Sistemi Operativi I

Corso di Laurea in Informatica

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Process/Thread Synchronization

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Synchronization as a solution to the critical section problem

Part III:
Process Synchronization

The Need for Synchronization

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5:00pm	Gets home	

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5:20pm		Gets home

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Time	Bob	Carla
5:00pm	Gets home	
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5:20pm		Gets home
5:25pm	Gets at the grocery	Looks in the fridge → No milk!

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5:25pm	Gets at the grocery	Looks in the fridge → No milk!
5:30pm	Buys milk	Leaves home for the grocery

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5:45pm	Gets home, puts the milk in the fridge	Gets at the grocery

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5:50pm		Buys milk

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5:50pm		Buys milk
6:05pm		Gets home, puts the milk in the fridge

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5:45pm	Gets home, puts the milk in the fridge	Gets at the grocery
5:50pm		Buys milk
6:05pm		Gets home, puts the milk in the fridge
6:05pm	Oh f*%#k!	Oh f*%#k!

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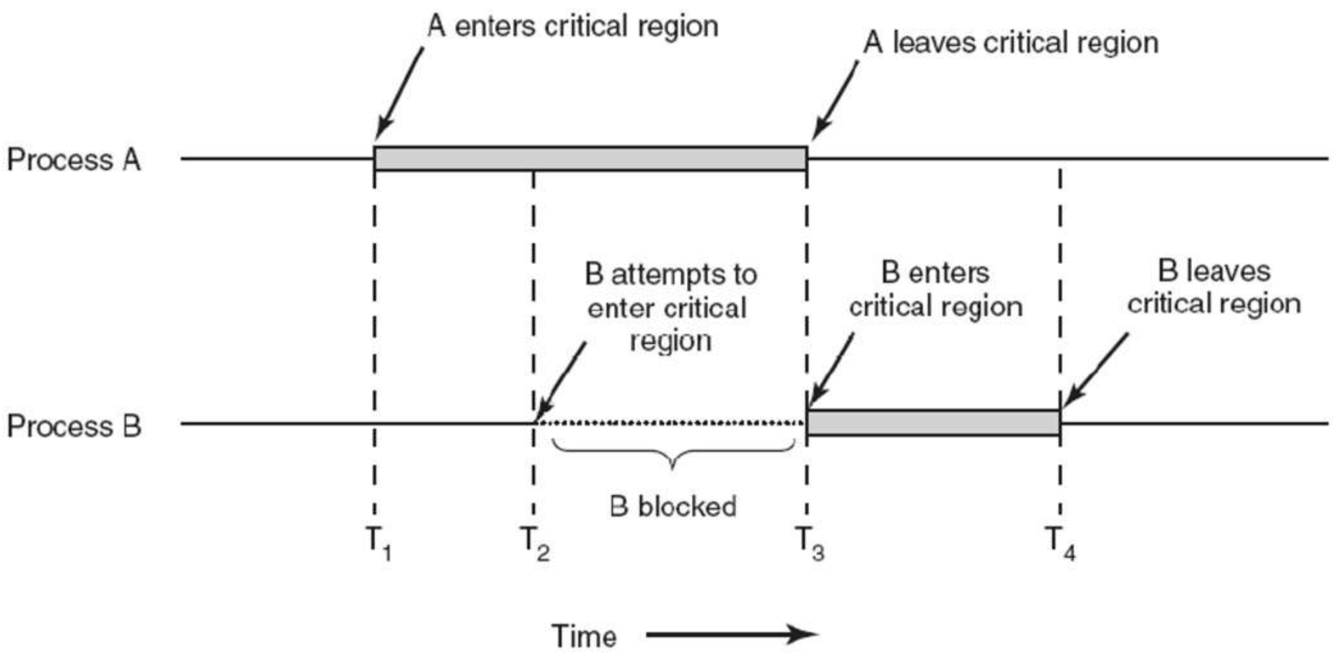
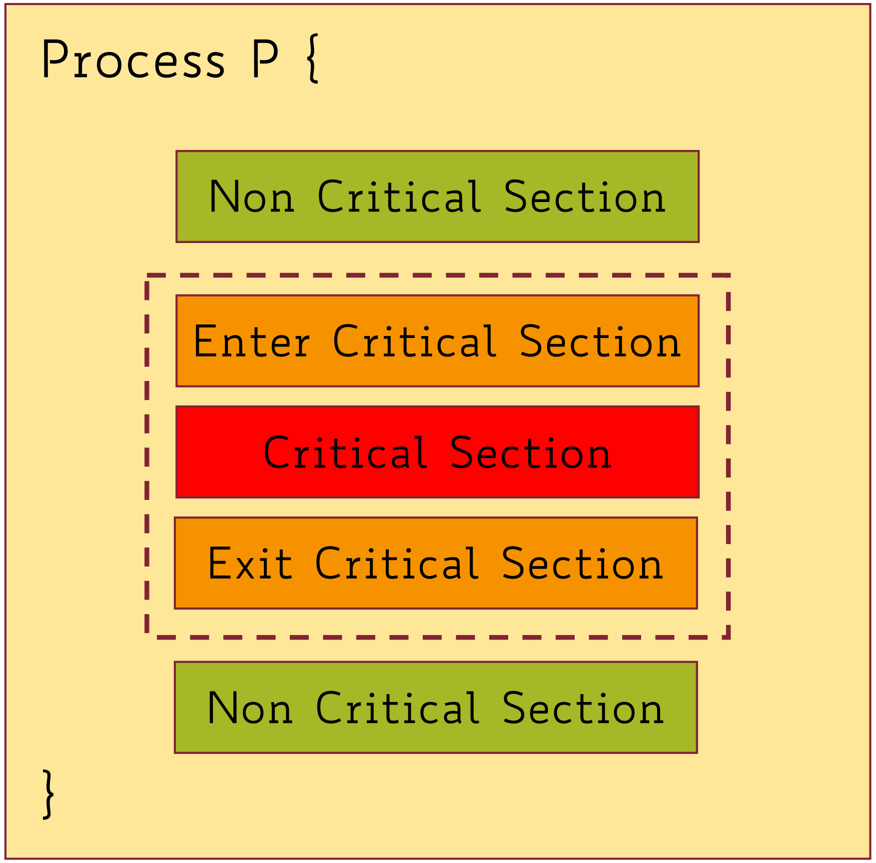
- In practice, though, they might incur in unpleasant situations (e.g., buying too much milk!)

