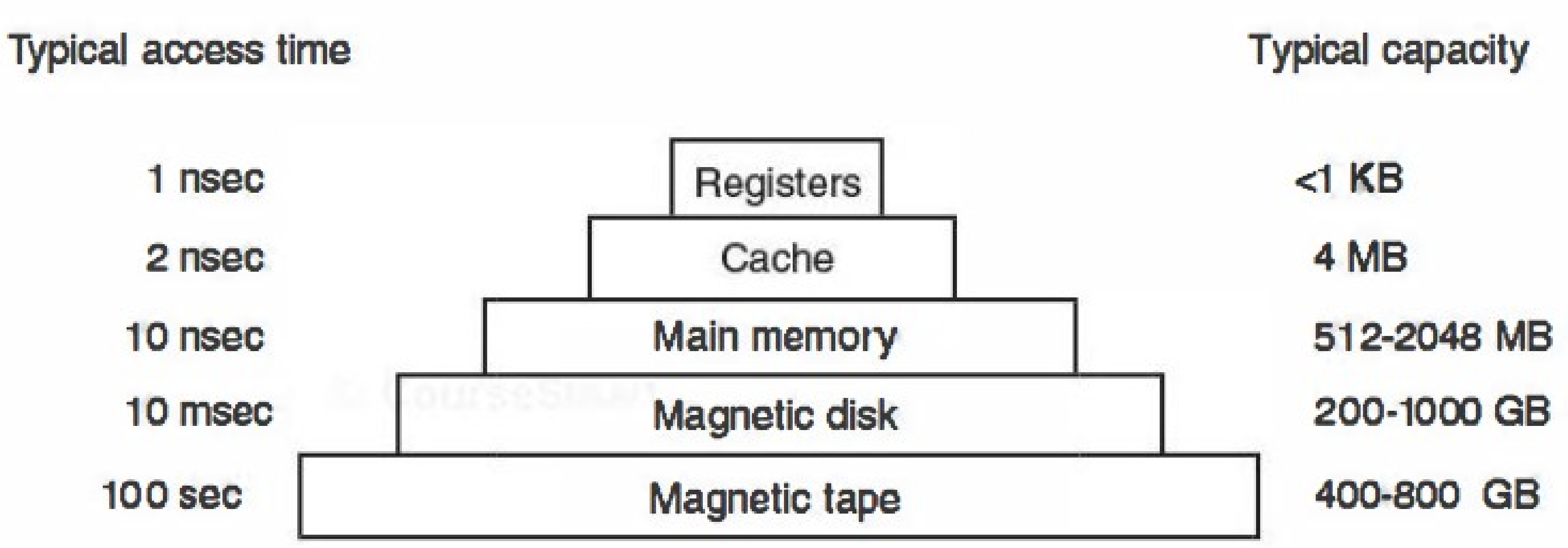
  - Volatile main memory(RAM)

tens of megabytes, medium-speed, medium-price

  - Nonvolatile disk storage

tens or hundreds of gigabytes, slow, cheap

Memory Hierarchy



Memory Management

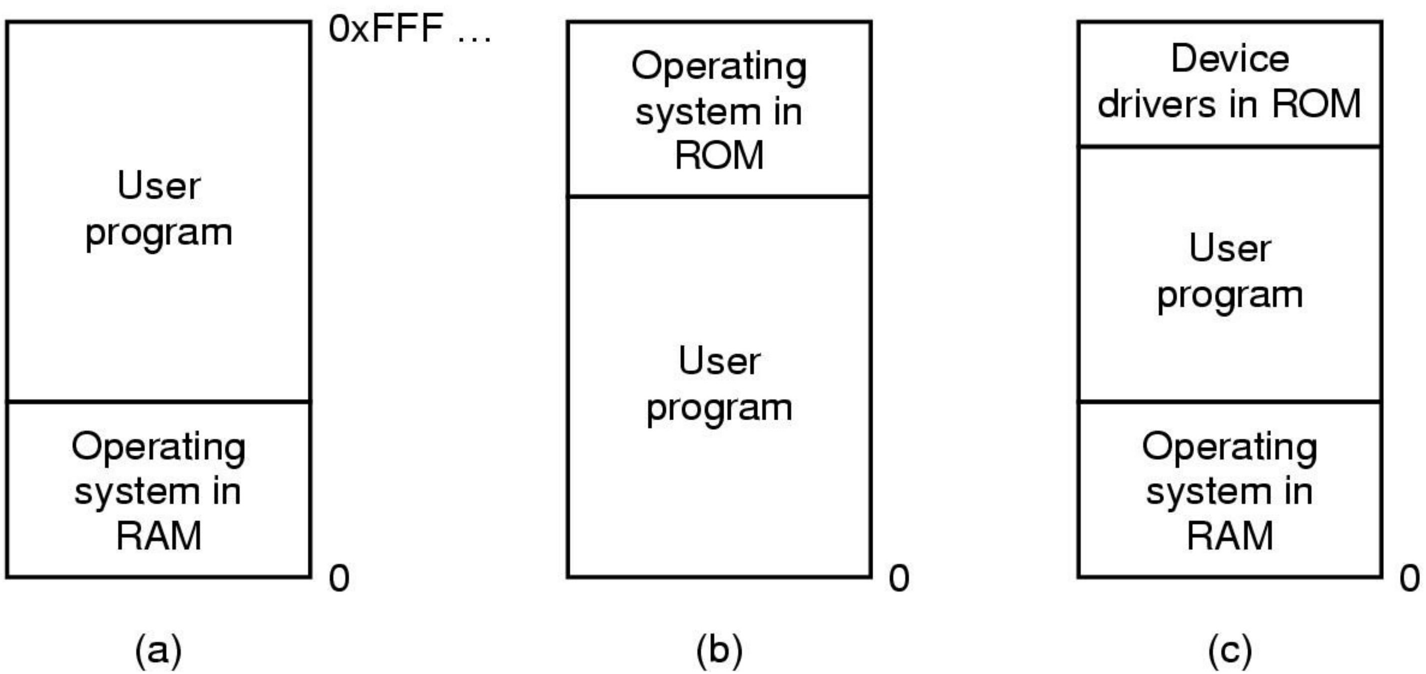
- extend main memory
- control data transmission between main memory and storage
- main memory allocation and revoke
- main memory share and protection

No Memory Abstraction

No Memory Abstraction

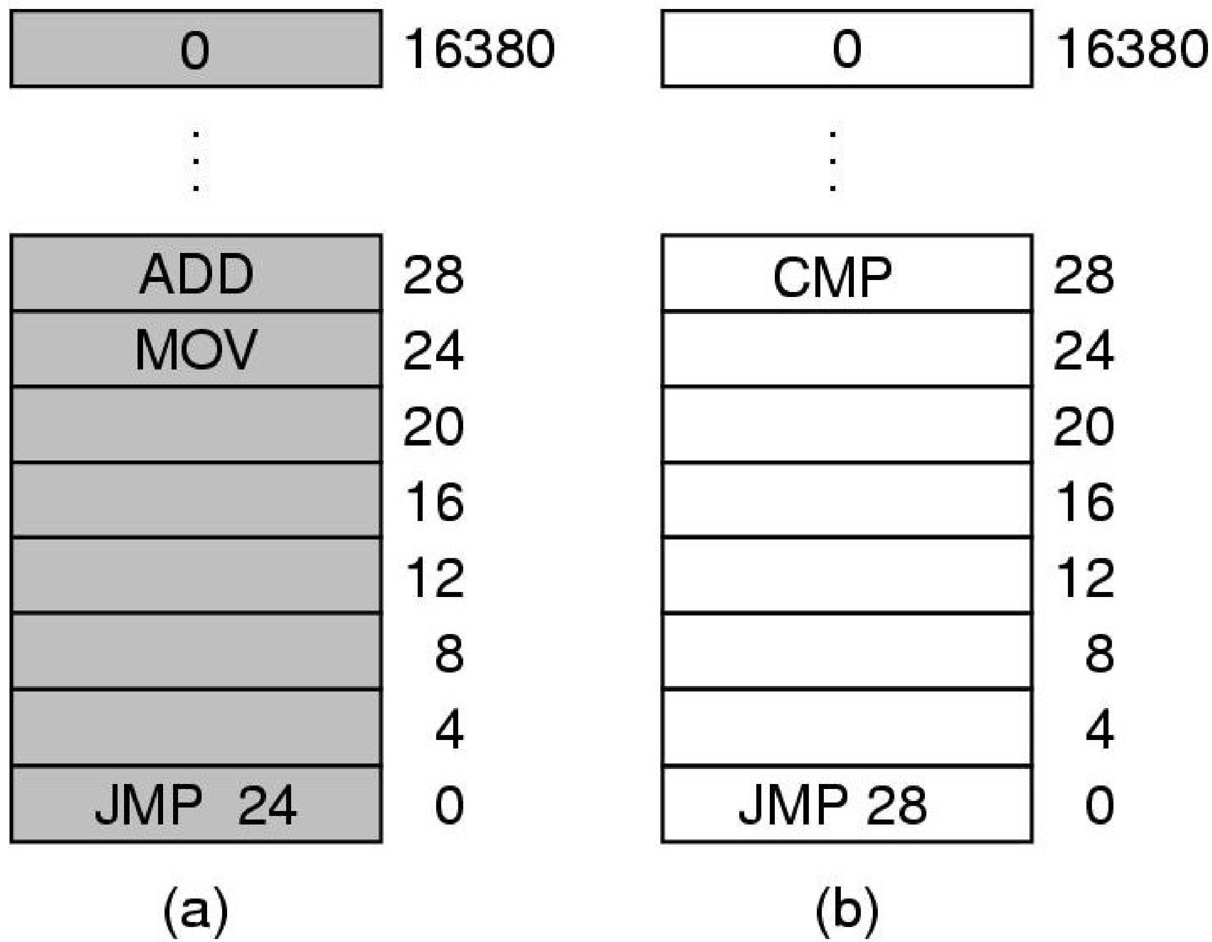
- early mainframe computers (<1960)
- early minicomputers (<1970)
- early personal computers (<1980)

RAM(Random Access Memory), ROM(Read-Only Memory)



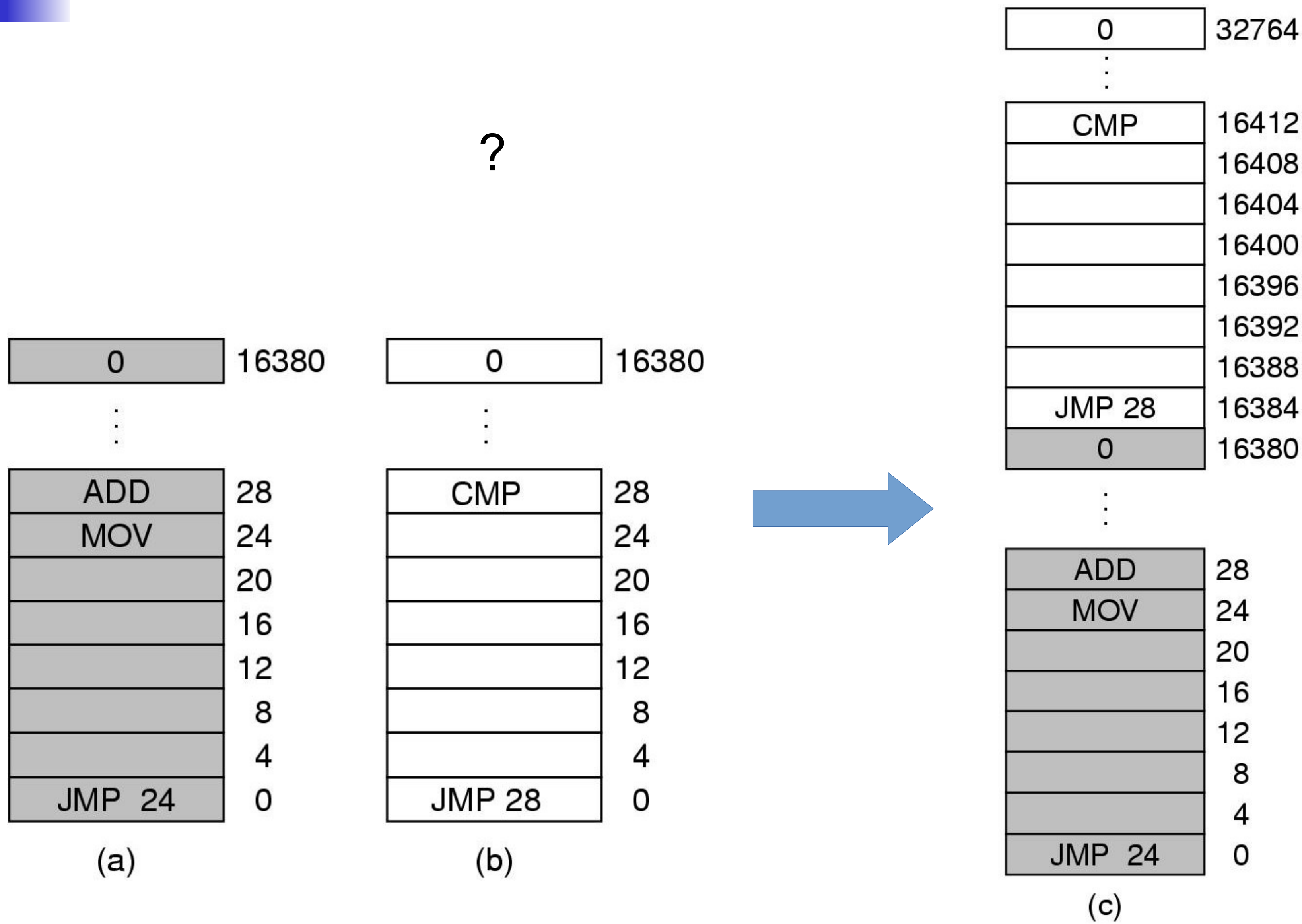
Three simple ways of organizing memory with an operating system and one user process.

