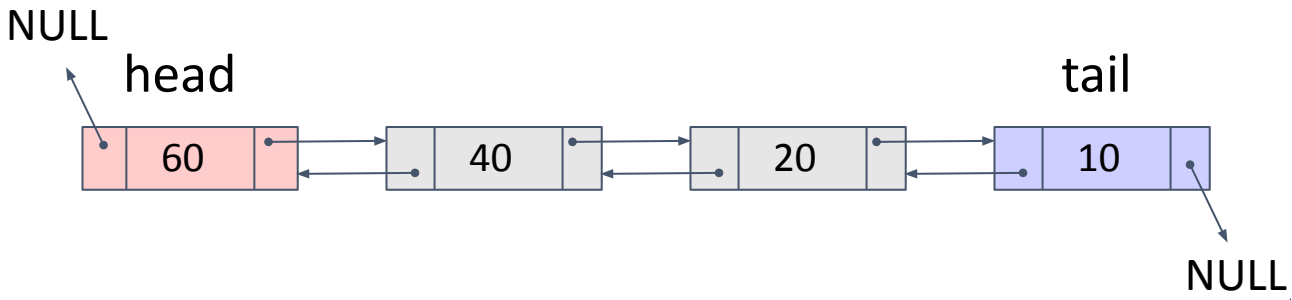
CSE 220
Data Structures

Lecture 05:
Dummy Headed Circular DLLs

Anwarul Bashir Shuaib [AWBS]
Lecturer
Department of Computer Science and Engineering
BRAC University

Review: Doubly Linked Lists

- Each node contains **three** things:
  - Data
  - A reference to the **next** node
  - A reference to the **previous** node



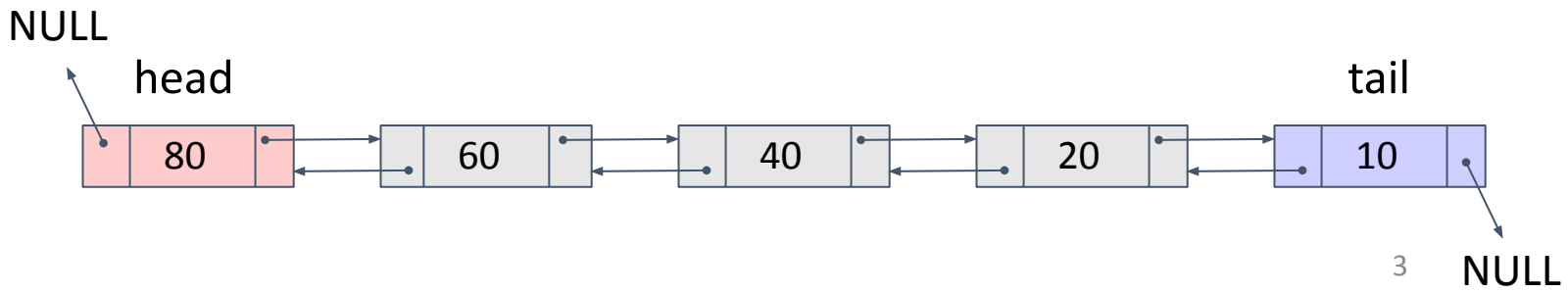
- This version is also known as “Doubly Linked Lists (DLL)” as each node contains the reference to both the **next node and the previous node**.

Review: Element Insertion (At the beginning)

Prepend 80 to the list

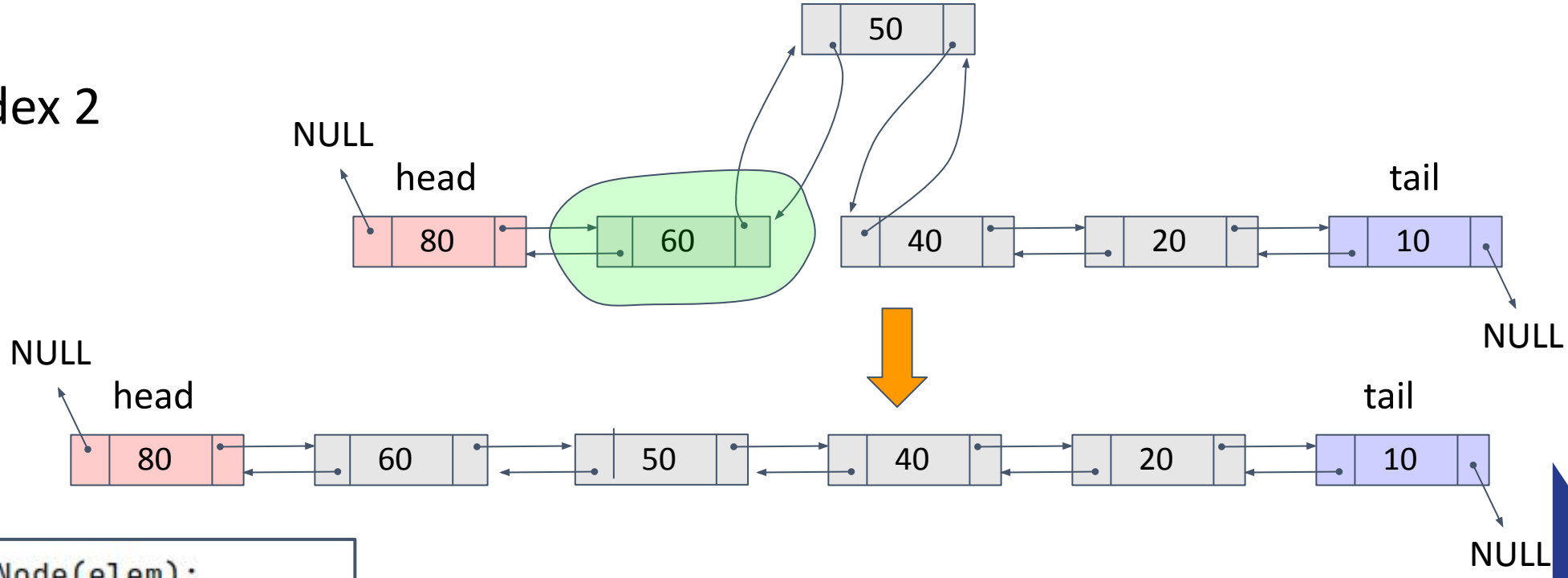
```
// Insert at the beginning
Node newNode = new Node( elem: 80);
newNode.next = head;
head.prev = newNode;
head = newNode;
```

$O(1)$



Review: Element Insertion (Middle)

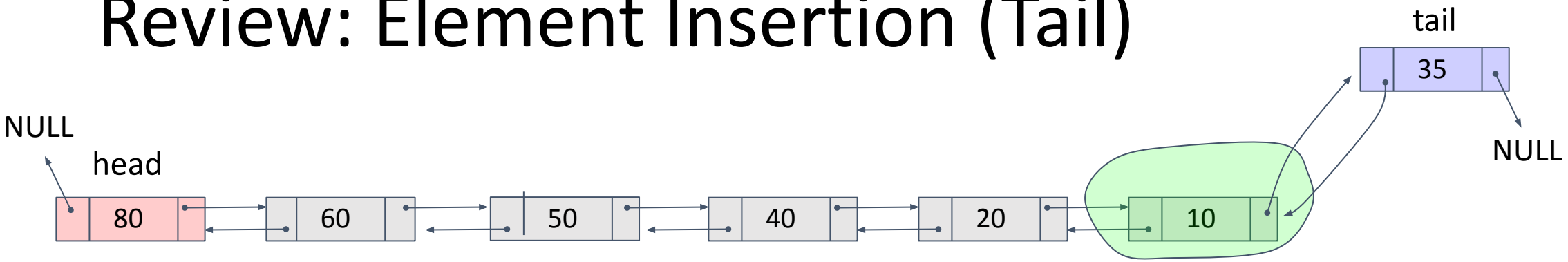
Insert 50 at index 2




```
Node newNode = new Node(elem);
Node prev = getNode( index: index - 1);
newNode.next = prev.next;
newNode.prev = prev;
prev.next = newNode;
newNode.next.prev = newNode;
```

