

CS350: Data Structures

Queues

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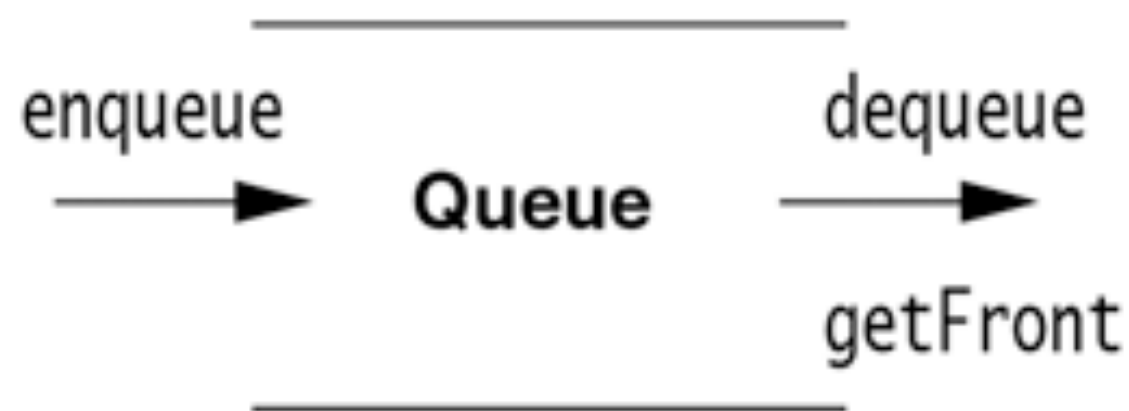
Queues

- **Queues are another very common data structure that can be used for a variety of data storage purposes**
- **Similar to a line of people waiting for a ride at an amusement park**
 - People enter the line/queue at the rear
 - People wait behind others that entered the line/queue before them
 - People exit from the front of the line/queue to get on the ride
 - People in the middle of the line/queue cannot get out without first advancing to the front of the line
 - There is no cutting
- **May also be referred to as a **FIFO** (First-In-First-Out)**

Queue Operations

- **Stacks have two main operations**

- **Enqueue** - inserts an element into the back of the queue
- **Dequeue** - removes a single element from the front of the queue



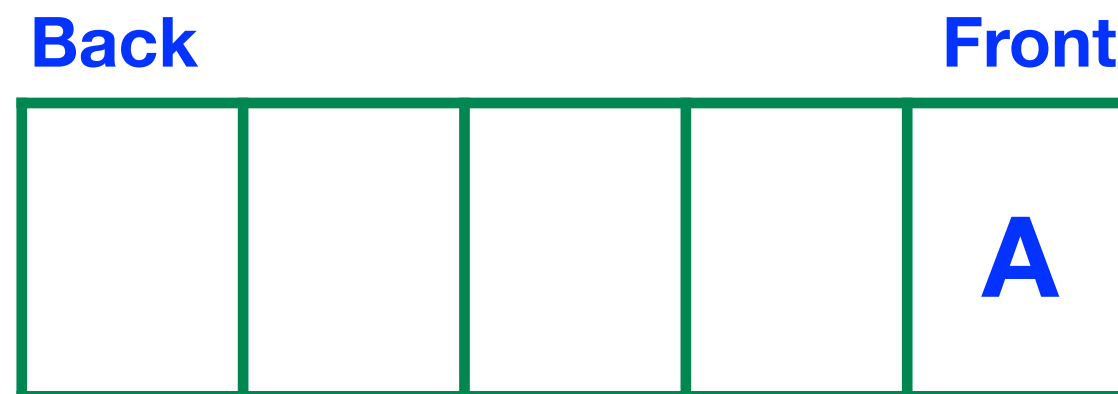
Queue Operations

Start with Empty Queue



Queue Operations

Enqueue Value: A



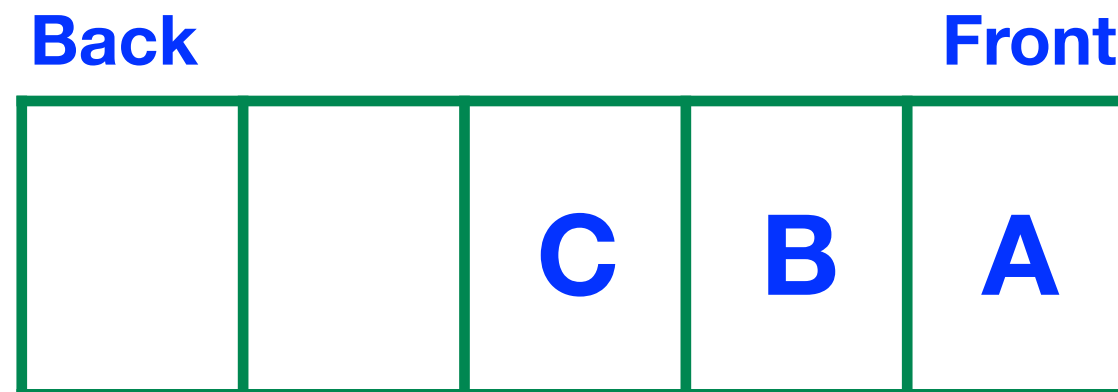
Queue Operations

Enqueue Value: B



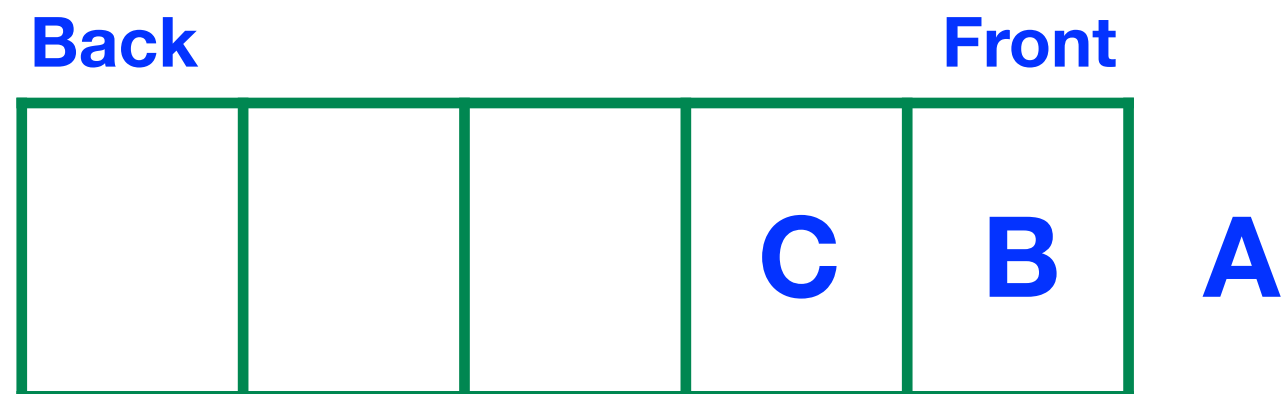
Queue Operations

Enqueue Value: C



Queue Operations

Dequeue the Front of the Queue:



