# Little Book of Semaphores, Chapter 1

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### Synchronization

- When more than one thread is running, synchronization may be important:
- Serialization: Event A must happen before event B.
- Mutual exclusion: Events A and B must not happen at the same time.

#### **Threads**

- For a single core, there is only one instruction happening at a time.
- A sequence of such instructions is a thread.
- A desktop computer will have many threads running at one time.
- The OS may run threads in parallel, on different CPUs.
- The OS may run only one thread at a time, and interleave many threads on a single CPU.

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- How can you find out?
- You could call and ask the time, but how would you know if your clocks were synchronized?

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- How can you do it?
- Synchronize with messages:

You \_\_\_\_\_\_ You \_\_\_\_\_ Eat breakfast Work Eat lunch Call Bob

Eat breakfast
Wait for call
Eat lunch

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- Synchronize with messages:

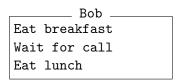
You

Eat breakfast

Work

Eat lunch

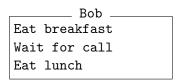
Call Bob



- You ate lunch sequentially (order guaranteed)
- You ate breakfast concurrently (order undetermined)

- You want to guarantee that you ate lunch before Bob.
- How can you do it?
- Synchronize with messages:

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- Two events are concurrent if we cannot tell by looking at the program which will happen first.

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You

Eat breakfast
Take rock from box
Eat lunch
Put rock back in box

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You ate breakfast concurrently (order undetermined). Lunch?

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- You ate lunch concurrently (order undetermined).
- This version does not enforce order, but **mutual exclusion**.
- Can you find a version that enforces order?

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- You ate lunch concurrently (order undetermined).
- This version does not enforce order, but mutual exclusion.
- Can you find a version that enforces order?
- Can you find a message version that enforces mutual exclusion?



x = 5
print x

```
x = 7 Thread B
```

- What path yields output 5 and final value 5?
- What path yields output 7 and final value 7?

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- What paths are possible and what are their effects?
- Can we prove bad effects impossible, and desirable effects certain?

# Concurrent Updates

### Concurrent Updates

$$x = x + 1$$

Thread A load x add 1 store x

Thread B load x add 1 store x

#### Concurrent Updates

Any operation that cannot be interrupted is said to be atomic.