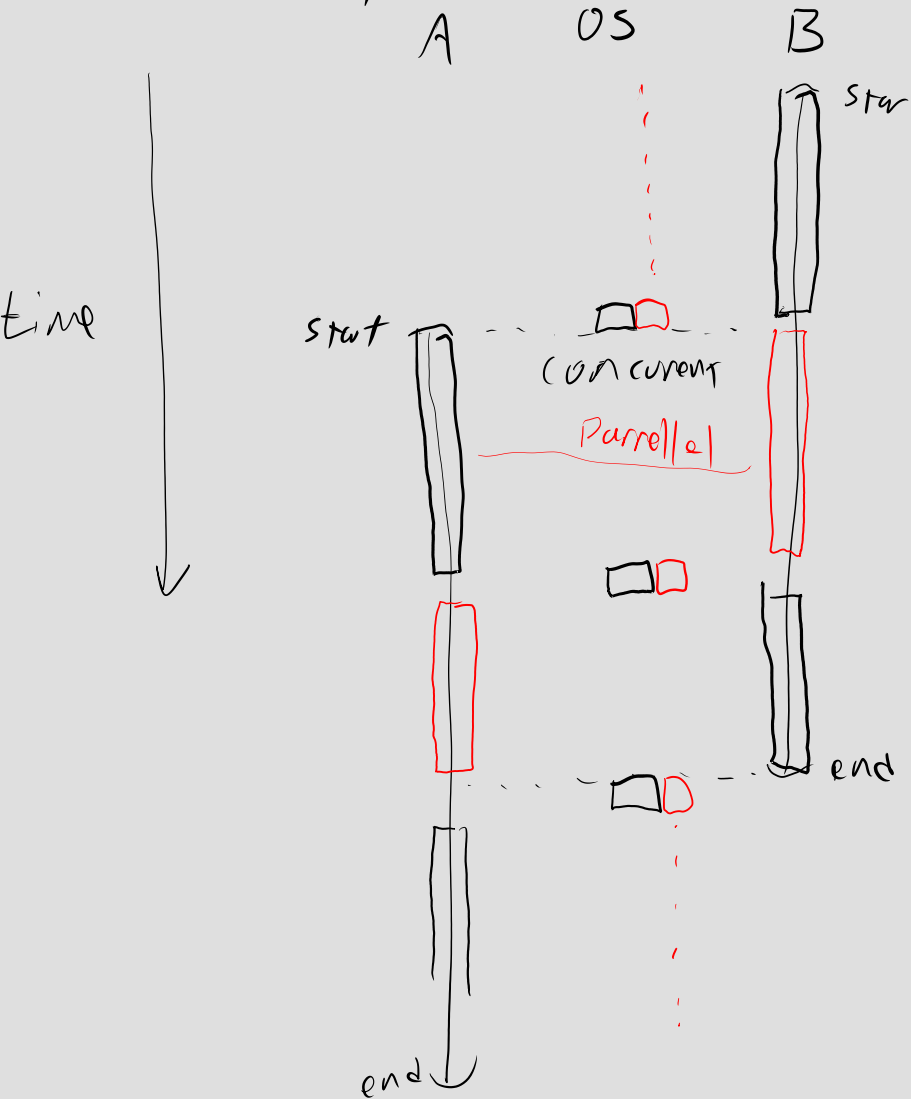


# Concurrency



## Parallel

both working now  
→ 2+ process  
work things

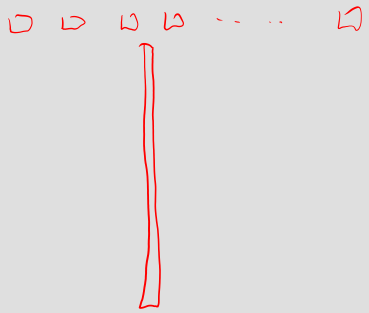
Speed

## CONCURRENT

both begun  
neither ended

UX

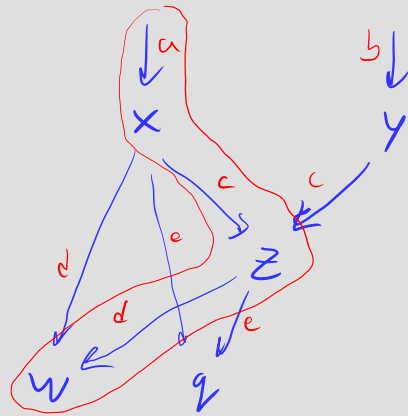
- more man
- see vide
- web brow
-



dependency

$$\begin{aligned}
 x &= a(\dots) \\
 y &= b(\dots) \\
 z &= c(x, y) \\
 w &= d(x, z) \\
 q &= e(z, x)
 \end{aligned}$$

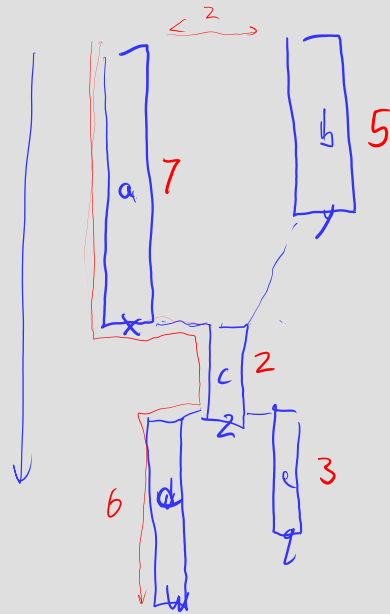
dep. graph



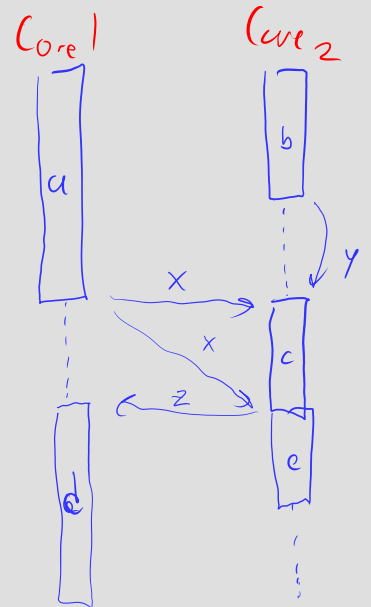
$$\text{avg deg of concurrency work} \rightarrow 23 \\
 = \frac{\text{len(Crit Path)} \rightarrow 15}{}$$

