

COMP 250

INTRODUCTION TO COMPUTER SCIENCE

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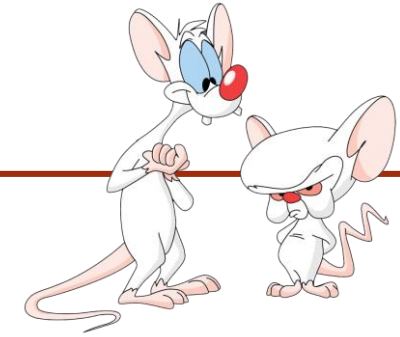
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Week 7-2: Queues

Giulia Alberini, Fall 2020

Slides adapted from Michael Langer's

WHAT ARE WE GOING TO DO IN THIS VIDEO?



- **Queues**

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ADT (ABSTRACT DATA TYPE)

- List

`add(i, e), remove(i), get(i), set(i), ..`

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- Stack

`push(e), pop(), ..`

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- Queue

`enqueue(e), dequeue()`

QUEUE

dequeue
(remove from front)

enqueue
(add at back)

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e.g. Server



clients

EXAMPLES

- keyboard buffer

- CPU processes

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(applications do not run in parallel)

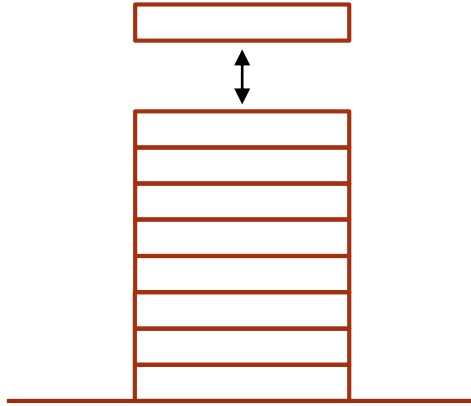
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- web server

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- students in the zoom waiting room

- ...



Stack

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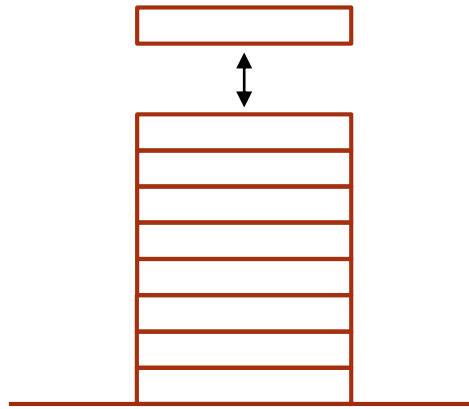
push(e)

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pop()

LIFO

(last in, first out)



Stack

push(e)

pop()

LIFO

(last in, first out)



Queue

enqueue(e)

dequeue()

FIFO

(first in, first out)

“first come, first serve”

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QUEUE EXAMPLE

enqueue(a)

enqueue(b)

dequeue()

a

a b

b

returns a

time

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QUEUE EXAMPLE

enqueue(a)

enqueue(b)

dequeue()

enqueue(c)

enqueue(d)

enqueue(e)

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returns a

a

ab

b

bc

bcd

bcde

time

QUEUE EXAMPLE

enqueue(a)

enqueue(b)

dequeue()

enqueue(c)

enqueue(d)

enqueue(e)

dequeue()

enqueue(f)

enqueue(g)

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a

ab

b

bc

bcd

bcde

cde

cdef

cdefg

returns a

returns b

time

HOW TO IMPLEMENT A QUEUE?

enqueue(e)

dequeue()

singly linked list

doubly linked list

array list

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HOW TO IMPLEMENT A QUEUE?

enqueue(e)

dequeue()

singly linked list

addLast(e)

removeFirst()

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doubly linked list

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array list

HOW TO IMPLEMENT A QUEUE?

enqueue(e)

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singly linked list

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removeFirst()

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doubly linked list

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(same, or addFirst() & removeLast())

array list

HOW TO IMPLEMENT A QUEUE?

enqueue(e)

dequeue()

singly linked list

addLast(e)

removeFirst()

<https://powcoder.com>

doubly linked list

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(same, or addFirst() & removeLast())

array list

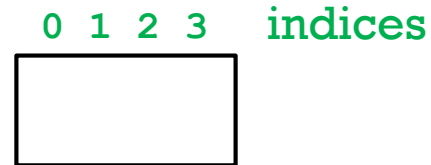
addLast(e)

removeFirst()

SLOW!

