QUEUES

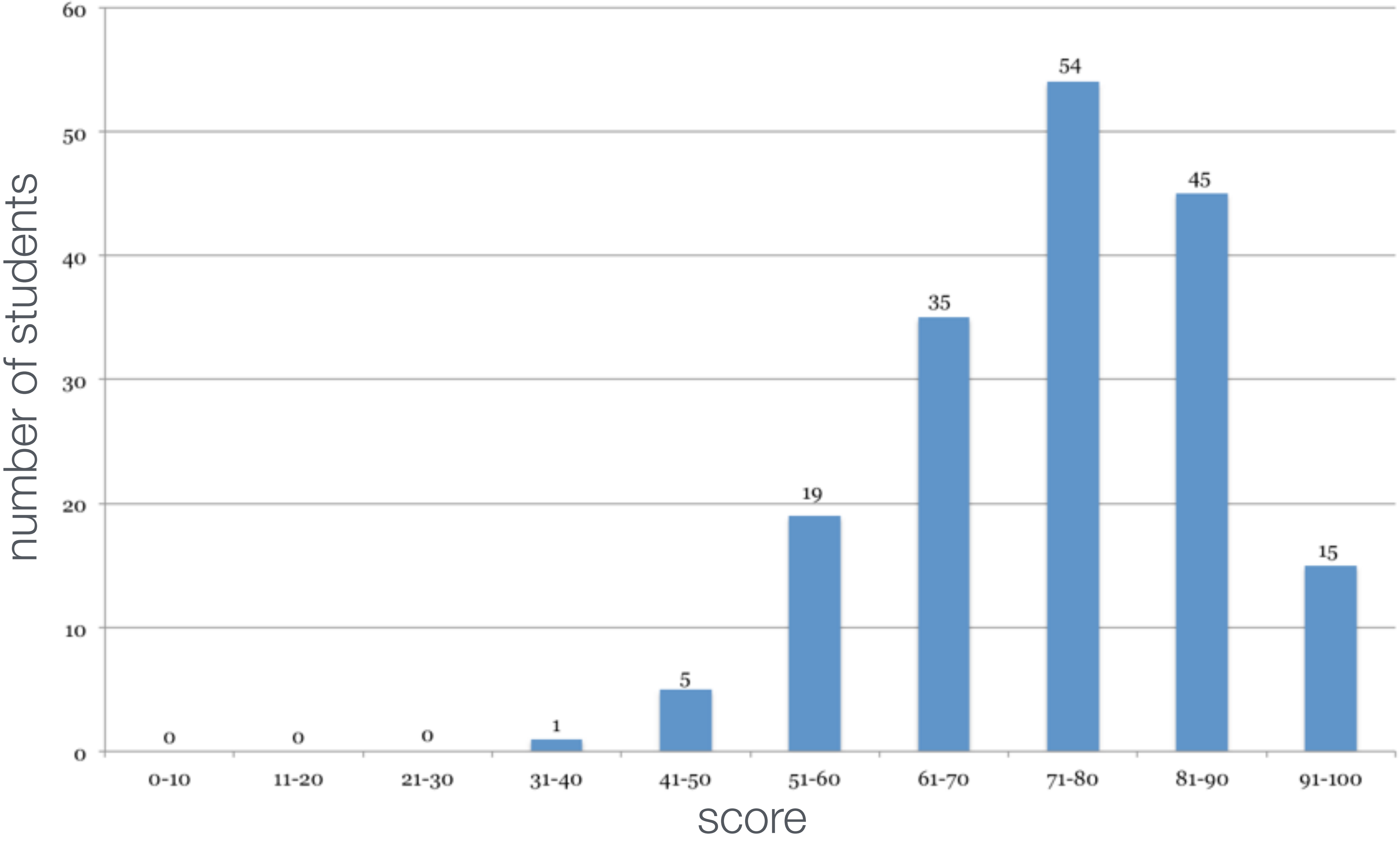
cs2420 | Introduction to Algorithms and Data Structures | Spring 2015

administrivia…

-assignment 6 due tonight at midnight

-assignment 7 is out

midterm scores



last time…

-a **stack** is a data structure in which insertion and removal is restricted to the **top** (or end) of the list

