

?

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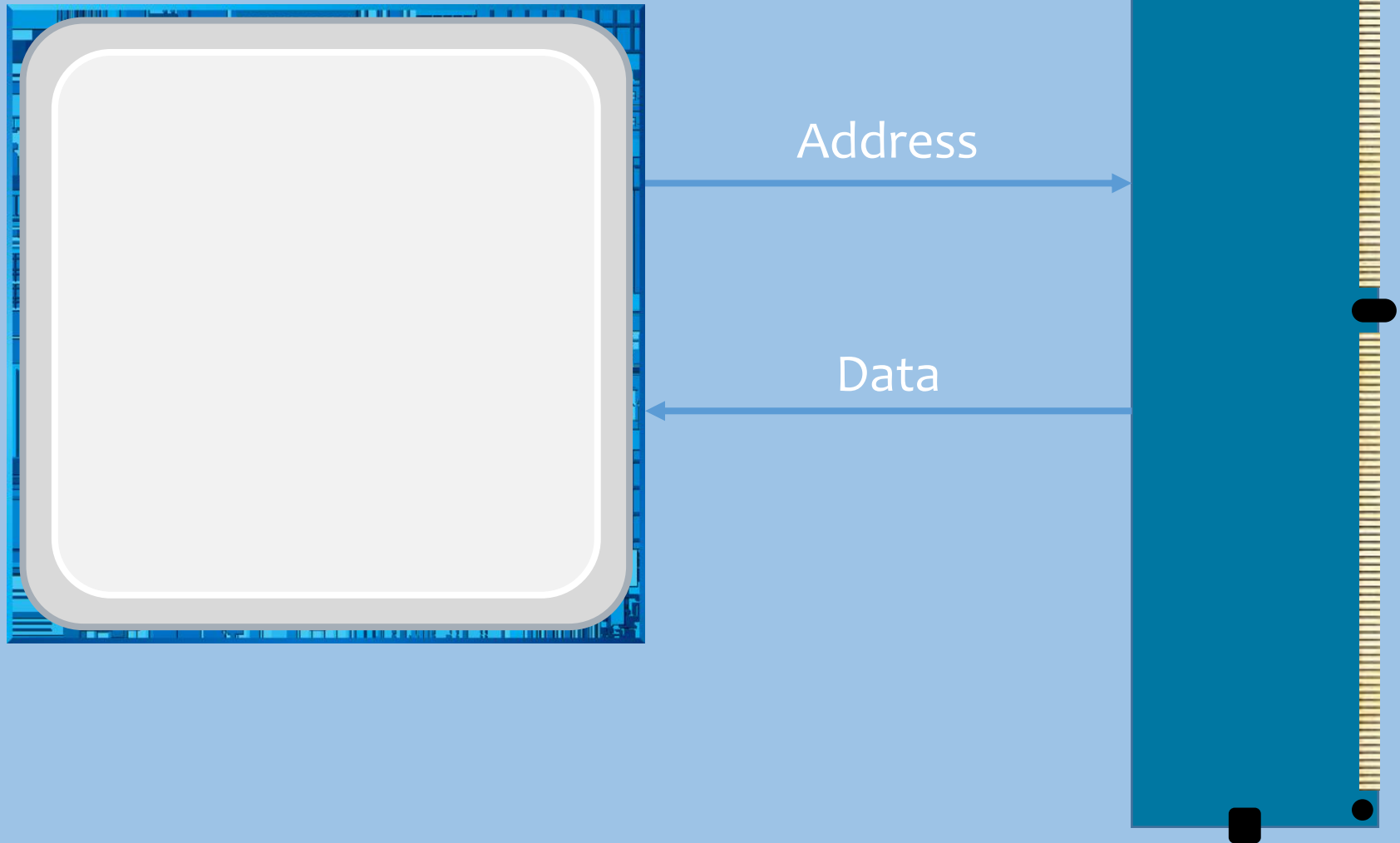
Memory Allocation

① ?

② ?

③ ?

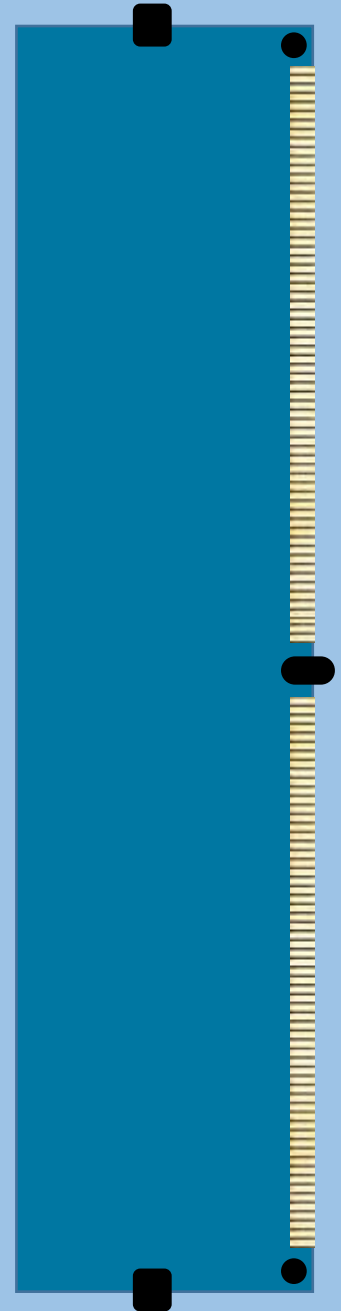
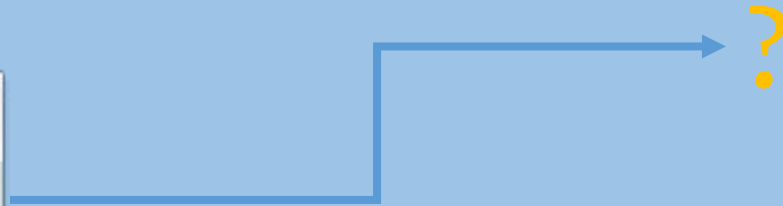
Physical Address