IMPLEMENTING A QUEUE WITH AN ARRAY LIST (BAD)

length = 4



enqueue (a)

enqueue (b)

dequeue ()

a---

ab--

b---

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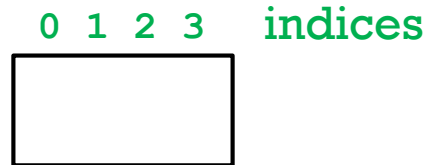
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Requires shift

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IMPLEMENTING A QUEUE WITH AN ARRAY LIST (BAD)

length = 4



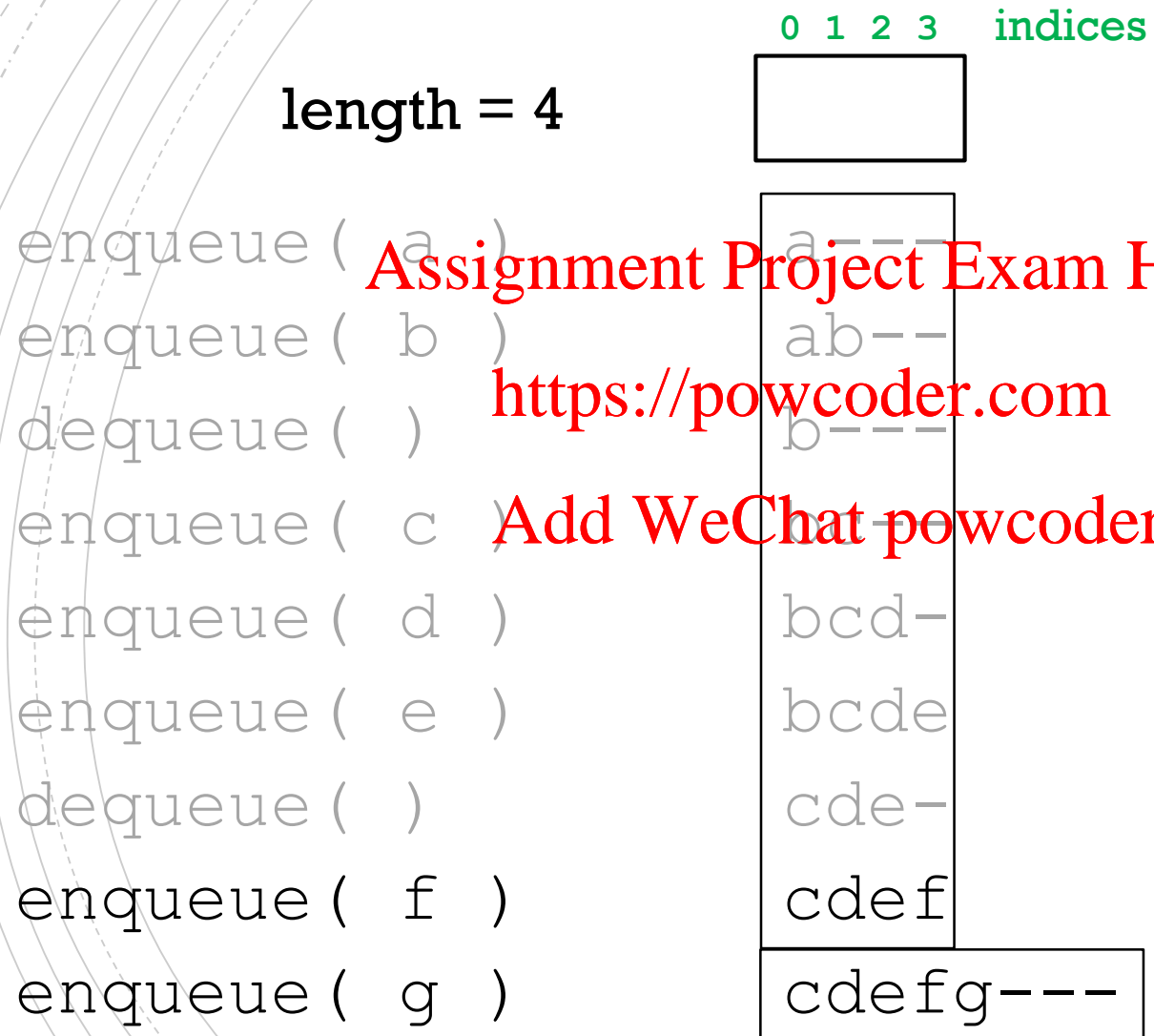
enqueue (a) a ---
enqueue (b) ab --
dequeue () b --- Requires shift
enqueue (c) bc --
enqueue (d) bcd -
enqueue (e) bcde
dequeue () cde - Requires shift

