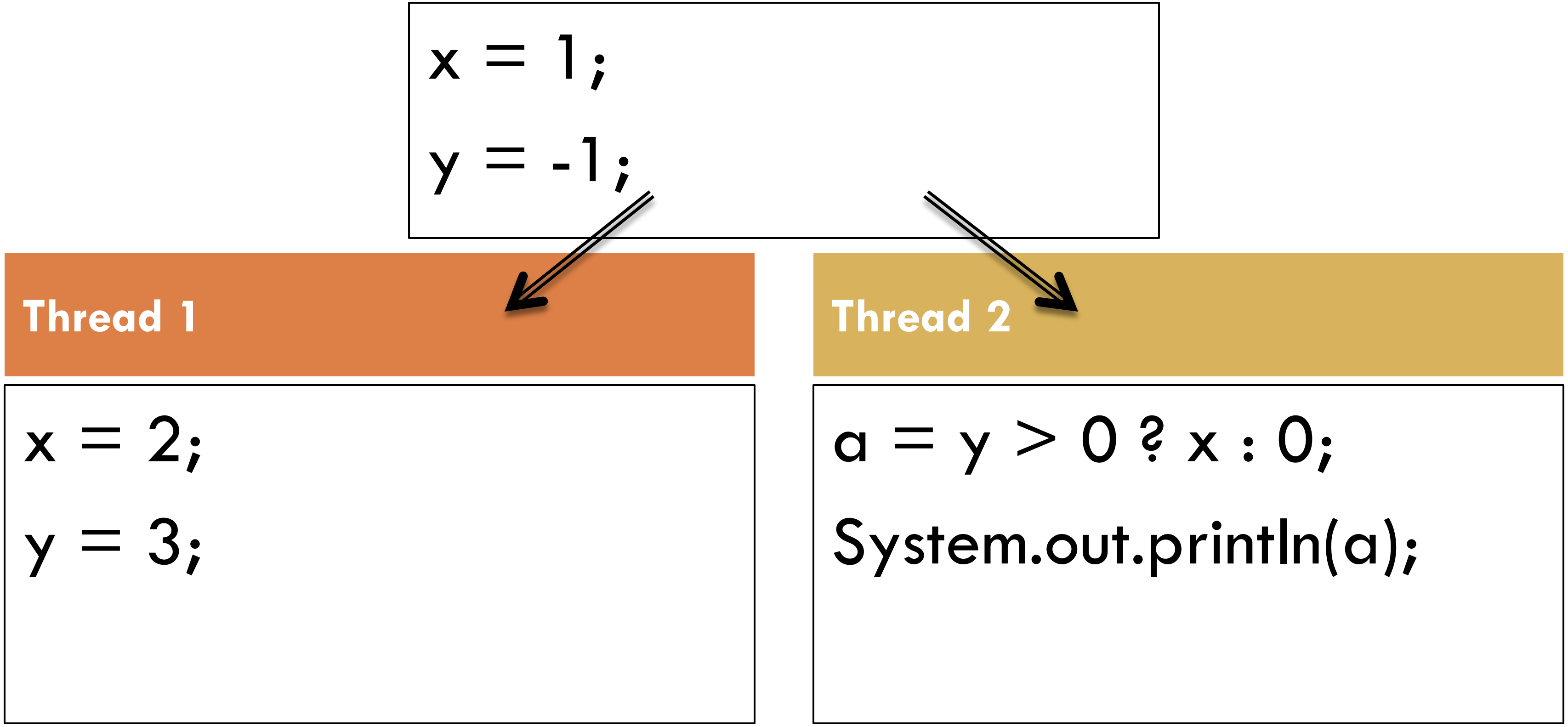
CONCURRENCY 2

CS 2110 – Spring 2016

Consistency



```
x = 1;
y = -1;
```

Thread 1

```
x = 2;
y = 3;
```

Thread 2

```
a = y > 0 ? x : 0;
System.out.println(a);
```

What is printed?

0, 1, and 2 can be printed!

Consistency

Thread 1 on Core 1	Thread 2 on Core 2
Write 2 to x in local cache	
Write 3 to y in local cache	
3 gets pushed to y in memory	
	Read 3 from y in memory
	Read 1 from x in memory
	Write 1 to a
	Print 1
2 gets pushed to x in memory	

