# CS350: Data Structures

# Linked Lists

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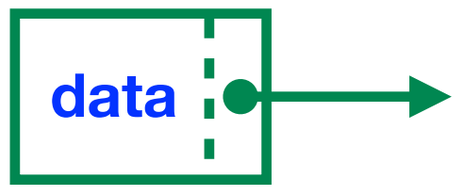
# Linked Lists

- **Come in a variety of different forms**
  - singly linked lists
  - doubly linked lists
  - circular linked lists

- **Composed of a set of nodes that hold data and contain one or more pointers to neighboring nodes in the list**
  - singly linked lists contain only a pointer to the next node in the list
  - doubly linked lists contain a pointer to the next node and the previous node in the list



# Linked List Operations

- **Basic operations include:**
  - **`insert`** / **`add`**
  - **`remove`**

- **Additional operations may include:**
  - **`getFirst`**
  - **`getLast`**
  - **`find`**
  - **`isEmpty`**
  - **`makeEmpty`**

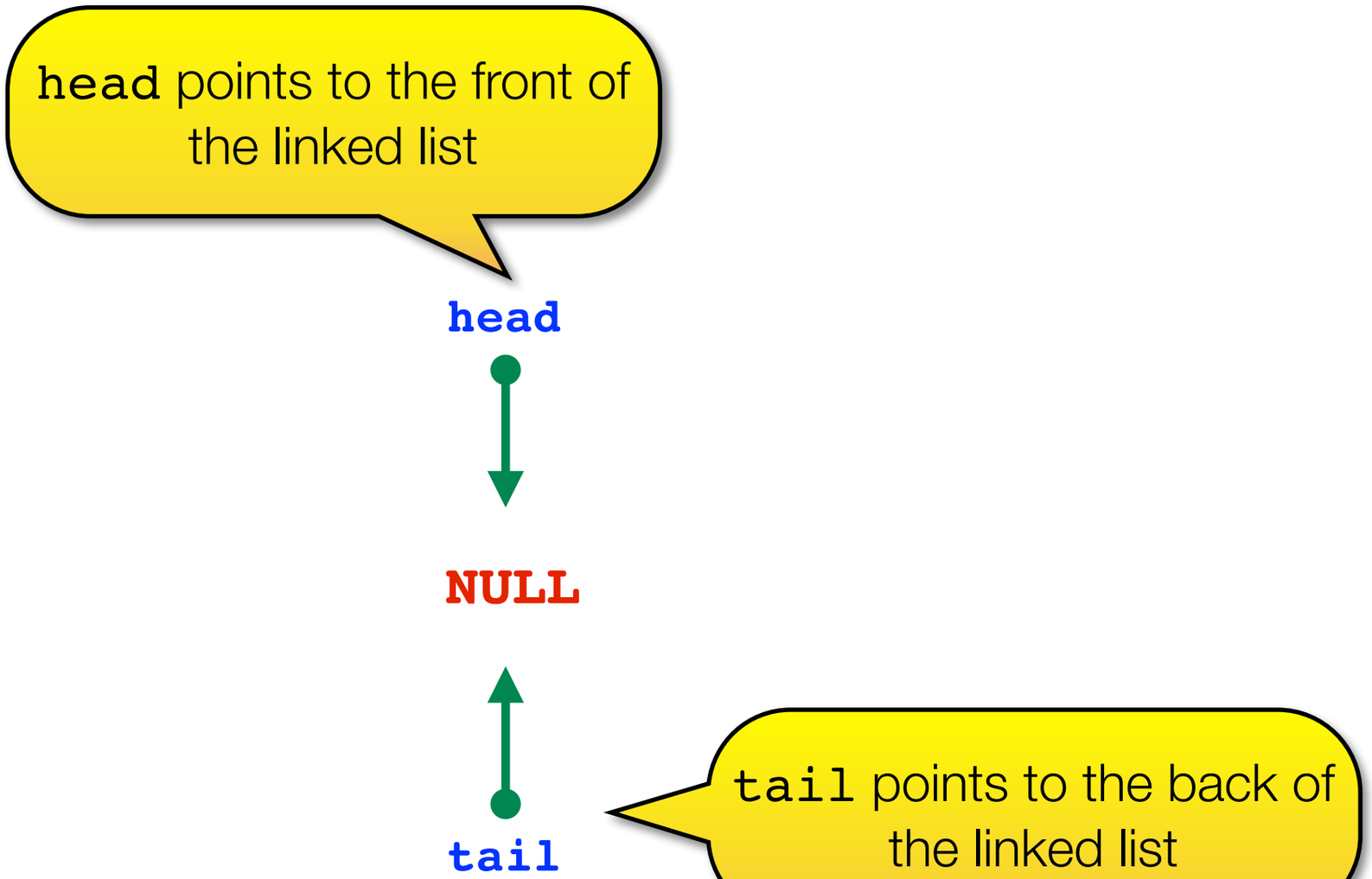
# Linked List Insertion

- **Basic implementation uses a `head` pointer that points to the first node in the list**
  - 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**

