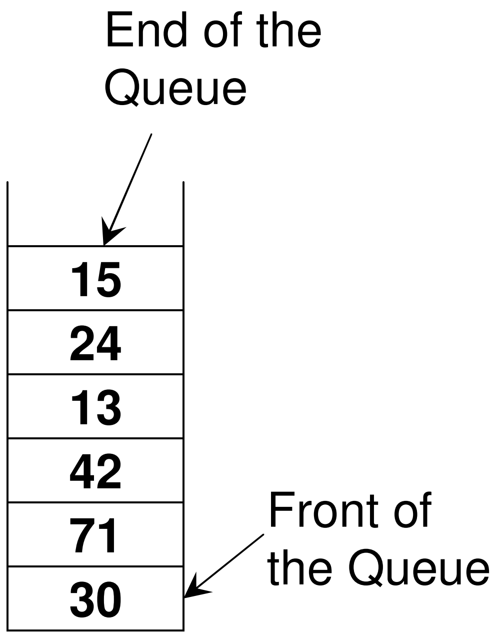
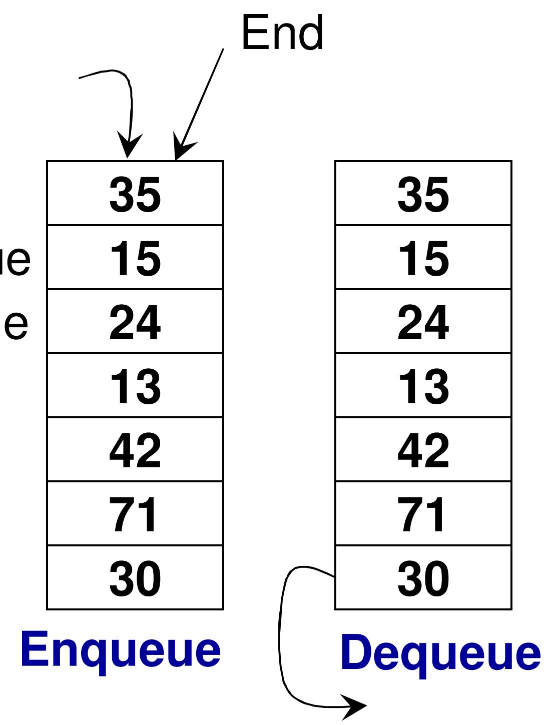
Module 4:
Queue ADT

Dr. Natarajan Meghanathan
Professor of Computer Science
Jackson State University
Jackson, MS 39217
E-mail: natarajan.meghanathan@jsums.edu

Queue ADT

- Features (Logical View)
  - A List that operates in a First In First Out (FIFO) fashion
  - Insertion can be done at the end of the list and deletion is done from the front of the list
    - The first added item has to be removed first
  - Operations:
    - Enqueue( ) – adding an item to the end of the Queue
    - Dequeue( ) – delete the item from the front of the Queue
    - Peek( ) – read the item at the front of the Queue
    - IsEmpty( ) – whether there is any element in the Queue
  - All the above operations should be preferably implemented in O(1) time.





Implementation of Queue

Dynamic Array vs. Singly/Doubly Linked List

- Enqueue
  - Array: O(n) time, due to need for resizing when the queue gets full
  - Singly Linked List: Θ(n) time: traversal of the entire list is needed
  - Doubly Linked List: O(1) time
- Dequeue
  - Array: Θ(n) time, as elements need to be shifted one position to the left
  - Singly Linked List: O(1) time, as the headPtr just needs to be adjusted
  - Doubly Linked List: O(1) time
- Peek
  - Array: O(1) time
  - Singly Linked List: O(1) time, as the first node info needs to be just seen
  - Doubly Linked List: O(1) time

- With a doubly-linked list based implementation of the queue, we can enqueue by inserting the new node from the tail of the list and dequeue (or peek) by removing (or reading the value of) the node next to the head node.

