Readers/Writers problem

- There is a number of threads.
  In order to ensure the integrity of the shared data being both read from and written to we need to allow:
  - only one writer access to the data at a time
  - if a writer is active there must be no active readers
  - if no writer is active there can be multiple readers
- We also need to make sure that no process misses out entirely.
- Three types of solutions:
  1. writer preferred - waiting writers go before waiting readers
  2. reader preferred – waiting readers go before waiting writers
  3. neither preferred - try to treat readers and writers fairly (a simple queue is not good enough we want parallel readers whenever possible)
- Both 1 and 2 can lead to indefinite postponement.
- See pthread_rwlock (rdlock and wrlock) - which solution do they provide?

Getting the program correct

```
exclusive_access = Semaphore.new(1)
number_deposited = Semaphore.new(0)

shared_buffer = 0

producer = Thread.new do
  while true
     next_result = whatever
     exclusive_access.wait()
     shared_buffer = next_result
     number_deposited.signal()
     exclusive_access.signal()
  end
end

consumer = Thread.new do
  while true
     exclusive_access.wait()
     number_deposited.wait()
     next_result = shared_buffer
     exclusive_access.signal()
     puts next_result
  end
end
```

Programming using low level constructs like semaphores is prone to mistakes.
What is wrong with this semaphore solution to the producer/consumer problem? 2 different problems.

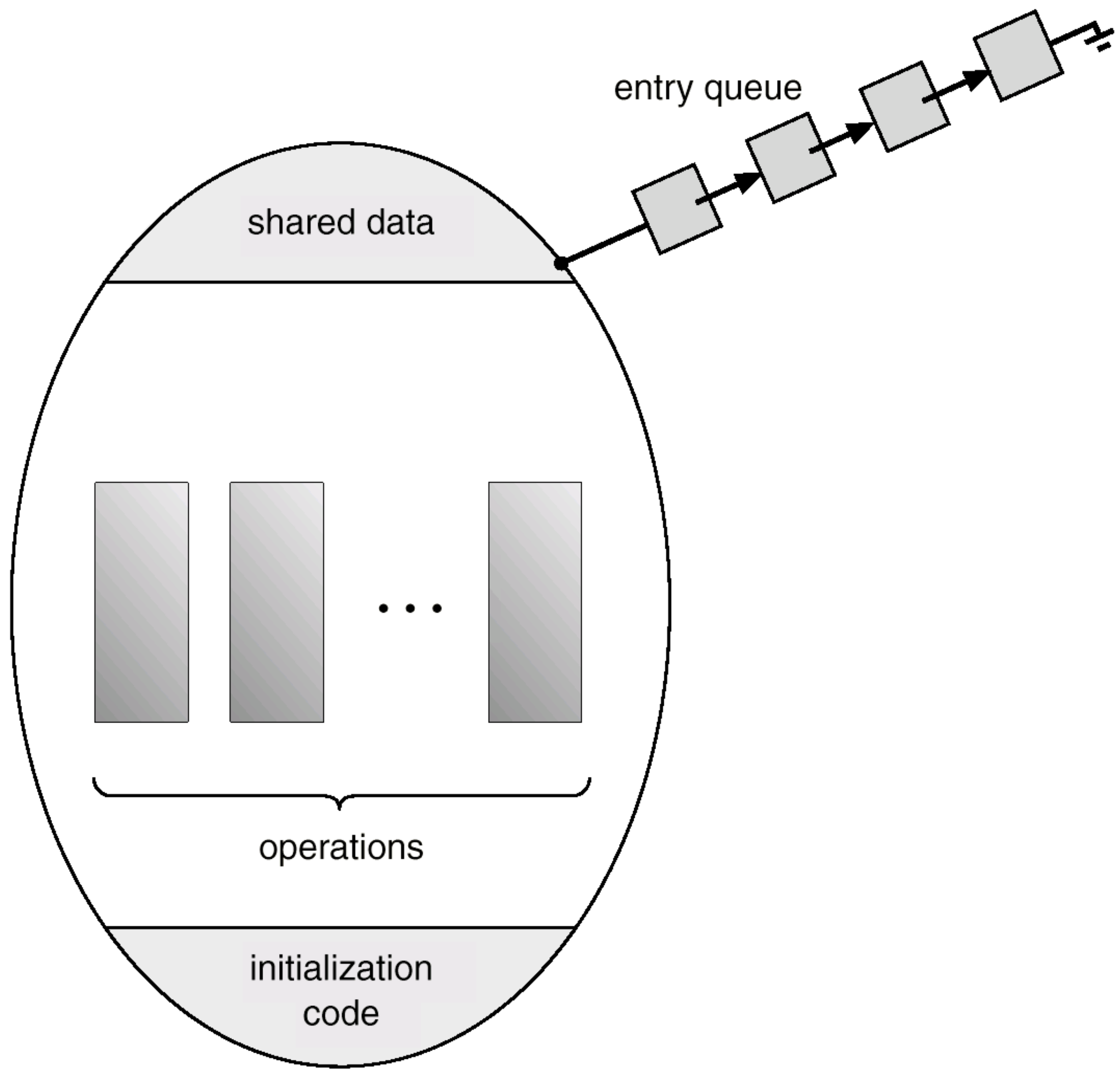
Bad programmers

- **Another popular problem is forgetting to unlock or signal.**
  We want an automatic (more or less) way of helping programmers lock and unlock.
- Java, Ruby and other languages try to avoid or minimise problems by implementing a form of monitor.