Issues of No Memory Abstraction



Two Processes

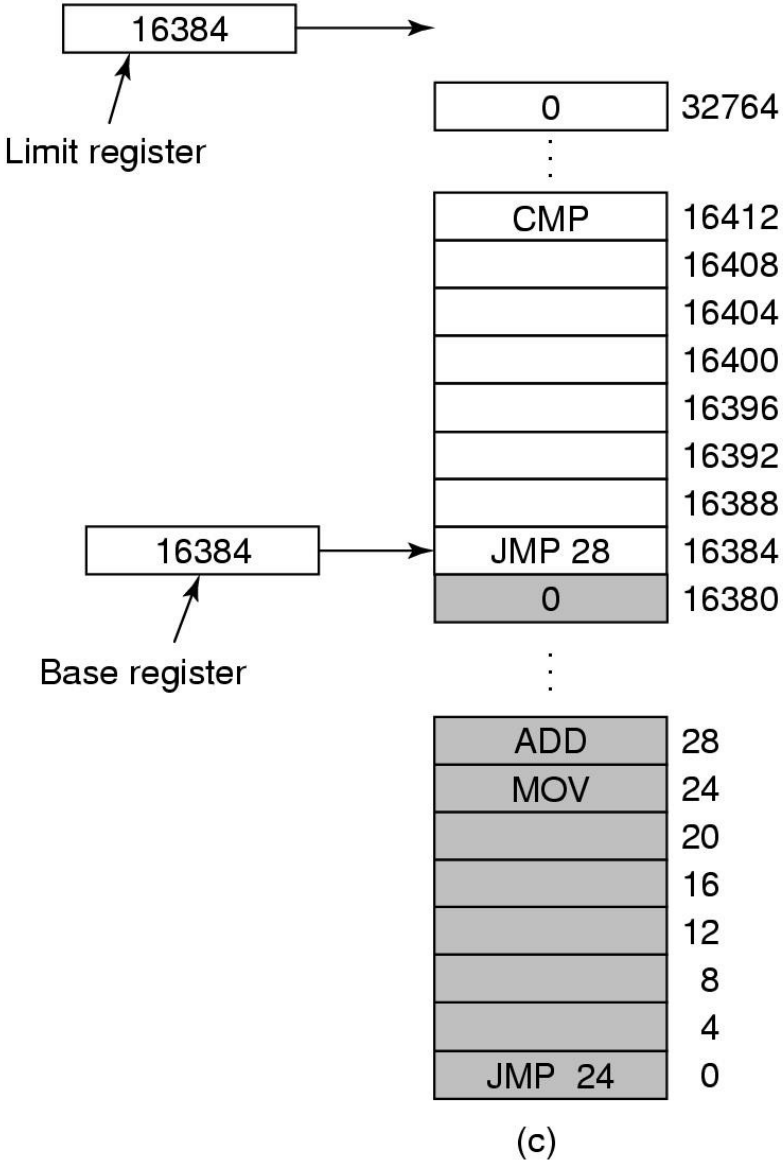
Issues of No Memory Abstraction



Issues of No Memory Abstraction

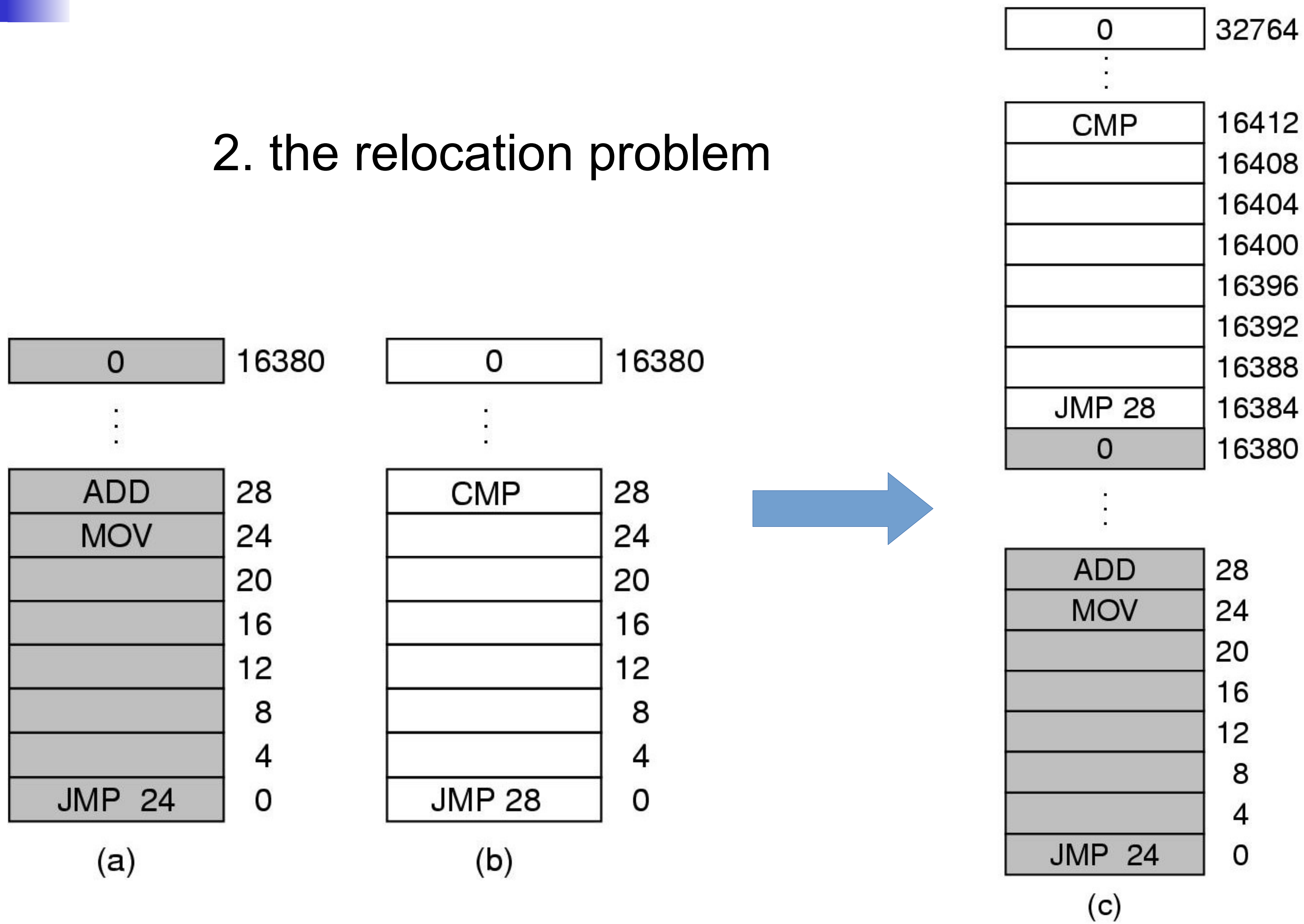
1.separate address space

Base register
Limit register



Issues of No Memory Abstraction

2. the relocation problem



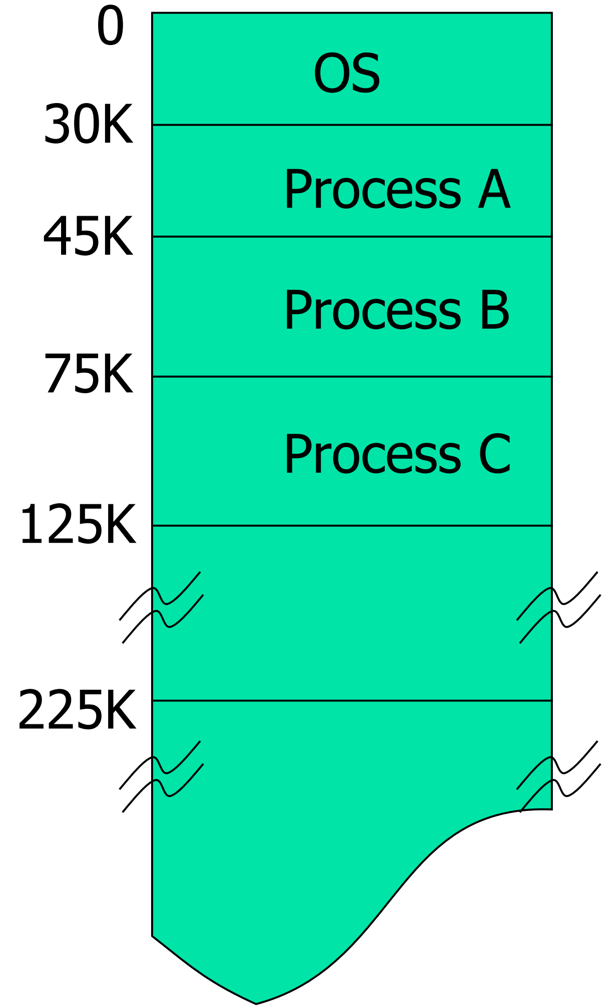
Basic Memory Management - contiguous allocation