Code 4.1: Dynamic Array-based Queue

C++

```
private:
        int *array;
        int maxSize;
        int endOfQueue;

public:
        Queue(int size){
                array = new int[size];
                maxSize = size;
                endOfQueue = -1;
        }       // Same as endOfArray

        bool isEmpty(){

                if (endOfQueue == -1)
                        return true;

                return false;
        }
```

Java

```
private int array[];
private int maxSize;
private int endOfQueue;

public Queue(int size){
        array = new int[size];
        maxSize = size;
        endOfQueue = -1;
}

public boolean isEmpty(){

        if (endOfQueue == -1)
                return true;

        return false;
}
```

Code 4.1 (C++)

```
void resize(int s){

        int *tempArray = array;

        array = new int[s];

        for (int index = 0; index < min(s, endOfQueue+1); index++){
                array[index] = tempArray[index];
        }

        maxSize = s;
}
```

```
void enqueue(int data){       // same as insert 'at the end'

        if (endOfQueue == maxSize-1)
                resize(2*maxSize);

        array[++endOfQueue] = data;

}
```

Code 4.1 (Java)

```
public void resize(int s){

        int tempArray[] = array;

        array = new int[s];

        for (int index = 0; index < Math.min(s, endOfQueue+1); index++){
                array[index] = tempArray[index];
        }
        maxSize = s;
  }
```

```
public void enqueue(int data){        // same as insert 'at the end'

        if (endOfQueue == maxSize-1)
                resize(2*maxSize);

        array[++endOfQueue] = data;
 }
```

/* Store the front value in a temporary variable
Copy the elements from index+1 to index
starting from index = 0 to index = endOfQueue-1 */

Code 4.1 (C++)

```
int dequeue(){

        if (endOfQueue >= 0){
                int returnVal = array[0];

                for (int index = 0; index < endOfQueue; index++)
                        array[index] = array[index+1];

                endOfQueue--;
                // the endOfQueue is decreased by one

                return returnVal;
        }
        else
                return -1000000; // an invalid value indicating
                                                // queue is empty
}
```

```
int peek(){

        if (endOfQueue >= 0)
                return array[0];
        else
                return -1000000;// an invalid value indicating
                                                // queue is empty
 }
```

/* Store the front value in a temporary variable
Copy the elements from index+1 to index
starting from index = 0 to index = endOfQueue-1 */

Code 4.1 (Java)

```
public int dequeue(){

        if (endOfQueue >= 0){
                int returnVal = array[0];

                for (int index = 0; index < endOfQueue; index++)
                        array[index] = array[index+1];

                endOfQueue--;
                // the endOfQueue is decreased by one

                return returnVal;
        }
        else
                return -1000000; // an invalid value indicating
                                                        // queue is empty
}
```

```
int peek(){

        if (endOfQueue >= 0)
                return array[0];
        else
                return -1000000;// an invalid value indicating
                                                        // queue is empty
 }
```

Code 3.2: Doubly Linked List-based Implementation of Queue

Class Node (C++) Overview

```
private:
    int data;
    Node* nextNodePtr;
    Node* prevNodePtr;
public:
    Node( )
    void setData(int)
    int getData()
    void setNextNodePtr(Node* )
    Node* getNextNodePtr( )
    void setPrevNodePtr(Node* )
    Node* getPrevNodePtr( )
```

Class Queue (C++)

