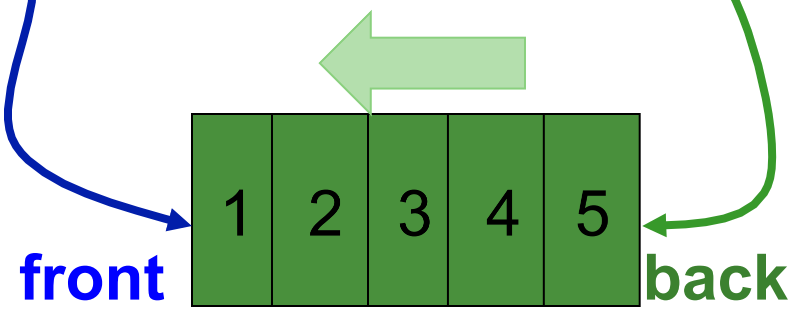
CS200: Queues

- Prichard Ch. 8

Queues

- First In First Out (FIFO) structure
- Imagine a checkout line
- So removing and adding are done from opposite ends of structure.



  - add to back, remove from front
- Used in operating systems (e.g. print queue).

Possible Queue Operations

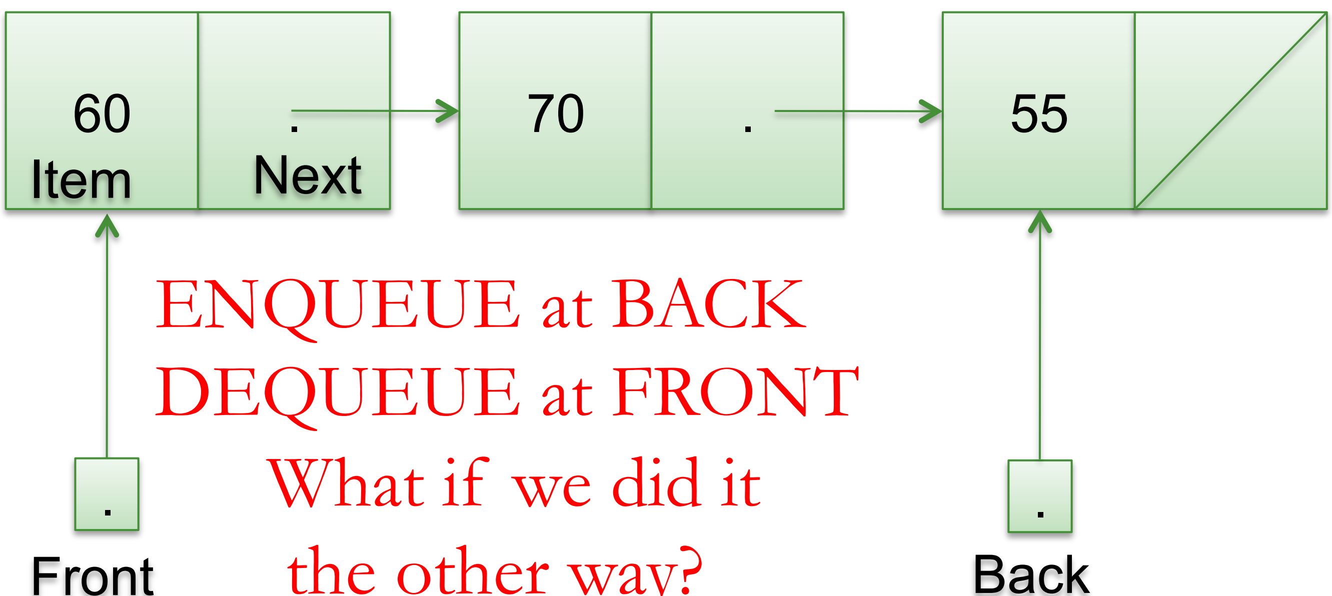
- **enqueue**`(in newItem: QueueItemType)`
  - Add new item at the ***back*** of a queue
- **dequeue**`(): QueueItemType`
  - Retrieve and remove the item at the ***front*** of a queue
- **peek**`(): QueueItemType`
  - Retrieve item from the ***front*** (added earliest) of the queue, but leave it in the queue.
- **isEmpty**`():boolean`
- **createQueue**`()`

Reference-Based Implementation 1

A linked list with two external references

- A reference to the front
- A reference to the back

At which end do we enqueue / dequeue?



ENQUEUE at BACK

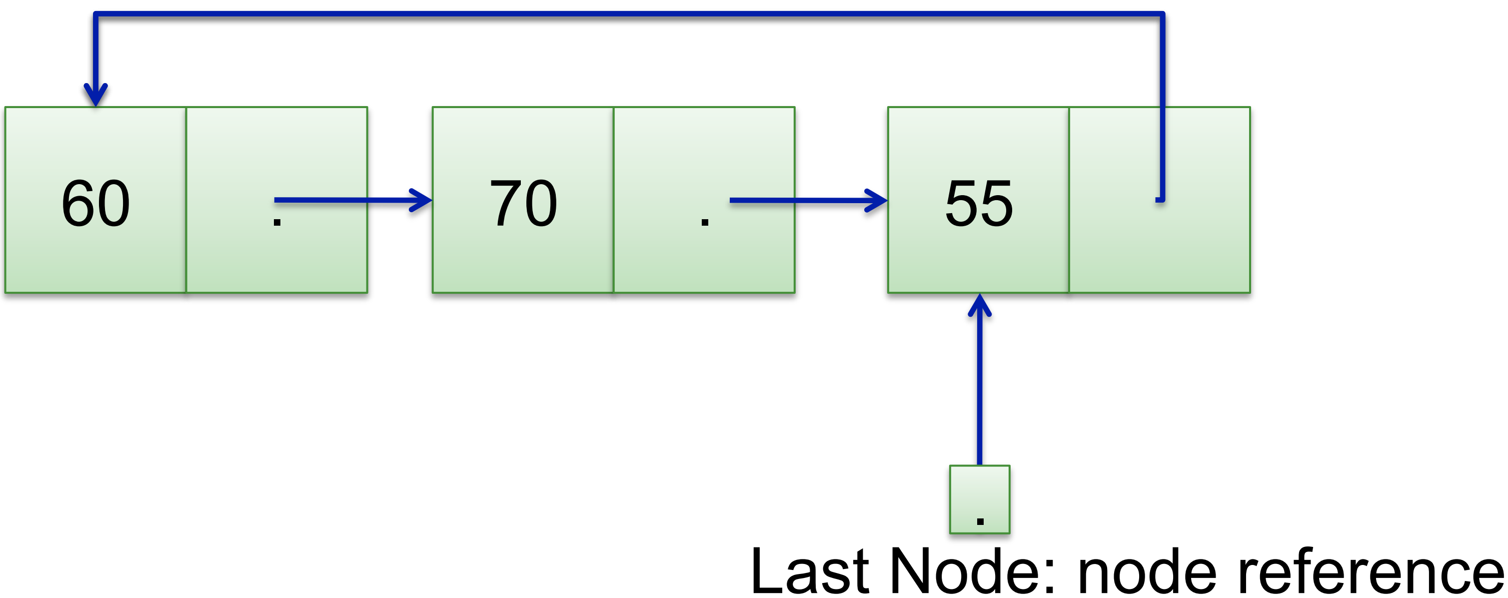
DEQUEUE at FRONT

What if we did it the other way?

