

welcome back!

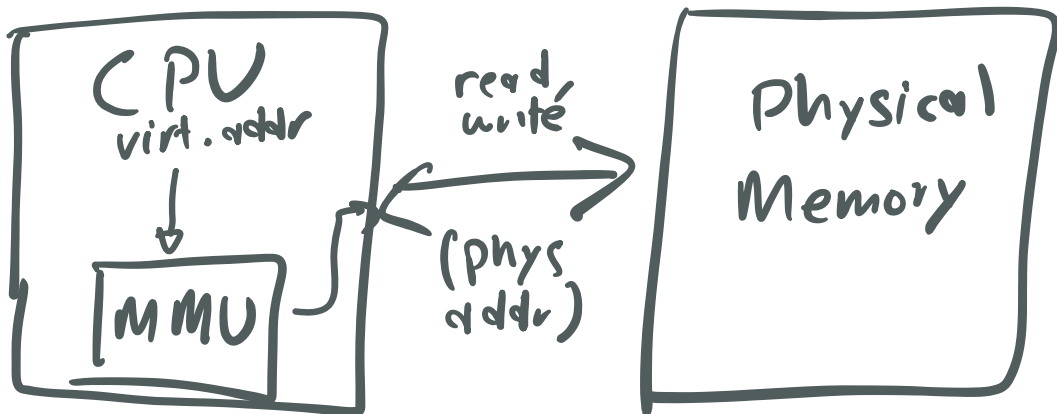
[virtualization]

[Concurrency ← next time]

