# 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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- You wonder who ate lunch first.
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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

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

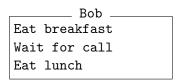
You

Eat breakfast

Work

Eat lunch

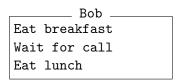
Call Bob



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

- You want to guarantee that you ate lunch before Bob.
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- You ate lunch sequentially (order guaranteed)
- You ate breakfast concurrently (order undetermined)
- Two events are concurrent if we cannot tell by looking at the program which will happen first.

### Concurrent programs are non-deterministic

Thread A al Print "yes"

\_\_\_\_\_ Thread B \_\_\_\_\_ b1 Print "no"

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- Make a rule that you can only eat lunch if you have the rock.

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

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

# Which operations are atomic?

• Each hardware implementation may be different.

### Which operations are atomic?

- Each hardware implementation may be different.
- Require hardware to provide specific known atomic operations.
- Write programs that *only* assume these operations are atomic.