-also called FIRST-IN, LAST-OUT (FILO)

- -insertion always adds an item to the end
- -deletion always removes an item from the end

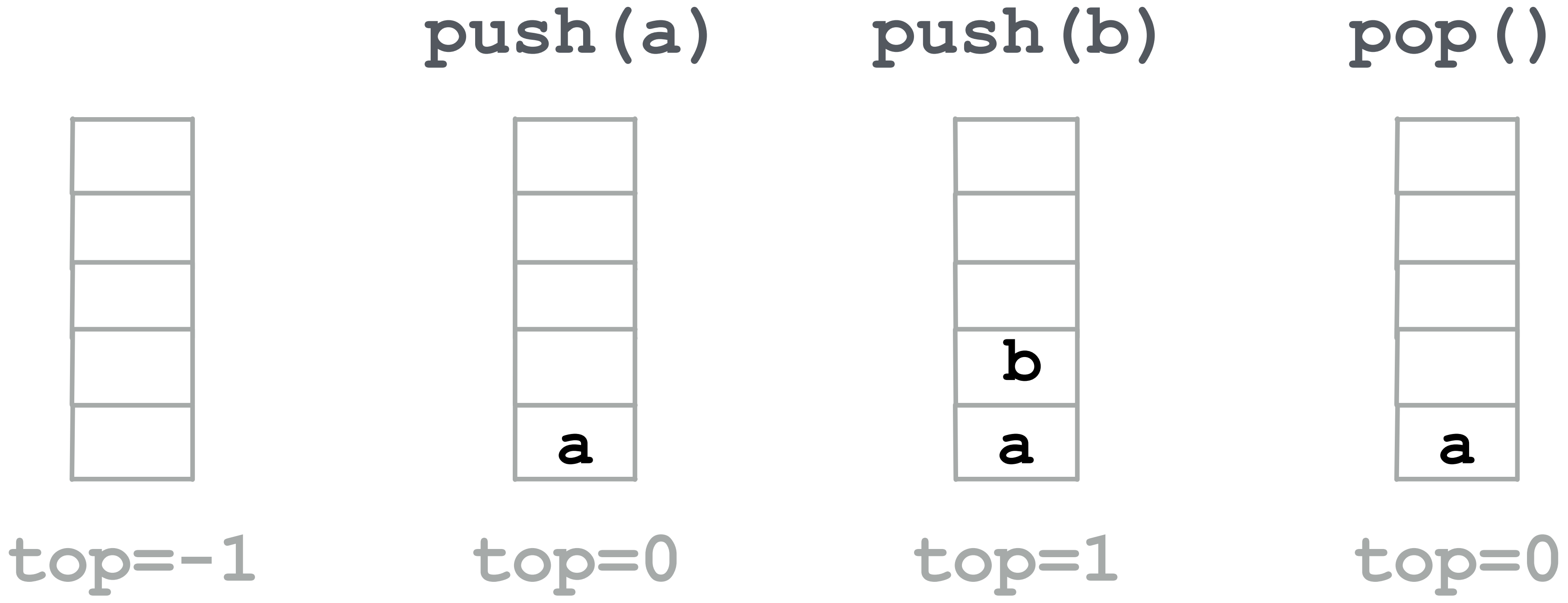
performance

-`push`, `pop`, and `peek` must all be **O(1)**

-we need a very efficient data structure if we expect to only access the last element

HOW CAN WE IMPLEMENT A STACK SO THAT ALL 3 OPERATIONS ARE GUARANTEED TO BE **O(1)**?