Virtual Memory

illusion: large, sparse  
address space

=> ease of programming

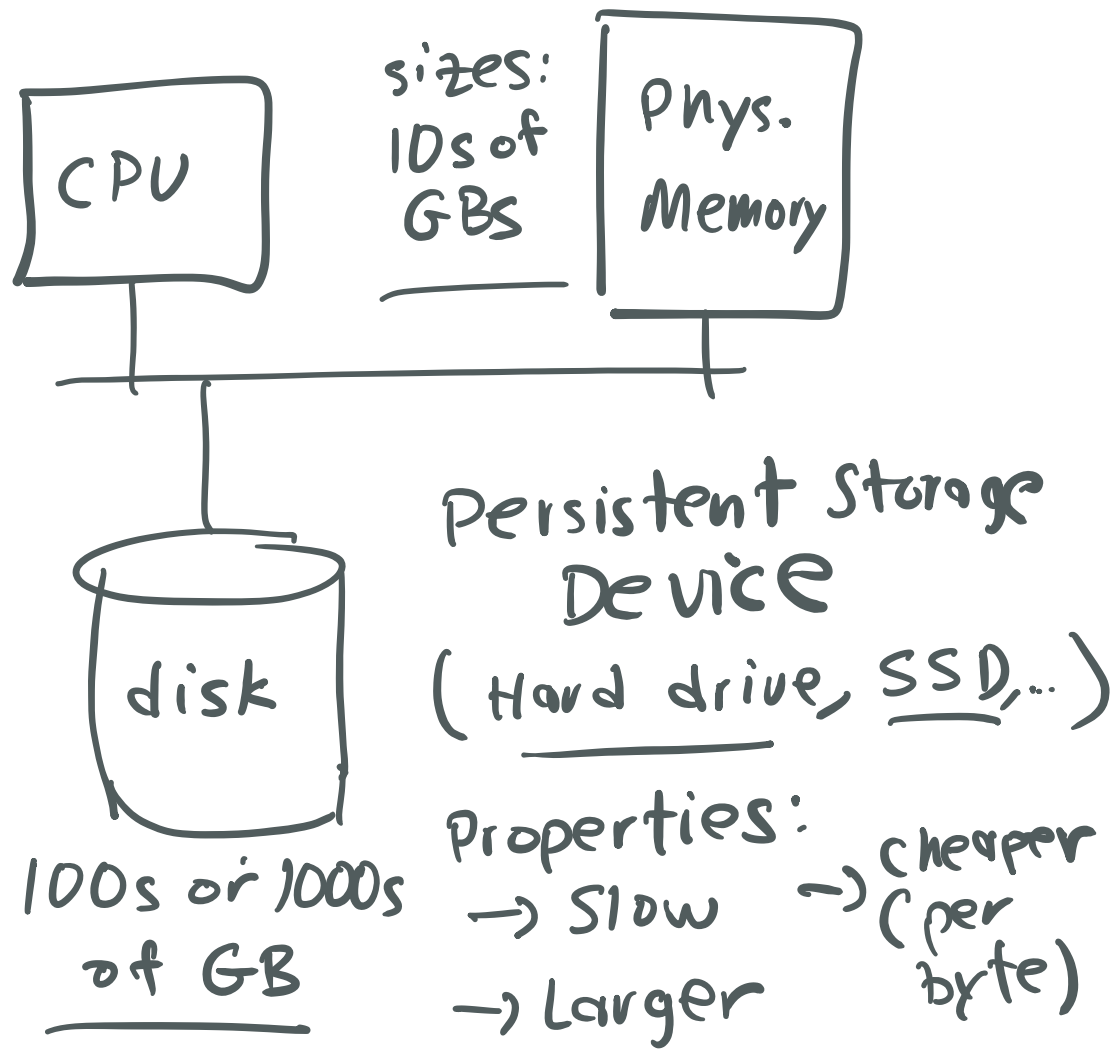


Q 7) what if process uses  
"a lot" of memory?  
(more than what

exists in phys mem?)  
Q2) what if many programs use too much memory?

Mechanisms : How?

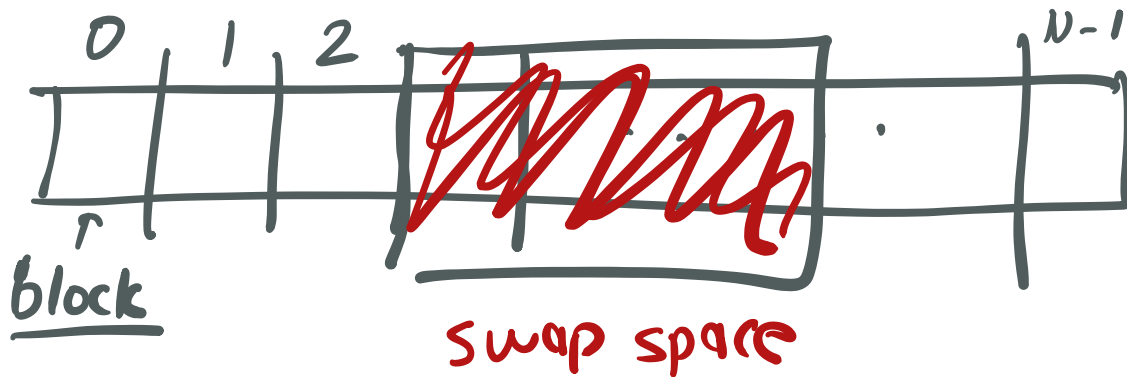
Policies :



# Hardware Support:

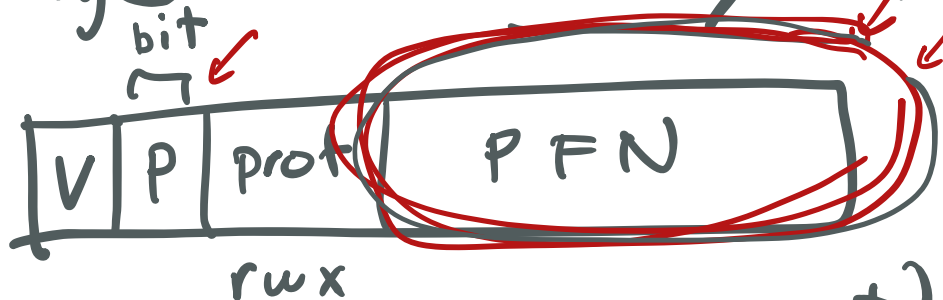
Disk:

"swap space"  
disk space to hold pages  
of process's address  
spaces that don't fit  
in memory

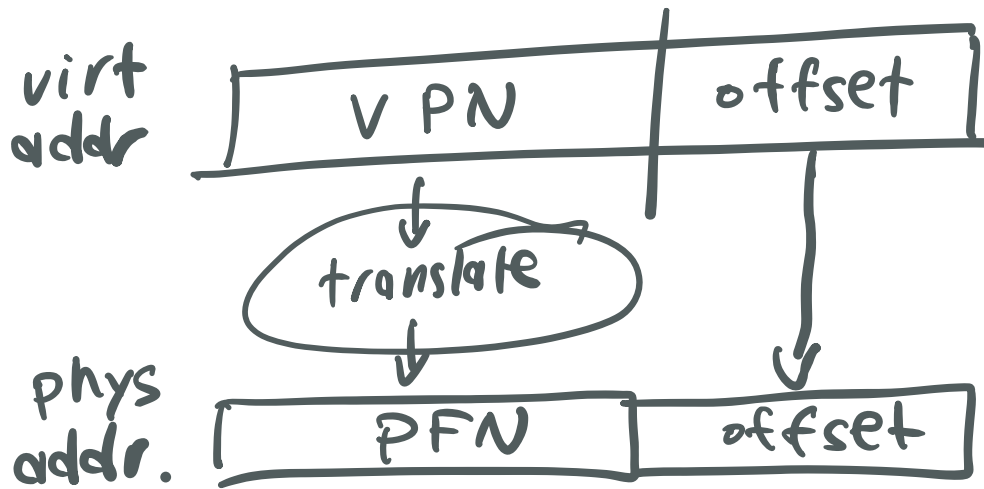


Page Table support:  
(per process)

Page Table Entry:



V: valid (legally access or not)  
 P: Present if 1 → in phys mem  
 if 0 → not



new case:  
valid, not present: what happens?

