Memory (Part II):
Mechanisms for Memory Management: Paging & Segmentation

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CSCI 460 Operating Systems
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Some slides & figures adapted from Stallings instructor resources.

Some slides adapted from Adam Bates's F'18 CS423 course @ UIUC
https://courses.engr.illinois.edu/cs423/sp2018/schedule.html

Goals for Today

Learning Objectives

- Understand basics of memory management, including
  - memory partitioning and common techniques
  - paging and segmentation — what they are, and their relative advantages and disadvantages
- Understand basics of loading and linking

Announcements

- Use Google Sheet to share info about your project:

  https://docs.google.com/spreadsheets/d/1uMk0pcho_B2v8_7t_E3S-IpsdUfhjBKsT5XdBcfPOBI/edit?usp=sharing
- PA2 posted later this week…

Relocation of Processes into Partitions

- Logical Address

  a reference to a memory location independent of the current assignment of data to memory → need ***translation***

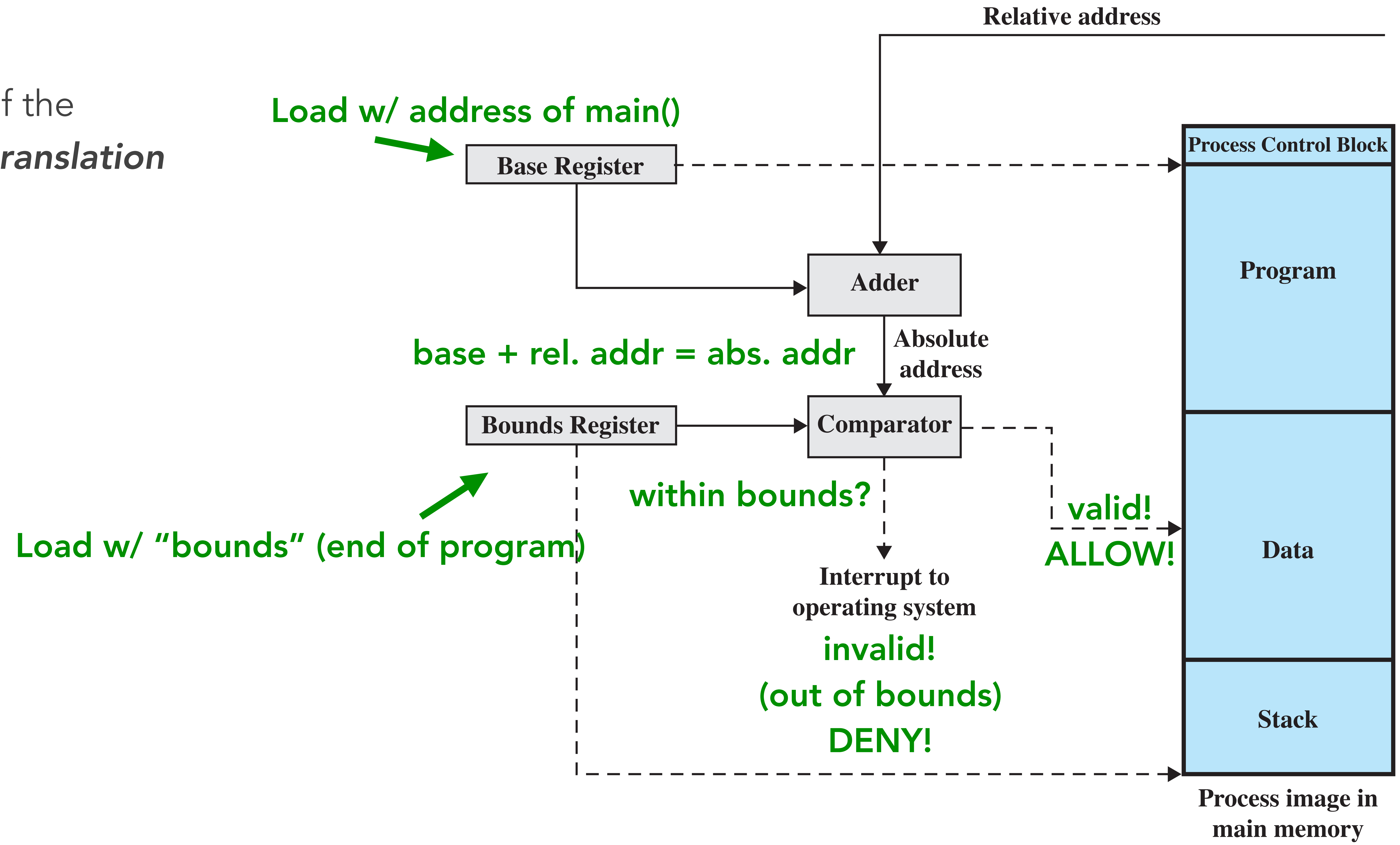
- Relative Address

  An example of a logical address.