Queue Interface

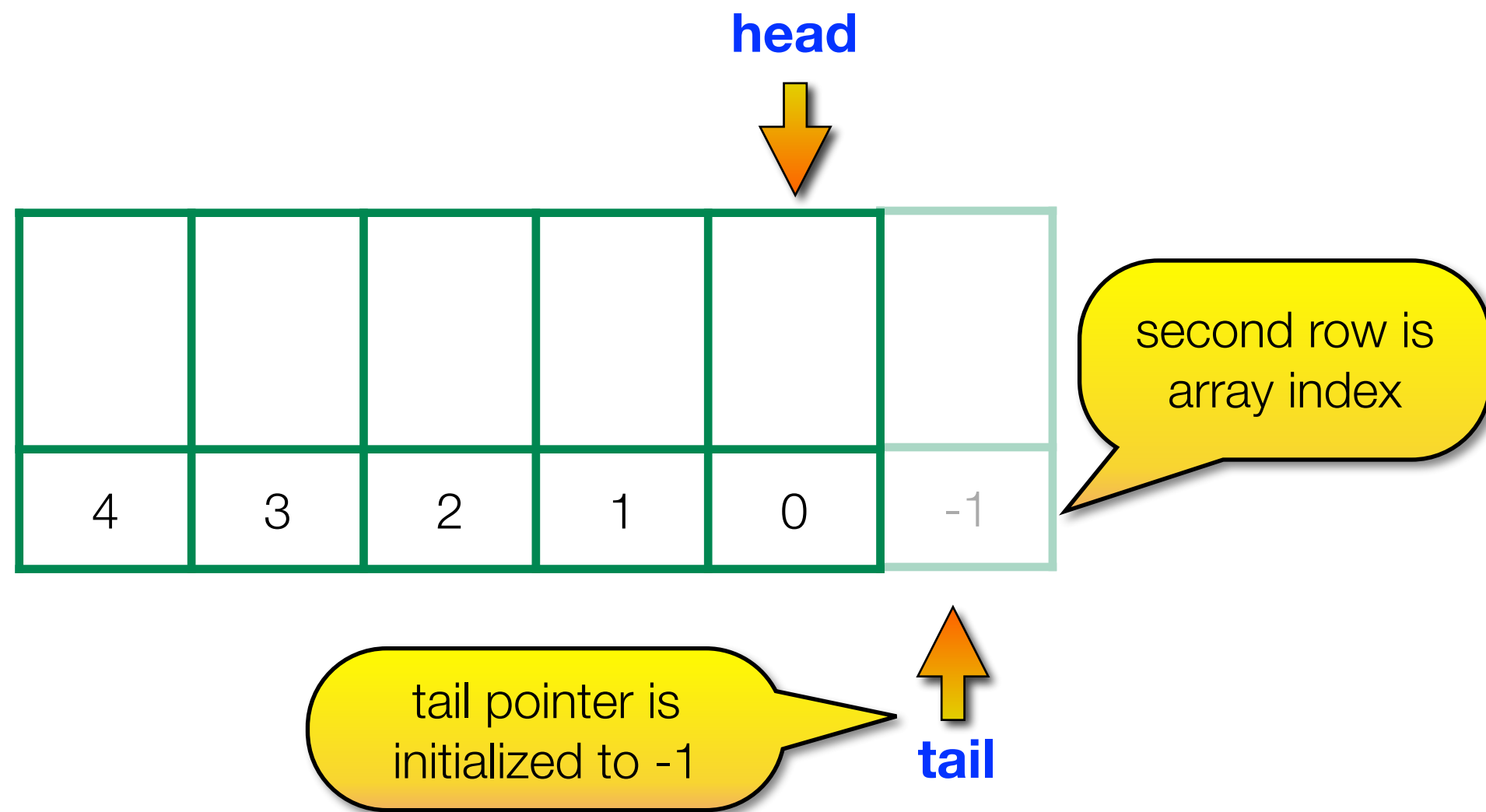
```
public interface Queue<AnyType> {  
    public void    enqueue( AnyType x );  
  
    public AnyType dequeue( );  
  
    public AnyType getFront( );  
  
    public boolean isEmpty( );  
  
    public void    makeEmpty( );  
}
```

Queue Implementations

- **Queues can be implemented in multiple ways**
- **Two popular methods for implementing queues include**
 - (1) Arrays
 - (2) Linked Lists
- **Both of these implementation approaches allow for constant time operations - $O(1)$**