$$\rightarrow \frac{23}{15} \rightarrow$$

time



Critical Path



# Shared memory

com = memory

Core<sub>1</sub>                      race condition

$x \neq 1$

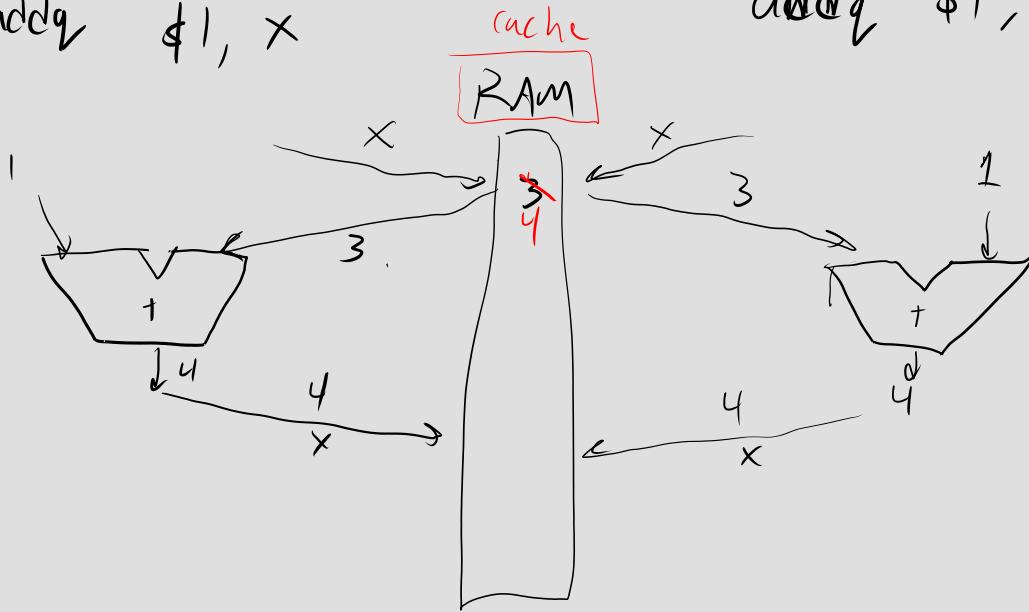
addq \$1, x

Core<sub>2</sub>

$x += 1$

addq \$1, x

time ↓

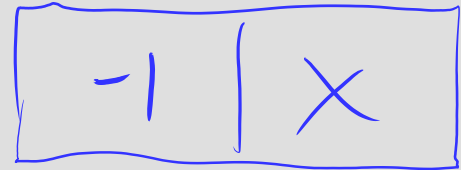
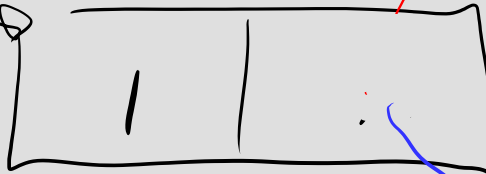
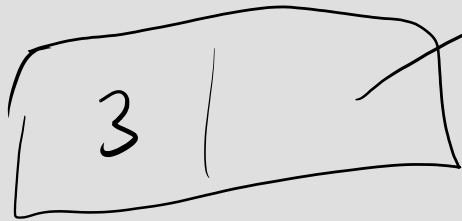
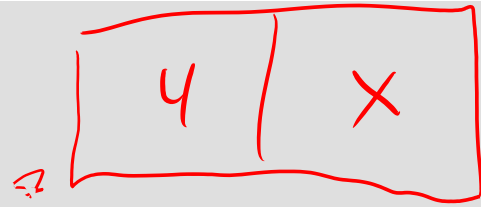


