

CS350: Data Structures

Doubly Linked Lists

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Doubly Linked Lists

- **Adds an additional pointer to a the list nodes that points to the previous node in the list**
- **Traversable in either the forward or backward direction**
- **Resolves the issue of removing the last node in the linked list**
 - Becomes a $O(1)$ operation as opposed to $O(N)$

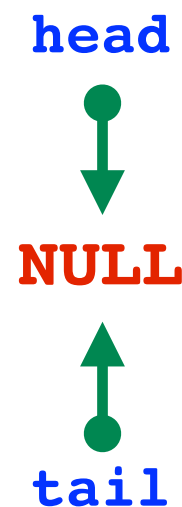


Doubly Linked List Operations

- **Basic operations include:**
 - **insert / add**
 - **remove / removeFirst / removeLast**
- **Additional operations may include:**
 - **getFirst / getLast**
 - **find**
 - **isEmpty**
 - **makeEmpty**

Doubly Linked List Implementation

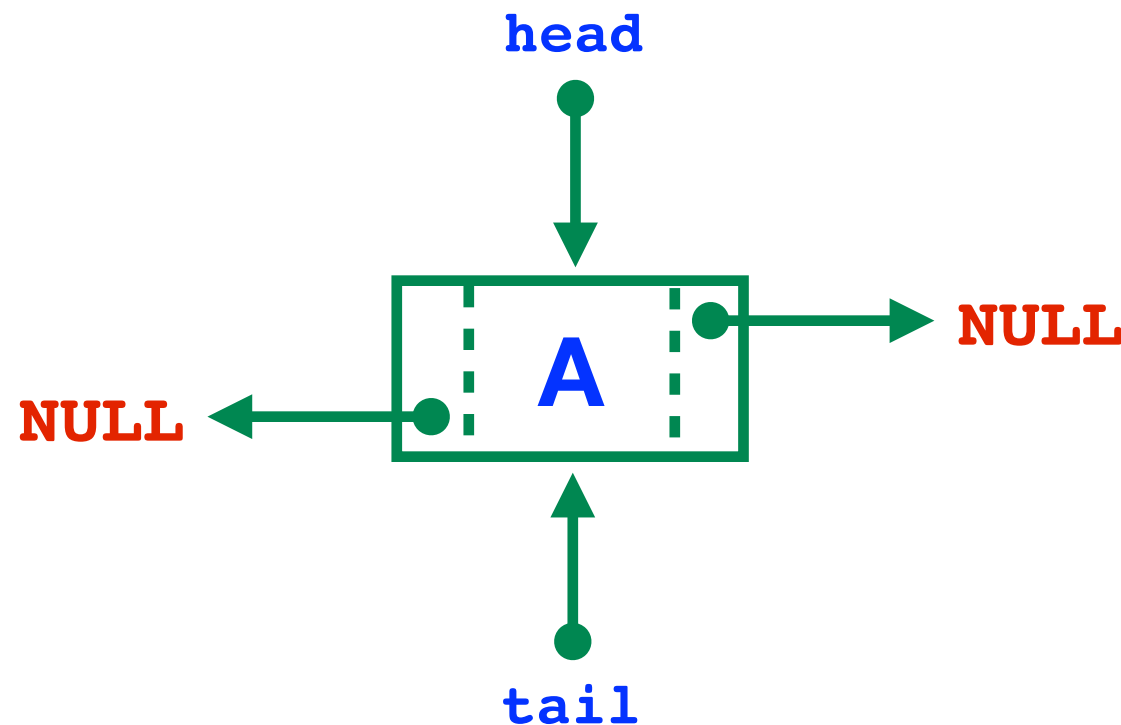
- **Basic implementation uses `head` and `tail` pointers that points to the first node and the last node in the list**
 - Both pointers points to **NULL** upon initialization when no nodes exist in the list



- **Depending on implementation, insertion may take place at the head of the list, at the tail of the list, or at some other specified node**