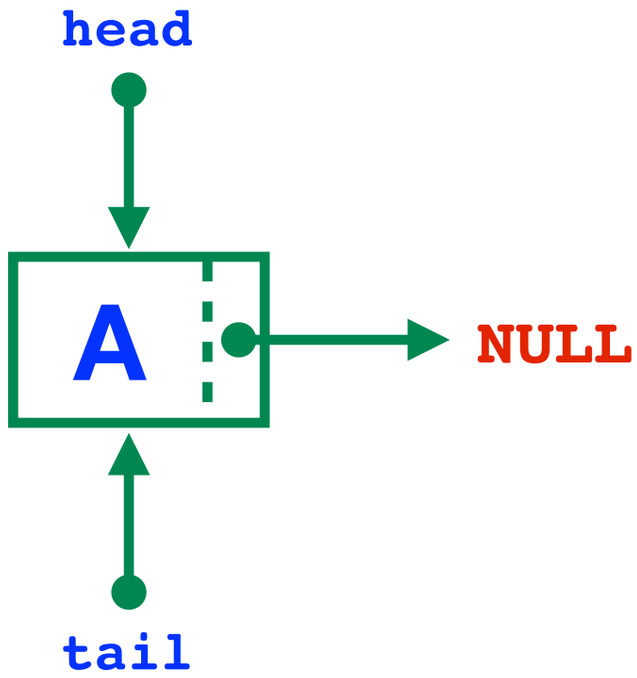
# Linked List Insertion

## Start with Empty List



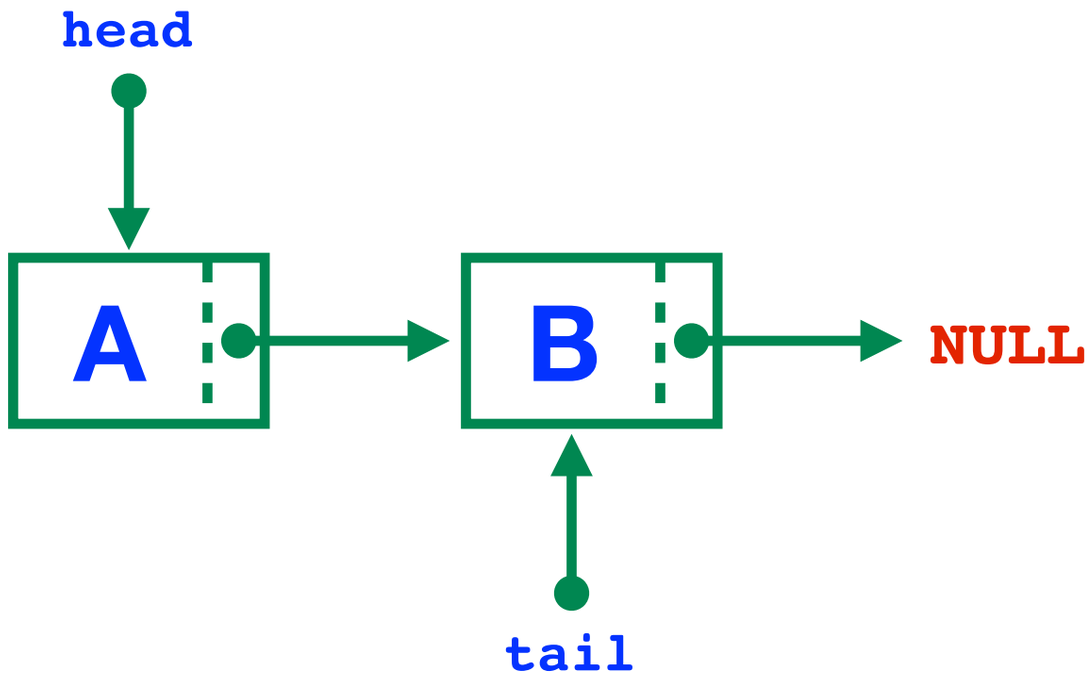
# Linked List Insertion

**Insert Value: A**



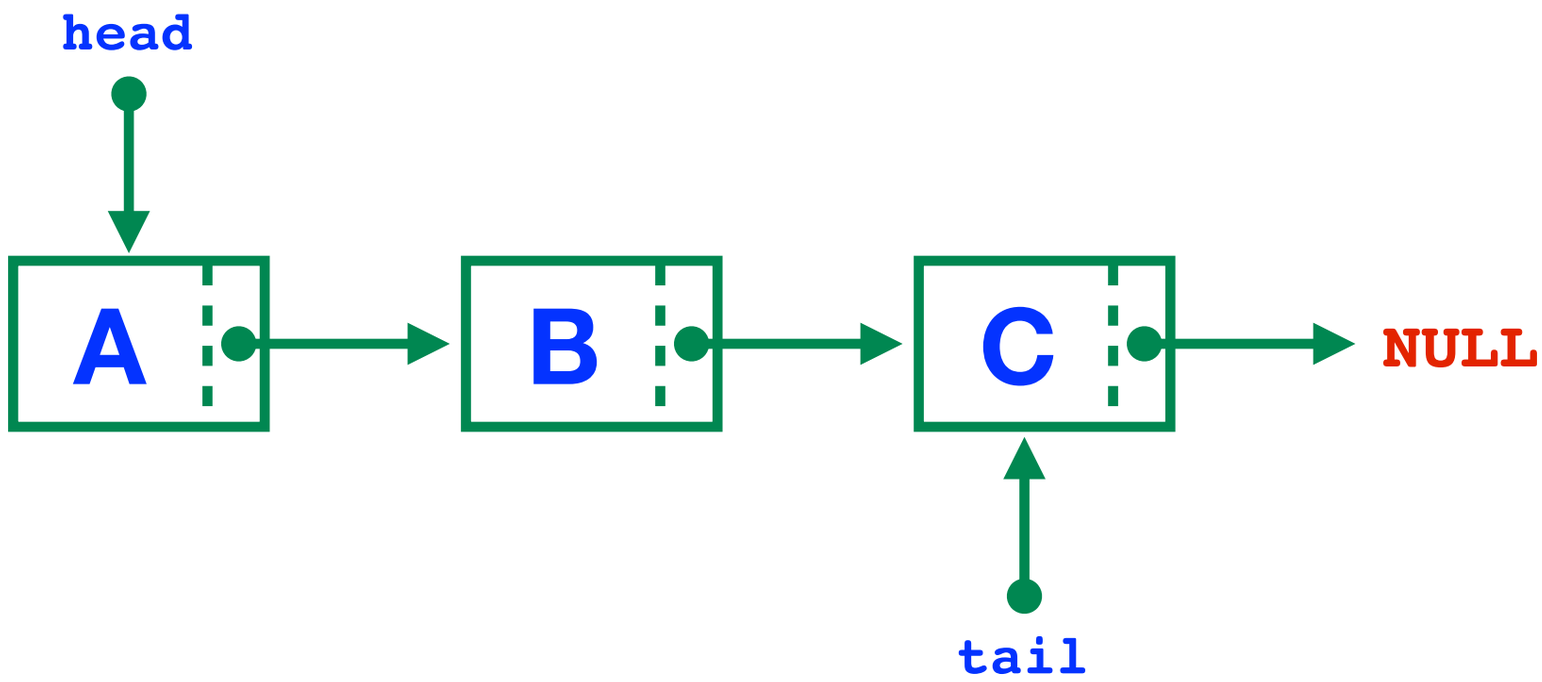
# Linked List Insertion

**Insert Value:  B**



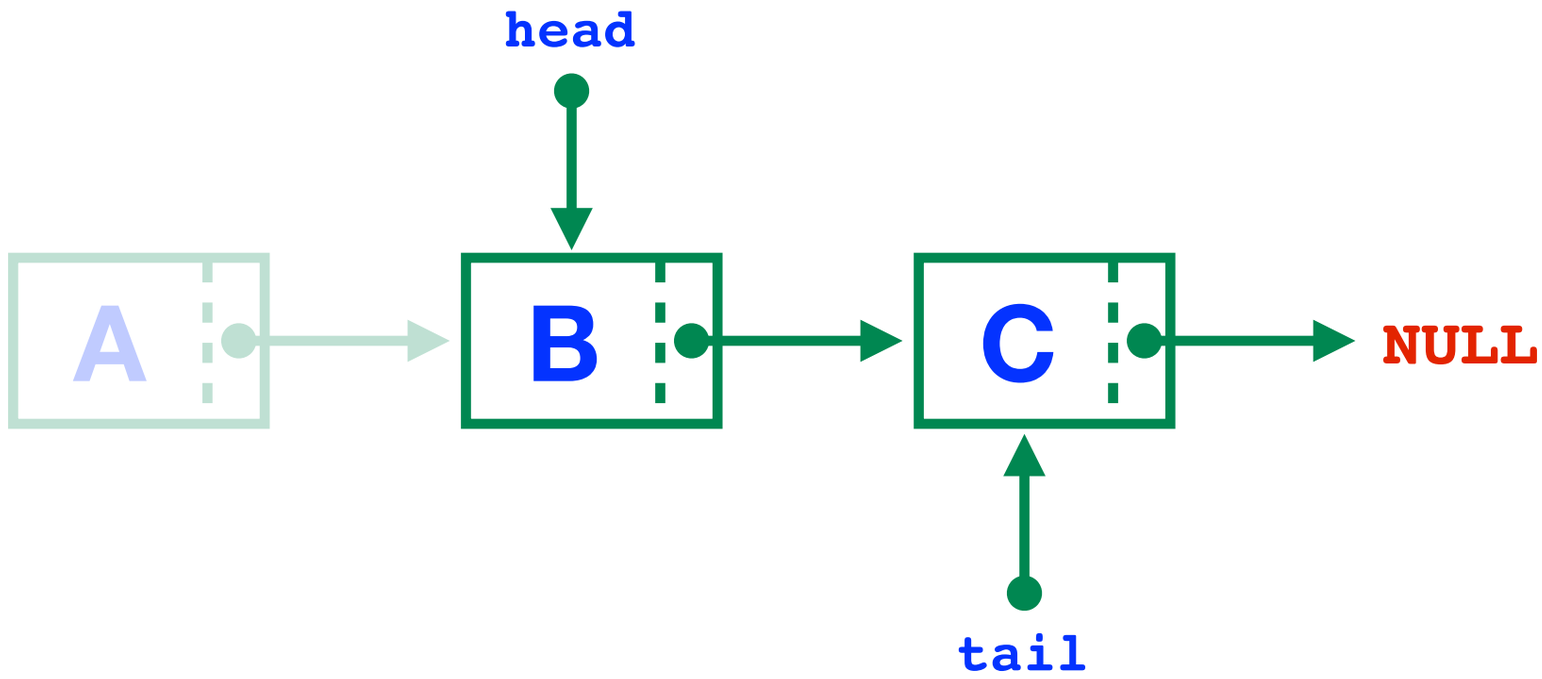
# Linked List Insertion

**Insert Value: C**



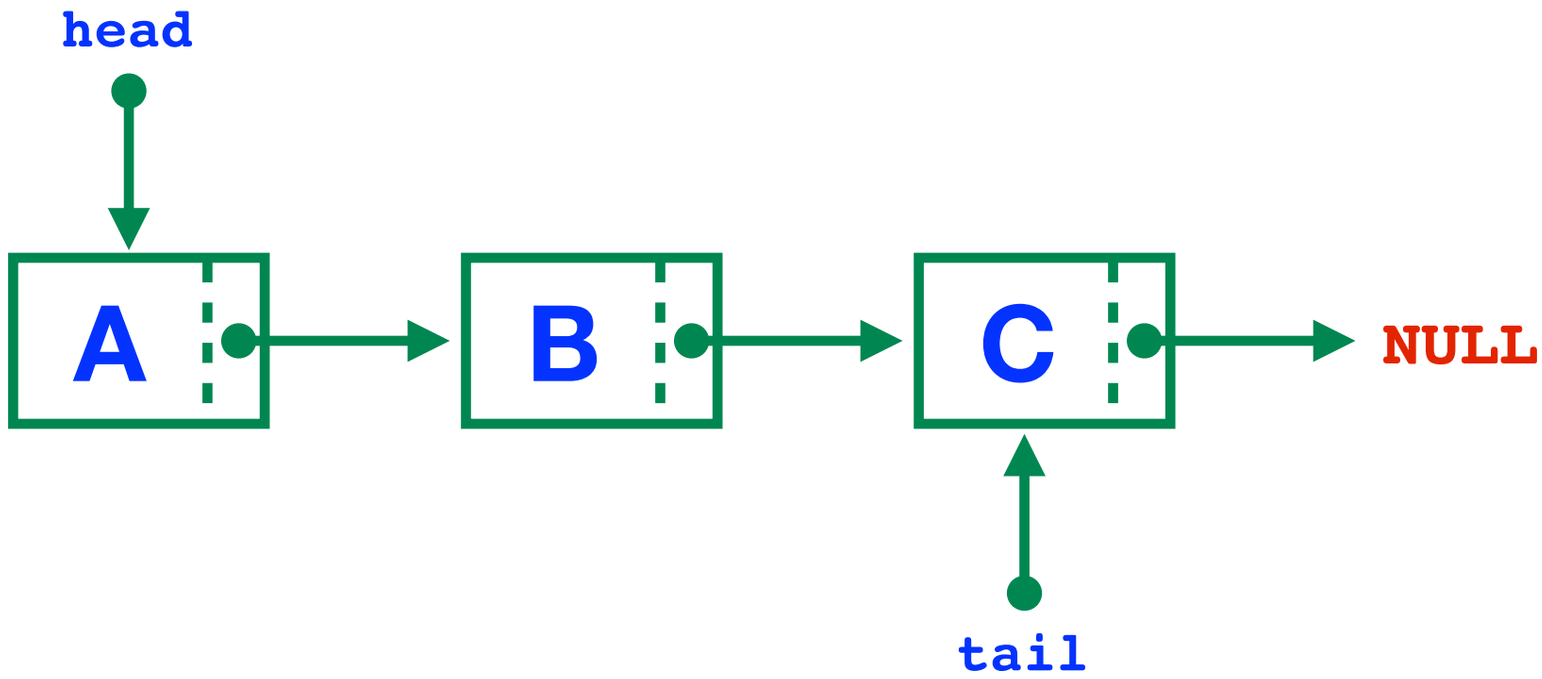
# Linked List Removal

## Remove First Value:



# Linked List Removal

- **Removing last value is not very efficient when using singly linked lists**
  - Want to make next-to-last node in list the last node
  - Must traverse entire list, starting from the **`head`**, to find the next-to-last node in the list
  - O(N)



# Linked List Implementation

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

# Linked List Implementation

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

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

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

# Linked List Implementation

## Fixed insert method

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

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

# Linked List Implementation

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

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

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

# Linked List Implementation

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

public void insertAtHead (E data) {
   LinkedListNode<E> newNode = new LinkedListNode<E>();
   newNode.data = data;  // assign data to newNode
   newNode.next = head;