Problem



Process A



Problem



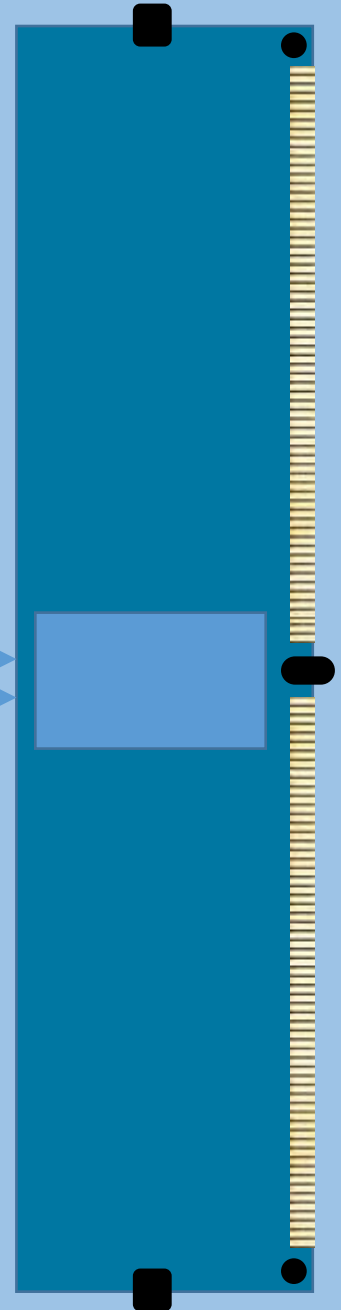
Process A

PA 0xABC



Process B

PA 0xABC



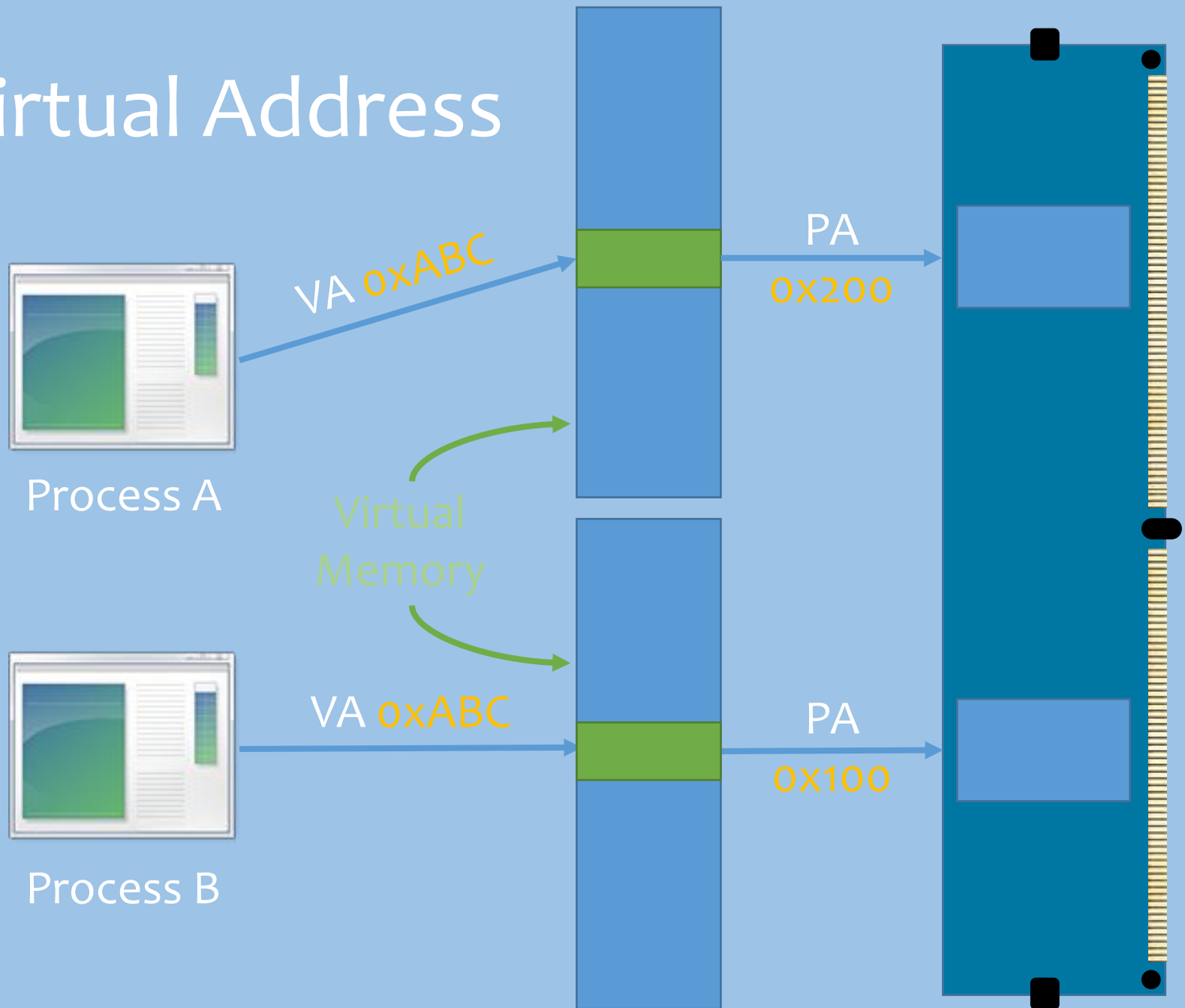


David John Wheeler

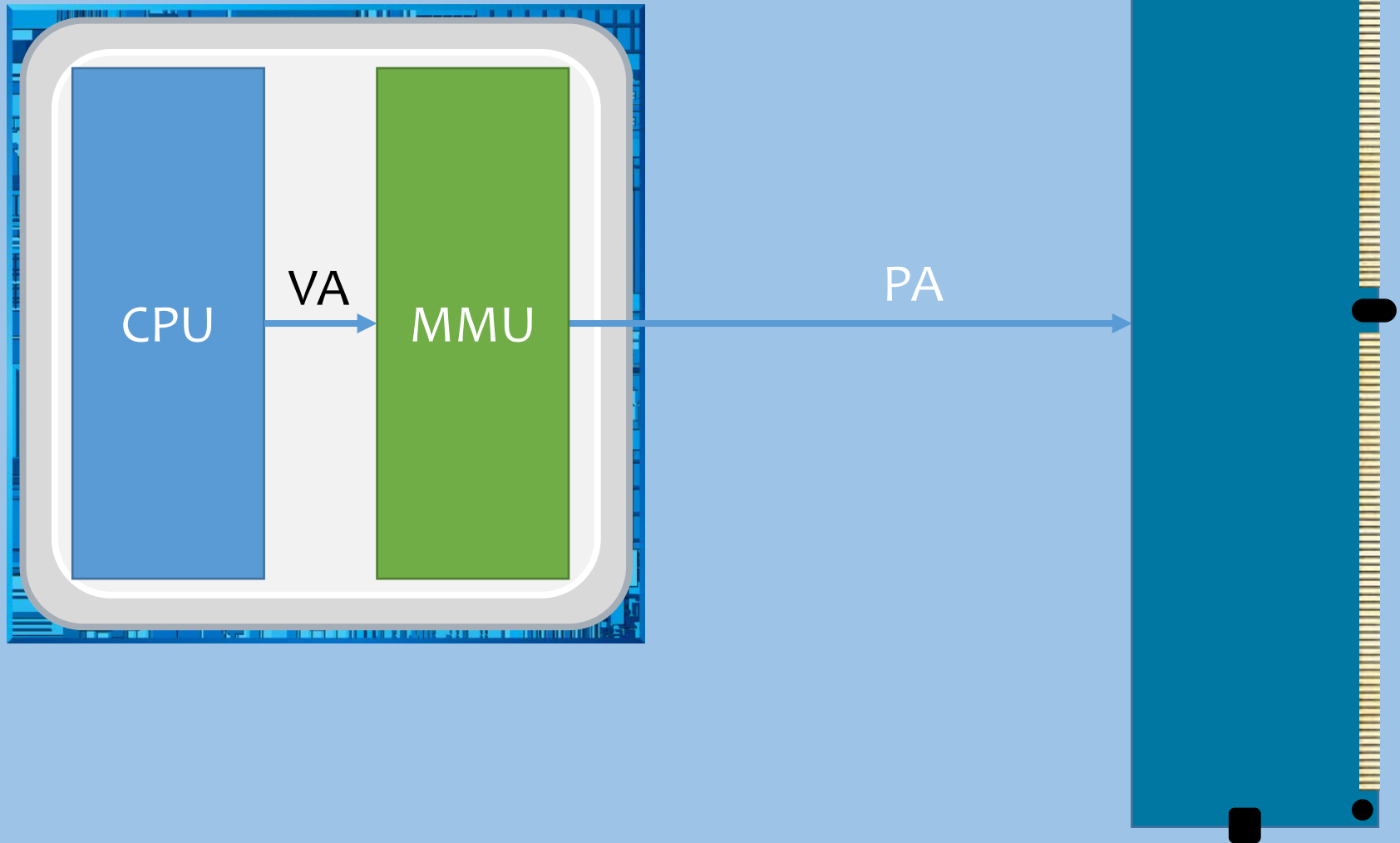
1985 Computer Pioneer Award
for assembly language programming

“ All problems in computer science can be solved by another level of indirection ... except of course for the problem of too many indirections. ”