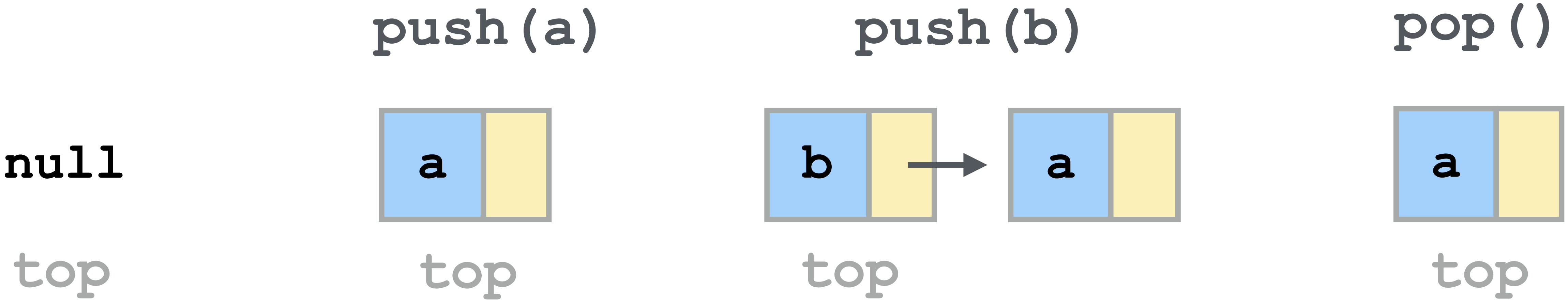
as an array…



push(a) push(b) pop()

top=-1 top=0 top=1 top=0

as a linked list…

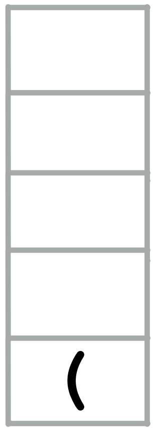


EXAMPLE: symbol matcher

push

pop

```
for(i=0; i<N; i++)
{
  arr[i] = i;
}
```



today…

-ANOTHER STACK EXAMPLE: postfix notation

-queues

-priority queues

-homework 7 hints

EXAMPLE: postfix notation

-we usually see expression written in **infix notation**

-place an *operator* in between a left and right *operand*

- `a + b`

-the order of operations is not clear from the expression without parentheses

- although, left-to-right is often assumed
- `1 + 2 * 3 = ?`
    - *answer is 7, but some calculators will give 9!*

postfix expressions

-a syntax lacking parentheses that can be parsed without ambiguity

  -also called *reverse polish notation*

-to operands, followed by an operator

```
a b +

1 2 3 * +
```

→ *2 * 3 is evaluated first, result is then added to 1*

HOW CAN WE USE A STACK TO EVALUATE A POSTFIX EXPRESSION?

```
1 2 3 * + 4 -
```

(ANSWER IS 3)

HINT:

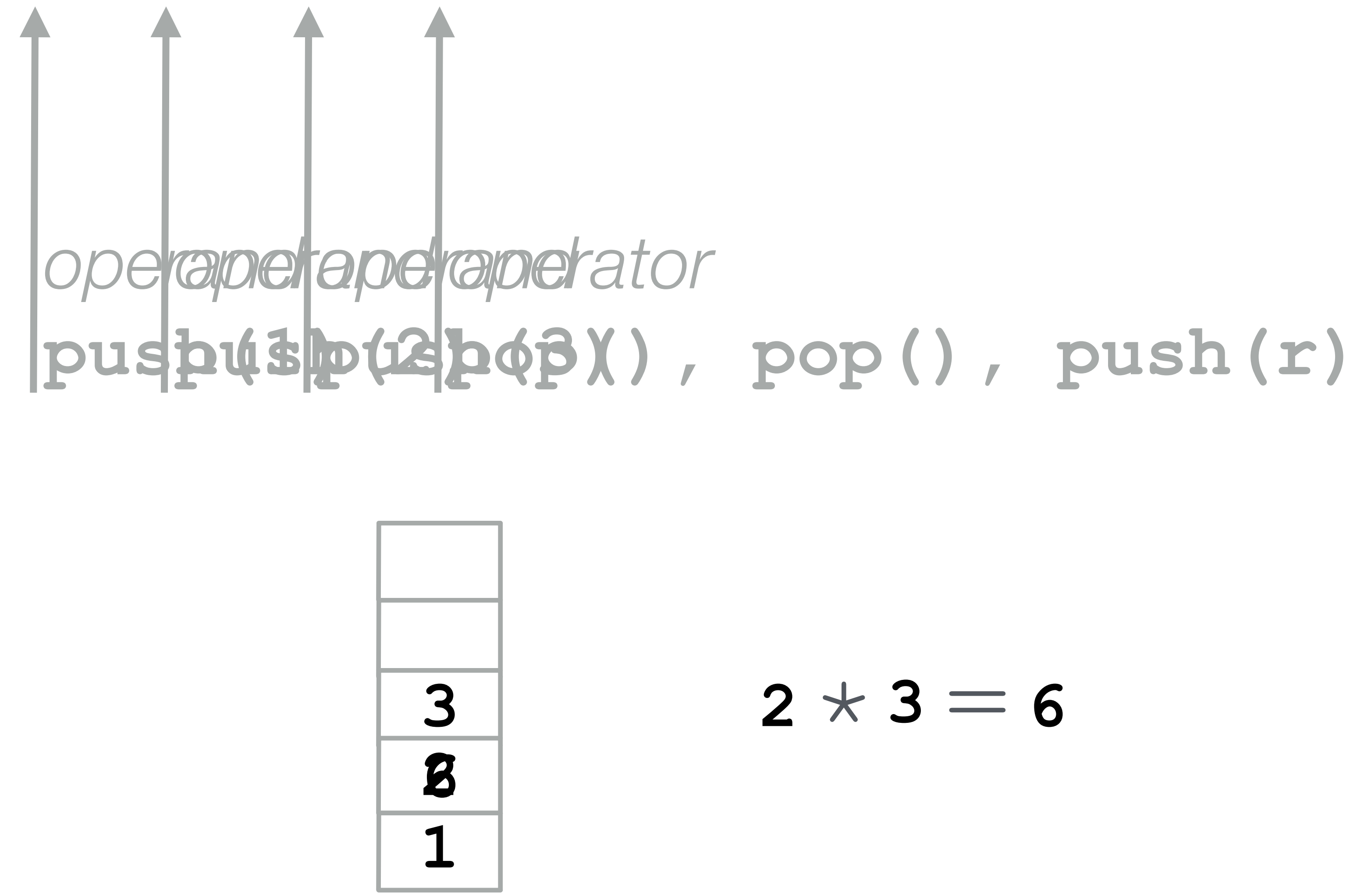
- when an *operand* is seen, __________
- when an *operator* is seen, ___________
- when the expression is done, ___________

-when an operand is seen, **push it onto the stack**

-when an operator is seen, **the right and left operands are popped, the operation is evaluated, and the result is pushed back onto the stack**

-when the expression is done, **the single item remaining on the stack is the answer**