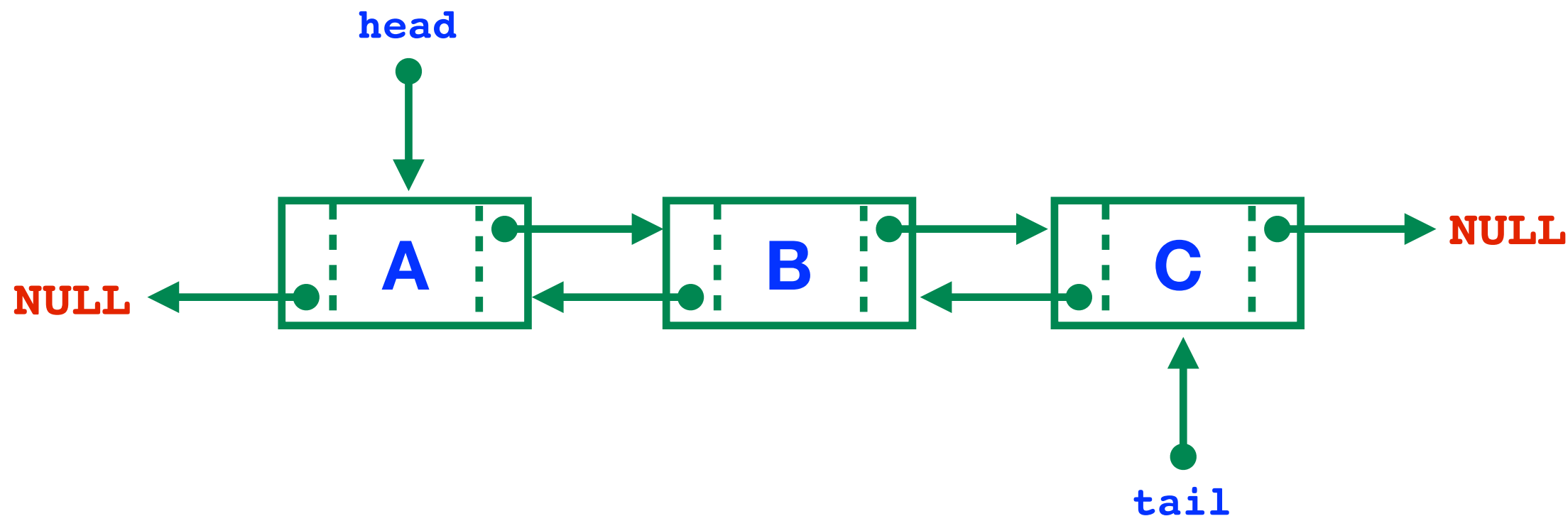
After Inserting a Node

- In this illustration, nodes are inserted at the tail end (nodes can be inserted at either the head or the tail)
 - After inserting the first node, *A*
 - The *head* and the *tail* pointers are reassigned to point to the first node



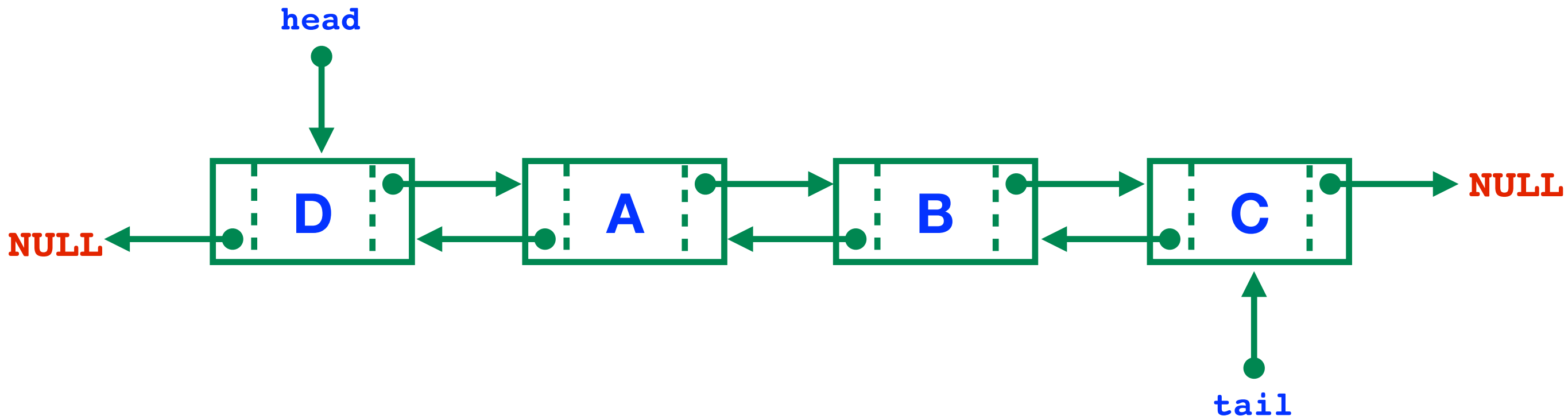
After Inserting Additional Nodes

- In this illustration, nodes are inserted at the tail end (nodes can be inserted at either the head or the tail)
 - After inserting nodes in the sequence A, B, C
 - The **tail** pointer advances with each insertion at the **tail** end