Reference-Based Implementation 2

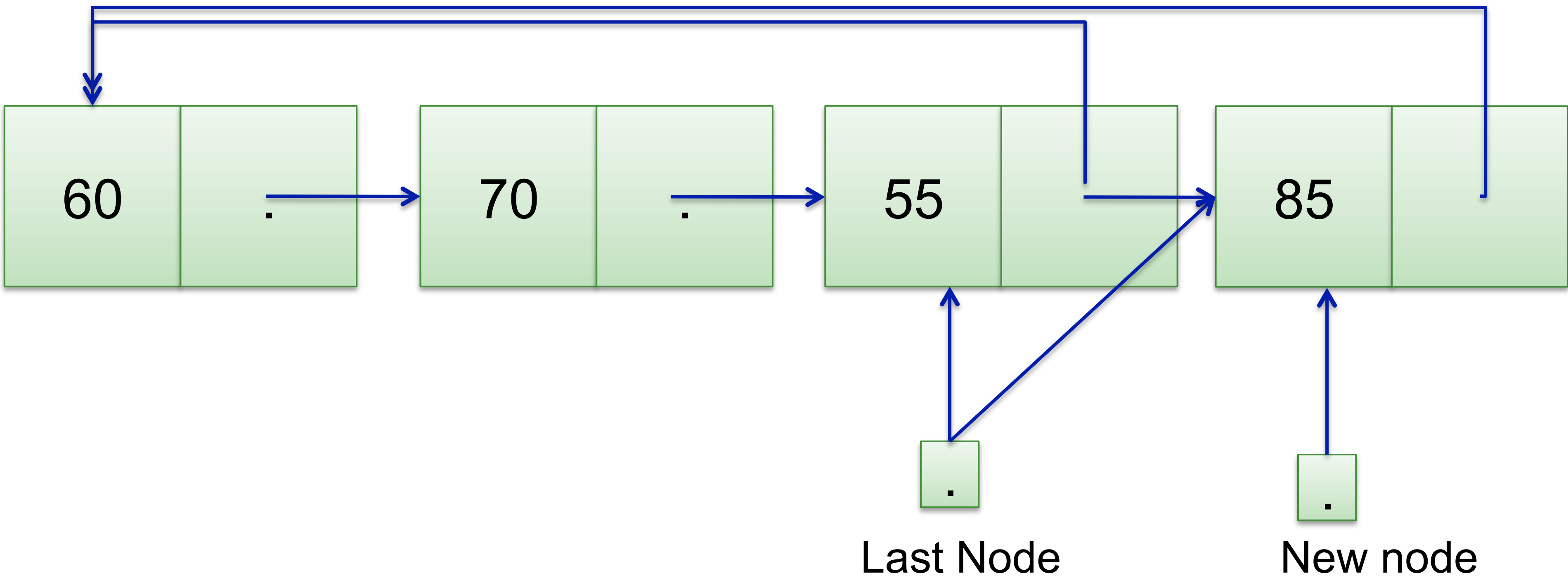
A circular linked list with one external reference

- lastNode references the back of the queue
- lastNode.getNext() references the front



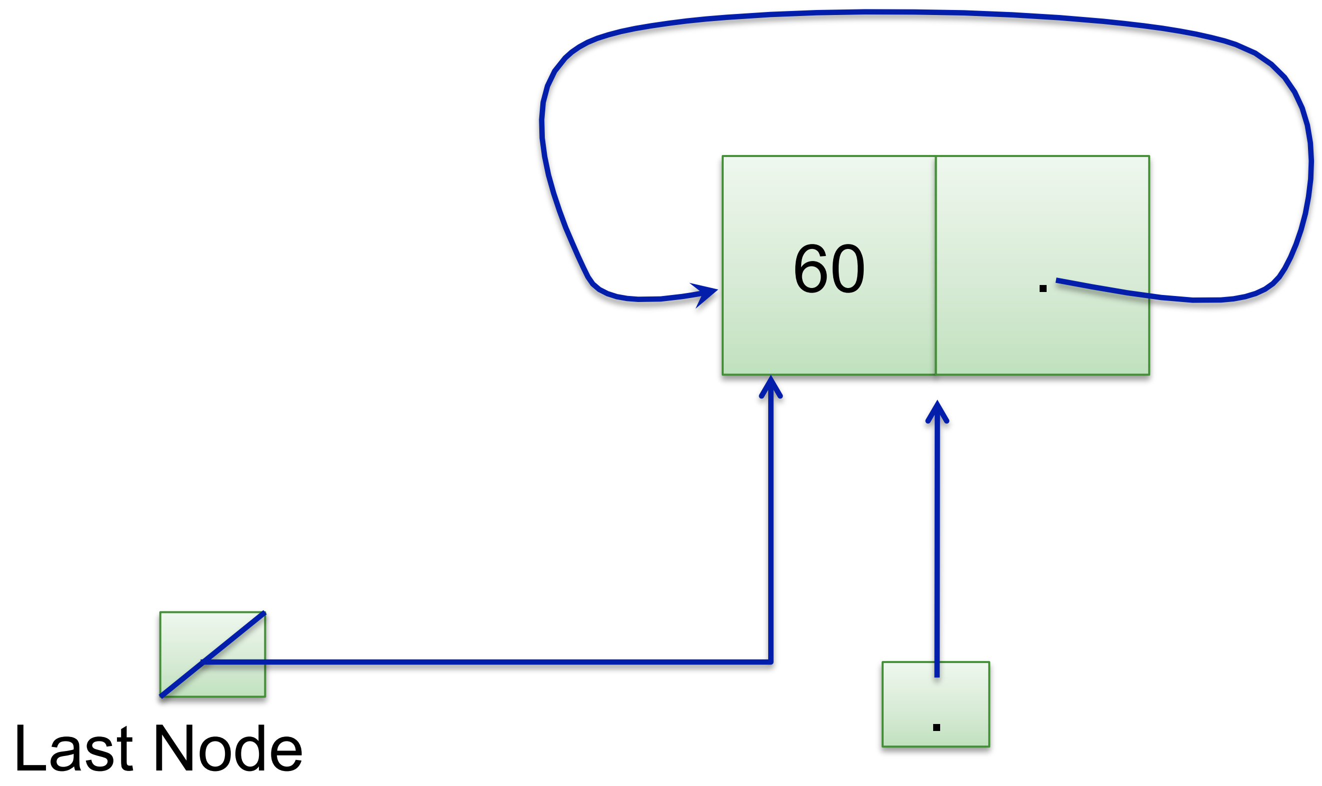
Inserting an item into a nonempty queue

1. newNode.next = lastNode.next;
2. lastNode.next = newNode;
3. lastNode = newNode;