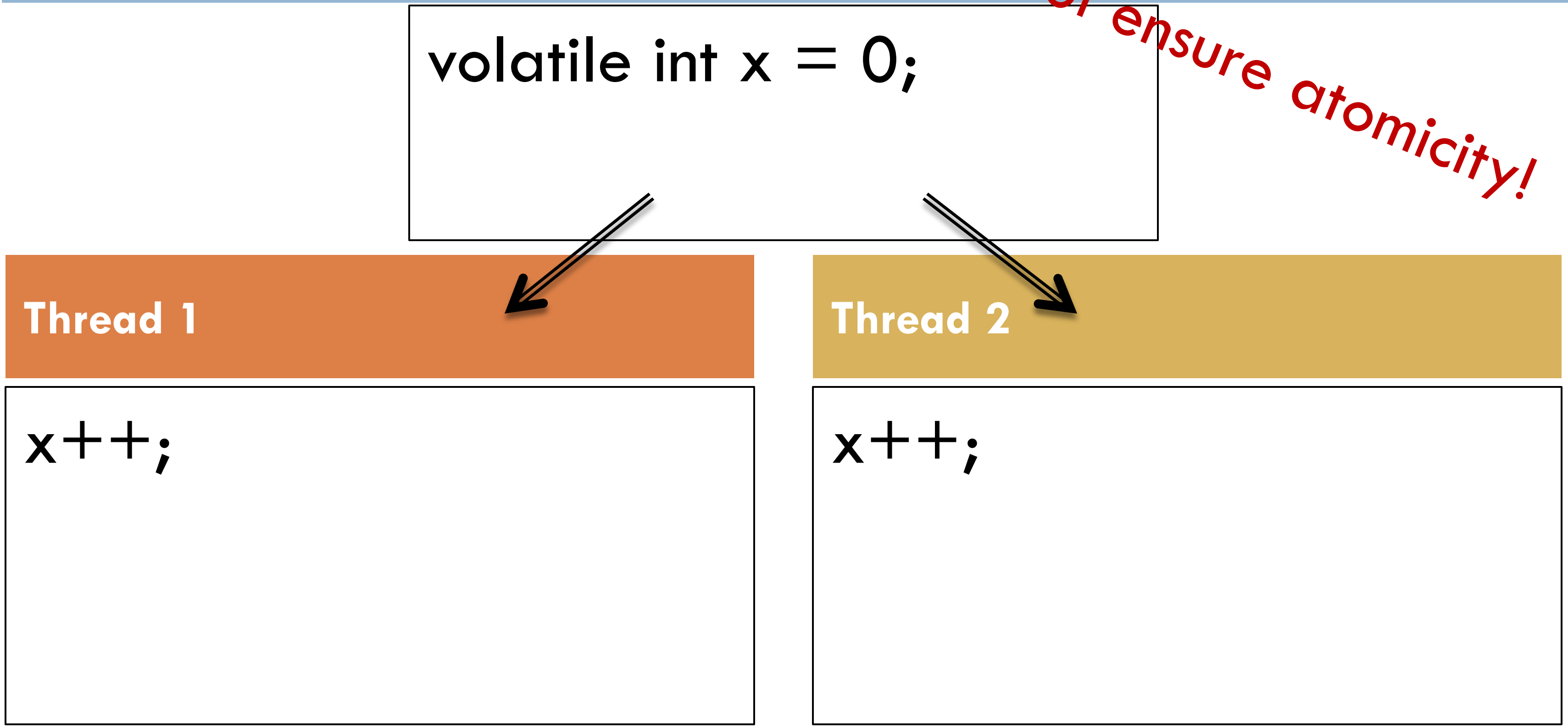
Not sequentially consistent!

Harsh Reality

- Sequential Consistency
  - There is an interleaving of the parallel operations that explains the observations and events
  - Currently unknown how to implement efficiently
- Volatile keyword
  - Java fields can be declared volatile
  - Writing to a volatile variable ensures all local changes are made visible to other threads
  - x *and* y would have to be made volatile to fix code

Atomicity

volatile does not ensure atomicity!



```
volatile int x = 0;
```

Thread 1

```
x++;
```

Thread 2

```
x++;
```

What is the value of x?

Can be both 1 and 2!

java.util.concurrent.atomic

- class AtomicInteger, AtomicReference<T>, …
  - Represents a value
- method set(newValue)
  - has the effect of writing to a volatile variable
- method get()
  - returns the current value
- effectively an extension of volatile
- but what about atomicity???

Compare and Set (CAS)

- boolean compareAndSet(expectedValue, newValue)
  - If value doesn’t equal expectedValue, return false
  - if equal, store newValue in value and return true
  - executes as a single atomic action!
  - supported by many processors
  - without requiring locks!

```
AtomicInteger n = new AtomicInteger(5);
n.compareAndSet(3, 6); // return false – no change
n.compareAndSet(5, 7); // returns true – now is 7
```

Incrementing with CAS

```
/** Increment n by one. Other threads use n too. */
public static void increment(AtomicInteger n) {
        int i = n.get();
        while (n.compareAndSet(i, i+1))
                i = n.get();
}

// AtomicInteger has increment methods doing this
```

Lock-Free Data Structures

- Usable by many concurrent threads
- using only atomic actions – no locks!
- compare and swap is god here
- but it only atomically updates one variable at a time!

Let’s implement one!