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IMPLEMENTING A QUEUE WITH AN ARRAY LIST (BAD)



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requires expansion

IMPLEMENTING A QUEUE WITH AN EXPANDING ARRAY (ALSO BAD)

Use **head** and **tail** indices
(**tail** = **head** + size - 1)

	0	1	2	3	
enqueue (a)	a	-	-	-	(0, 0)
enqueue (b)	a	b	-	-	(0, 1)
dequeue ()	-	b	-	-	(1, 1)
enqueue (c)	-	b	c	-	(1, 2)
enqueue (d)	-	b	c	d	(1, 3)
enqueue (e)				?	

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IMPLEMENTING A QUEUE WITH AN EXPANDING ARRAY (ALSO BAD)

Use **head** and **tail** indices

(**tail** = **head** + size - 1)

	0	1	2	3				
enqueue (a)	a	-	-	-	(0, 0)			
enqueue (b)	a	b	-	-	(0, 1)			
dequeue ()	-	b	-	-	(1, 1)			
enqueue (c)	-	b	c	-	(1, 2)			
enqueue (d)	-	b	c	d	(1, 3)			
enqueue (e)	-	b	c	d	e	(1, 4)		
dequeue ()	-	-	c	d	e	(2, 4)		
enqueue (f)	-	-	c	d	e	f	(2, 5)	
enqueue (g)	-	-	c	d	e	f	g	(2, 6)

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Make
bigger
array and
copy to it.

IMPLEMENTING A QUEUE WITH AN EXPANDING ARRAY

- to dequeue: retrieve the element at head and increase the index head

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- to enqueue: add the element at tail + 1

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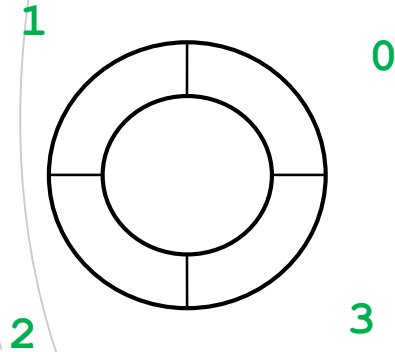
An expanding array is an inefficient usage of space!

A better idea is...

