CS350: Data Structures

Queues

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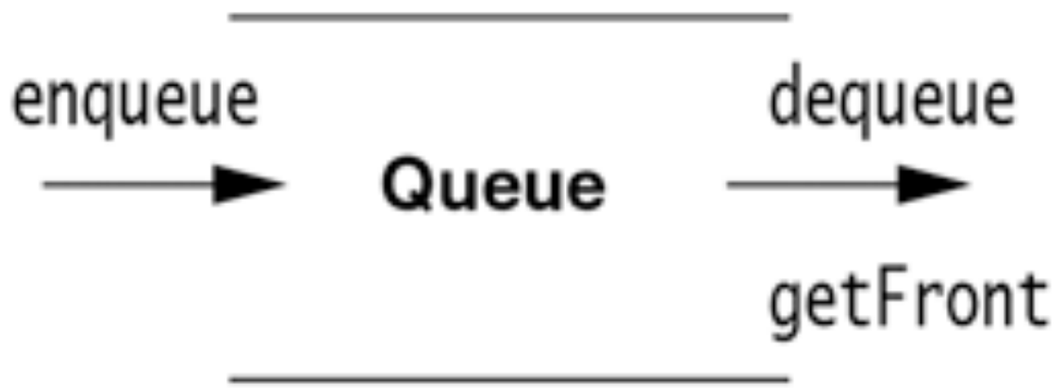
Queues

- **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

- **Queues have two main operations**
  - **`Enqueue`** - inserts an element into the back of the queue
  - **`Dequeue`** - removes a single element from the front (i.e. the head) of the queue



Queue Operations

Start with Empty Queue

Queue Operations

Enqueue Value: A

Queue Operations

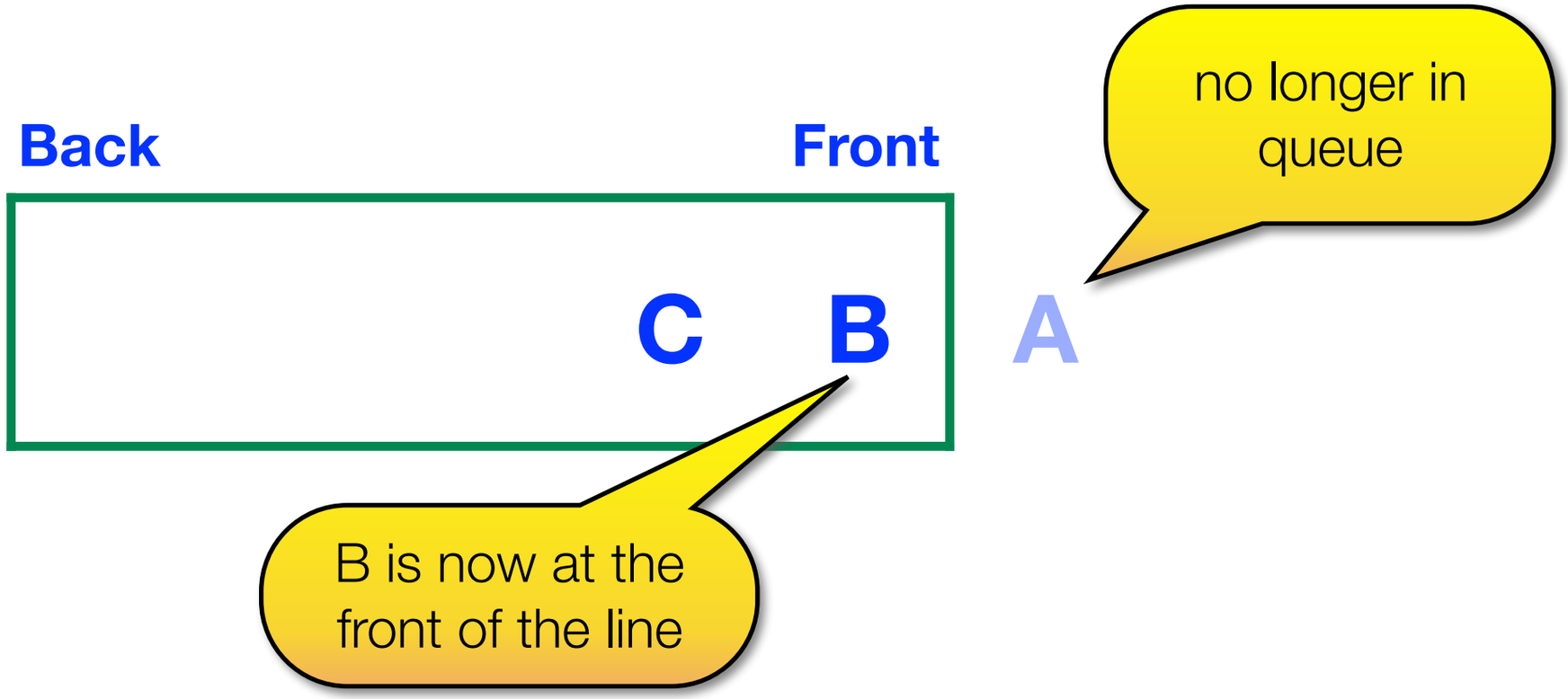
Enqueue Value: B

Queue Operations

Enqueue Value: C

Queue Operations

Dequeue the Front of the Queue:



Queue Interface (Java)

```
public interface Queue<AnyType> {

    public void    enqueue( AnyType x );

    public AnyType dequeue( );

    public AnyType getHead( );

    public boolean isEmpty( );

    public void    makeEmpty( );
}
```

