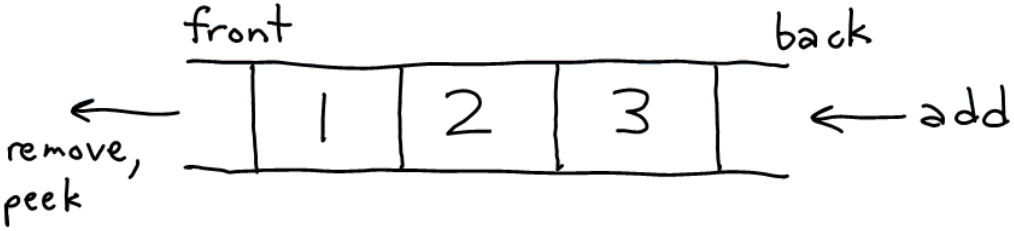
CSE 373
Data Structures and Algorithms

Lecture 2: Queues

Queue ADT

- **queue**: A list with the restriction that insertions are done at one end and deletions are done at the other
  - First-In, First-Out ("FIFO")
  - Elements are stored in order of insertion but don't have indexes.
  - Client can only add to the end of the queue, and can only examine/remove the front of the queue.



- basic queue operations:
  - **add** (enqueue): Add an element to the back.
  - **remove** (dequeue): Remove the front element.
  - **peek**: Examine the element at the front.

Queues in computer science

- Operating systems:
  - queue of print jobs to send to the printer
  - queue of programs / processes to be run
  - queue of network data packets to send

- Programming:
  - modeling a line of customers or clients
  - storing a queue of computations to be performed in order

- Real world examples:
  - people on an escalator or waiting in a line
  - cars at a gas station (or on an assembly line)

Using `Queues`

`add(`**value**`)`	places given value at back of queue
`remove()`	removes value from front of queue and returns it; throws a `NoSuchElementException` if queue is empty
`peek()`	returns front value from queue without removing it; returns `null` if queue is empty
`size()`	returns number of elements in queue
`isEmpty()`	returns `true` if queue has no elements

```
Queue<Integer> q = new LinkedList<Integer>();
q.add(42);
q.add(-3);
q.add(17);     // front [42, -3, 17] back

System.out.println(q.remove()); // 42
```

- **IMPORTANT**: When constructing a queue you must use a new `LinkedList` object instead of a new `Queue` object.

Queue idioms

- As with stacks, must pull contents out of queue to view them.

```
while (!q.isEmpty()) {
    do something with q.remove();
}
```

  - another idiom: Examining each element exactly once.

```
int size = q.size();
for (int i = 0; i < size; i++) {
    do something with q.remove();
    (including possibly re-adding it to the queue)
}
```

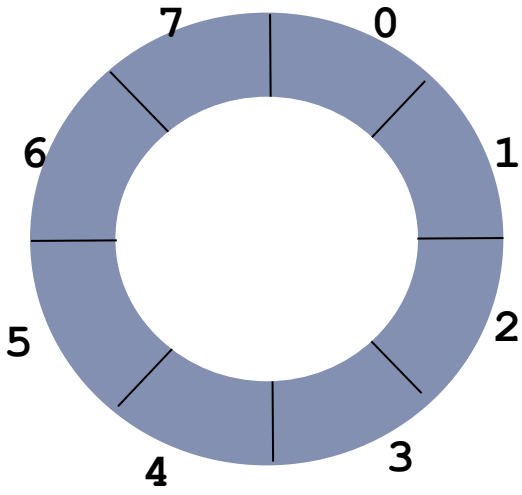
    - Why do we need the `size` variable

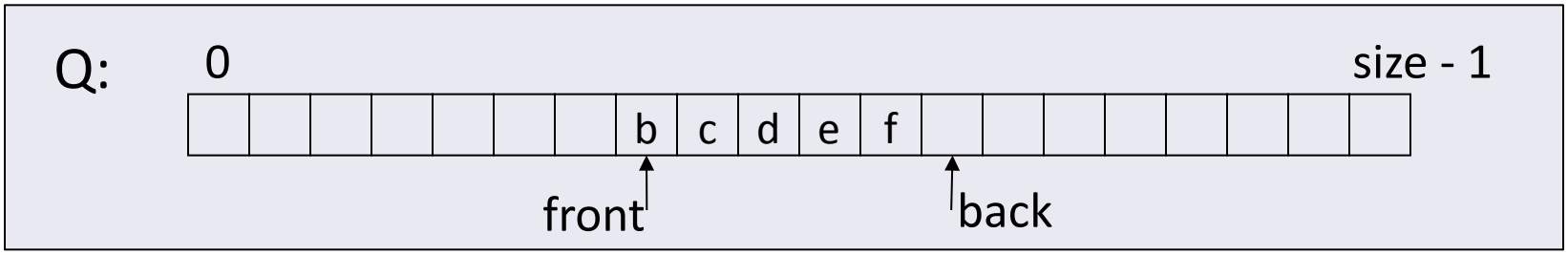
Implementing Queue ADT: Array Queue

- Keep track of the number of elements in the queue, `size`.
- Enqueue at the back of the array (`size`).
- Dequeue at the front of the array (index 0).
  - what is bad about this implementation?
  - what if we enqueue at 0 and dequeue at `size`?

