Linked Data Structures

Objectives

- Understand linked structures
- Compare linked structures to array-based structures
- Understand implementations for linked structures
- Understand algorithms for managing a linked list

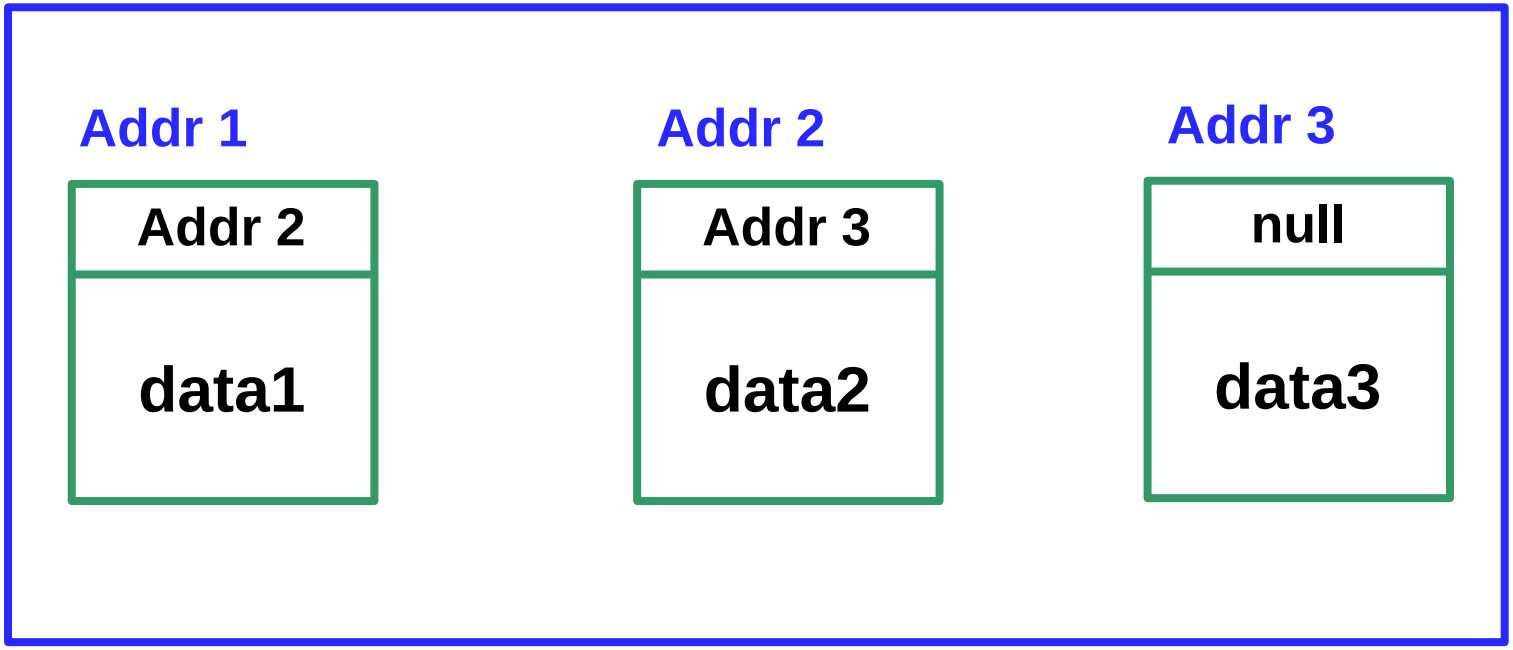
Array Limitations

- Fixed size
- Physically stored in consecutive memory locations, so to insert or delete items, may need to shift data

Linked Data Structures

- A ***linked*** data structure consists of items that are linked to other items
  - Each item ***points to*** another item