  Address = relative location to some known point (e.g., value in register)

- Physical Address

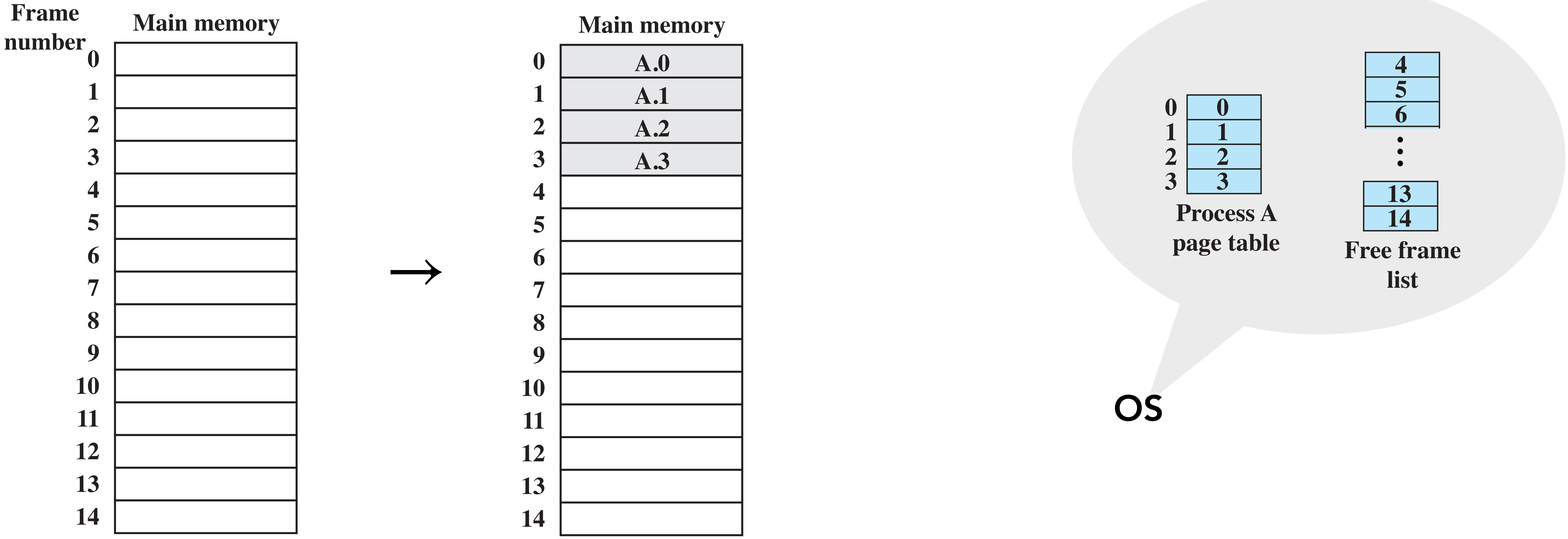
  The actual location in main memory



Paging

Basic Idea

- Partition main memory into **small fixed-sized chunks** of the same size
- Assign chunks of processes **(pages)** into available chunks of main memory **(frames)**
- Small processes need fewer pages; larger processes need more pages
- No more external fragmentation
- Minimal internal fragmentation → *only part of the last page of a process*