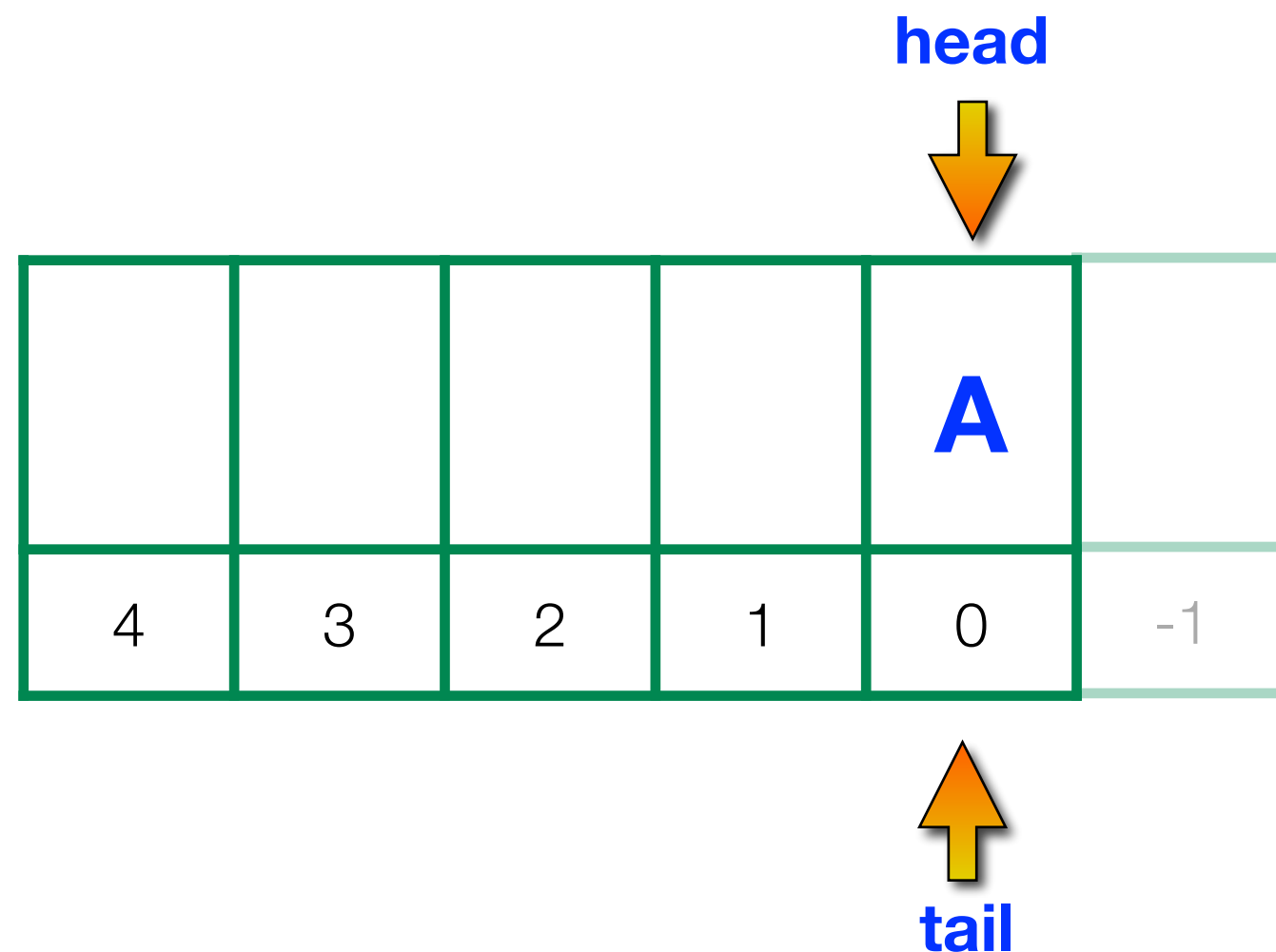
Queue Implementation Using an Array

Start with Empty Queue (i.e. an array)