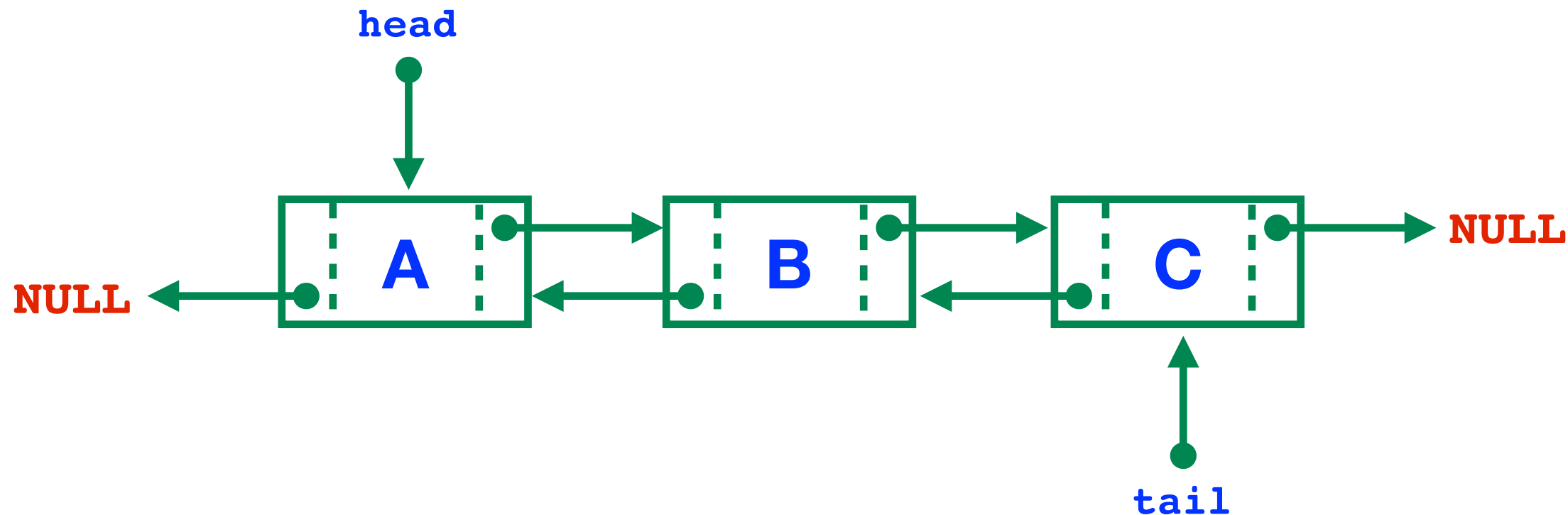
After Inserting Additional Nodes

- In this illustration, nodes are inserted at the head
 - After inserting the node D
 - The **head** pointer retreats with each insertion at the **head**