Frame number

Frame number	Main memory
0	
1	
2	
3	
4	
5	
6	
7	
8	
9	
10	
11	
12	
13	
14	

→

	Main memory
0	A.0
1	A.1
2	A.2
3	A.3
4	
5	
6	
7	
8	
9	
10	
11	
12	
13	
14	

Process A page table

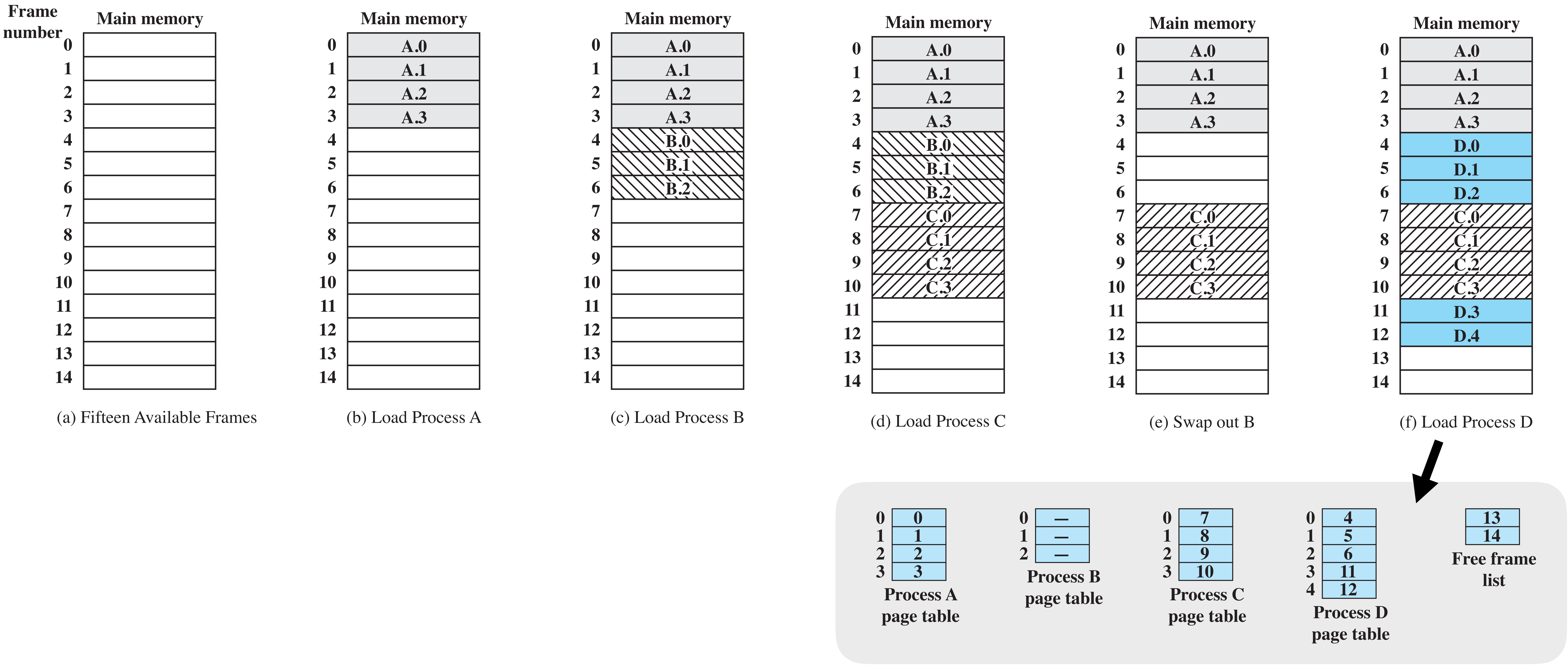
0	0
1	1
2	2
3	3

Free frame list

4
5
6
⋮
13
14

OS

Paging — Example: Assigning Process Pages to Free Frames



Frame number	Main memory	Main memory	Main memory	Main memory	Main memory	Main memory
0		A.0	A.0	A.0	A.0	A.0
1		A.1	A.1	A.1	A.1	A.1
2		A.2	A.2	A.2	A.2	A.2
3		A.3	A.3	A.3	A.3	A.3
4			B.0	B.0		D.0
5			B.1	B.1		D.1
6			B.2	B.2		D.2
7				C.0	C.0	C.0
8				C.1	C.1	C.1
9				C.2	C.2	C.2
10				C.3	C.3	C.3
11						D.3
12						D.4
13						
14						
	(a) Fifteen Available Frames	(b) Load Process A	(c) Load Process B	(d) Load Process C	(e) Swap out B	(f) Load Process D

Process A page table

0	0
1	1
2	2
3	3

Process B page table

0	—
1	—
2	—

Process C page table

0	7
1	8
2	9
3	10

Process D page table

0	4
1	5
2	6
3	11
4	12

Free frame list

13
14

Paging — Logical Addressing

HW assists with logical addressing when using paging — HW must know how to access page table

