



Operating Systems

Processes-Part4

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Inter-Process Communication

- Processes within a system may be *independent* or *cooperating*
- Cooperating process can affect or be affected by other processes, including *sharing data*.
- Reasons for cooperating processes:
 - Information sharing
 - Computation speedup
 - Modularity
 - Convenience



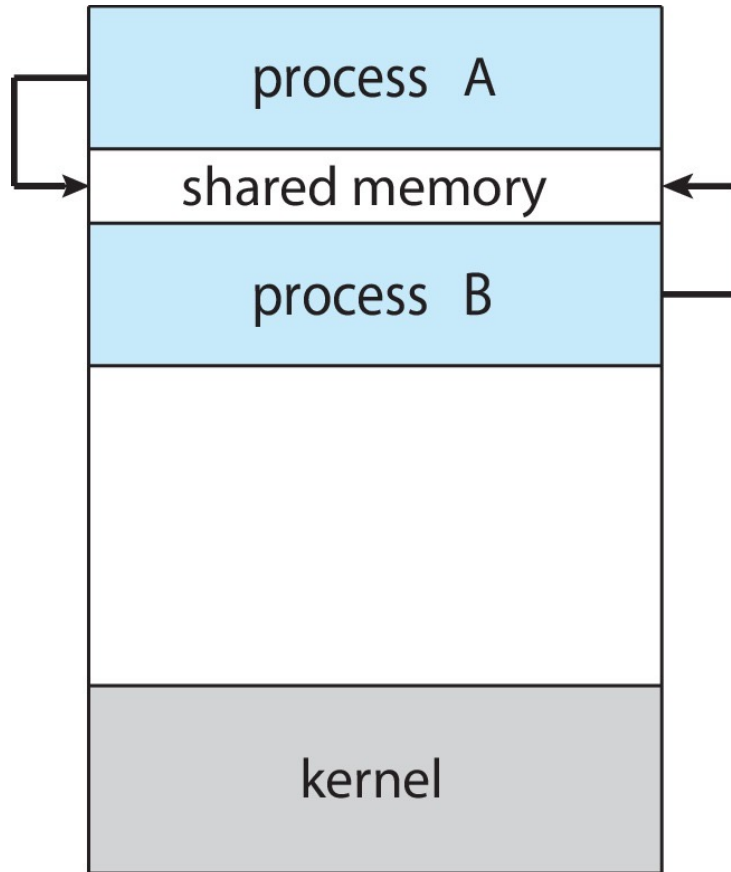
Inter-Process Communication (Cont.)

- Cooperating processes need **interprocess communication (IPC)**
- Two models of IPC
 - **Shared memory**
 - **Message passing**
 - ▶ **We do not cover this.**



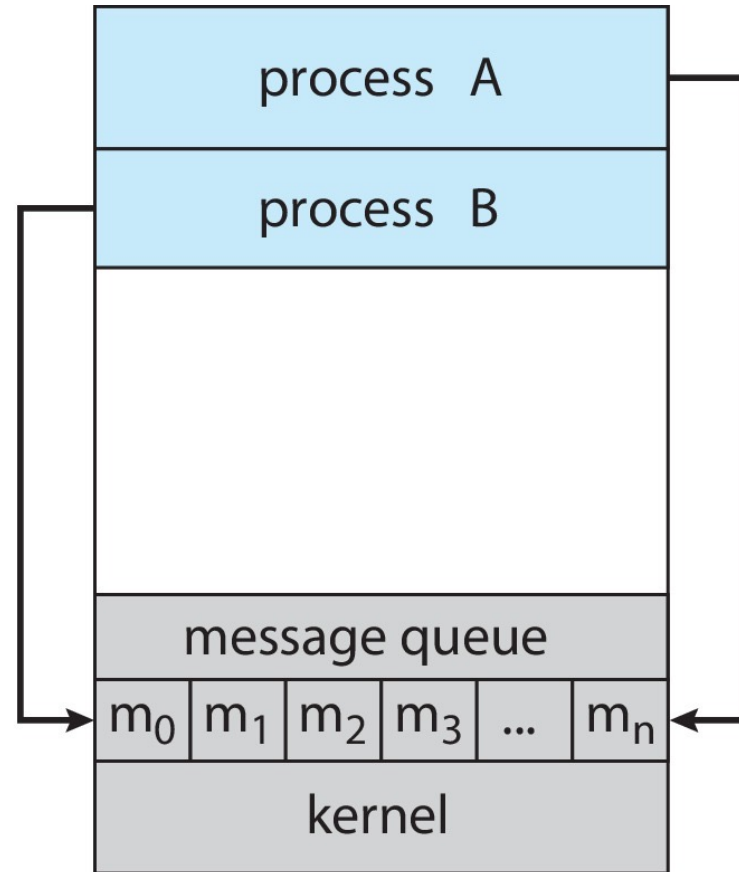
Communications Models

(a) Shared memory.



(a)

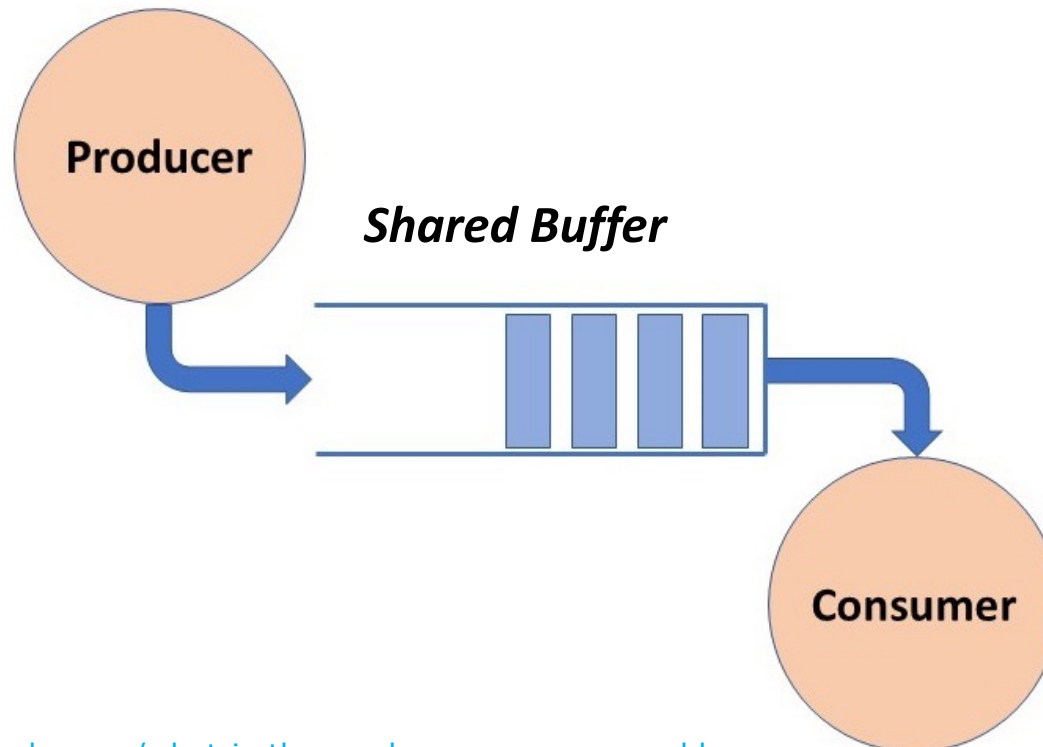
(b) Message passing.



(b)

Producer-Consumer Problem

- Paradigm for cooperating processes:
 - **Producer** process produces information that is consumed by a **consumer** process.



<https://www.educative.io/edpresso/what-is-the-producer-consumer-problem>

Producer-Consumer Problem-Variations

- **Unbounded-buffer** places no practical limit on the size of the buffer:
 - Producer never waits
 - Consumer waits if there is no buffer to consumer
- **Bounded-buffer** assumes that there is a fixed buffer size
 - Producer must wait if all buffers are full
 - Consumer waits if there is no buffer to consume



IPC – Shared Memory

- An area of memory shared among the processes that wish to communicate.
- The communication is ***under the control of the users*** processes ***not the operating system.***
- Major issues is to provide mechanism that will allow the user processes ***to synchronize their actions*** when they access shared memory.
- Synchronization is discussed in great details in Chapters 6 & 7.