Virtual Address



Memory Management Unit

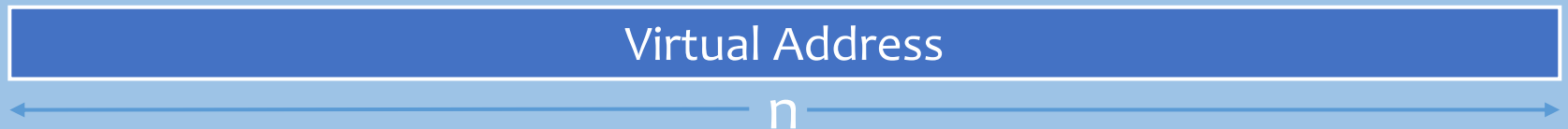


Address Space

Virtual
Address Space
 $\{0, 1, \dots, N - 1\}$



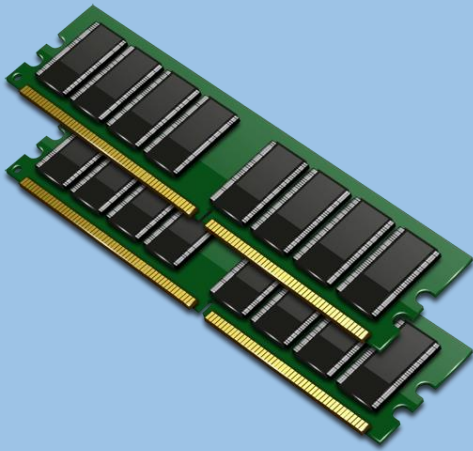
Physical
Address Space
 $\{0, 1, \dots, M - 1\}$



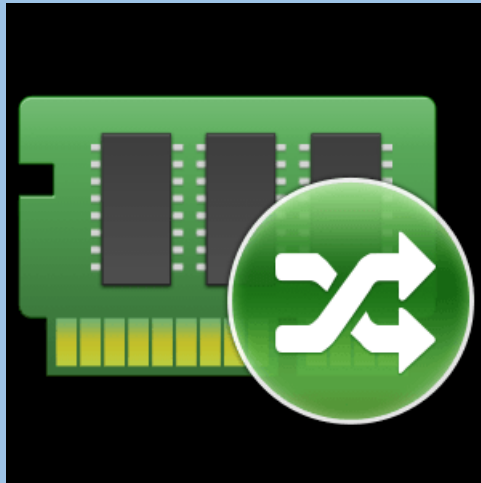
Virtual Address

Number of virtual address bits (n)	Number of virtual addresses (N)	Largest possible virtual address
8		
	$2^8=64K$	
		$2^{32}-1=?G-1$
	$2^{28}=256T$	
64		

Why Virtual Memory?



Efficiency

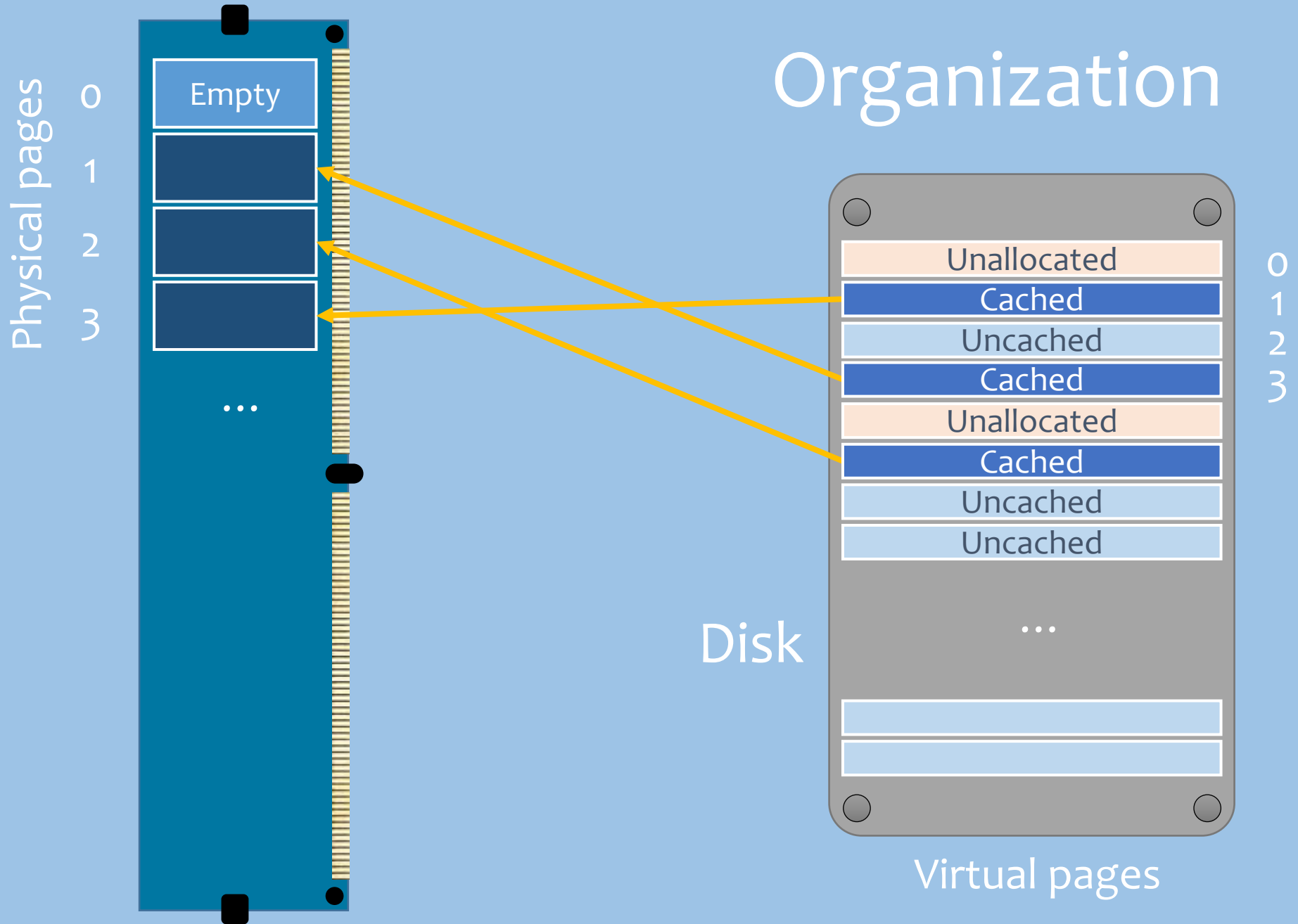


Simplification



Protection

Organization



Physical pages

0

1

2

3

Empty

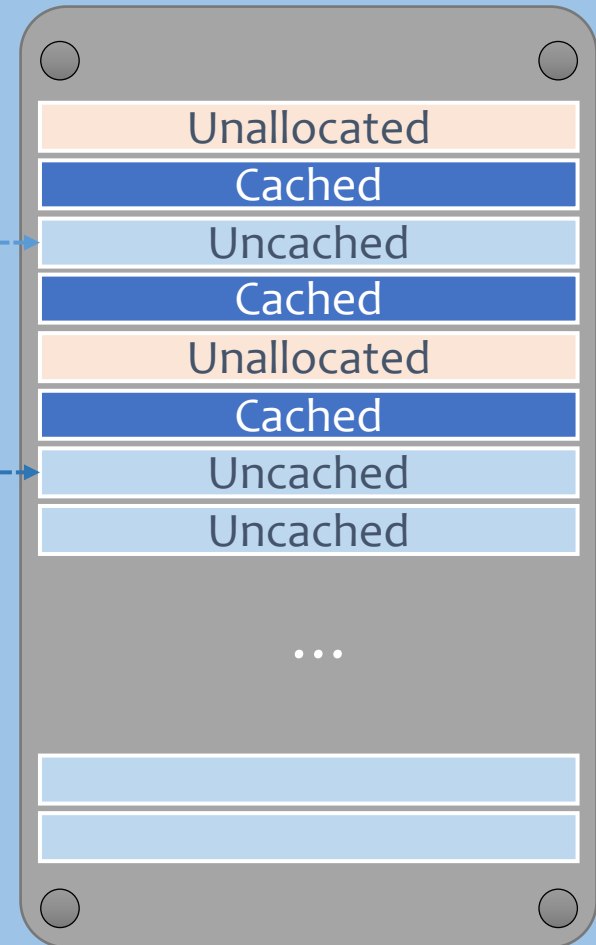
...