Memory



Linked Data Structures

- A ***linked*** data structure consists of items that are linked to other items
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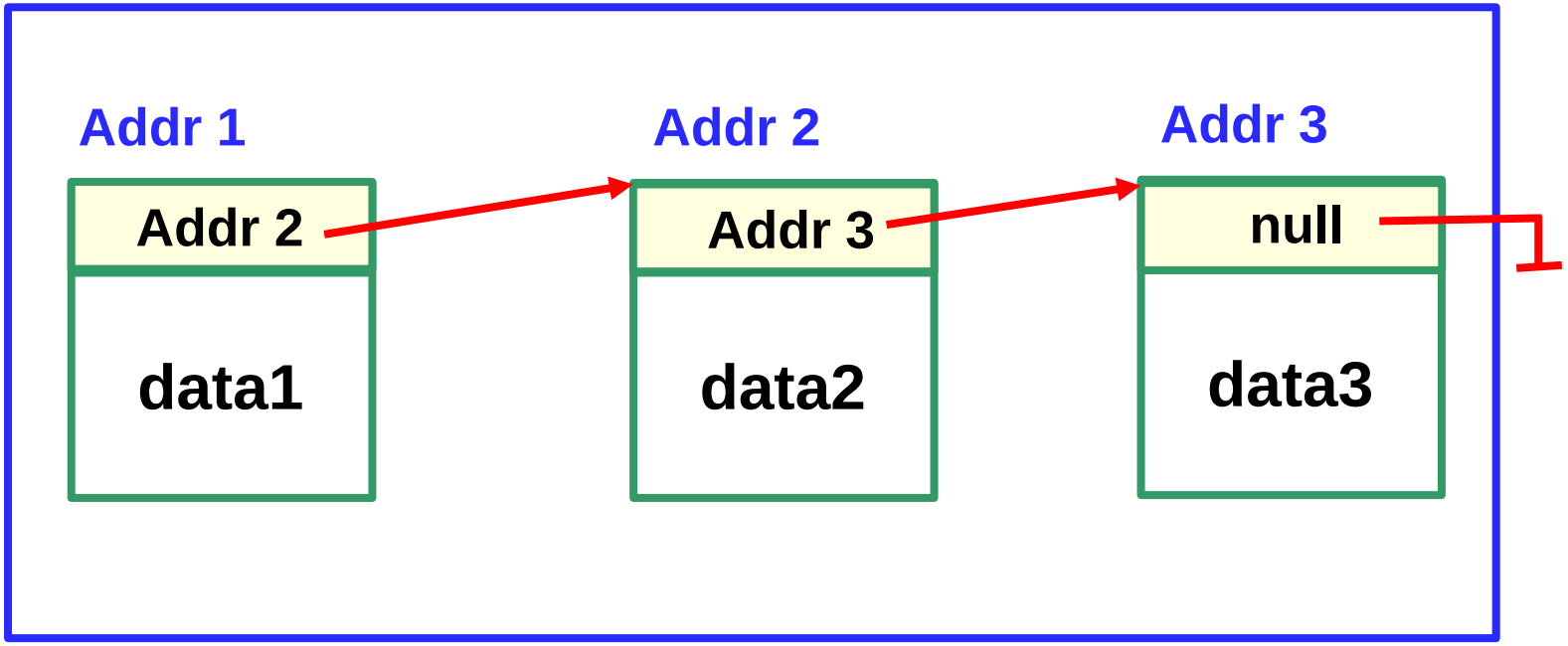
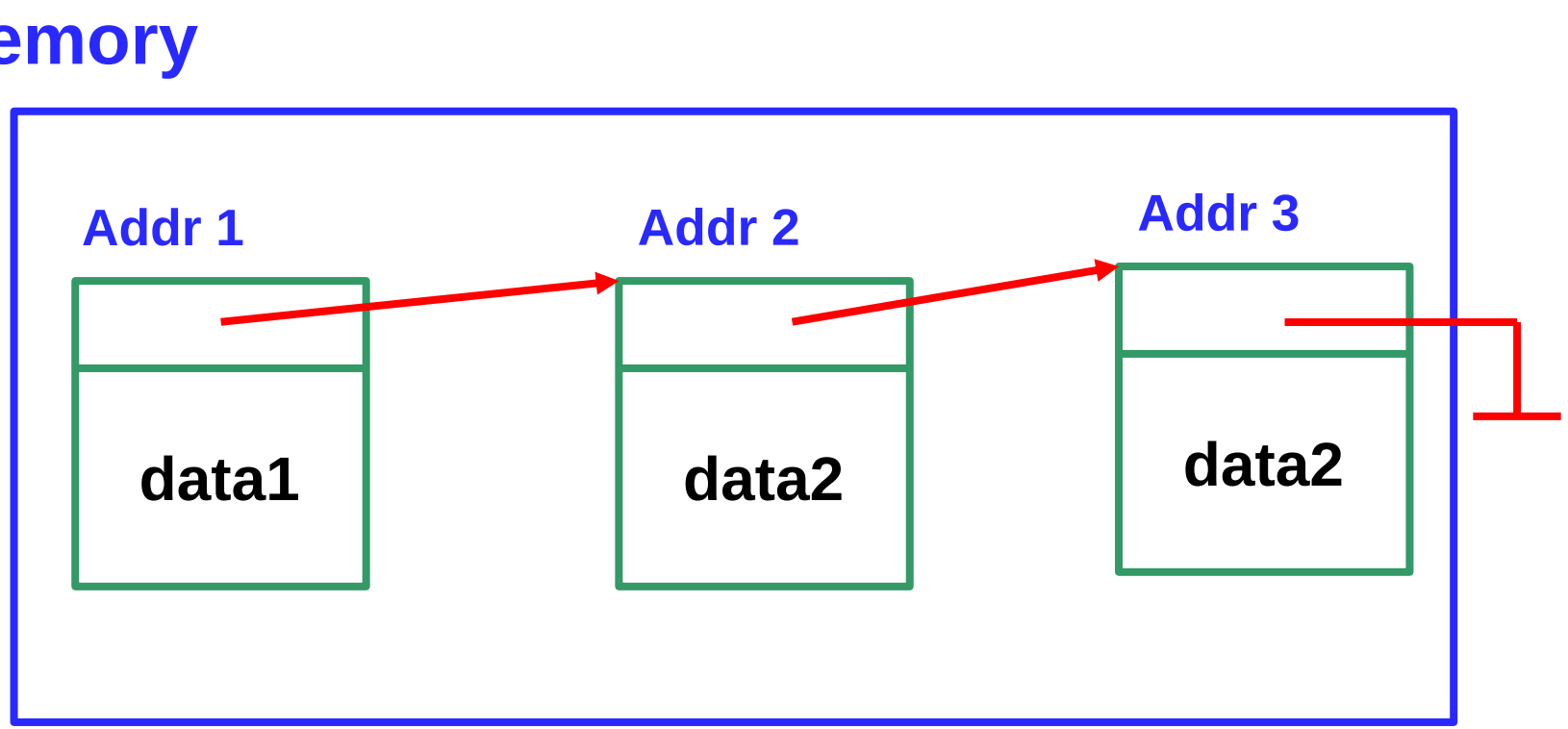