Inserting a New Item

- Insert a ***new item*** into the **empty queue**



Insert new item into the queue

```
public void enqueue (Object newItem){
    Node newNode = new Node(newItem);

    if (isEmpty()){
      newNode.next = newNode;
    } else {

      newNode.next = lastNode.next;
      lastNode.next = newNode;
    }

    lastNode = newNode;
}
```

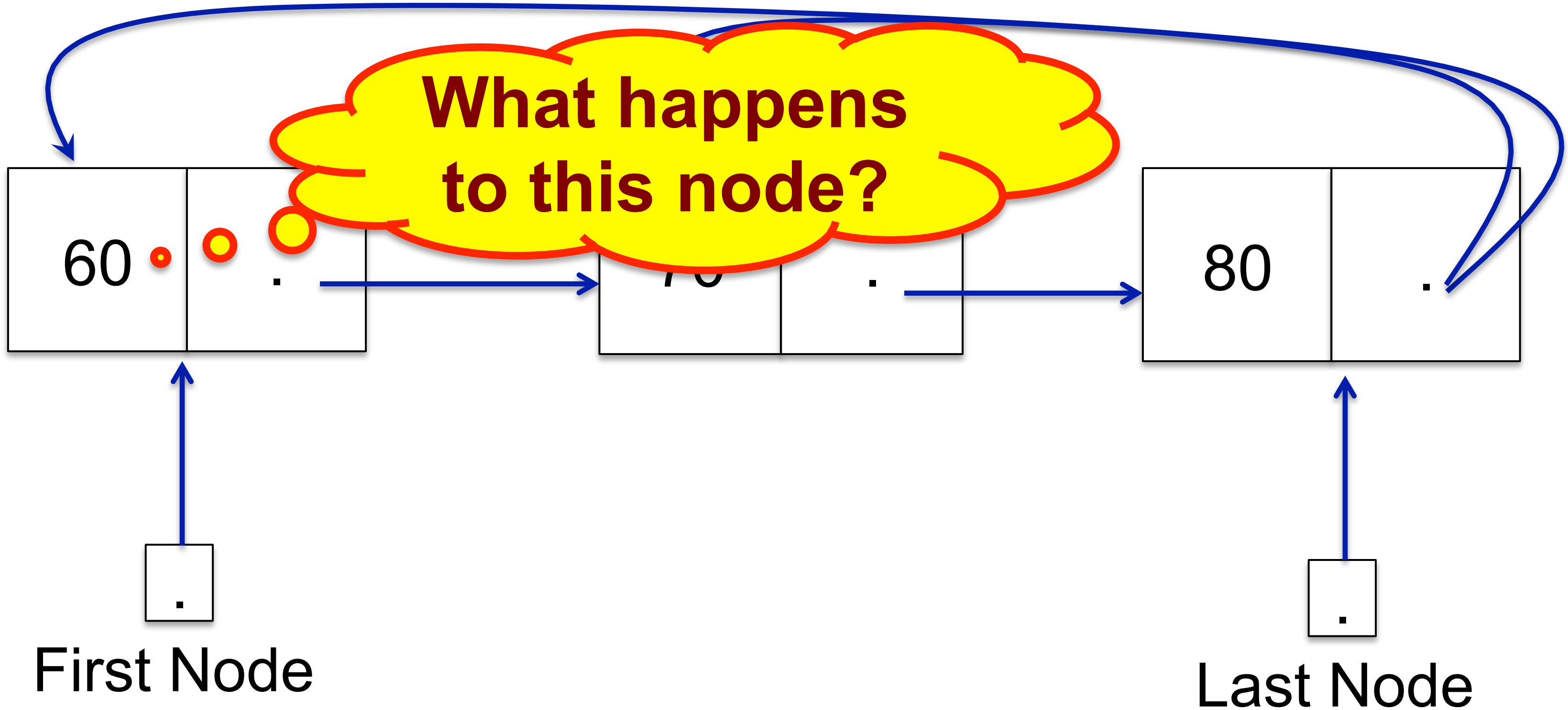
A. Empty queue

B. items in queue

Removing an item from queue

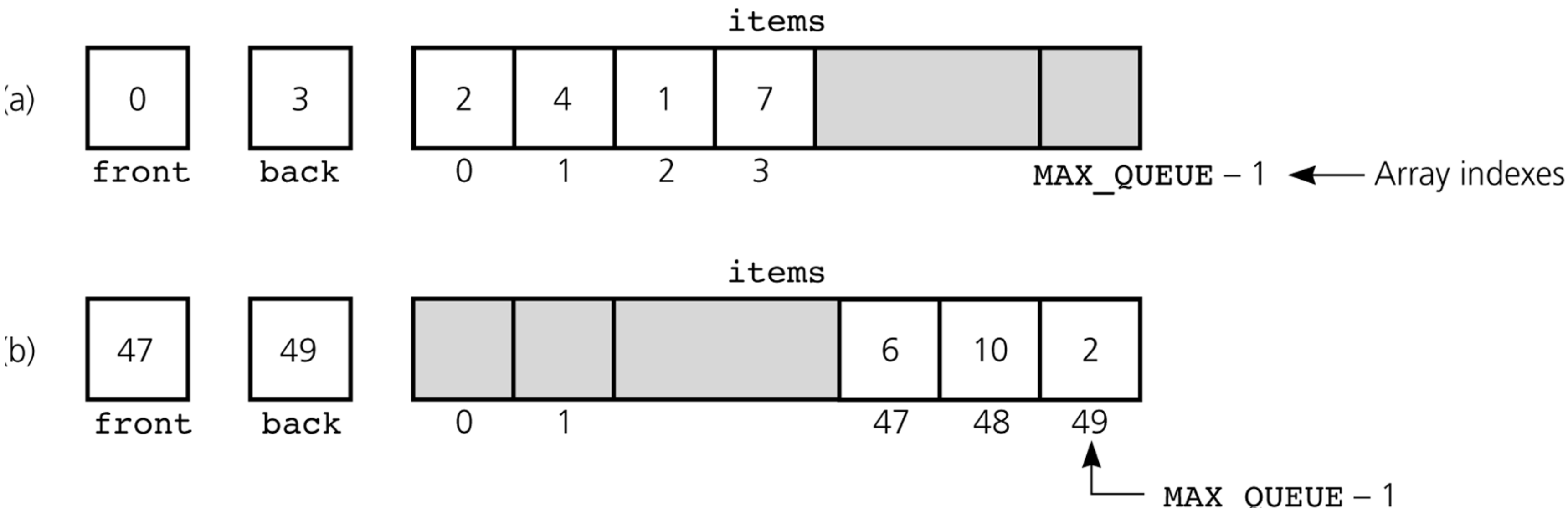
```
public Object dequeue() throws QueueException{
    if (!isEmpty()){
        Node firstNode = lastNode.next;
        if (firstNode == lastNode) {
            lastNode = null;
        }
        else{
            lastNode.next = firstNode.next;
        }
        return firstNode.item;
    }
    else { exception handling..
    }
}
```