Page
table

0	null
1	
0	
1	
0	null
1	
0	
	...

Valid

Page table



0

1

2

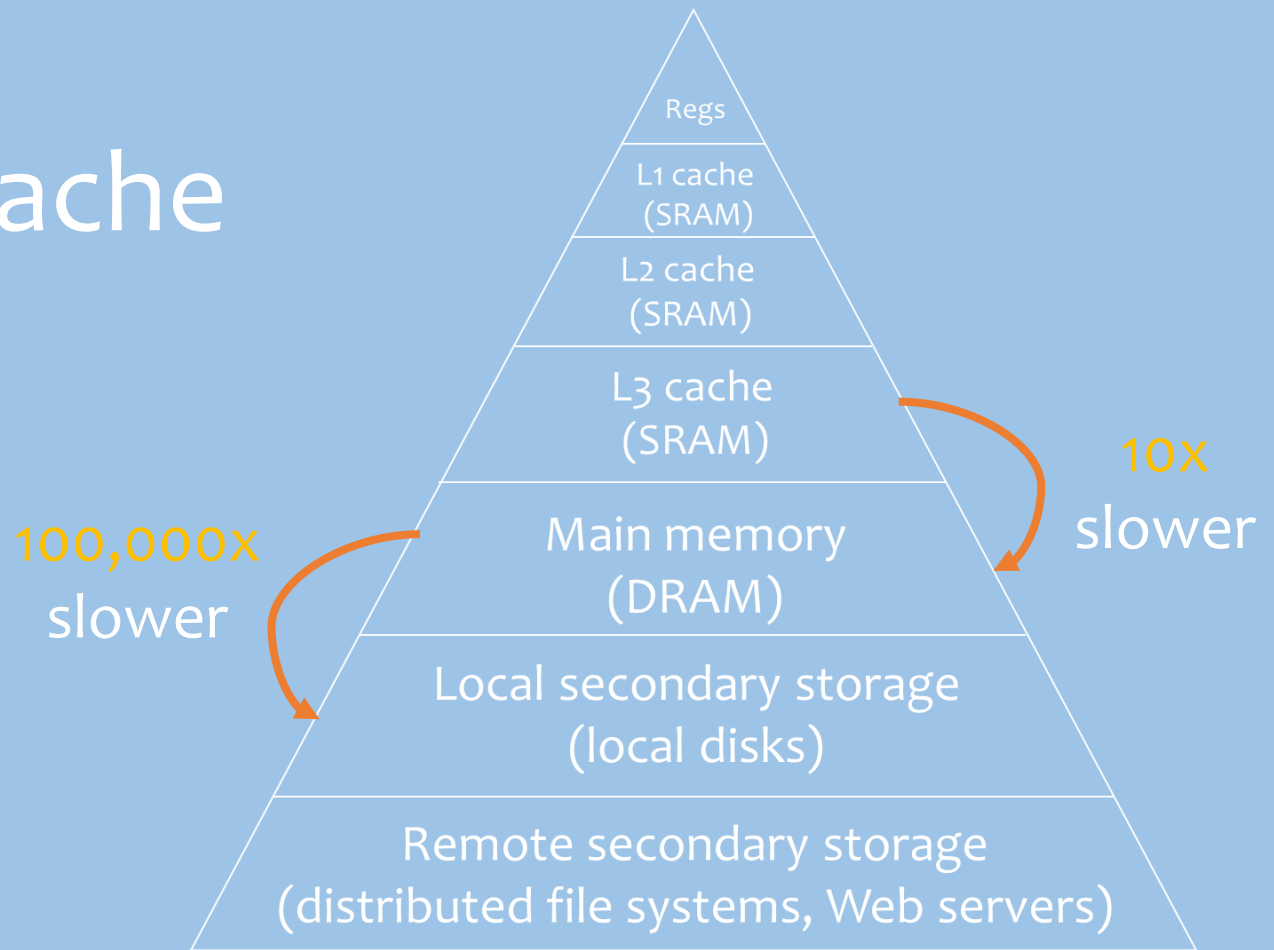
3

Virtual pages

Page Table Entries

n	$P=2^p$	Number of PTEs
16	4K	
16	8K	
32	4K	
32	8K	

DRAM Cache

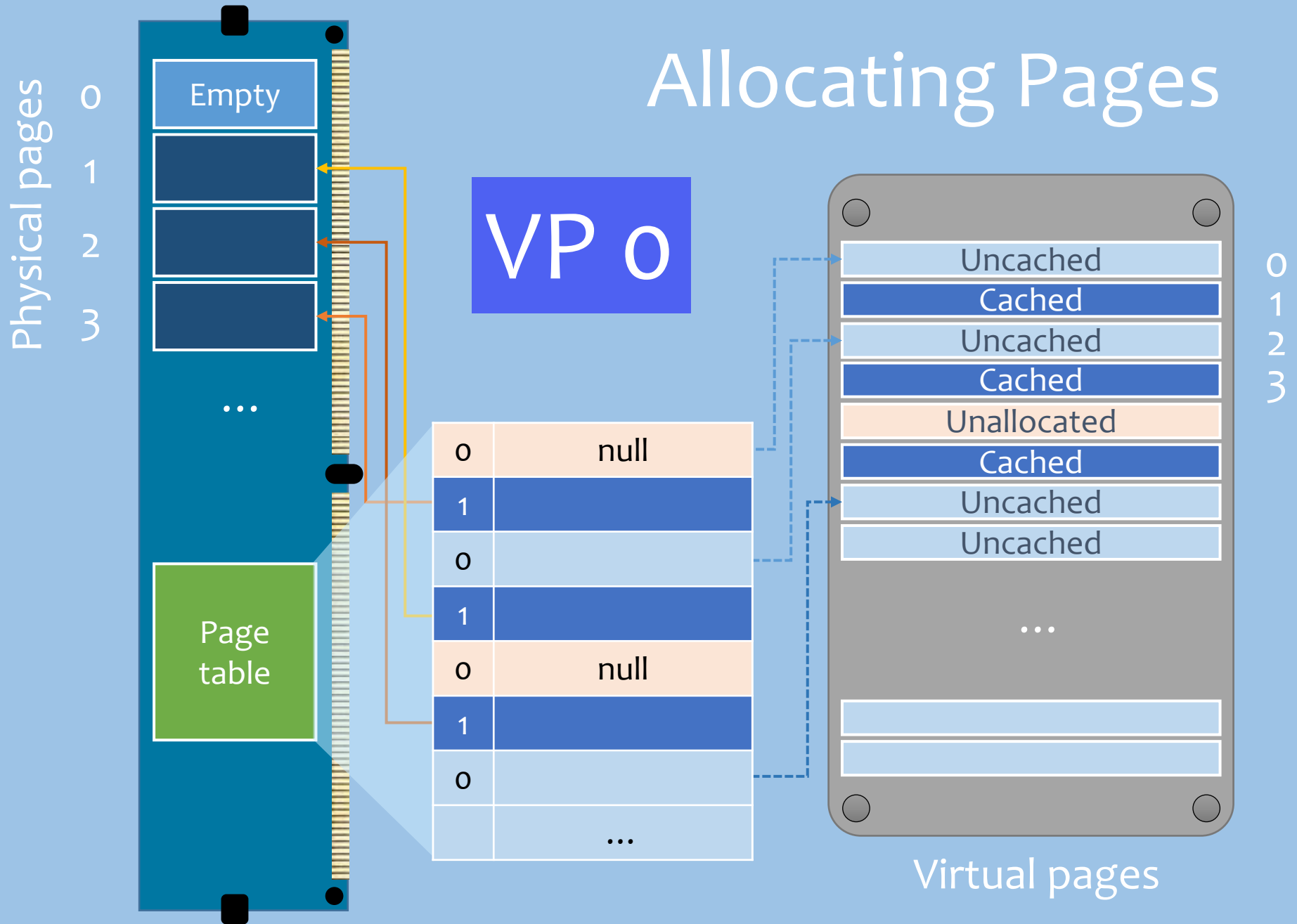


② Fully Associative



③ Write-back

Allocating Pages



Physical pages

0

1

2

3

Empty

...

