# Concurrency

Haviland – Ch. 8.3.3

# Concurrency

- The two key concepts driving computer systems and applications are
  - communication: the conveying of information from one entity to another
  - concurrency: the sharing of resources in the same time frame
- Concurrency can exist in a single processor as well as in a multiprocessor system
- Managing concurrency is difficult, as execution behaviour is not always reproducible.

# Concurrency Example

- Program a:

```
#!/usr/bin/sh
count=1
while [ $count -le 20 ]
do
  echo -n "a"
  count=`expr $count + 1`
done
```

- Program b

```
#!/usr/bin/sh
count=1
while [ $count -le 20 ]
do
  echo -n "b"
  count=`expr $count + 1`
done
```

- When run sequentially `(a; b)` output is sequential.
- When run concurrently `(a&; b&)` output is interspersed and different from run to run.

# Race conditions

- A race condition occurs when multiple processes are trying to do something with shared data and the final outcome depends on the order in which the processes run.
  - E.g., If any code after a fork depends on whether the parent or child runs first.
- A parent process can call wait() to wait for termination (may block)
- A child process can wait for parent to terminate by polling (wasteful) (How would you do this?)
- Standard solution is to use signals.

# Example 1

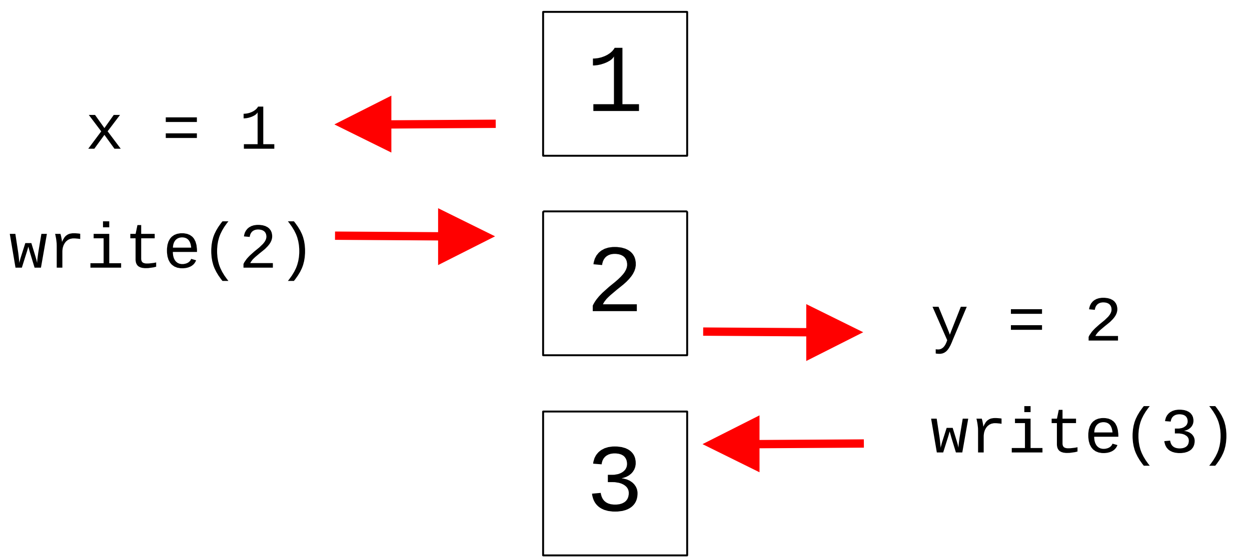
Process A

```
x = get(count)
write(x + 1)
```

Process B

```
y = get(count)
write(y + 1)
```

Count




The value of count is what we expect.