CIRCULAR ARRAY

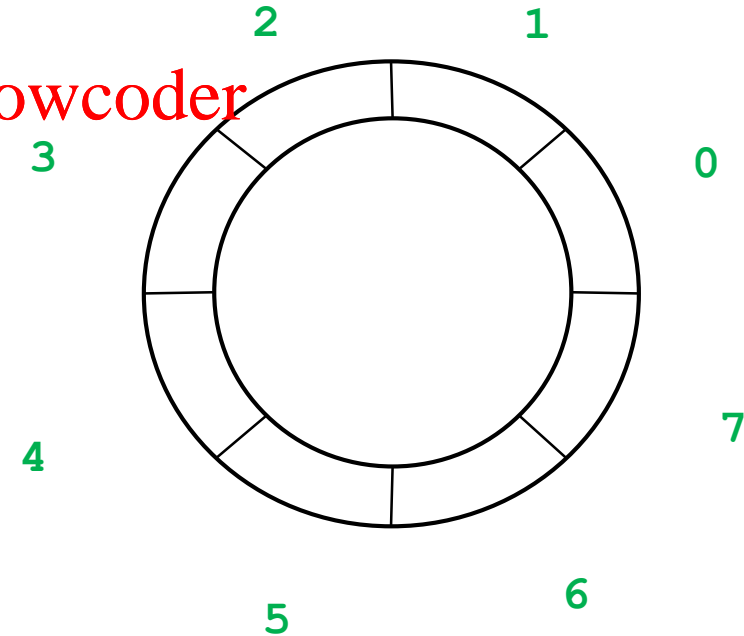
length = 4

0123



length = 8

01234567



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IMPLEMENTING A QUEUE WITH A CIRCULAR ARRAY (GOOD)

$$\text{tail} = (\text{head} + \text{size} - 1) \bmod \text{length}$$

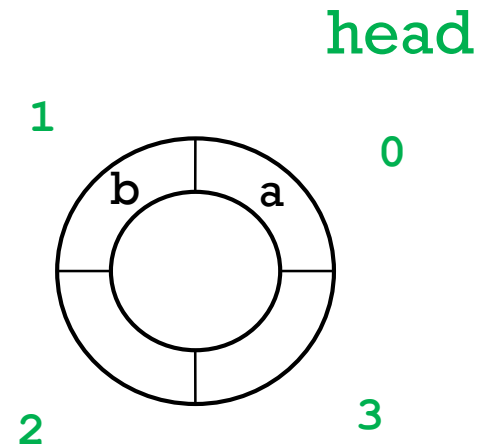
```
enqueue( a )  
enqueue( b )  
dequeue() ?
```

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head=0 tail=1



IMPLEMENTING A QUEUE WITH A CIRCULAR ARRAY (GOOD)

$\text{tail} = (\text{head} + \text{size} - 1) \bmod \text{length}$

```
enqueue ( a )  
enqueue ( b )  
dequeue ()  
enqueue ( c ) ?
```

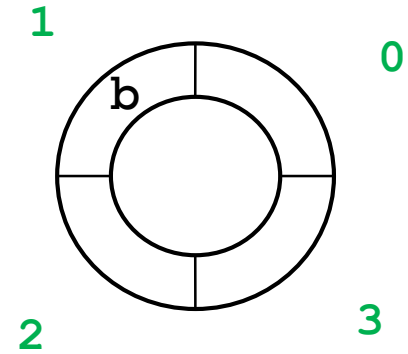
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head=1 tail=1

head
tail



IMPLEMENTING A QUEUE WITH A CIRCULAR ARRAY (GOOD)

$$\text{tail} = (\text{head} + \text{size} - 1) \bmod \text{length}$$

```
enqueue ( a )  
enqueue ( b )  
dequeue ()  
enqueue ( c )  
enqueue ( d ) ?
```

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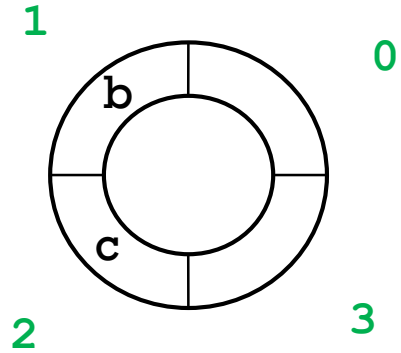
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head=1 tail=2

head

tail



IMPLEMENTING A QUEUE WITH A CIRCULAR ARRAY (GOOD)

$$\text{tail} = (\text{head} + \text{size} - 1) \bmod \text{length}$$

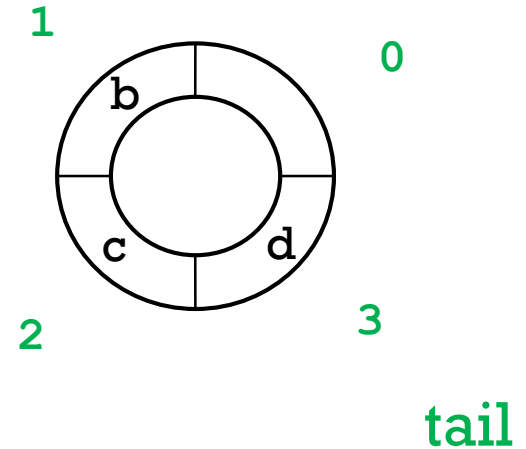
```
enqueue ( a )
enqueue ( b )
dequeue ( )
enqueue ( c )
enqueue ( d )
enqueue ( e ) ?
```