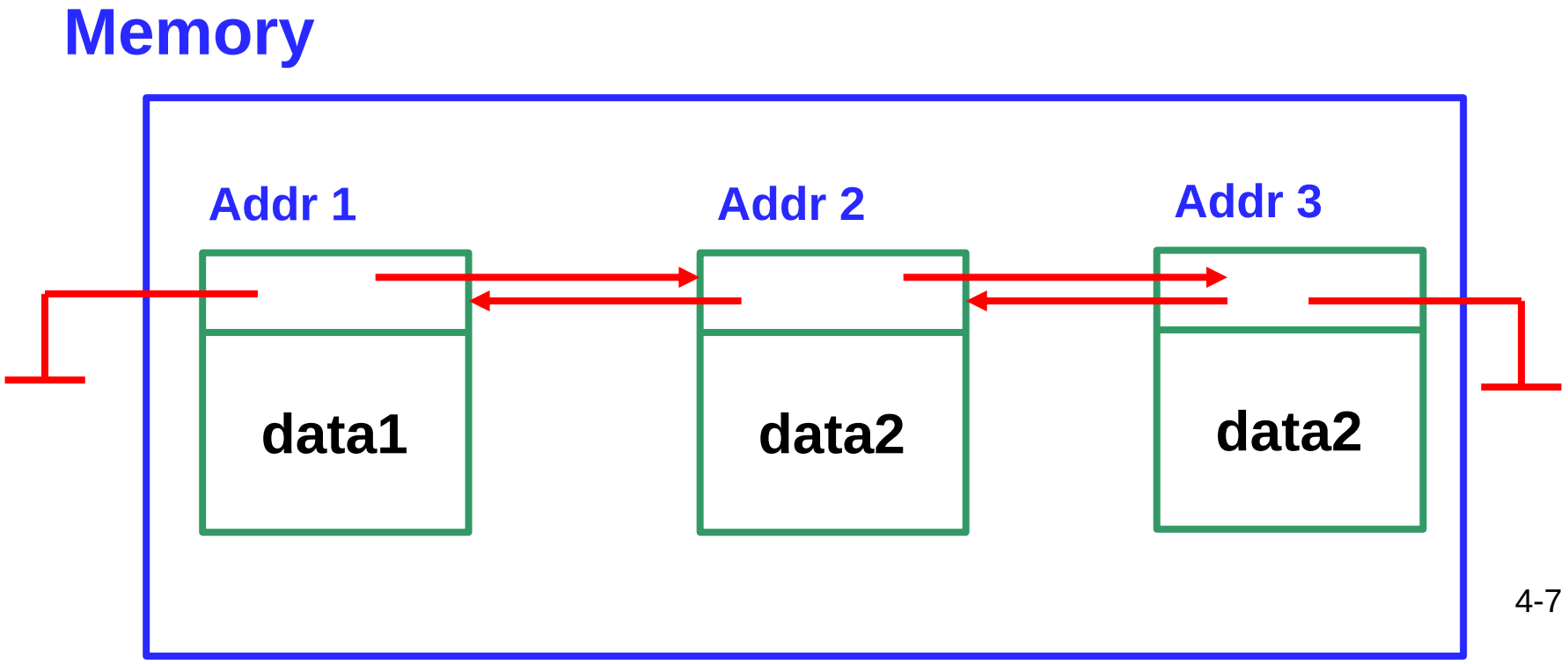
Linear Linked Data Structures

- Singly linked list: each item points to the next item