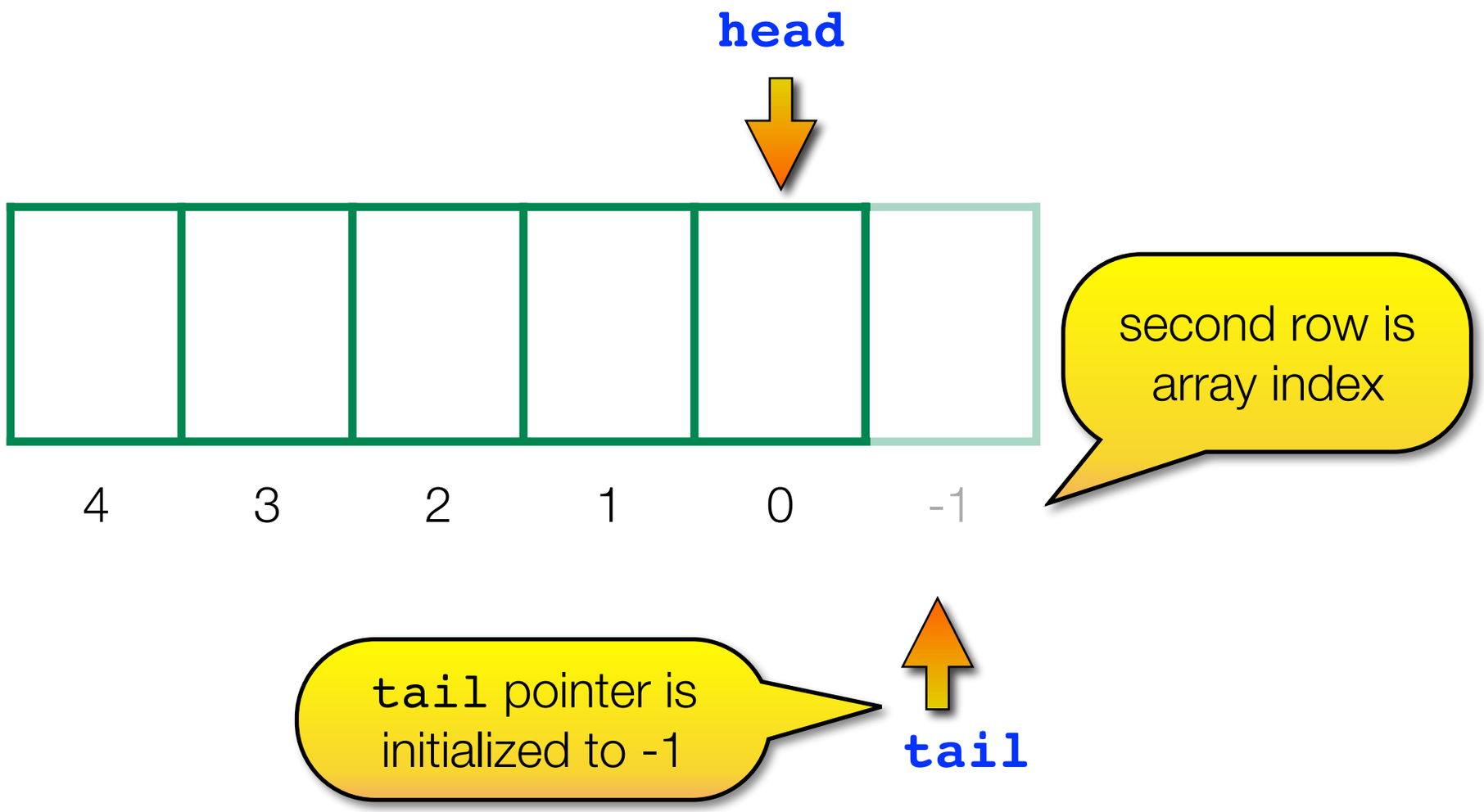
Queue Implementations

- **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)**

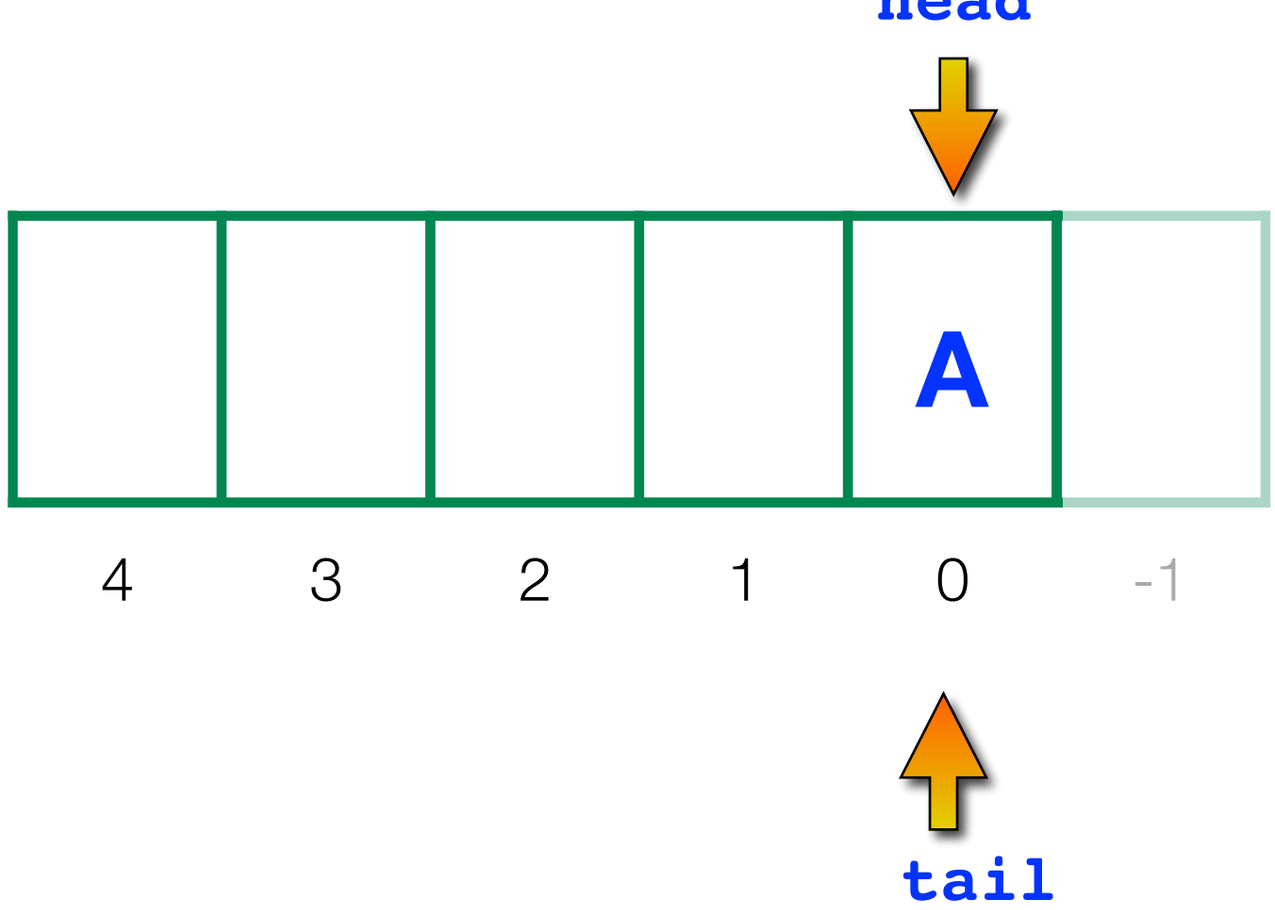
Queue Implementation Using an Array

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



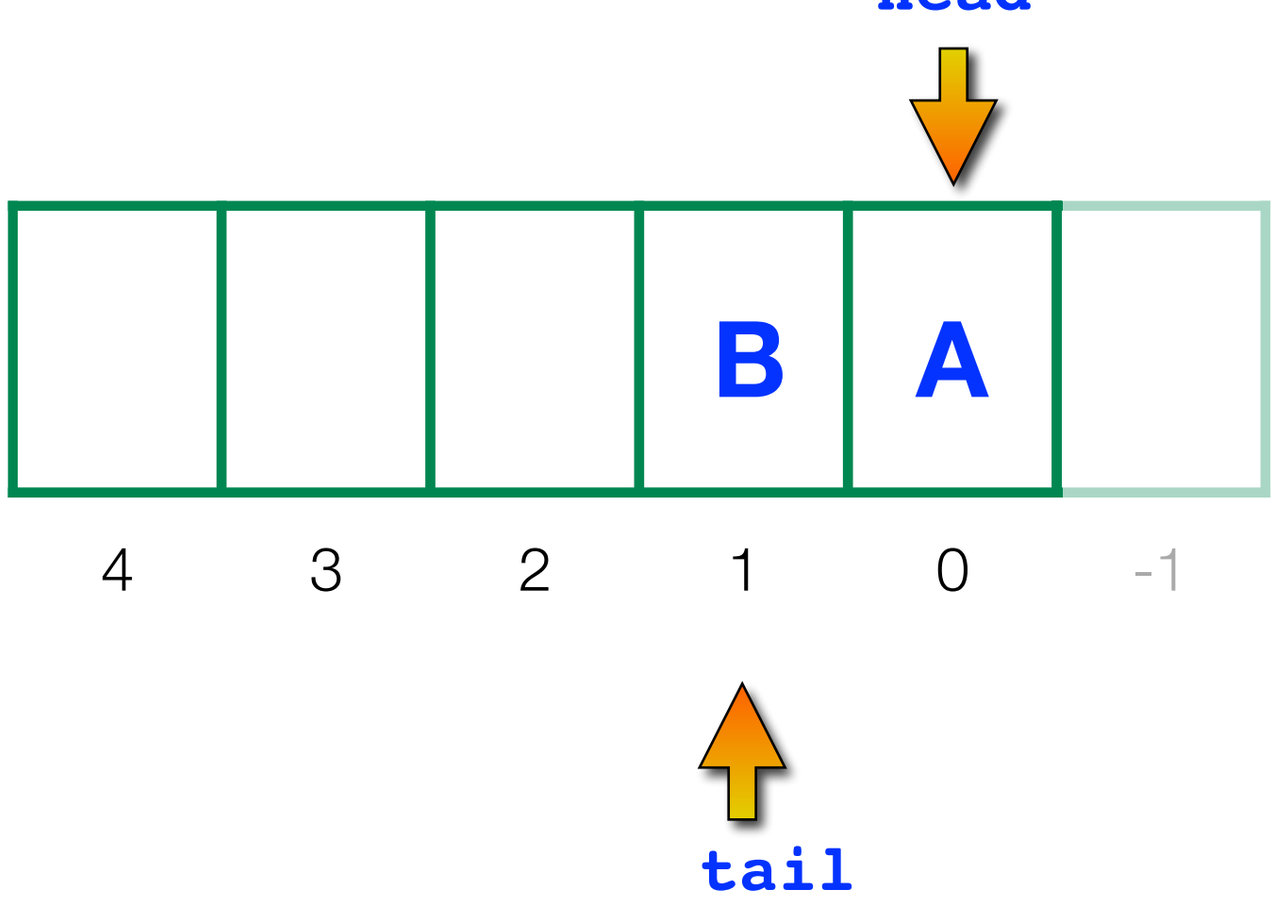
Queue Implementation Using an Array

After Enqueuing Value: A



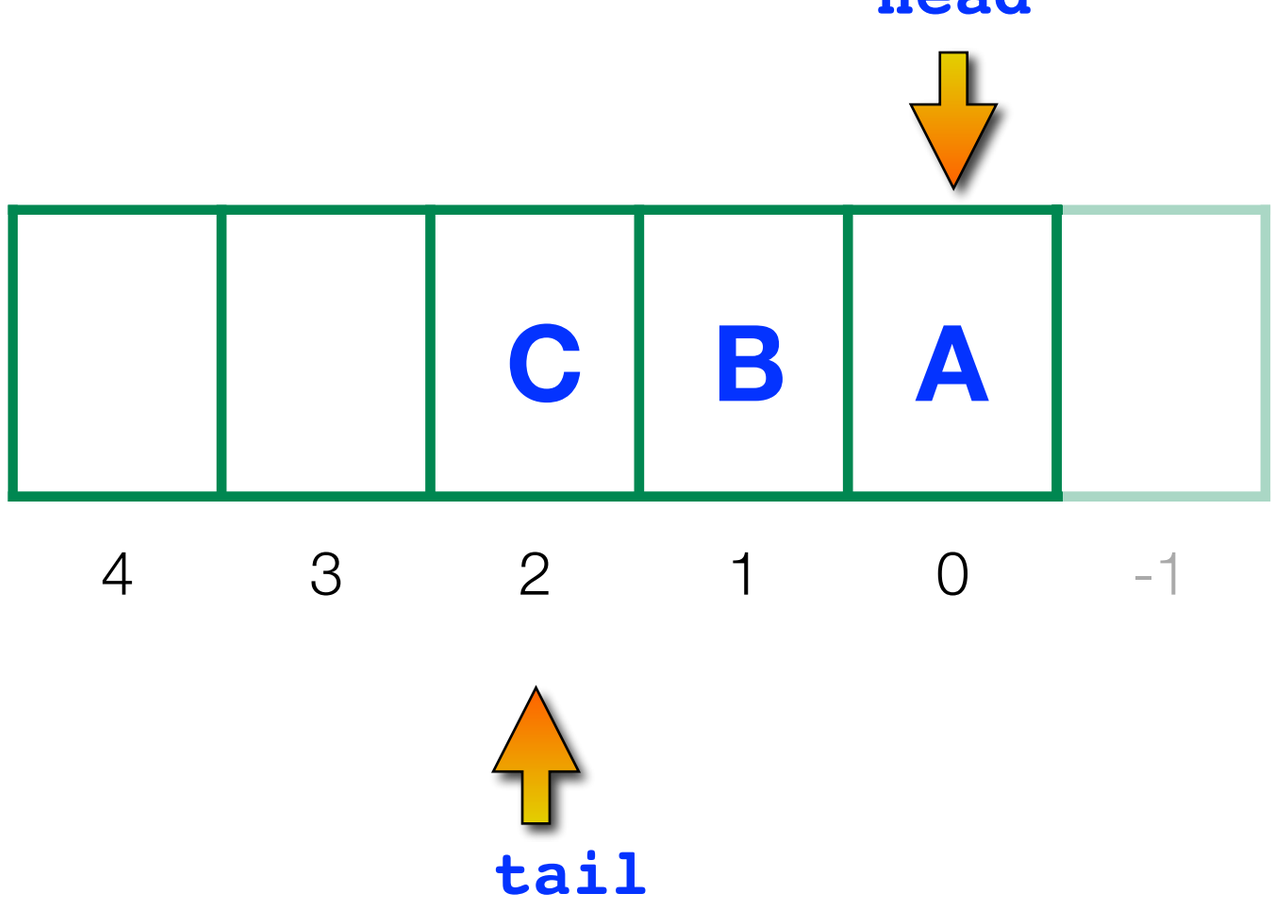