Multiprogramming with Fixed Partitions

- Partition
  - Fixed, size

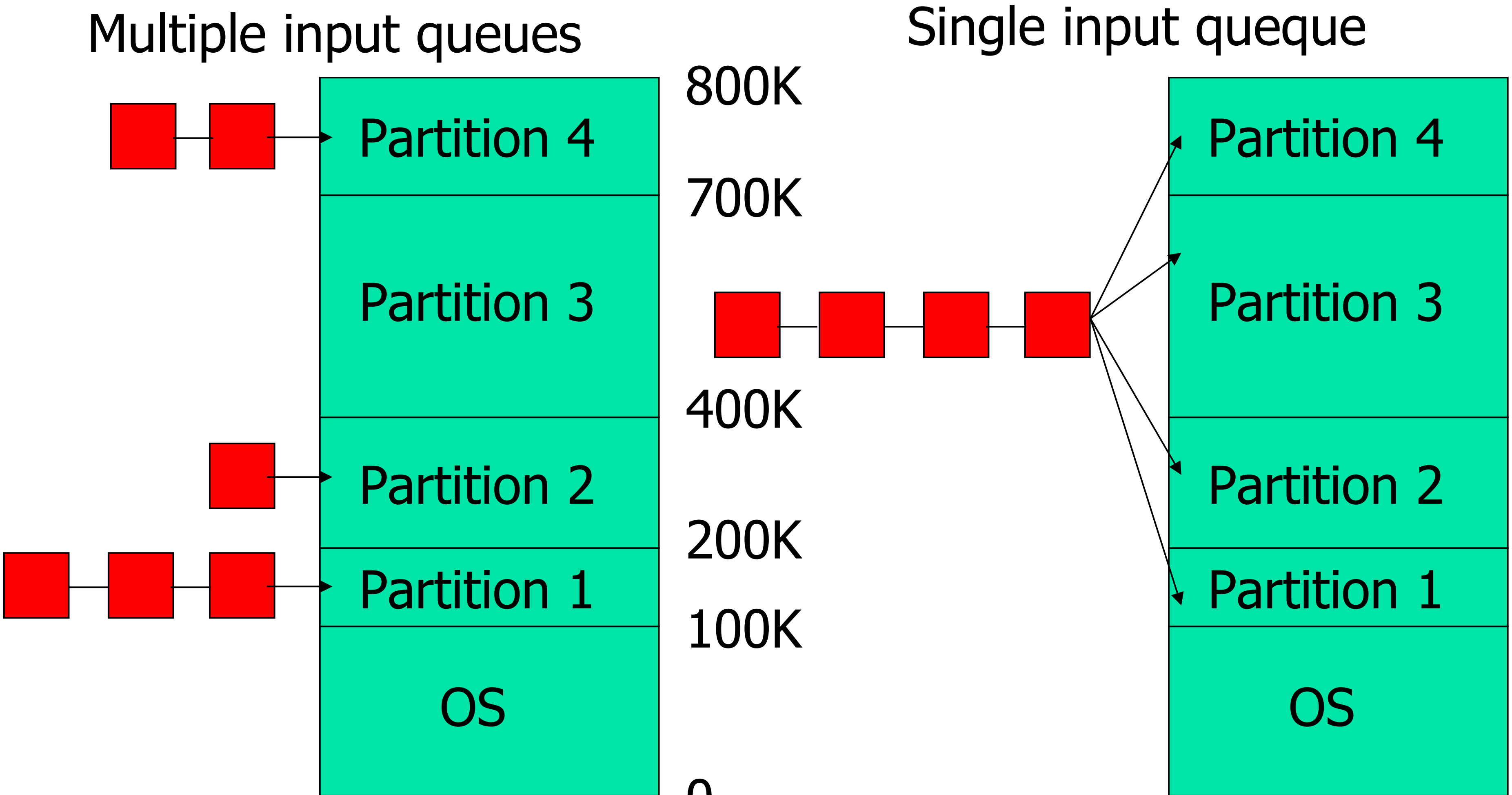
ID	Size (KB)	Start Addr (K)	State
1	15	30	used
2	30	45	used
3	50	75	used
4	100	125	available

(a) partition desc table



(b) memory layout

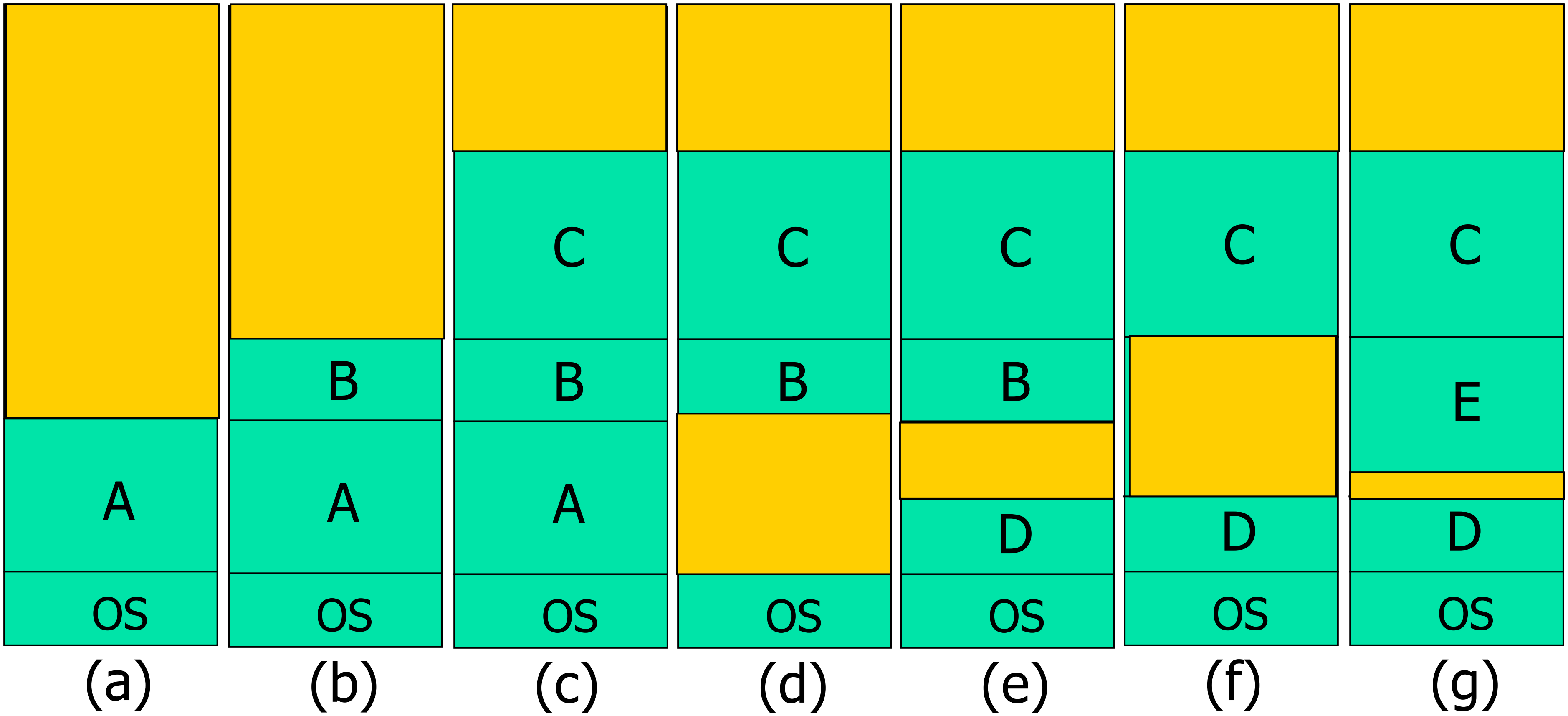
Multiprogramming with Fixed Partitions



(a) (b)

Multiprogramming with Variable Partitions

- Allocate a contiguous partition dynamiclly



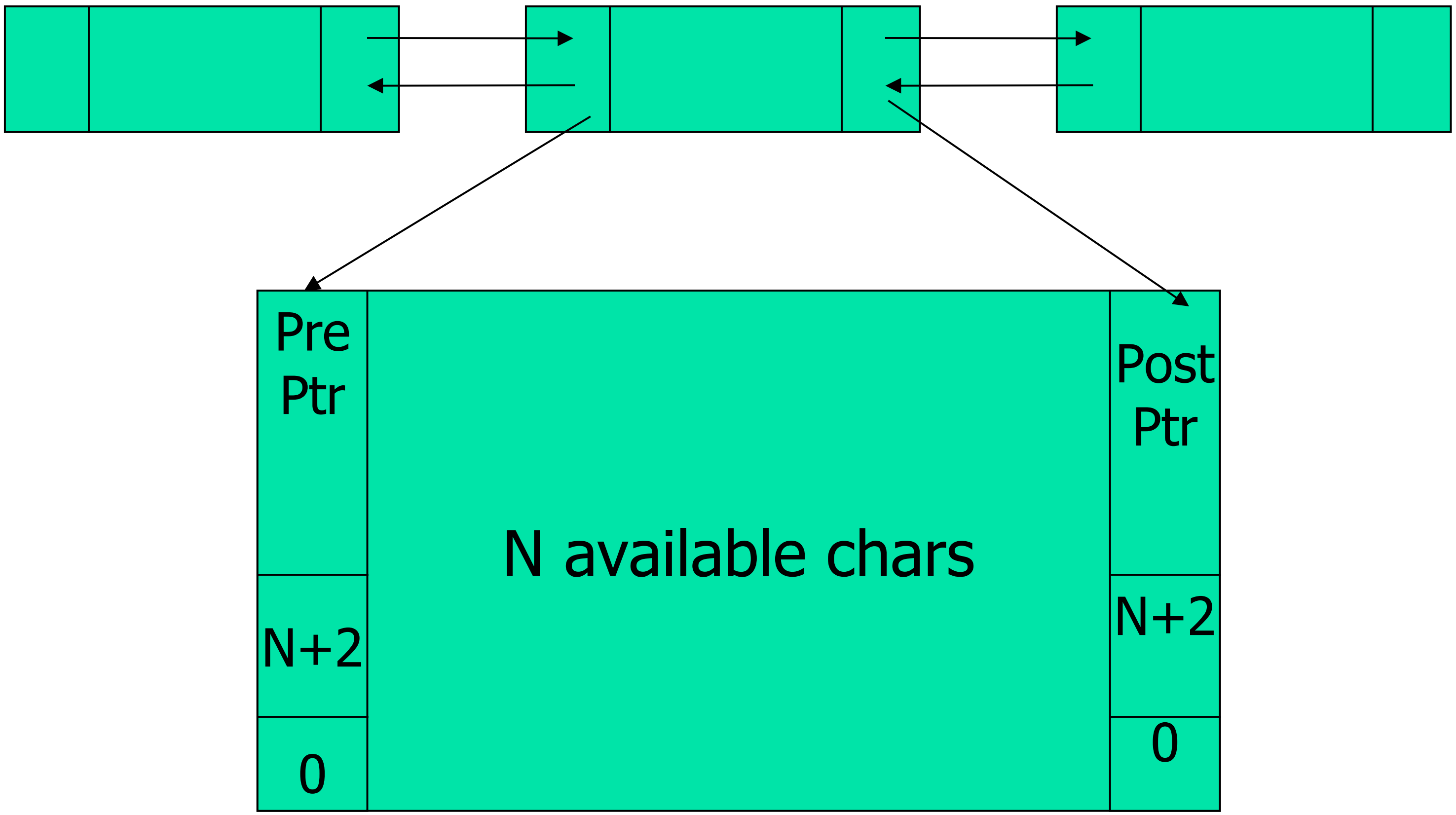
Multiprogramming with Variable Partitions

- Structure
- Algorithm
- Allocating and Revoking Procedures

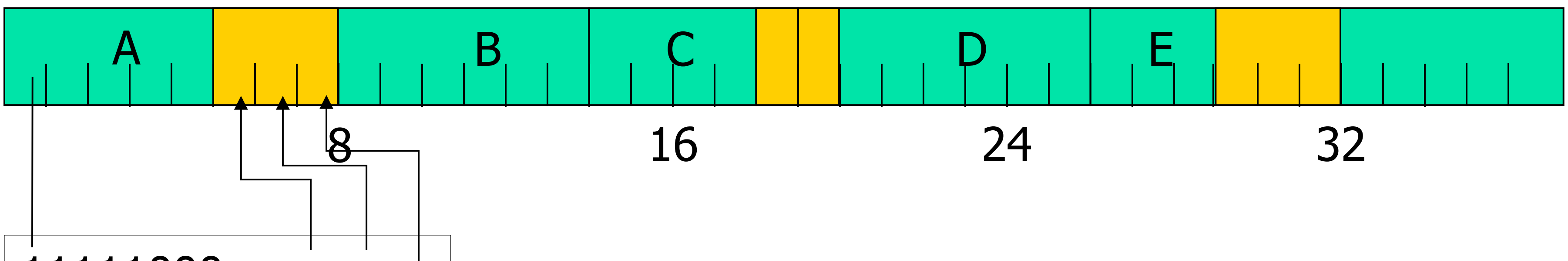
Variable Partitions: Partition Array Table

ID	Size (KB)	Start Addr (K)	state
1	64	44	available
2	24	132	available
3	40	210	used
4	30	270	available
5	…	…	…