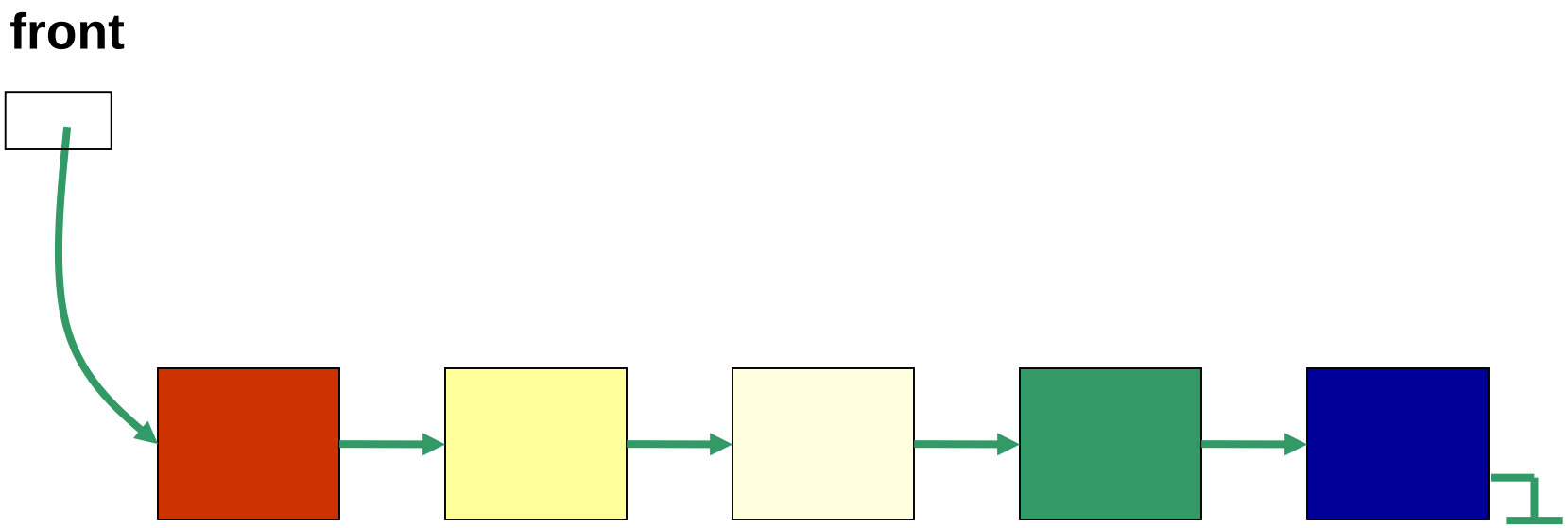


Linked Data Structures

- Doubly linked list: each item points to the next