$O(n)$

Review: Element Insertion (Tail)

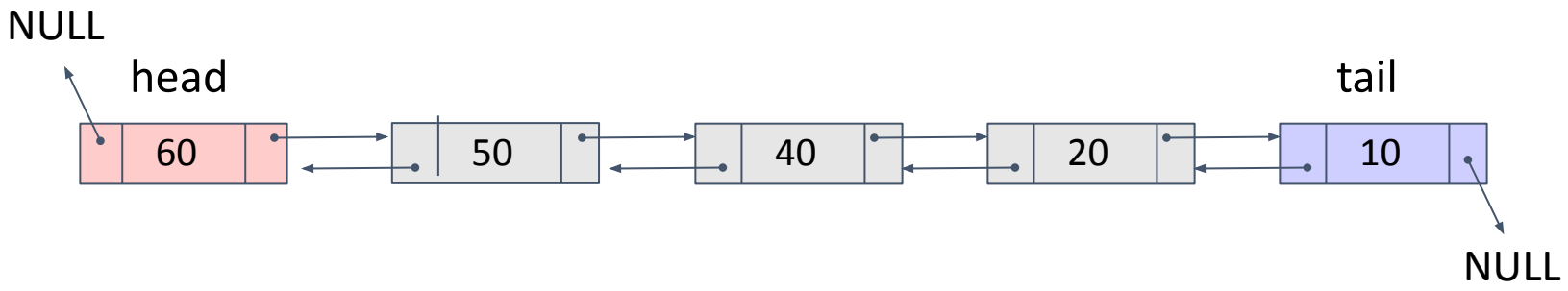


Can we optimize tail insertions?

```
Node newNode = new Node(elem);
Node prev = tail;
newNode.prev = prev;
prev.next = newNode;
tail = newNode;
```

$O(1)$

Review: Node Removal (Head)



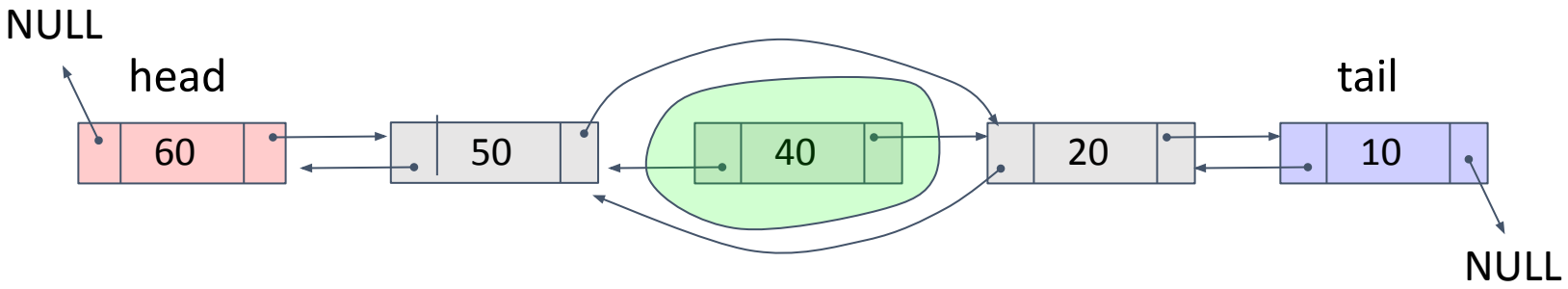

```
if (head == null) return;
head = head.next;
if (head == null) {
    tail = null;
    return;
}
head.prev = null;
```

Special case when list becomes empty

$O(1)$

Review: Node Removal (Middle)

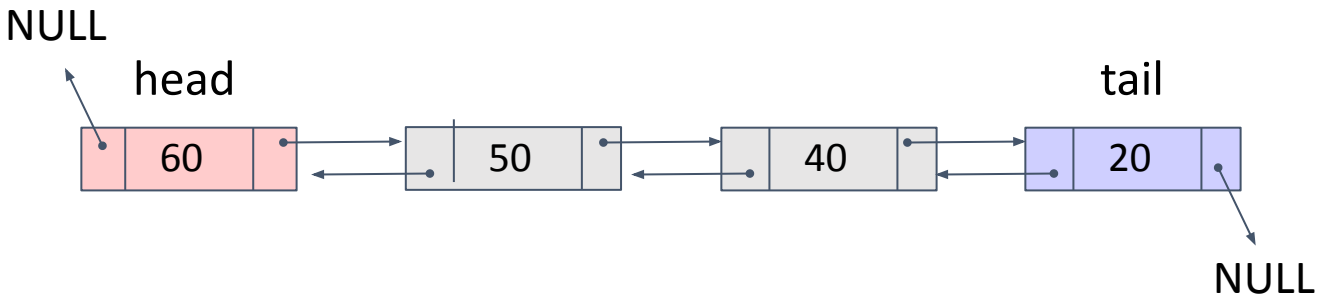
Delete the node at index 2



Garbage collected

```
Node node = getNode(index);
node.prev.next = node.next;
node.next.prev = node.prev;
```

Review: Node Removal (Tail)



Can we optimize tail deletions?

```
Node node = getNode(index);
if (node.next == null) { // Deleting the tail
    tail = node.prev;
    tail.next = null;

}
```

$O(n)$

```
tail = tail.prev;
tail.next = null;
```

$O(1)$

Doubly Linked Lists – Continued

- DLLs provide efficient node insertions and deletions on the head and tail.

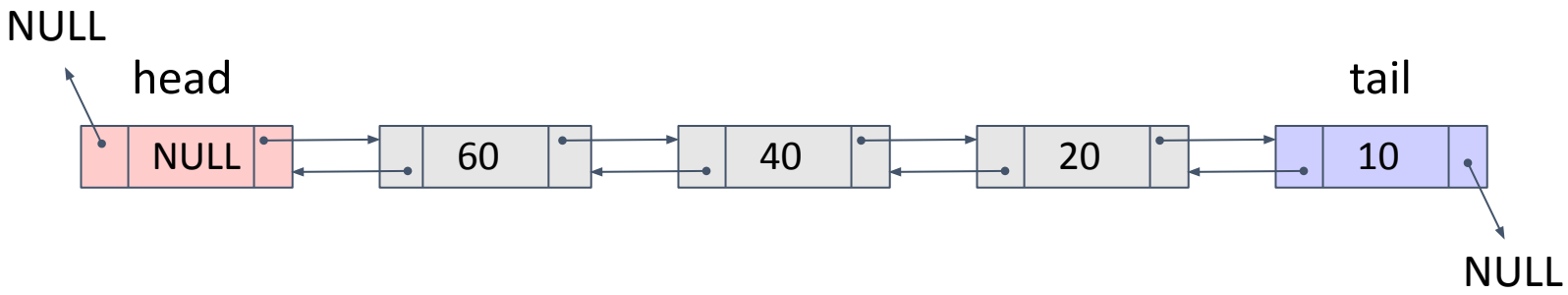
  But…

  Problem in Traditional DLLs:

  - If `head` is `null`, insertions and deletions require extra handling.
  - When inserting at the beginning, `head` must be updated explicitly.
  - Edge cases exist when deleting the first or last node.

