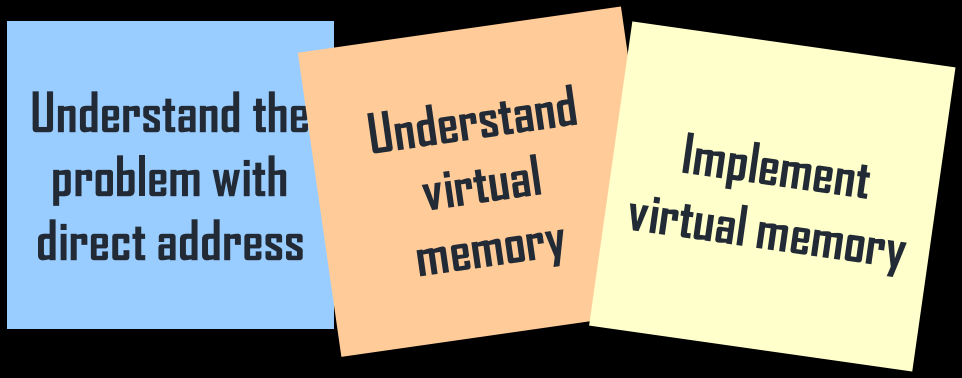


TRUONG DAI HOC KHOA HOC TU NHIEN
KHTN
TP. HO CHI MINH

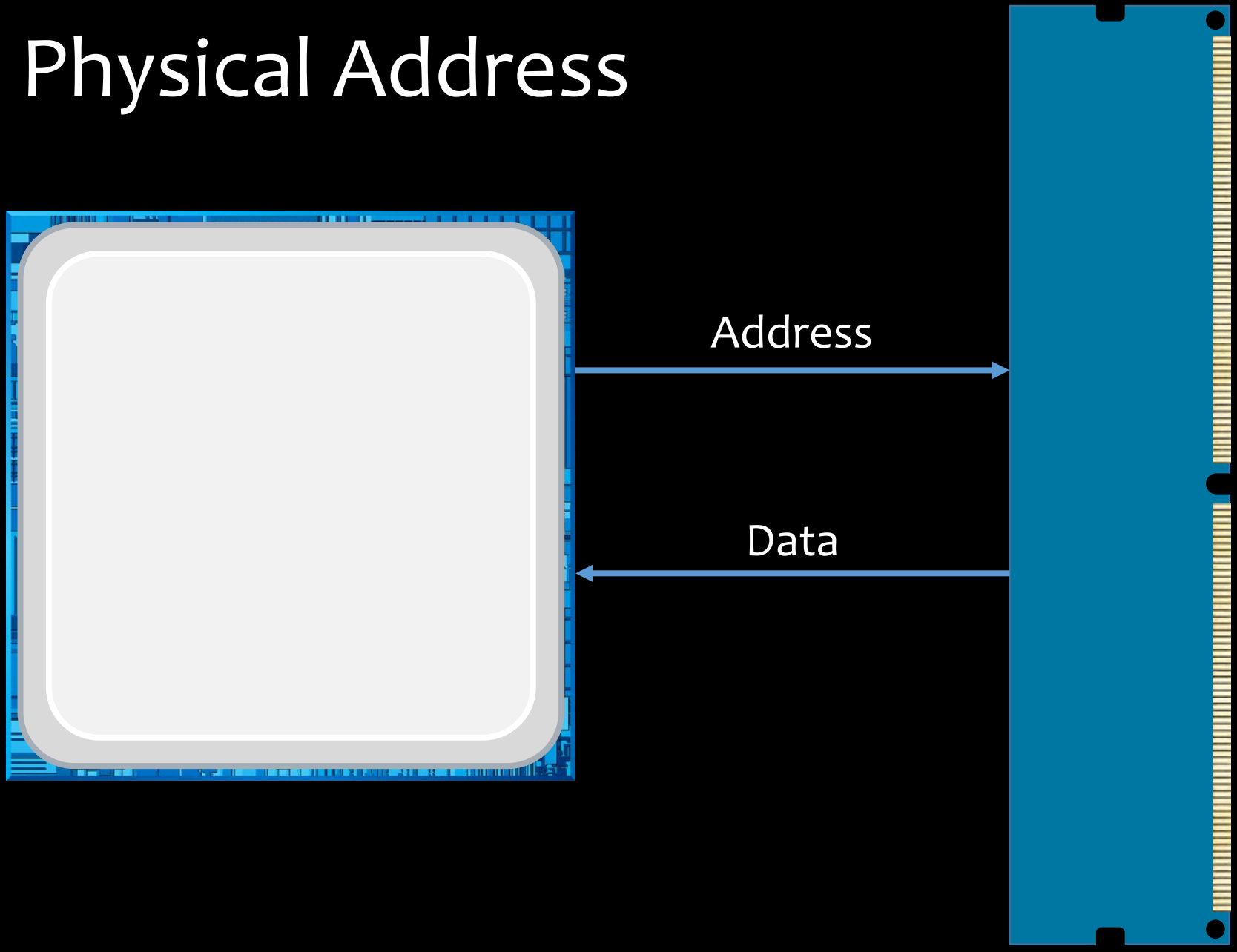
Virtual Memory

① Address Spaces

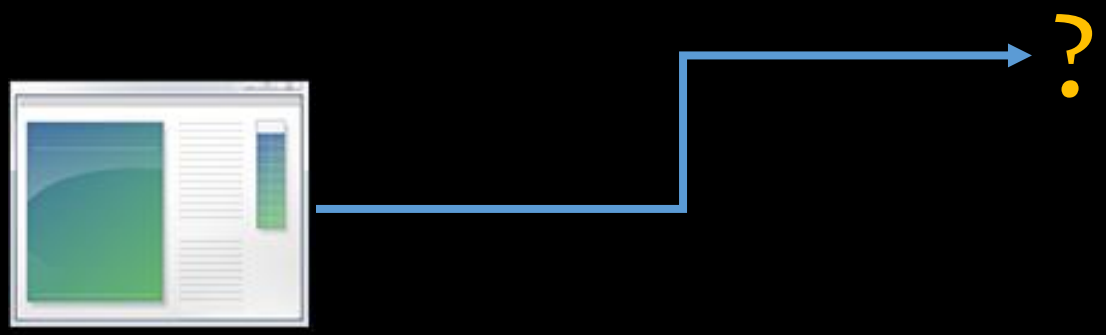
② VM for Memory Management

③ Address Translation