Page
table

VP 1

0

1

0

1

0

1

0

null

...

Page Hit

Uncached

Cached

Uncached

Cached

Unallocated

Cached

Uncached

Uncached

...

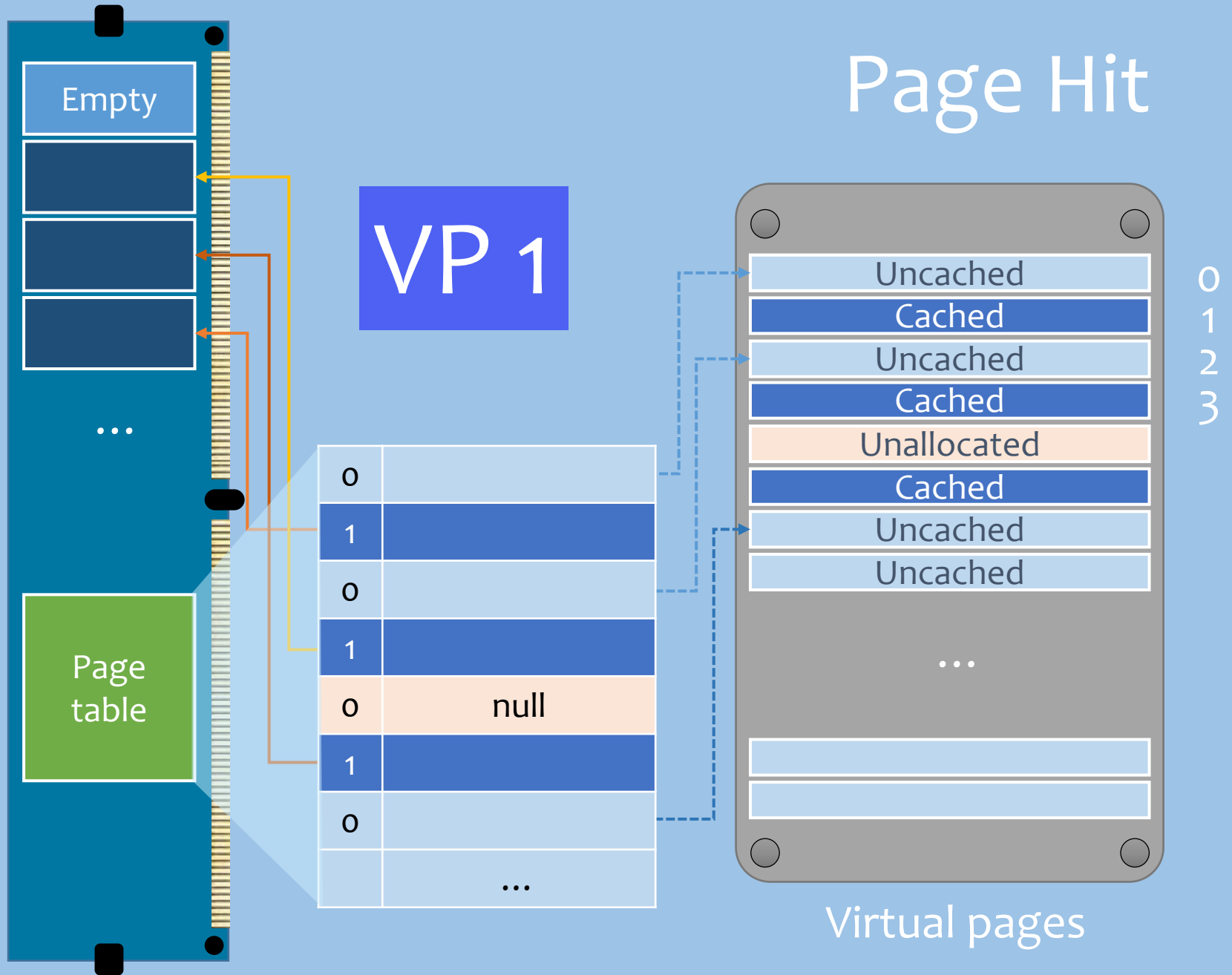
0

1

2

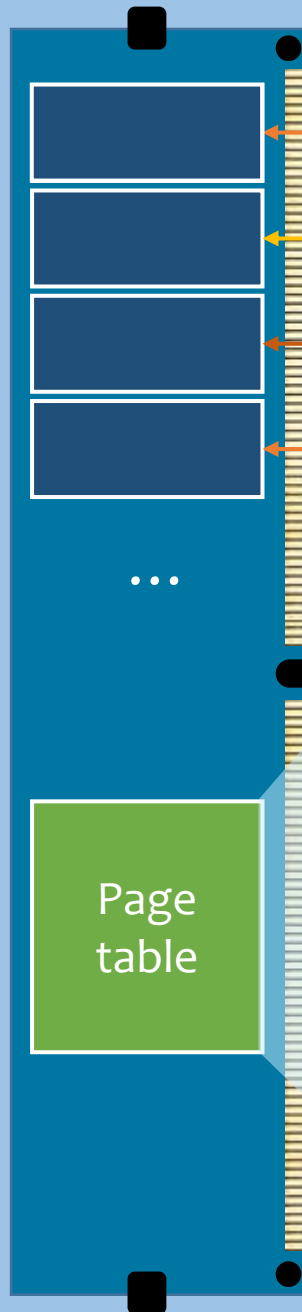
3

Virtual pages



Physical pages

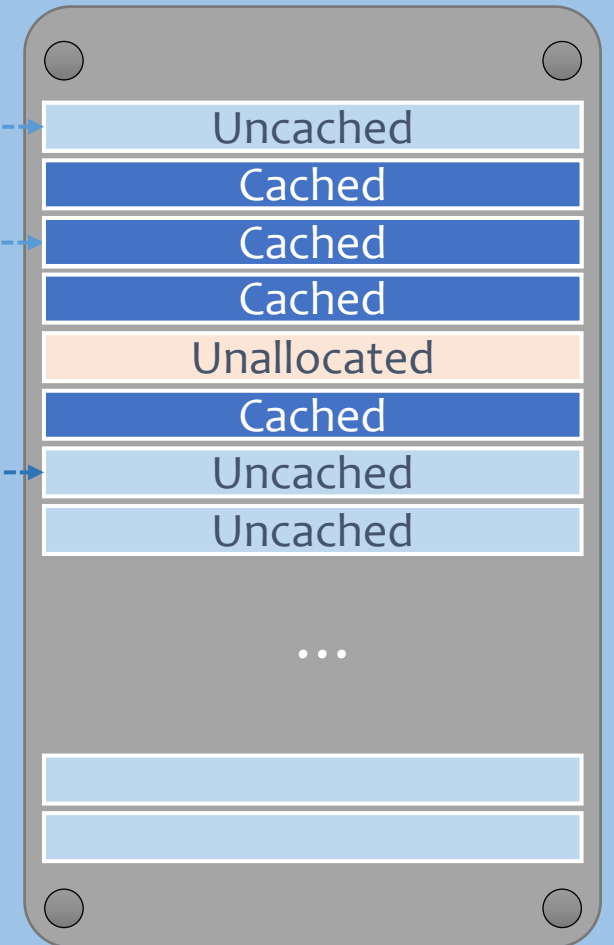
0
1
2
3
...



VP 2

0	
1	
1	
1	
0	null
1	
0	
	...