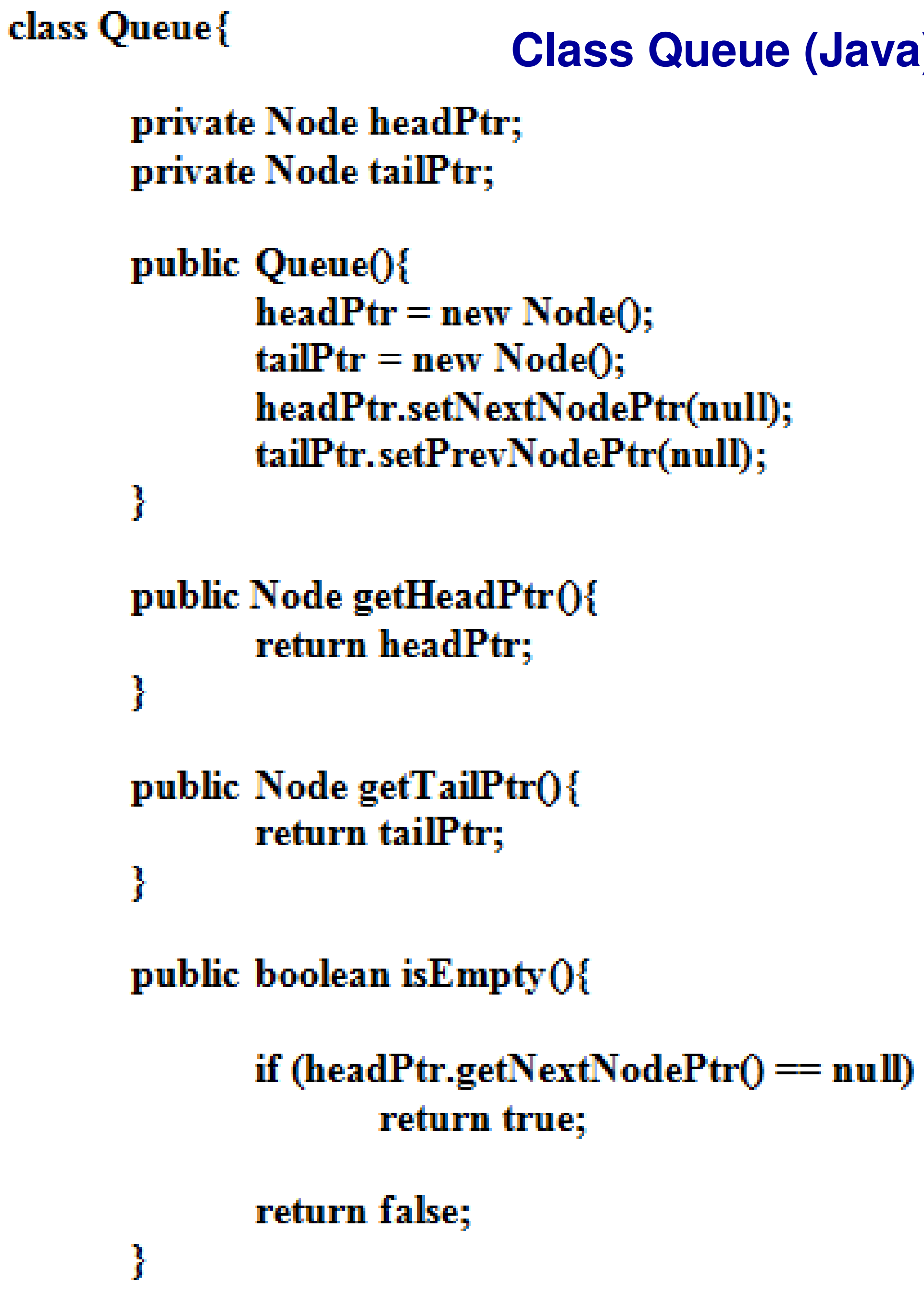
```
private:
        Node* headPtr;
        Node* tailPtr;

public:
        Queue(){
                headPtr = new Node();
                tailPtr = new Node();
                headPtr->setNextNodePtr(0);
                tailPtr->setPrevNodePtr(0);
        }

        Node* getHeadPtr(){
                return headPtr;
        }

        Node* getTailPtr(){
                return tailPtr;
        }

        bool isEmpty(){

                if (headPtr->getNextNodePtr() == 0)
                        return true;

                return false;
        }
```

Code 3.2: Doubly Linked List-based Implementation of Queue

Class Node (Java) Overview

```
private  int data;
private  Node nextNodePtr;
private  Node prevNodePtr;

public  Node( )
public  void setData(int)
public  int getData()
public  void setNextNodePtr(Node)
public  Node getNextNodePtr( )
public  void setPrevNodePtr(Node)
public  Node getPrevNodePtr( )
```