Variable Partitions: Inline Linked Structure



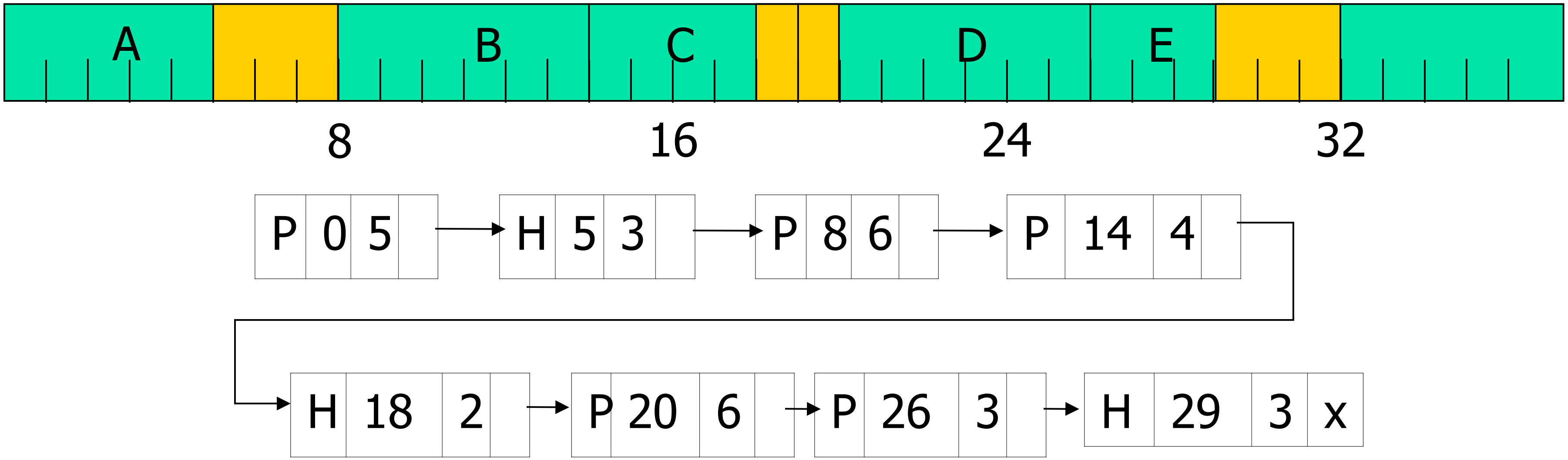
Variable Partitions: Bitmap 位图



11111000
11111111
11001111
11111000

Variable Partitions: Linked List

P: Process
H: Free space



Algorithms of Variable Partitions

- First Fit: FF
- Next FF
- Best Fit: FF
  - 最佳适应算法
  - external fragmentation
    - 碎片
- Worst Fit:WF

Algorithms of Variable Partitions

- Quick Fit
  - Multi-queues for 4KB, 8KB,16KB free contiguous space
  - Advantages
  - Disadvantage
    - Overhead of merging free partitions

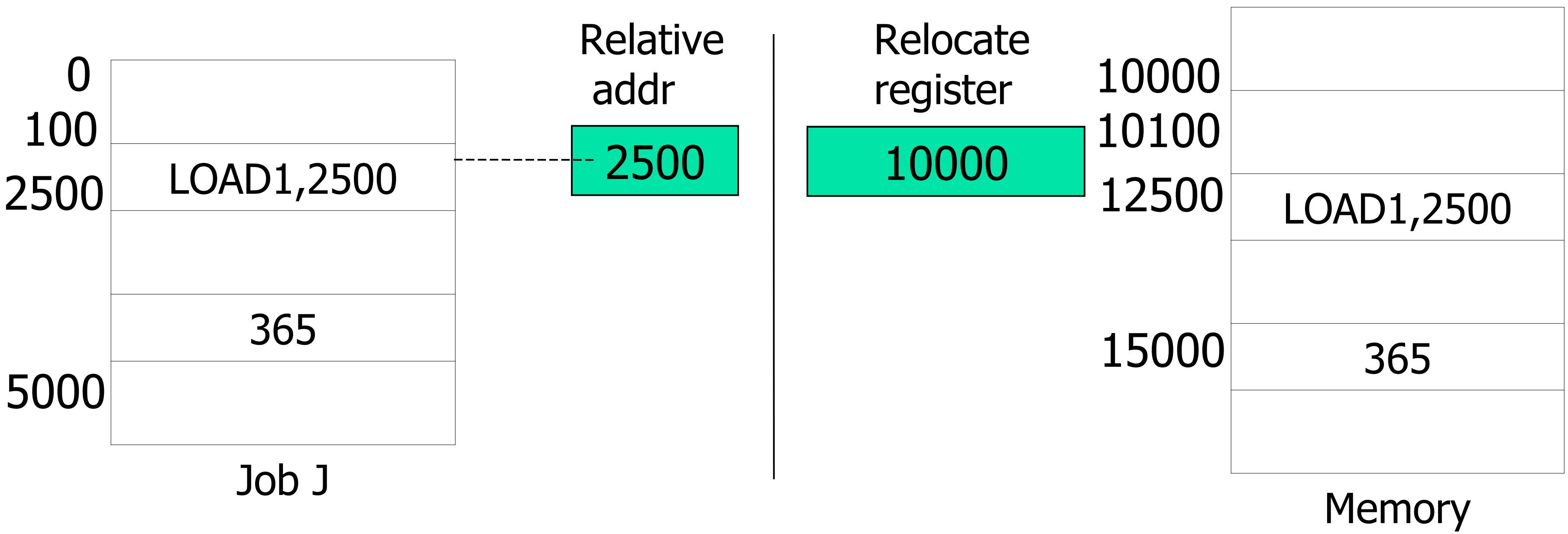
Algorithms of Variable Partitions

- Buddy memory allocation
  - 伙伴式的内存管理
  - 1963,Harry Markowitz,who won the 1990 Nobel Memorial Prize in Economics
  - each block is subdivided into two smaller blocks
  - 2^i
  - internal fragmentation

Case: buddy memory allocation

Step	64K	64K	64K	64K	64K	64K	64K	64K	64K	64K	64K	64K	64K	64K	64K	64K
1	2^4															
2.1	2^3								2^3							
2.2	2^2				2^2				2^3							
2.3	2^1		2^1		2^2				2^3							
2.4	2^0	2^0	2^1		2^2				2^3							
2.5	A: 2^0	2^0	2^1		2^2				2^3							
3	A: 2^0	2^0	B: 2^1		2^2				2^3							
4	A: 2^0	C: 2^0	B: 2^1		2^2				2^3							
5.1	A: 2^0	C: 2^0	B: 2^1		2^1		2^1		2^3							
5.2	A: 2^0	C: 2^0	B: 2^1		D: 2^1		2^1		2^3							
6	A: 2^0	C: 2^0	2^1		D: 2^1		2^1		2^3							
7.1	A: 2^0	C: 2^0	2^1		2^1		2^1		2^3							
7.2	A: 2^0	C: 2^0	2^1		2^2				2^3							
8	2^0	C: 2^0	2^1		2^2				2^3							
9.1	2^0	2^0	2^1		2^2				2^3							
9.2	2^1		2^1		2^2				2^3							
9.3	2^2				2^2				2^3							
9.4	2^3								2^3							
9.5	2^4															

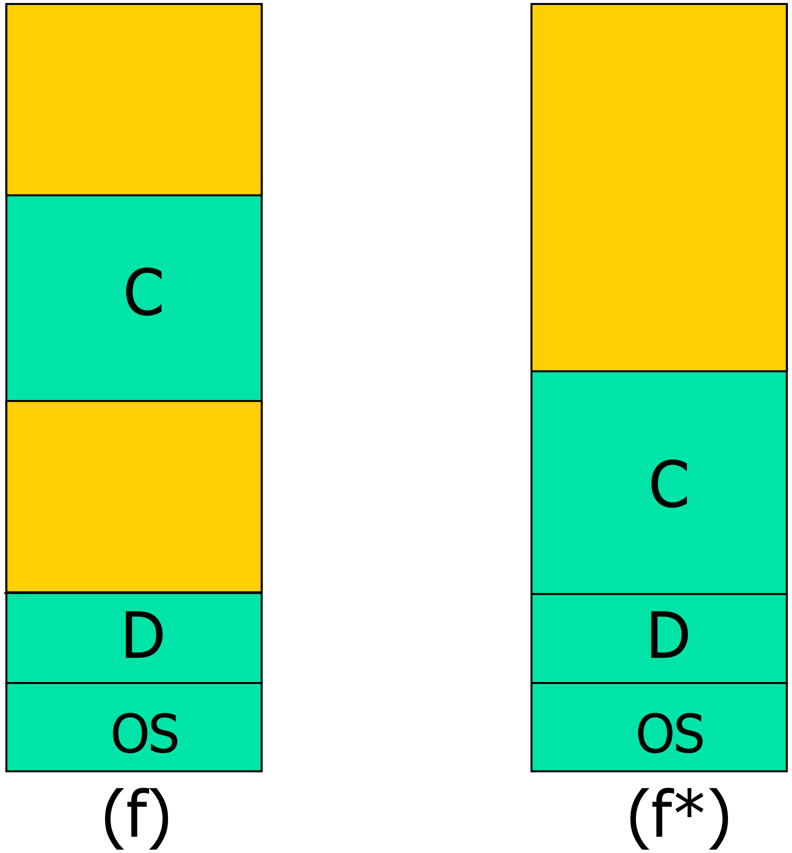
Dynamical Relocation



Memory Compaction

- 紧凑

?fragmentation

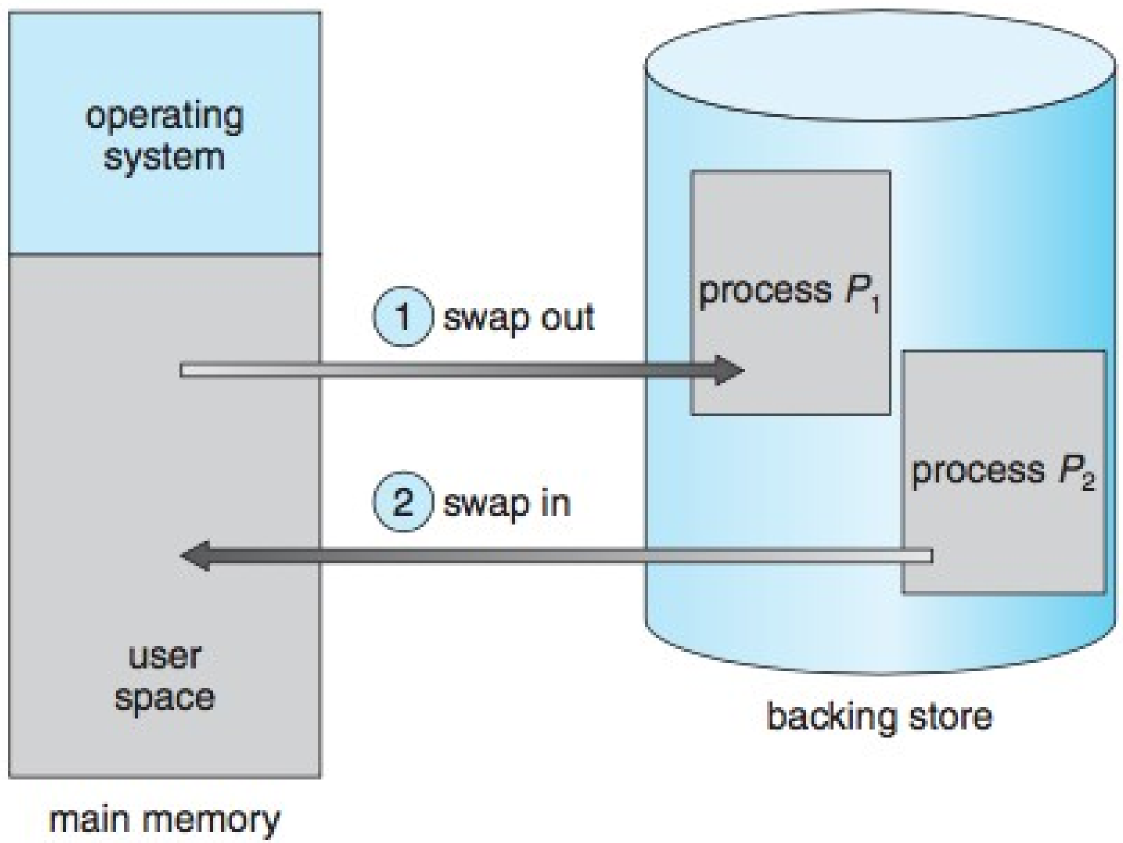


Before comp.

After comp.