What mechanism do we need to get independent yet cooperating processes to communicate with each other and have a consistent view of the "world" (i.e., computational state)?

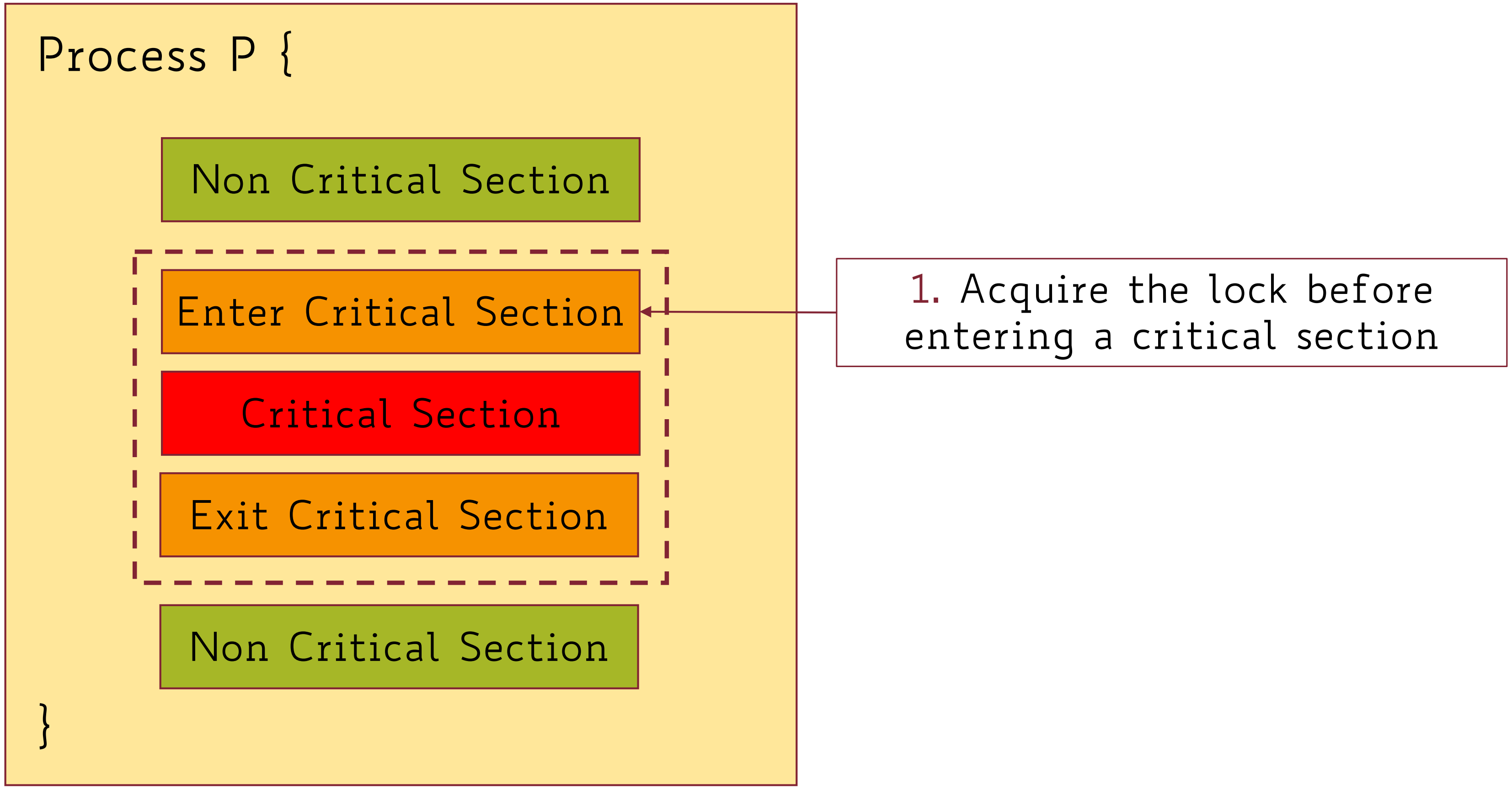