   if (!isEmpty()) {
      head = newNode;
   } else {
      head = tail = newNode;
   }
}
```

# Linked List Implementation

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

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

# Considerations for Linked List Implementation

- **Implementation as previously shown requires a error checking in the `insert` and `remove` methods to check for edge cases (i.e. checking for an empty list)**

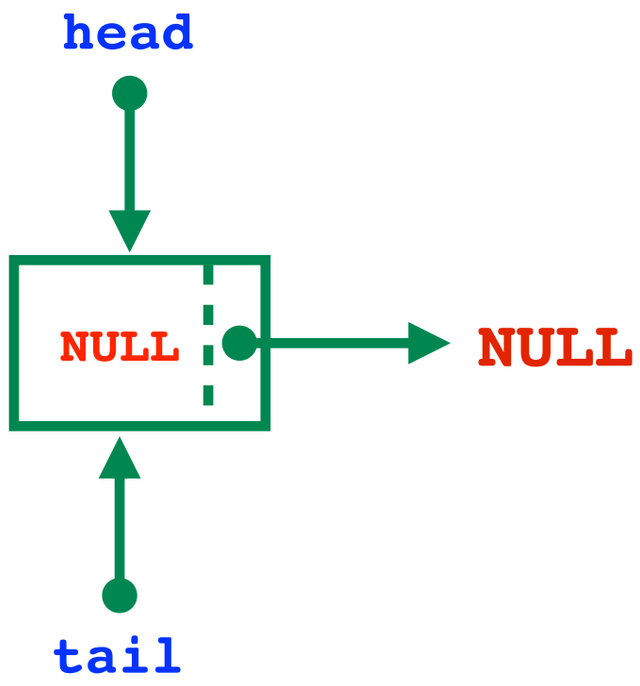
- **To improve the speed of the Linked List operations, it is possible to remove these tests**
  - Tradeoff: speedup comes at the expense of one additional ‘dummy’ node in the Linked List

- **Idea: create a dummy node that exists in the linked list at ALL times ... it is created as part of the list and points to the `head` node**
  - Eliminates the need to always check for `NULL`
  - Generalized the `insert` and `remove` methods

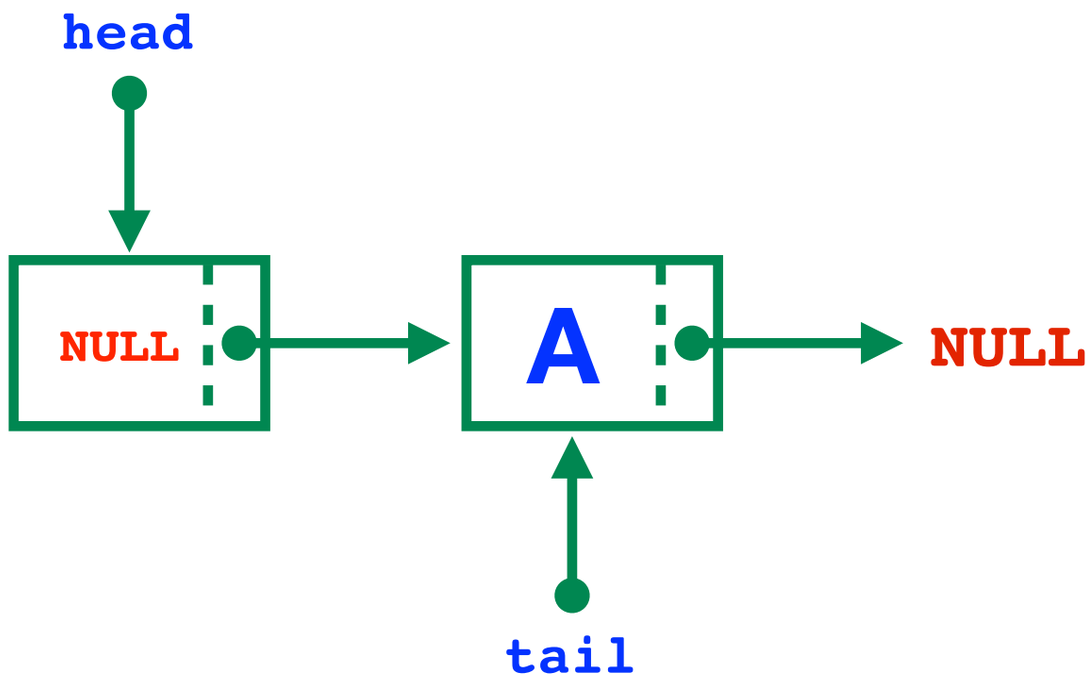
# Linked List with Header Node

- **Implementation as previously shown requires error checking in the `insert` and `remove` methods to check for edge cases (i.e. checking for an empty list)**

## Empty list




## List with single node



# Linked List Implementation

```
// Inserts at the tail of the list
// When using dummy header node, no need to test for null

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

# Linked List Implementation

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

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