Swapping

- bring in each process in its entirety, running it for a while, then putting it back on the disk

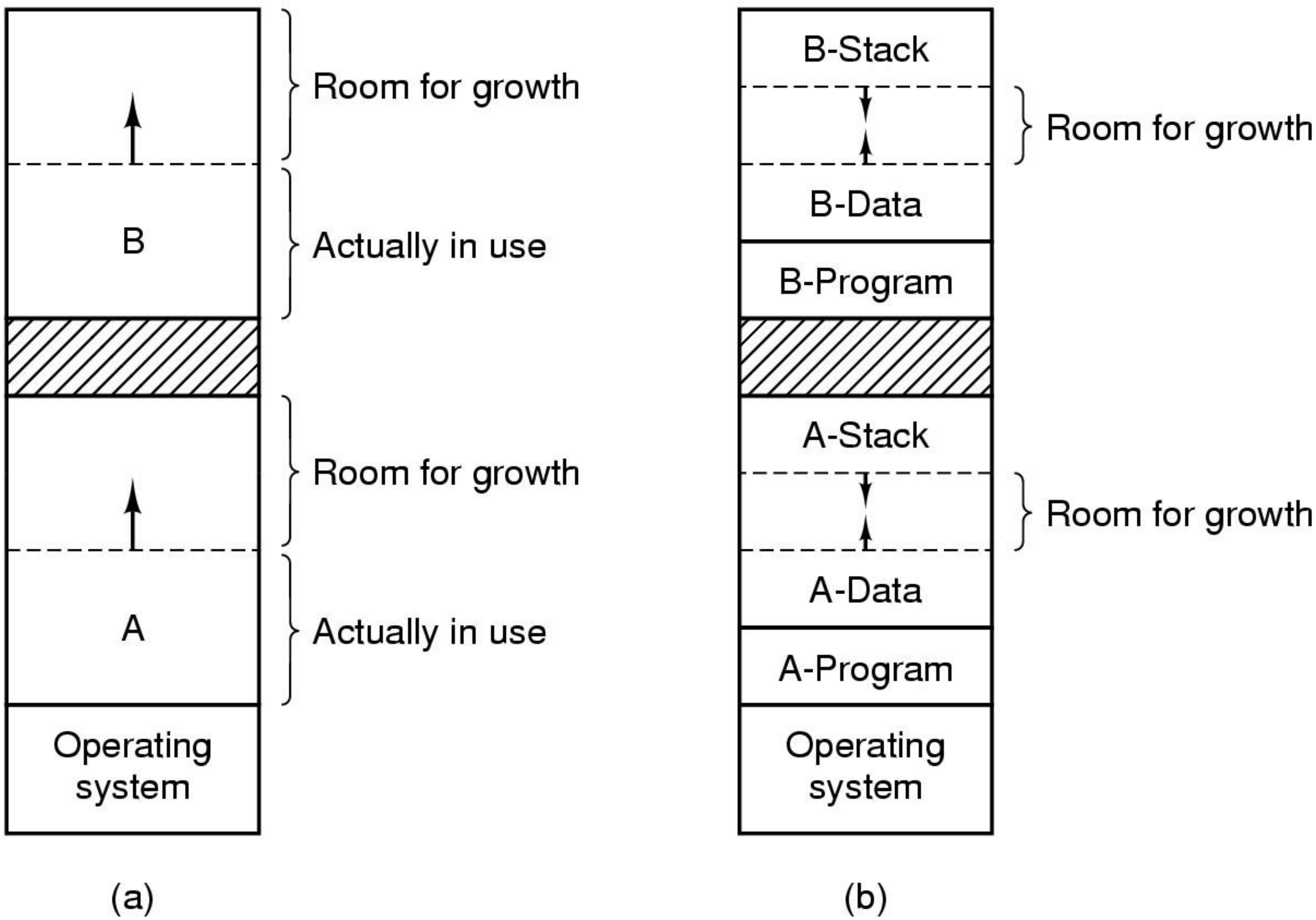


Overlay

- Replacement of a block of stored instructions or data with another
- a way to describe sections which are to be loaded as part of a single memory image but are to be run at the same memory address

```
OVERLAY [start] : [NOCROSSREFS] [AT ( ldaddr )]
  {
    secname1
      {
        output-section-command
        output-section-command
        ...
      } [:phdr...] [=fill]
    secname2
      {
        output-section-command
        output-section-command
        ...
      } [:phdr...] [=fill]
    ...
  } [>region] [:phdr...] [=fill] [,]
```

Issues of Variable Partitions



(a) Allocating space for growing data segment.

(b) Allocating space for growing stack, growing data segment.

Basic Memory Management - discrete allocation

Discrete Memory Allocation

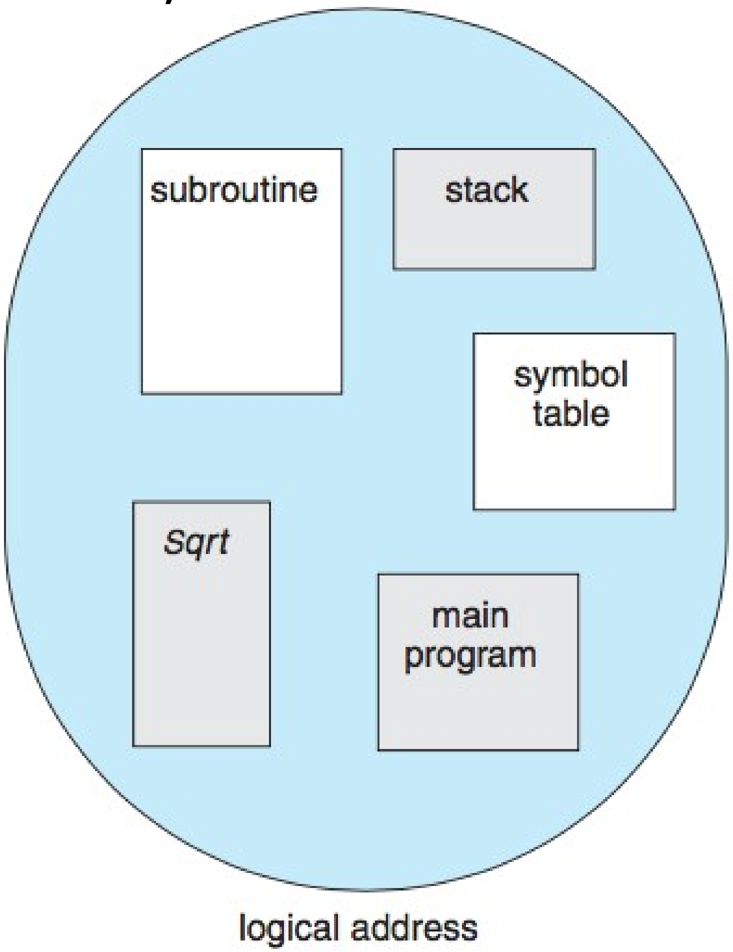
- Segmentation
- Paging

Segmentation

two tuple:<segment-number, offset>

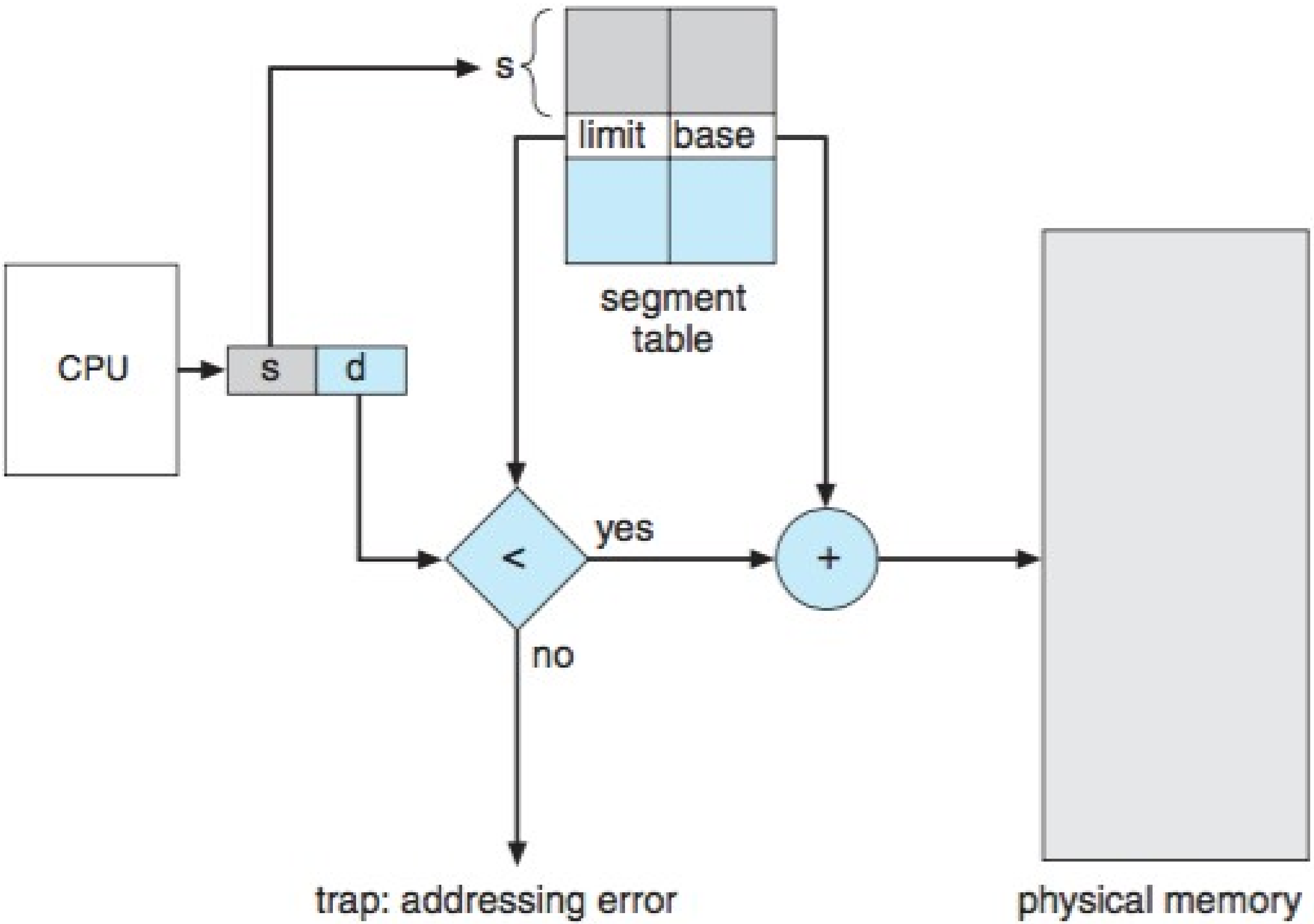
- Logical Segmentations
  - 1. The code
  - 2. Global variables
  - 3. The heap, from which memory is allocated
  - 4. The stacks used by each thread
  - 5. The standard C library