$n + m$ bit addresses where

- n = # bits for page number (leftmost bits)
- m = # bits for offset within page (rightmost bits)

  → PAGESIZE = 2^m

NOTE: In general, we set page/frame size to be a power of 2

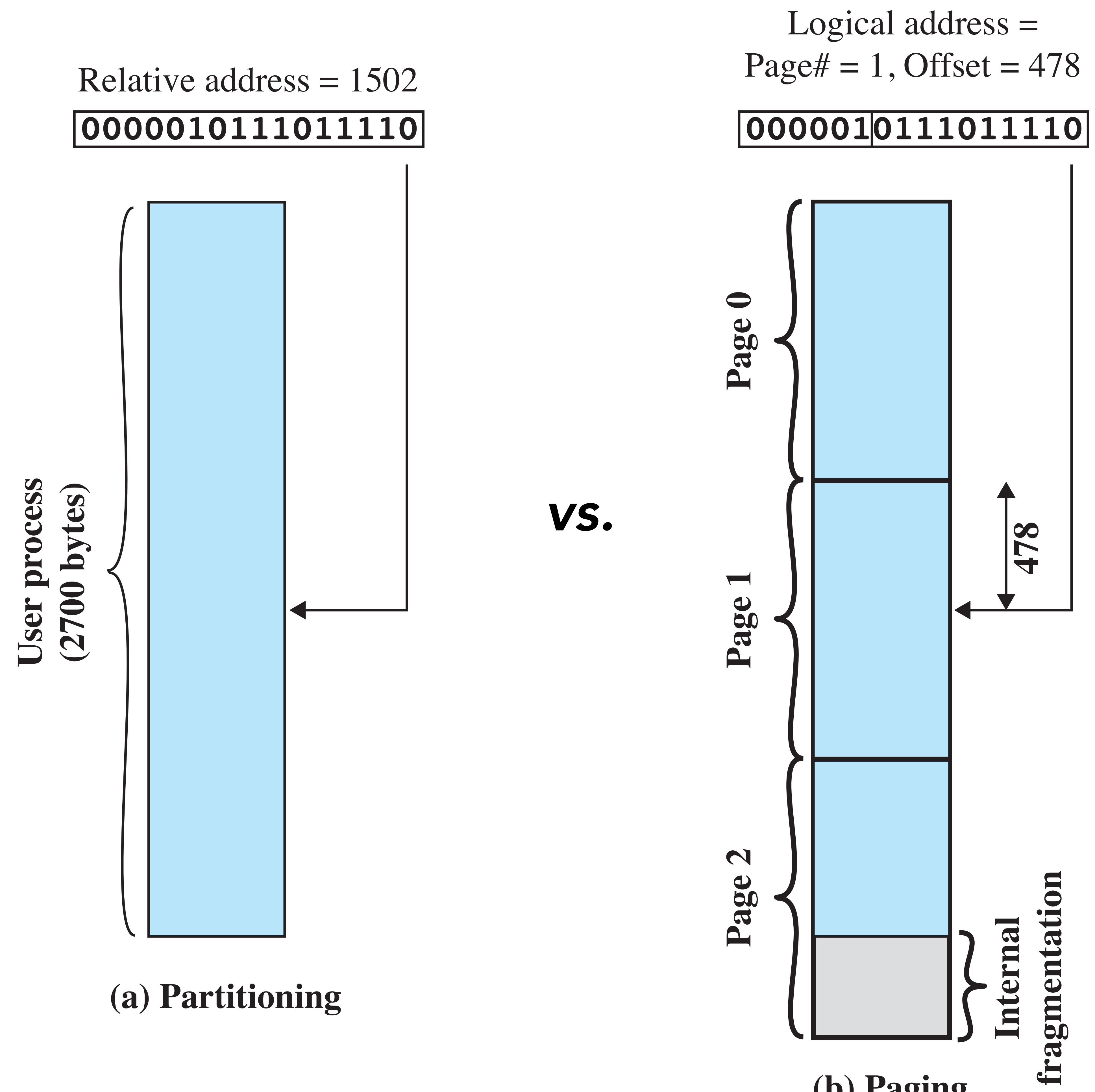
→ relative address == logical address

Example:

- 16-bit addresses
- Page Size = 1K (1024 Bytes)

Q: *How many bits are needed to accommodate pages/frames of size 1K?*
→ *10 bits needed for offset field → 1K =* 2^{10}