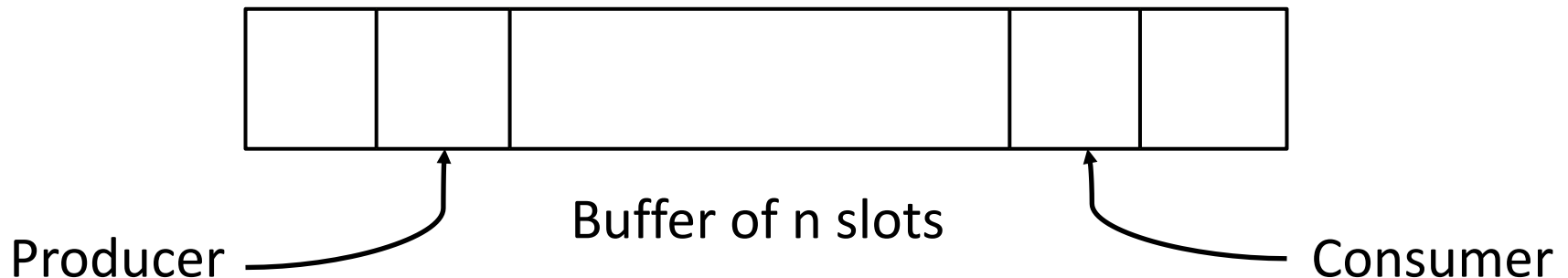


Bounded-Buffer – Shared-Memory Solution

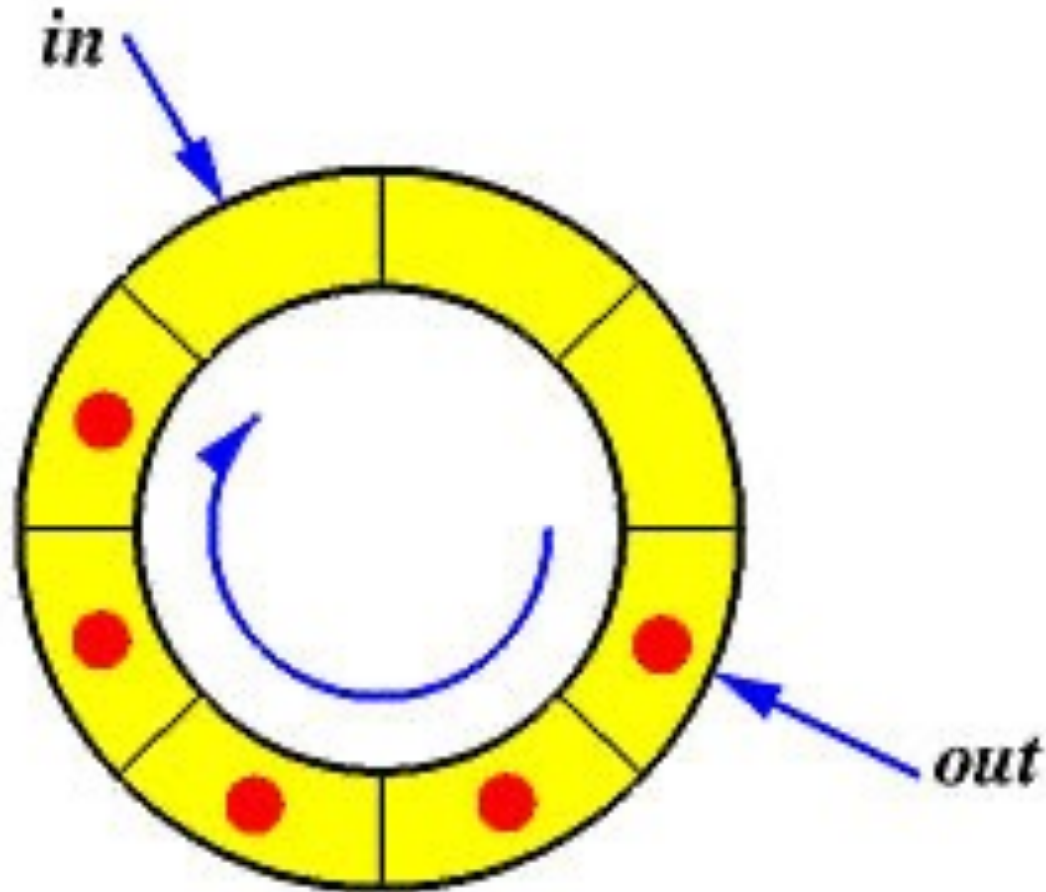
- Shared data

```
#define BUFFER_SIZE 10
typedef struct {
    . . .
} item;
item buffer[BUFFER_SIZE];
int in = 0;
int out = 0;
```

- Solution is correct but can only use **BUFFER_SIZE - 1** elements.

