Design and Analysis of Operating Systems
CSCI 3753

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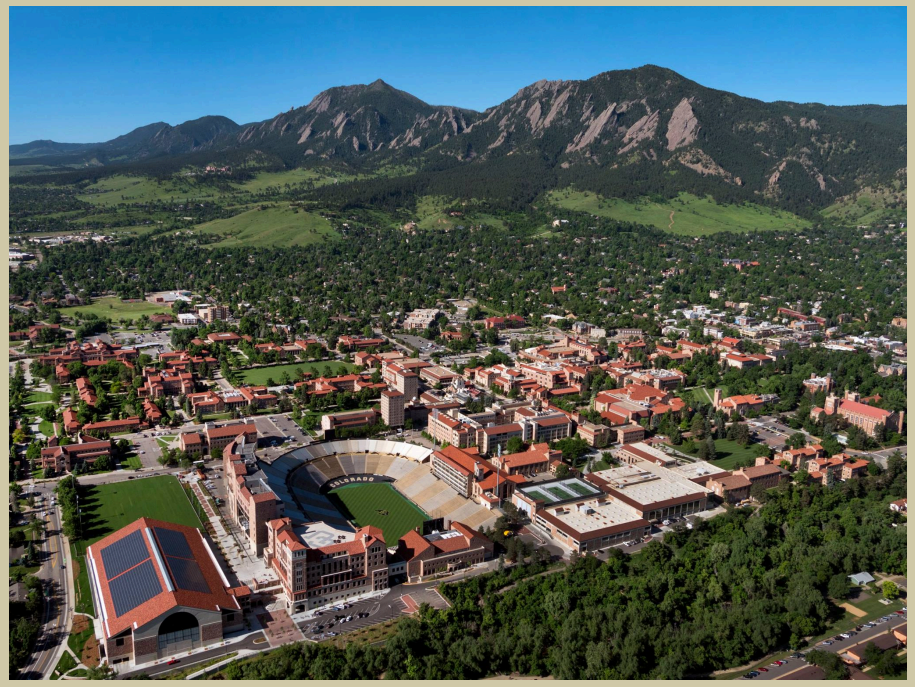
Bounded Buffer Problem



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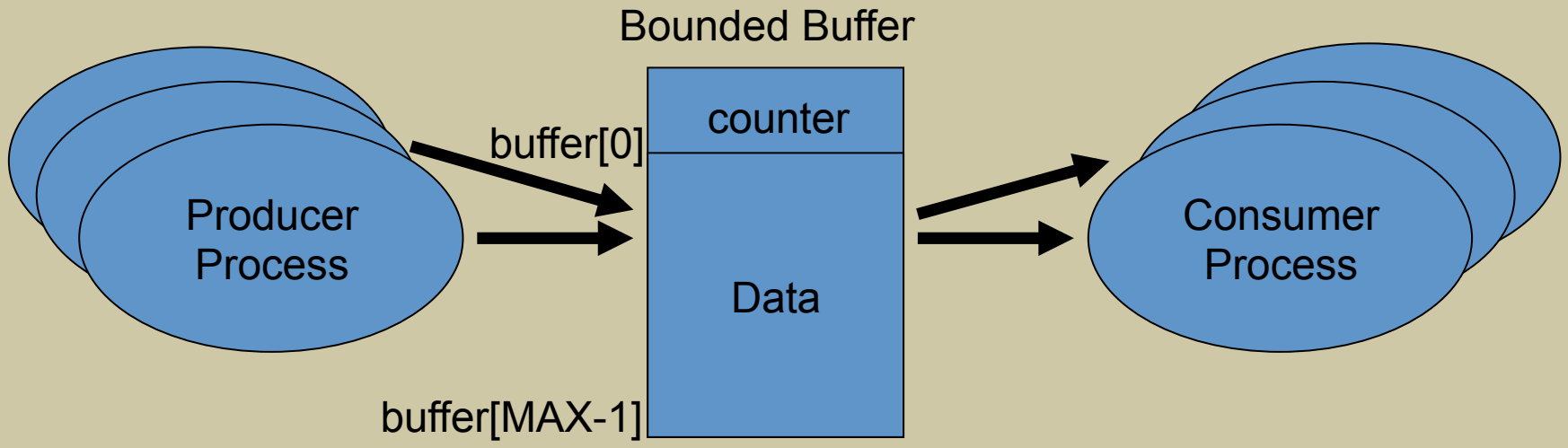
Producer-Consumer Problem