Page Fault

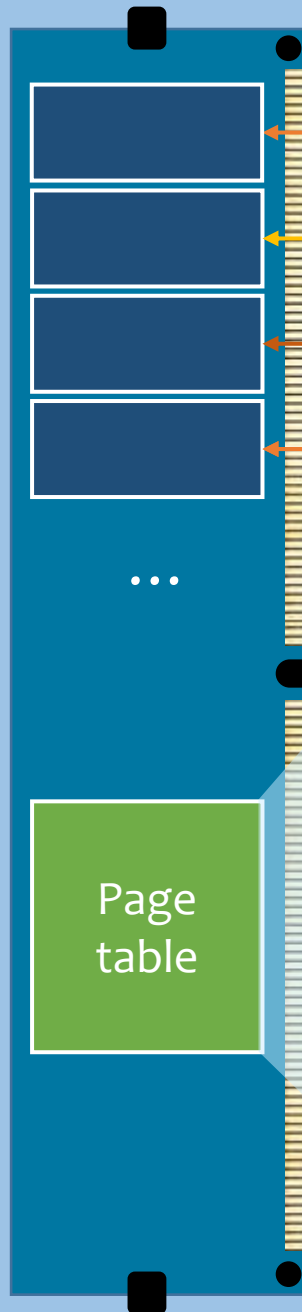


0
1
2
3
...

Virtual pages

Physical pages

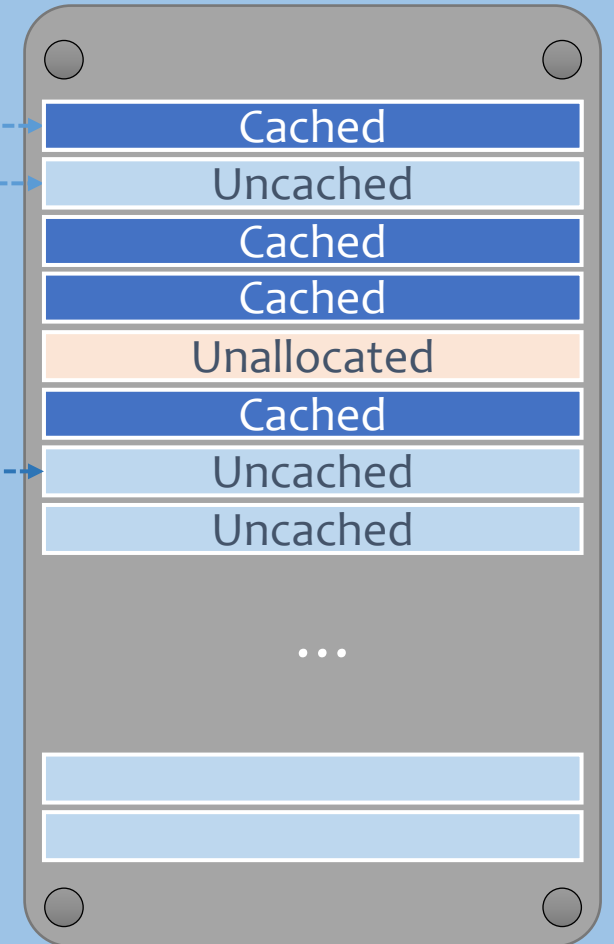
0
1
2
3
...



VP 0

1	
0	
1	
1	
0	null
1	
0	
	...