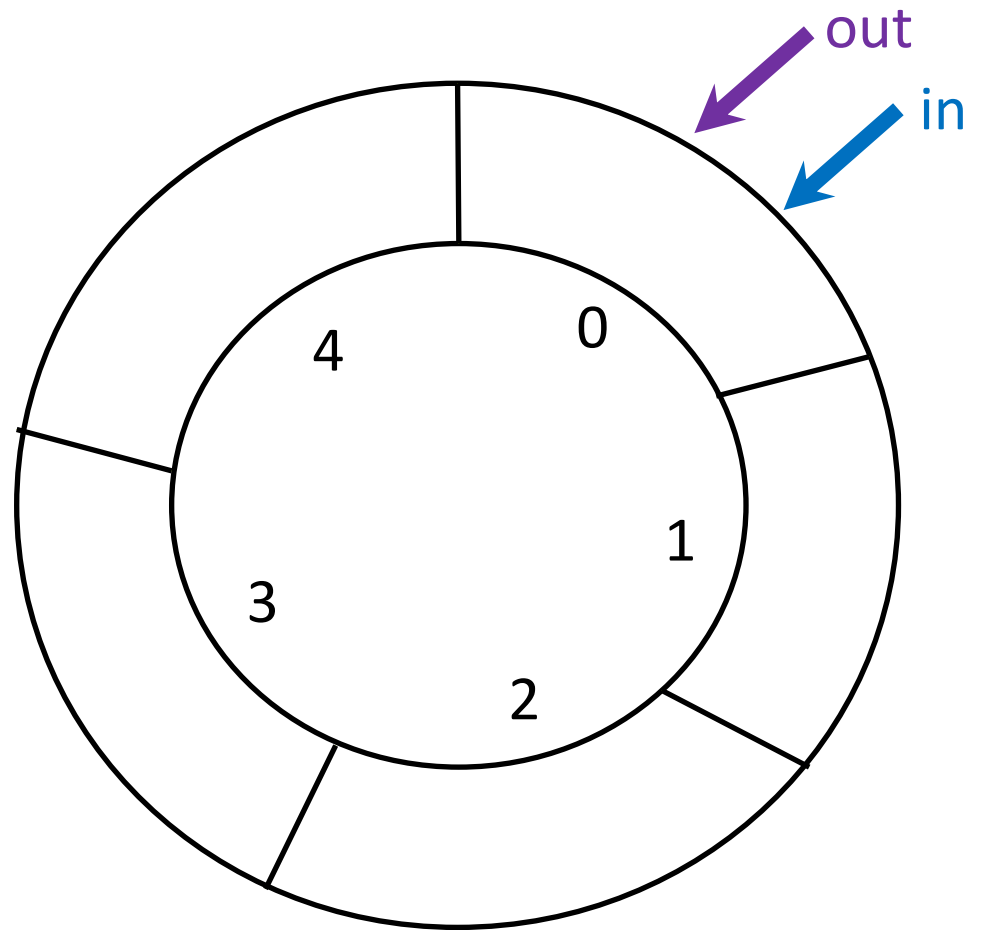


Circular Bounded-Buffer



Source: <https://pages.mtu.edu/~shene/NSF-3/e-Book/SEMA/TM-example-buffer.html>

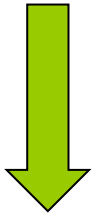
Start Point



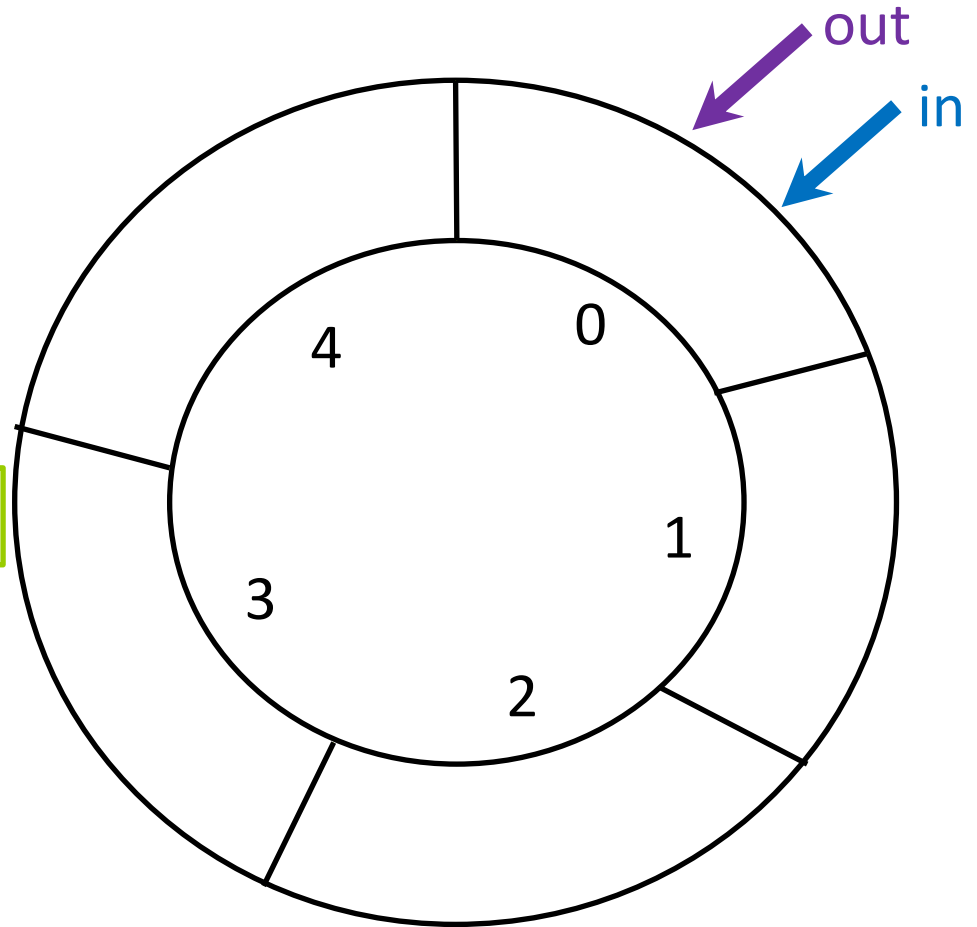
Producer

Produce an item

```
while (((in + 1) %  
BUFFER_SIZE) == out;
```



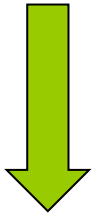
$(0 + 1) \% 5 = 1 \neq 0$



Producer

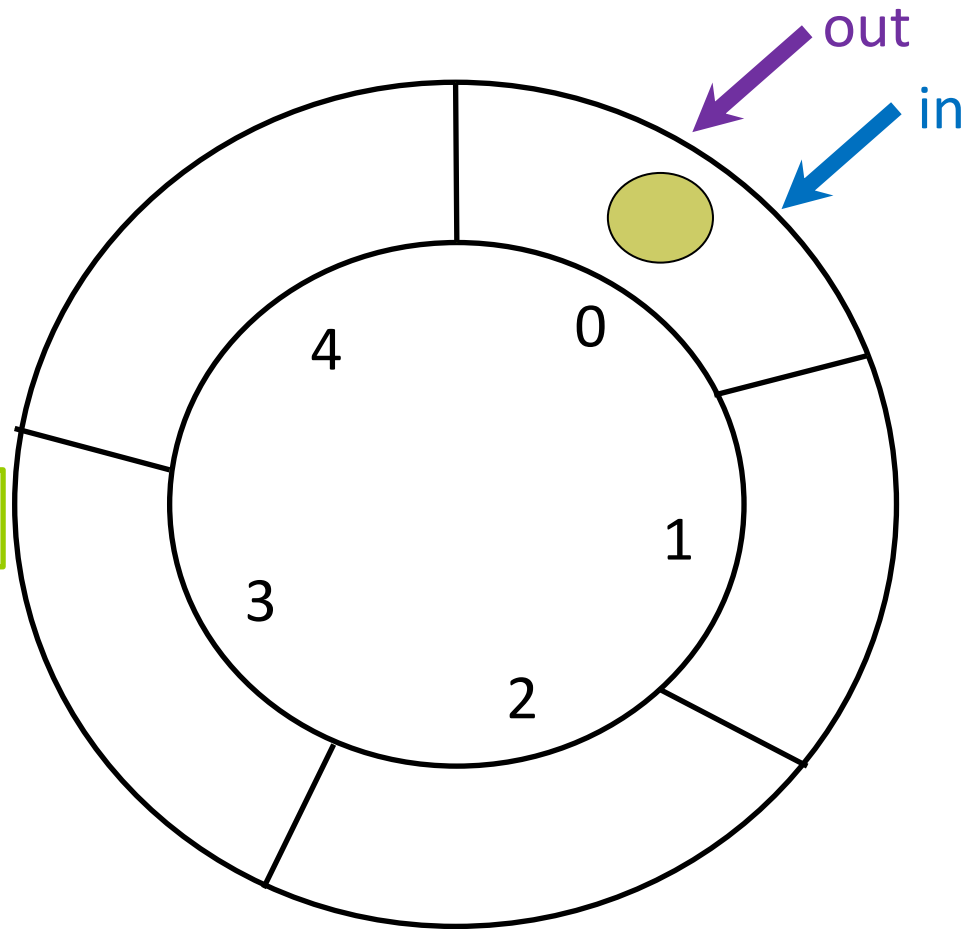
Produce an item

```
while (((in + 1) %  
BUFFER_SIZE) == out;
```



$(0 + 1) \% 5 = 1 \neq 0$

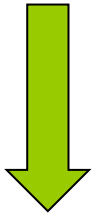
```
buffer[0] = item;
```



Producer

Produce an item

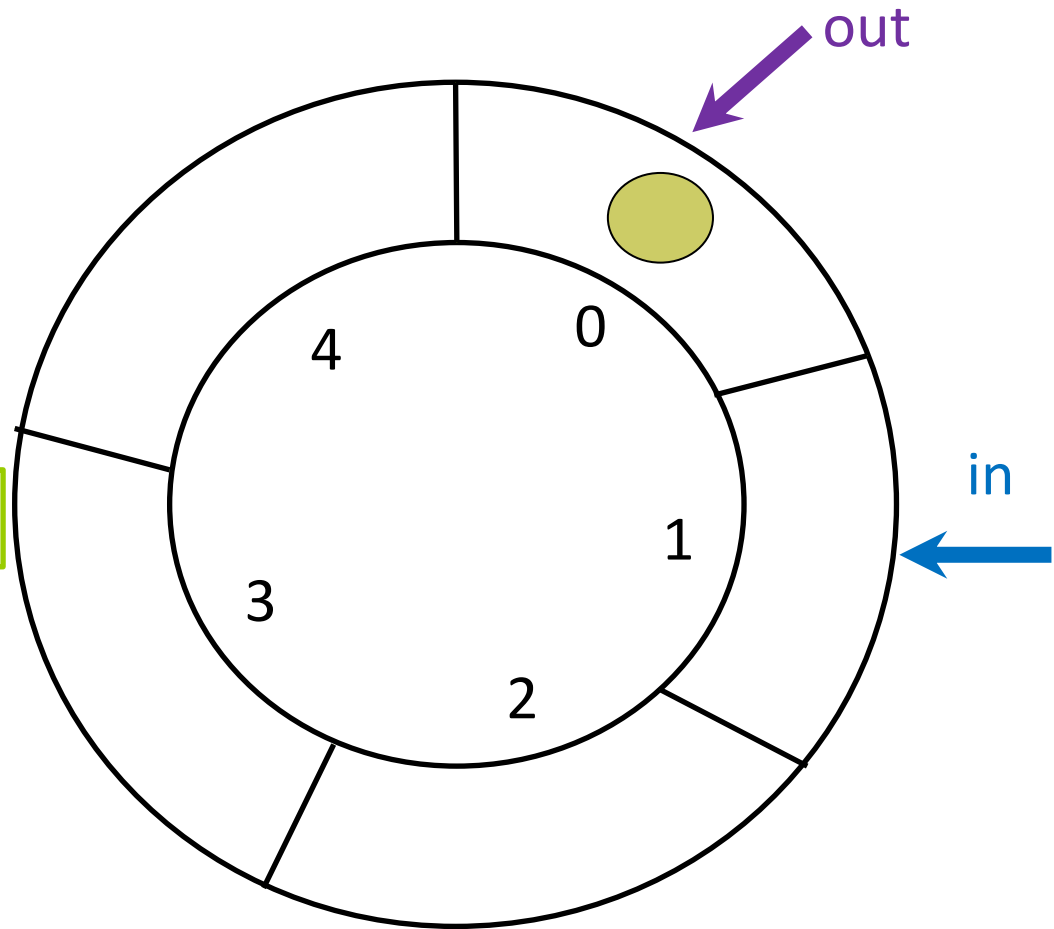
```
while (((in + 1) %  
BUFFER_SIZE) == out;
```