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head=1 tail=3



IMPLEMENTING A QUEUE WITH A CIRCULAR ARRAY (GOOD)

$$\text{tail} = (\text{head} + \text{size} - 1) \bmod \text{length}$$

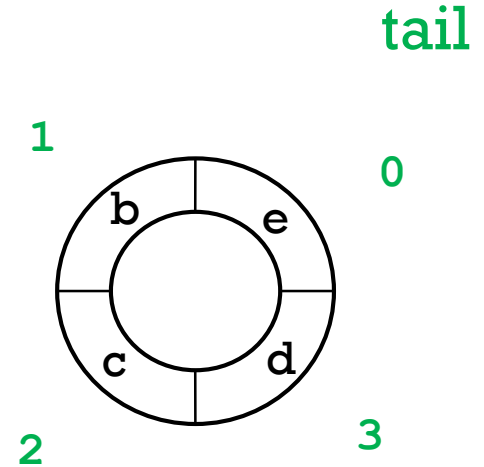
```
enqueue ( a )  
enqueue ( b )  
dequeue ()  
enqueue ( c )  
enqueue ( d )  
enqueue ( e )  
dequeue () ?
```

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head=1 tail=0



IMPLEMENTING A QUEUE WITH A CIRCULAR ARRAY (GOOD)

$$\text{tail} = (\text{head} + \text{size} - 1) \bmod \text{length}$$

```
enqueue ( a )  
enqueue ( b )  
dequeue ()  
enqueue ( c )  
enqueue ( d )  
enqueue ( e )  
dequeue ()
```

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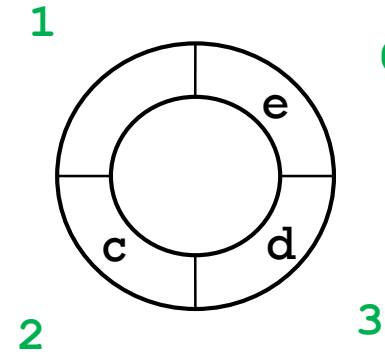
0123
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head=2 tail=0

head

tail



IMPLEMENTING A QUEUE WITH A CIRCULAR ARRAY (GOOD)

$\text{tail} = (\text{head} + \text{size} - 1) \bmod \text{length}$

```
enqueue ( a )  
enqueue ( b )  
dequeue ()  
enqueue ( c )  
enqueue ( d )  
enqueue ( e )  
dequeue ()  
enqueue ( f )  
enqueue ( g ) ?
```