Queue Implementation Using an Array

After Enqueuing Value: B



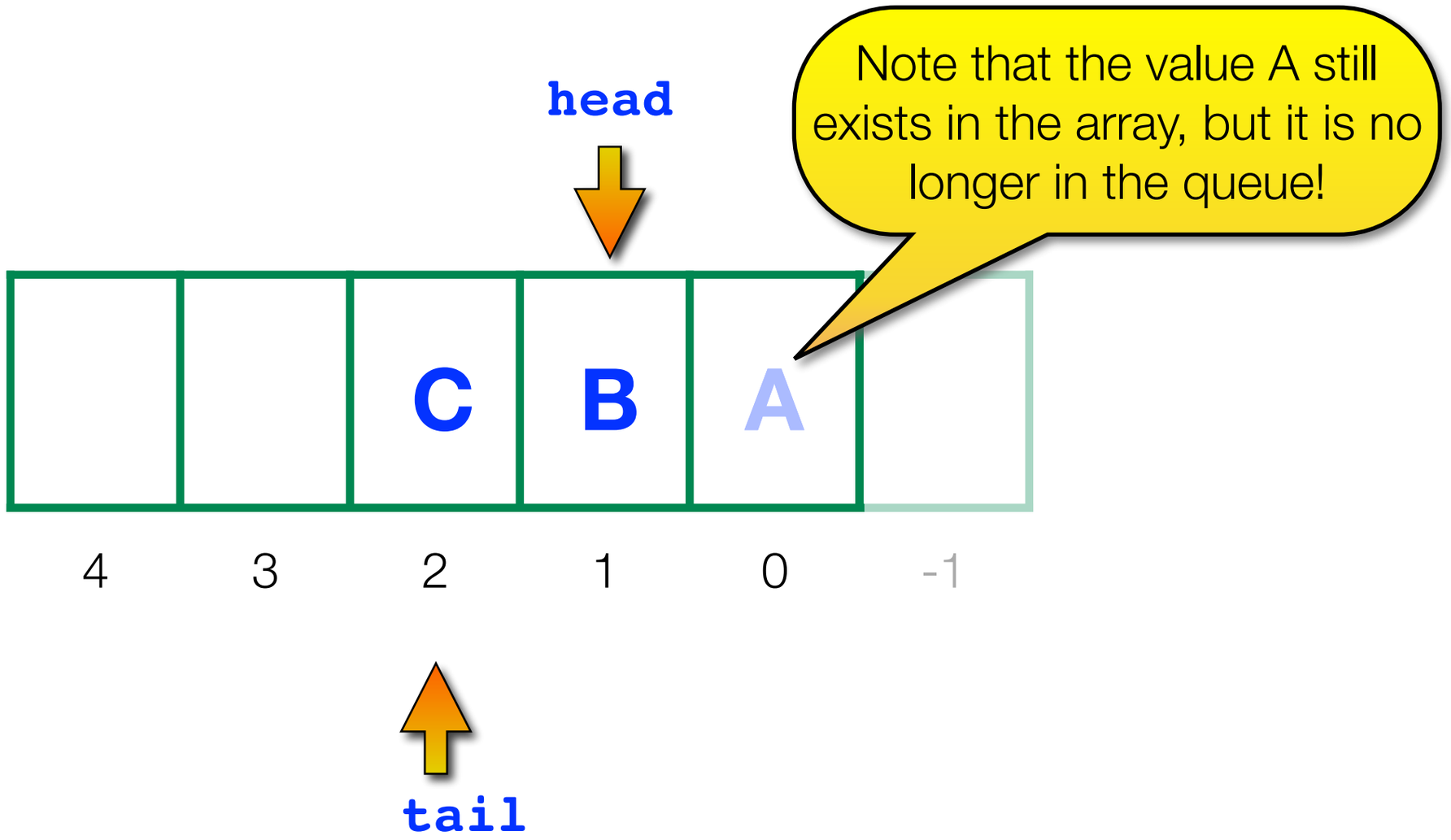
Queue Implementation Using an Array

After Enqueuing Value: C



Queue Implementation Using an Array

After Dequeuing the Head 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 an 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 (Java)

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