Removing an Item




```
Node firstNode = lastNode.next;
if (firstNode == lastnode) {
              lastNode = null;}
   else{lastNode.next = firstNode.next;}
return firstNode.item;
```

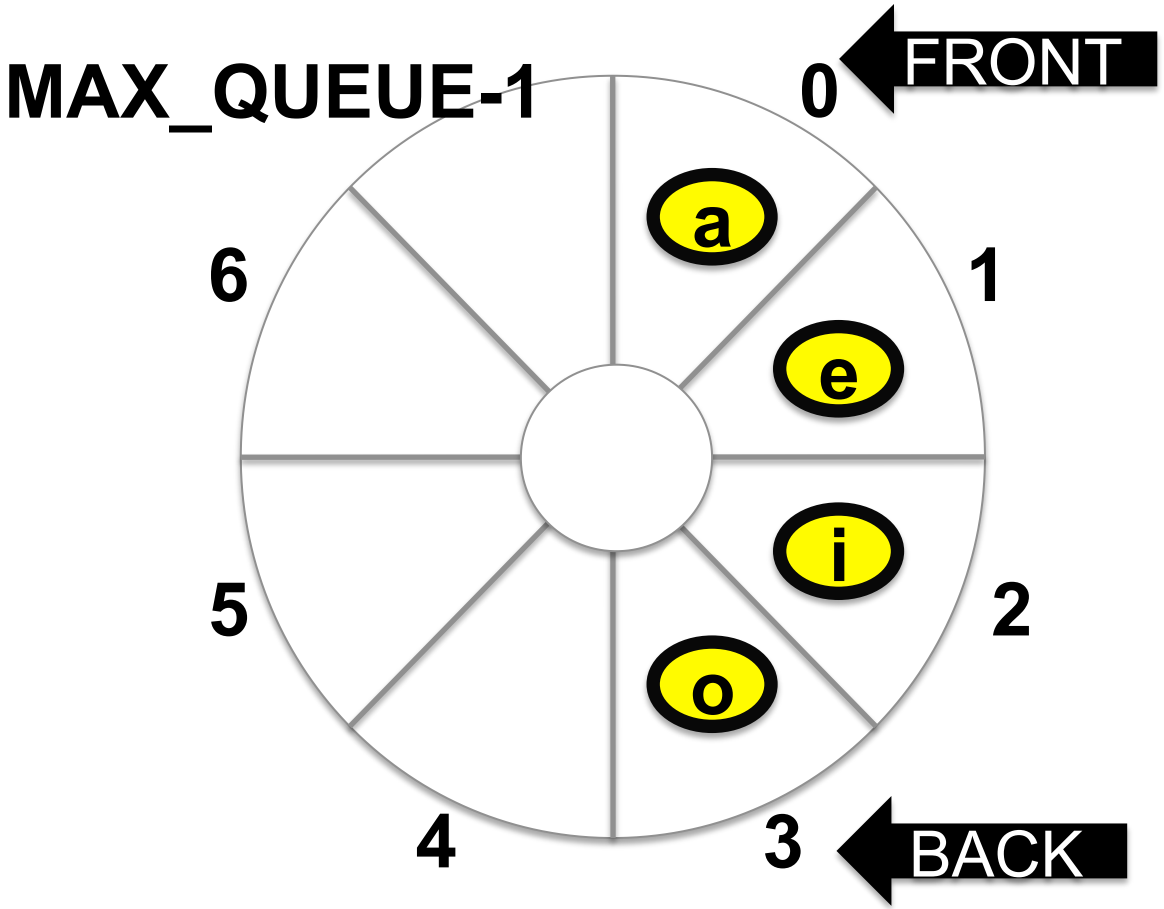
Naïve Array-Based Implementation



Drift wastes space

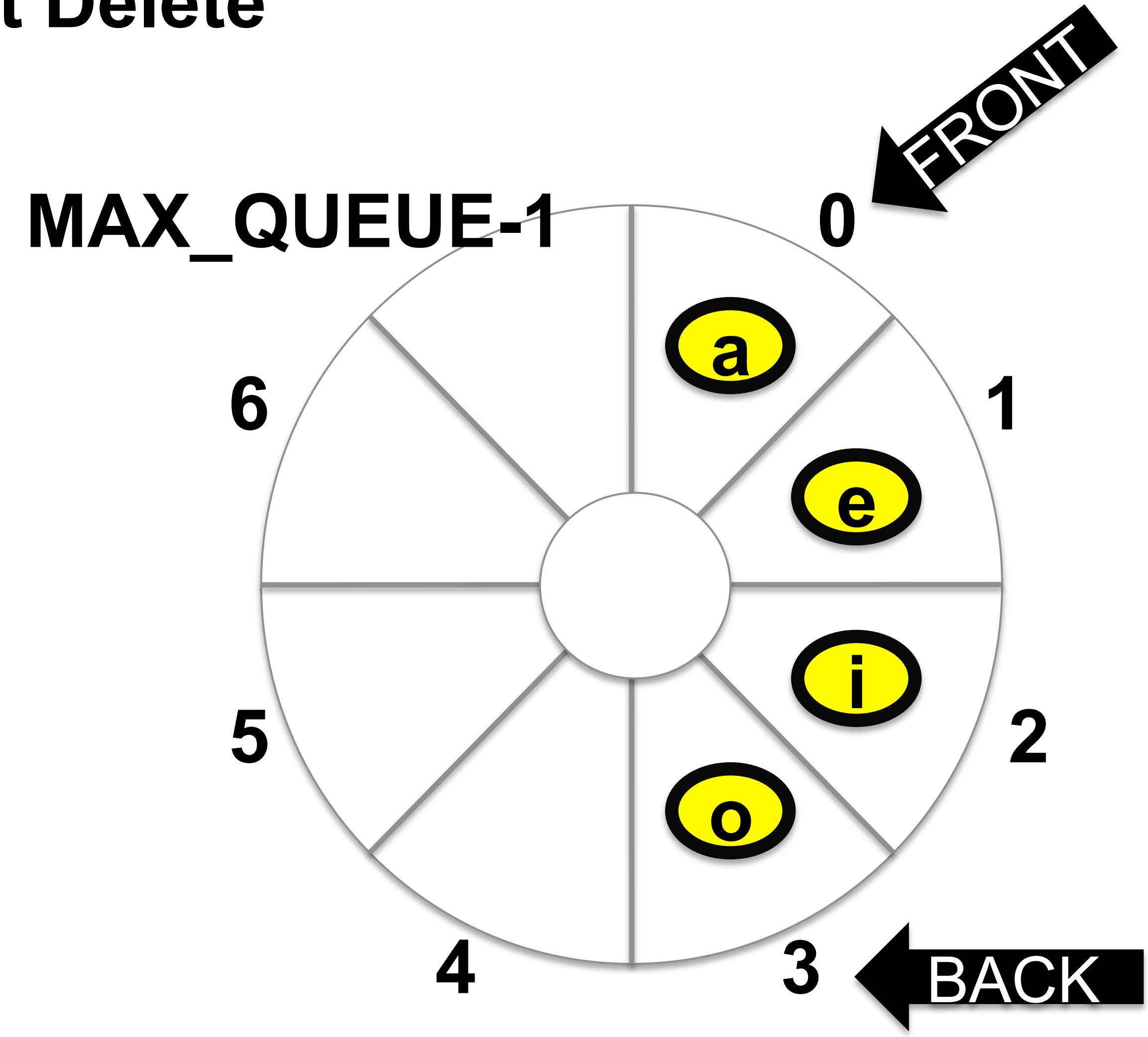
How do we initialize front and back?
(Hint: what does a queue with a single element look like?
what does an empty queue look like?
)