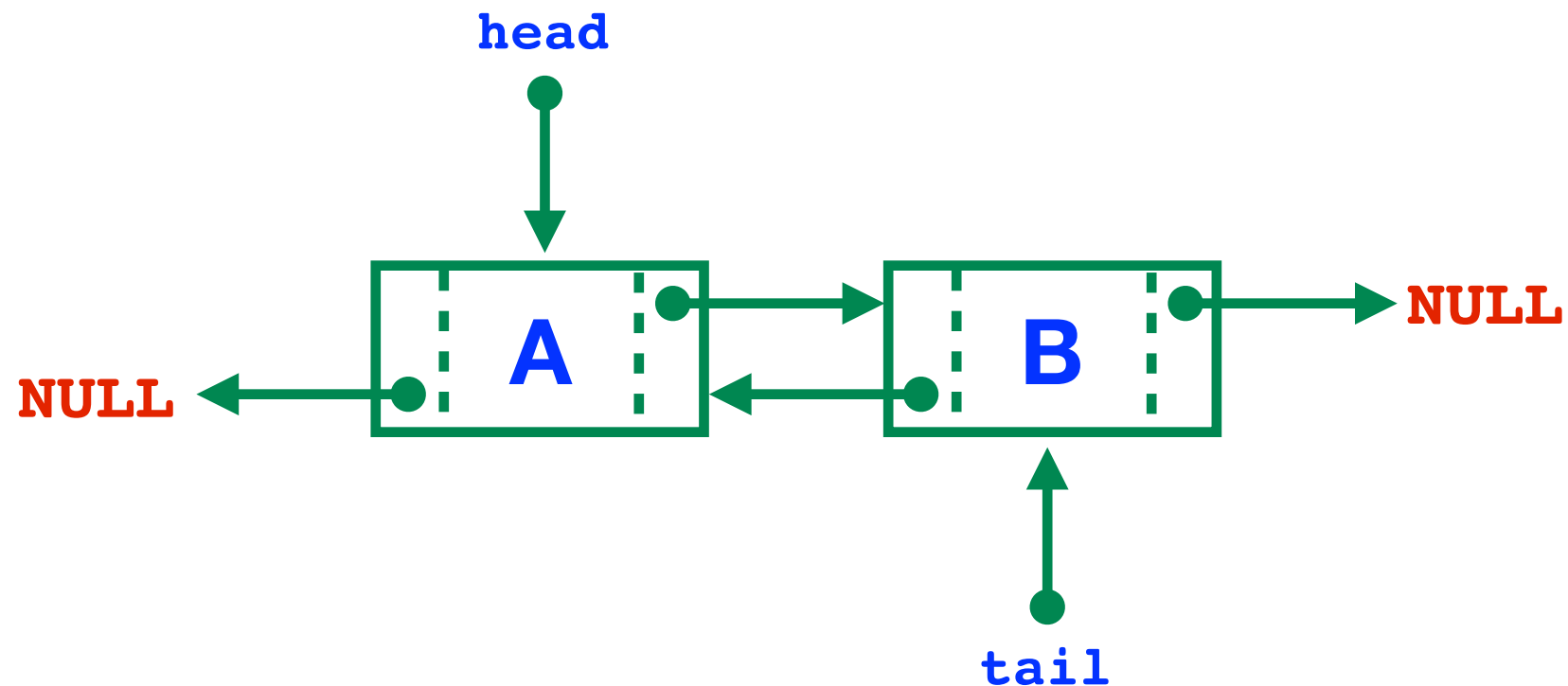
After Removing the First Node

- Nodes can be removed from the **head** of the list or the **tail**
 - After removing a single node from the **head** of the list
 - The **head** pointer advances with a removal from the **head** of the list



After Removing the Last Node

- **Nodes can be removed from the **head** of the list or the **tail****
 - After removing a single node from the **tail** of the list
 - The **tail** pointer retreats with a removal from the **tail** of the list



Doubly Linked List Implementation

```
public class DLinkedListNode<E> {  
    public E data;  
    public LinkedListNode<E> next;  
    public LinkedListNode<E> prev;  
}
```

Doubly Linked List Implementation

```
// Inserts at the tail of the list
```

```
public void append (E data) {  
    DLinkedListNode<E> newNode = new DLinkedListNode<E>( );  
    newNode.data = data;    // assign data to newNode  
    newNode.prev = tail;  
    tail.next = newNode;  
    tail = newNode;  
}
```

This method is oversimplified, what happens if this is called when the list is empty?

Doubly Linked List Implementation

Fixed append method

```
// Inserts at the tail of the list

public void append (E data) {
    DLinkedListNode<E> newNode = new DLinkedListNode<E>();
    newNode.data = data; // assign data to newNode
    if (isEmpty()) {
        head = tail = newNode;
    } else {
        newNode.prev = tail;
        tail.next = newNode;
        tail = newNode;
    }
}
```

Doubly Linked List Implementation

```
// Inserts at the head of the list

public void prepend (E data) {
    DLinkedListNode<E> newNode = new DLinkedListNode<E>( );
    newNode.data = data;    // assign data to newNode
    newNode.next = head;
    head.prev = newNode;
    head = newNode;
}
```

This method is oversimplified, what happens if this is called when the list is empty?