also known as

Bounded Buffer Problem

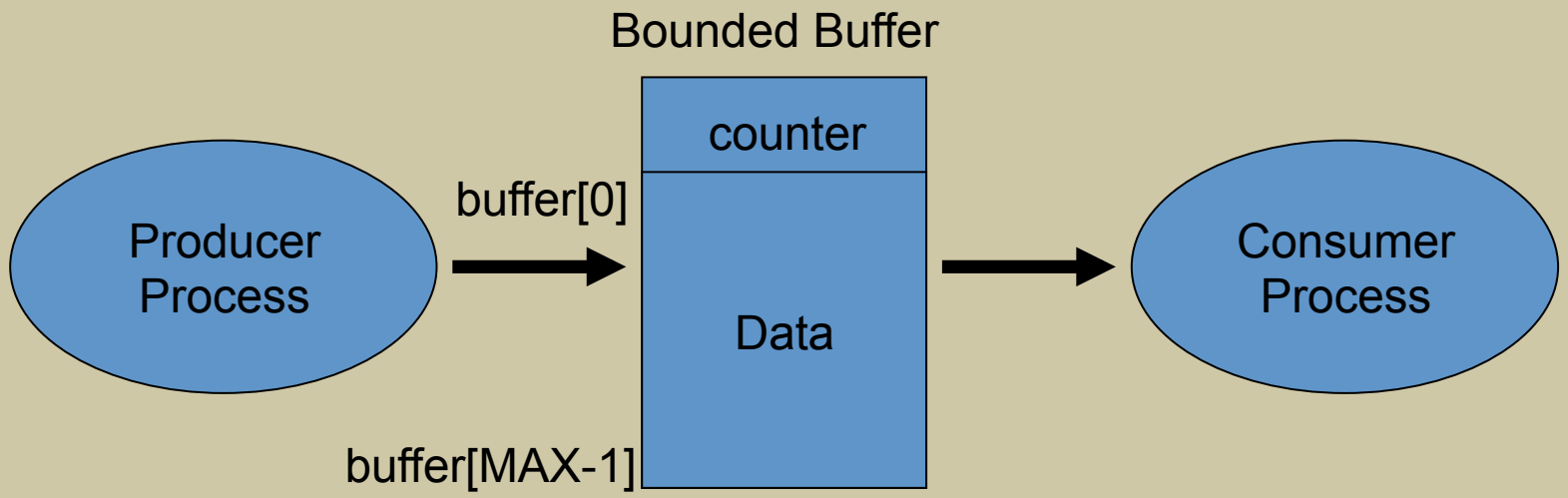
- We have already seen this problem with one producer and one consumer
- General problem: multiple producers and multiple consumers
- **Producers** puts new information in the buffer
- **Consumers** takes out information from the buffer

Bounded-Buffer Problem



- Producer places data into a buffer at the next available position
- Consumer takes information from the earliest item

Prior Bounded-Buffer Approach




```
while(1) {
  produce (nextdata)
  while(count==MAX);
  Acquire(lock);
  buffer[count] = nextdata;
  count++;
  Release(lock);
}
```

```
while(1) {
  while(count==0);
  Acquire(lock);
  data = buffer[count-1];
  count--;
  Release(lock);
  consume(data);
}
```