`1 2 3 * + 4 -`

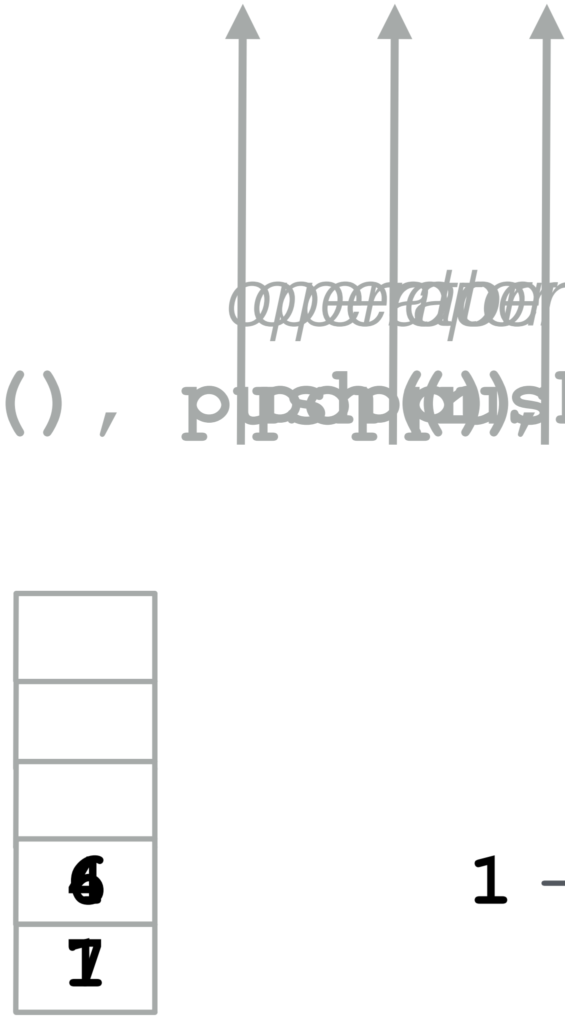


operand *operand* *operand* *operator*

push(1) **push(2)** **push(3)** **pop(), pop(), push(r)**

2 * **3** = **6**

`1 2 3 * + 4 −`



operator *operand* *operator*

pop(), pop(), push(r) **push(4)** **pop(), pop(), push(r)**

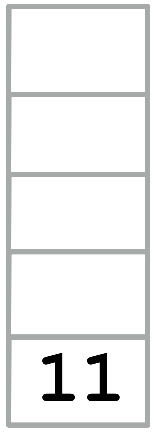
1 + **6** = **7**

```
1 2 3 * + 4 -
```

operator EOL

`pop(), pop(), push(r)`

`pop()`



ANSWER IS **11**

7 + 4 = 11

queue

-a **queue** is a FIRST-IN, FIRST-OUT data structure

- -FIFO

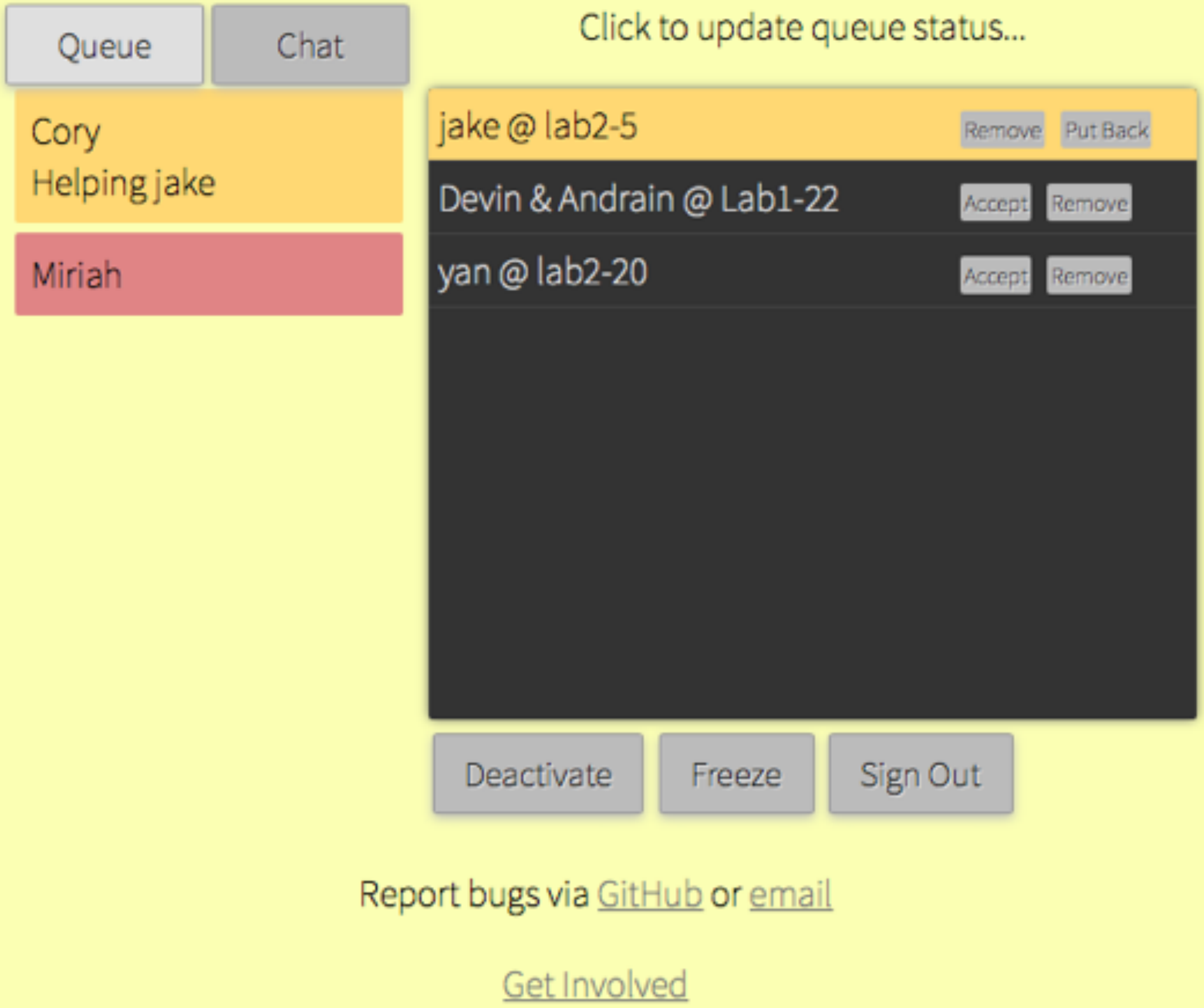
-insert on the back, remove from the front