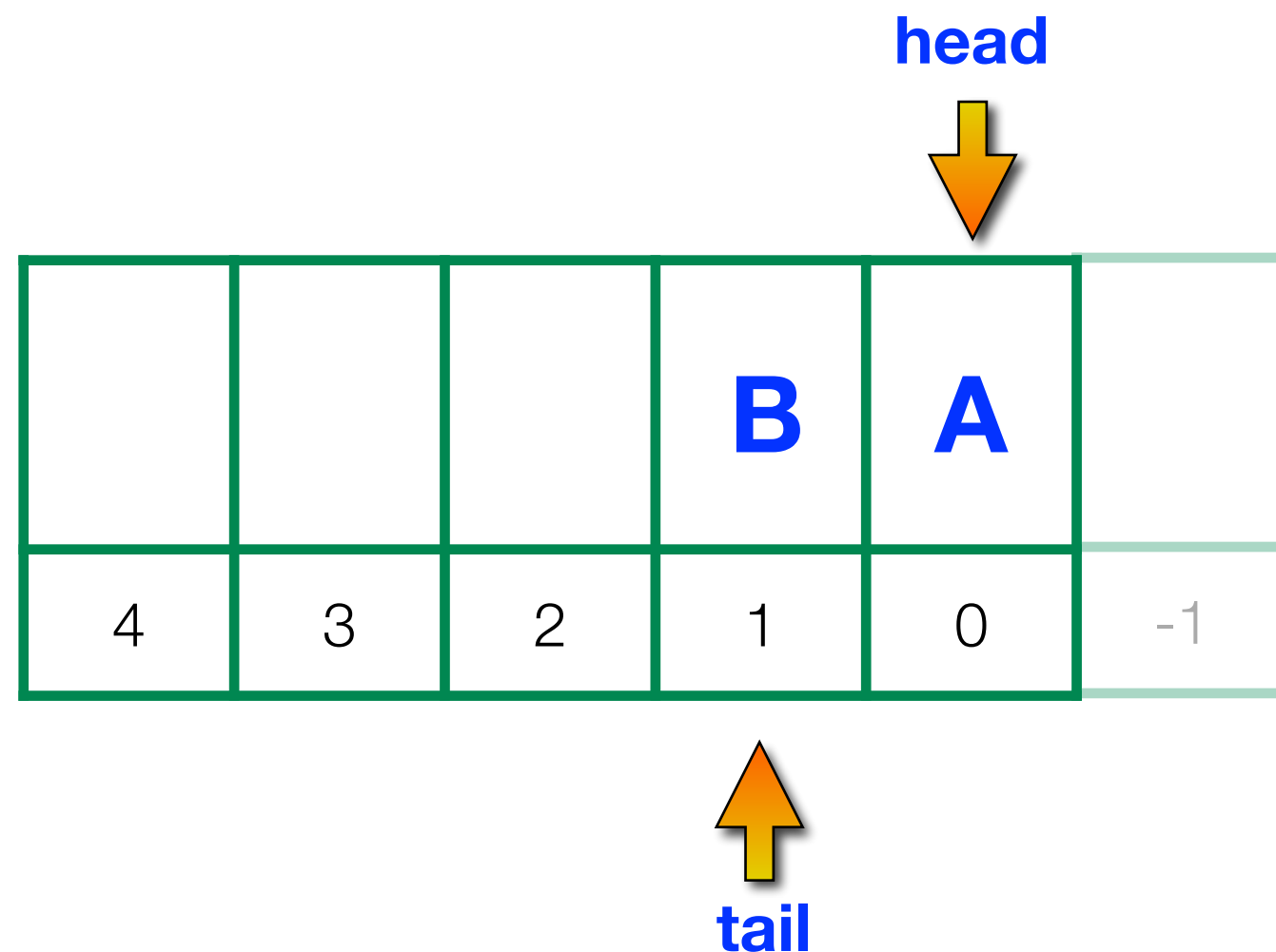
Queue Implementation Using an Array

Enqueue Value: A



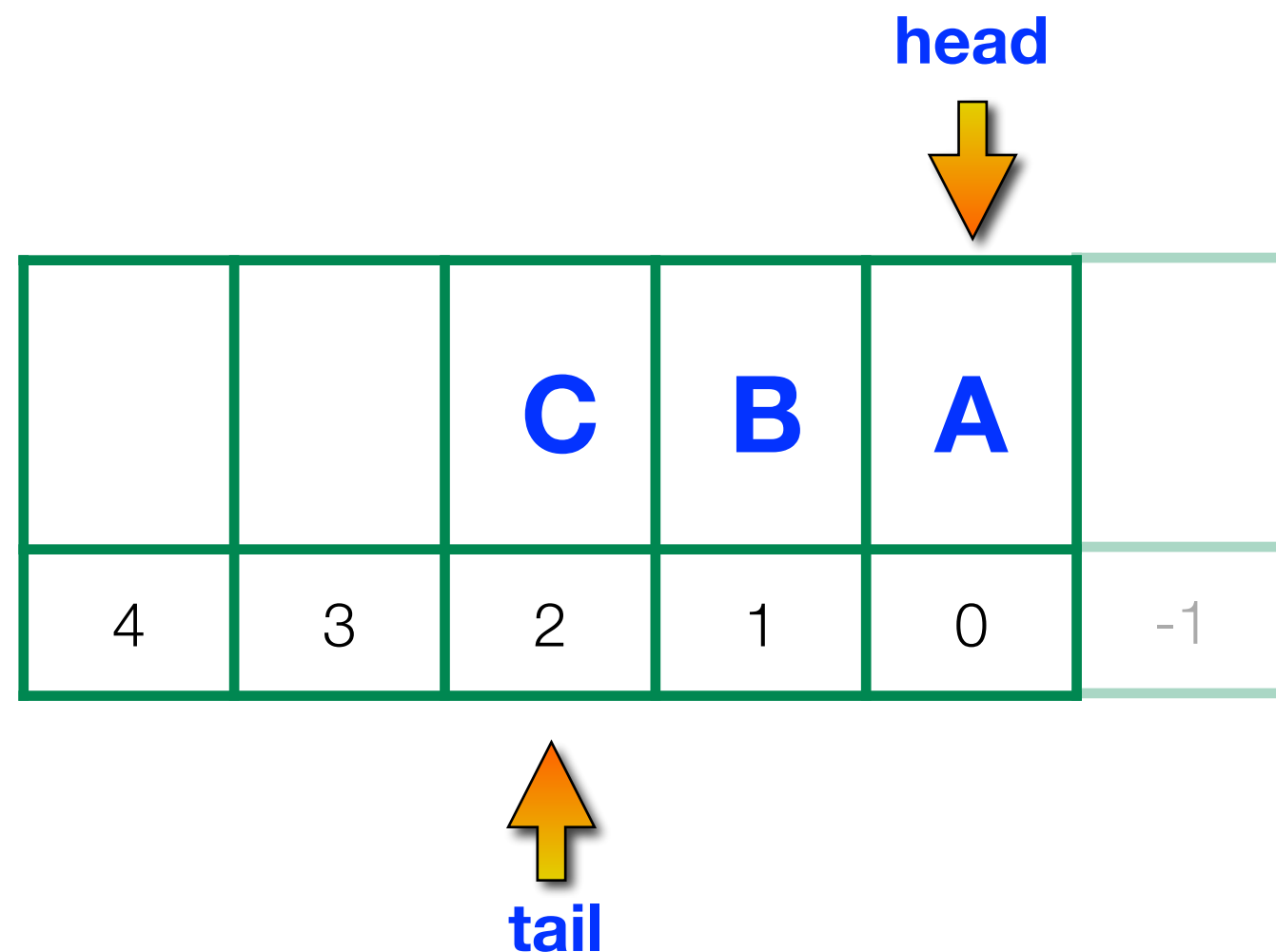
Queue Implementation Using an Array

Enqueue Value: B



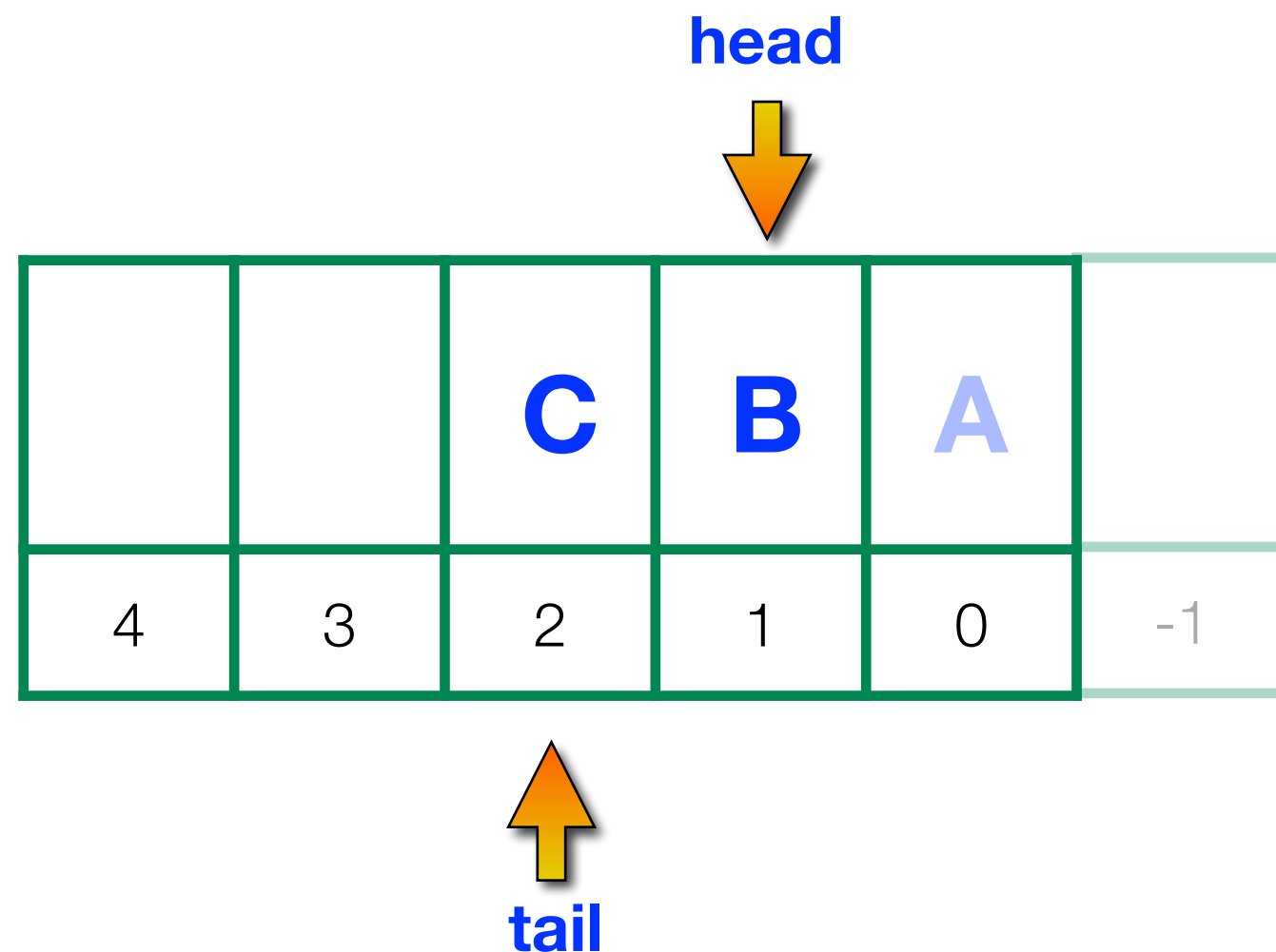
Queue Implementation Using an Array

Enqueue Value: C



Queue Implementation Using an Array

Dequeue the Front of the Queue:



Queue Implementation Using an Array

- **Considerations when using an array implementation**

- Enqueue, and Dequeue operations run in constant time ... in most cases
- What happens when your array is full and you want to Enqueue another element?
 - Array must be increased in size which takes time and more memory
 - Time to copy and create new array is $O(N)$
 - Time to copy array is amortized over the lifetime of the array
 - May not be suitable for all types of systems (e.g. RTOS)

Queue Implementation Using an Array

```
/**
 * Queue constructor
 */
public ArrayQueue( )
{
    theArray = (AnyType []) new Object[ DEFAULT_CAPACITY ];
    makeEmpty( );
}
```

Queue Implementation Using an Array

```
/**
 * Test if the queue is logically empty.
 * @return true if empty, false otherwise.
 */
public boolean isEmpty( )
{
    return currentSize == 0;
}
```

Queue Implementation Using an Array

```
/**  
 * Make the queue logically empty.  
 */  
public void makeEmpty( )  
{  
    currentSize = 0;  
    front = 0;  
    back = -1;  
}
```

Queue Implementation Using an Array

```
/**
 * Insert a new item into the queue.