# msg-passing

send

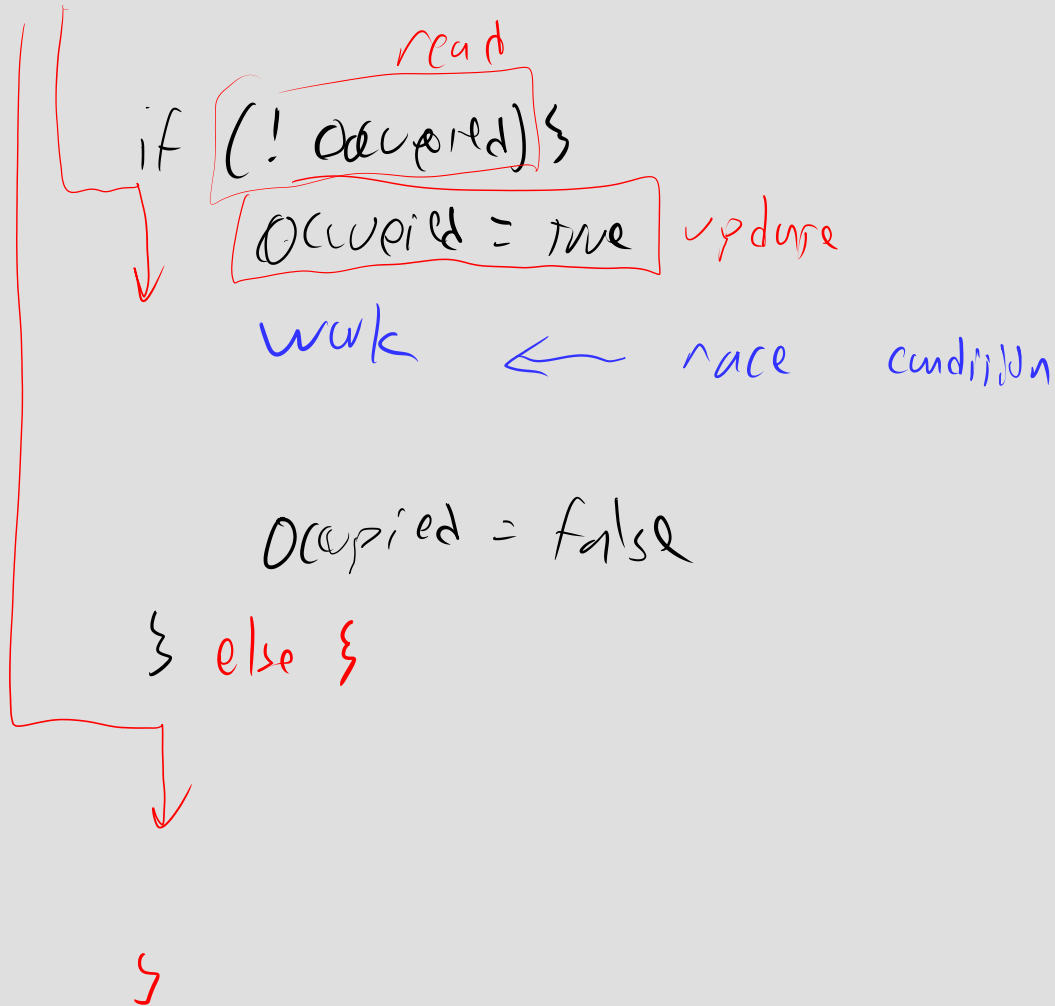
recv





occupied = False

Mutual exclusion (broken)