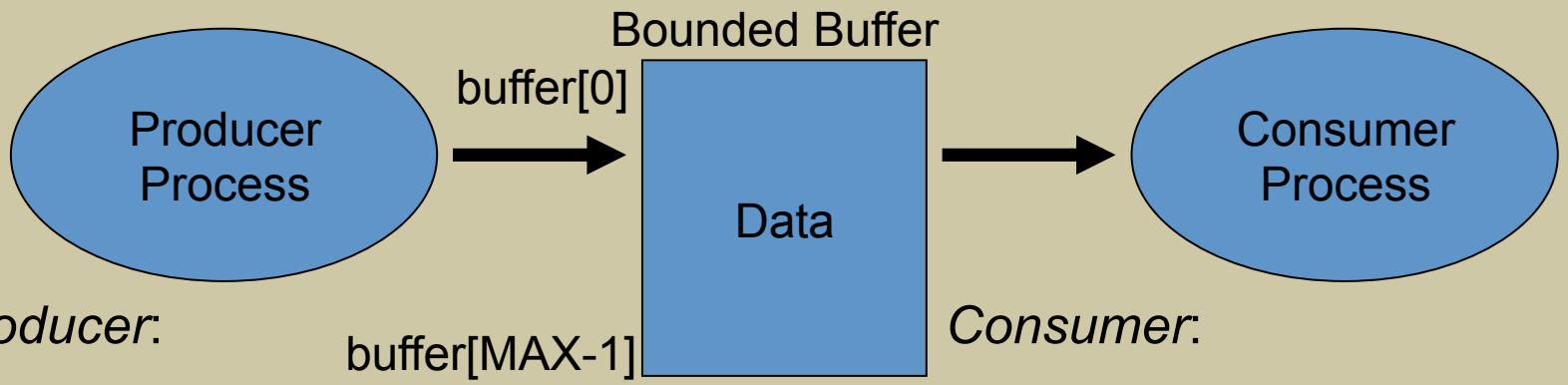
while(TS(&lock)) ;

Busy-wait!

Bounded-Buffer Goals

- In a prior approach, both the producer and consumer are ***busy-waiting*** using locks
- Instead, want both to sleep as necessary
  - Goal #1: Producer should block when buffer is full
  - Goal #2: Consumer should block when the buffer is empty
  - Goal #3: Mutual exclusion when buffer is partially full
    - Producer and consumer should access the buffer in a synchronized mutually exclusive way

Bounded Buffer Solution



Producer:

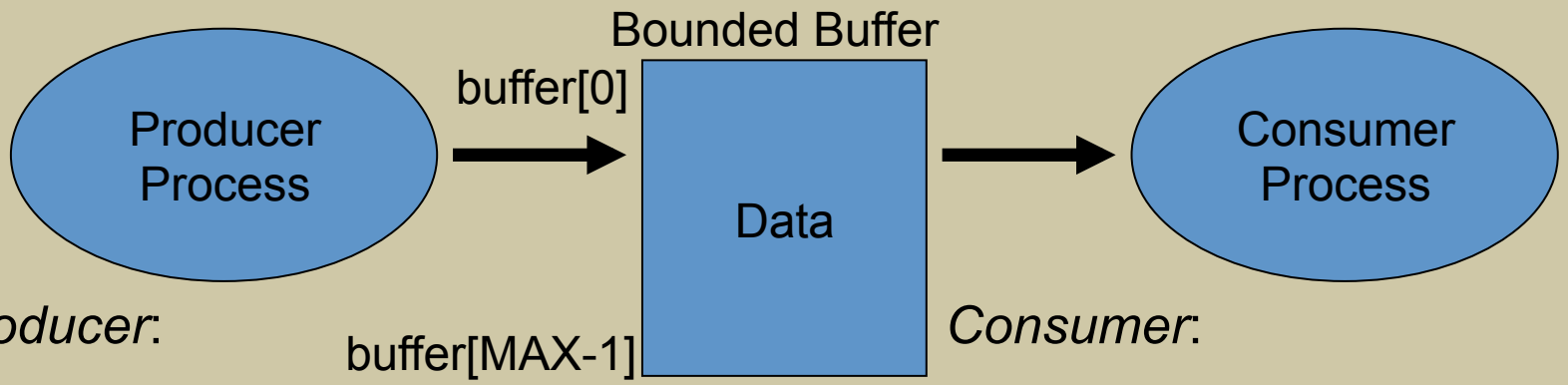
```
while(1) {
    …
    P(mutex)  // Goal 3: mutual
                 exclusion
       add item to buffer
    V(mutex)
    …
}
```