$(0 + 1) \% 5 = 1 \neq 0$

```
buffer[0] = item;
```

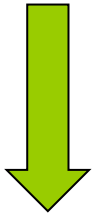
```
in = (0 + 1) % 5;
```



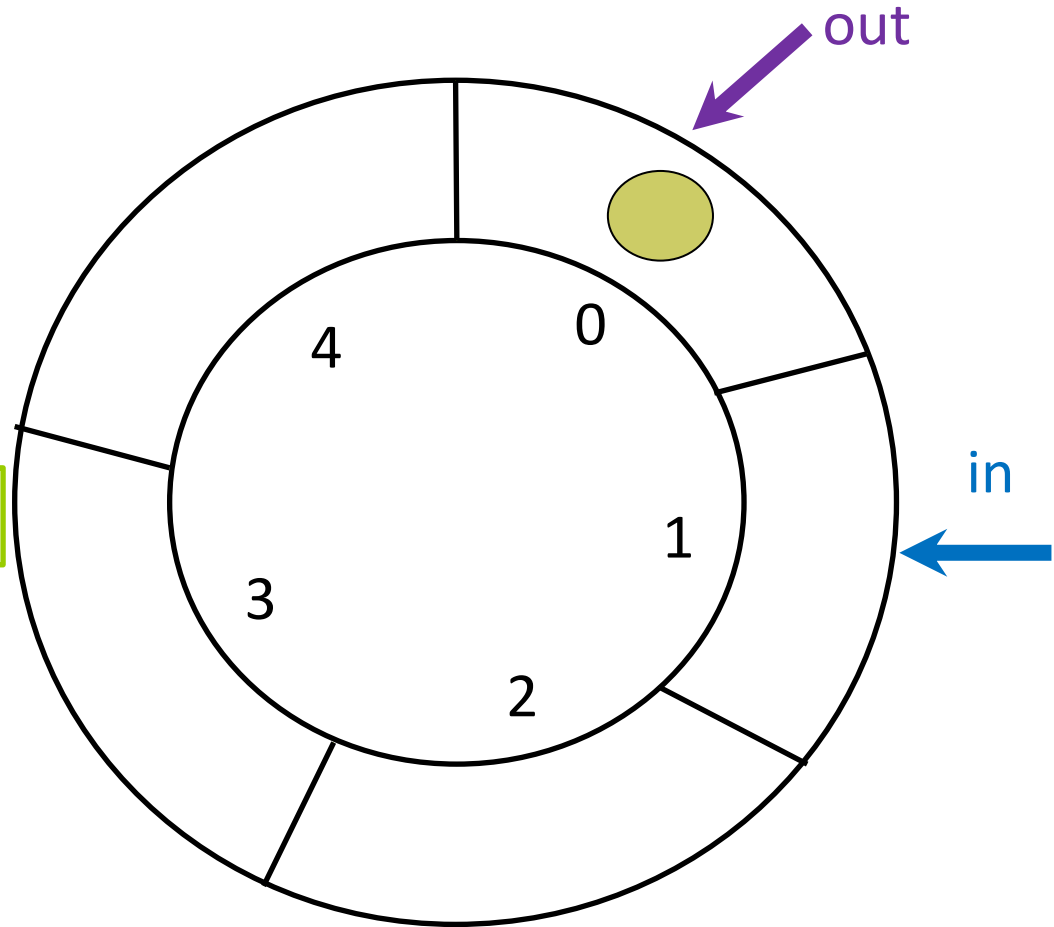
Producer

Produce an item

```
while (((in + 1) %  
BUFFER_SIZE) == out;
```



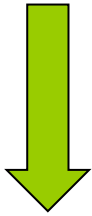
$(1 + 1) \% 5 = 2 \neq 0$



Producer

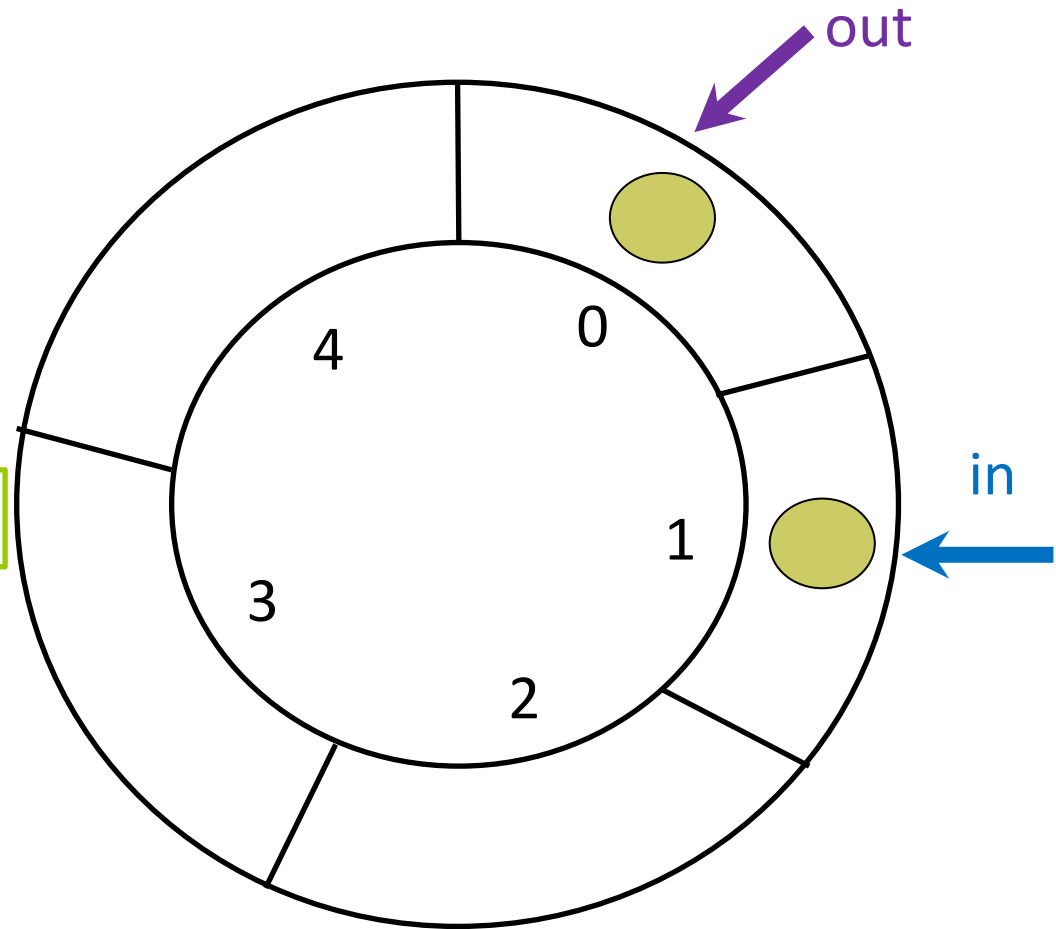
Produce an item

```
while (((in + 1) %  
BUFFER_SIZE) == out;
```



$(1 + 1) \% 5 = 2 \neq 0$

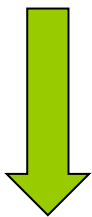
```
buffer[1] = item;
```



Producer

Produce an item

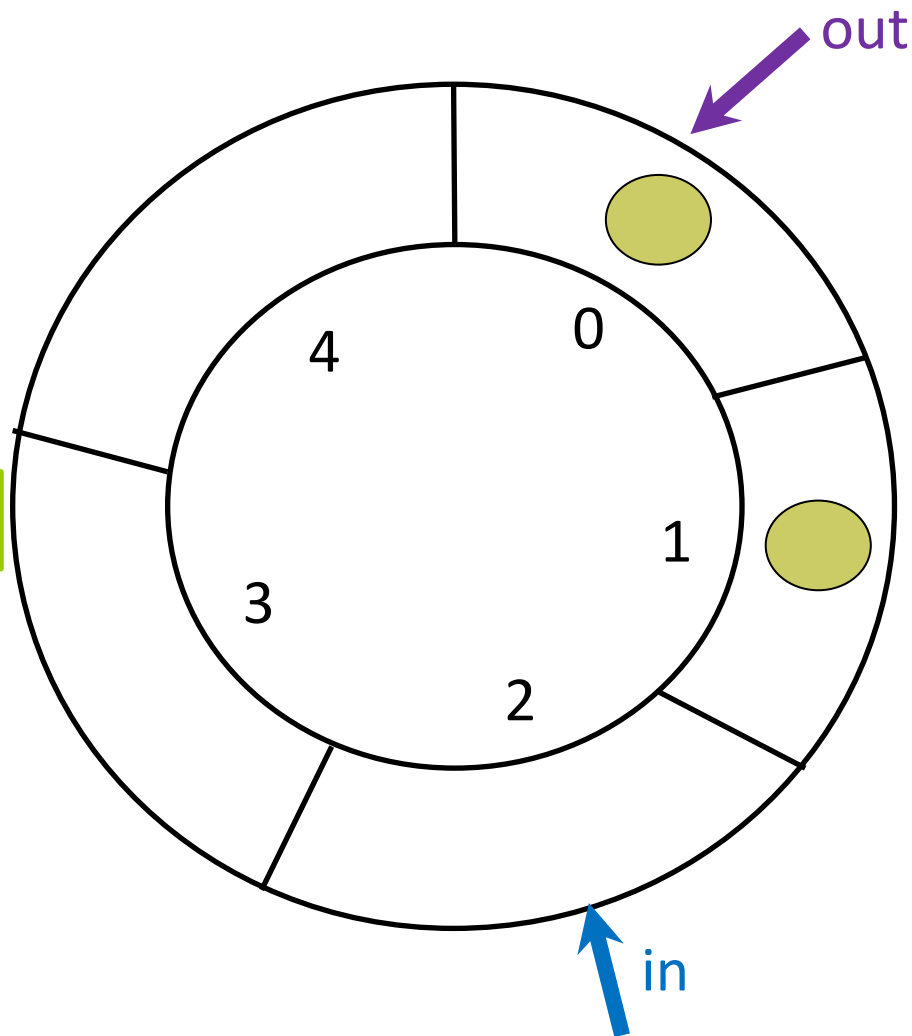
```
while (((in + 1) %  
BUFFER_SIZE) == out;
```