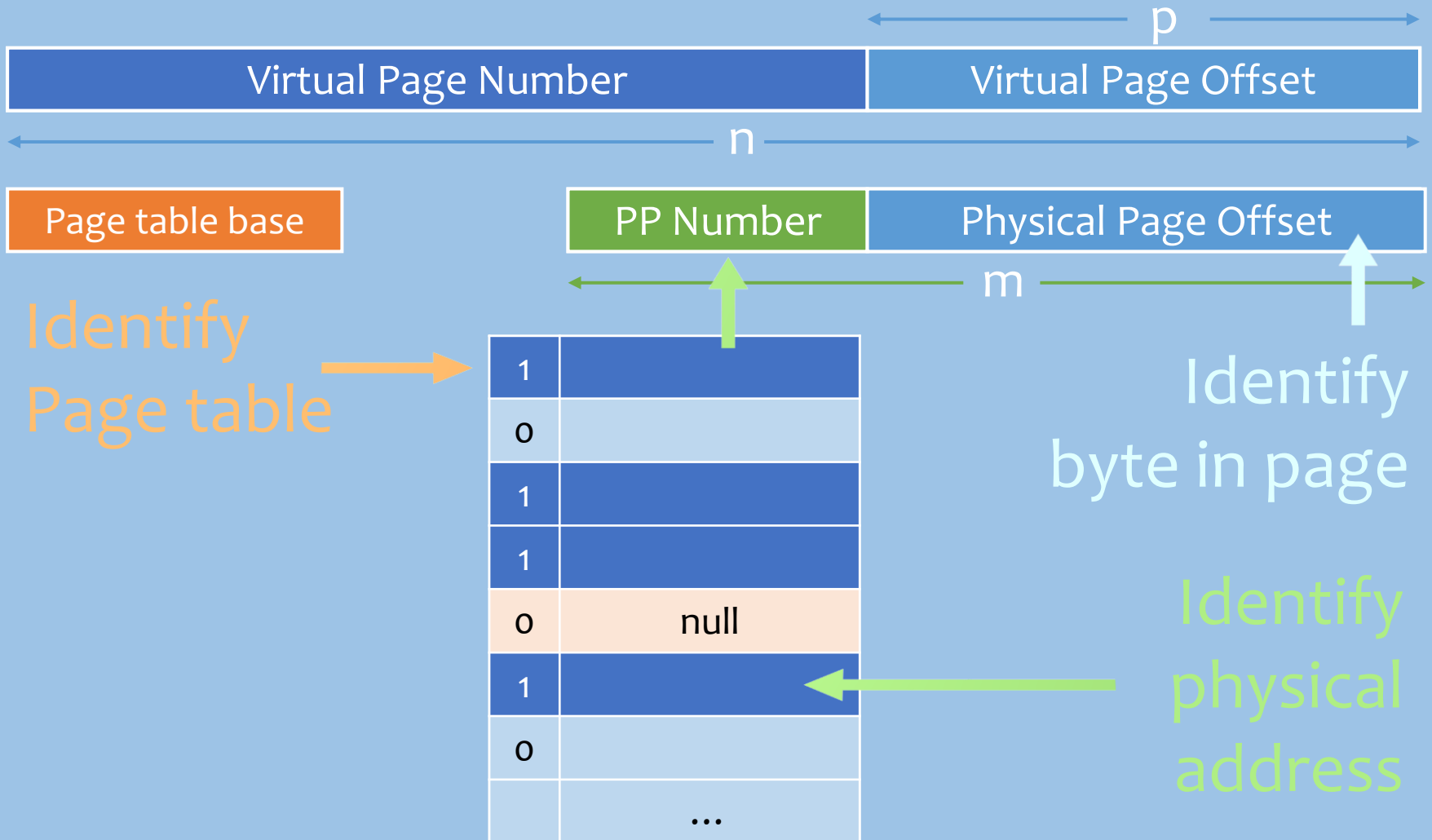
Thrashing



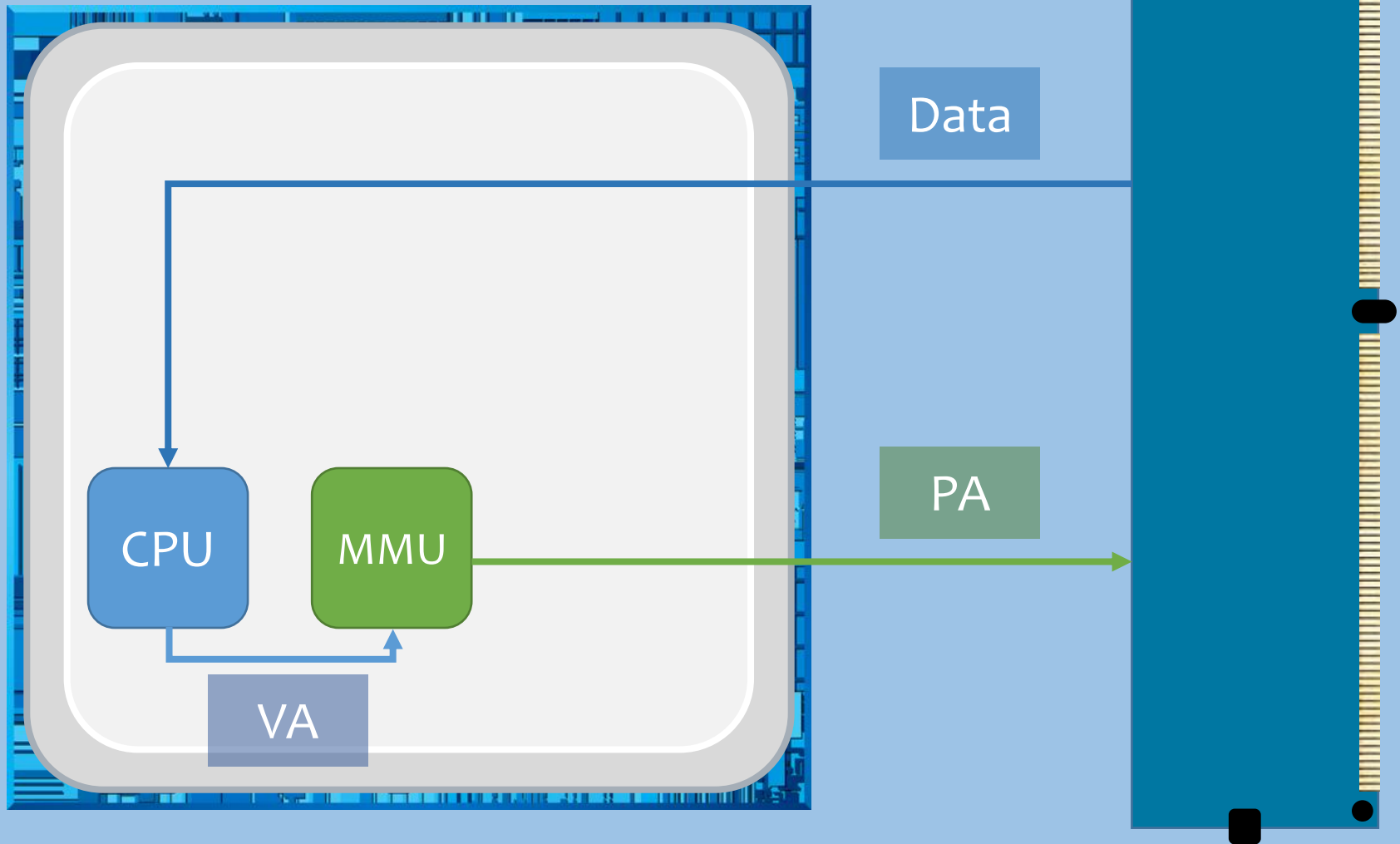
0
1
2
3
...