?fragmentation



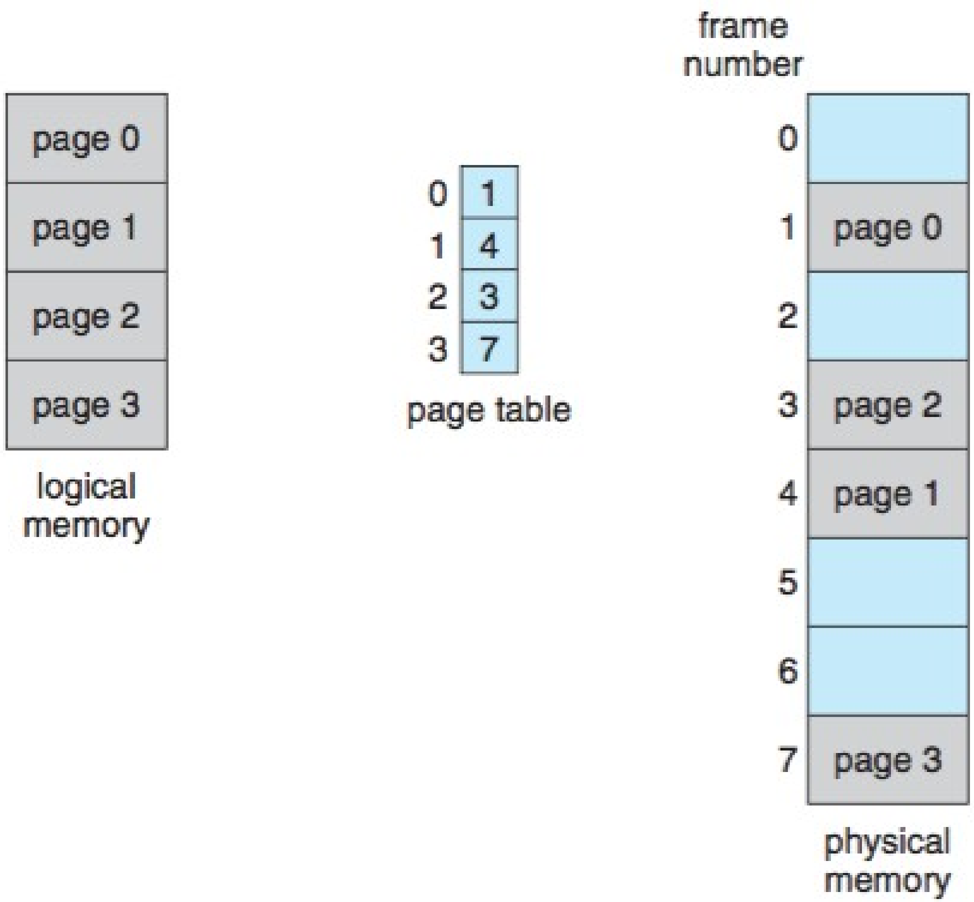
Programmer’s view of a program

Segmentation



Segmentation hardware

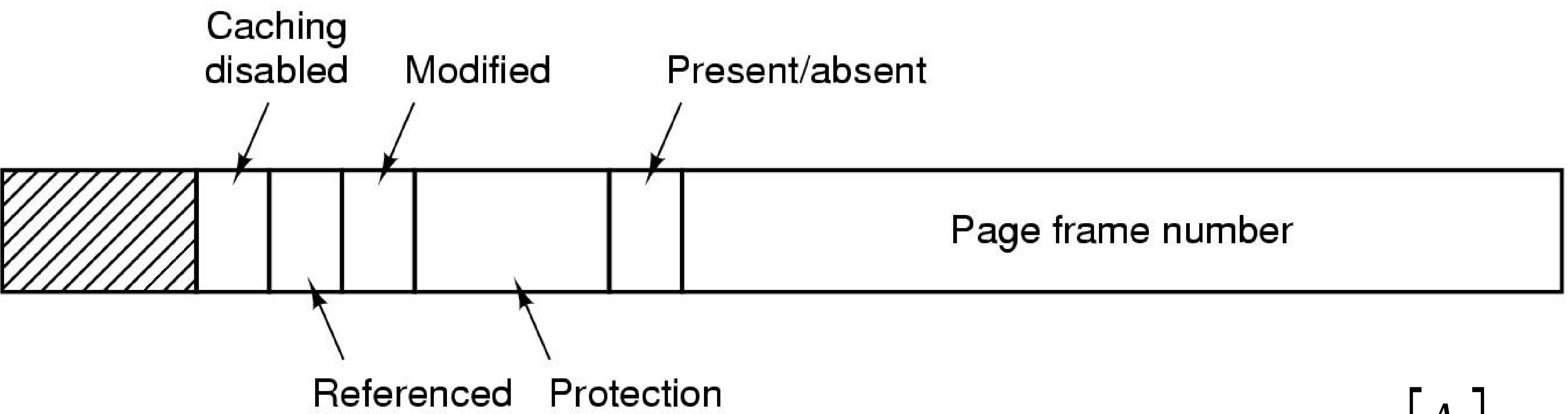
Paging



- Page
- Frame
- Page Table

Paging model of logical and physical memory

Paging: page table



Address= (Page number, offset)

One Tuple

?fragmentation

$$PageNum = INT\left[\frac{A}{L}\right]$$

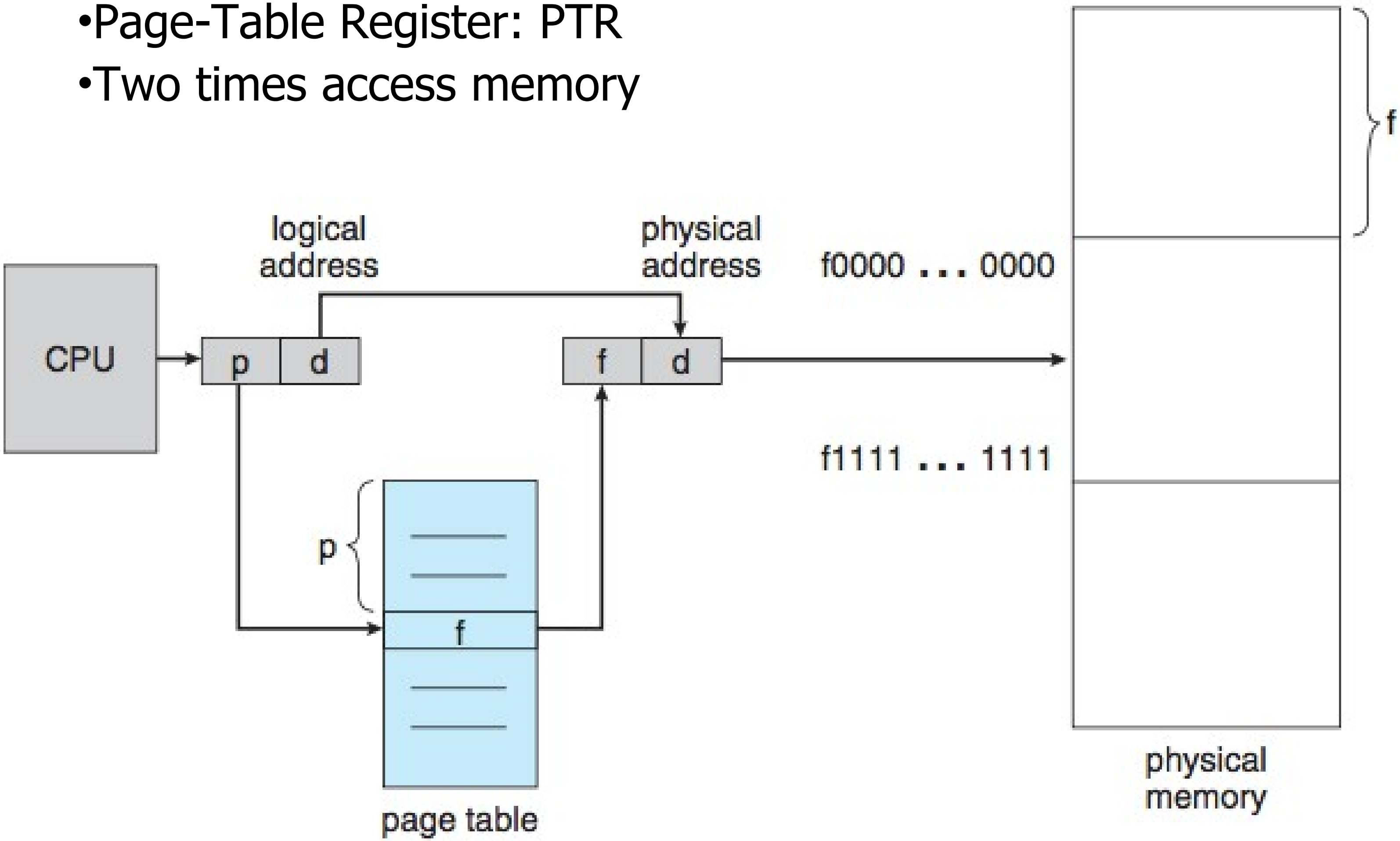
$$offset = |A| \; MOD \; L$$

A :Logical Address

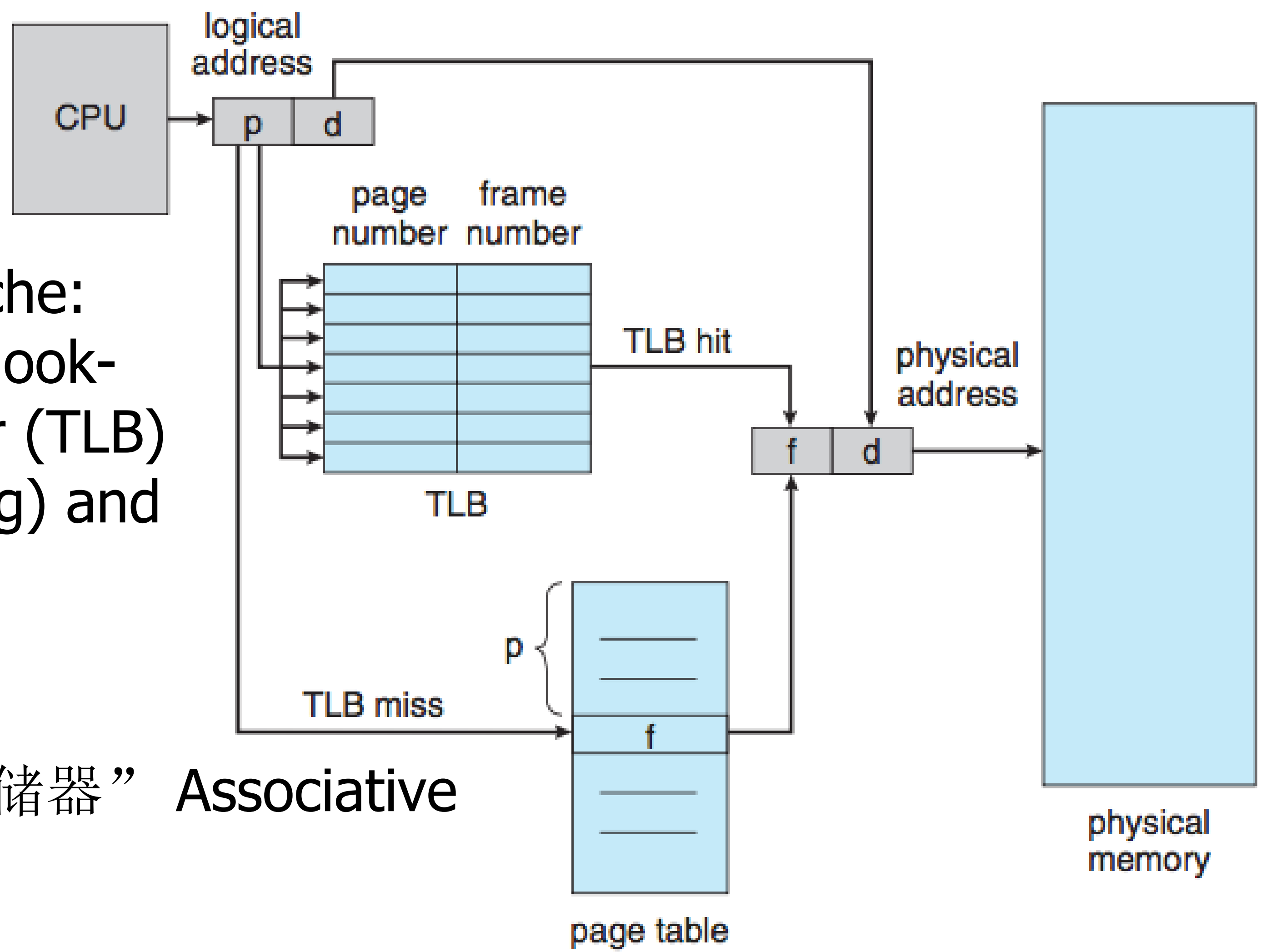
L :Page Size

Paging: hardware

- Page-Table Register: PTR
- Two times access memory



Paging: hardware with TLB



hardware cache:

- translation look-aside buffer (TLB)
  - key (or tag) and value

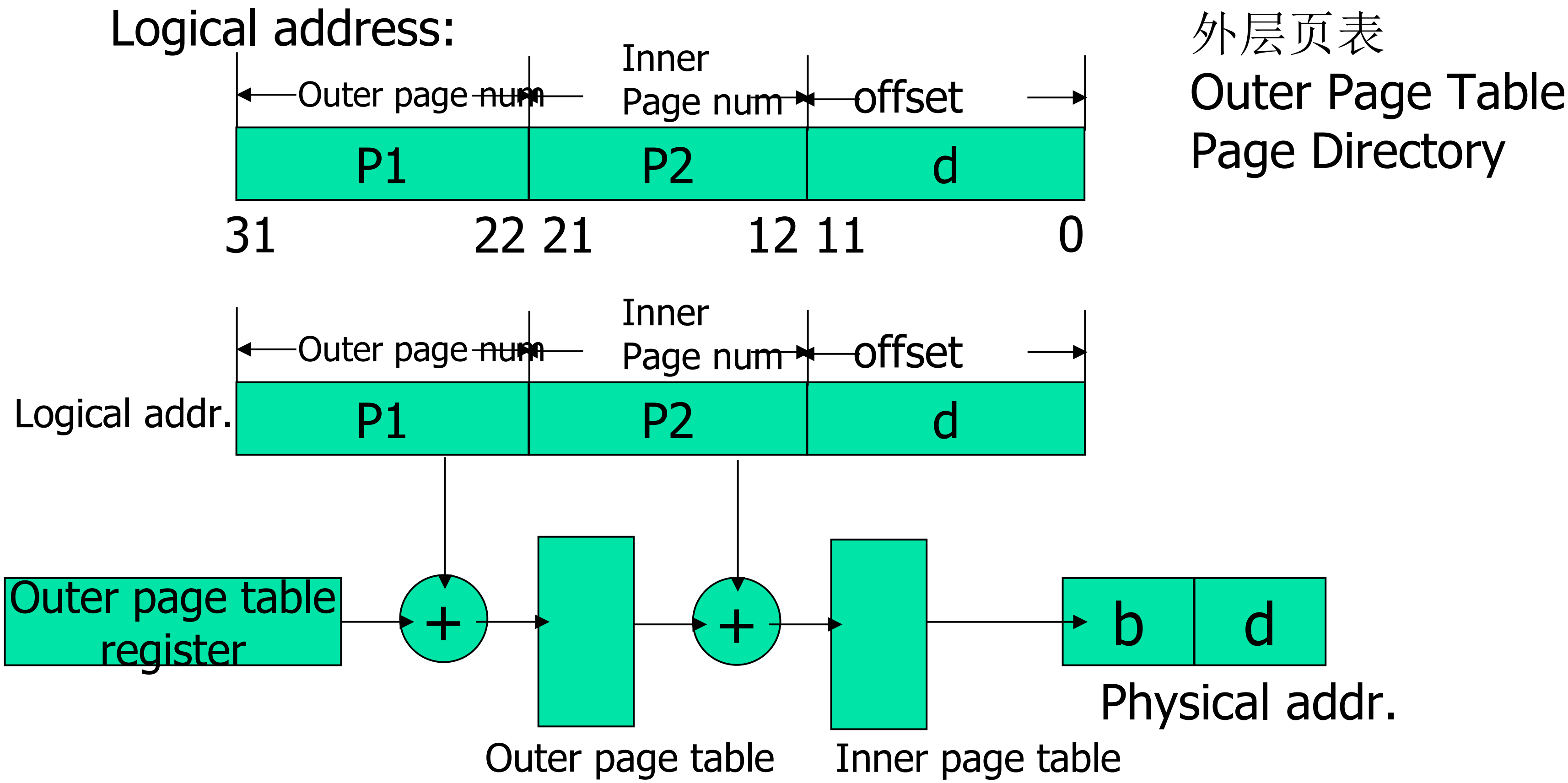
- 快表，
- “联想存储器” Associative Memory

Paging: hardware with TLB

Valid	Virtual page	Modified	Protection	Page frame
1	140	1	RW	31
1	20	0	R X	38
1	130	1	RW	29
1	129	1	RW	62
1	19	0	R X	50
1	21	0	R X	45
1	860	1	RW	14
1	861	1	RW	75

