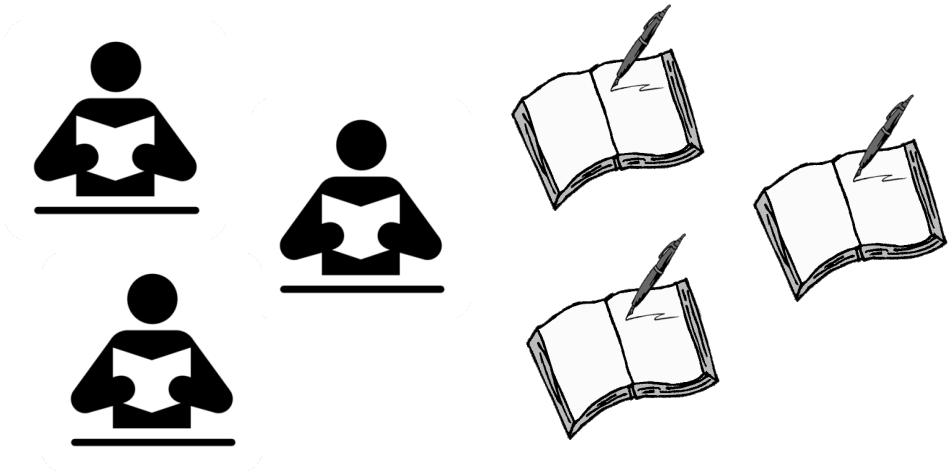
Readers/Writers Problem



Readers/Writers with Semaphores

```
class ReadWrite {
   public:
      void Read();
      void Write();
   private:
      int readers = 0;
      Semaphore mutex = 1;
      Semaphore wrt = 1;
}

ReadWrite::Write() {
   wrt.Wait();
   <perform write>
   wrt.Signal();
}
```

```
ReadWrite::Read() {
   mutex.Wait();
   readers++;
   if (readers == 1)
        wrt.Wait();
   mutex.Signal();
   <perform read>
   mutex.Wait();
   readers--;
   if (readers == 0)
        wrt.Signal();
   mutex.Signal();
}
```

Readers/Writers with Monitors

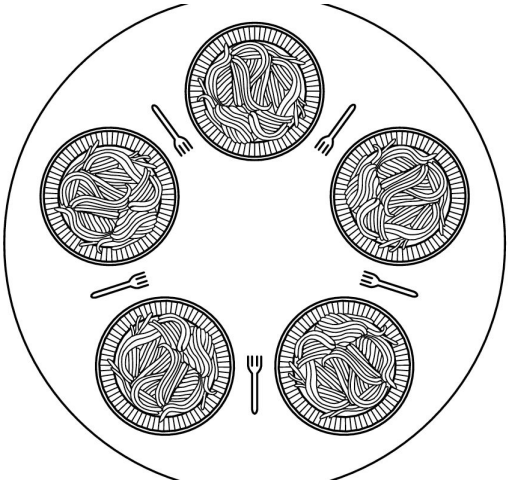
```
private int numReaders = 0;
private int numWriters = 0;

private synchronized void prepareRead() {
  while (numWriters > 0) wait();
  numReaders++;
}

private synchronized void doneRead() {
  numReaders--;
  if (numReaders == 0) notify();
}

public ... doRead() {
  // reads NOT synchronized
  prepareRead();
  <do the reading>
  doneRead();
}
```


Readers/Writers with Monitors

```
private int numReaders = 0;
private int numWriters = 0;

private synchronized void prepareRead() {
  while (numWriters > 0) wait();
  numReaders++;
}

private synchronized void doneRead() {
  numReaders--;
  if (numReaders == 0) notify();
}

public ... doRead() {
  // reads NOT synchronized
  prepareRead();
  <do the reading>
  doneRead();
}
```

```
private void prepareWrite() {
    numWriters++;
    while (numReaders > 0) wait();
}

private void doneWrite() {
    numWriters--;
    notify();
}

public synchronized void doWrite (...) {
    // writes synchronized
    prepareWrite();
    <do the writing>
    doneWrite();
}
```

Dining Philosophers



Dining Philosophers with Locks

```
Lock chopsticks[5];

void philosopher(int i) {
  while (true) {

    chopsticks[i].acquire(); // left chopstick
    chopsticks[(i+1)%5].acquire(); // right chopstick

    eat();

    chopsticks[i].release();
    chopsticks[(i+1)%5].release();

    think();
  }
}
```

Dining Philosophers with Monitors

```
monitor DiningPhilosophers  {
   enum {THINK, HUNGRY, EAT}
      state[5];
   condition self[5];
}

void synchronized pickup(int i) {
   state[i] = HUNGRY;
   test(i);
   if (state[i] != EAT)
      self[i].wait();
}

void synchronized putdown(int i) {
   state[i] = THINK;
   // test left and right neighbors
   test((i+4)%5);
   test((i+1)%5);
}
```

```
void test(int i) {
  // check left and right of i
  if (state[(i+4)%5] != EAT &&
      state[i] == HUNGRY &&
      state[(i+1)%5] != EAT) {
    state[i] = EAT;
    self[i].signal();
  }
}


void init() {
  for (int i = 0; i < 5; i++)
    state[i] = THINK;
  }
}
```


Deadlocks

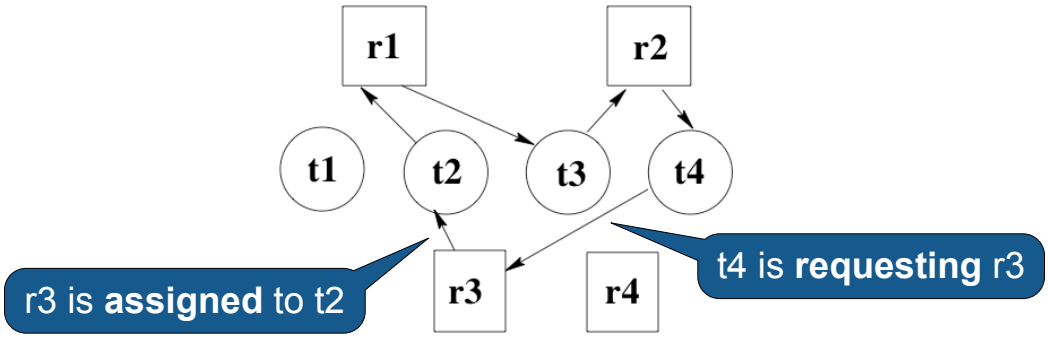
Process A:

```
printer.wait();
disk.wait();

// copy from disk
// to printer

printer.signal();
disk.signal();
```

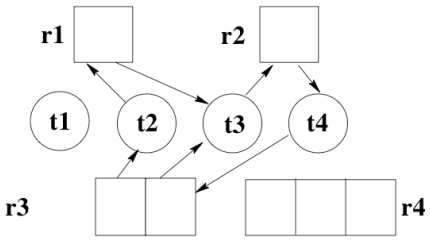
Process B:

```
disk.wait();
printer.wait();

// copy from disk
// to printer

printer.signal();
disk.signal();
```

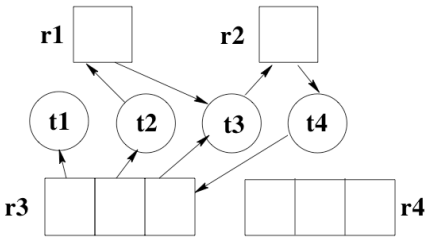
Resource Allocation Graph



Multiple Copies of Resources



Deadlock!



No deadlock!