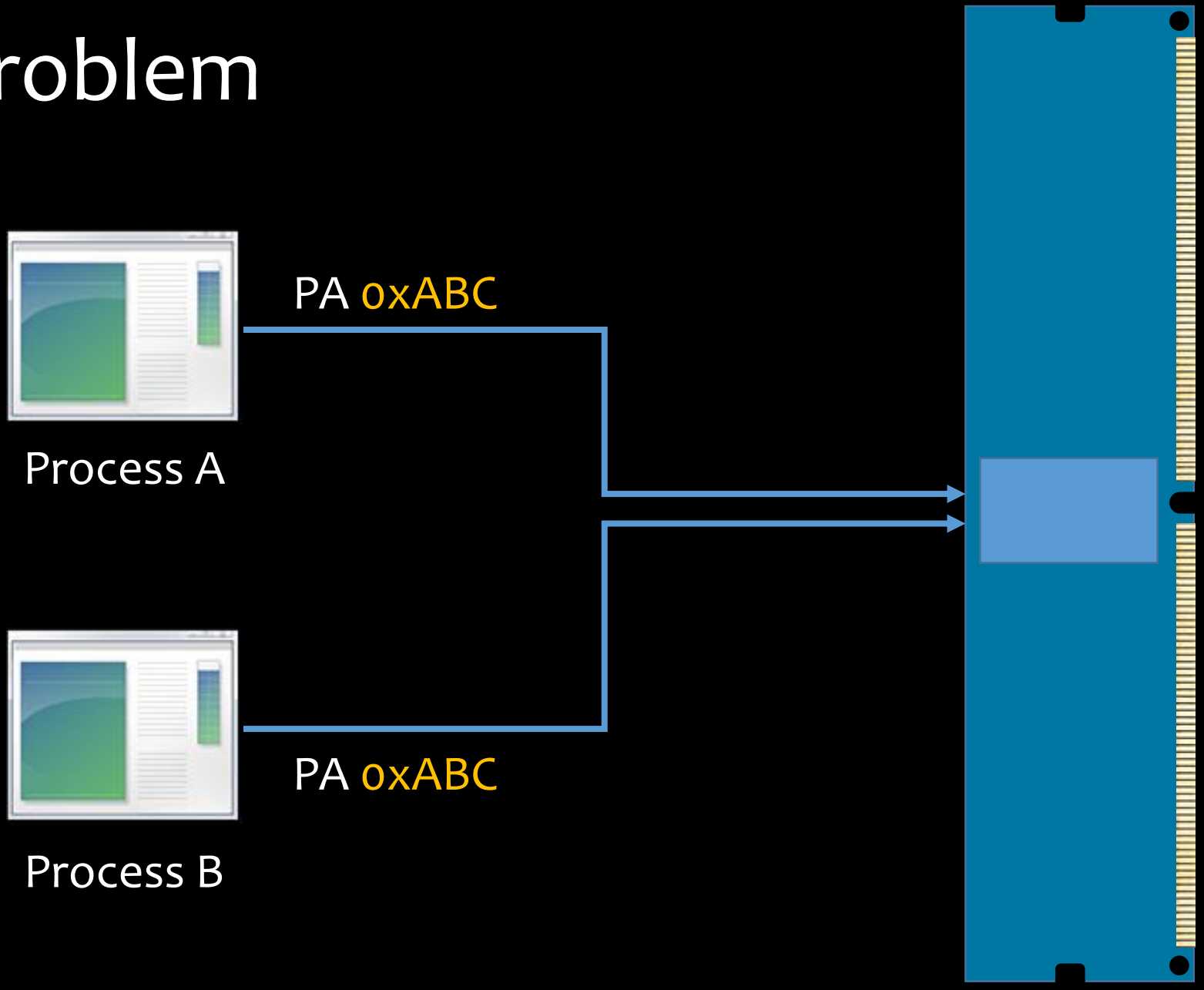
Physical Address



Problem



Problem

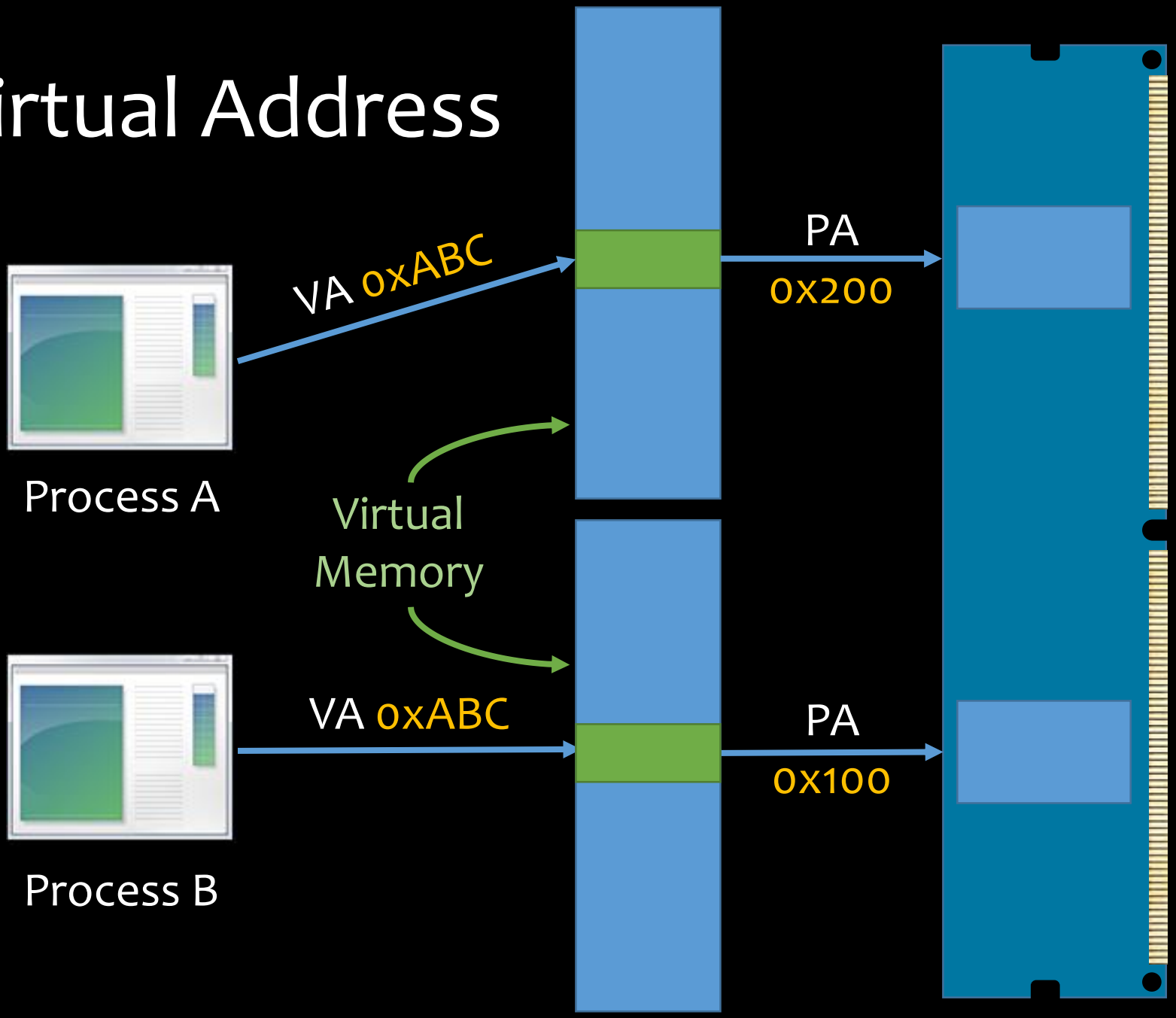


David John Wheeler

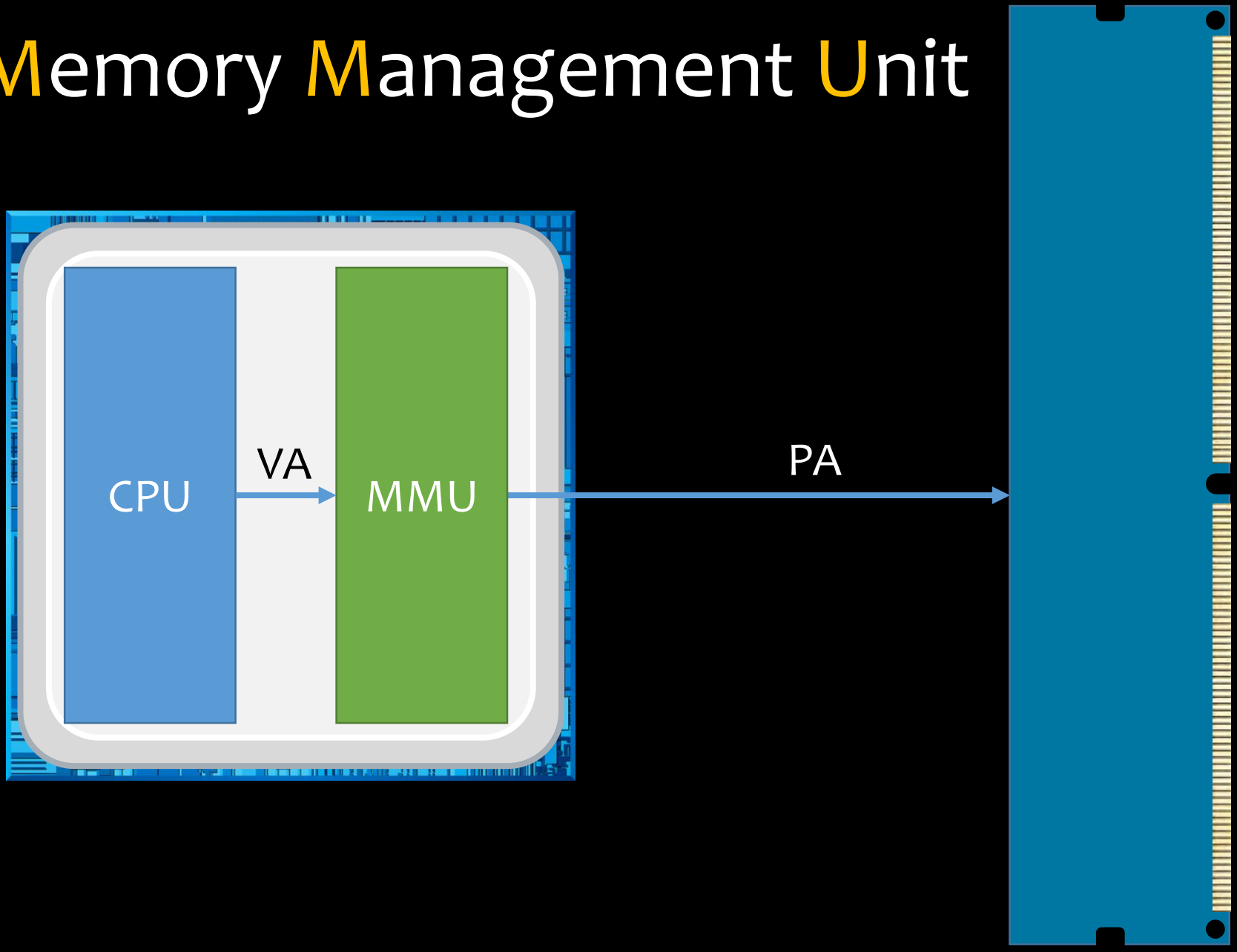
1985 Computer Pioneer Award
for assembly language programming