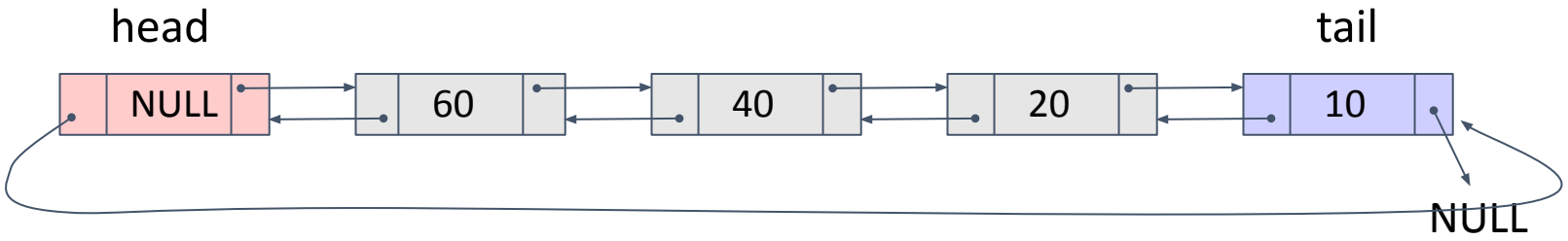
Dummy Headed Circular DLLs

- Almost same as DLLs, except:
  - The DLL has a dummy head (a head containing null as the element)
  - `head.prev` points to tail, and `tail.next` points to head.



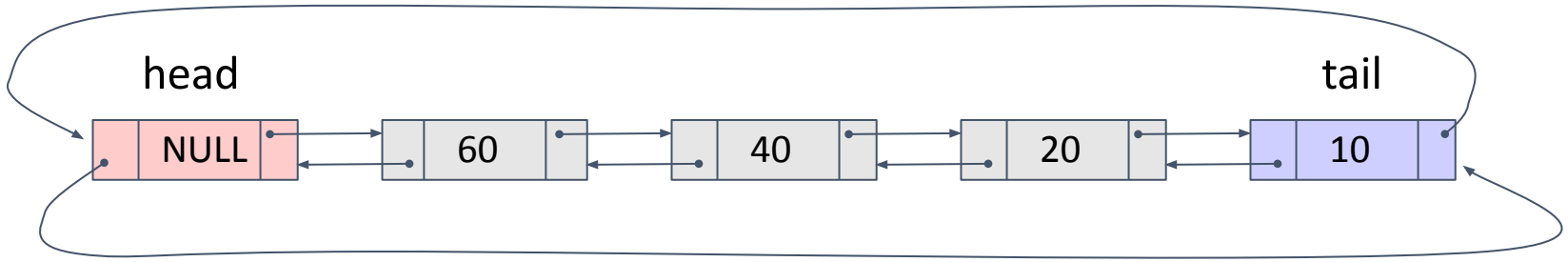
Dummy Headed Circular DLLs

- Almost same as DLLs, except:
  - The DLL has a dummy head (a head containing null as the element)
  - `head.prev` points to tail, and `tail.next` points to head.



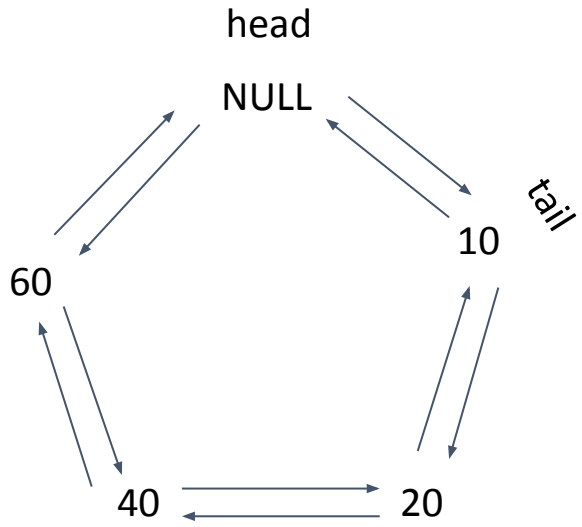
Dummy Headed Circular DLLs

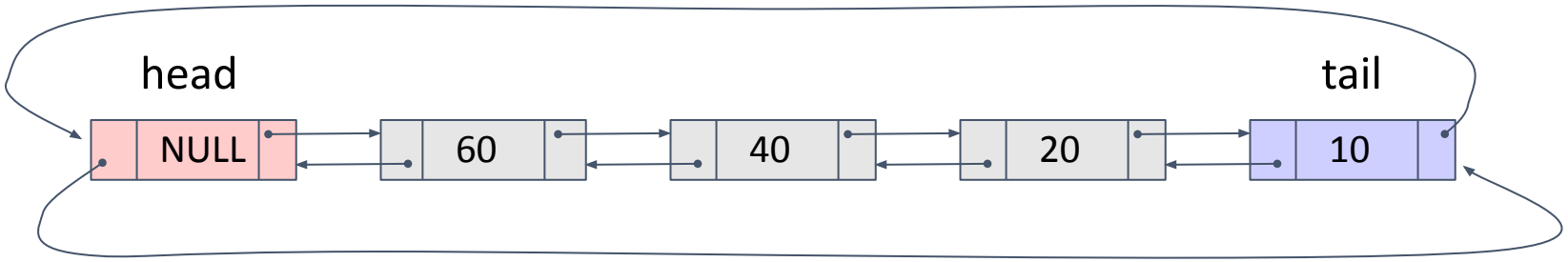
- Almost same as DLLs, except:
  - The DLL has a dummy head (a head containing null as the element)
  - `head.prev` points to tail, and `tail.next` points to head.



Dummy Headed Circular DLLs

- Why called “Circular”?





Dummy Headed Circular DLLs

Advantage of Dummy Head:

- The dummy node **always exists**, so `head` is never `null`.
- Insertions at the start don’t need to update `head` separately.
- Deletions are uniform—no need to check if the node is the first or last.

Dummy Headed DLL Class

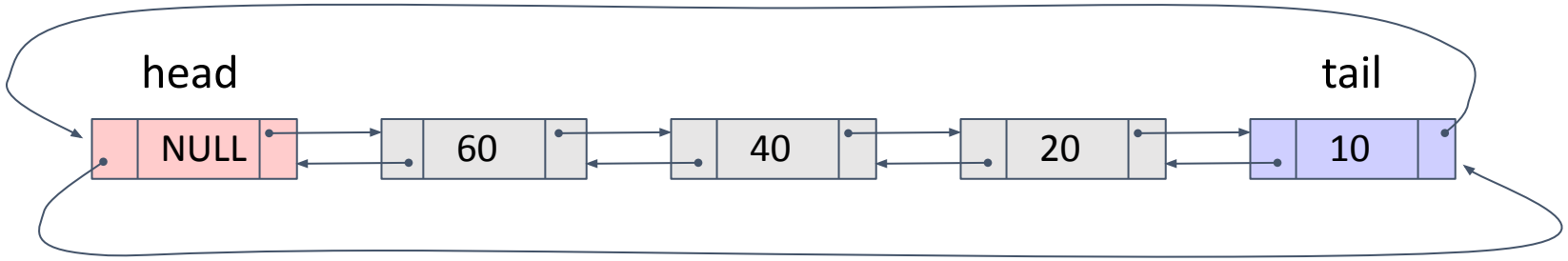
DLL Class

```
private static class Node {
    int elem;
    Node next;
    Node prev;

    Node(int elem) {
        this.elem = elem;
        this.next = null;
        this.prev = null;
    }
}

private Node head;
private Node tail;
```

