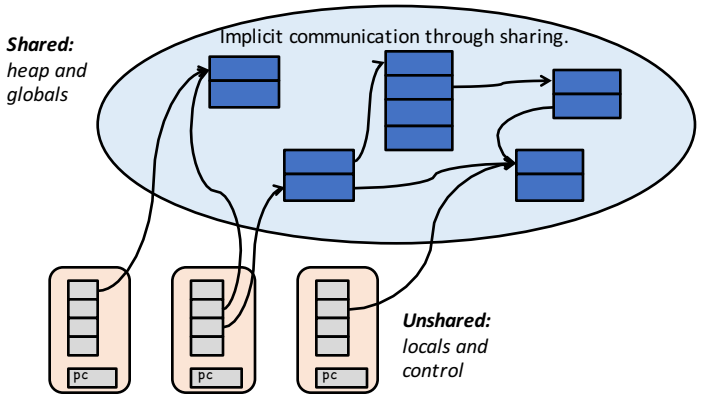
# Concurrency with Threads and Actors

Adapted from slides by Steve Freund

## Shared-Memory Multithreading




## Concurrency and Race Conditions

```
int bal = 0;
```

Thread 1
```
t1 = bal
bal = t1 + 10
```

Thread 2
```
t2 = bal
bal = t2 - 10
```

Thread 1 | Thread 2

```
t1 = bal
bal = t1 + 10
```

```
t2 = bal
bal = t2 - 10
```

**bal == 0**

## Concurrency and Race Conditions

```
int bal = 0;
```

Thread 1
```
t1 = bal
bal = t1 + 10
```

Thread 2
```
t2 = bal
bal = t2 - 10
```

Thread 1 | Thread 2

```
t1 = bal
```

```
t2 = bal
```

```
bal = t1 + 10
```

```
bal = t2 - 10
```

**bal == -10**

## Concurrency and Race Conditions

```
Lock m = new Lock();
int bal = 0;
```

Thread 1

```
synchronized(m) {
  t1 = bal
  bal = t1 + 10
}
```

Thread 2

```
synchronized(m) {
  t2 = bal
  bal = t2 - 10
}
```

Thread 1

```
acquire(m)
t1 = bal
bal = t1 + 10
release(m)
```

Thread 2

```
acquire(m)
t2 = bal
bal = t2 - 10
release(m)
```

## Account Monitor

acquire lock of receiver object

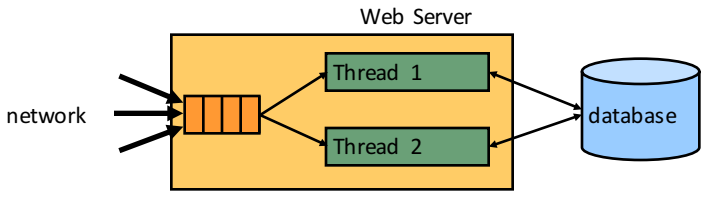
```
class Account {
  private int balance;

  public synchronized void add(int n) {
    balance += n;
  }

  public synchronized String toString() {
    return "balance = " + balance;
  }
}
```

## Producer-Consumer Buffers

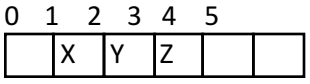
- Buffer with finite size
  - Producers add values to it
  - Consumers remove values from it
- Used "everywhere"
  - buffer messages on network, OS events, events in simulation, messages between threads...




## Java Buffer

```
public class Buffer<T> {

    private T[] elementData;
    private int elementCount;
    private int start;
    private int end;
```



## Java Buffer

```
public class Buffer<T> {

    private T[] elementData;
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```
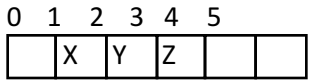
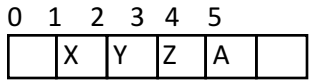




elementCount = 3

b.insert("A");

## Java Buffer

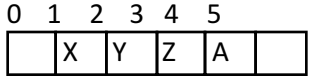
```
public class Buffer<T> {

    private T[] elementData;
    private int elementCount;
    private int start;
    private int end;
```




elementCount = 4

## Java Buffer

```
public class Buffer<T> {

    private T[] elementData;
    private int elementCount;
    private int start;
    private int end;
```

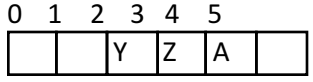



elementCount = 4

s = b.delete();

## Java Buffer

```
public class Buffer<T> {

    private T[] elementData;
    private int elementCount;
    private int start;
    private int end;
```




elementCount = 3

## Consumers

```
class Consumer extends Thread {
    private final Buffer<Character> buffer;

    public Consumer(Buffer<Character> b) {
        buffer = b;
    }

    public void run() {
        while (true) {
            char c = buffer.delete();
            System.out.print(c);
        }
    }
}
```

## Producers

```
class Producer extends Thread {
    private final Buffer<Character> buffer;

    public Producer(Buffer<Character> b) {
        buffer = b;
    }

    public void run() {
        while (moreData()) {
            char c = next();
            buffer.insert(c);
        }
    }
}
```

## Using Buffers