Doubly Linked List Implementation

// Removes node from head of list and returns its value

```
public E removeFirst() {  
    if (head != null) {  
        E nodeData = head.data;  
        head.next.prev = null;  
        head = head.next;  
        return nodeData;  
    } else {  
        return null;  
    }  
}
```

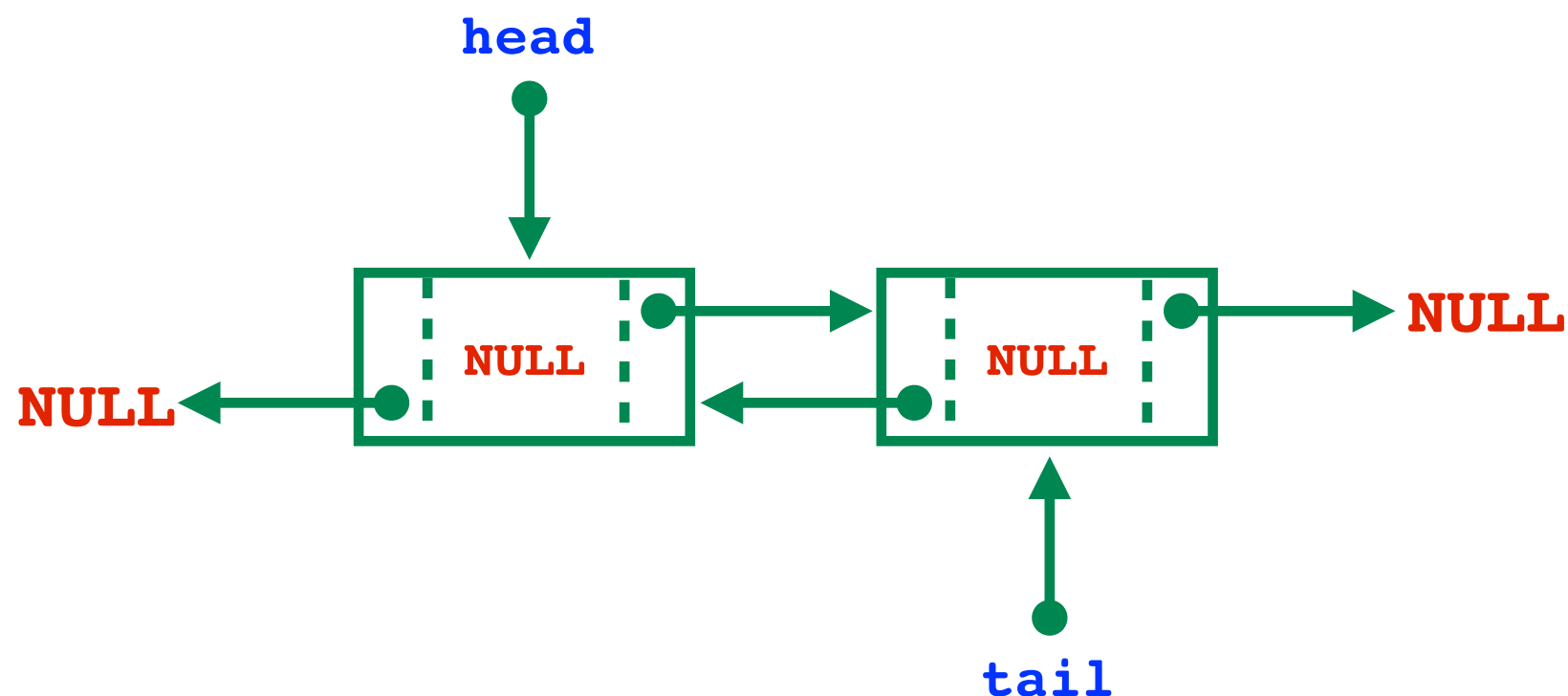
Considerations for Linked List Implementation

- **Implementation as previously shown requires a error checking in the insertion and removal methods to check for edge cases (i.e. checking for an empty list)**
- **To improve the speed of operations, it is possible to remove these tests**
 - Tradeoff: speedup comes at the expense of one/two additional 'dummy' nodes in the Linked List
- **Idea: create one or two dummy nodes (sentinel nodes) that exists in the linked list at ALL times**
 - Eliminates the need to always check for **NULL**
 - Generalized the insertion and removal methods