-operations:

- -*enqueue*… adds an item to the back of the queue
- -*dequeue*… removes and returns the item at the front

↑TERMINOLOGY AVOIDS CONFUSION WITH A STACK!

-like a stack, all operations are **O(1)**



Click to update queue status...

Cory
Helping jake

Miriah

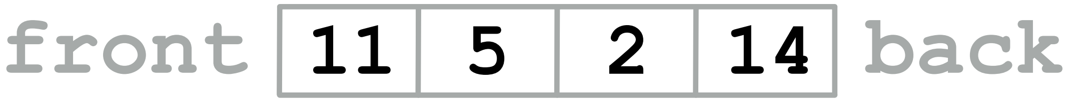
jake @ lab2-5

Devin & Andrain @ Lab1-22

yan @ lab2-20

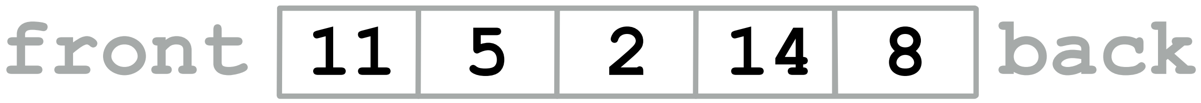
Report bugs via GitHub or email

Get Involved



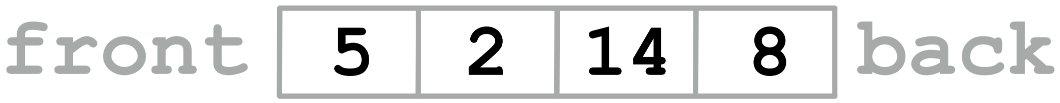
front 11 5 2 14 back

```
enqueue(8)
```



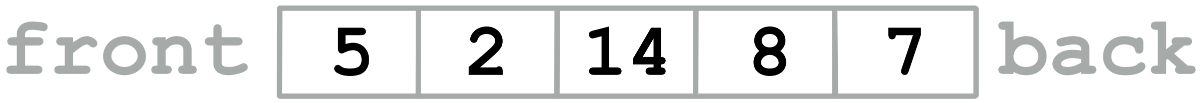
front 11 5 2 14 8 back

```
enqueue(8)
dequeue()
```



front 5 2 14 8 back

```
enqueue(8)
dequeue()
enqueue(7)
```



front 5 2 14 8 7 back

HOW CAN WE IMPLEMENT A QUEUE SO THAT ALL OPERATIONS ARE GUARANTEED TO BE **O(1)**?