item *and* to the previous item



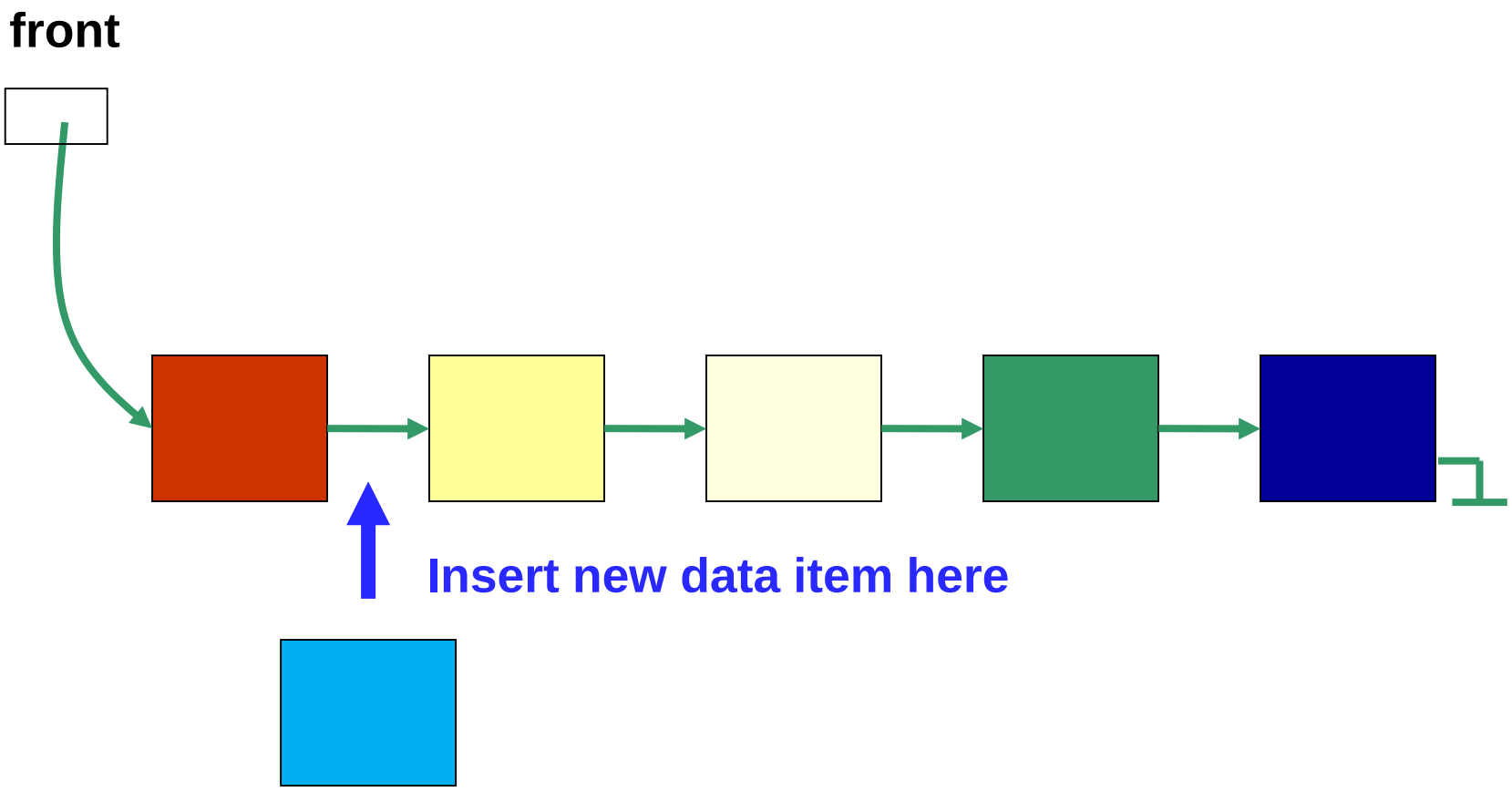
Conceptual Diagram of a Singly-Linked List