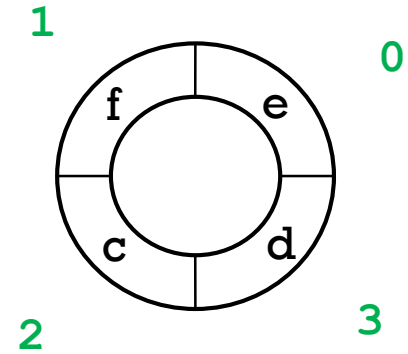
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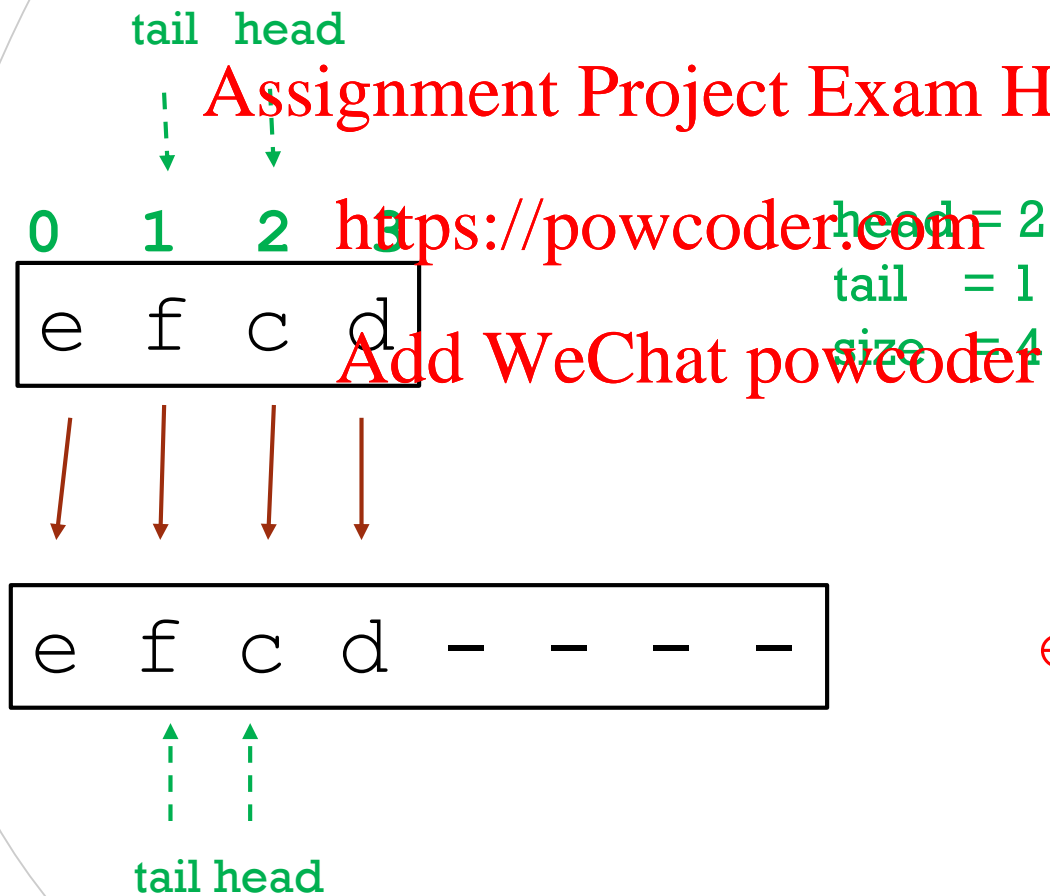
head=2 tail=1