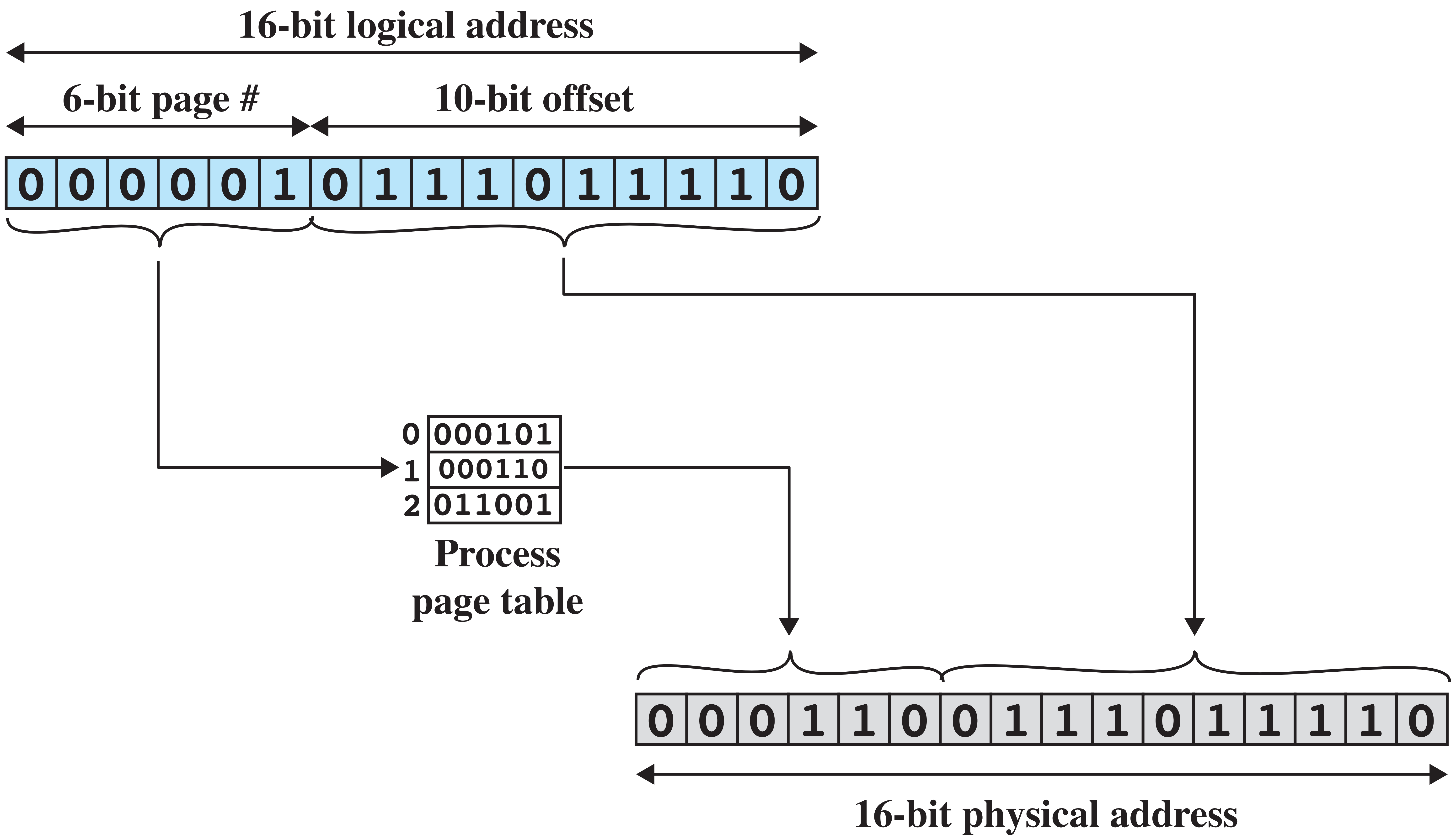
Q: *How many pages are possible with 6-bits available for page numbers?*
→ 6 bits left over for page # field → 64 pages



(a) Partitioning

(b) Paging (page size = 1K)

Paging — Example of Logical-to-Physical Address Translation



Segmentation

Basic Idea

- Programs can be broken up into ***segments*** that need not be in contiguous memory; may occupy more than one segment
- Partition main memory into ***unequally-sized segments***
  - *Similar to dynamic partitioning… but not the same*
- Assign segments of processes into chunks of main memory allocated on demand
- No internal fragmentation
- Potential for external fragmentation