The Critical Section Problem



The Anatomy of a Critical Section



Locking Critical Section



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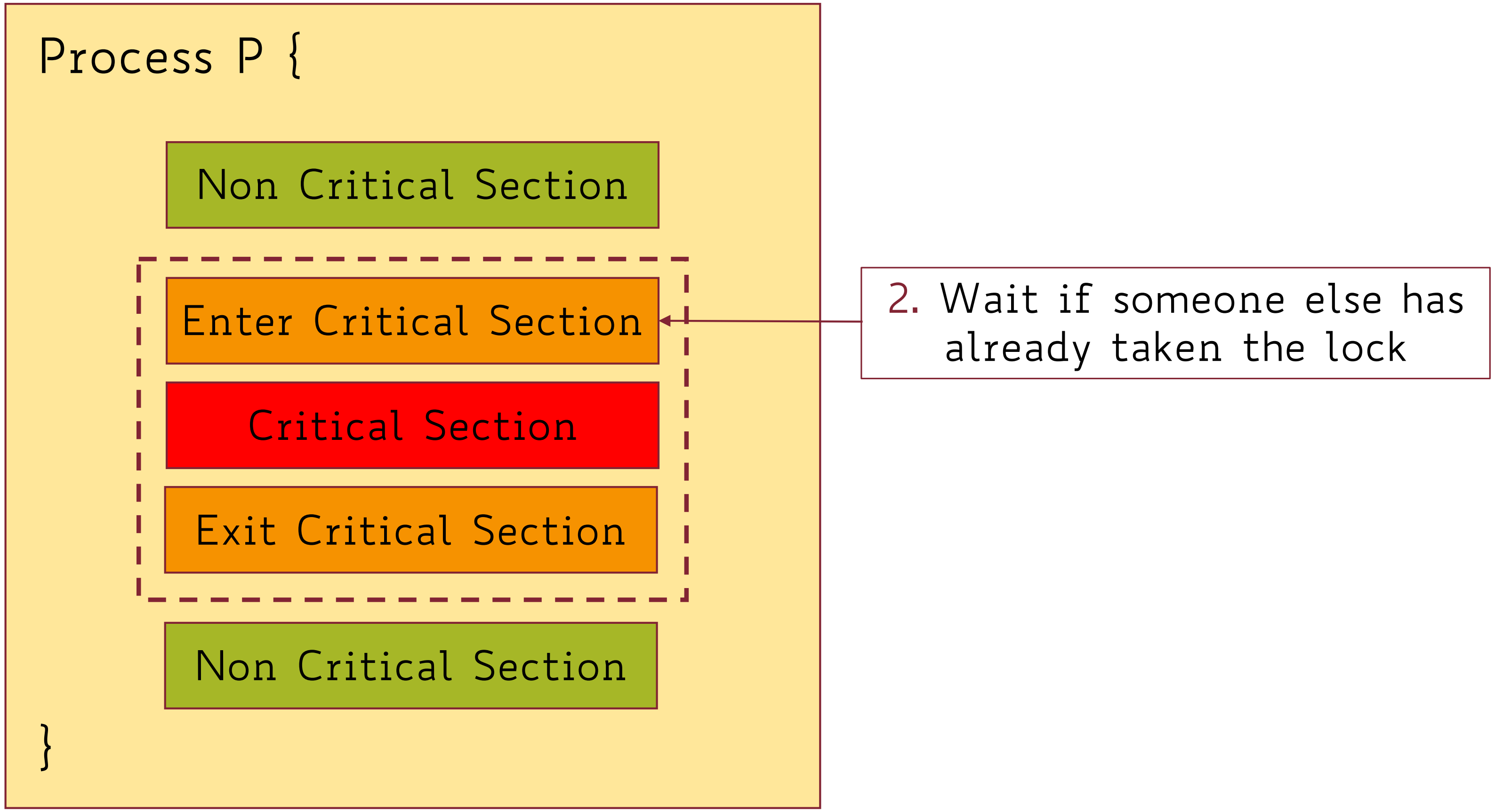