head



INCREASE THE LENGTH OF THE ARRAY AND COPY

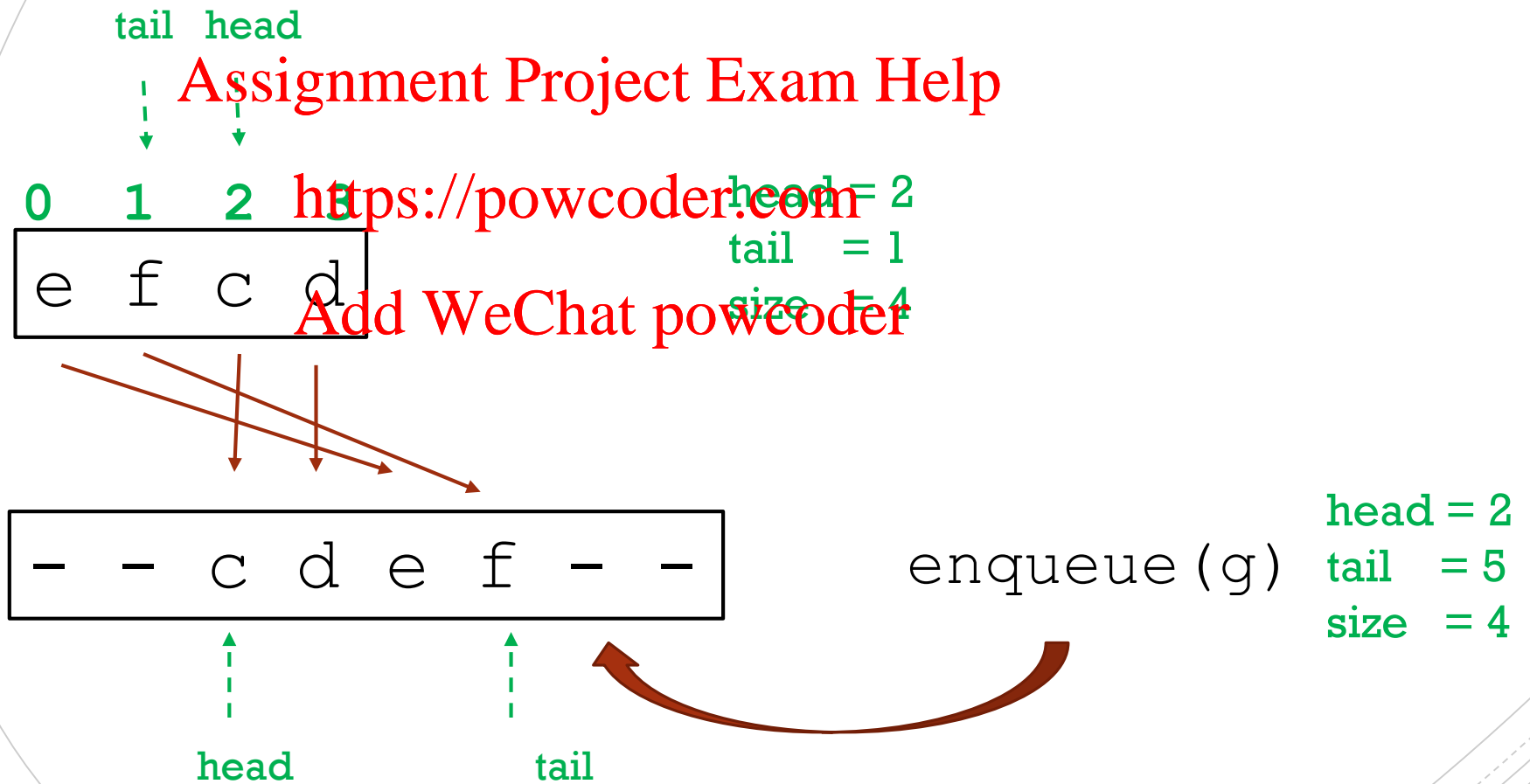
Be careful, on how you copy! The following would not work:



enqueue(g) ?

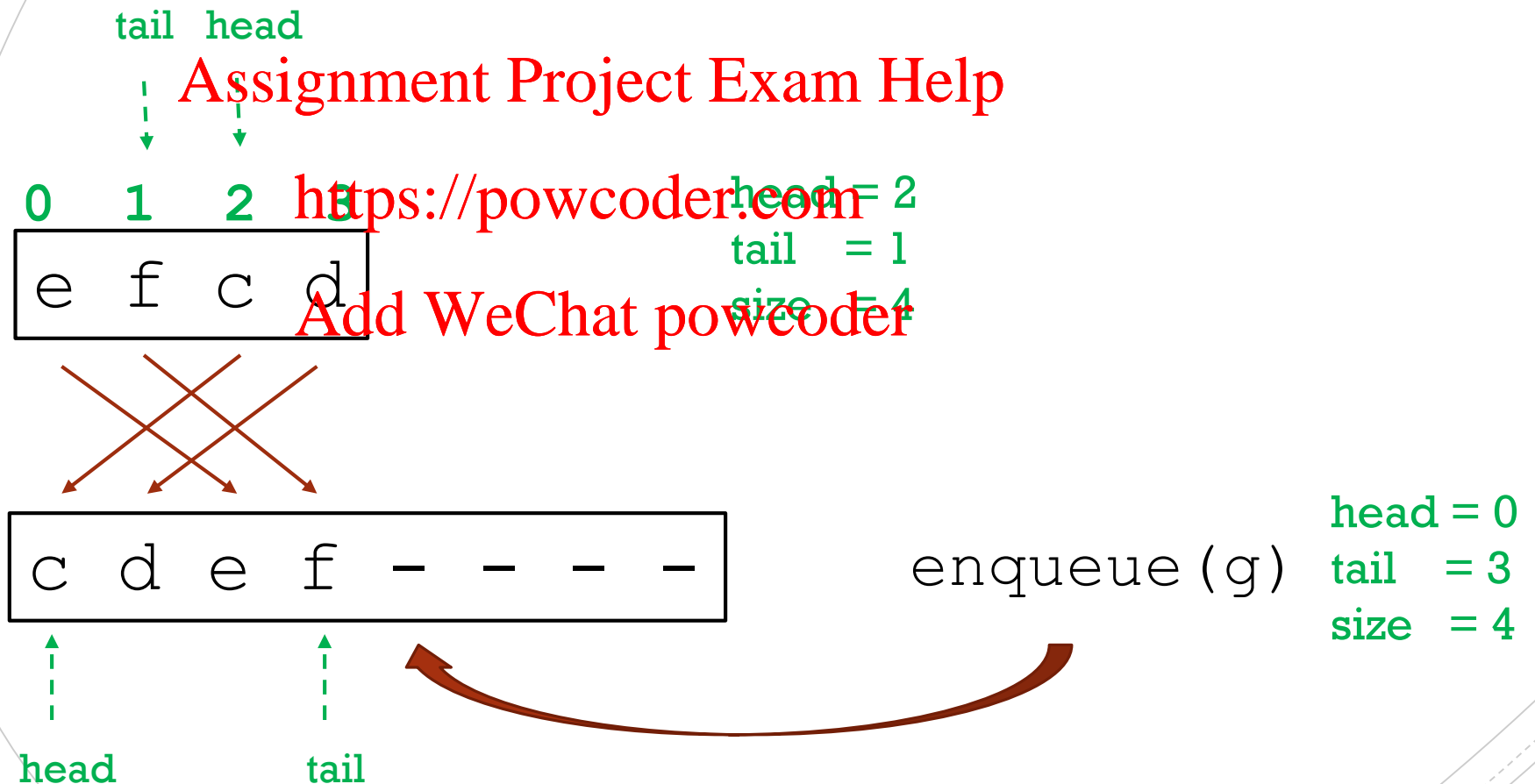
INCREASE THE LENGTH OF THE ARRAY AND COPY