Monitors

- Brinch Hansen (1973) Hoare (1974)
- You can think of a monitor as an object which only allows one thread to be executing inside it.
  It has:
- the shared resource - it can only be accessed by the monitor
- publicly accessible procedures - they do the work
- a queue to get in
- a scheduler - which thread gets access next
- local state - not visible externally except via access procedures
- initialization code
- condition variables

Monitors (cont.)



Example monitor

```
monitor Account

 money = 0.00 # the shared resource

  def deposit(amount)
    money = money + amount
  end

  def withdraw(amount)
   if (amount < money)
     money = money - amount
     return true
   else
     return false
   end
  end

  def balance
    return money
  end

end
```

Here is an example in some Pseudo-code language which includes monitors:

Condition variables

- But sometimes our threads have to wait for some condition.
- A condition variable is a queue which can hold threads. We have wait and signal operations on condition variables.
- `conditionVariable.wait` puts the current thread to sleep on the corresponding queue
- `conditionVariable.signal` wakes up one thread from the queue (if there are any waiting)
- No internal state is kept of how many signals and waits there have been.
- Simpler than the similar instructions on semaphores.
- A signal with nothing waiting does nothing.
- A wait always puts a thread to sleep.

e.g. condition variables

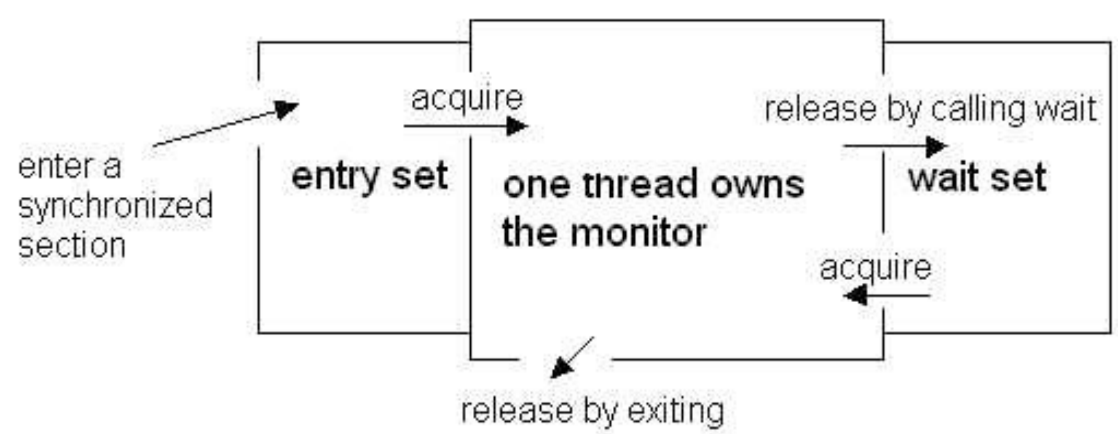
```
monitor SimpleBuffer

   def initialize
      buffer_free = true
      buffer = 0
      empty = new_condition_var
      full = new_condition_var
   end

   def insert(value)
         while !buffer_free
            empty.wait
         buffer = value
         buffer_free = false
         full.signal
   end

   def retrieve
         while buffer_free
            full.wait
          data = buffer
          buffer_free = true
         empty.signal
         return data
   end

end
```

But which thread runs?

- <u>But doesn't signal mean we have two threads running in the monitor?</u>
- Two choices:
- stop the thread which called signal
- don't start the new one until the current thread leaves the monitor
- Usually we use the second answer but:
- the thread may signal on other condition variables as well and we have to make scheduling decisions
- it may also change the conditions again and the next thread shouldn't really run

Java monitors

- Java has a single lock variable per object (it also has one per class).
- Each object also has a *wait set* associated with it (carefully not called a queue).
- Synchronized methods and blocks must check this variable before allowing entry.



Java monitors (cont.)

- There is a count associated with each lock variable.
- The count goes up every time a thread which owns the lock on that object calls a synchronized method or block on that object.
- And it goes down when it leaves the method or block.
- When the count gets to zero the thread exits the monitor and the lock is released.

```
...
  synchronized (anObject) {
   do things to the object;
  }
```

Java monitors are different

- `signal` is called `notify()`.
- It doesn't provide condition variables in the language (but (1.5 and later) provides them as classes).
- `wait()` and `notify()` have a single set for the whole object, i.e. one condition variable.
- The object can have unsynchronized methods which are not private.
- Also fields which are not private. Not a good idea.
- after a `notify()` running threads run till they leave the `synchronized` area
- programmers are told to use a `while` loop with the conditional `wait`

Before next time

- Read from the textbook

  7.1.3 The Dining-Philosophers Problem

  8.3 Deadlock Characterization

  8.4 Methods for Handling Deadlock

  8.5 Deadlock Prevention

  8.6 Deadlock Avoidance