Solving Drift:
Circular implementation of a queue



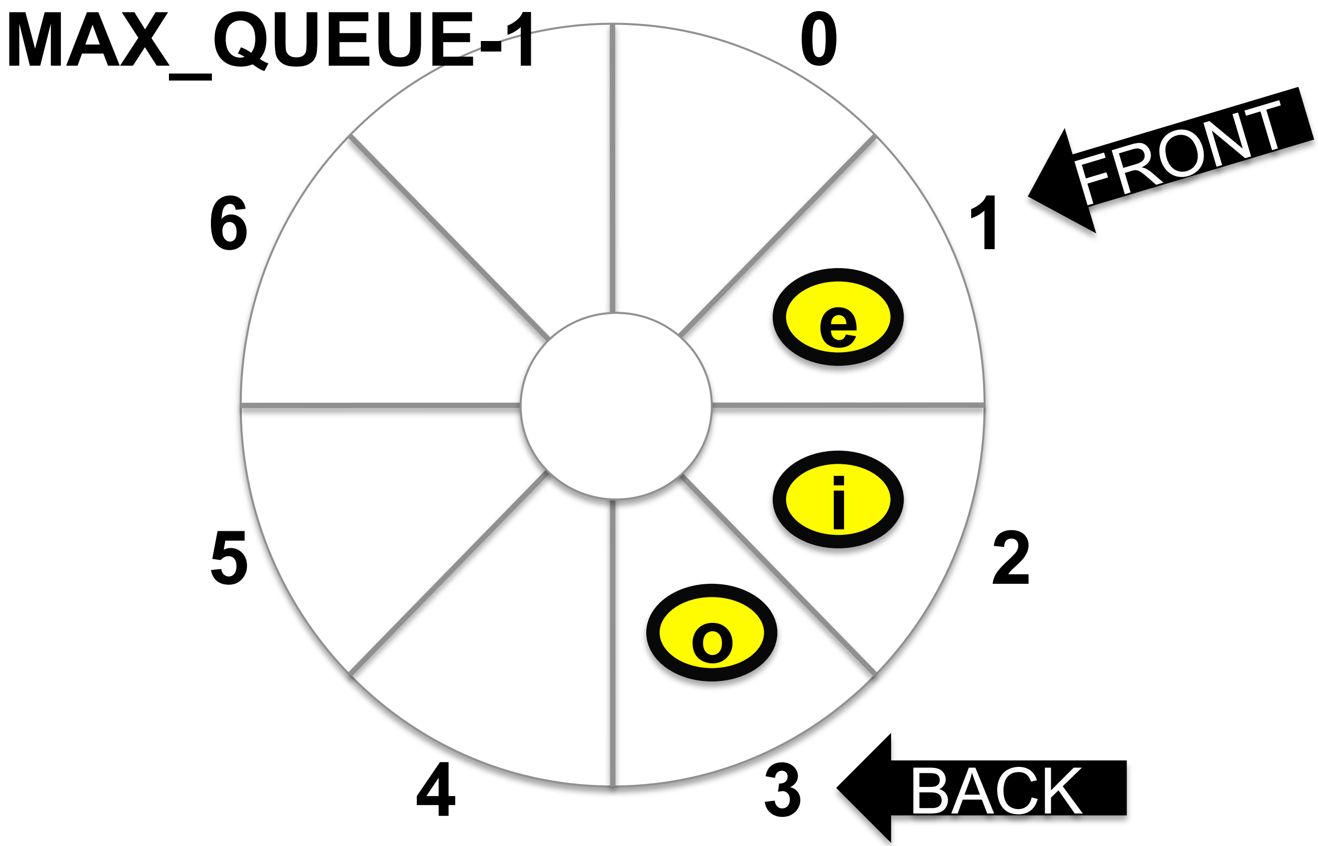
Solving Drift:

- **First Delete**



Solving Drift:

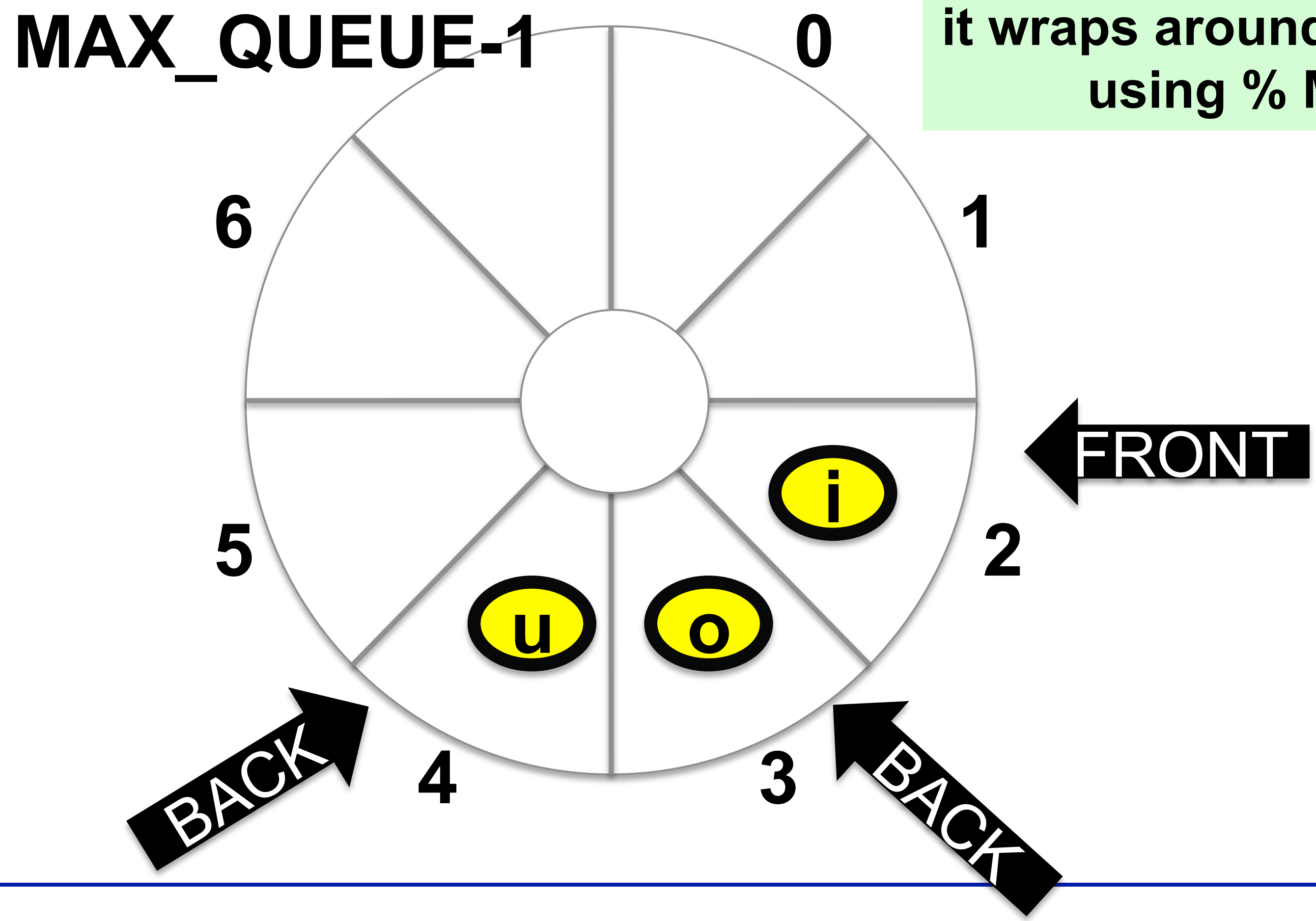
- **Second Delete**



Solving Drift

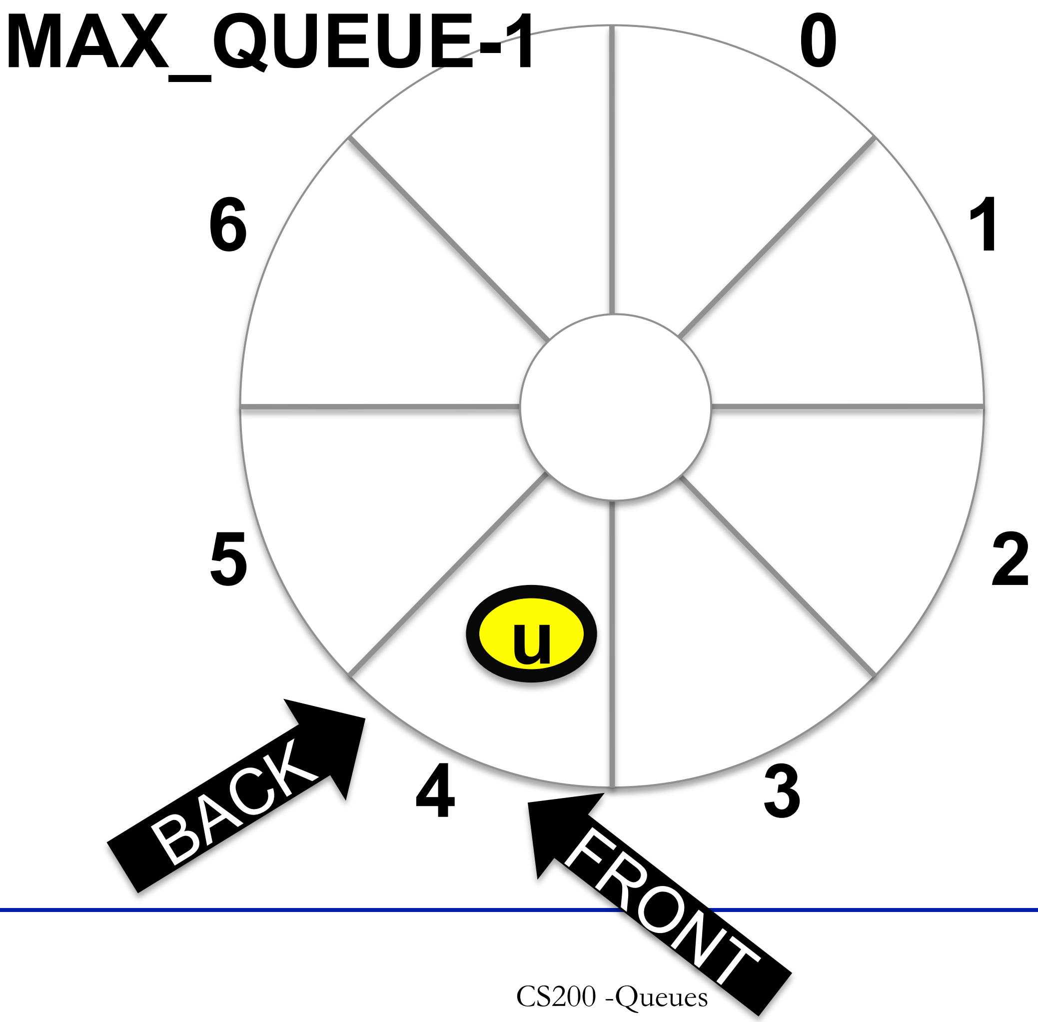
- **Insert u**

When either front or back advances past MAX_QUEUE-1, it wraps around (to 0: using % MAX_QUEUE)