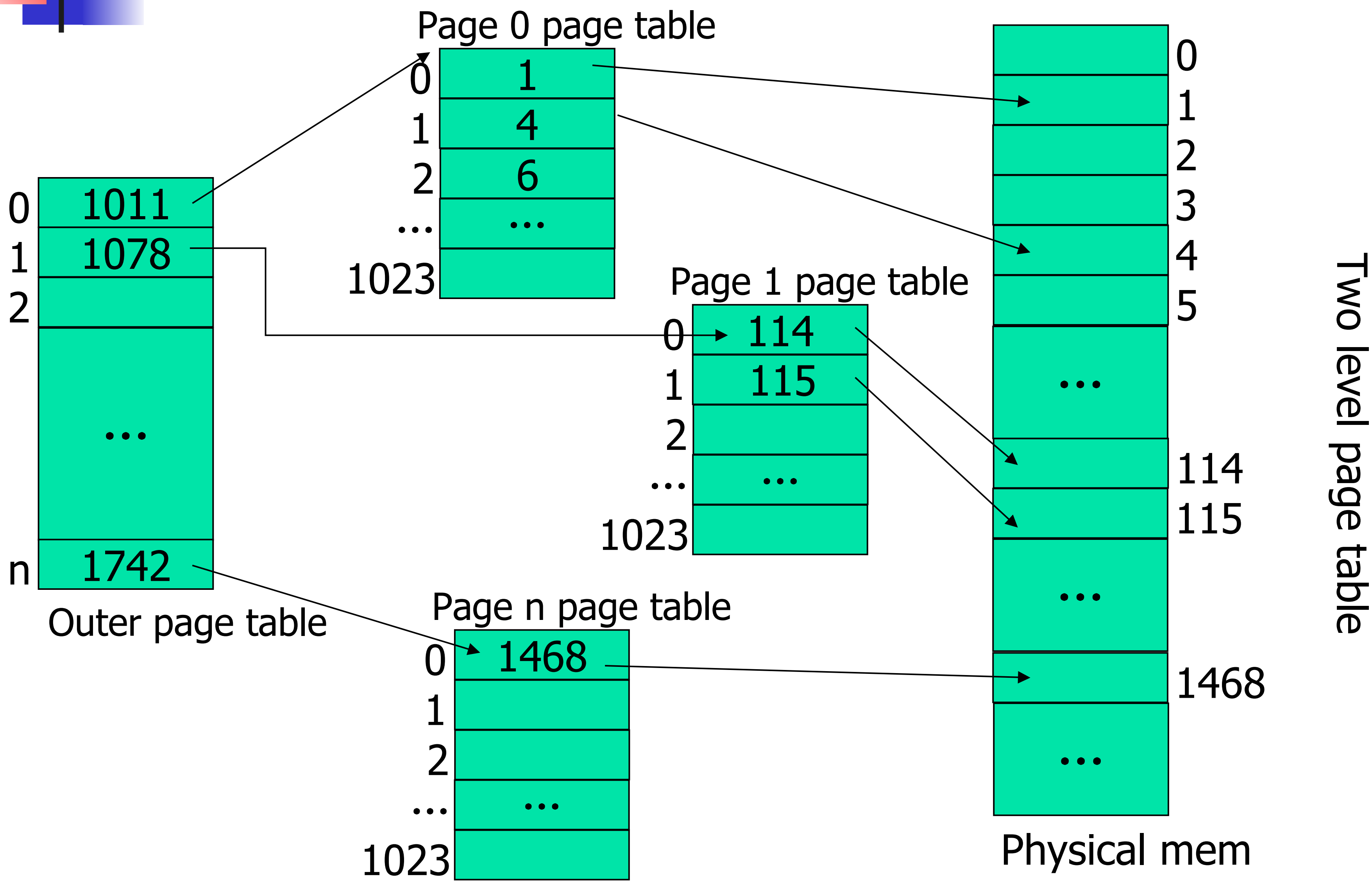
A TLB to speed up paging

Paging: Muti-level Page Table



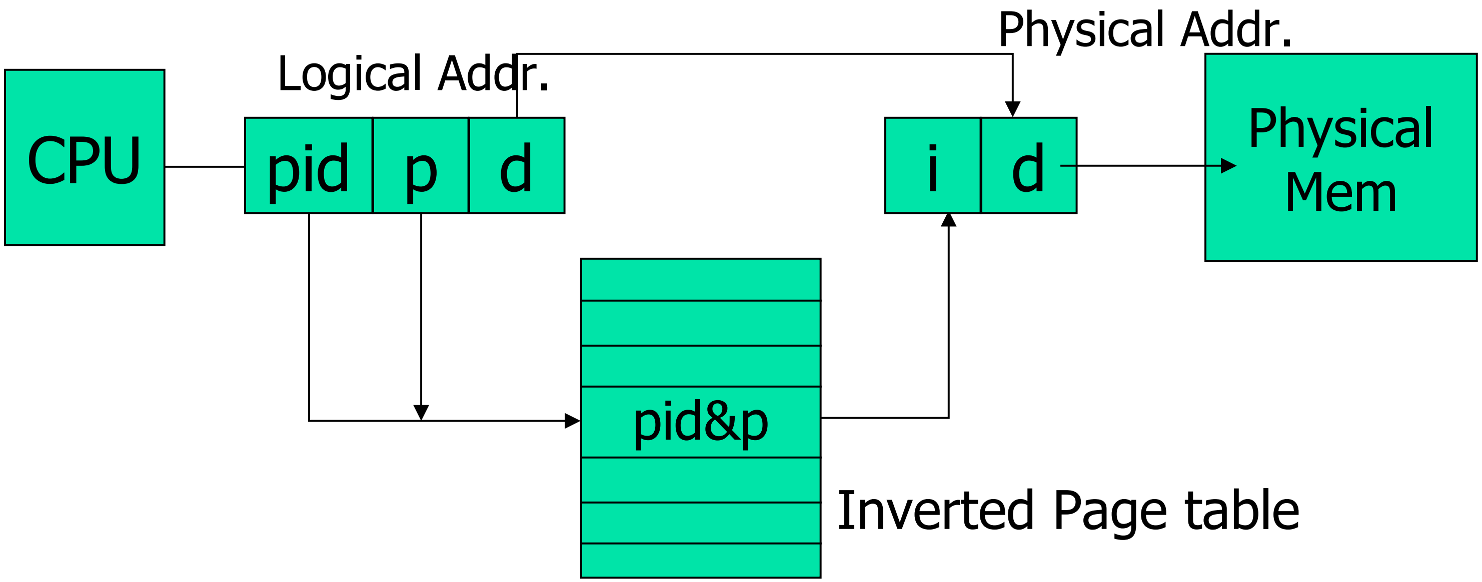
Two level page table

Paging: Muti-level Page Table



Inverted Page Tables

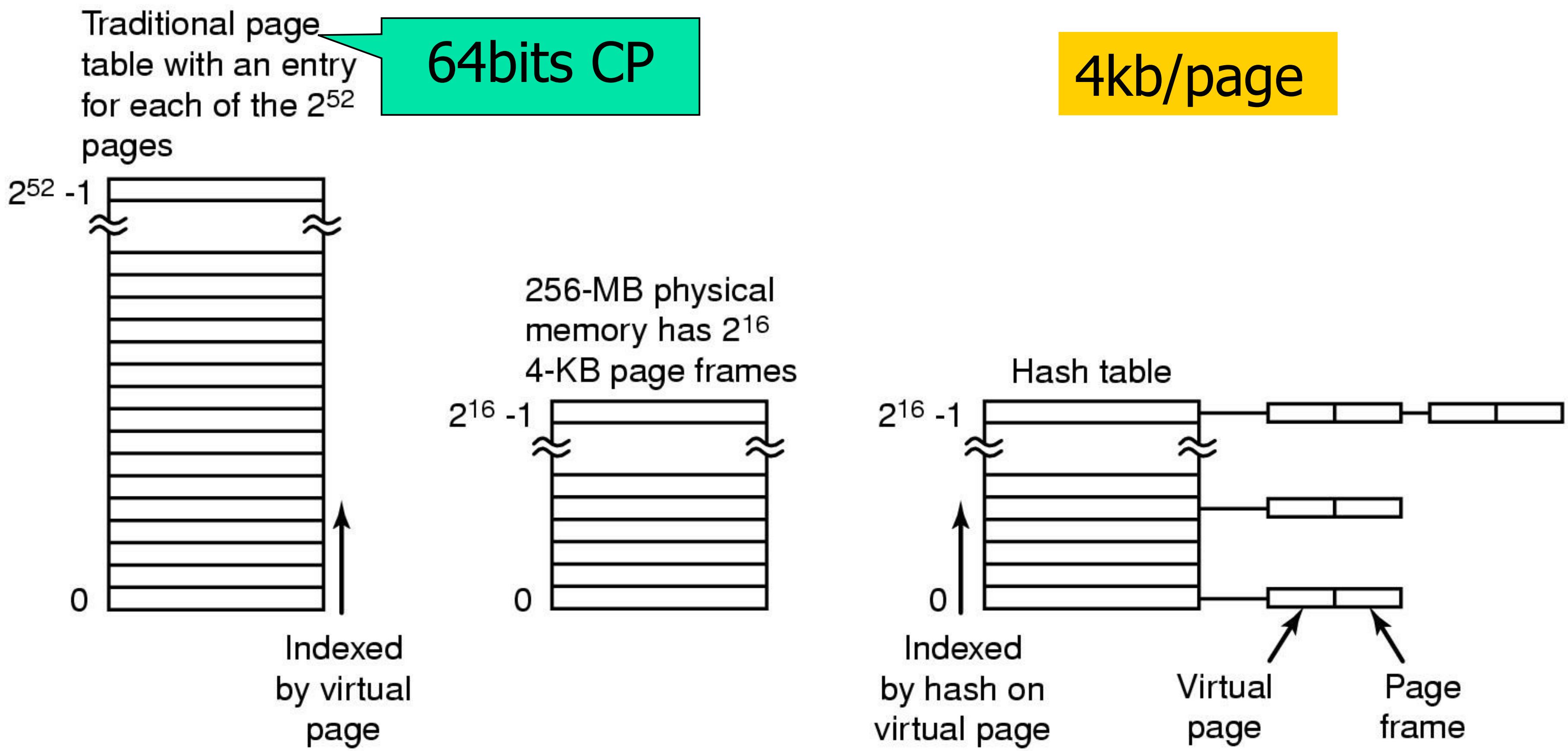
<process-id, page-number, offset>



Inverted Page Tables

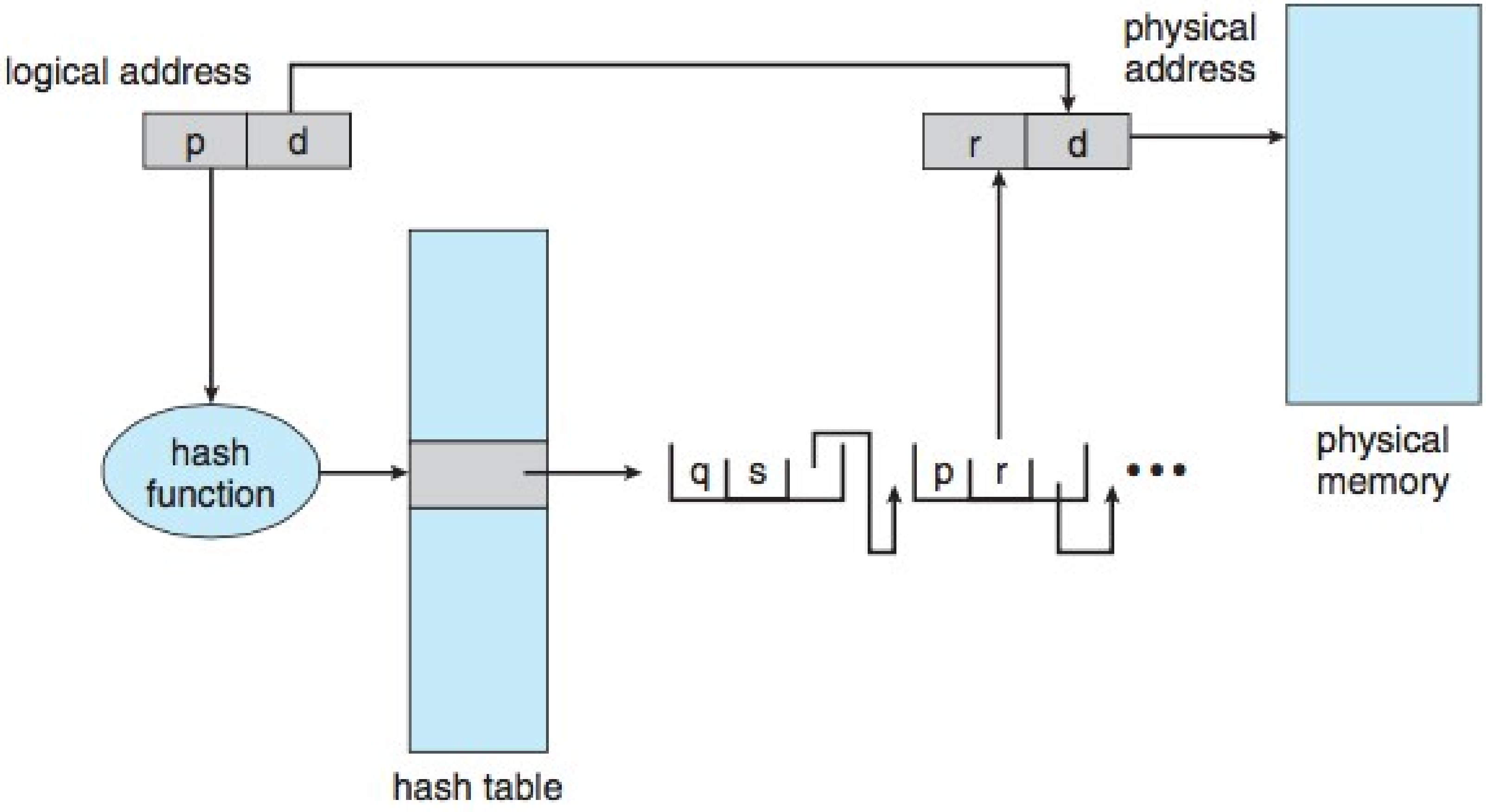
64bits CP

4kb/page



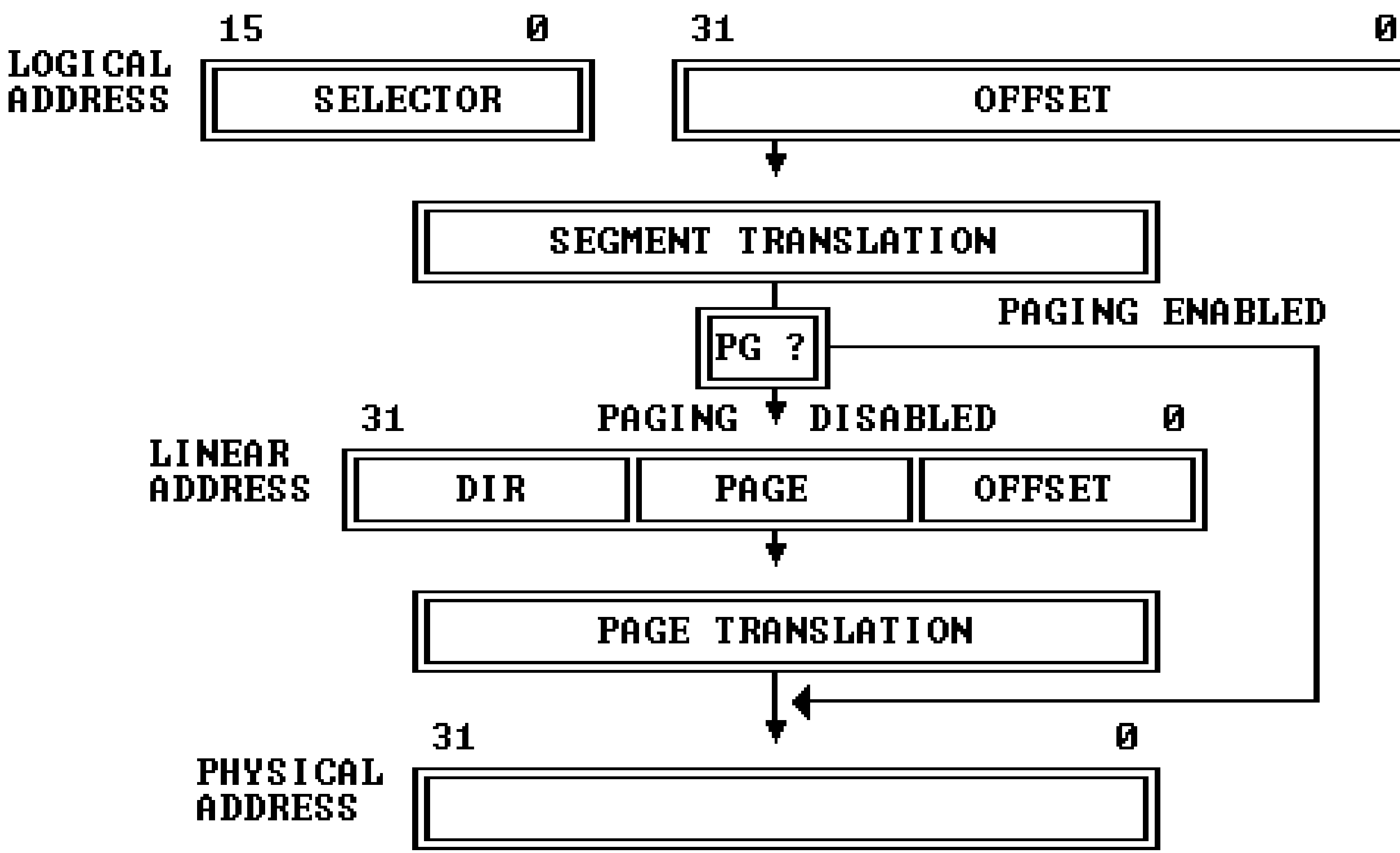
Comparison of a traditional page table with an inverted page table

Hashed Page Tables

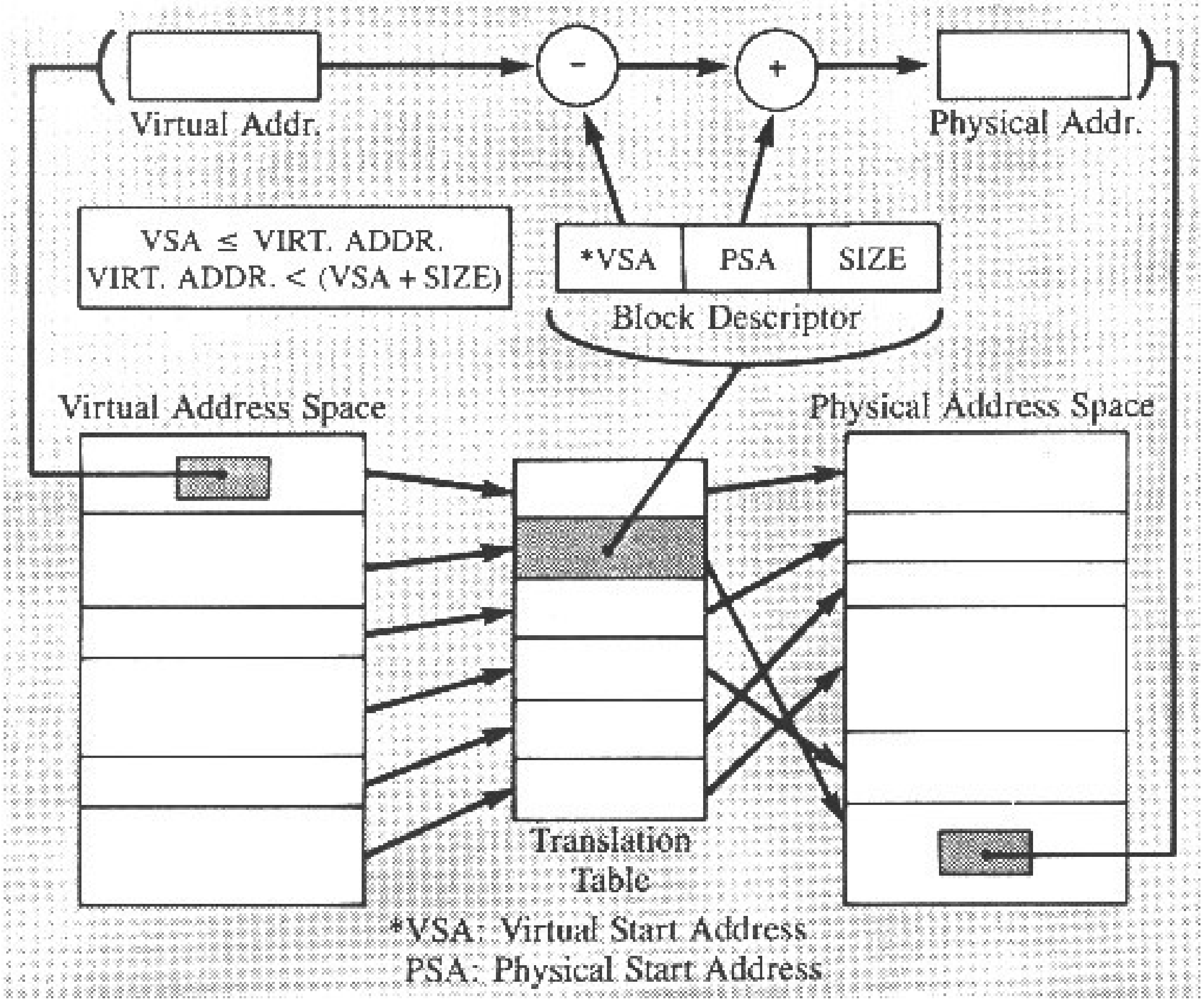


CURR MEMORY TRANSLATION

Logical Addr. -> (Virutal/)Linear Addr. -> Physical Addr.



CURR MEMORY TRANSLATION



Summary

- Memory Partitioning
- Swapping
- Segmentation
- Paging