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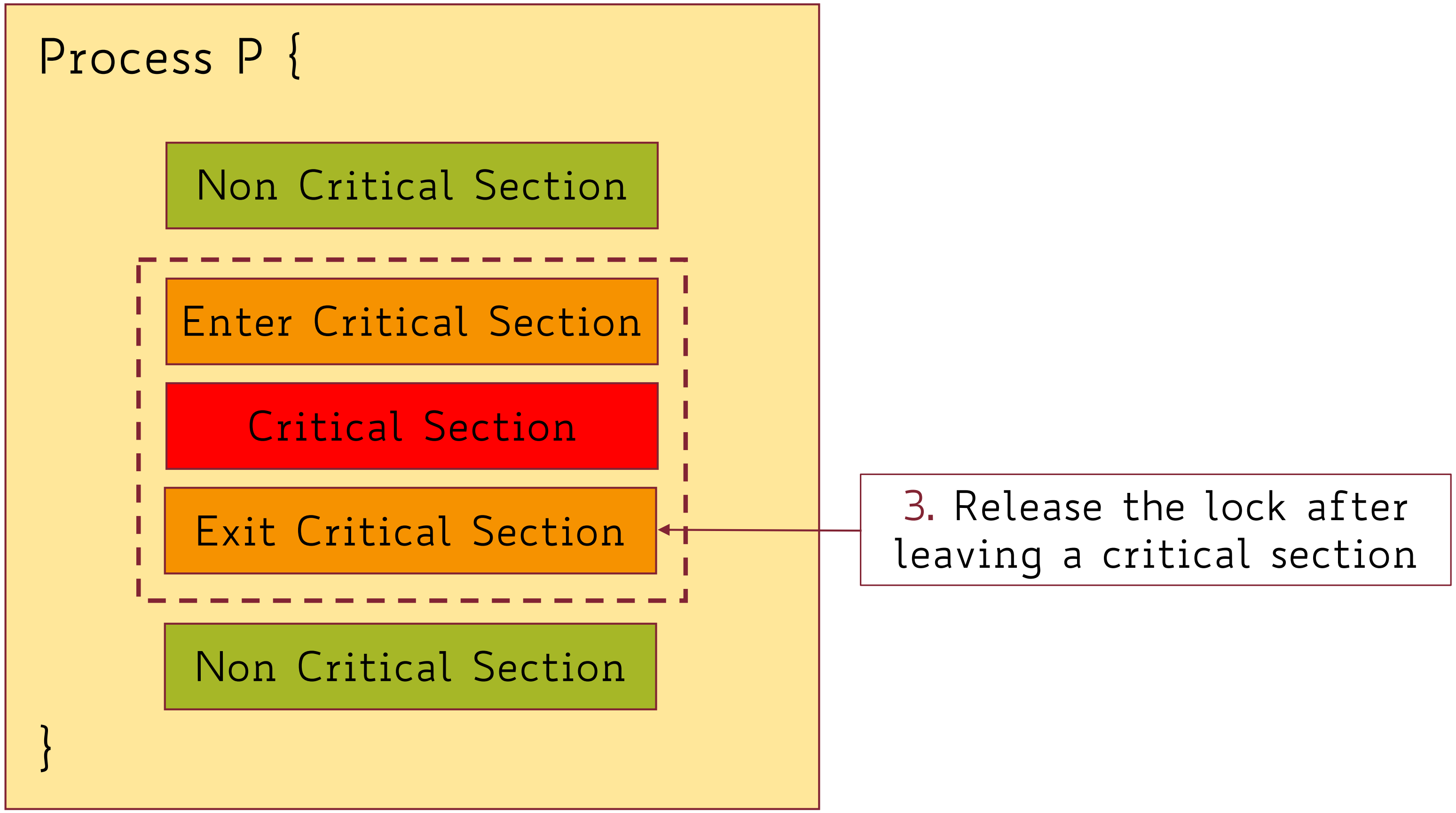