Optional

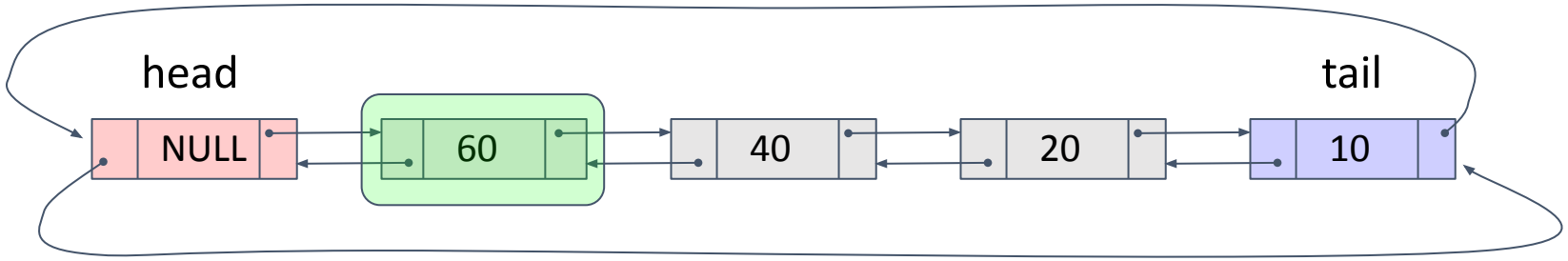
```
public DoublyCircularLinkedList() {
    head = new Node( elem: -1); // Dummy node
    head.next = head;
    head.prev = head;
}
```

Iteration



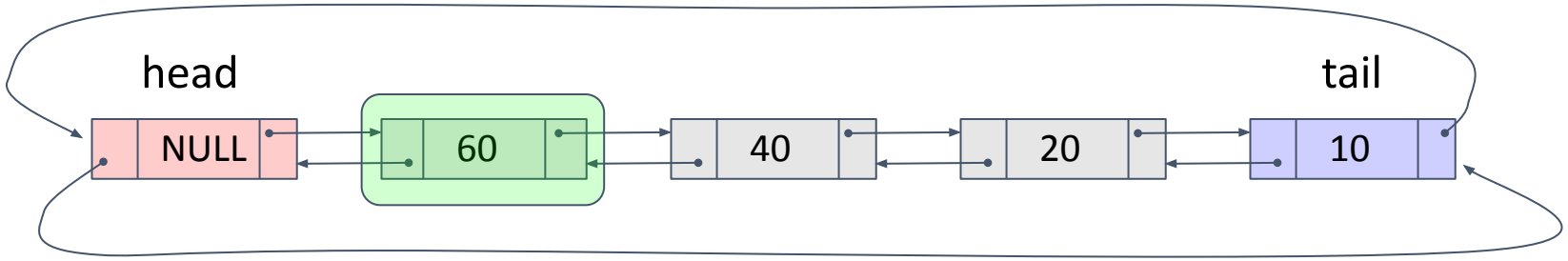

```
// 2. Iteration of the linked list
public void iterate() {



}
```

Iteration



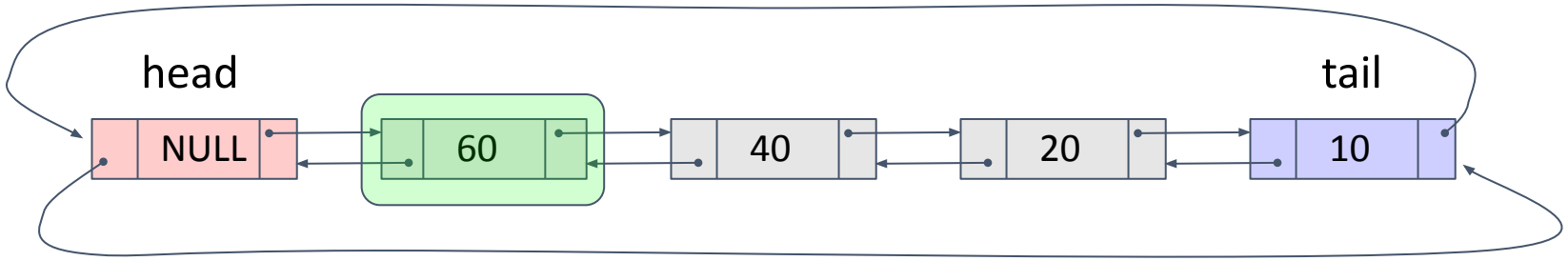

```
// 2. Iteration of the linked list
public void iterate() {
    Node current = head.next;



}
```

Iteration




```
// 2. Iteration of the linked list
public void iterate() {
    Node current = head.next;
    while (current != head) {


    }

}
```

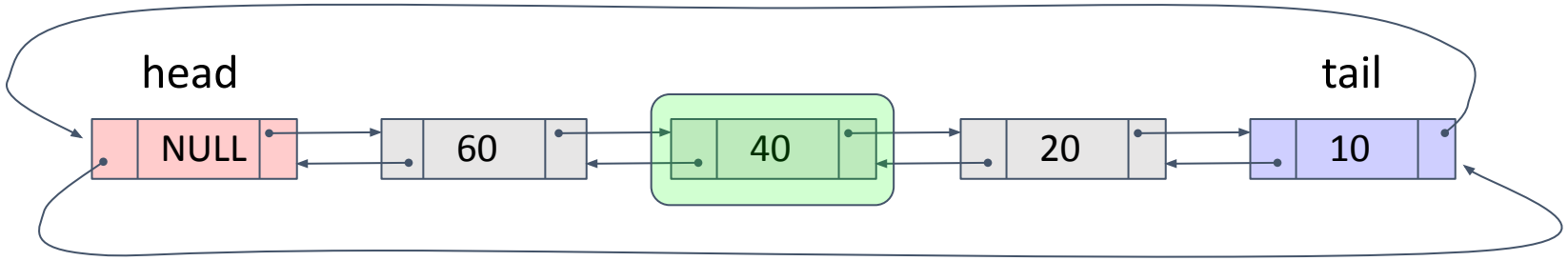
Iteration




```
// 2. Iteration of the linked list
public void iterate() {
    Node current = head.next;
    while (current != head) {
        System.out.print(current.elem + " ");

    }

}
```

60

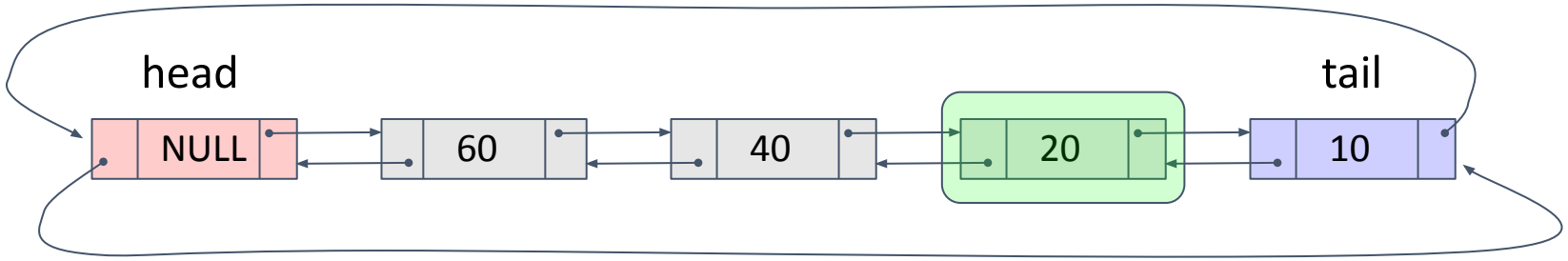
Iteration




```java
// 2. Iteration of the linked list
public void iterate() {
    Node current = head.next;
    while (current != head) {
        System.out.print(current.elem + " ");
        current = current.next;
    }

}
```