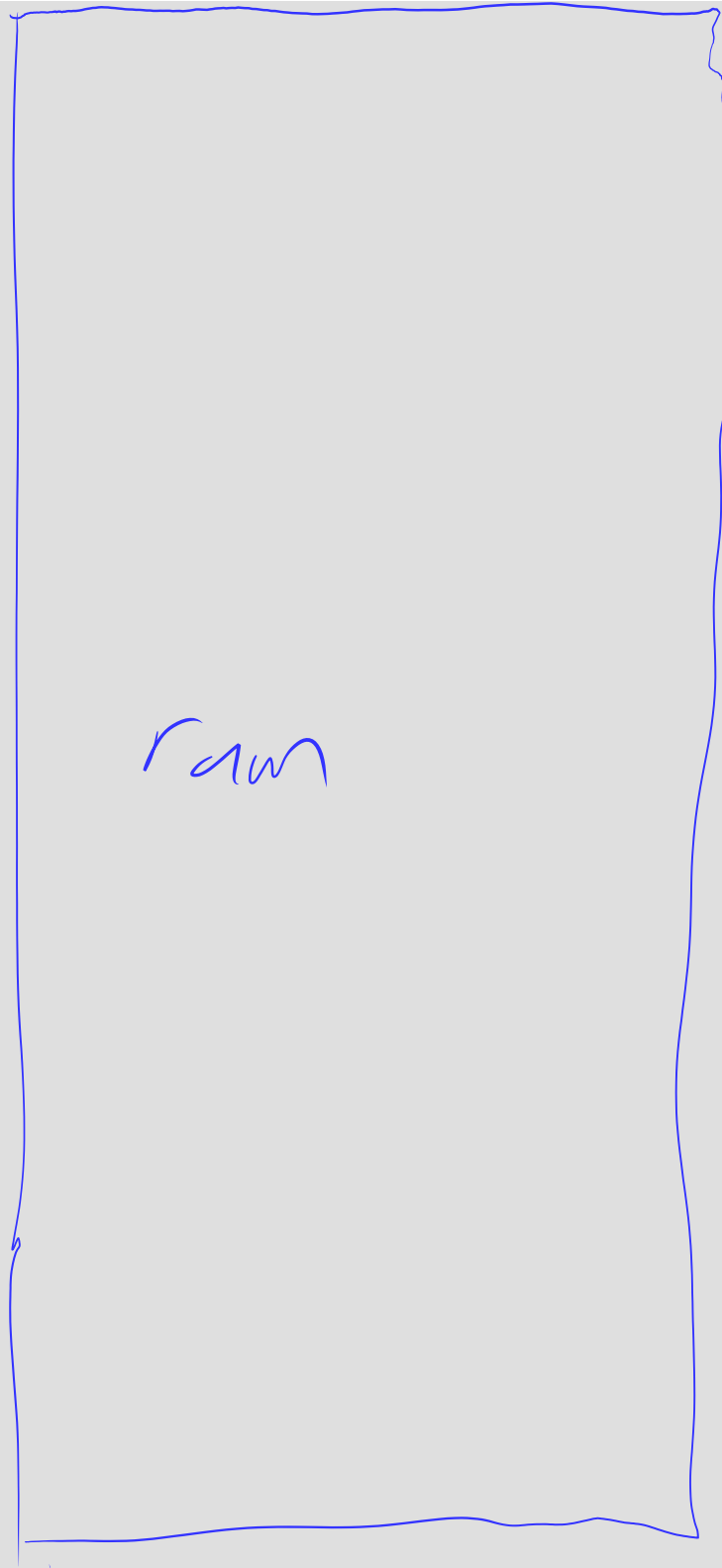