```
class Example {
  public static void main(String[] args) {
    Buffer<String> buffer = new Buffer<String>(5);
    Producer prod = new Producer(buffer);
    Consumer cons = new Consumer(buffer);
    prod.start();
    cons.start();
  }
}
```

## Unsafe Buffer Ops

```
public class Buffer<T> {
    private T[] elementData;
    private int elementCount;
    private int start;
    private int end;

    public void insert(T t) {
      end = (end + 1) % elementData.length;
      elementData[end] = t;
      elementCount++;
    }
    public T delete() {
      T elem = elementData[start];
      start = (start + 1) % elementData.length;
      elementCount--;
      return elem;
    }
    ...
```

## Safe Buffer Ops

```
public class Buffer<T> {
    private T[] elementData;
    private int elementCount;
    private int start;
    private int end;

    public synchronized void insert(T t) throws InterruptedException {
      while (elementCount == elementData.length) wait();
      end = (end + 1) % elementData.length;
      elementData[end] = t;
      elementCount++;
      notifyAll();
    }
    public synchronized T delete() throws InterruptedException {
      while (elementCount == 0) wait();
      T elem = elementData[start];
      start = (start + 1) % elementData.length;
      elementCount--;
      notifyAll();
      return elem;
    }
```

## Consumers With Handler

```
class Consumer extends Thread {
    private final Buffer<Character> buffer;

    public Consumer(Buffer<Character> b) {
        buffer = b;
    }

    public void run() {
        try {
            while (true) {
                char c = buffer.delete();
                System.out.print(c);
            }
        } catch (InterruptedException e) {
            // thread interrupted, so stop loop
        }
    }
}
```

## Accounts again

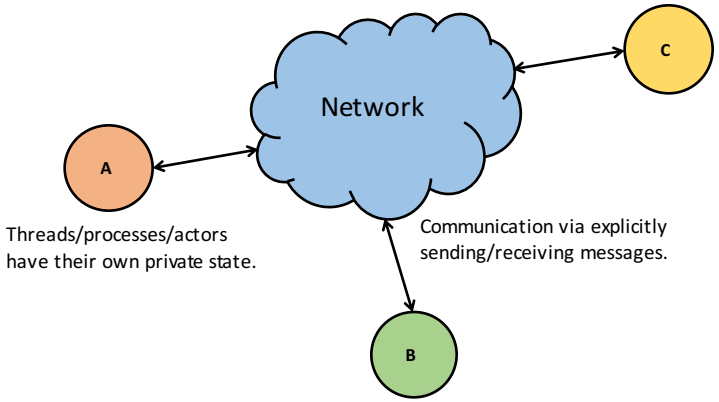
```
class Account {
  int balance;

  synchronized void add(int n) {
    balance += n;
  }

  synchronized void transfer(Account other,
                             int n) {
    balance -= n;
    other.add(n);
  }
```

## Deadlock

| Thread 1 | Thread 2 |
|---|---|
| a.transfer(b,n) | b.transfer(a,n) |
| acquire(a) | acquire(b) |
| a.bal -= n | |
| wait for b | b.bal -= n |
| | wait for a |

```
class Account {
  int balance;

  synchronized void add(int n) {
    balance += n;
  }

  synchronized void transfer(Account other,
                             int n) {
    balance -= n;
    other.add(n);
  }
```

## Message-passing, actors, "shared nothing"




## Simple Actor

```
class SimpleActor(val verb: String) extends Actor {
  def act() = {
    for (i <- 1 to 5) {
      println("I'm " + verb + "ing");
      Thread.sleep(1000);
    }
  }
  start();
}
```

## Parroting Actor

```
class Parrot extends Actor {
  def act() = {
    loop {
      react {
        case msg => println("Recieved:   " + msg);
      }
    }
  }
  start();
}
...
val p = new Parrot()
p ! "foo"
```

## Matching Messages

```
abstract class Message { }
case class Hello() extends Message { }
case class Num(val n : Int) extends Message { }

class FussyParrot extends Actor {
  def act() = {
    loop {
      react {
        case Hello     => println("Hello to you too");
        case Num(n)    => println("Number " + n);
      }
    }
  }
  start();
}
```

## Bank Account

```
abstract class Message { }
case class DepositAmt(n : Int) extends Message;
case class GetBalance() extends Message;

class Account(var balance : Int) extends Actor {
  def act = {
    loop {
      react {
        case DepositAmt(i) => balance = balance + i;
        case GetBalance()  => sender ! balance;
      }
    }
  }
  start();
}
```

## Back and forth

```
class PickANumber extends Actor {
  def act() = {
    var done = false;

    println("Send me an upper bound...");
    val num = receive { case n : Int => Random.nextInt(n); }

    while (!done) {
      receive {
        case i : Int if (i == num) => sender ! "You Win."; done = true;
        case i : Int if (i < num)  => sender ! "Too Low.";
        case i : Int if (i > num)  => sender ! "Too High.";
      }
    }
    println("Done...");
  }
  start()
}
```