60 40

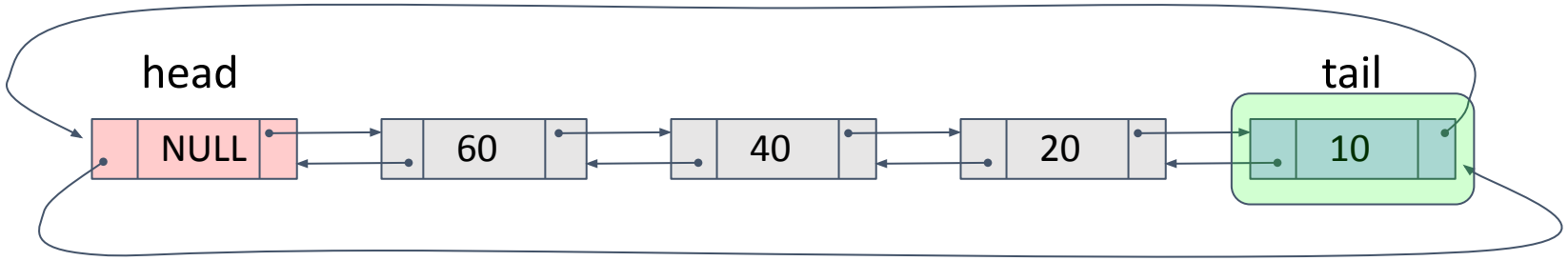
Iteration




```
// 2. Iteration of the linked list
public void iterate() {
    Node current = head.next;
    while (current != head) {
        System.out.print(current.elem + " ");
        current = current.next;
    }

}
```

60 40 20

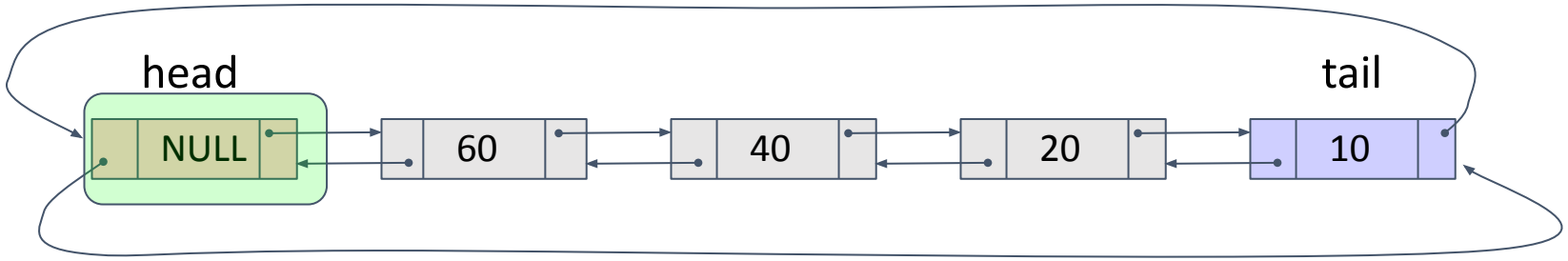
Iteration




```
// 2. Iteration of the linked list
public void iterate() {
    Node current = head.next;
    while (current != head) {
        System.out.print(current.elem + " ");
        current = current.next;
    }

}
```

60 40 20 10

Iteration



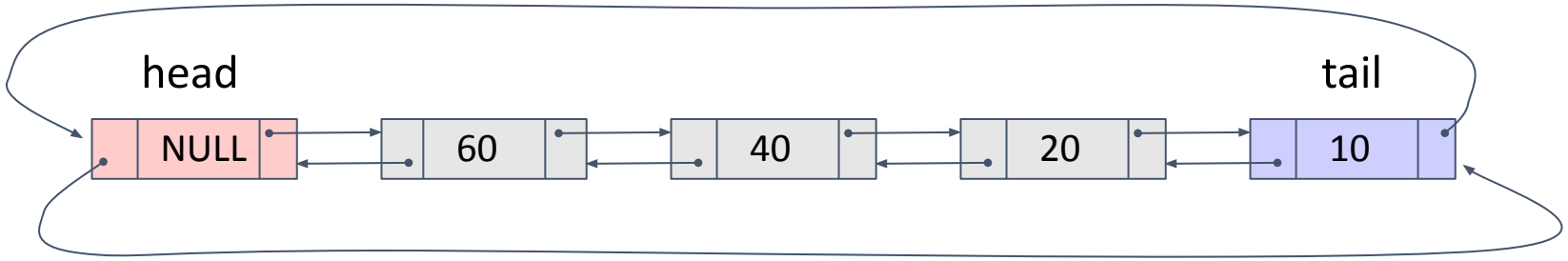

```java
// 2. Iteration of the linked list
public void iterate() {
    Node current = head.next;
    while (current != head) {
        System.out.print(current.elem + " ");
        current = current.next;
    }

}
```

Termination

60 40 20 10

InsertAtStart

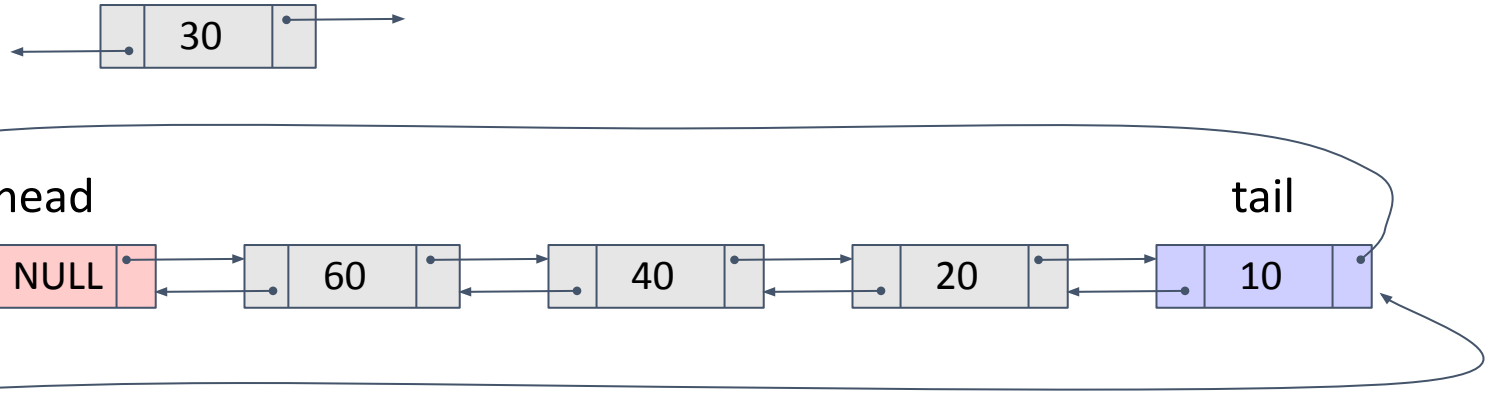
Insert 30 at start




```
public void insertAtStart(int elem) {



}
```