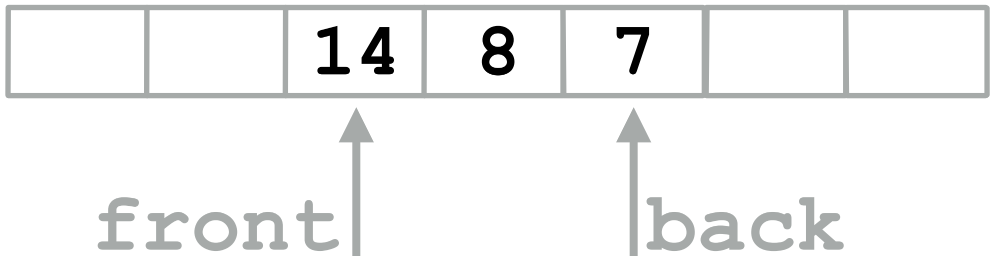
as an array…

-keep track of `front` and `back` indices

-`front` and `back` advance through the array

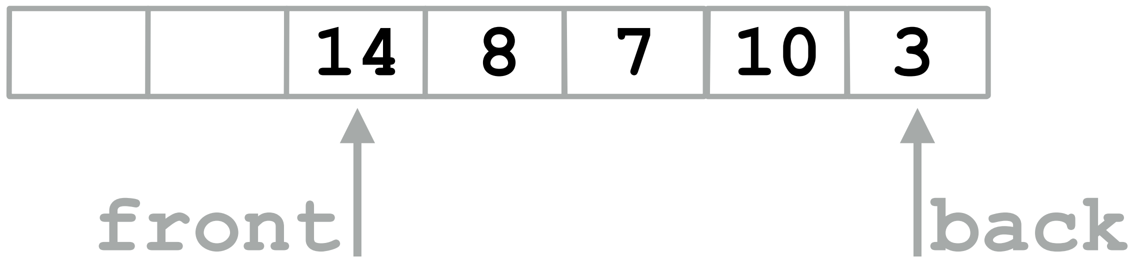
  -*enqueueing* advances `back`

  -*dequeueing* advance `front`

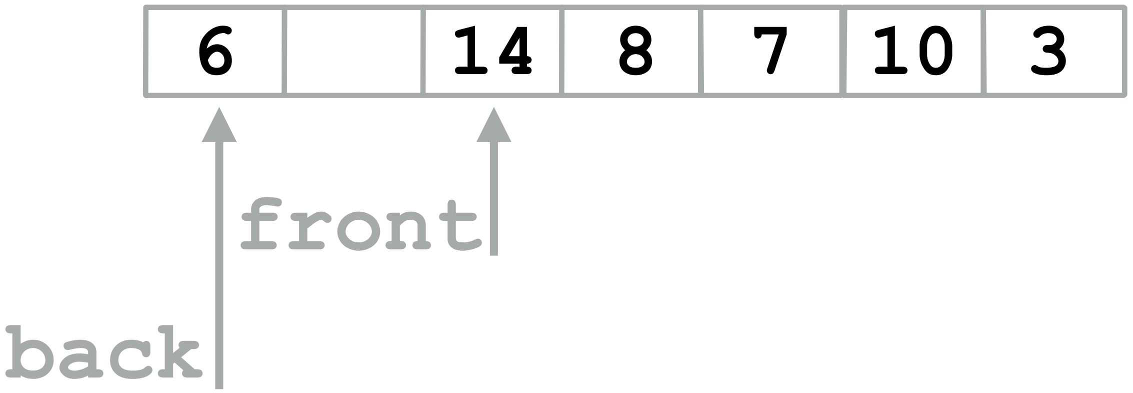


-what happens when `back` reaches the end of the array?

`enqueue(3)`



`enqueue(6)`



performance

-using wrap-around, all operations are **O(1)** on average

-but, **O(N)** array growing is still a problem in the worst case!

-how do we hand array growth if there is wrap-around in the queue?