Queue with Single Item

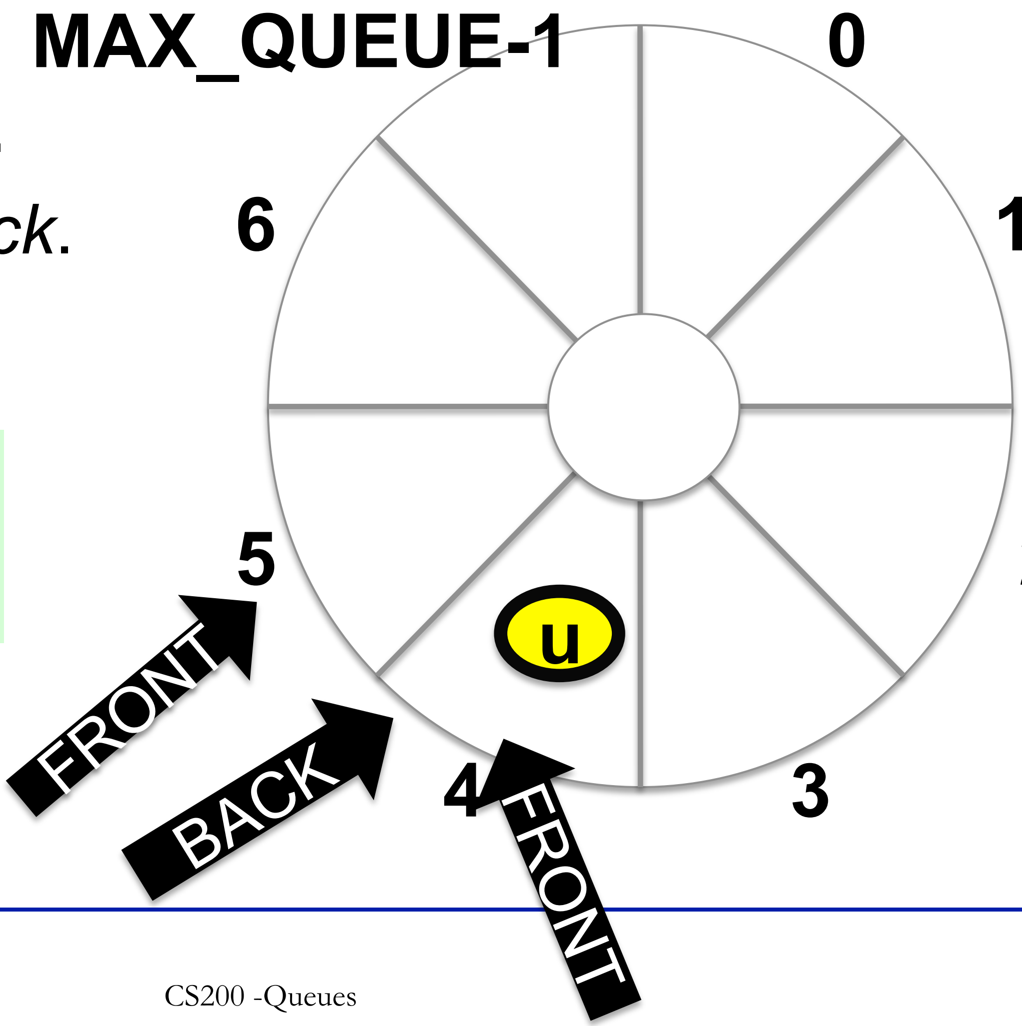
- *back* and *front* are pointing at the same slot.



Empty Queue: remove Single Item

Remove last item.

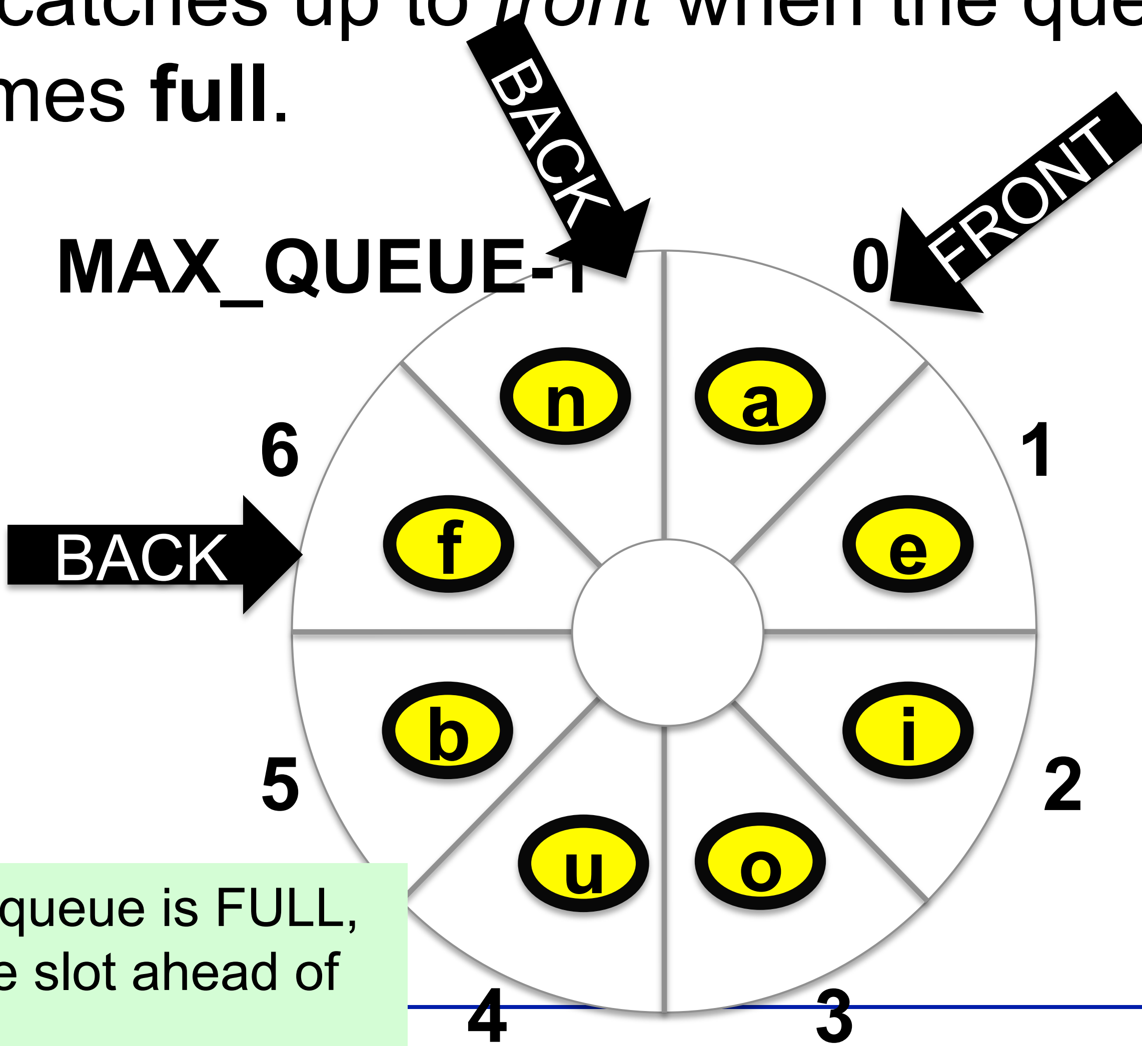
- *front* passed *back*.



When the queue is EMPTY, *front* is one slot ahead of *back*.

Insert the last item

back catches up to *front* when the queue becomes **full**.



Problem?

Solution?

Maintain size:

0:empty
max_queue: full

When the queue is FULL, *front* is one slot ahead of *back*.