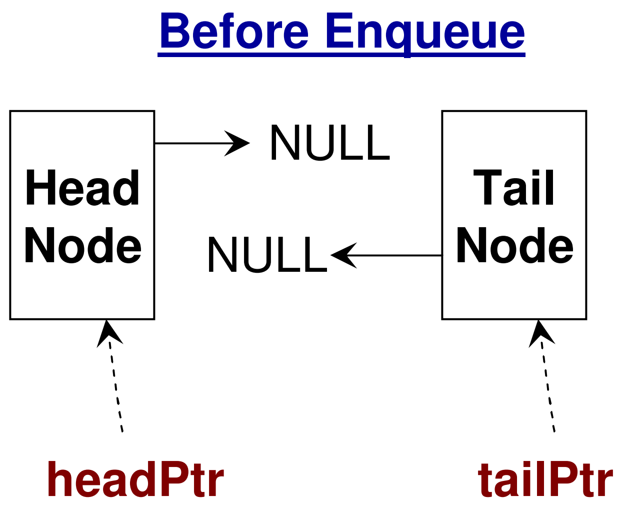
Class Queue (Java)

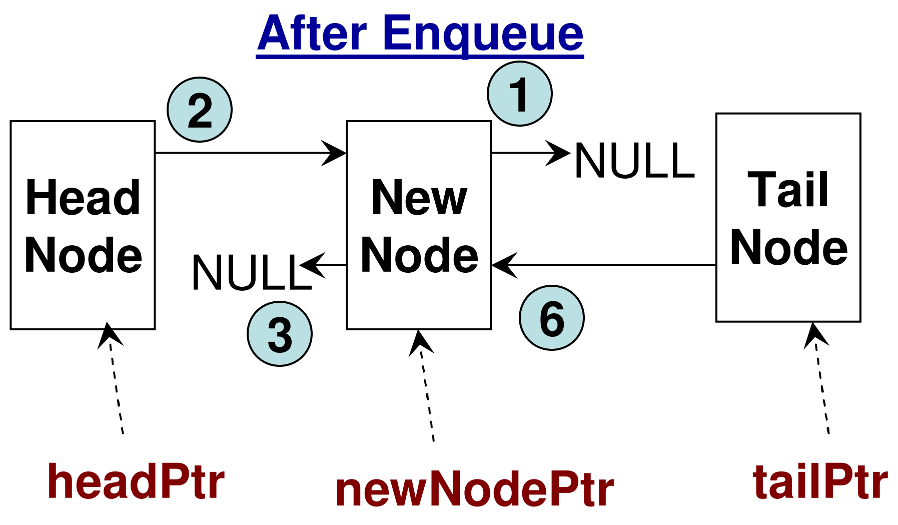


```
class Queue{

        private Node headPtr;
        private Node tailPtr;

        public Queue(){
                headPtr = new Node();
                tailPtr = new Node();
                headPtr.setNextNodePtr(null);
                tailPtr.setPrevNodePtr(null);
        }

        public Node getHeadPtr(){
                return headPtr;
        }

        public Node getTailPtr(){
                return tailPtr;
        }

        public boolean isEmpty(){

                if (headPtr.getNextNodePtr() == null)
                        return true;

                return false;
        }
```