$(1 + 1) \% 5 = 2 \neq 0$

```
buffer[1] = item;
```

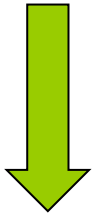
```
in = (1 + 1) % 5;
```



Producer

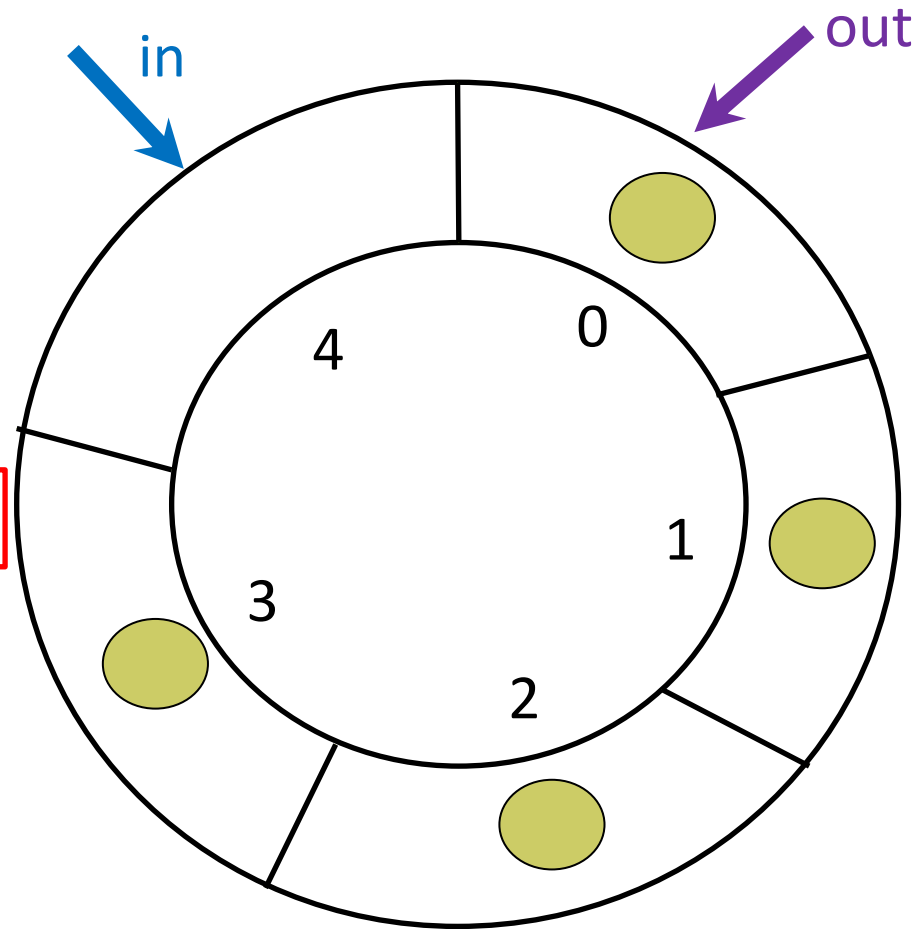
Produce an item

```
while (((in + 1) %  
BUFFER_SIZE) == out;
```