Instead you can copy so that the head remains in the same position.



INCREASE THE LENGTH OF THE ARRAY AND COPY

OR you can copy so that the head moves to position 0.



ENQUEUE(e)

```
enqueue( element ){
    if (size == queue.length) {
        // increase length of array
        create a bigger array tmp[ ] // e.g. 2*length
        for i = 0 to queue.length - 1
            tmp[i] = queue[(head + i) mod queue.length]
        head = 0
        queue = tmp
    }
    queue[(head + size) mod length] = element
    size++
}
```

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Note that we don't have a tail variable here. Instead, recall that $tail = (head + size - 1) \bmod length$, and note that the new element is added in position $(tail + 1) \bmod length$.

DEQUEUE()

```
def dequeue():  
    if size <= 0:  
        raise error  
  
    element = queue[head]  
    size = size - 1  
    head = (head + 1) % length  
    return element  
}
```

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WHAT IF SIZE IS 0?

What is the relation between `head` and `tail` when size is equal to 0?

`tail = (head + size - 1) mod length`

`array = (head, tail, size)`

Initial state `-- (0, 3, 0)`

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WHAT IF SIZE IS 0?

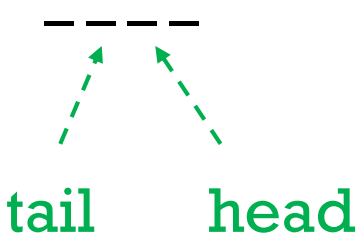
What is the relation between **head** and **tail** when size is equal to 0?

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 $\text{tail} = (\text{head} + \text{size} - 1) \% \text{length}$

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 $\text{array} = (\text{head}, \text{tail}, \text{size})$

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Initial state	----	(0, 3, 0)
enqueue (a)	a---	(0, 0, 1)
enqueue (b)	ab--	(0, 1, 2)
dequeue ()	-b--	(1, 1, 1)
dequeue ()	--	(2, 1, 0)



tail **head**

ADT (ABSTRACT DATA TYPE)

Defines a data type by the values and operations from the user's perspective only. It ignores the details of the implementation.

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Examples:

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- list
- stack
- queue
- ...



Coming Soon

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In the next videos:

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Back to Java: interfaces!

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