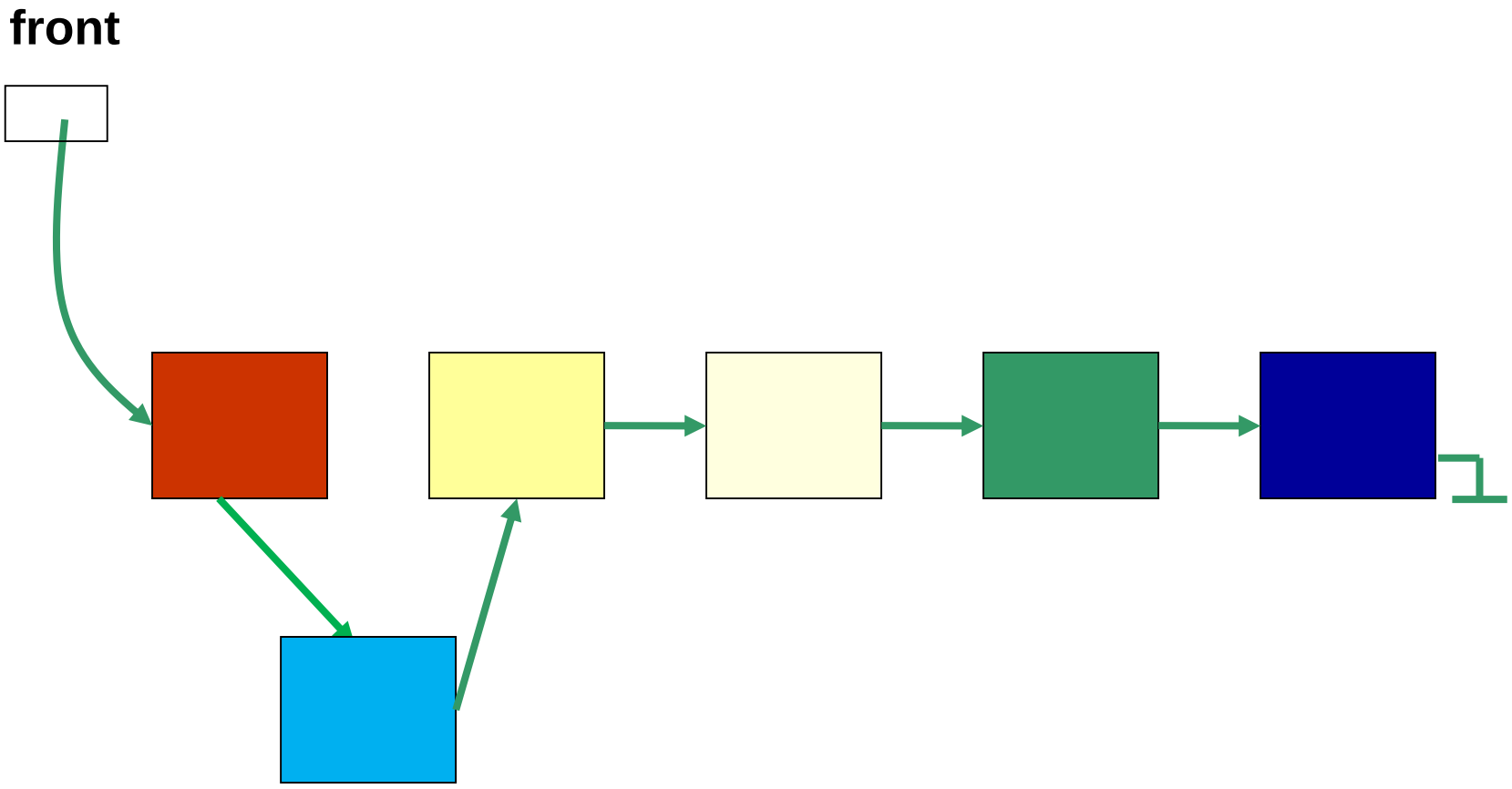
Advantages of Linked Lists

- The items do ***not*** have to be stored in consecutive memory locations, so we can insert and delete items without shifting data.