InsertAtStart

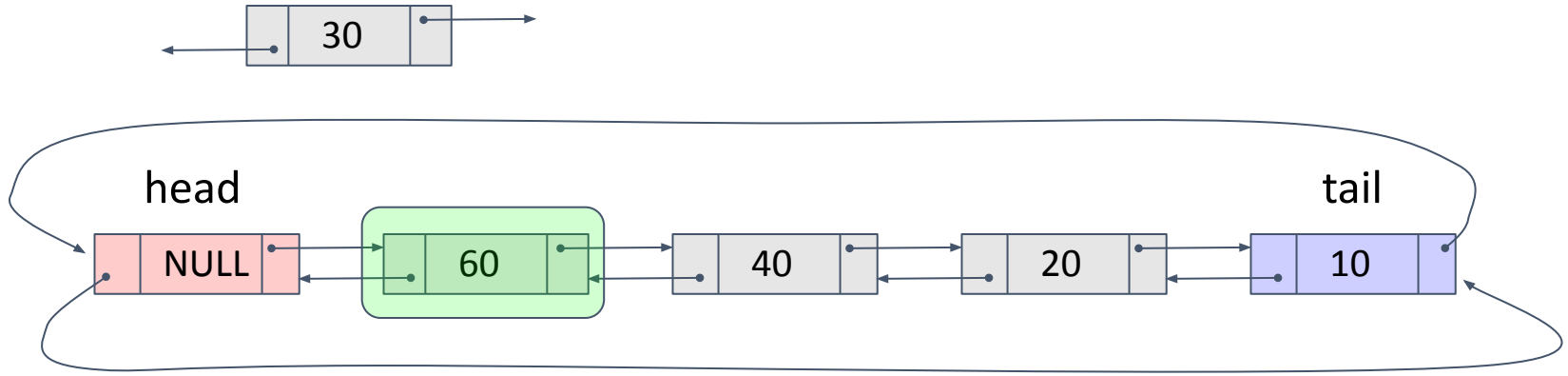
Insert 30 at start




```
public void insertAtStart(int elem) {
    Node newNode = new Node(elem);



}
```

InsertAtStart

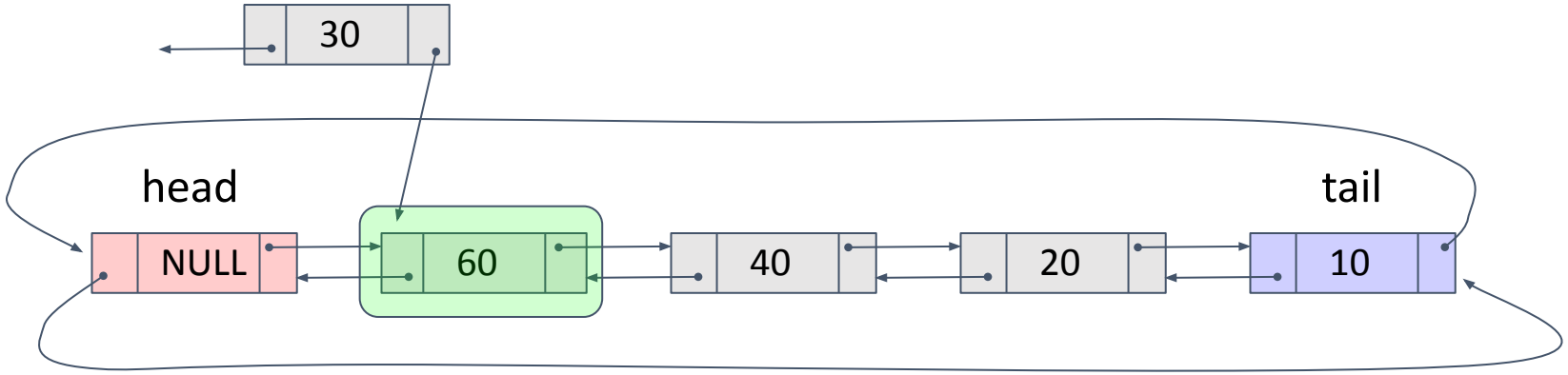
Insert 30 at start




```
public void insertAtStart(int elem) {
    Node newNode = new Node(elem);
    Node first = head.next;



}
```

InsertAtStart

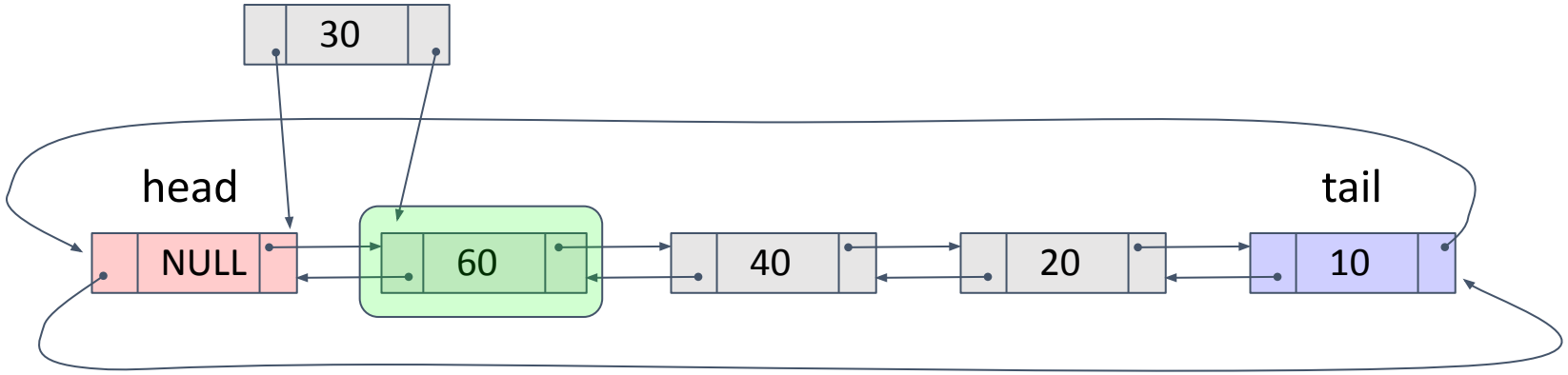
Insert 30 at start




```
public void insertAtStart(int elem) {
    Node newNode = new Node(elem);
    Node first = head.next;

    newNode.next = first;



}
```

InsertAtStart

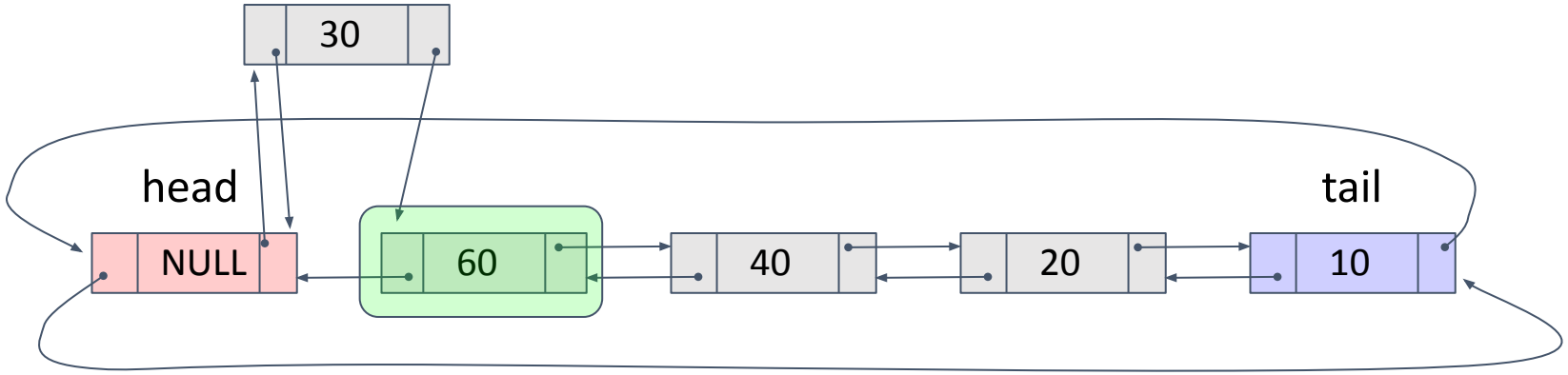
Insert 30 at start




```
public void insertAtStart(int elem) {
    Node newNode = new Node(elem);
    Node first = head.next;

    newNode.next = first;
    newNode.prev = head;


}
```