Queue Implementation Using an Array (Java)

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

Queue Implementation Using an Array (Java)

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

Queue Implementation Using an Array (Java)

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

Queue Implementation Using an Array (Java)

```
/**
 * 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[ head ];
    head = increment( head );
    return returnValue;
}
```

Queue Implementation Using an Array (Java)

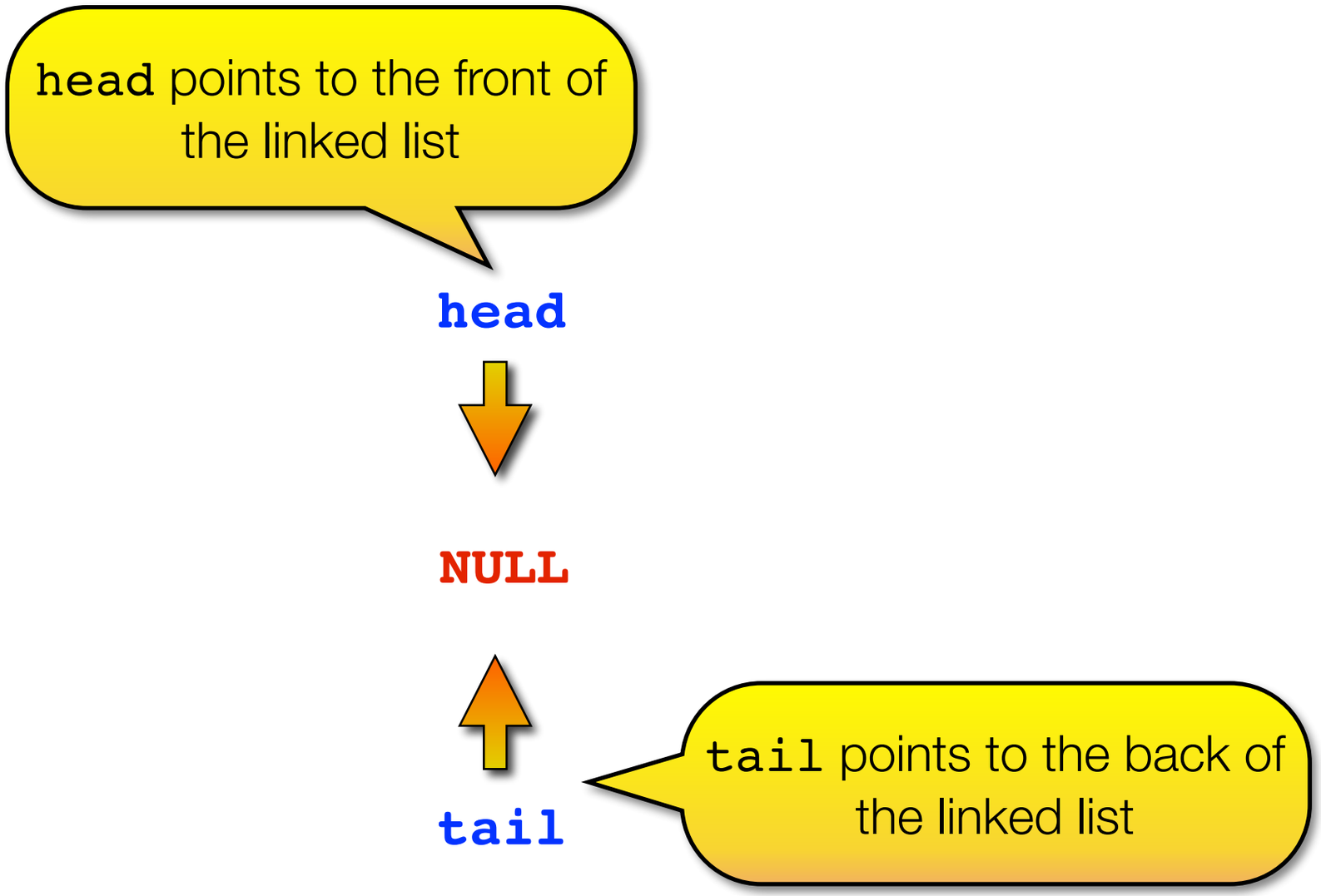
```
/**
 * Internal method to increment with wraparound.
 * @param x any index in theArray's range.
 * @return x+1, or 0 if x is at the end of theArray.
 */
private int increment( int x )
{
    if( ++x == theArray.length )
        x = 0;
    return x;
}
```