Doubly Linked List with Two Sentinel Nodes

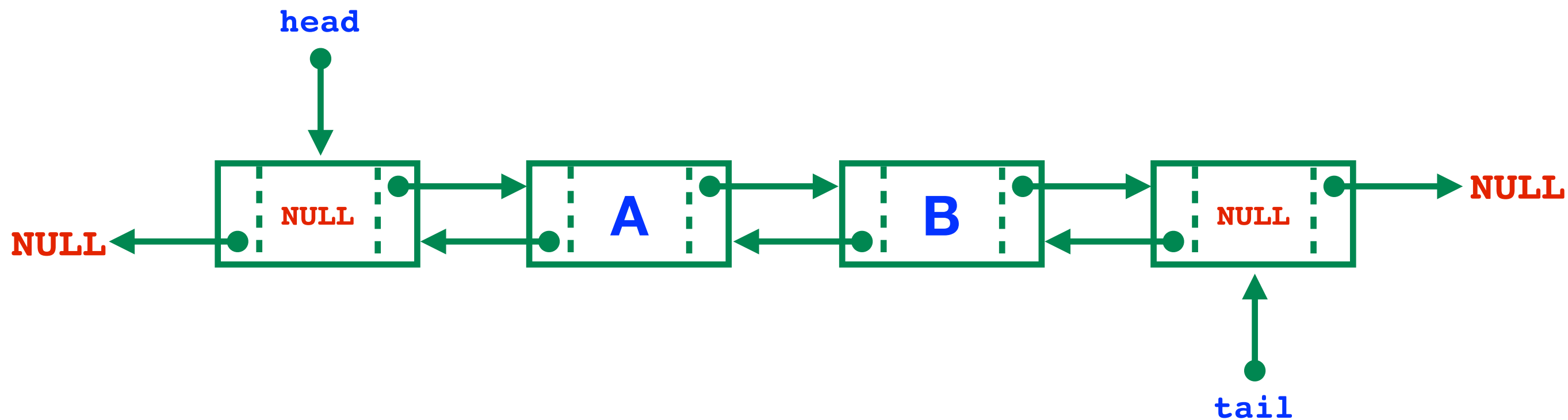
- **To check for empty:** `(head.next == tail);`
- **When traversing the list check to see if current position points to either the `head` or the `tail` to determine if at the end of the list**

Empty list



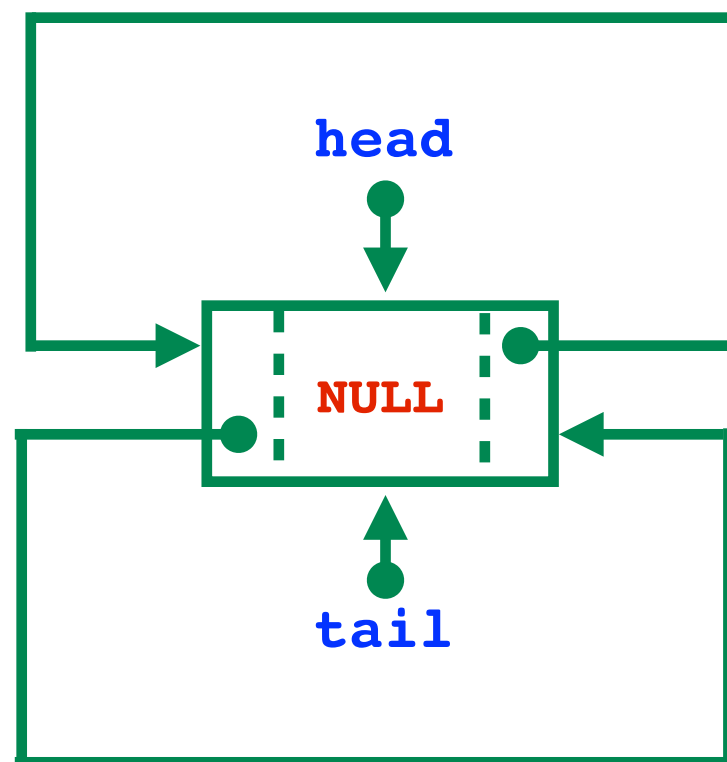
Doubly Linked List with Two Sentinel Nodes

List with two nodes



Doubly Linked List with a Single Sentinel Node

Empty list



How should `isEmpty()` be implemented?

Doubly Linked List with a Single Sentinel Node

List with two nodes