Virtual pages

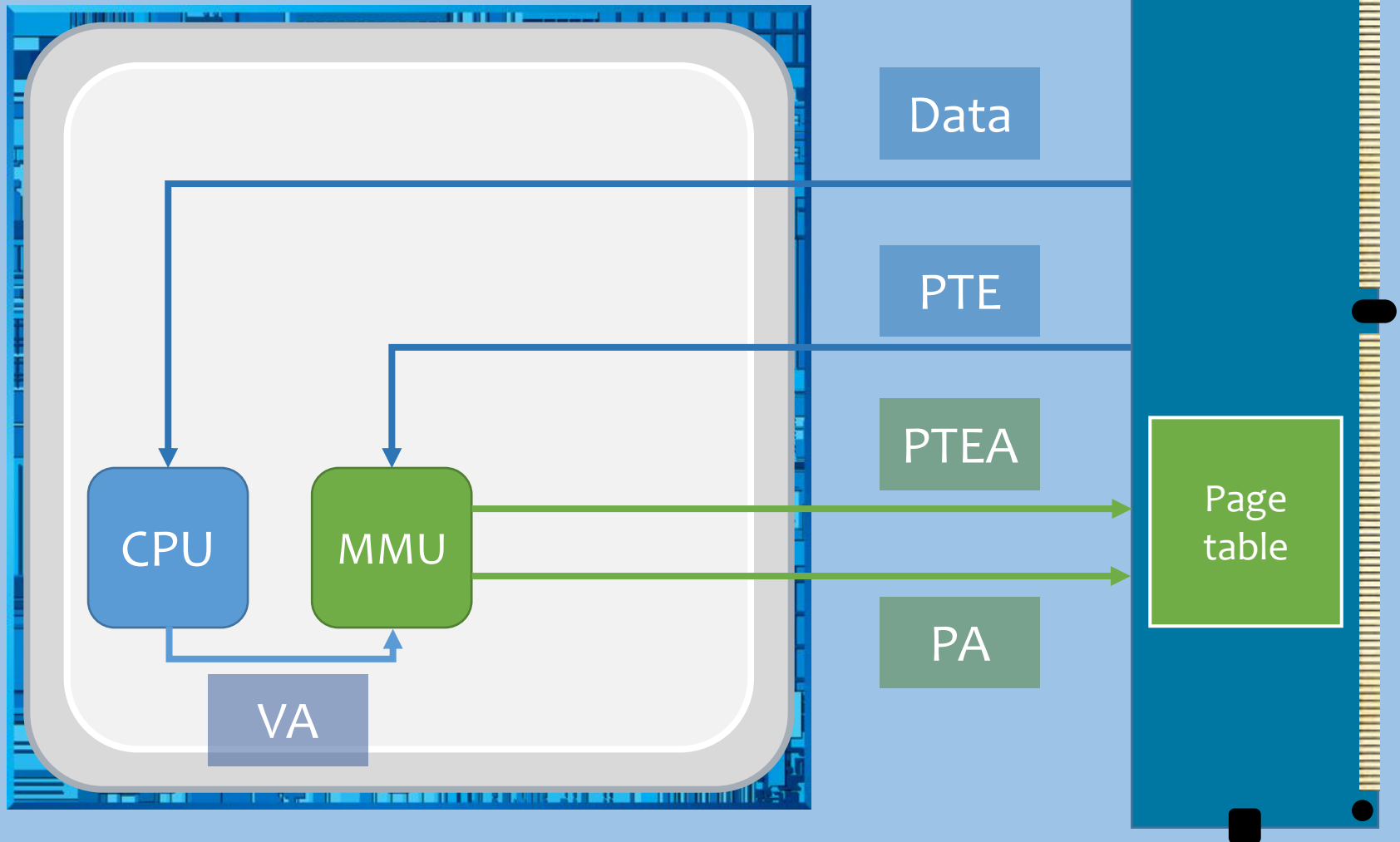
Address Translation



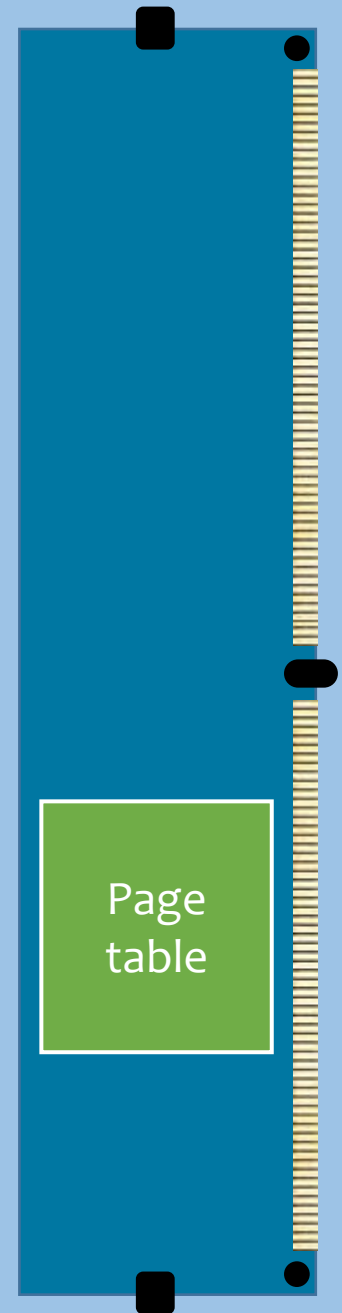
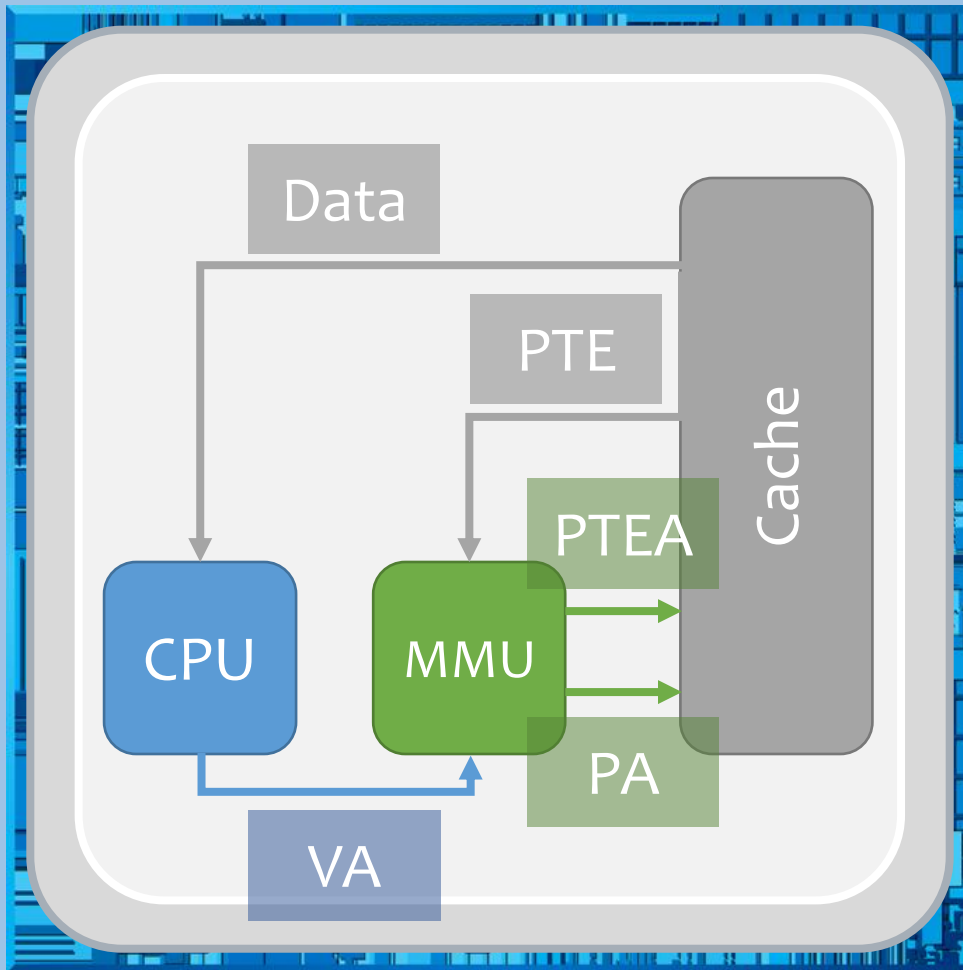
Page Hit



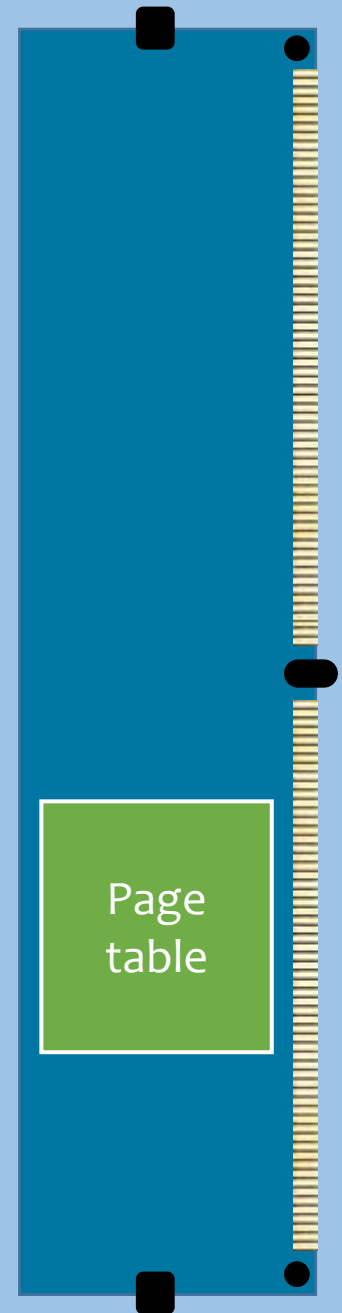
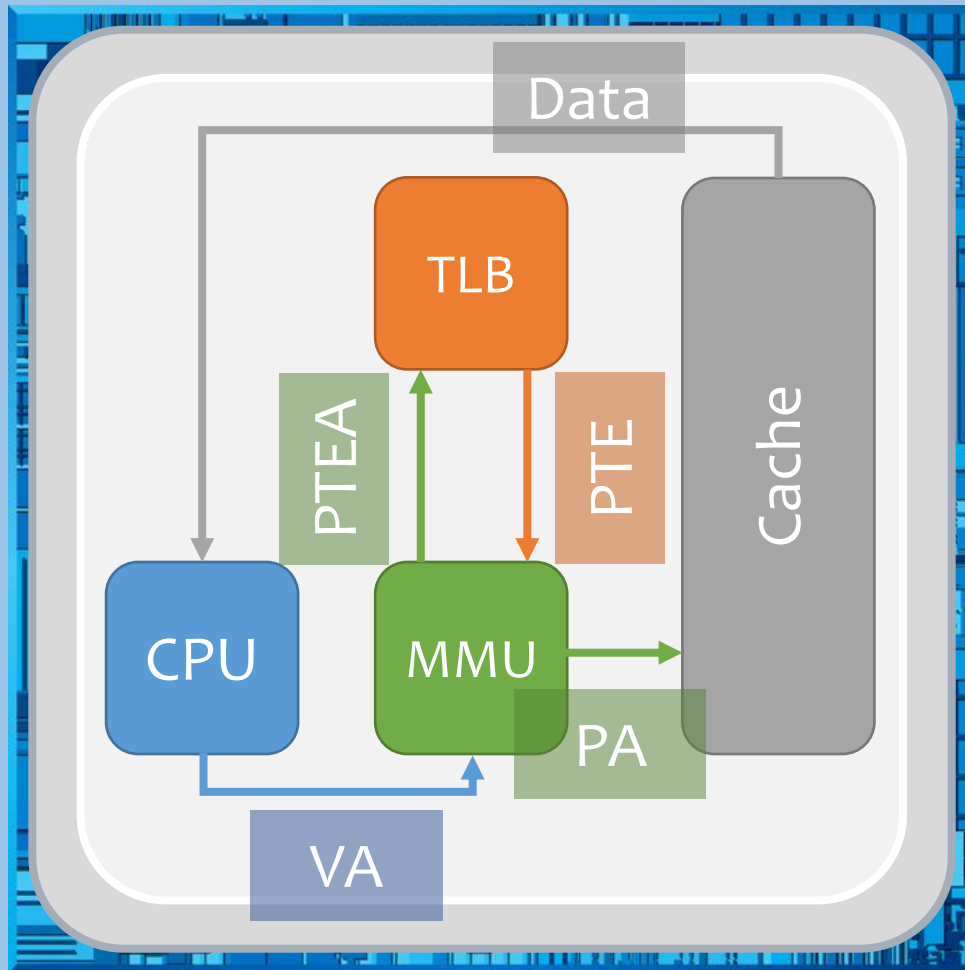
Page Hit



Page Hit



Page Hit



Translation Lookaside Buffer



Summary

- Address
 - Physical
 - Virtual
- Page Hit / Page Fault
- Translation Lookaside Buffer