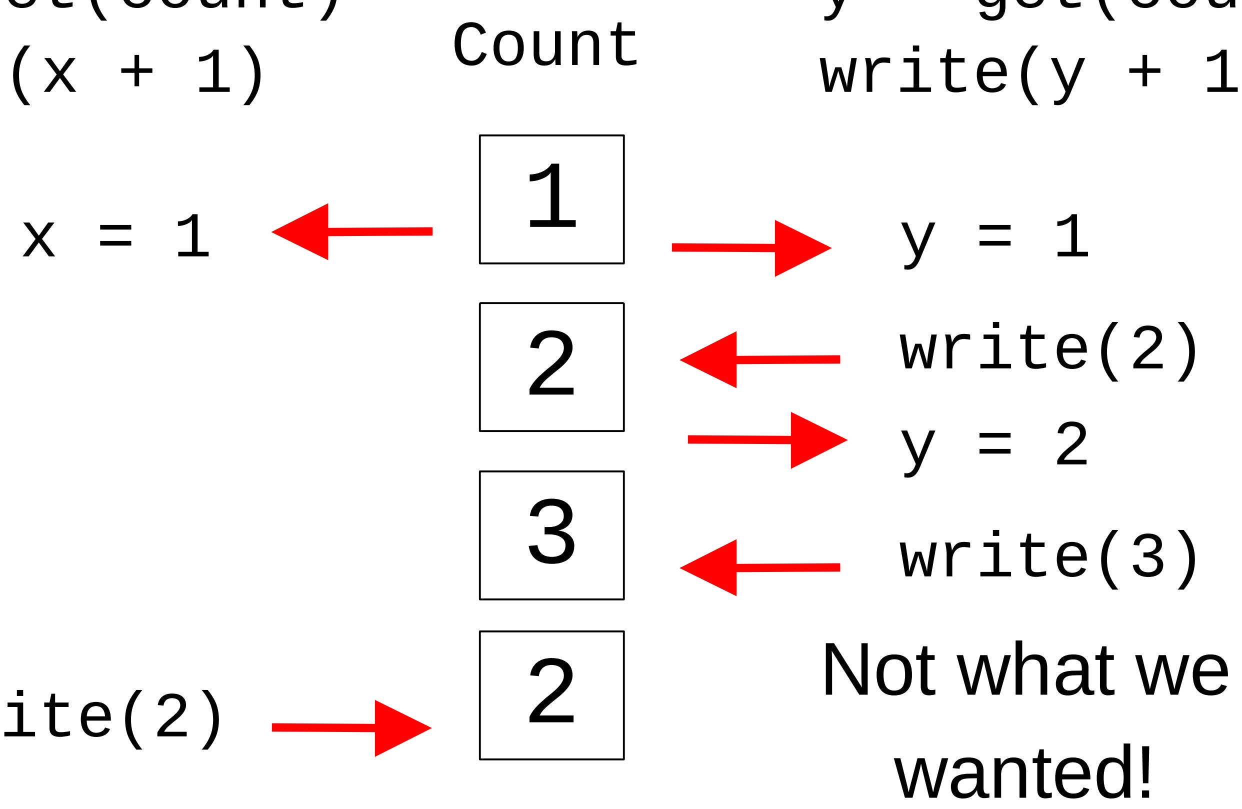
# Example 2

Process A

```
x = get(count)
write(x + 1)
```

Process B

```
y = get(count)
write(y + 1)
```



# Example: Race Conditions

Try running several instances of this

```
#!/bin/sh
c=1
while [ $c –le 10 ]
do
  sd=`cat sharedData`
  sd=`expr $sd + 1`
  echo $sd > sharedData
  c=`expr $c + 1`
  echo d = $sd
done
#file sharedData must exist and hold
#one integer
```

# Producer/Consumer Problem

- Simple example: `who | wc –l`
- Both the writing process (`who`) and the reading process (`wc`) of a pipeline execute concurrently.
- A pipe is usually implemented as an internal OS buffer.
- It is a resource that is concurrently accessed by the reader and the writer, so it must be managed carefully.

# Producer/Consumer

- consumer should be blocked when buffer is empty
- producer should be blocked when buffer is full
- producer and consumer should run independently as far as buffer capacity and contents permit
- producer and consumer should never be updating the buffer at the same instant (otherwise data integrity cannot be guaranteed)
- producer/consumer is a harder problem if there are more than one consumer and/or more than one producer.

# Protecting shared resources

- Programs that manage shared resources must protect the integrity of the shared resources.
- Operations that modify the shared resource are called critical sections.
- Critical section must be executed in a mutually exclusive manner.
- Semaphores are commonly used to protect critical sections.

# Semaphores

- Code that modifies shared data usually has the following parts:
  - **Entry section**: The code that requests permission to modify the shared data.
  - **Critical Section**: The code that modifies the shared variable.
  - **Exit Section**: The code that releases access to the shared data.
  - **Remainder**: The remaining code.

# Semaphores

- acquire(v)
  - block until the value of the semaphore variable v is greater than 0
  - then decrement v

- release(v)
  - increment v