$(4 + 1) \% 5 = 0 == 0$

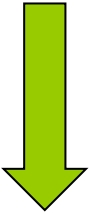
No more space



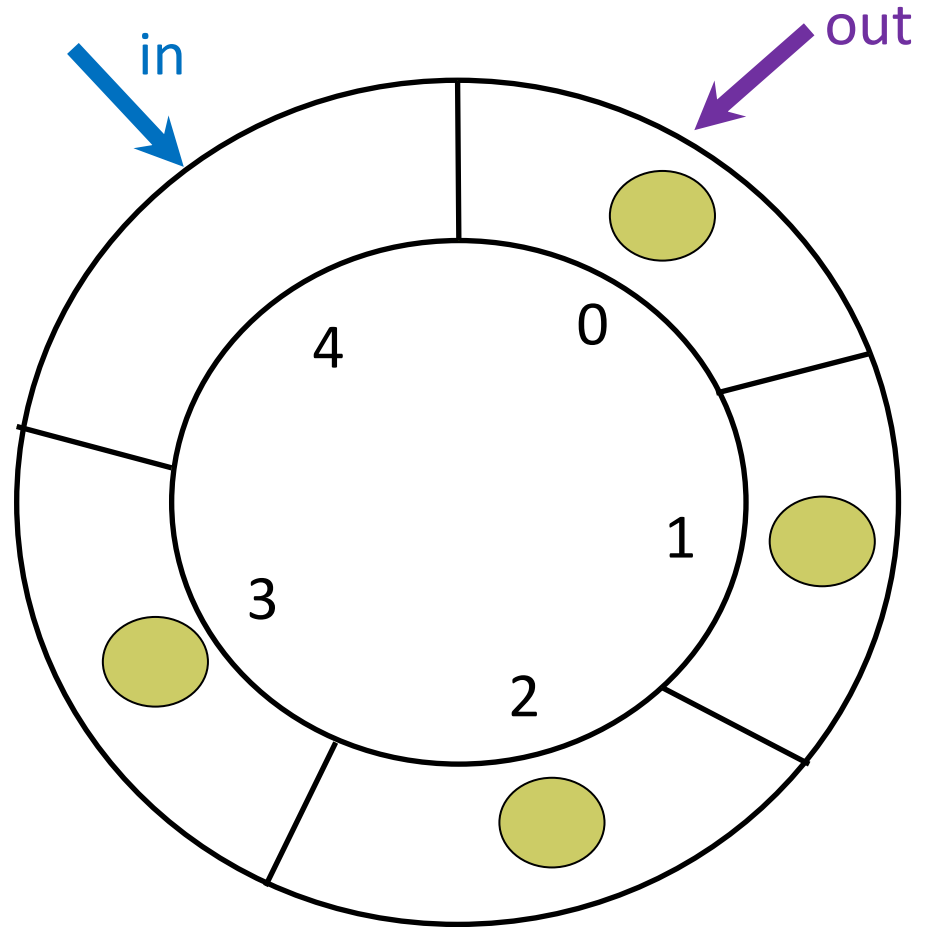
Consumer

Consume an item

```
while (in == out);
```



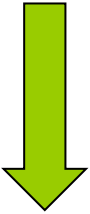
4 != 0



Consumer

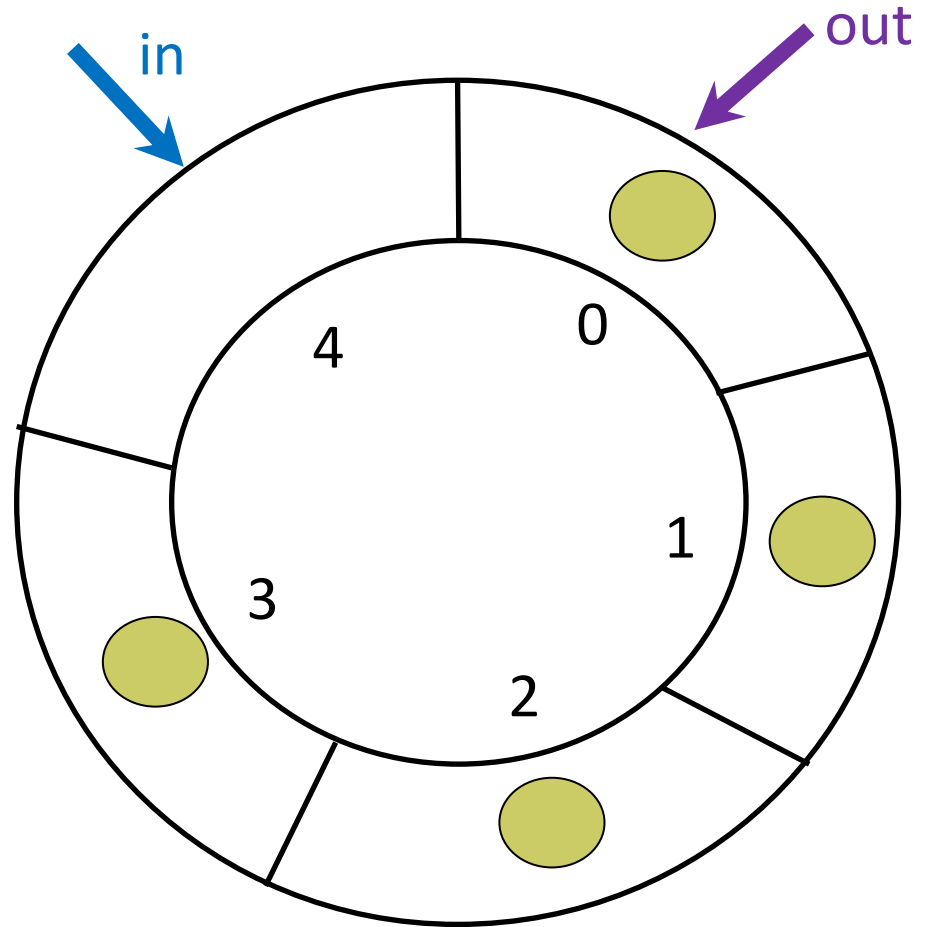
Consume an item

```
while (in == out);
```



4 != 0

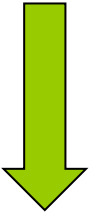
```
item = buffer[0];
```



Consumer

Consume an item

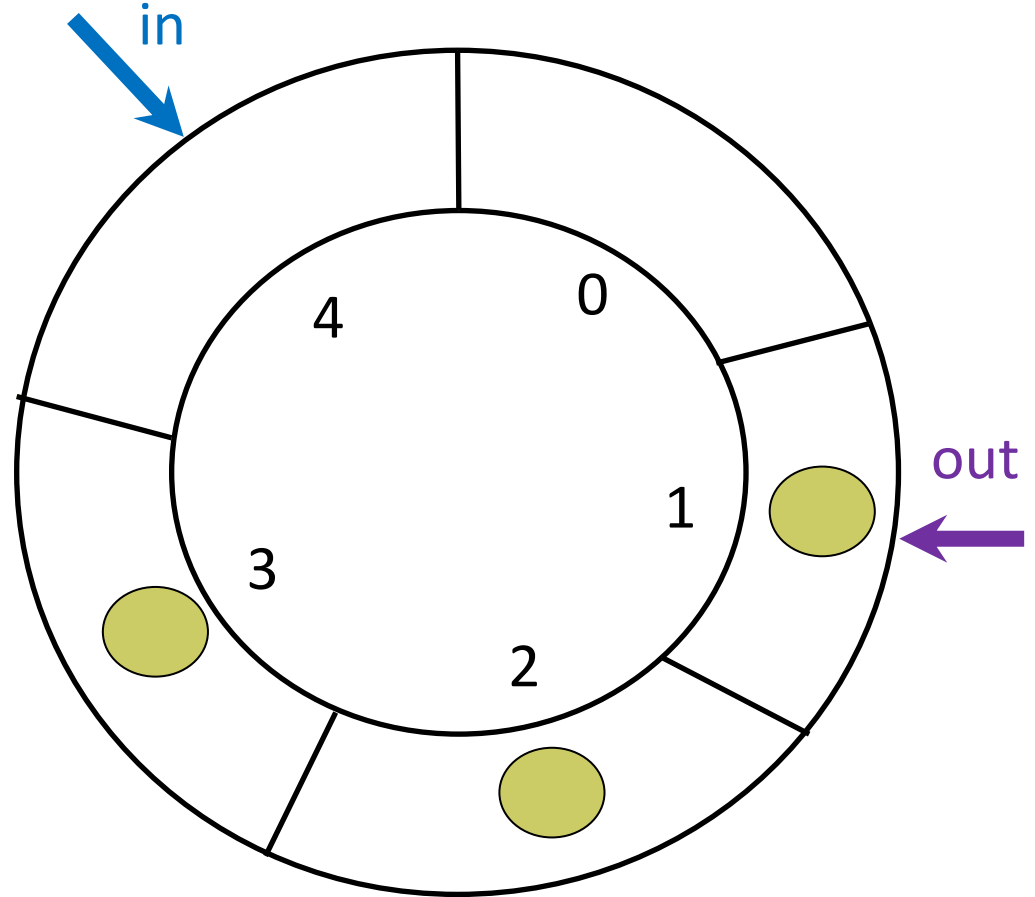
```
while (in == out);
```



4 **!=** 0

```
item = buffer[0];
```

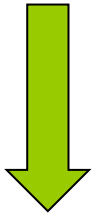
```
out = (0 + 1) % 5;
```



Producer

Produce an item

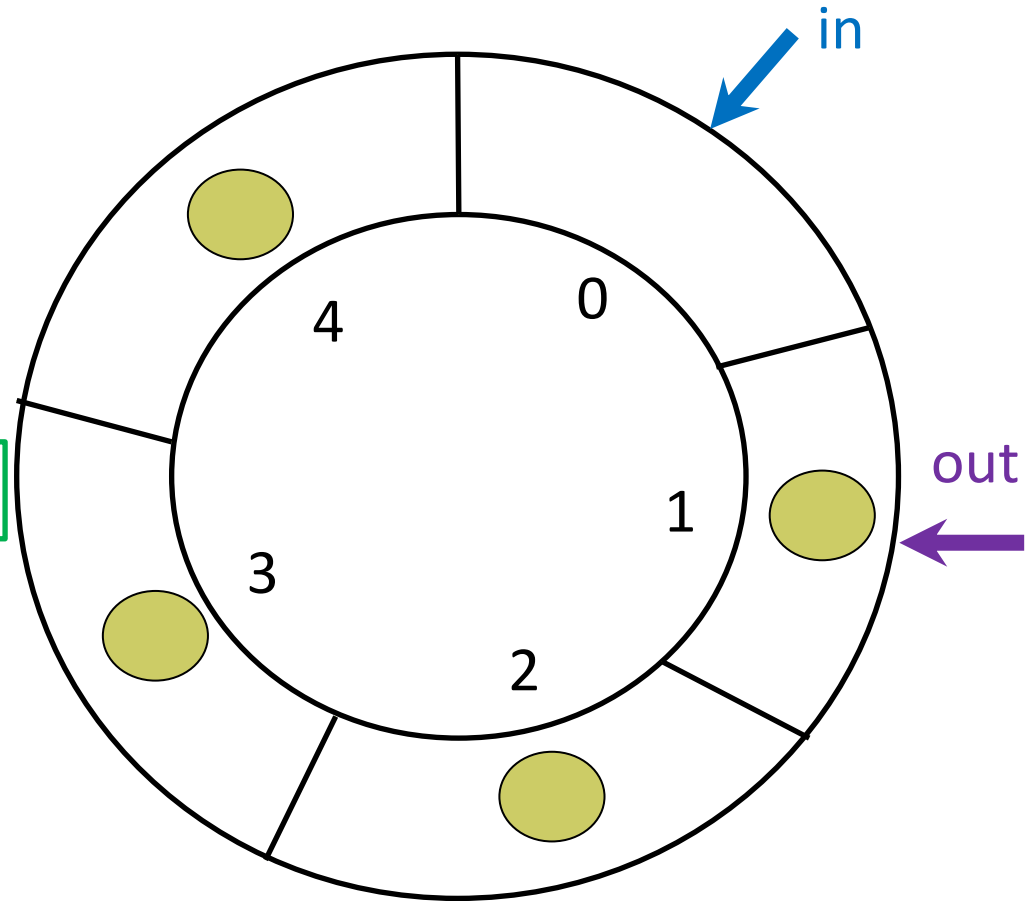
```
while (((in + 1) %  
BUFFER_SIZE) == out;
```