> 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

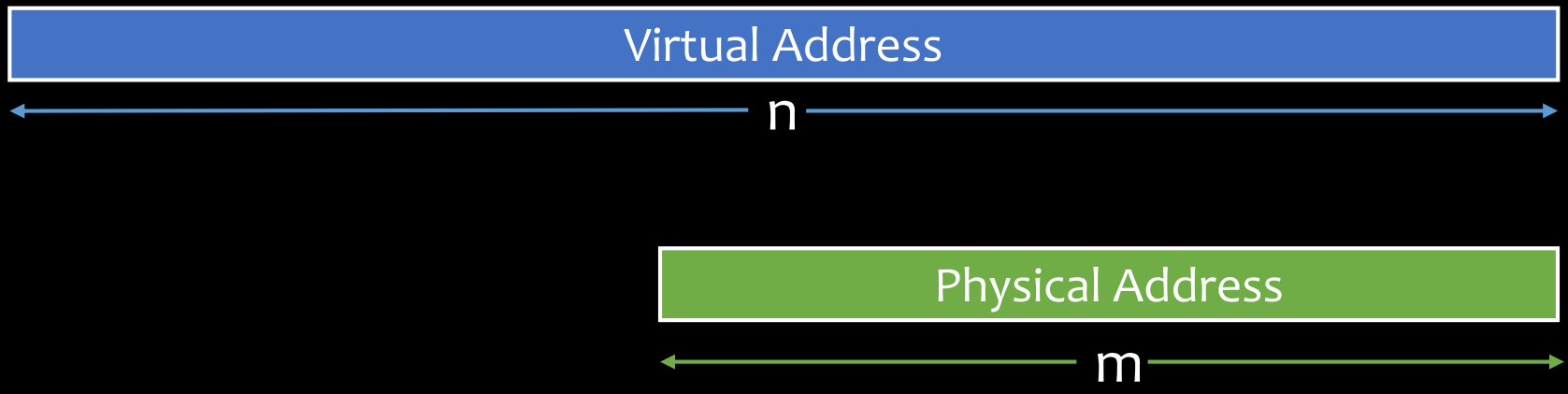
Virtual
Address Space

$\{0,1,\ldots,N-1\}$

$\gg$

Physical
Address Space

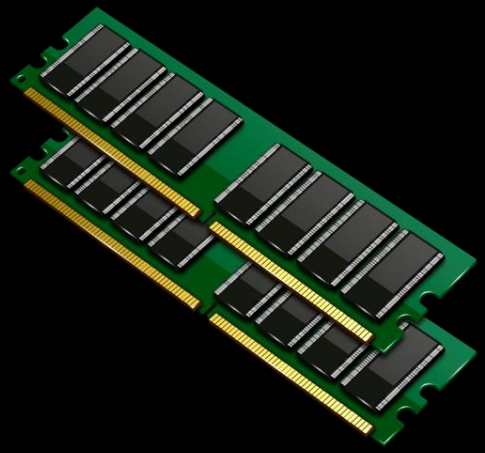
$\{0,1,\ldots,M-1\}$



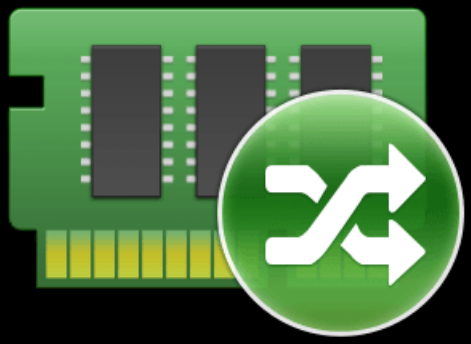
Virtual Address

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

Why Virtual Memory?



