

# 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 could call and ask the time, but how would you know if your clocks were synchronized?

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Work
Eat lunch
Call Bob

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- 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	
a1	Print "yes"

Thread B	
b1	Print "no"

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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?

# Shared variables

Thread A

```
x = 5  
print x
```

Thread B

```
x = 7
```

## Shared variables

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- 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 5 and final value 7?
- 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

Thread A

```
x = x + 1
```

Thread B

```
x = x + 1
```

# Concurrent Updates

Thread A

```
x = x + 1
```

Thread B

```
x = x + 1
```

Thread A

```
load x  
add 1  
store x
```

Thread B

```
load x  
add 1  
store x
```

# Concurrent Updates

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```

Thread B

```
x = x + 1
```

Thread A

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load x  
add 1  
store x
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Thread B

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load x  
add 1  
store x
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Any operation that cannot be interrupted is said to be **atomic**.

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- Require hardware to provide specific known atomic operations.
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- Example: **semaphores**