Segmentation — Logical Addressing

- Each segment needs to provide
  - starting address of segment
  - segment length
- Load address of segment table into register when process starts running

- $n + m$ bit addresses where
  - n = # bits for segment number (leftmost bits)
  - m = # bits for offset within segment (rightmost bits)

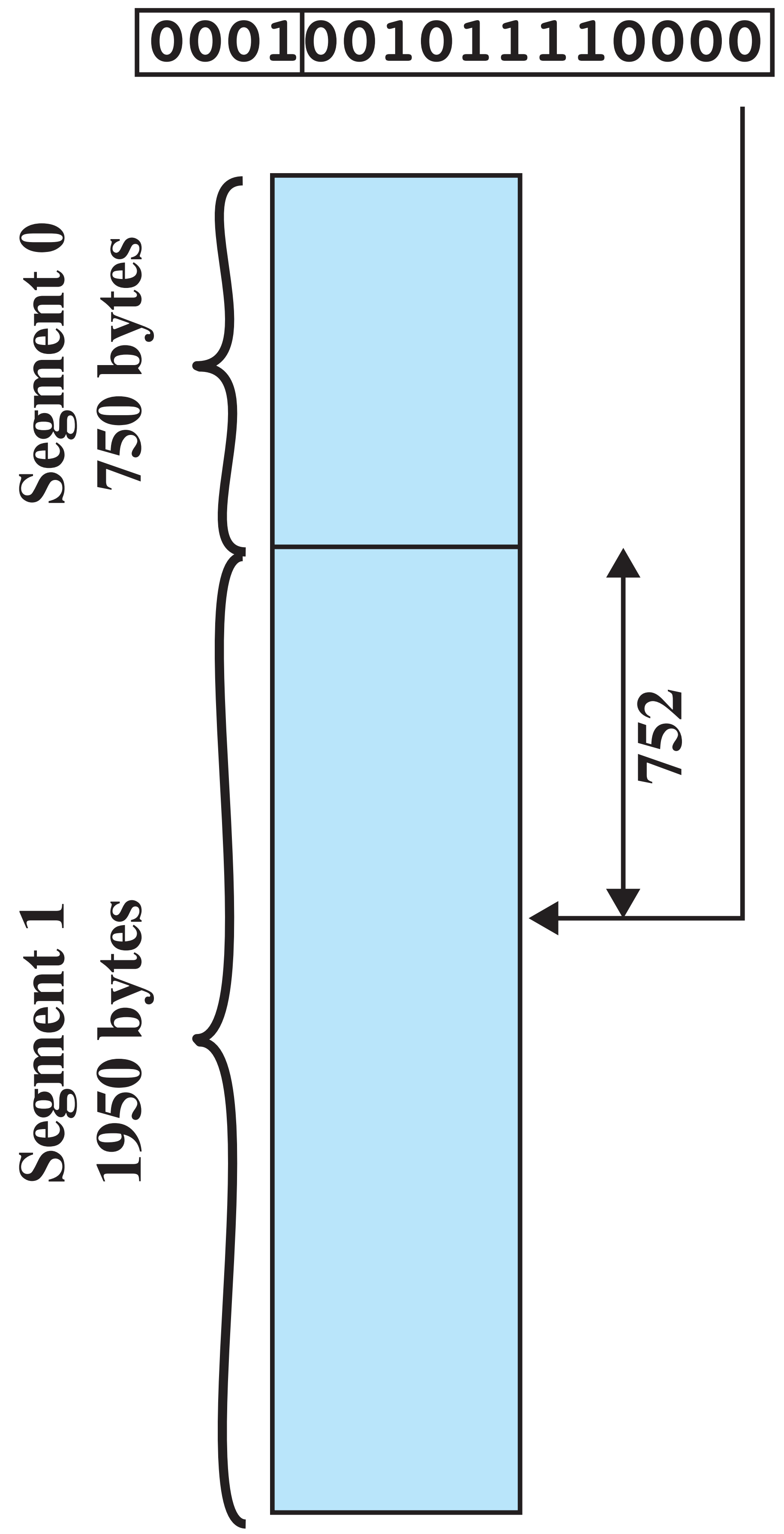
Example:

- 16-bit addresses
  - n = 4 bits
  - m = 12 bits

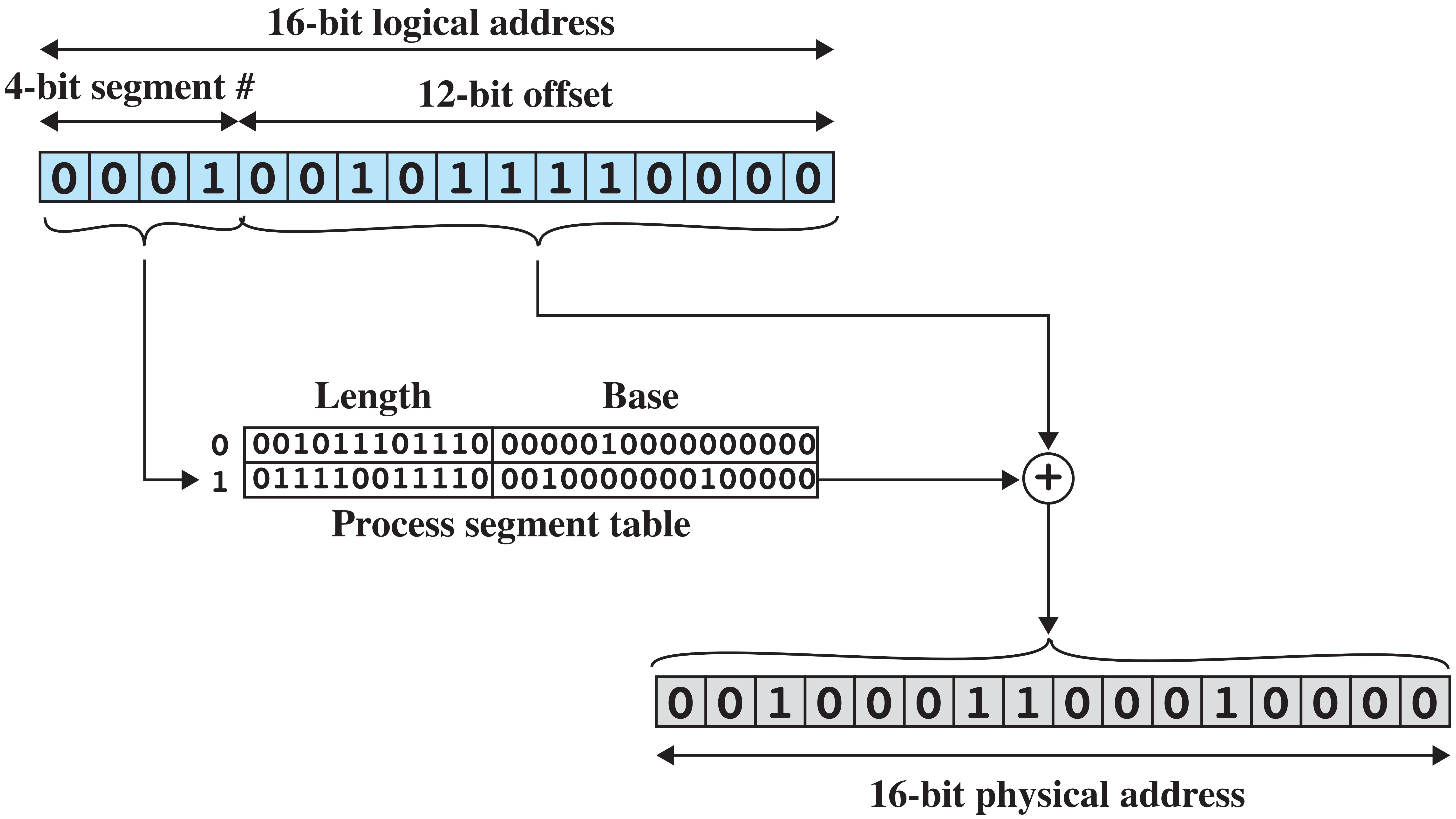
Q: *What is the maximum size of a segment?*
→ 4K = 2^{12}

Q: *How many segments are possible?*
→ 4 bits used for segment #→ 16 pages

Logical address =
Segment# = 1, Offset = 752



Segmentation — Example of Logical-to-Physical Address Translation



	Length	Base
0	001011101110	0000010000000000
1	011110011110	0010000000100000

Process segment table