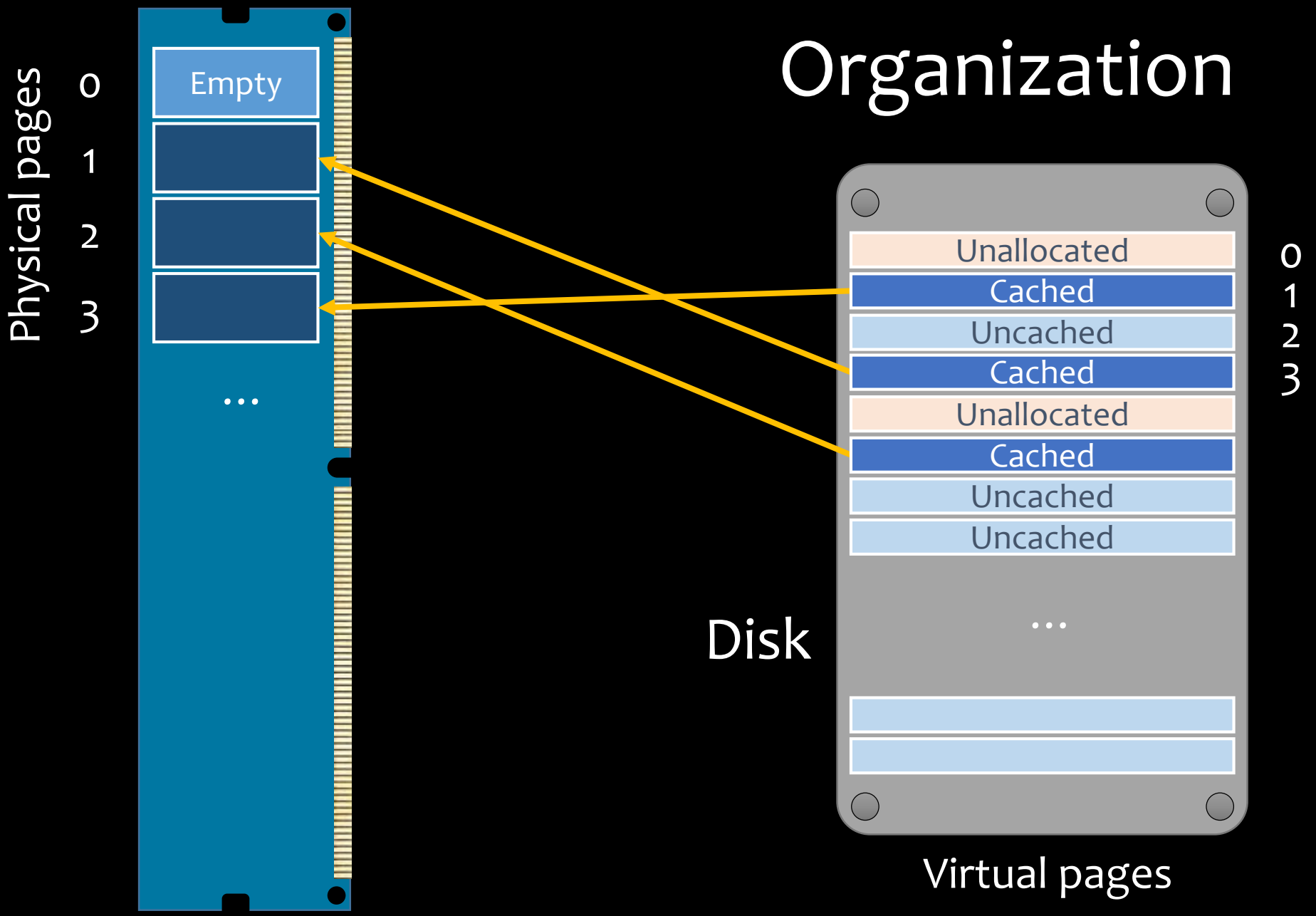
Efficiency

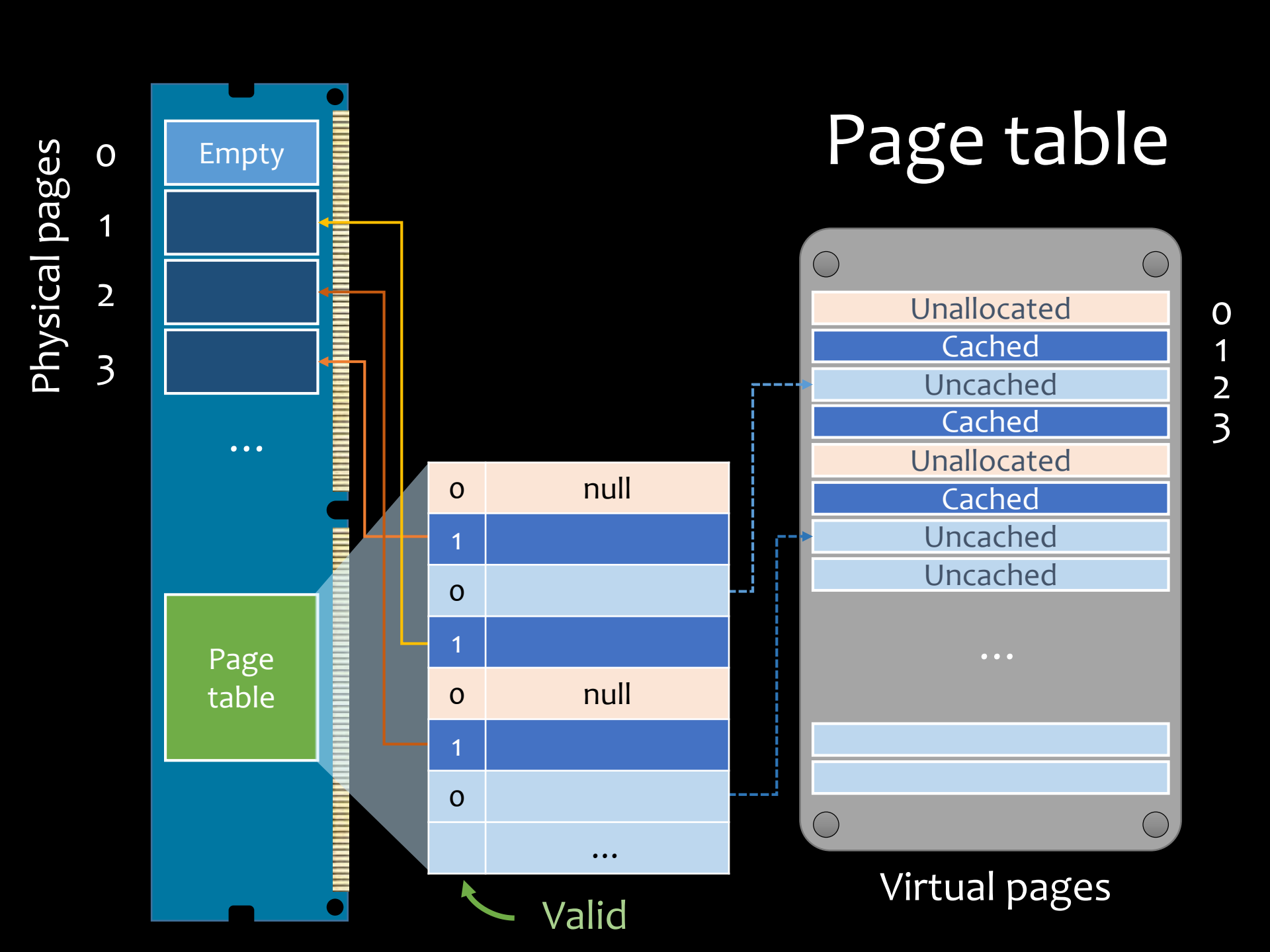


Simplification

Protection

Organization

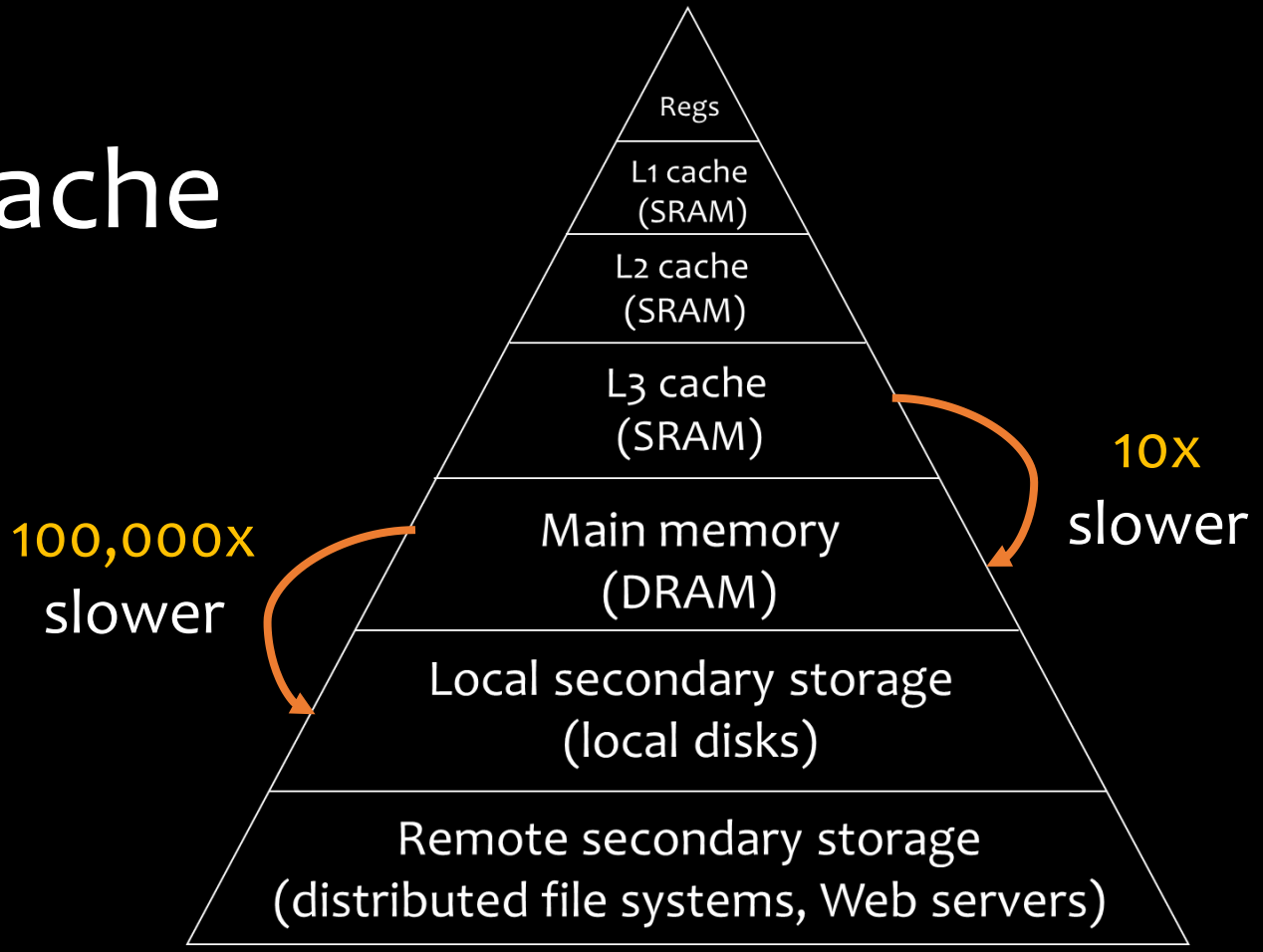



Page table
Physical pages
0
1
2
3
Empty
...
Page table
0 null
1
0
1
0 null
1
0
...
Valid
Unallocated
Cached
Uncached
Cached
Unallocated
Cached
Uncached
Uncached
...
0
1
2
3
Virtual pages

