

# Consistency

CS 272 Software Development

#	Thread 1: x++;	Thread 2: <b>x;</b>
	read value of <b>x</b>	read value of <b>x</b>
	calculate <b>x + 1</b>	calculate <b>x - 1</b>
	assign <b>x</b> to calculated result	assign <b>x</b> to calculated result

```
Thread 1: x \leftrightarrow ;
                                                  Thread 2: x--;
1 read \mathbf{x} = \mathbf{1}
   calculate 1 + 1 = 2
  assign x = 2
                                                   read x = 2
                                                   calculate 2 - 1 = 1
                                                   assign x = 1
```

https://www.cs.usfca.edu/

```
Thread 1: x \leftrightarrow ;
                                                 Thread 2: x--;
1 read \mathbf{x} = \mathbf{1}
   calculate 1 + 1 = 2
  assign x = 2
                                                  read x = 2
                                                  calculate 2 - 1 = 1
                                                  assign x = 1
   final value x = 1
```

```
Thread 1: x++;
                                     Thread 2: x--;
                                      read x = 1
                                      calculate 1 - 1 = 0
                                      assign x = 0
read x = 0
calculate 0 + 1 = 1
assign x = 1
```

```
Thread 2: x--;
Thread 1: x \leftrightarrow ;
                                          read x = 1
                                          calculate 1 - 1 = 0
                                          assign x = 0
read x = 0
calculate 0 + 1 = 1
assign x = 1
final value x = 1
```

```
Thread 1: x \leftrightarrow ;
                                                   Thread 2: x--;
1 read \mathbf{x} = \mathbf{1}
                                                    read x = 1
   calculate 1 + 1 = 2
                                                    calculate 1 - 1 = 0
   assign x = 2
                                                    assign x = 0
```

```
Thread 1: x \leftrightarrow ;
                                                 Thread 2: x--;
1 read \mathbf{x} = \mathbf{1}
                                                  read x = 1
   calculate 1 + 1 = 2
                                                  calculate 1 - 1 = 0
   assign x = 2
                                                  assign x = 0
   final value x = 0
```

```
Thread 1: x++;
                                             Thread 2: x--;
1 read \mathbf{x} = \mathbf{1}
                                             read x = 1
  calculate 1 + 1 = 2
                                             calculate 1 - 1 = 0
                                             assign x = 0
  assign x = 2
  final value x = 2
```

#### **Problems**

- Concurrent operations causes **inconsistent** results
- Data shared by threads not **thread safe** access
  - Value may be modified in between read and use
  - Further complicated by caching of values in memory
- Operators x++ and x-- are not atomic operations
  - Operations can be divided or interrupted

## **Thread Safety**

- An object is thread safe if it maintains a valid or consistent state even when accessed concurrently
- Includes all constants and immutable objects
  - String or primitive types that are final
- Includes some mutable objects
  - o StringBuffer, java.util.concurrent.\*

# **Providing Consistency**

- If multithreading...
  - If **sharing data** between threads...
    - If shared data not already thread safe...
      - must synchronize access to that data

# **Synchronization**

- Using the synchronized keyword and intrinsic (or monitor) lock objects to protect blocks of code
- Using the volatile keyword to protect\* variables
- Using wait() and notifyAll() to coordinate threads
- Using conditional synchronization via lock objects

# Synchronization Issues

- Too little synchronization causes **inconsistent** results
  - Code no longer functional
- Too much synchronization causes blocking
  - Instead of faster code, results in slower code
     (threads can't run concurrently, more complex code)
  - Can actually cause deadlock\*



CHANGE THE WORLD FROM HERE