Enqueue Operation

Scenario 1: There is no node currently in the Queue

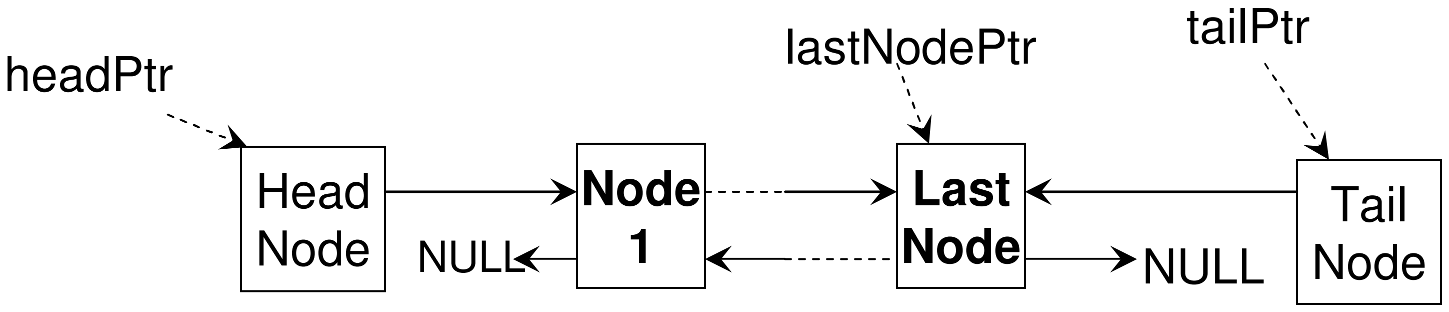




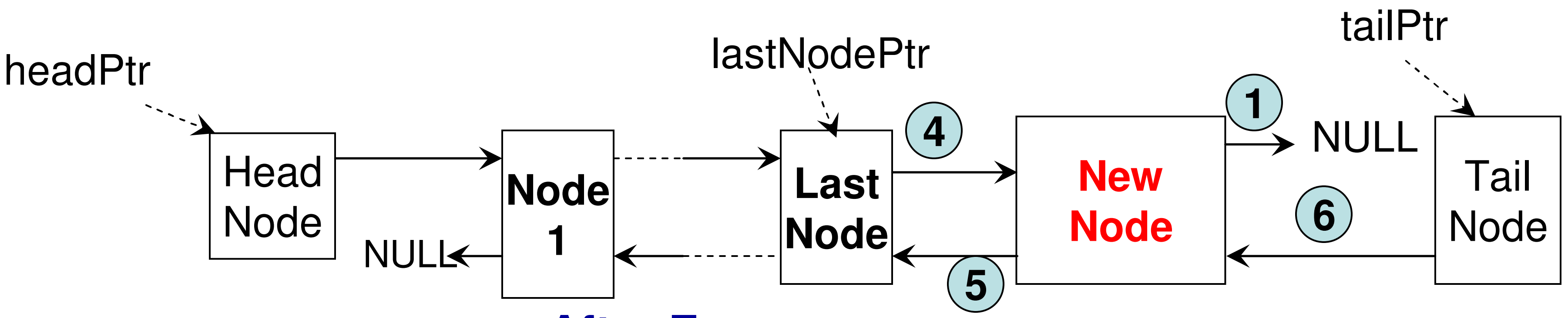
Enqueue Operation

Scenario 2: There is at least one node already in the Queue

// Before the new node is inserted, the prevNodePtr for the "tail node"
// would be pointing to the last node in the queue and the nextNodePtr
// for that last node would be pointing to NULL.



Before Enqueue



After Enqueue

Code 4.2 (C++)

```
void enqueue(int data){

    Node* newNodePtr = new Node();
    newNodePtr->setData(data);
    newNodePtr->setNextNodePtr(0); ①

    Node* lastNodePtr = tailPtr->getPrevNodePtr();

                    // There is no other node in the Queue (Scenario 1)
    if (lastNodePtr == 0){
        headPtr->setNextNodePtr(newNodePtr);②
        newNodePtr->setPrevNodePtr(0); ③
    }
    else{ // There is at least one node already in the Queue (Scenario 2)
        lastNodePtr->setNextNodePtr(newNodePtr); ④
        newNodePtr->setPrevNodePtr(lastNodePtr); ⑤
    }

    tailPtr->setPrevNodePtr(newNodePtr); ⑥
}
```

Whatever be the case, the prevNodePtr for the tail node will point to the newly pushed node

Code 4.2 (Java)

```
public void enqueue(int data){

        Node newNodePtr = new Node();
        newNodePtr.setData(data);
        newNodePtr.setNextNodePtr(null); ①

        Node lastNodePtr = tailPtr.getPrevNodePtr();

                        // There is no other node in the Queue (Scenario 1)
        if (lastNodePtr == null){
                headPtr.setNextNodePtr(newNodePtr); ②
                newNodePtr.setPrevNodePtr(null); ③
        }
        else{ // There is at least one node already in the Queue (Scenario 2)
                lastNodePtr.setNextNodePtr(newNodePtr); ④
                newNodePtr.setPrevNodePtr(lastNodePtr); ⑤
        }

        tailPtr.setPrevNodePtr(newNodePtr); ⑥
}
```