Locking Critical Section

Process P {

Non Critical Section

Enter Critical Section

Critical Section

Exit Critical Section

Non Critical Section

}

All synchronization involves waiting!

Synchronization: Goals

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  - Mutual Exclusion → only one process/thread can be in its critical section at a time!
  - Liveness → If no process is in its critical section, and one or more want to execute it then any one of these must be able to get into its critical section
  - Bounded Waiting → A process requesting entry into its critical section will get a turn eventually, and there is a limit on how many others get to go first

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- In the milk example:
  - Ensuring mutual exclusion means no more milk than what is needed will be bought (i.e., only one between Bob and Carla will buy milk if needed)

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  - Ensuring mutual exclusion means no more milk than what is needed will be bought (i.e., only one between Bob and Carla will buy milk if needed)
  - Ensuring liveness means that someone should buy some milk (i.e., the option where both Bob and Carla do not do anything is surely safe but undesirable)
  - Ensuring bounding waiting means that eventually Bob and Carla will enter their critical section

Too Much Milk: Solution 1

Use a note

```
# Thread Bob

if (!milk and !note):
    leave_note()
    buy_milk()
    remove_note()
```

```
# Thread Carla

if (!milk and !note):
    leave_note()
    buy_milk()
    remove_note()
```

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Does this solution work?

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Does this solution work regardless of the scheduling?

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    buy_milk()
    remove_note()
```

Does this solution work regardless of the scheduling?

No! mutual exclusion can be violated

Too Much Milk: Solution 2

Use 2 (labeled) notes

```
# Thread Bob

leave_note(Bob)

if (!note(Carla)):
    if (!milk):
        buy_milk()

remove_note()
```

```
# Thread Carla

leave_note(Carla)

if (!note(Bob)):
    if (!milk):
        buy_milk()

remove_note()
```

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Use 2 (labeled) notes

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```
# Thread Carla

leave_note(Carla)

if (!note(Bob)):
    if (!milk):
        buy_milk()

remove_note()
```

Does this solution work regardless of the scheduling?

No! Liveness propery can be violated

Too Much Milk: Solution 3

Use 2 (labeled) notes... more cleverly

```
# Thread Bob

leave_note(Bob)

while (note(Carla)):
    do_nothing()
if (!milk):
    buy_milk()

remove_note()
```

```
# Thread Carla

leave_note(Carla)

if (!note(Bob)):
    if (!milk):
        buy_milk()

remove_note()
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Too Much Milk: Solution 3

Use 2 (labeled) notes… more cleverly

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if (!note(Bob)):
    if (!milk):
        buy_milk()

remove_note()
```

Does this solution work regardless of the scheduling?

Yes!