InsertAtStart

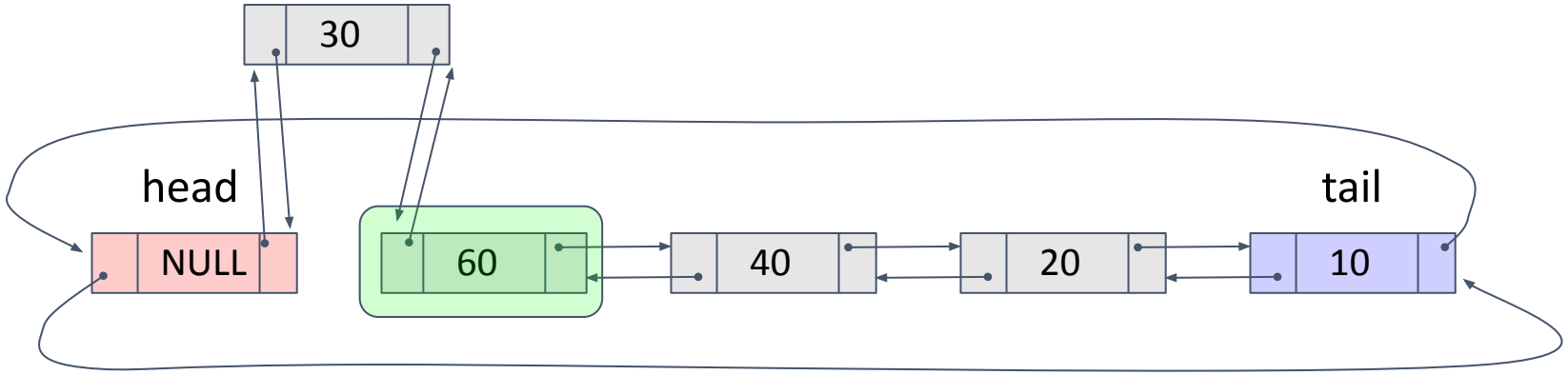
Insert 30 at start




```
public void insertAtStart(int elem) {
    Node newNode = new Node(elem);
    Node first = head.next;

    newNode.next = first;
    newNode.prev = head;
    head.next = newNode;

}
```

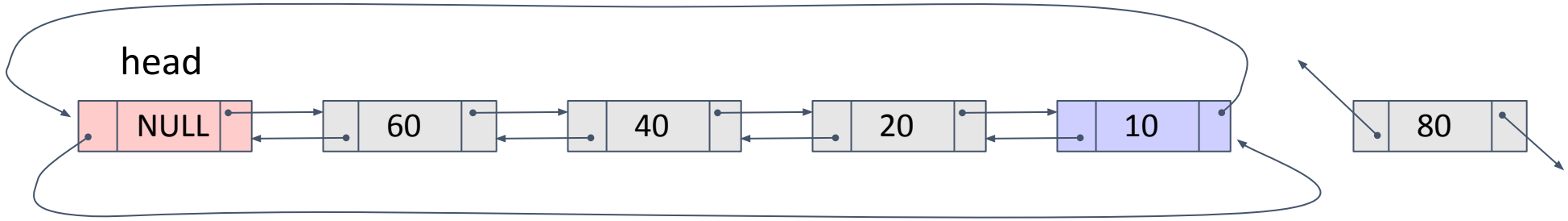
InsertAtStart

Insert 30 at start




```
public void insertAtStart(int elem) {
    Node newNode = new Node(elem);
    Node first = head.next;

    newNode.next = first;
    newNode.prev = head;
    head.next = newNode;
    first.prev = newNode;
}
```

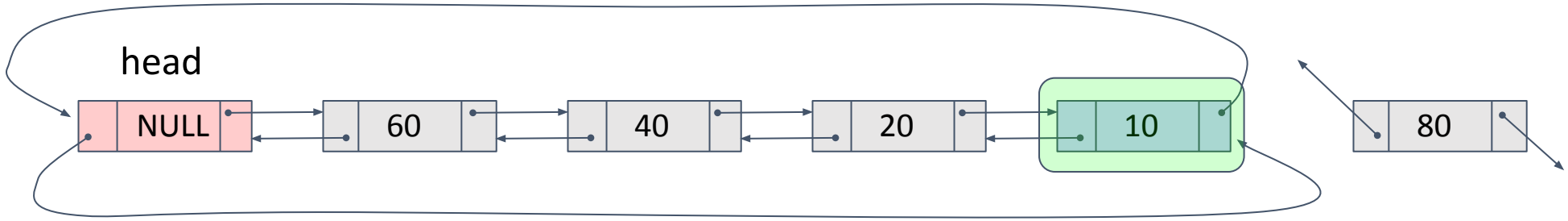
InsertAtEnd




```
public void insertAtEnd(int elem) {
    Node newNode = new Node(elem);



}
```

Insert 80 at end

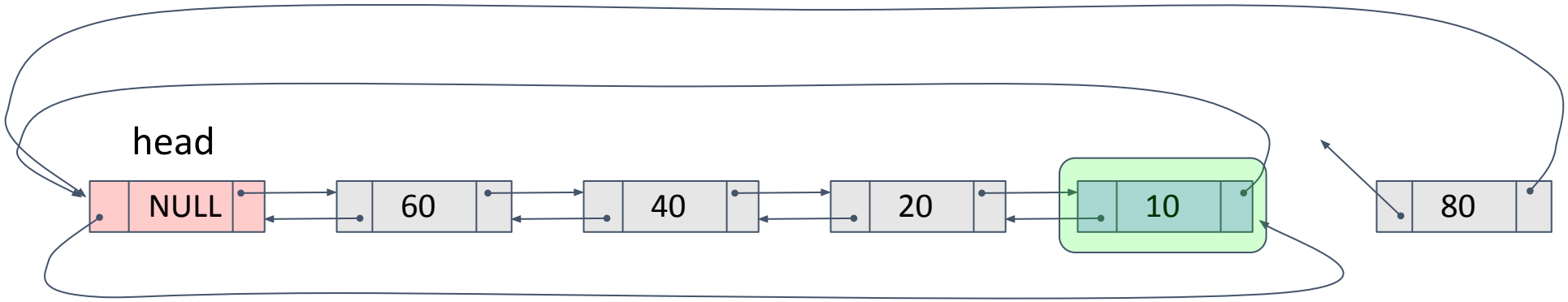
InsertAtEnd




```
public void insertAtEnd(int elem) {
    Node newNode = new Node(elem);
    Node last = head.prev;



}
```