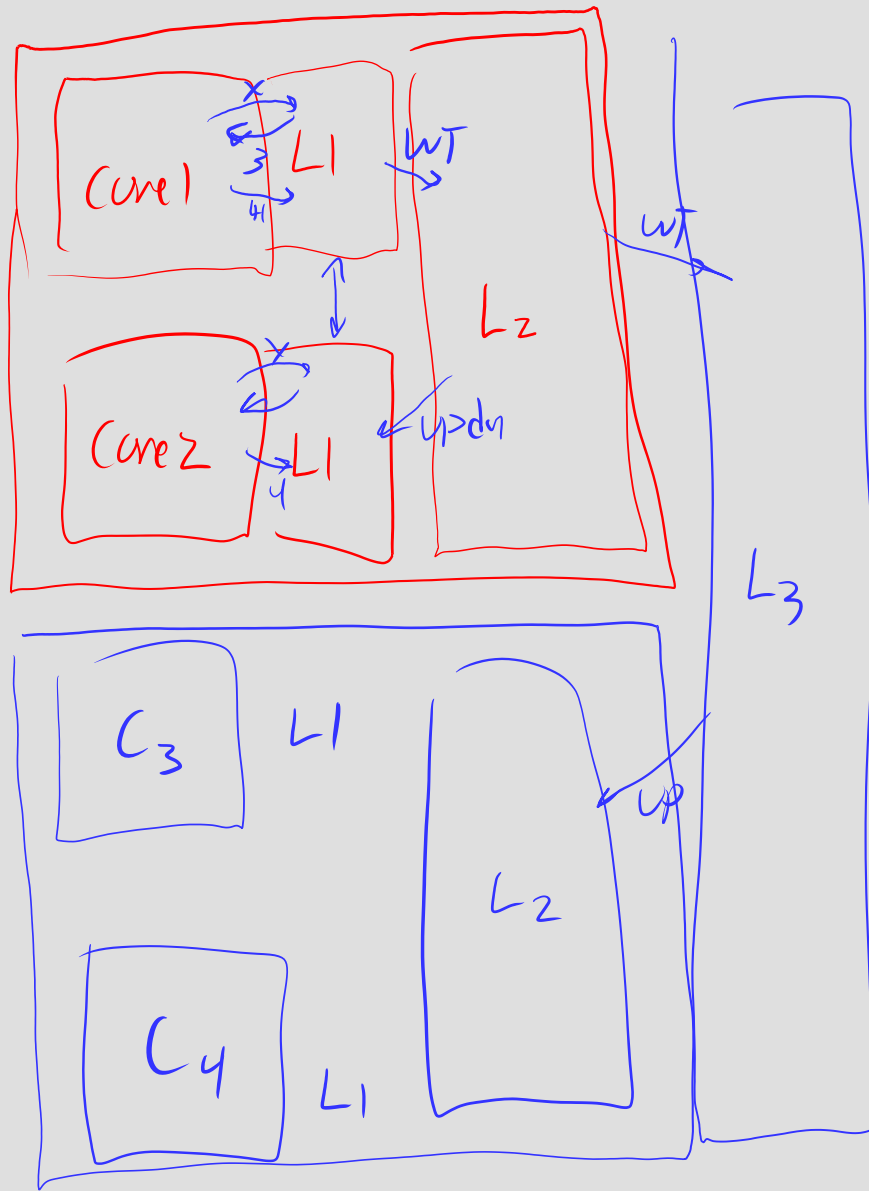