Too Much Milk: Solution 3

```
# Thread Bob

leave_note(Bob)

while (note(Carla)):
    do_nothing()
if (!milk):
    buy_milk()

remove_note()
```

Y:

```
# Thread Carla

leave_note(Carla)

if (!note(Bob)):
    if (!milk):
        buy_milk()

remove_note()
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Too Much Milk: Solution 3

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# Thread Bob

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Case 1: no note from Bob

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Case 1: no note from Bob

Thread Bob must be executing different code

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Y: if (!note(Bob)):
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Case 1: no note from Bob

Thread Bob must be executing different code

Carla will buy milk only if needed

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```
# Thread Carla

leave_note(Carla)

if (!note(Bob)):        <- Y:
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        buy_milk()

remove_note()
```

Case 2: Bob has left a note

Too Much Milk: Solution 3

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# Thread Bob

leave_note(Bob)

while (note(Carla)):
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if (!milk):
    buy_milk()

remove_note()
```

Y:

```
# Thread Carla

leave_note(Carla)

if (!note(Bob)):
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remove_note()
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Case 2: Bob has left a note

So has Carla, therefore Bob will be waiting (loop)

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if (!note(Bob)):     <- Y:
    if (!milk):
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remove_note()
```

Case 2: Bob has left a note

So has Carla, therefore Bob will be waiting (loop)

Carla will remove his note and Bob will buy milk if needed

Too Much Milk: Solution 3

```
# Thread Bob

leave_note(Bob)

while (note(Carla)):
    do_nothing()
if (!milk):
    buy_milk()

remove_note()
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X:

Case 1: no note from Carla

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# Thread Carla

leave_note(Carla)

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X: → while (note(Carla)):

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Bob will buy milk only if needed

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# Thread Bob

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while (note(Carla)):        <- X:
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remove_note()
```

Case 2: Carla has left a note

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# Thread Carla

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if (!note(Bob)):
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remove_note()
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Too Much Milk: Solution 3

```
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leave_note(Bob)

while (note(Carla)):
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remove_note()
```

X:

Case 2: Carla has left a note

Bob will wait doing nothing until Carla removes her note

```
# Thread Carla

leave_note(Carla)

if (!note(Bob)):
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Too Much Milk: Solution 3

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  - busy waiting → thread Bob is consuming CPU cycles doing nothing

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  - asymmetrical → thread Bob and Carla are different (adding more threads will mess up things even more!)
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This solution assumes loads and stores being atomic (i.e., non-interruptable)

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So? How Do We Implement Synchronization?

We need to have appropriate "tools" (i.e., primitive constructs) provided by programming languages used as atomic building blocks for synchronization

- Locks → At each time, only one process holds a lock, executes its critical section, and finally releases the lock
- Semaphores → A generalization of locks

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- Semaphores → A generalization of locks
- Monitors → To connect shared data to synchronization primitives

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- Locks → At each time, only one process holds a lock, executes its critical section, and finally releases the lock
- Semaphores → A generalization of locks
- Monitors → To connect shared data to synchronization primitives

Require some HW support and waiting

Locks

- Provide mutual exclusion to shared data using 2 atomic primitives:

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  - lock.release() → unlock and wake up any thread waiting in acquire()
- Rules for using a lock:
  - Always acquire the lock before accessing shared data
  - Always release the lock after finishing with shared data
  - Lock must be initially free
- Only one process/thread can acquire the lock, others will wait!

Too Much Milk: Solution Using Locks

Use lock primitives

```
# Thread Bob

lock.acquire()

if (!milk):
    buy_milk()

lock.release()
```

```
# Thread Carla

lock.acquire()

if (!milk):
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lock.release()
```

Too Much Milk: Solution Using Locks

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This solution is clean and symmetric

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Q: How do we make acquire() and release() atomic?

HW Support for Synchronization

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High-level atomic operations (SW)	lock, monitor, semaphore, send/receive

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Implementing high-level synchronization primitives requires low-level hardware support

High-level atomic operations (SW)	lock, monitor, semaphore, send/receive
Low-level atomic operations (HW)	disabling interrupts, atomic instructions (test&set)

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- Access or modification to those shared variable often identifies critical sections
- A critical section is a piece of code that cannot be executed in parallel or concurrently by multiple threads
- Synchronization primitives ensure only one thread at a time executes a critical section (mutual exculsion), e.g., locks