 * @param x the item to insert.
 */
public void enqueue( AnyType x )
{
    if( currentSize == theArray.length )
        doubleQueue( );
    back = increment( back );
    theArray[ back ] = x;
    currentSize++;
}
```

Queue Implementation Using an Array

```
/**
 * Return and remove the least recently inserted item
 * from the queue.
 * @return the least recently inserted item in the queue.
 * @throws UnderflowException if the queue is empty.
 */
public AnyType dequeue( )
{
    if( isEmpty( ) )
        throw new UnderflowException( "ArrayQueue dequeue" );
    currentSize--;

    AnyType returnValue = theArray[ front ];
    front = increment( front );
    return returnValue;
}
```

Queue Implementation Using an Array

```
/**
 * Internal method to increment with wraparound.
 * @param x any index in theArray's range.
 * @return x+1, or 0 if x is at the end of theArray.
 */
private int increment( int x )
{
    if( ++x == theArray.length )
        x = 0;
    return x;
}
```

Queue Implementation Using an Array

```
/**
 * Internal method to expand theArray.
 */
private void doubleQueue( )
{
    AnyType [ ] newArray;

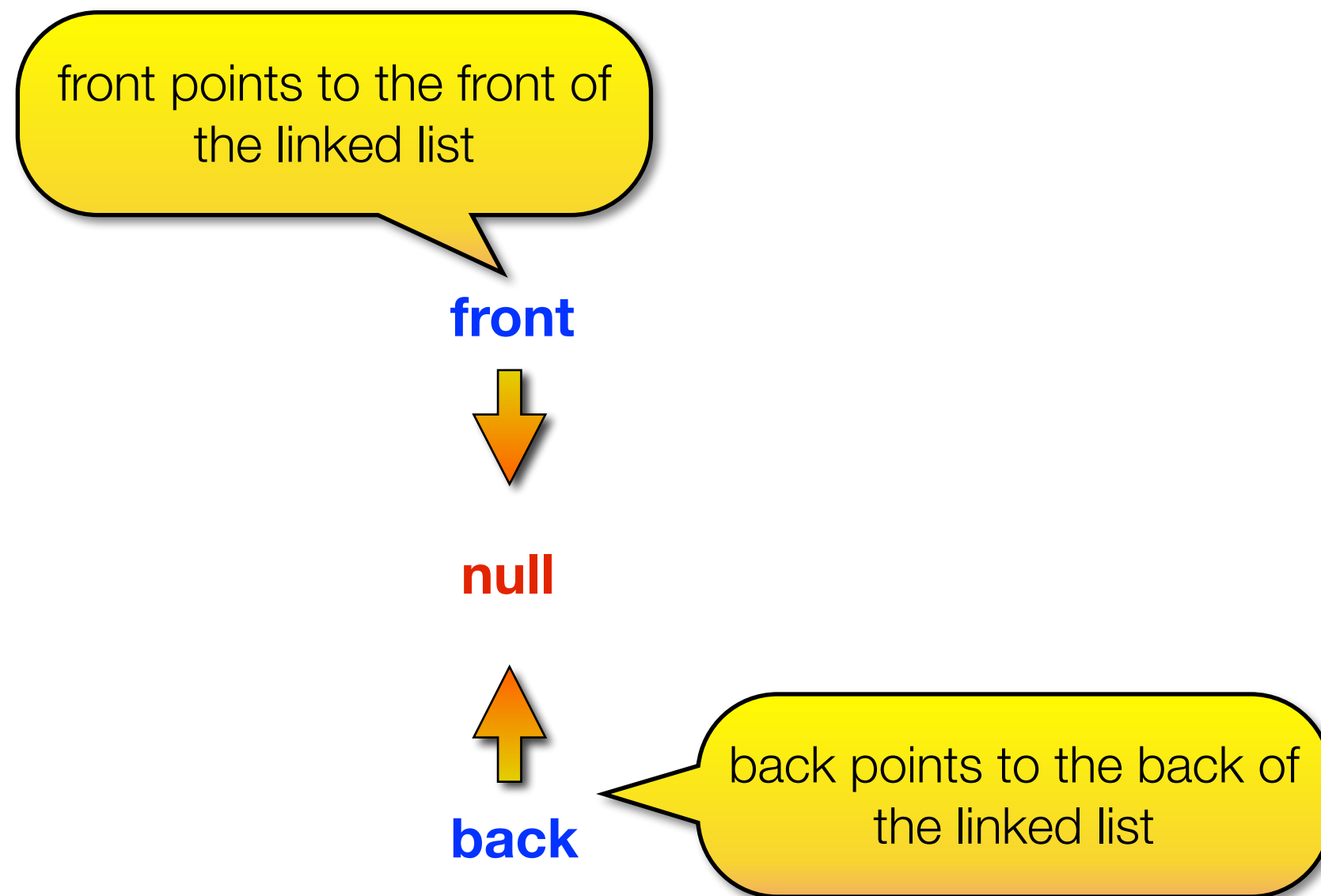
    newArray = (AnyType []) new Object[ theArray.length * 2 ];

    // Copy elements that are logically in the queue
    for( int i = 0; i < currentSize; i++,
        front = increment( front ) )
        newArray[ i ] = theArray[ front ];

    theArray = newArray;
    front = 0;
    back = currentSize - 1;
}
```