Queue Implementation Using an Array (Java)

```
    /**
     * 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++,
                                    head = increment( head ) )
            newArray[ i ] = theArray[ head ];

        theArray = newArray;
        head = 0;
        tail = currentSize - 1;
    }
```

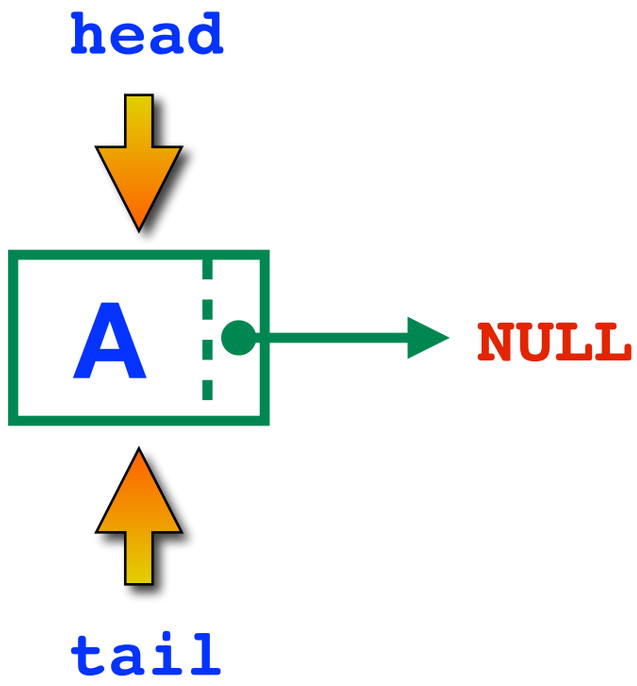
Queue Implementation Using a LinkedList

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



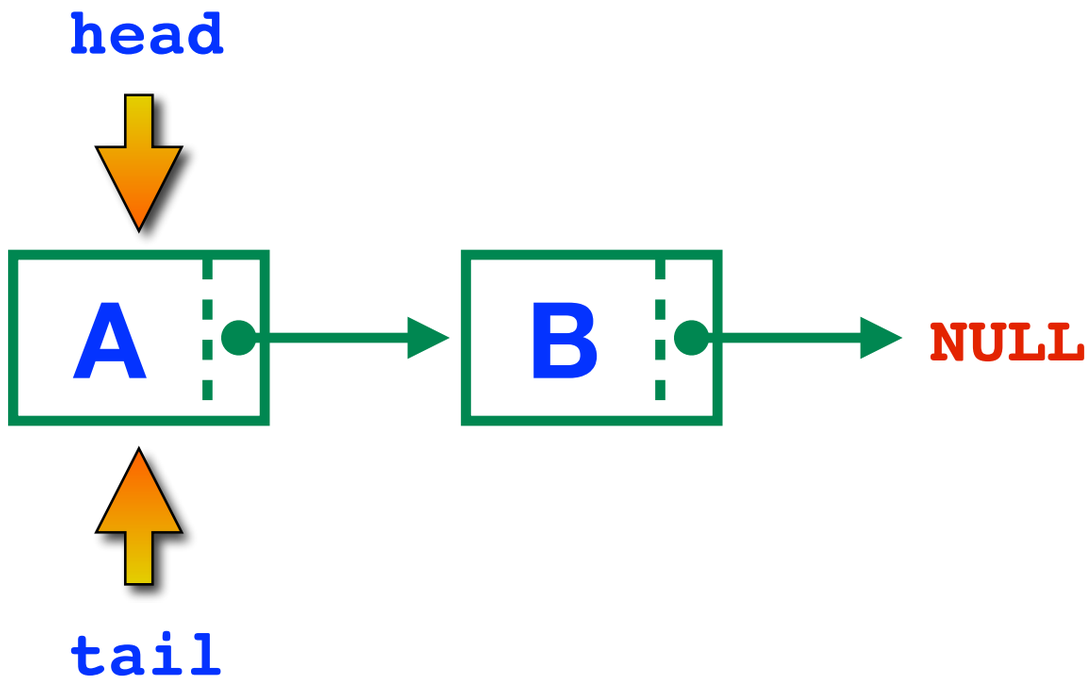
Queue Implementation Using a LinkedList

Enqueuing Value: A
Create node, then set head and tail



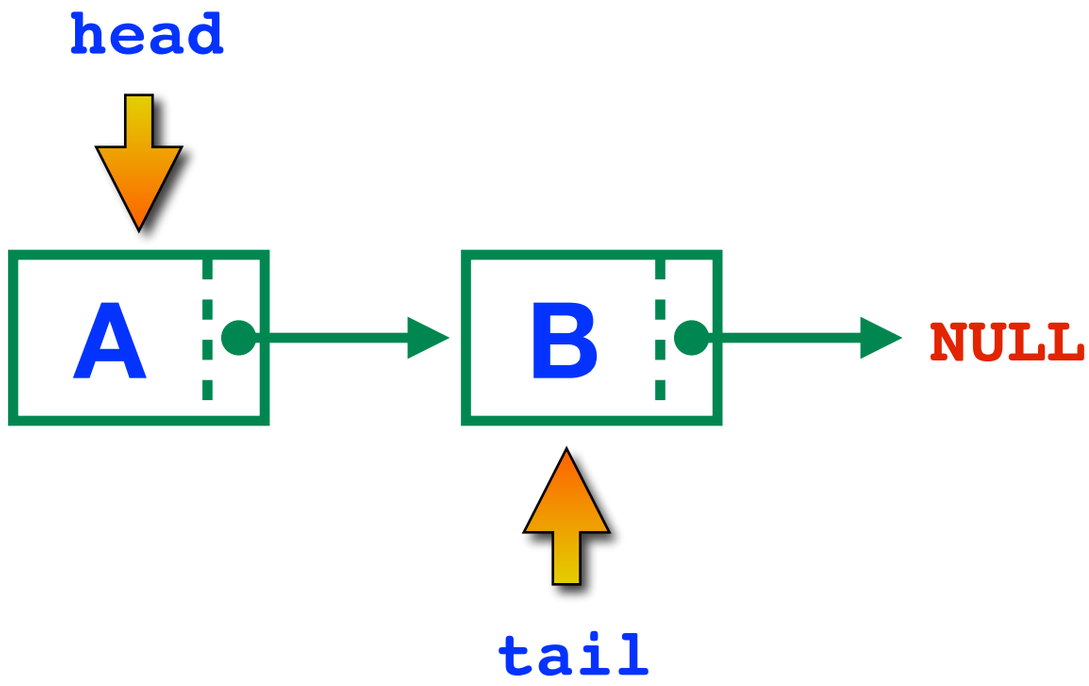
Queue Implementation Using a LinkedList

Enqueuing Value: B