⇒ fault ⇒ OS

OS: "page fault handler"

if mem is full:

(page replacement)

TLB [ evict a page (which page?) [policy] ]

... - OS - ... to hold the

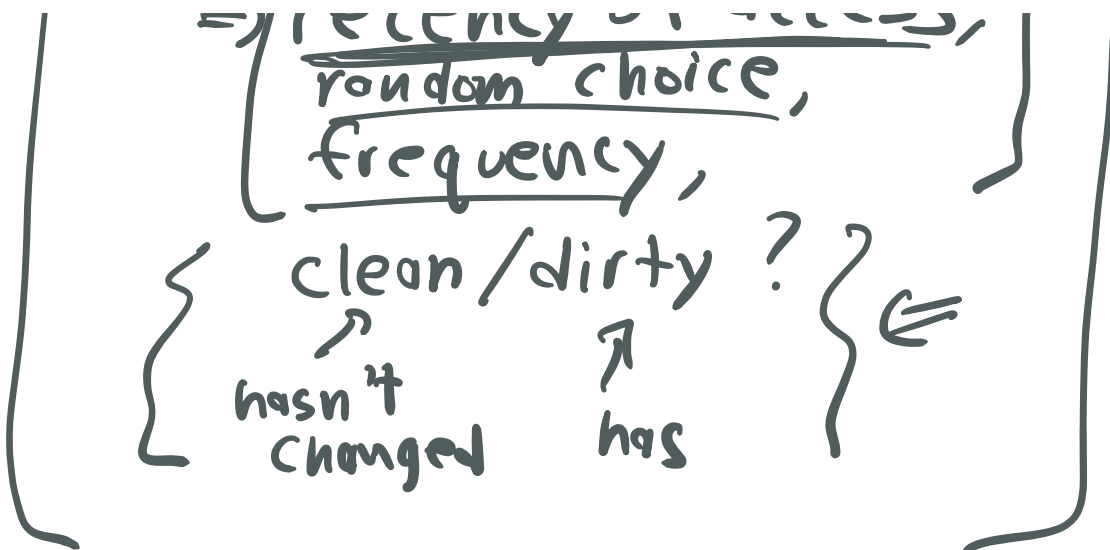
have RRIV about to be fetched page

{ fetch page (disk I/O)  
=> may put process to "sleep"  
(blocked on I/O)

=> update page table, etc.

Policy: Eviction / Replacement

[ Considerations:  
- frequency of access ]



⇒ Policies: "Optimal" : kick out furthest page in future reference stream  
 (comparison)  
Recency : kick out Least recently used (LRU)

	<u>LRU</u>		<u>MRU</u>	hit	miss
0			0		✓
1		0	1		✓
2	<u>0</u>	1	2		✓
0	1	2	0	✓	
1	2	0	1	✓	

3	0	1	3	1	3	✓	✓
0	1	3	0	3	0	✓	✓
3	1	0	3	1	3	✓	✓
1	0	3	1	2	1	✓	✓
2	3	1	2	1	1	✓	✓
1	3	2	1	1	1	✓	✓

accesses	LRU	MRU	hit	miss
0		0		✓
1		1		✓
2	0	2		✓
0	1	0	✓	
1	2	1	✓	
3	0	3	✓	
0	1	0	✓	
2	0	2	✓	
1	3	1	✓	

(evict)

0

2 ← evict

0

0

0 ← evict

[2]	<u>3</u>	1	2		✓
1	3	2	1		✓

Problem w/ LRU:  
 work to do, even on hits  
 (rearrange this list)

Perfect LRU:  
 => hardware record time  
 of every access to  
 each page  
 (store this in each  
page table entry)

Problem:  
too long to find LRU page

Approximate LRU:

7 bit / page in PTE  
 ["use" bit, "reference" bit]



⇒ when h/w accesses that page,  
h/w set use bit to 1

⇒ eviction: just find a  
page where (use bit == 0)

also:

⇒ when scanning for a page  
to evict, if use bit == 1,  
clear it,  
move to next page