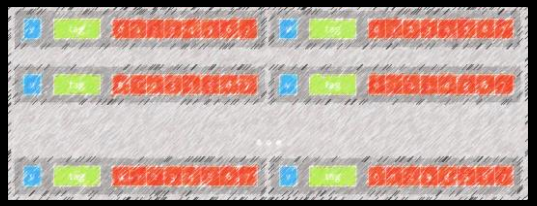
Page Table Entries

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

DRAM Cache



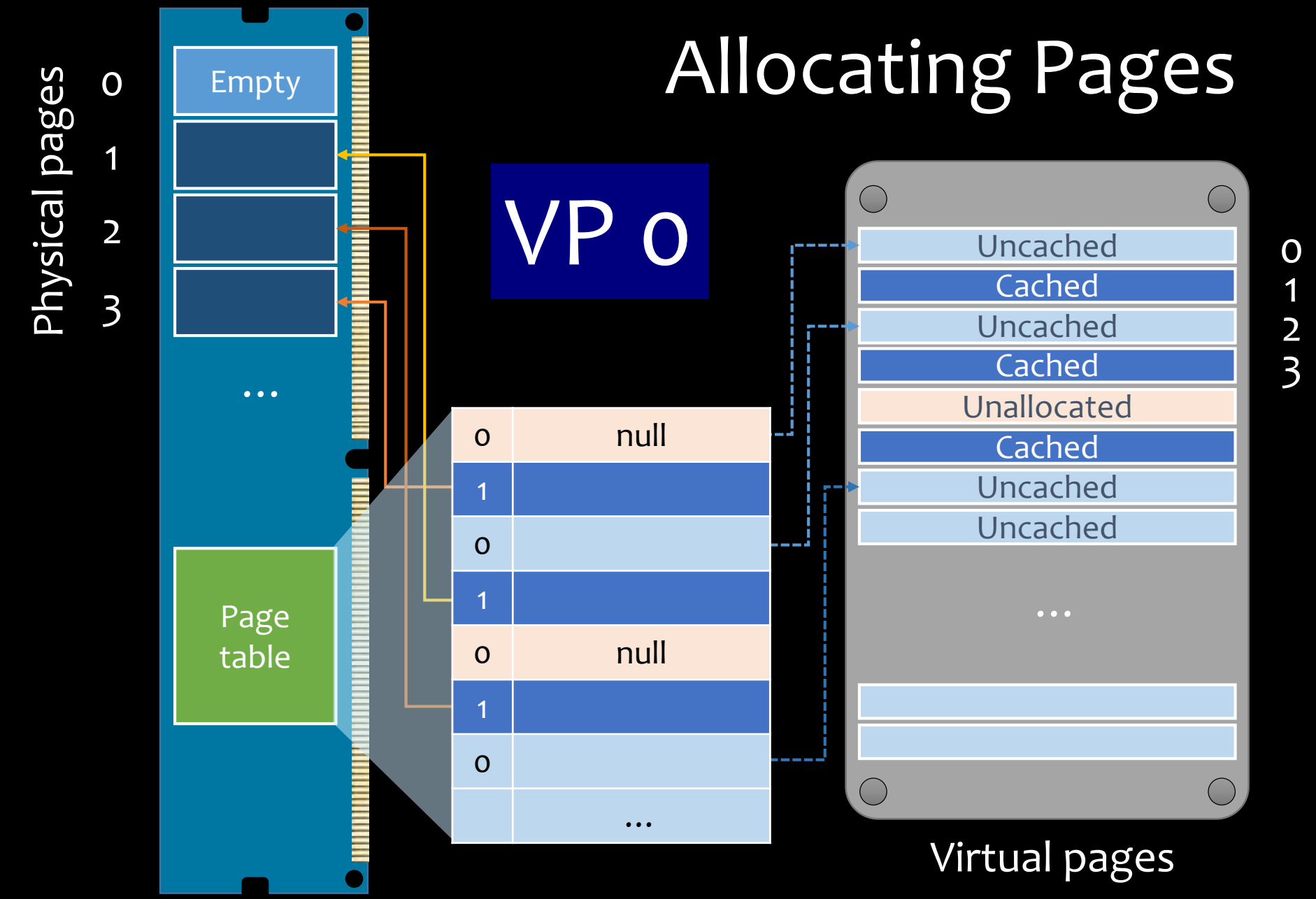
① Large Page

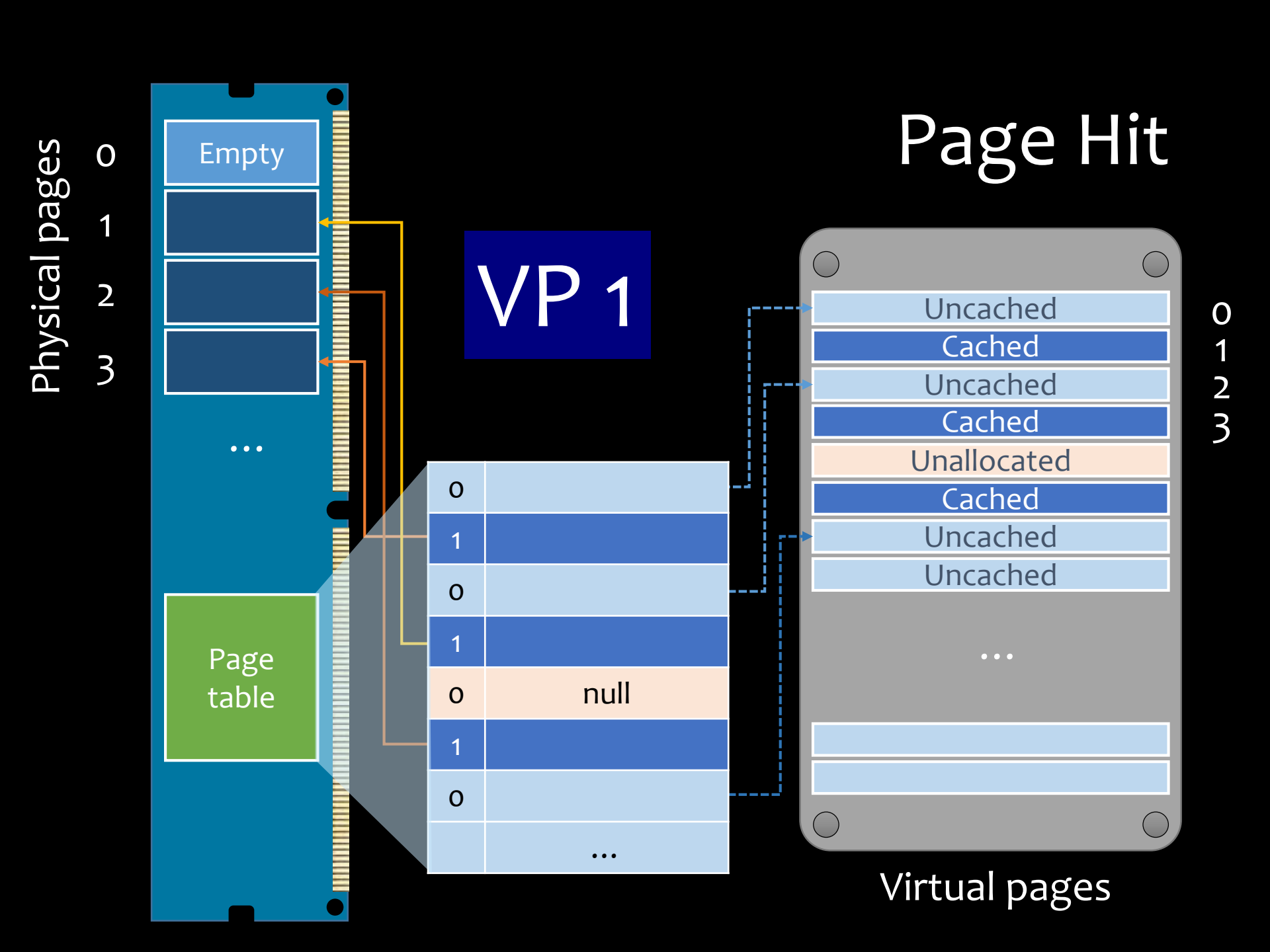


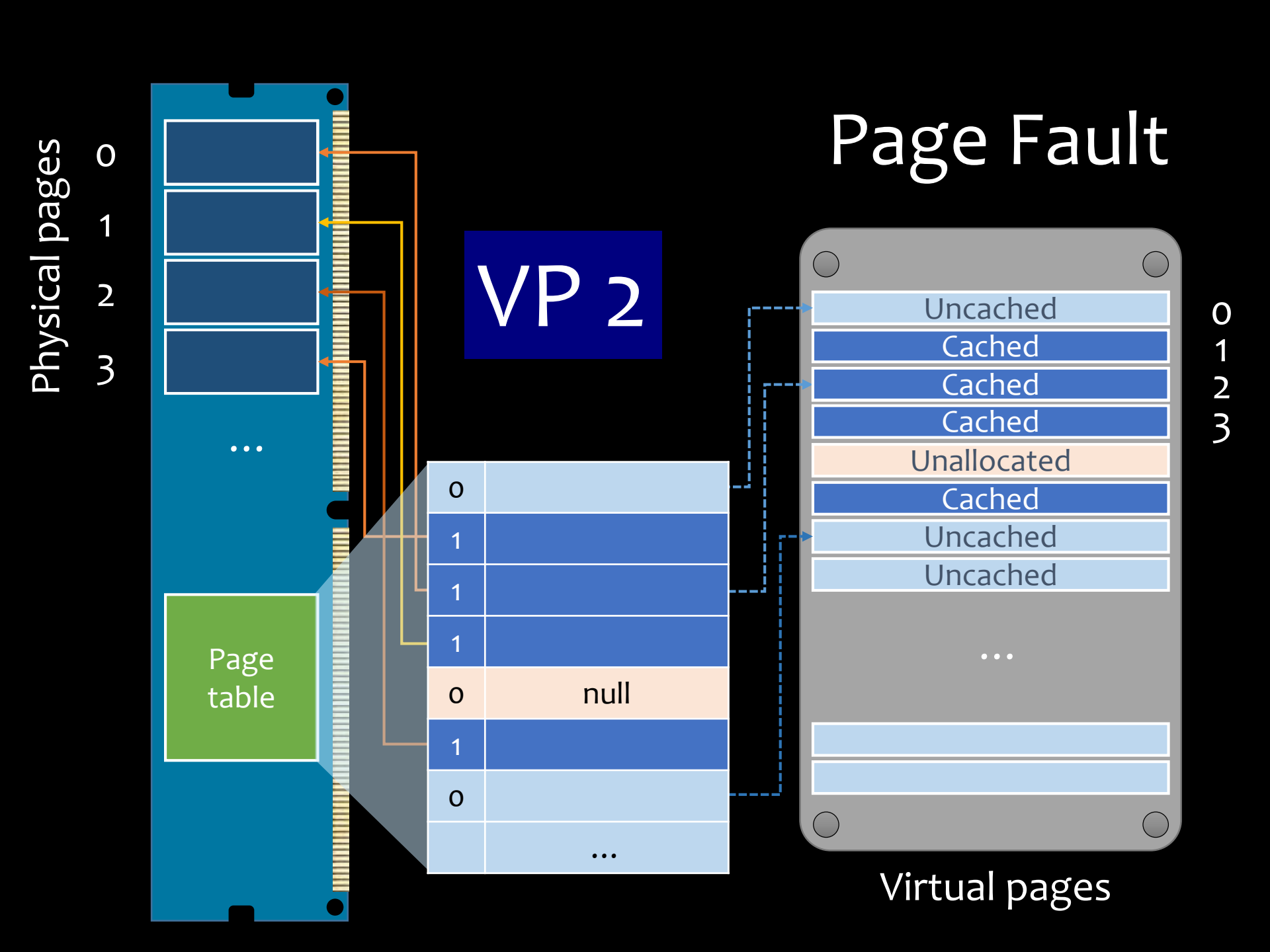
② Fully Associative

③ Write-back

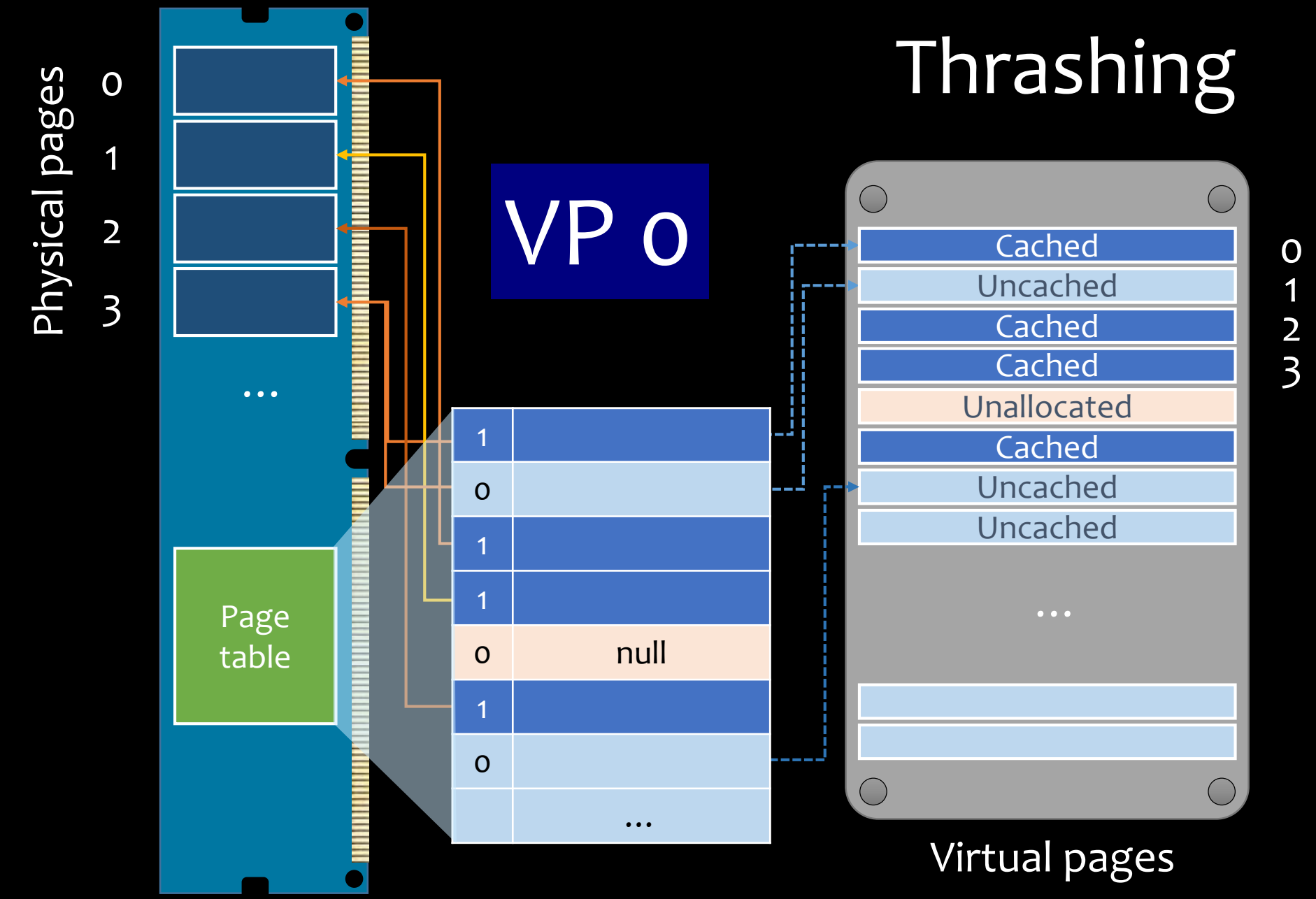
Allocating Pages