$(4 + 1) \% 5 = 0 \neq 1$

```
buffer[4] = item;
```

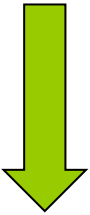
```
in = (4 + 1) % 5;
```



Consumer

Consume an item

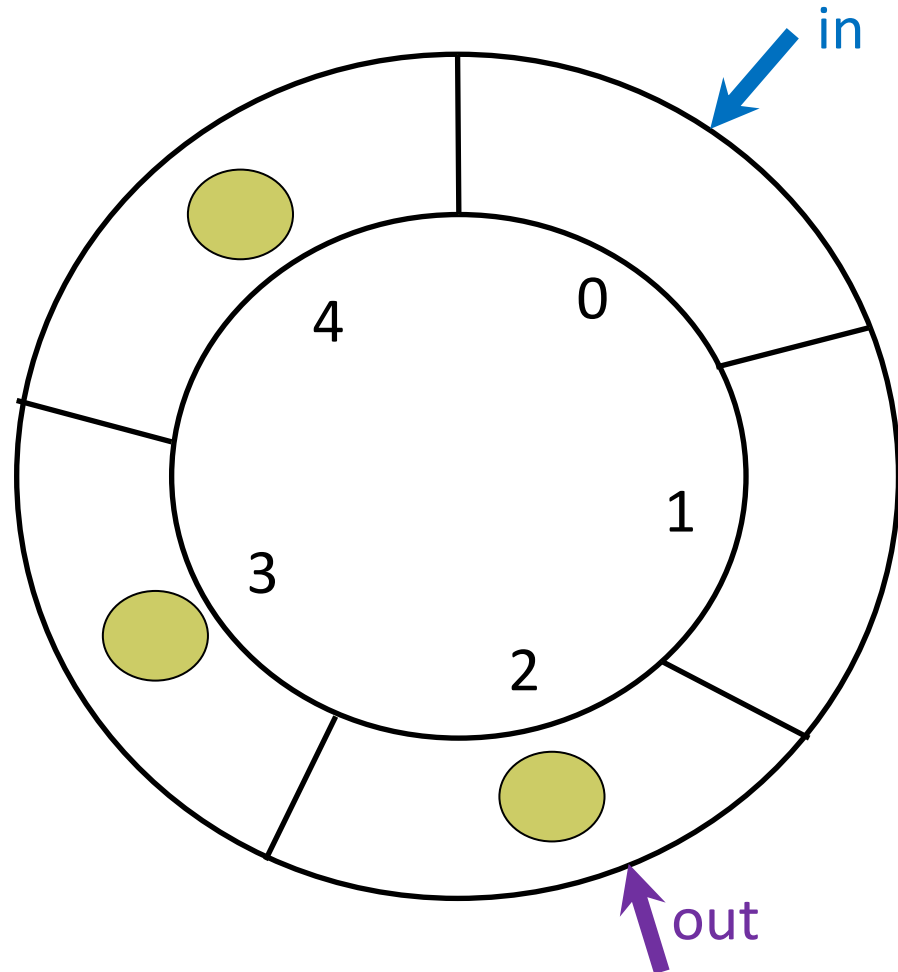
```
while (in == out);
```



1 != 0

```
item = buffer[1];
```

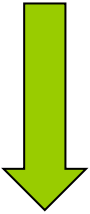
```
out = (1 + 1) % 5;
```



Consumer

Consume an item

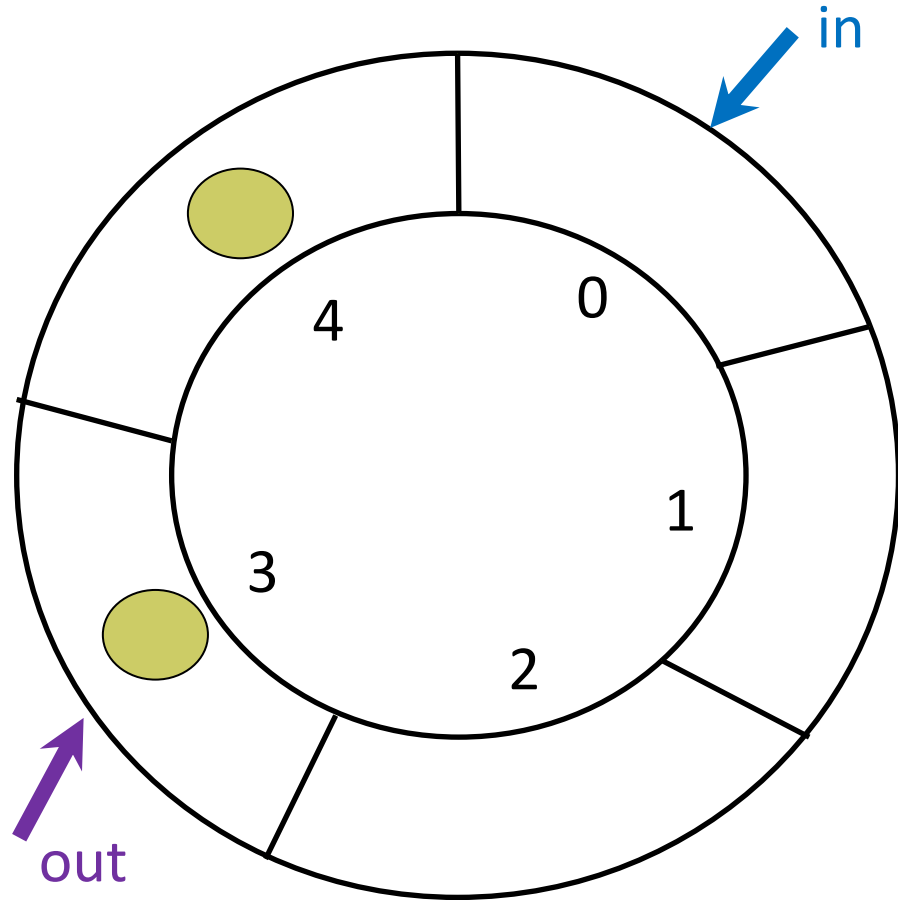
```
while (in == out);
```



2 **!=** 0

```
item = buffer[2];
```

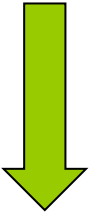
```
out = (2 + 1) % 5;
```



Consumer

Consume an item

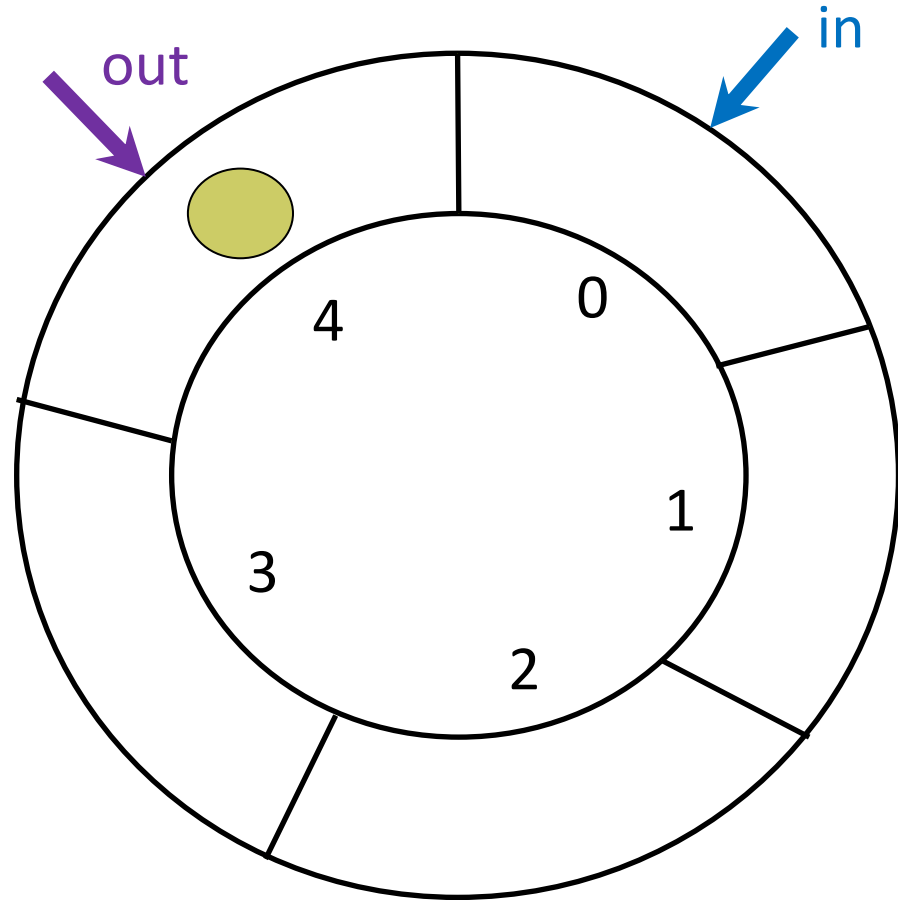
```
while (in == out);
```



3 **!=** 0

```
item = buffer[3];
```

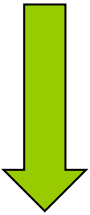
```
out = (3 + 1) % 5;
```



Consumer

Consume an item

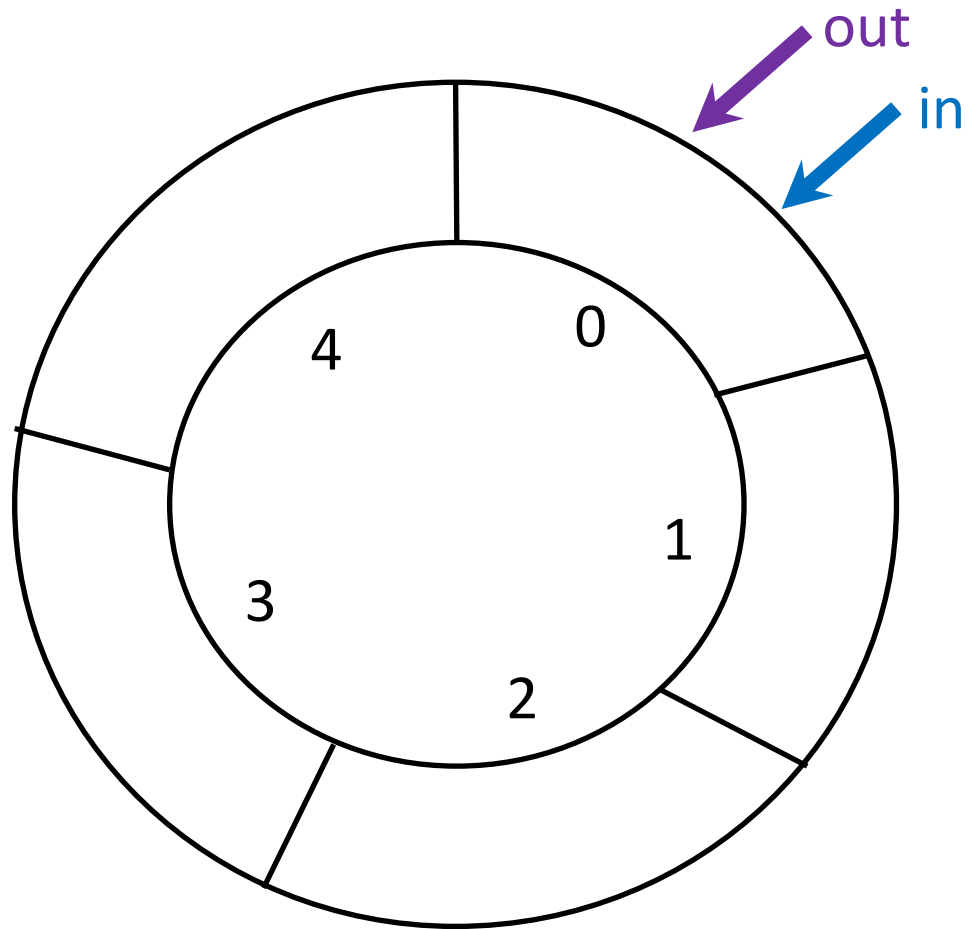
```
while (in == out);
```



3 != 0

```
item = buffer[4];
```

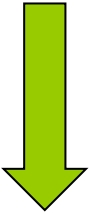
```
out = (4 + 1) % 5;
```



Consumer

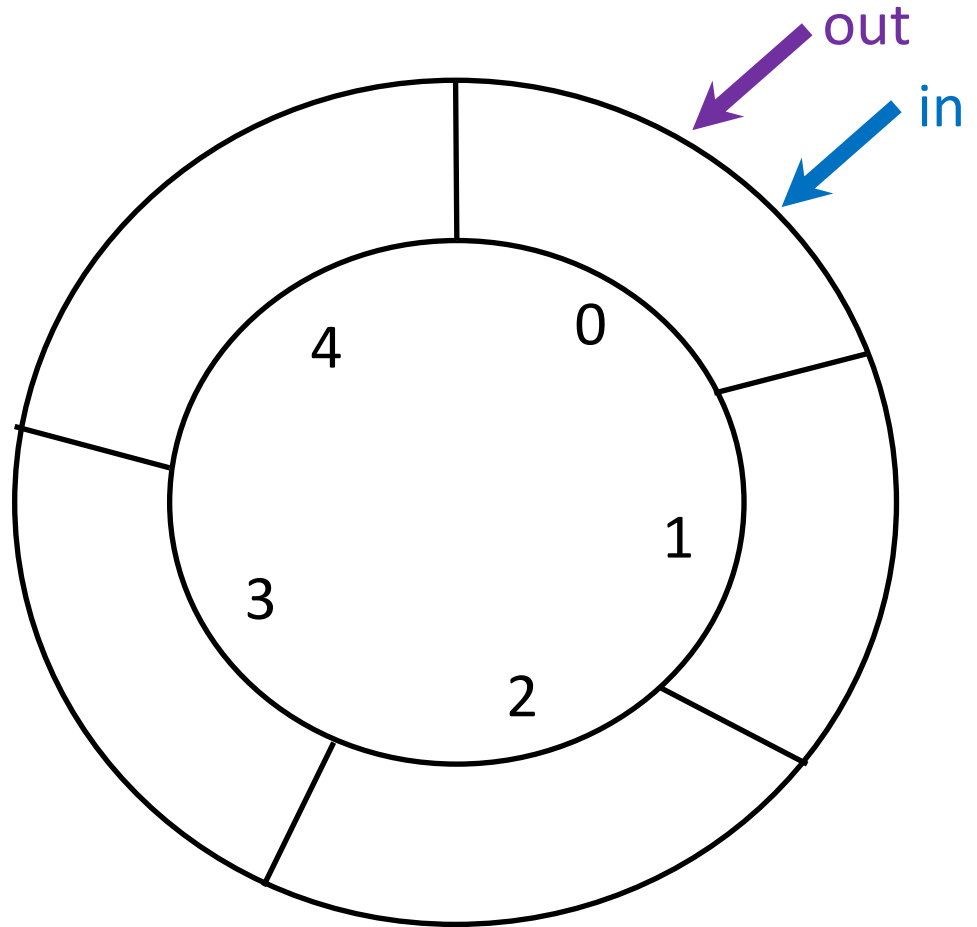
Consume an item

```
while (in == out);
```



0 == 0

Nothing to consume.



Producer Process – Shared Memory

```
item next_produced;

while (true) {
    /* produce an item in next produced */
    while (((in + 1) % BUFFER_SIZE) == out)
        ; /* do nothing */
    buffer[in] = next_produced;
    in = (in + 1) % BUFFER_SIZE;
}
```

Consumer Process – Shared Memory

```
item next_consumed;

while (true) {
    while (in == out)
        ; /* do nothing */
    next_consumed = buffer[out];
    out = (out + 1) % BUFFER_SIZE;

    /* consume the item in next consumed */
}
```

What about Filling all the Buffers?

- Suppose that we wanted to provide a solution to the consumer-producer problem that **fills all the buffers**.