Consumer:

```
while(1) {
    ...
    P(mutex)  // Goal 3: mutual
                 exclusion
       remove item from buffer
    V(mutex)
    ...
}
```

Assume $mutex_{init} = 1$

Bounded Buffer Solution (2)



Producer:

Consumer:

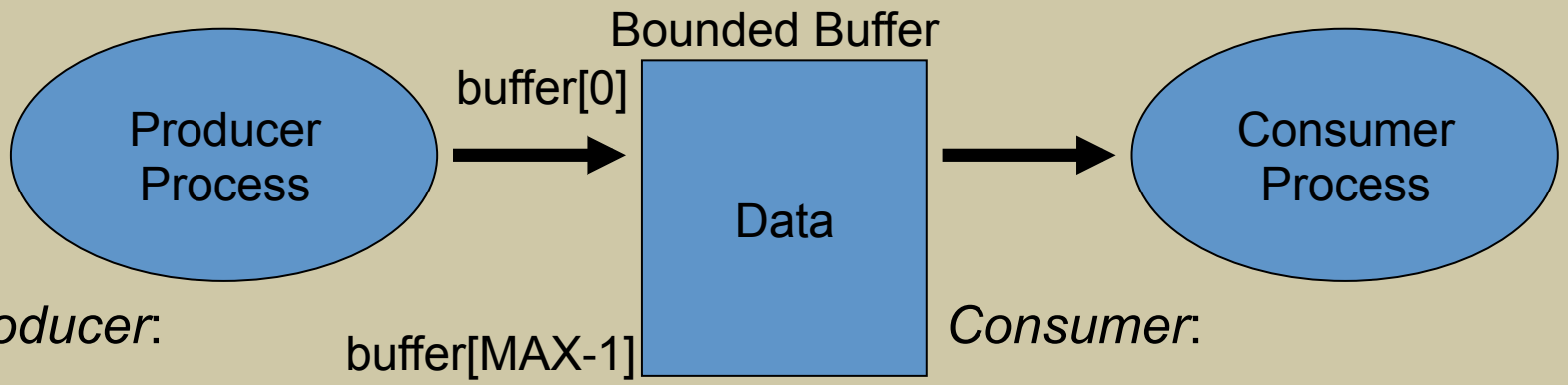
Goal #1: Producer should block when buffer is full

```
while(1) {
  P(empty) // Goal 1: full buffer
              blocks producer
    P(mutex)
       add item to buffer
    V(mutex)
    …
}
```

```
while(1) {
    ...
    P(mutex)
       remove item from buffer
    V(mutex)
  V(empty) // Goal 1: full buff
              blocks producer
}
```

Assume $mutex_{init}$=1, $empty_{init}$=MAX

Bounded Buffer Solution (3)



Producer:

Consumer:

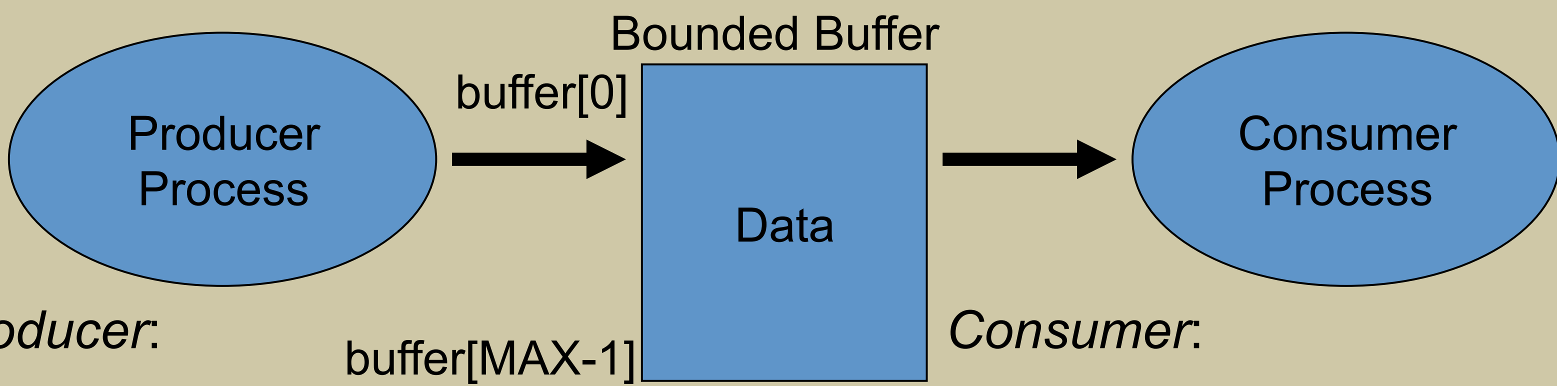
Goal #2: Consumer should block when the buffer is empty

```
while(1) {
  P(empty)
    P(mutex)
       add item to buffer
    V(mutex)
  V(full) // Goal 2: empty buffer
             blocks consumer
}
```

```
while(1) {
  P(full) // Goal 2: empty
            buff blocks consumer
    P(mutex)
       remove item from buffer
    V(mutex)
  V(empty)
}
```

Assume $mutex_{init}$=1, $empty_{init}$=MAX, $full_{init}$=0

Bounded Buffer Solution (4)



Producer:

```
while(1) {
  P(empty)
    P(mutex)
      add ite
    V(mutex)
  V(full)
}
```

Consumer:

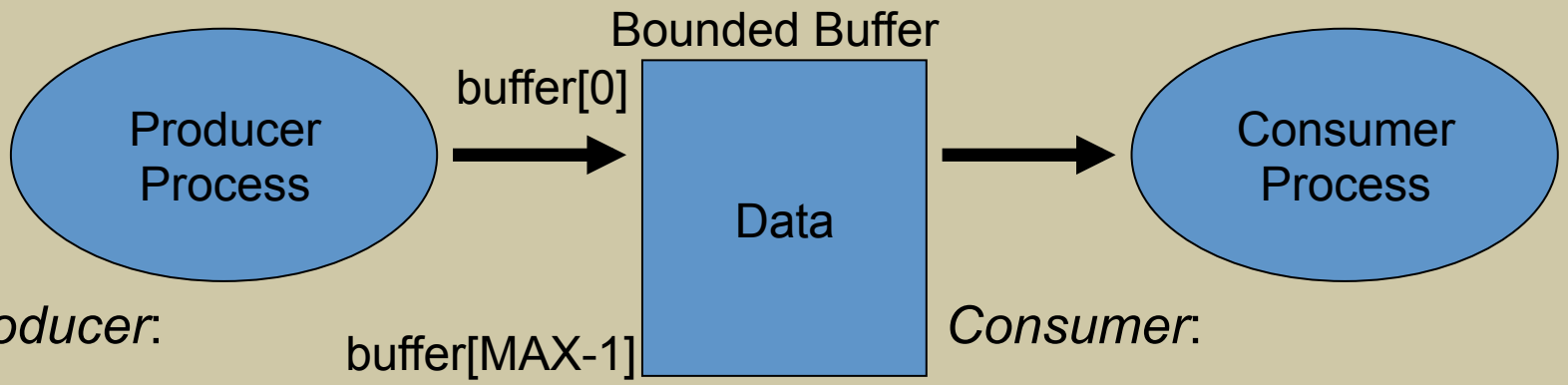
```
while(1) {
    
    :ex)
      emove item from buffer
    :ex)
  )
}
```

Achieves:

1) mutual exclusion
2) blocked producer if buffer full
3) blocked consumer if buffer empty
4) no deadlock
5) is efficient (no busy wait)