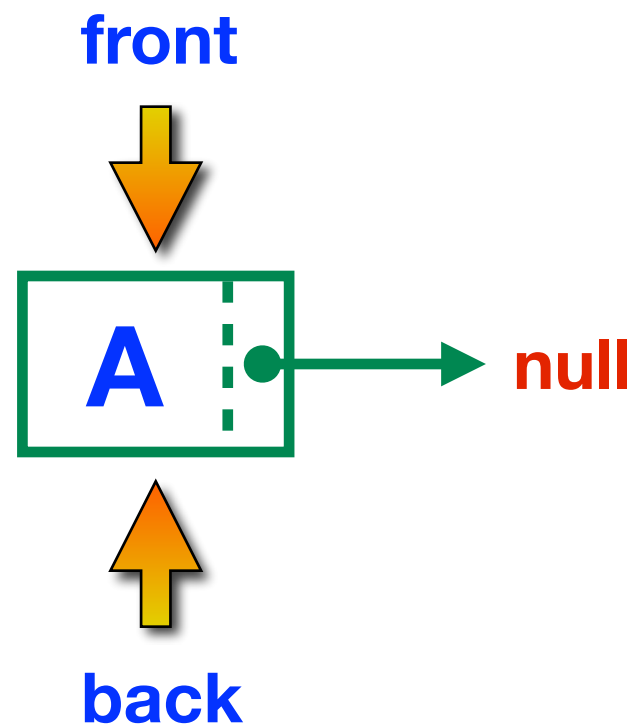
Queue Implementation Using a LinkedList

Start with Empty Queue (i.e. a null LinkedList)