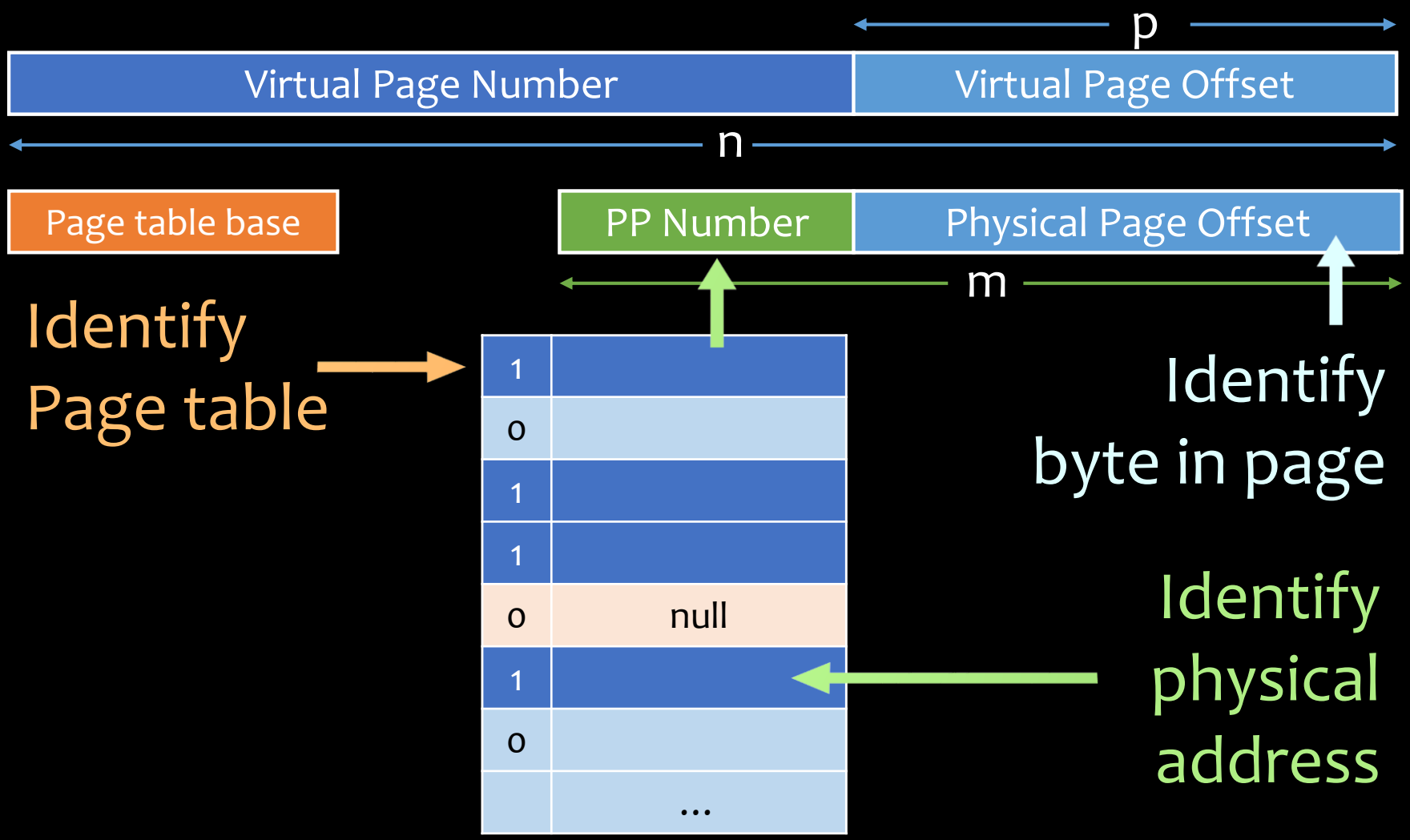

Page Hit
Physical pages
0
1
2
3
Empty
...
Page table
VP 1
0
1
0
1
0
1
0
null
...
Uncached
Cached
Uncached
Cached
Unallocated
Cached
Uncached
Uncached
...
0
1
2
3
Virtual pages


Page Fault
Physical pages
0
1
2
3
...
VP 2
Page table
0
1
1
1
0
null
1
0
...
Uncached
Cached
Cached
Cached
Unallocated
Cached
Uncached
Uncached
...
0
1
2
3
Virtual pages