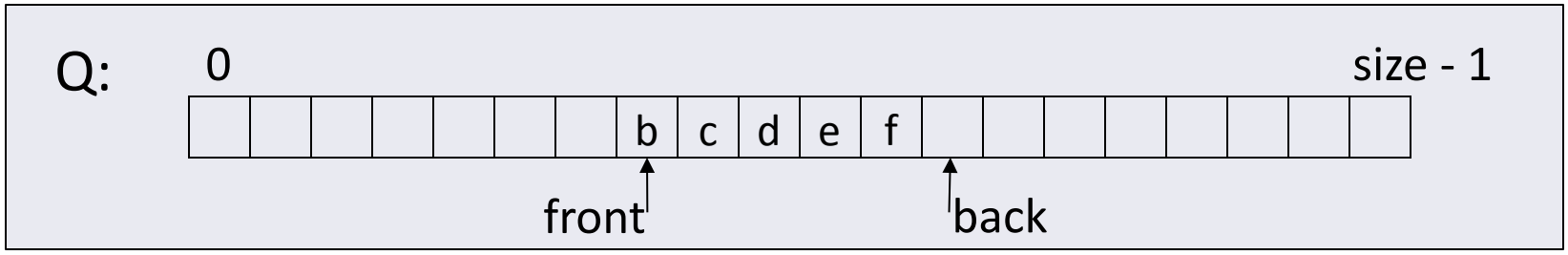
Implementing Queue ADT: Circular Array Queue

- **Neat trick**: use a ***circular array*** to insert and remove items from a queue in constant time.
- The idea of a circular array is that the end of the array "wraps around" to the start of the array.





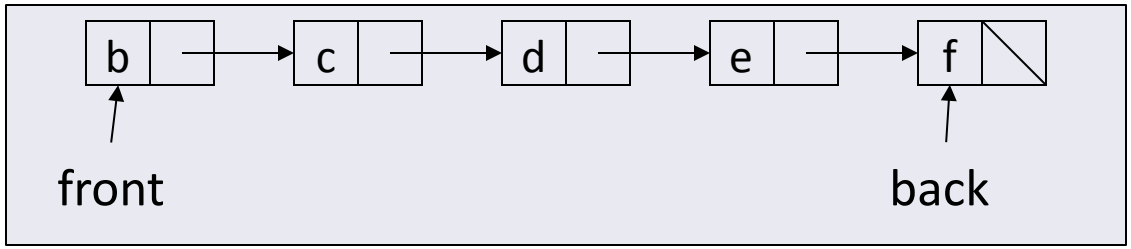
Circular Array Queue




```
// Basic idea only!
enqueue(x) {
  Q[back] = x;
  back = (back + 1) % size
}
```

```
// Basic idea only!
dequeue() {
  x = Q[front];
  front = (front + 1) % size;
  return x;
}
```

Linked List Queue




```
// Basic idea only!
enqueue(x) {
  back.next = new Node(x);
  back = back.next;
}
```

```
// Basic idea only!
dequeue() {
  x = front.item;
  front = front.next;
  return x;
}
```

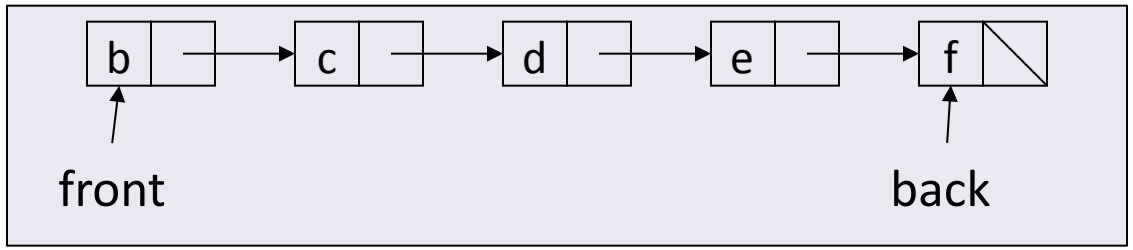
Queue: Circular Array vs. Linked List

- Circular Array
  - May waste unneeded space or run out of space
  - Space per element excellent
  - Operations very simple / fast
- Linked List
  - Always just enough space
  - But more space per element
  - Operations very simple / fast

- If we wanted add the ability to access the kth element to our queue, could both implementations support this?

Exercise: Linked List Queue Implementation

- Implement a queue class that stores String values using a singly linked list with both nodes to indicate the front and the back of the queue as below. The queue should implement the interface on the next slide.



String Queue Interface

```
/**
 * Interface for a queue of Strings.
 */
public interface StrQueue {
    /**
     * Tests if the queue is empty.
     */
    public boolean isEmpty();

    /**
     * Inserts an element at the end of the queue.
     */
    public void enqueue(String str);

    /**
     * Deletes and returns the element at the front of the queue.
     * @return the deleted value; throws NoSuchElementException if empty
     */
    public String dequeue();
}
```

Generic Queue Interface

```
/**
 * Interface for a queue.
 */
public interface Queue<E> {
    /**
     * Tests if the queue is empty.
     */
    public boolean isEmpty();

    /**
     * Inserts an element at the end of the queue.
     */
    public void enqueue(E e);

    /**
     * Deletes and returns the element at the front of the queue.
     * @return the deleted value; throws NoSuchElementException if empty
     */
    public E dequeue();
}
```