Assume $mutex_{init}$=1, $empty_{init}$=MAX, $full_{init}$=0

Bounded Buffer Solution (5)



Producer:

```
while(1) {
  P(space_avail)
    P(mutex)
       add item to buffer
    V(mutex)
  V(items_avail)
}
```

Consumer:

```
while(1) {
  P(items_avail)
    P(mutex)
       remove item from buffer
    V(mutex)
  V(space_avail)
}
```

Assume $mutex_{init}$=1,
$space\_avail_{init}$=MAX,
$items\_avail_{init}$=0

Bounded-Buffer Design

- **Goal #1: Producer should block when buffer is full**
  - Use a counting semaphore called *space_avail* that is initialized to $space\_avail_{init}$ = MAX
  - Each time the producer adds an object to the buffer, this decrements the # of empty slots, until it hits 0 and the producer blocks
- **Goal #2: Consumer should block when the buffer is empty**
  - Define a counting semaphore *items_avail* that is initialized to $items\_avail_{init}$ = 0
  - *items_avail* tracks the # of full slots and is incremented by the producer
  - Each time the consumer removes a full slot, this decrements *items_avail*, until it hits 0, then the consumer blocks
- **Goal #3: Mutual exclusion when buffer is partially full**
  - Use a mutex semaphore to protect access to buffer manipulation, $mutex_{init}$ = 1

Bounded Buffer Solution (6)

Will this solution work for multiple Producers and multiple Consumers?

Producer:

```
while(1) {
  P(space_avail)
    P(mutex)
       add item to buffer
    V(mutex)
  V(items_avail)
}
```

r:

```
while(1) {
  P(items_avail)
    P(mutex)
       remove item from buffer
    V(mutex)
  V(space_avail)
}
```

Assume $mutex_{init}$=1,
$space\_avail_{init}$=MAX,
$items\_avail_{init}$=0

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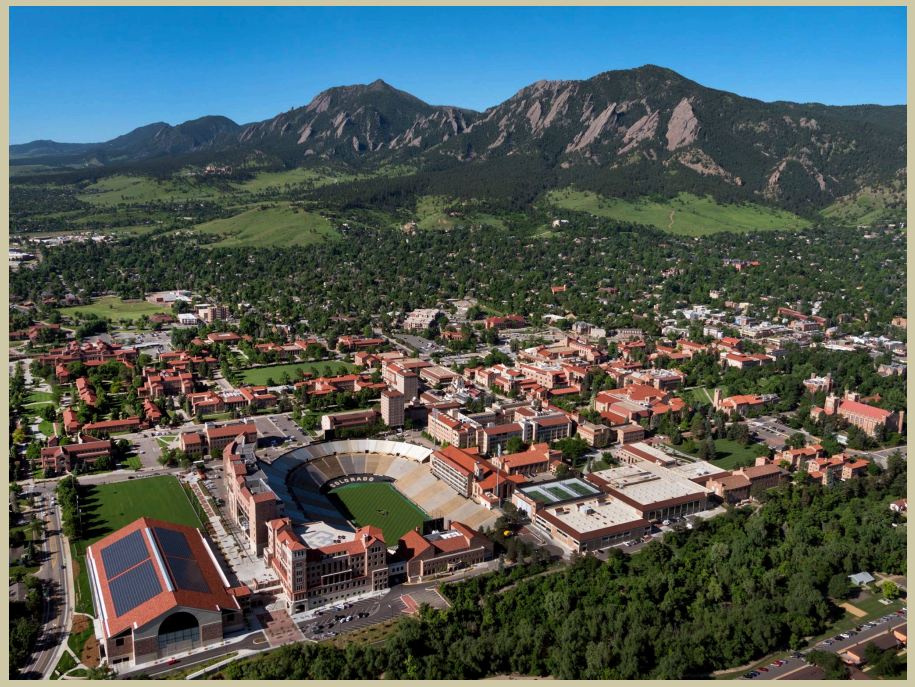

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