Insert 80 at end

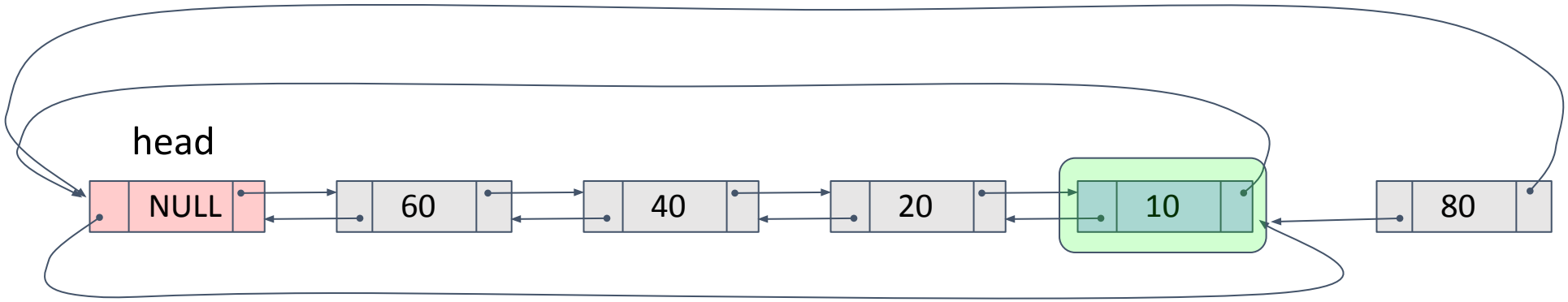
InsertAtEnd




```
public void insertAtEnd(int elem) {
    Node newNode = new Node(elem);
    Node last = head.prev;

    newNode.next = head;



}
```

Insert 80 at end

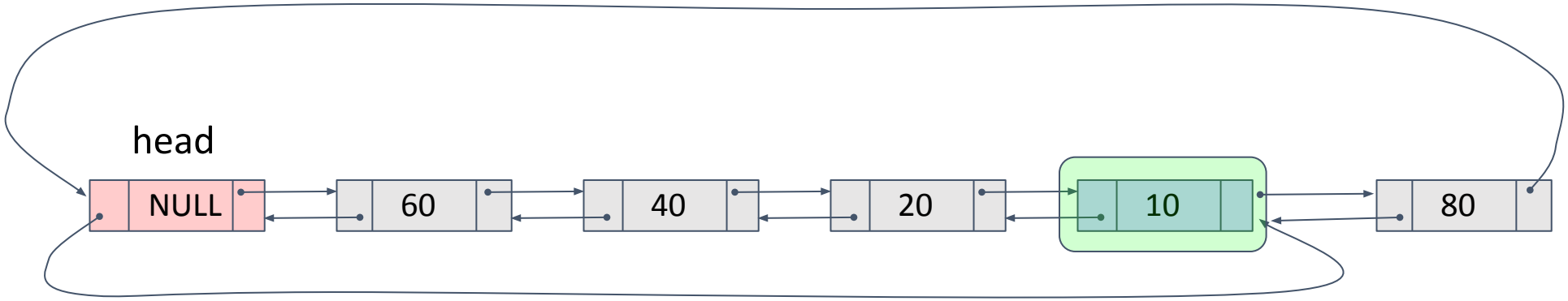
InsertAtEnd




```
public void insertAtEnd(int elem) {
    Node newNode = new Node(elem);
    Node last = head.prev;

    newNode.next = head;
    newNode.prev = last;


}
```

Insert 80 at end

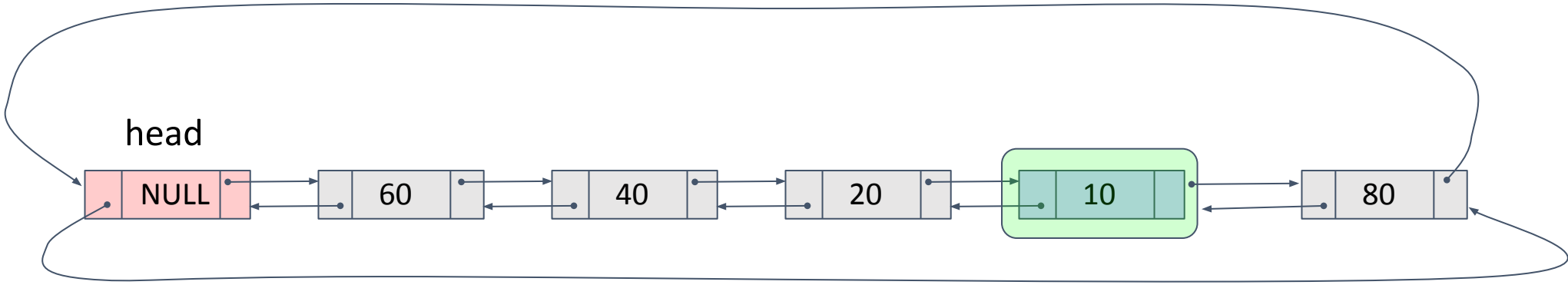
InsertAtEnd




```
public void insertAtEnd(int elem) {
    Node newNode = new Node(elem);
    Node last = head.prev;

    newNode.next = head;
    newNode.prev = last;
    last.next = newNode;

}
```

Insert 80 at end

InsertAtEnd




```
public void insertAtEnd(int elem) {
    Node newNode = new Node(elem);
    Node last = head.prev;

    newNode.next = head;
    newNode.prev = last;
    last.next = newNode;
    head.prev = newNode;
}
```

Insert 80 at end

Insert Anywhere

```
public void insertAtIndex(int index, int elem) {
    if (index < 0) return;

    if (index == 0) {
        insertAtStart(elem);
        return;
    }

    Node current = head.next;
    int currentIndex = 0;

    while (current != head) {
        if (currentIndex == index) {
            Node newNode = new Node(elem);
            Node prevNode = current.prev;

            newNode.next = current;
            newNode.prev = prevNode;
            prevNode.next = newNode;
            current.prev = newNode;

            return;
        }
        currentIndex++;
        current = current.next;
    }

    if (currentIndex == index) {
        insertAtEnd(elem);
    }
}
```

Insert Anywhere

Similar to DLLs

```java
public void insertAtIndex(int index, int elem) {
    if (index < 0) return;

    if (index == 0) {
        insertAtStart(elem);
        return;
    }

    Node current = head.next;
    int currentIndex = 0;

    while (current != head) {
        if (currentIndex == index) {
            Node newNode = new Node(elem);
            Node prevNode = current.prev;

            newNode.next = current;
            newNode.prev = prevNode;
            prevNode.next = newNode;
            current.prev = newNode;

            return;
        }
        currentIndex++;
        current = current.next;
    }

    if (currentIndex == index) {
        insertAtEnd(elem);
    }
}
```

Creation

```
public void createFromArray(int[] arr) {
    for (int elem : arr) {
        insertAtEnd(elem);
    }
}
```

Removal

```
public void remove(int index) {
    if (index < 0) return;

    Node current = head.next;
    int currentIndex = 0;

    while (current != head) {
        if (currentIndex == index) {
            Node prevNode = current.prev;
            Node nextNode = current.next;

            prevNode.next = nextNode;
            nextNode.prev = prevNode;

            return;
        }
        currentIndex++;
        current = current.next;
    }
    System.out.println("Index out of bounds");
}
```

Exercise

- Reverse a dummy headed circular DLL
- Detect cycles (hint: hare and tortoise algorithm)

Practice Problems

- Browser history design: https://leetcode.com/problems/design-browser-history
- Authentication manager: https://leetcode.com/problems/design-authentication-manager