- How can we do it?



What about Filling all the Buffers? (ont.)

- We can do so by having ***an integer counter*** that keeps track of the number of full buffers.
- Initially, counter is set to 0.
- The integer counter is incremented by the producer after it produces a new buffer.
- The integer counter is decremented by the consumer after it consumes a buffer.



Producer

```
while (true) {  
    /* produce an item in next produced */  
  
    while (counter == BUFFER_SIZE)  
        ; /* do nothing */  
    buffer[in] = next_produced;  
    in = (in + 1) % BUFFER_SIZE;  
    counter++;  
}
```



Consumer

```
while (true) {  
    while (counter == 0)  
        ; /* do nothing */  
    next_consumed = buffer[out];  
    out = (out + 1) % BUFFER_SIZE;  
    counter--;  
    /* consume the item in next  
consumed */  
}
```



Race Condition

- `counter++` could be implemented as

```
register1 = counter
```

```
register1 = register1 + 1
```

```
counter = register1
```

- `counter--` could be implemented as

```
register2 = counter
```

```
register2 = register2 - 1
```

```
counter = register2
```



Race Condition (cont.)

- Consider this execution interleaving with “count = 5”

initially:

S0: producer execute	register1 = counter	{register1 = 5}
S1: producer execute	register1 = register1 + 1	{register1 = 6}
S2: consumer execute	register2 = counter	{register2 = 5}
S3: consumer execute	register2 = register2 - 1	{register2 = 4}
S4: producer execute	counter = register1	{counter = 6 }
S5: consumer execute	counter = register2	{counter = 4}



Race Condition (cont.)

Question – why was there no race condition in the first solution
(where at most $N - 1$) buffers can be filled?

More in Chapter 6.