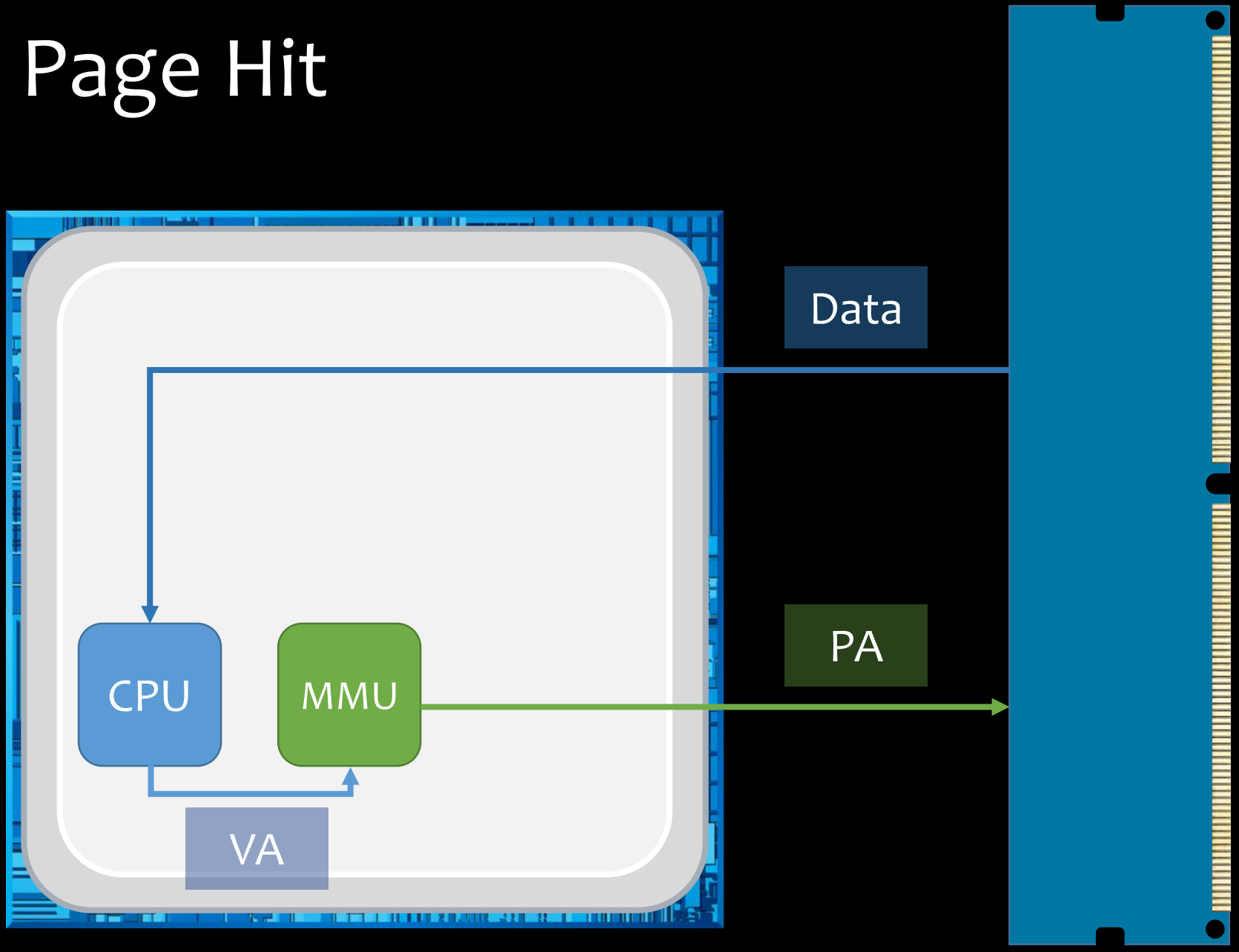
Thrashing


Physical pages
0
1
2
3
...
Page table
VP 0
1
0
1
1
0
null
1
0
...
Cached
Uncached
Cached
Cached
Unallocated
Cached
Uncached
Uncached
...
0
1
2
3
Virtual pages