Wrapping the values for front and back

- Initializing

```
front = 0
back = MAX_QUEUE-1
count = 0
```

- Adding

```
back = (back+1) % MAX_QUEUE;
items[back] = newItem;
++count;
```

- Deleting

```
deleteItem = items[front];
front = (front +1) % MAX_QUEUE;
--count;
```

enqueue with Array

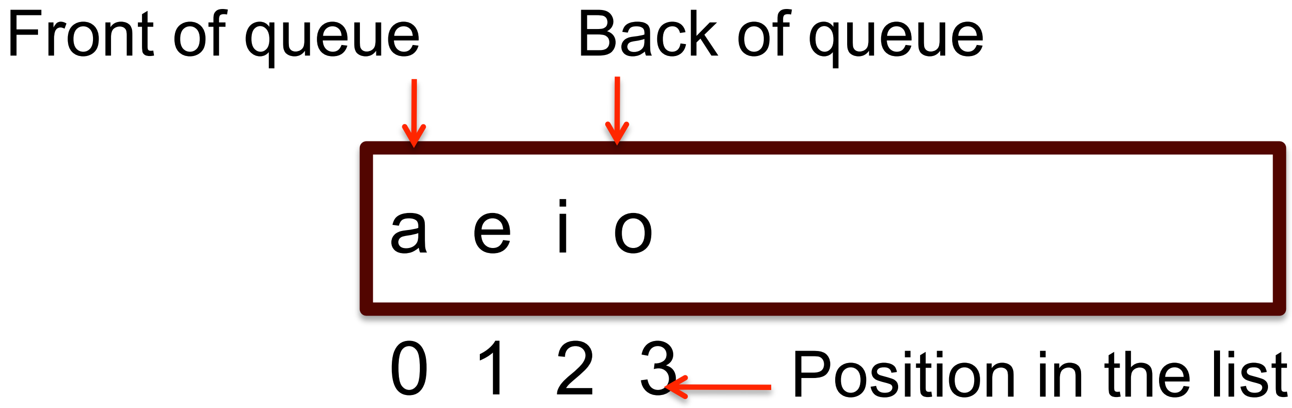
```
public void enqueue(Object newItem) throws
   QueueException{

    if (!isFull()){
        back = (back+1) % (MAX_QUEUE);
        items[back] = newItem;
        ++count;

    }else {
        throw new QueueException(your_message);
    }
}
```

dequeue()

```
public Object dequeue() throws QueueException{
    if (!isEmpty()){
        Object queueFront = items[front];
        front = (front+1) % (MAX_QUEUE);
        --count;
        return queueFront;
    }else{
      throw new QueueException (your_message);
    }
}
```

Implementation with (Array)List

- You can implement operation **`dequeue()`** as the list operation **`remove(0)`**.
- **`peek()`** as **`get(0)`**
- **`enqueue()`** as **`add(newItem)   // at tail`**



Questions

- *What is an advantage of the circular array implementation over linked list?*

A. Faster to enqueue
B. Uses less memory
C. Can more easily fix and enforce a maximum size
D. Fewer allocations

Expressions: infix to postfix conversion

Prichard: 7.4

Let's do some infix to postfix examples

2 + 3 * 4

2 * 3 + 4

2 + 3 - 4

2 + (3 - 4)

2 - 3 - 4

1 - (2 + 3 * 4) / 5

observations?

Expressions: infix to postfix conversion

2 + 3 * 4 → 2 3 4 * +

2 * 3 + 4 → 2 3 * 4 +

2 + 3 - 4 → 2 3 + 4 -

2 + (3 - 4) → 2 3 4 - +

2 - 3 - 4 → 2 3 - 4 -

1 - (2 + 3 * 4) / 5 → 1 2 3 4 * + 5 / -

1. operand order does not change
2. operators come after second operand and obey associativity and precedence rules
3. ( ) converts the inner expression to an independent postfix expression

infix to postfix implementation

- Use a **queue** to create the resulting postfix expression
  - the operands get immediately enqueued
- Use a **stack** to store the operators
  - operators get pushed on the stack
- when to pop and enqueue?
  - let's play

2 + 3 * 4

	stack	queue	action
2 + 3 * 4			enqueue
+ 3 * 4		2	push
3 * 4	+	2	enqueue
* 4	+	2 3	push
4	* +	2 3	enqueue
	* +	2 3 4	pop; enqueue
	+	2 3 4 *	pop; enqueue
		2 3 4 * +	

2 * 3 + 4

	stack	queue	action
2 * 3 + 4			enqueue
* 3 + 4		2	push
3 + 4	*	2	enqueue
+ 4	*	2 3	push + ?

NO!! * has higher precedence than + so * binds to 2 and 3

+ 4	*	2 3	pop; enqueue
+ 4		2 3 *	push
4	+	2 3 *	enqueue
	+	2 3 * 4	pop; enqueue
		2 3 * 4 +	

2 - 3 + 4

	stack	queue	action
2 - 3 + 4			enqueue
- 3 + 4		2	push
3 + 4	-	2	enqueue
+ 4	-	2 3	push + ?

NO!! - and + are left associative, so - binds to 2 and 3

	stack	queue	action
+ 4	-	2 3	pop; enqueue
+ 4		2 3 -	push
4	+	2 3 -	enqueue
	+	2 3 - 4	pop; enqueue
		2 3 - 4 +	

2 – (3 + 4)

	stack	queue	action
2 – (3 + 4)			enqueue
- (3 + 4)		2	push
(3 + 4)	-	2	delete or push?

the expression inside the ( ) makes its own independent postfix, so we push the (then use the stack as before until we see a) then we pop all the operators off the stack and enqueue them, until we see a (and delete the (

	stack	queue	action
3 + 4)	(-	2	enqueue
+ 4)	(-	2 3	push
4)	+ (-	2 3	enqueue

continued next page

2 – (3 + 4)

	stack	queue	action
4)	+ (-	2 3	enqueue
)	+ (-	2 3 4	pop, enqueue until (, delete (
	-	2 3 4 +	pop, enqueue until stack empty
		2 3 4 + -	

in2post algorithm

when encountering

- **operand:** enqueue
- **open:** push
- **close:**
  - pop and enqueue operators, until open on stack
  - pop open
- **operator:**
  - if stack empty or top is open push, else
  - pop and enqueue operators with greater or equal precedence, until operator with lower precedence on stack, or open on stack, or stack empty
- **end of input:**
  - pop and enqueue all operators until stack empty

Do it for: 1-(2+3*4)/5

What about unary operators?

- e.g. not in logic expressions such as:

  not true and false

  not (true or false)

  not not true

not has higher priority than and,

true and not false   is   true and (not false)

and has higher priority than or

not is right associative

not not true   is   not (not true)

not true and false

	stack	queue	action
not true and false			push
true and false	not		enqueue
and false	not	true	not higher priority pop, enqueue not
and false		true not	push
false	and	true not	enqueue
	and	true not false	pop, enqueue
		true not false and	

not(true or false)

	stack	queue	action
not (true or false)			push
(true or false)	not		push
true or false)	(not		enqueue
or false)	(not	true	push
false)	or (not	true	enqueue

not(true or false) continued

	stack	queue	action
	or		
	(		
false)	not	true	enqueue
	or		
	(		pop, enqueue
)	not	true false	until (
	not	true false or	pop, enqueue
		true false or not	

not not true

	stack	queue	action
not not true			push
not true	not		push or enqueue?

push! not is right associative, its operand is ahead of it

	stack	queue	action
true	not not		enqueue
	not not	true	pop and enqueue
		true not not	

in2post algorithm

when encountering

operand: enqueue

open: push

close:

pop and enqueue operators, until open on stack

pop open

end of input:

pop and enqueue all operators until stack empty

in2post continued

when encountering

and, or:

if stack empty or top is open push, else

pop and enqueue operators with greater or equal

precedence, until operator with lower precedence on

stack, or open on stack, or stack empty

not:

push

do it for not (not true or false)