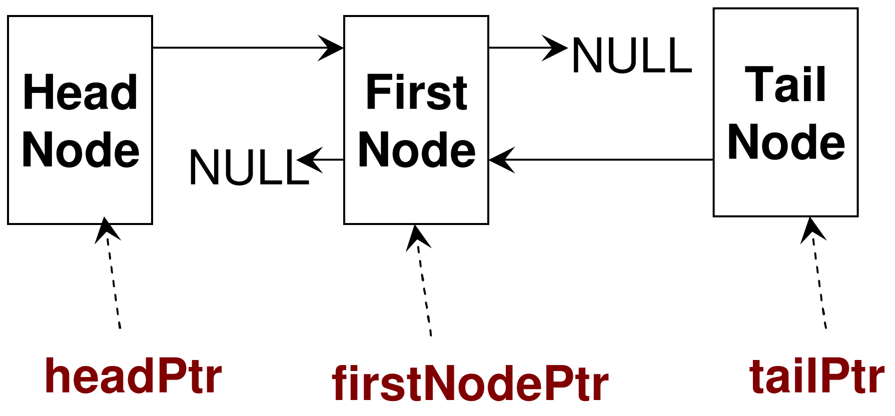
Whatever be the case, the prevNodePtr for the tail node will point to the newly pushed node

Dequeue Operation

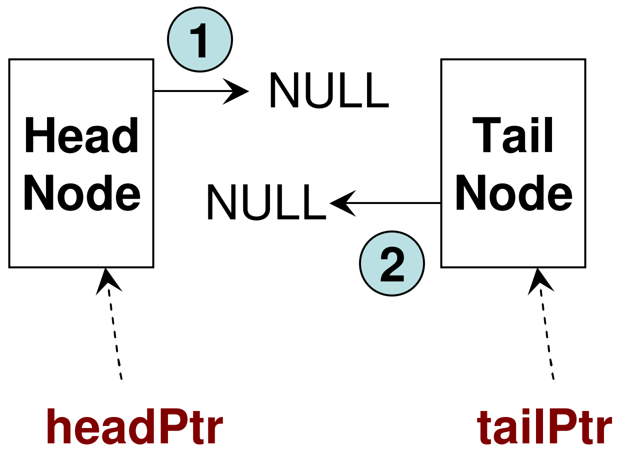
Scenario 1: There will be no node in the Queue after Dequeue (i.e., there is just one node in the Queue before the Dequeue)

// Before Dequeue: The Head Node's nextNodePtr and the Tail Node's prevNodePtr are both pointing to the only node in the queue.
// After Dequeue: Both the Head Node's nextNodePtr and the Tail Node's prevNodePtr are set to NULL