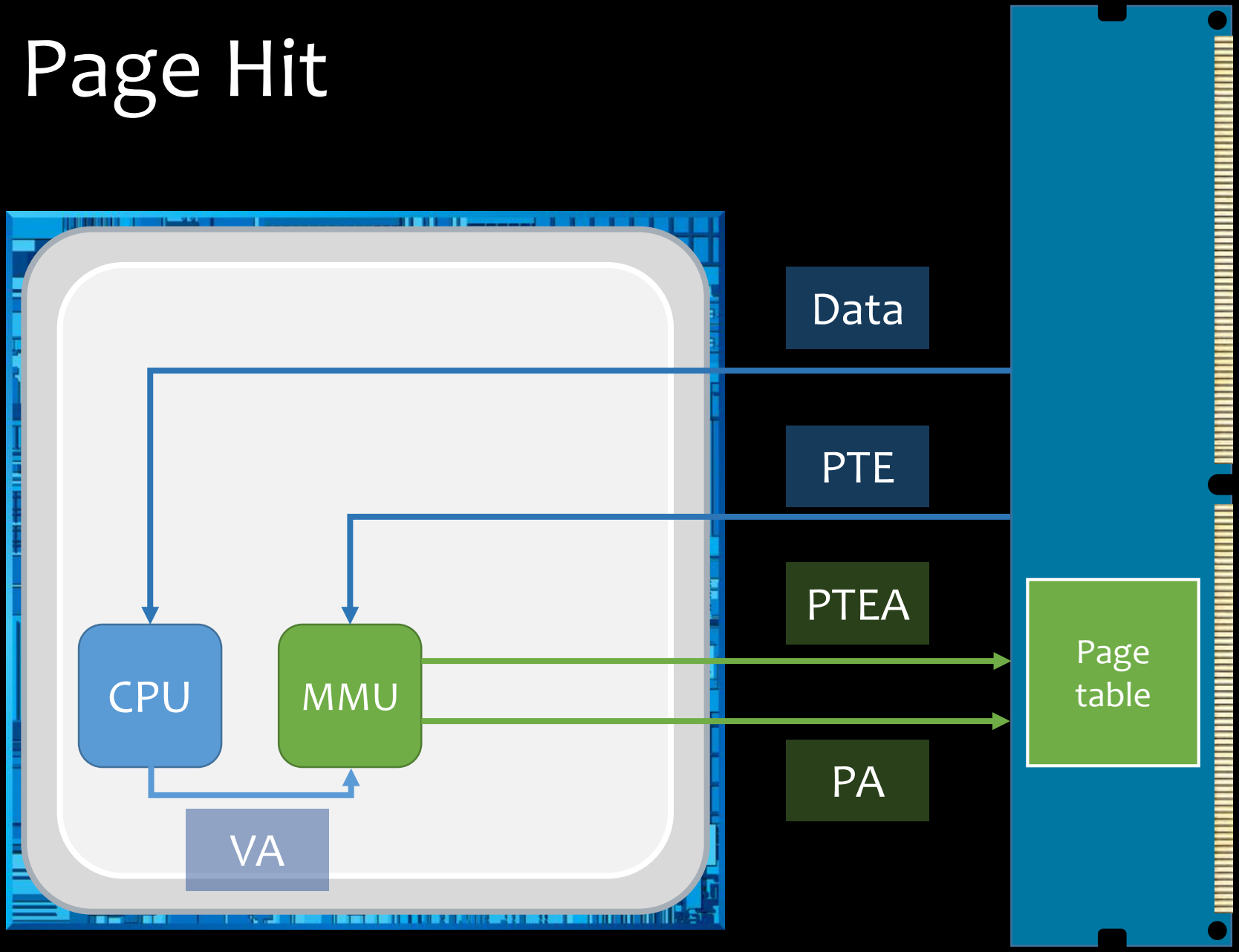
Address Translation



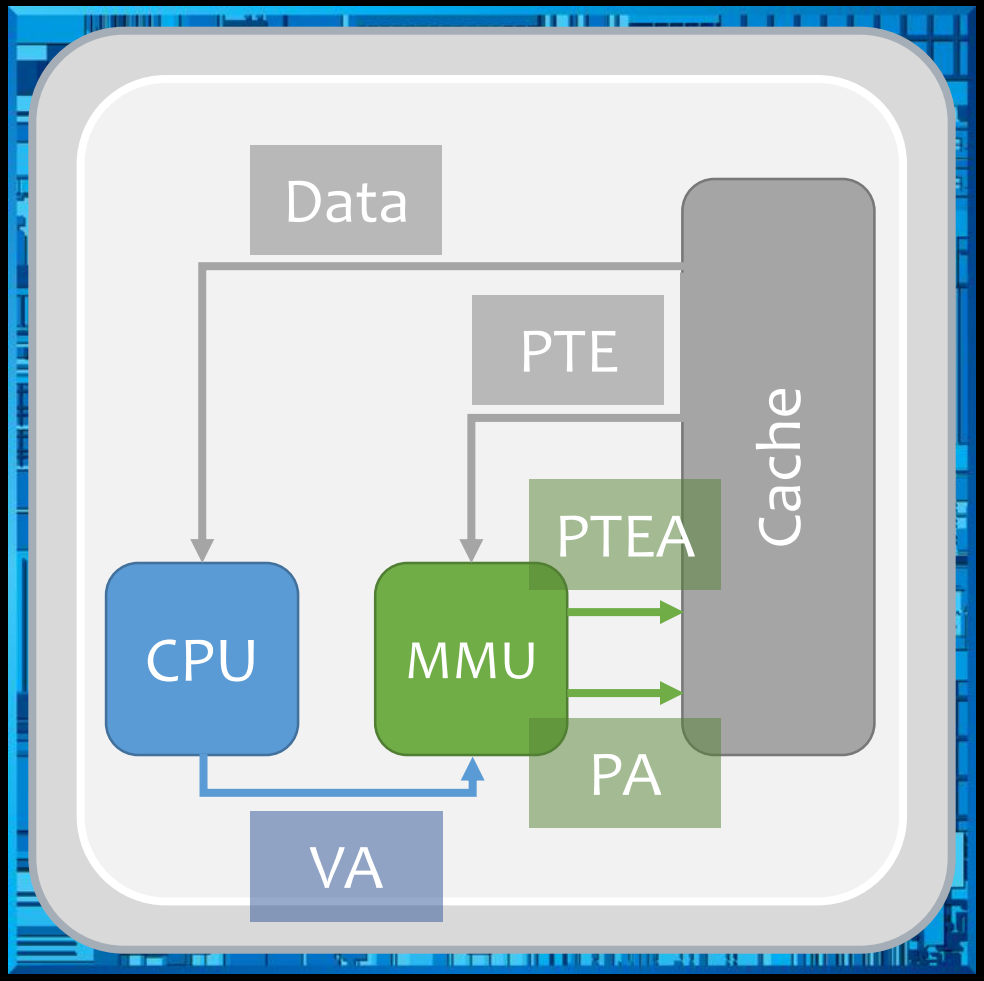
Page Hit

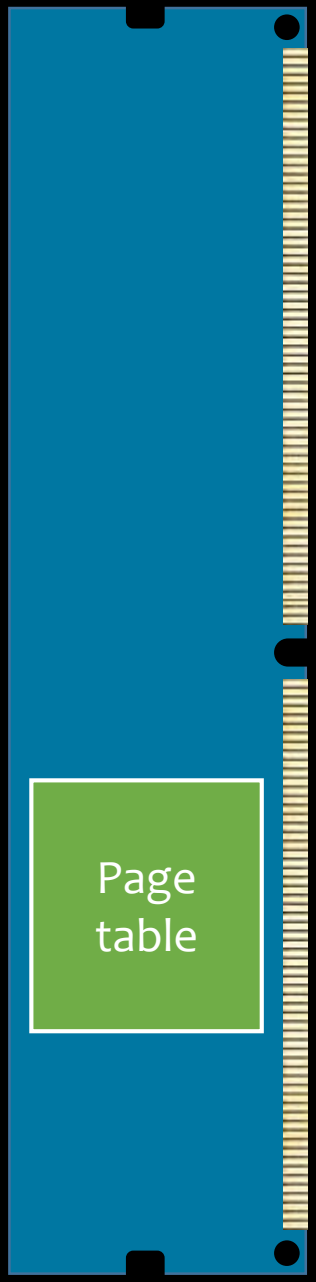


Page Hit

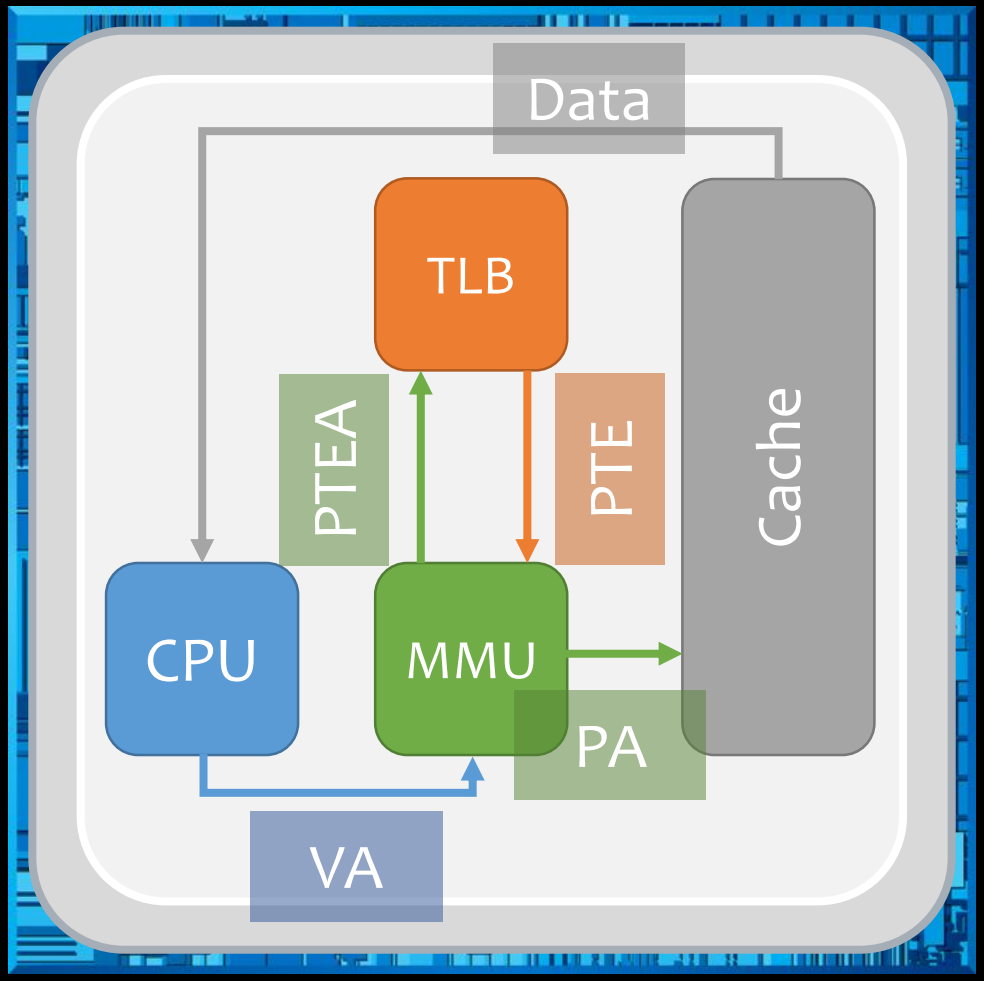


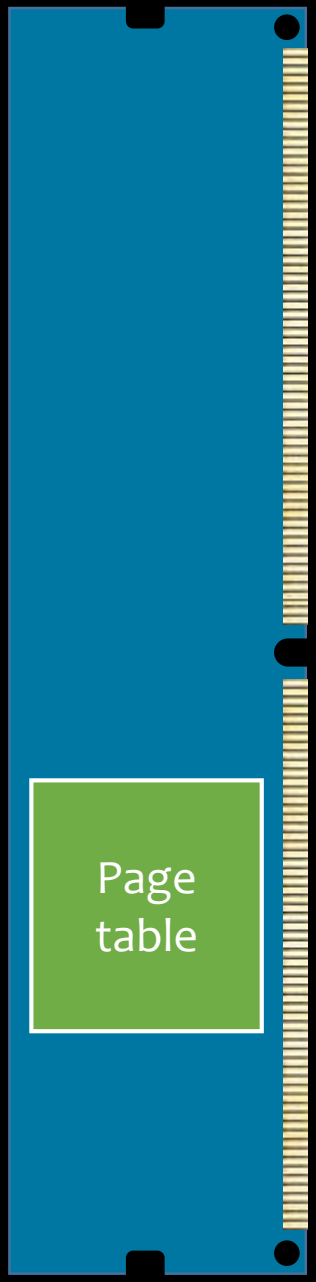
Page Hit



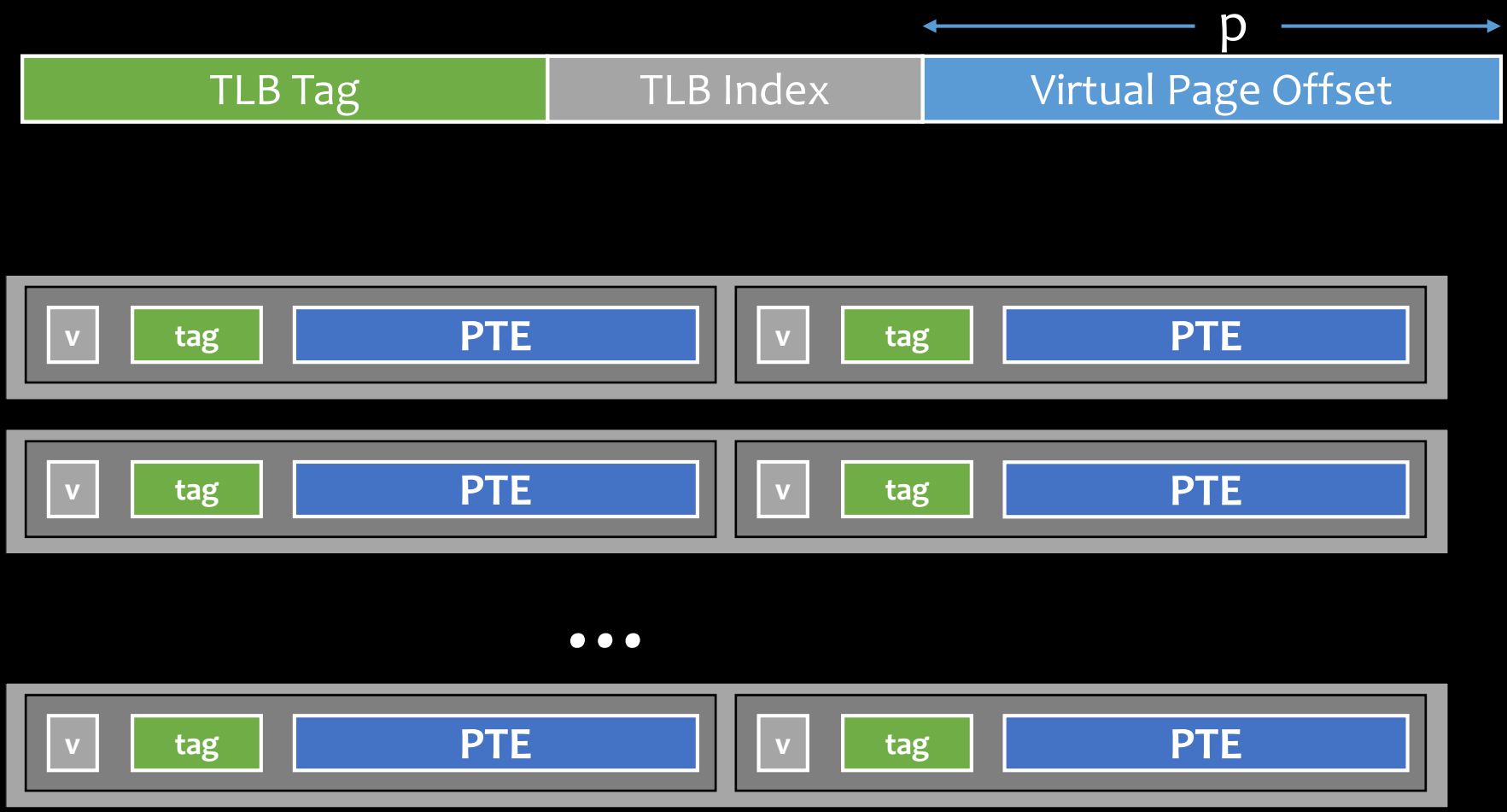


Page Hit





Translation Lookaside Buffer



Summary

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