data race  
- data (variable)

- read
  - change
- dep

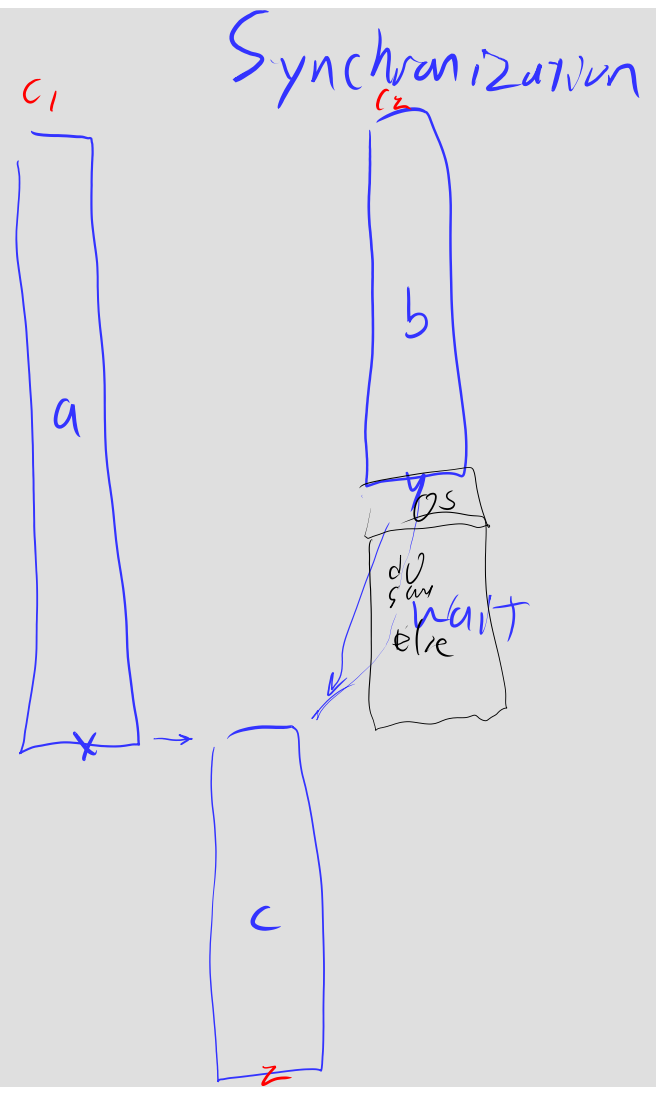
Control

Cache  
Coherency  
Consistency



$y = b()$   
syscall b is done

$x = a()$   
syscall a is done



```
C1:  
y = b( ... )  
while ( a is not done ) {  
    do nothing  
}  
z = c( x, y )
```

Busy  
Spin