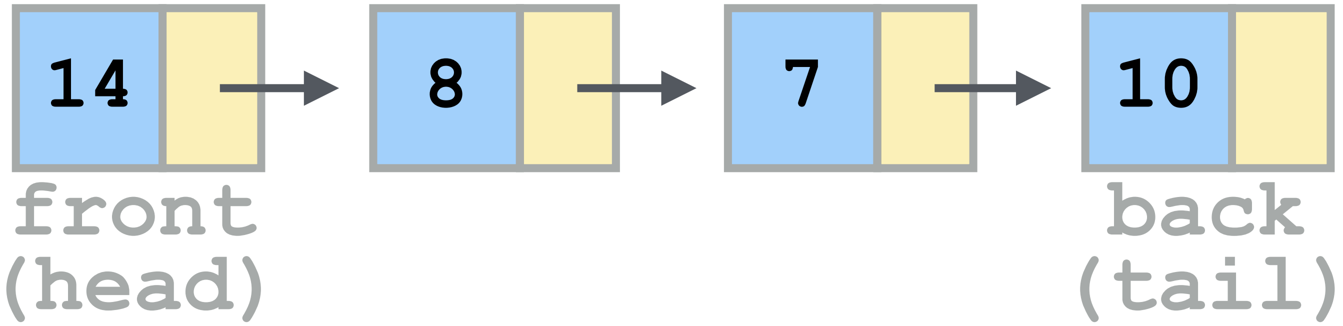
  - -how do we hand copying?
  - -this is non-trivial…

as a linked list…

-remember, inserting and deleting to the head and tail of a linked list is automatically O(1)

-`front` is analogous to `head`
-`back` is analogous to `tail`

-no messy wrap-around, or growth issues



-which linked list operations are analogous to *enqueue* and *dequeue*?

summary

-linked lists and wrap-around arrays are both O(1) for queue implementations

-BUT, arrays are much more complicated to code

-both queues and stacks require very little code on top of a good linked list implementation

priority queues

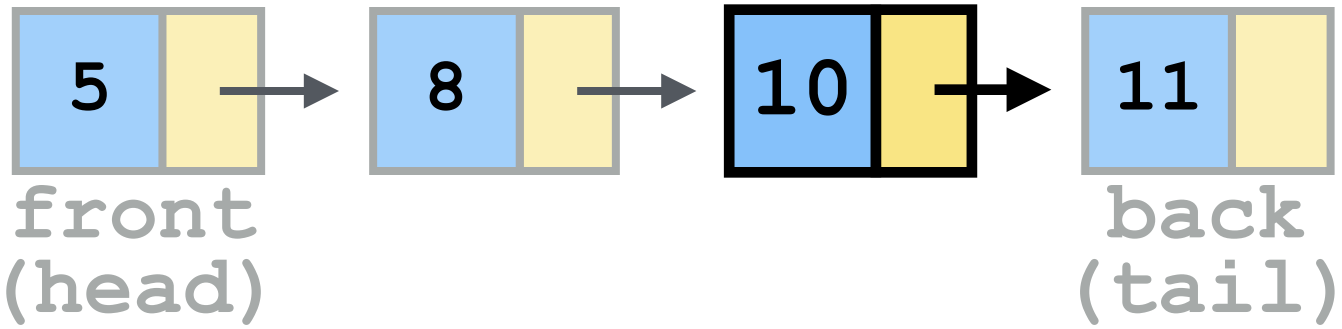
- like a queue, but items returned in order of ***priority***
    - *dequeue* operation always returns the item with the highest priority
    - if two items have the same priority, the first one in the queue is returned

- how can we implement this?
- can operations be **O(1)**?

using a linked list…

-always add items in correct, sorted spot

`enqueue(10)`



-dequeue will return smallest item **O(1)**

-what is the cost of *enqueue*?

-we will study a more advanced priority queue later…

homework hints…

-suppose we want to print the `String`:

`this is a quote: “hello”`

→ `println(“this is a quote: “hello””);`

-will this work?

`String` literals

-certain characters in `Strings` are special cases

“

‘

\ (escape character)

-to include a quote character, we must **escape** it

```
println(“this is a quote: \“hello\””);
```

-we can also escape the *escape* character

```
println(“this is a backslash: \\”);
```

`char` literals

-checking for a backslash:

```
if(c == ‘\\')
```

-checking for a double quote:

```
if(c == ‘\”')
```

-checking for a single quote:

```
 if(c == ‘\’')
```

```
public void test()
{
  /*  )  */
  System.out.println(“ \” [} “);
}

// {](
```

IS THIS BALANCED?

next time…

-reading

- -chapters 8 and 19 in book
- -chapter 6
  - *-http://opendatastructures.org/ods-java/*

-homework

- -assignment 6 due tonight