First, create new node



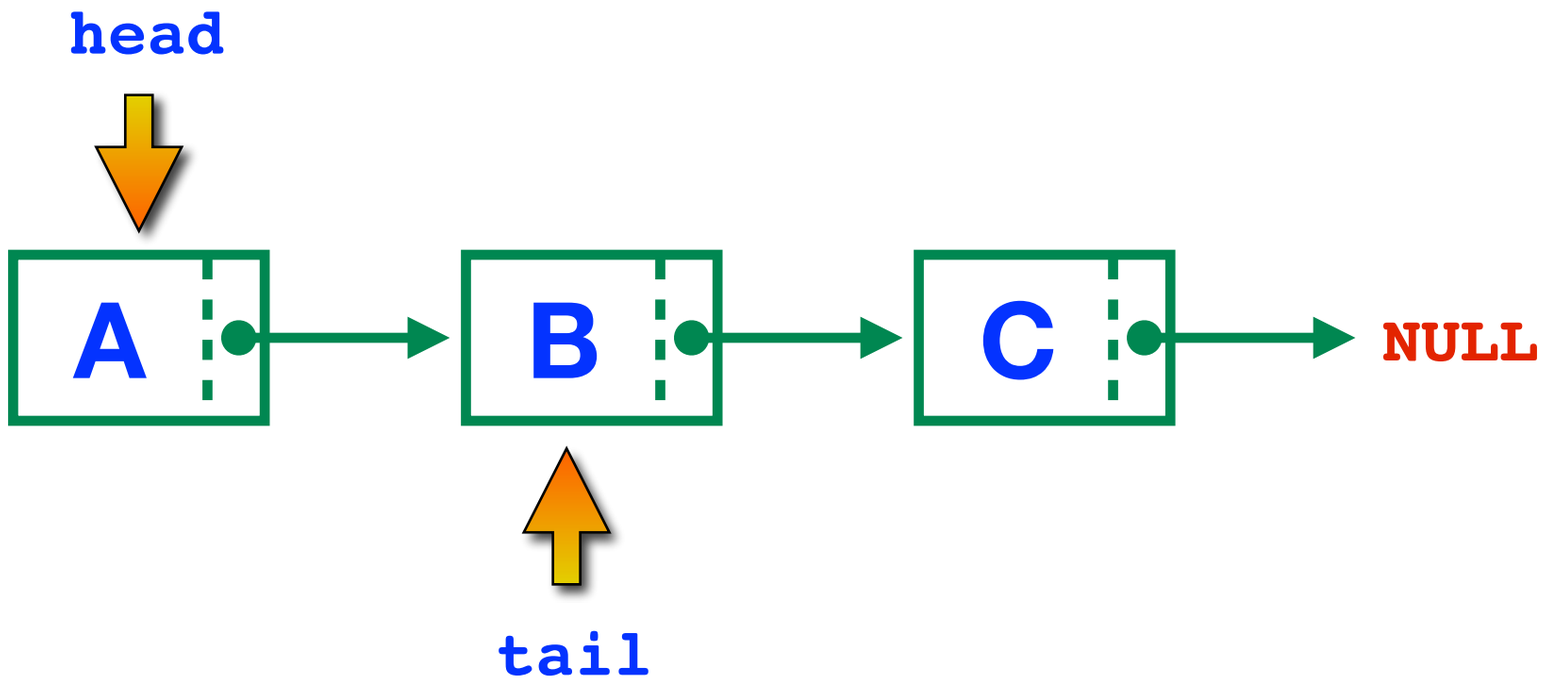
Queue Implementation Using a LinkedList

Enqueuing Value: B
Then set tail to new node



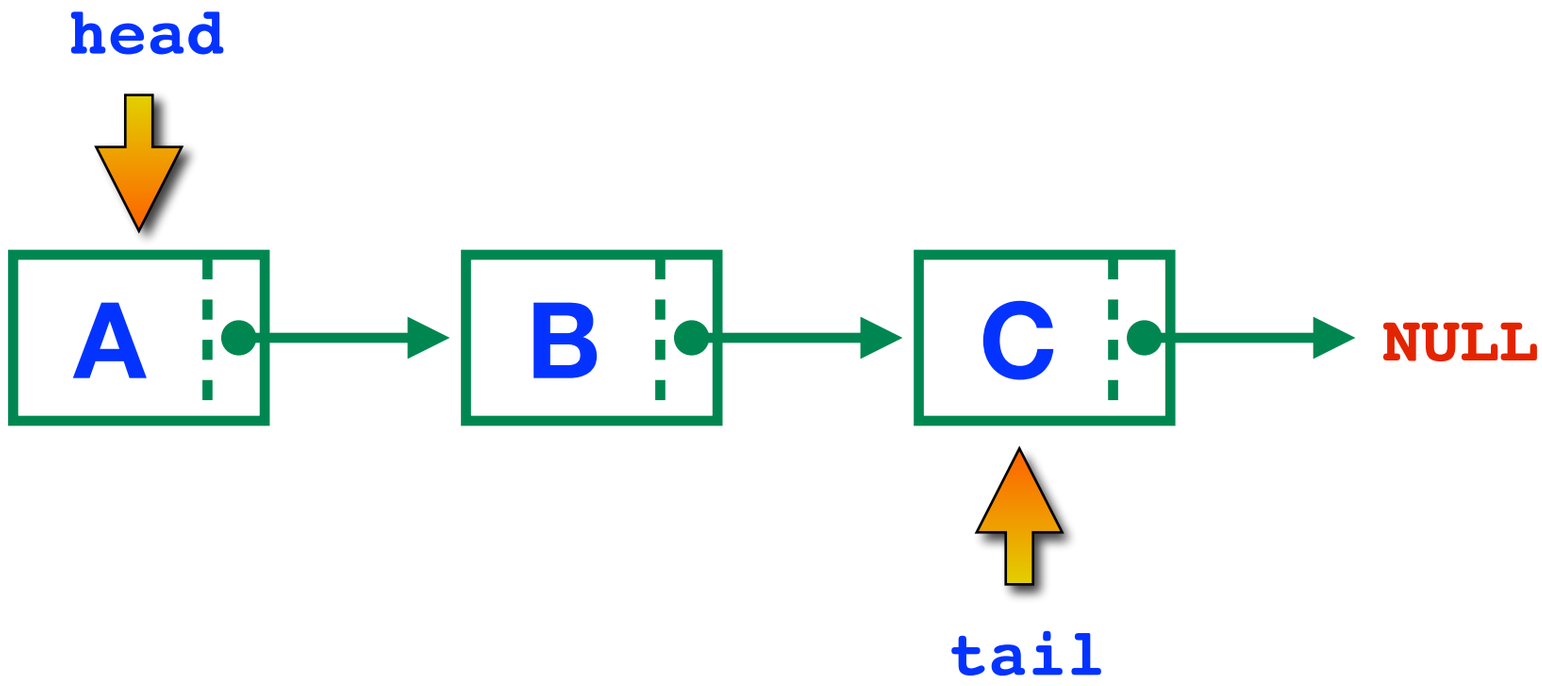
Queue Implementation Using a LinkedList

Enqueuing Value: C
First, create new node



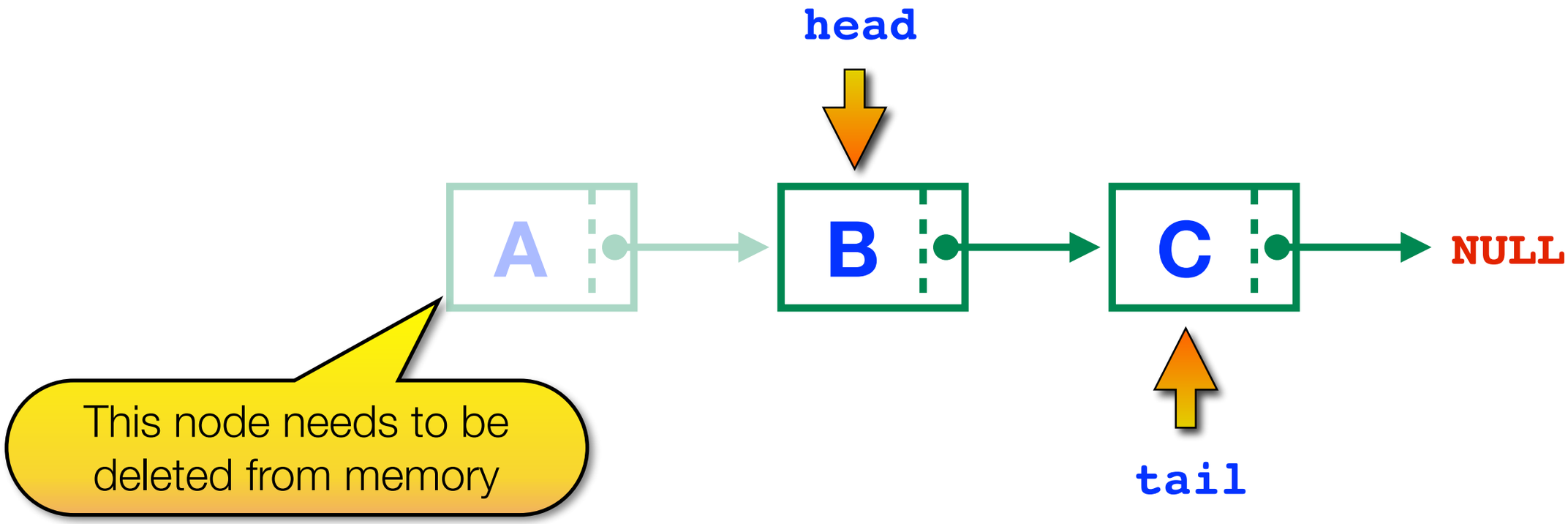
Queue Implementation Using a LinkedList

Enqueuing Value: C
Then set tail to new node



Queue Implementation Using a LinkedList

Dequeuing the Front of the Queue:
Advance head to "next" node
Delete the old head



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 (Java)

```
/**
 * Queue constructor
 */
public ListQueue( )
{
    head = tail = null;
}

private ListNode<AnyType> head;
private ListNode<AnyType> tail;
```

Queue Implementation Using a LinkedList (Java)

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

Queue Implementation Using a LinkedList (Java)

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

Queue Implementation Using a LinkedList (Java)

```
/**
 * 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
        tail = head = new ListNode<AnyType>( x );
    else                 // Regular case
        tail = tail.next = new ListNode<AnyType>( x );
}
```

Queue Implementation Using a LinkedList (Java)

```
/**
 * 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 = head.element;
    head = head.next;
    return returnValue;
}
```