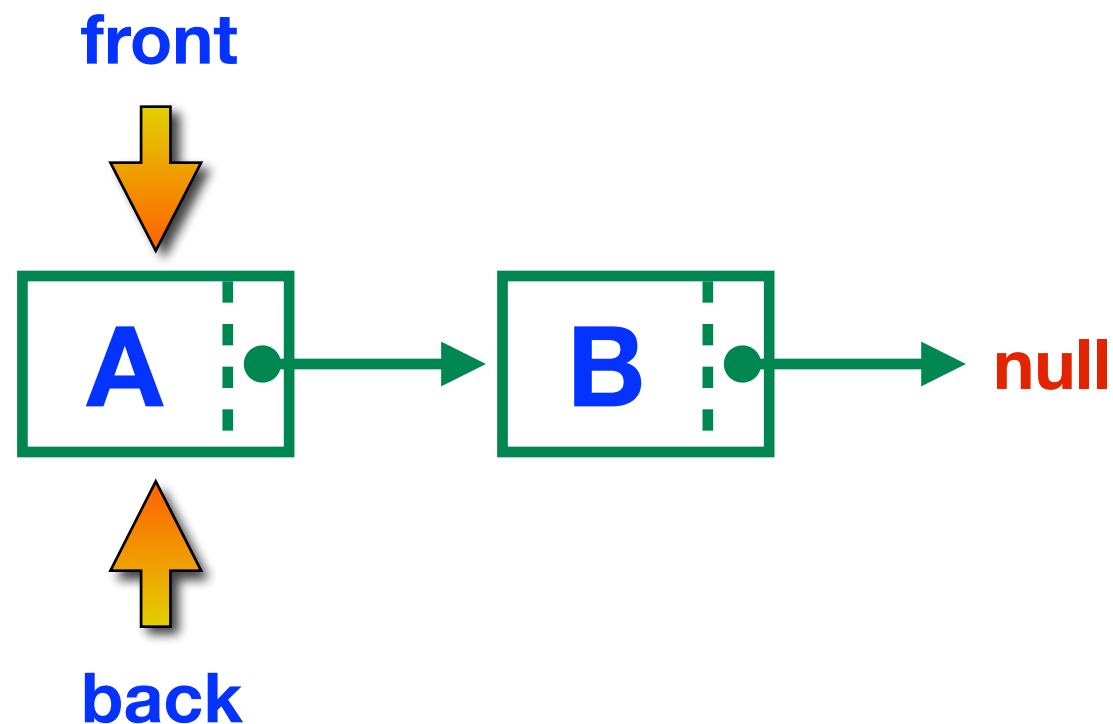
Queue Implementation Using a LinkedList

Enqueue Value: A



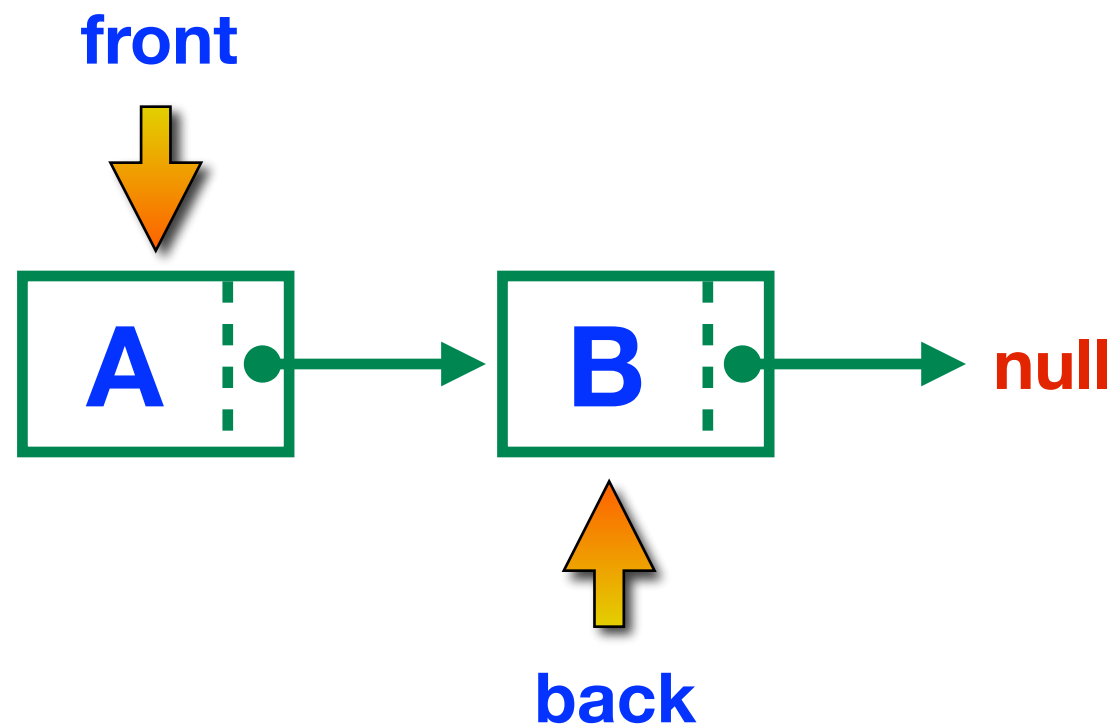
Queue Implementation Using a LinkedList

Enqueue Value: B



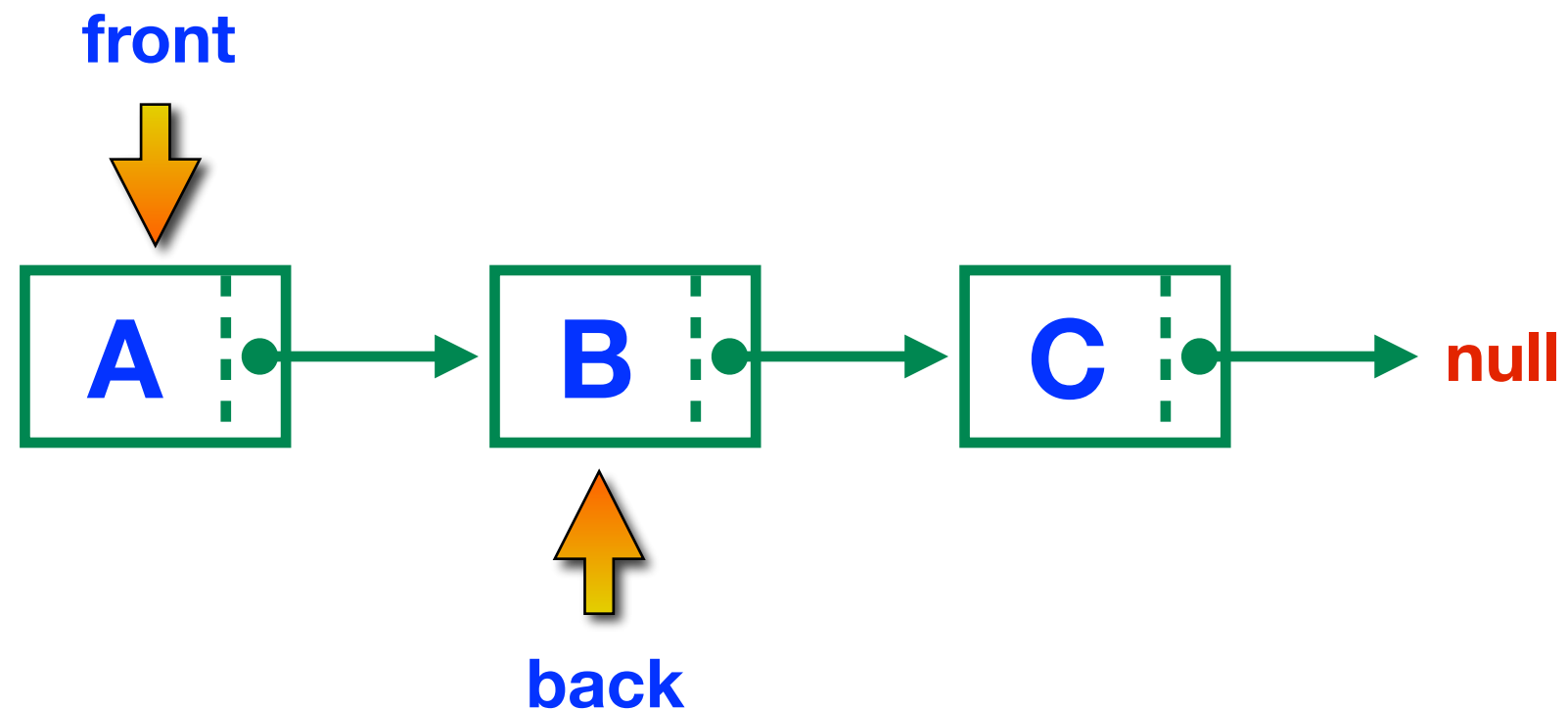
Queue Implementation Using a LinkedList

Enqueue Value: B



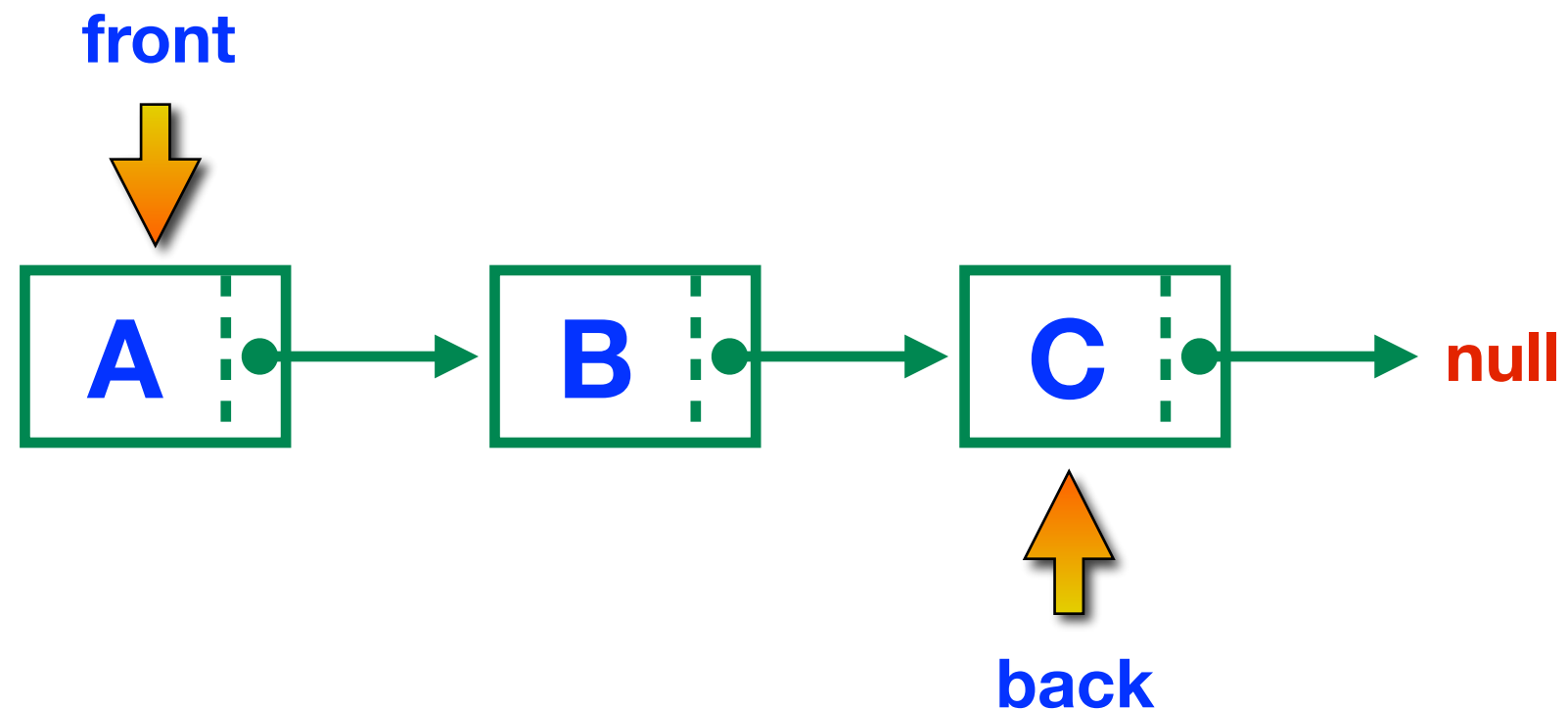
Queue Implementation Using a LinkedList

Enqueue Value: C



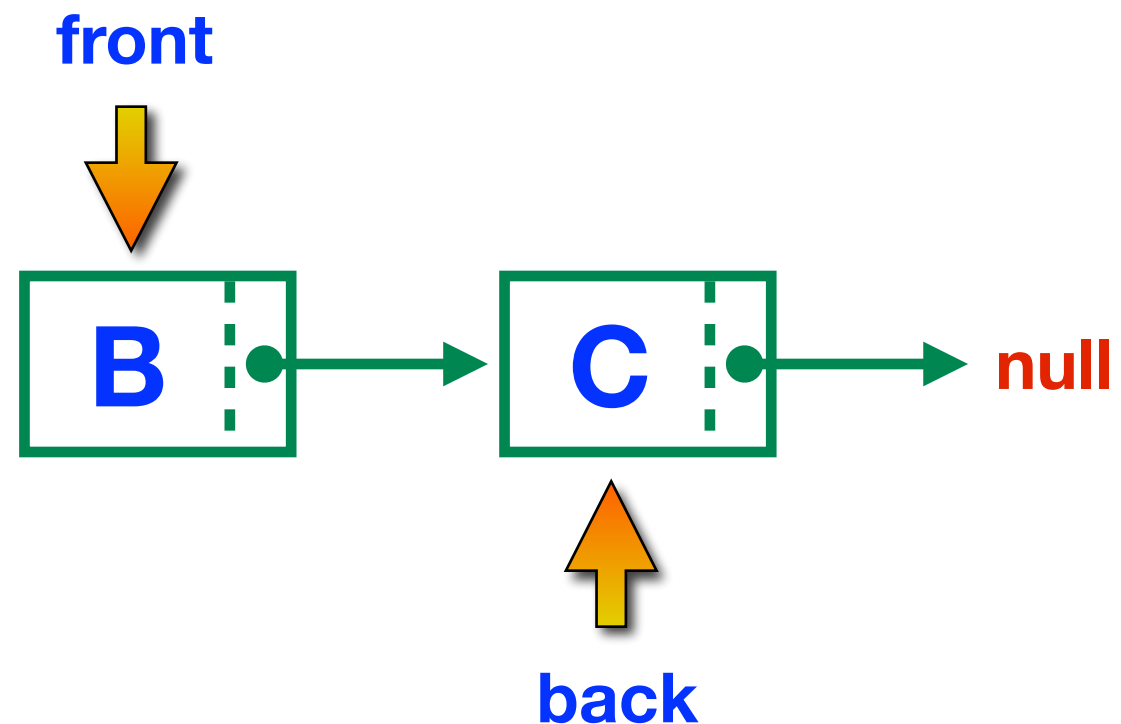
Queue Implementation Using a LinkedList

Enqueue Value: C



Queue Implementation Using a LinkedList

Dequeue the Front of the Queue:



Queue Implementation Using a LinkedList

- **Considerations when using an queue implementation**

- Enqueue and Dequeue operations run in constant time ... still
- Each element inserted into the queue requires a pointer to the data and a second pointer to the next node in the LinkedList

Queue Implementation Using a LinkedList

```
/**
 * Queue constructor
 */
public ListQueue( )
{
    front = back = null;
}

private ListNode<AnyType> front;
private ListNode<AnyType> back;
```


Queue Implementation Using a LinkedList

```
/**
 * Test if the queue is logically empty.
 * @return true if empty, false otherwise.
 */
public boolean isEmpty( )
{
    return front == null;
}
```

Queue Implementation Using a LinkedList

```
/**
 * Make the queue logically empty.
 */
public void makeEmpty( )
{
    front = null;
    back = null;
}
```

Queue Implementation Using a LinkedList

```
/**
 * Insert a new item into the queue.
 * @param x the item to insert.
 */
public void enqueue( AnyType x )
{
    if( isEmpty( ) )    // Make queue of one element
        back = front = new ListNode<AnyType>( x );
    else                // Regular case
        back = back.next = new ListNode<AnyType>( x );
}
```

Queue Implementation Using a LinkedList

```
/**
 * Return and remove the least recently inserted item
 * from the queue.
 * @return the least recently inserted item in the queue.
 * @throws UnderflowException if the queue is empty.
 */
public AnyType dequeue( )
{
    if( isEmpty( ) )
        throw new UnderflowException( "ListQueue dequeue" );

    AnyType returnValue = front.element;
    front = front.next;
    return returnValue;
}
```