Before Dequeue



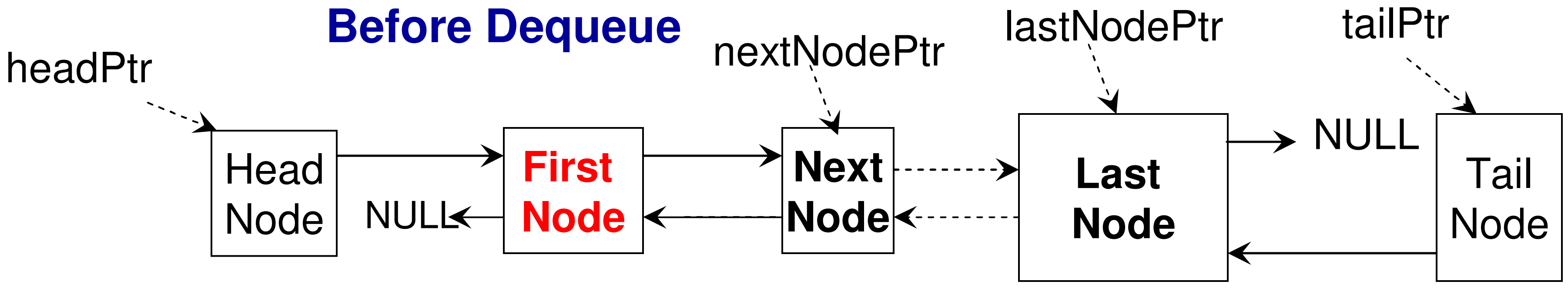
After Dequeue



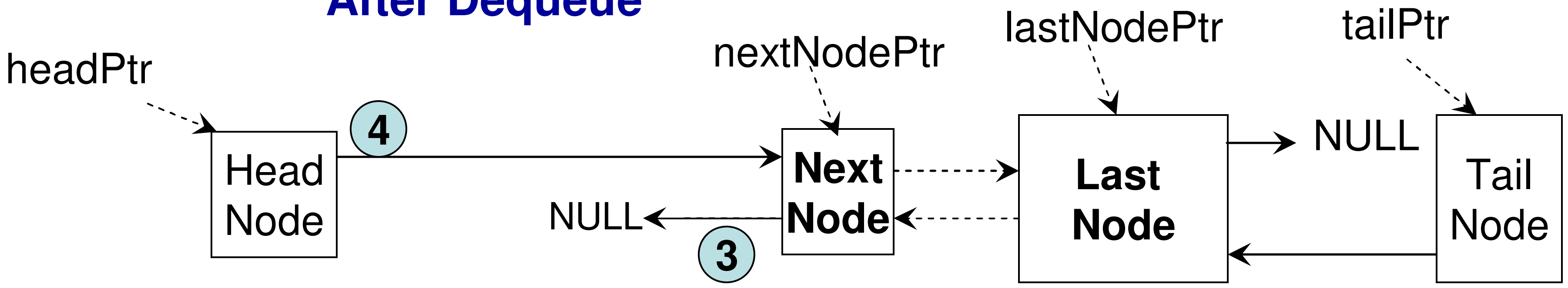
Dequeue Operation

Scenario 2: There will be at least one node in the Queue after the Dequeue operation is executed

Before Dequeue



After Dequeue



Code 4.2 (C++)

```
int dequeue(){

    Node* firstNodePtr = headPtr->getNextNodePtr();
    Node* nextNodePtr = 0;

    int poppedData = -100000; //empty queue

    if (firstNodePtr != 0){
        nextNodePtr = firstNodePtr->getNextNodePtr();
        poppedData = firstNodePtr->getData();
    }
    else
        return poppedData;

    if (nextNodePtr != 0){
  3     nextNodePtr->setPrevNodePtr(0);
  4     headPtr->setNextNodePtr(nextNodePtr);
    }
    else{
        headPtr->setNextNodePtr(0);  1
        tailPtr->setPrevNodePtr(0);
    }                              2

    return poppedData;
}
```

If there is at least one node in the Queue before Dequeue

Retrieve the nextNodePtr for the First node

There is more than one node in the Queue before Dequeue. Set the next node of the first node as the new first node and make the headPtr point to it as its next node. Set the prevNodePtr of the new first node to null. (Scenario 2)

There is going to be no node in the Queue after the Dequeue operation (Scenario 1).

Code 4.2 (Java)

```
public int dequeue(){

        Node firstNodePtr = headPtr.getNextNodePtr();
        Node nextNodePtr = null;

        int poppedData = -100000; //empty queue

        if (firstNodePtr != null){
                nextNodePtr = firstNodePtr.getNextNodePtr();
                poppedData = firstNodePtr.getData();
        }
        else
                return poppedData;

        if (nextNodePtr != null){
            3   nextNodePtr.setPrevNodePtr(null);
            4   headPtr.setNextNodePtr(nextNodePtr);
        }
        else{
                headPtr.setNextNodePtr(null); 1
                tailPtr.setPrevNodePtr(null); 2
        }

        return poppedData;
}
```

If there is at least one node in the Queue before Dequeue

Retrieve the nextNodePtr for the First node

There is more than one node in the Queue before Dequeue. Set the next node of the first node as the new first node and make the headPtr point to it as its next node. Set the prevNodePtr of the new first node to null. (Scenario 2)

There is going to be no node in the Queue after the Dequeue operation (Scenario 1).

Code 4.2 (C++)

```
int peek(){

        Node* firstNodePtr = headPtr->getNextNodePtr();

        if (firstNodePtr != 0)
                return firstNodePtr->getData();
        else
                return -100000; //empty queue
  }
```

Code 4.2 (Java)

```
public int peek(){

        Node firstNodePtr = headPtr.getNextNodePtr();

        if (firstNodePtr != null)
                return firstNodePtr.getData();
        else
                return -100000; //empty queue
 }
```