Advantages of Linked Lists

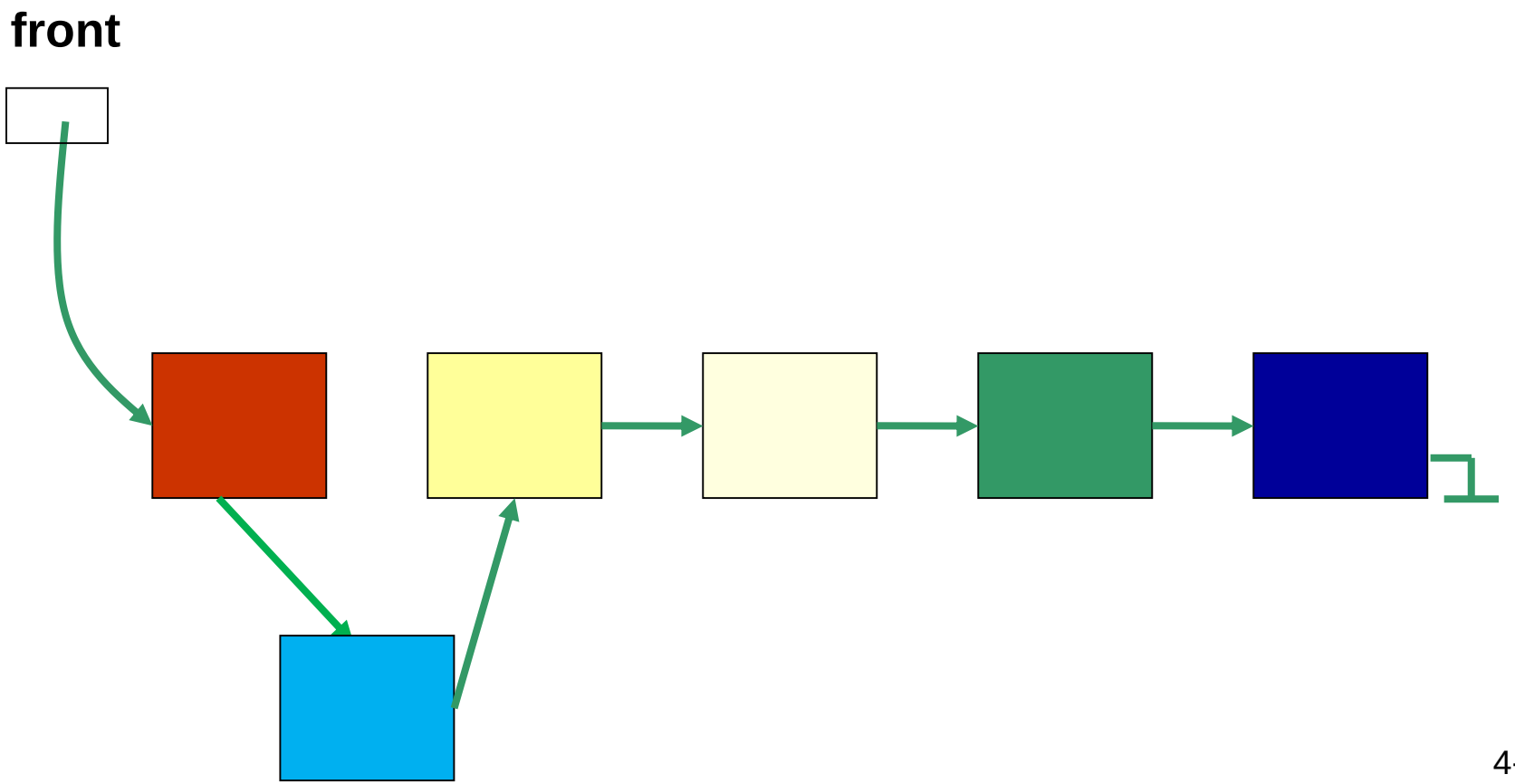


Advantages of Linked Lists



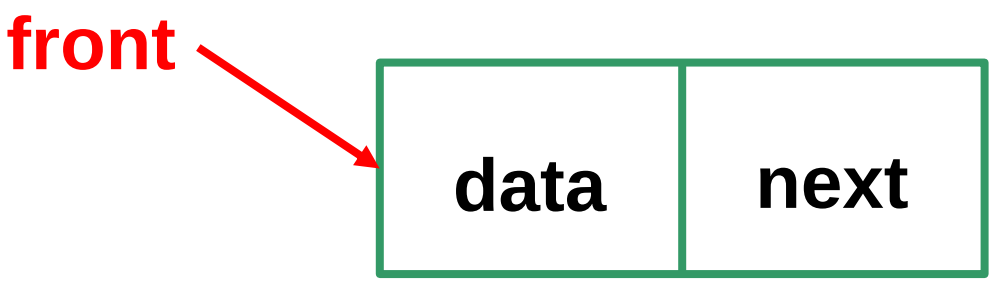
Advantages of Linked Lists

Linked lists can grow and shrink dynamically (i.e. at run time).



Nodes

- A linked list is an sequence of items called ***nodes***
- A ***node*** in a ***singly linked list*** consists of two fields:
  - A ***data*** portion
  - A ***link (pointer)*** to the ***next*** node in the structure
- The first item (node) in the linked list is accessed via a ***front*** or ***head*** pointer



Java Class for a Node of a Singly Linked List

```
public class LinearNode<T> {
    private LinearNode<T> next;
    private T dataItem;

    public LinearNode( ) {
       next = null;
       dataItem = null;
    }

    public LinearNode (T value) {
       next = null;
       dataItem = value;
    }
```

```
    public LinearNode<T> getNext( ) {
        return next;
    }
    public void setNext (LinearNode<T> node) {
        next = node;
    }
    public T getDataItem( ) {
        return dataItem;
    }
    public void setDataItem (T value) {
        dataItem = value;
    }
}
```

Example: Create a LinearNode Object

- Example: create a node that contains the integer 7

Wrapper class

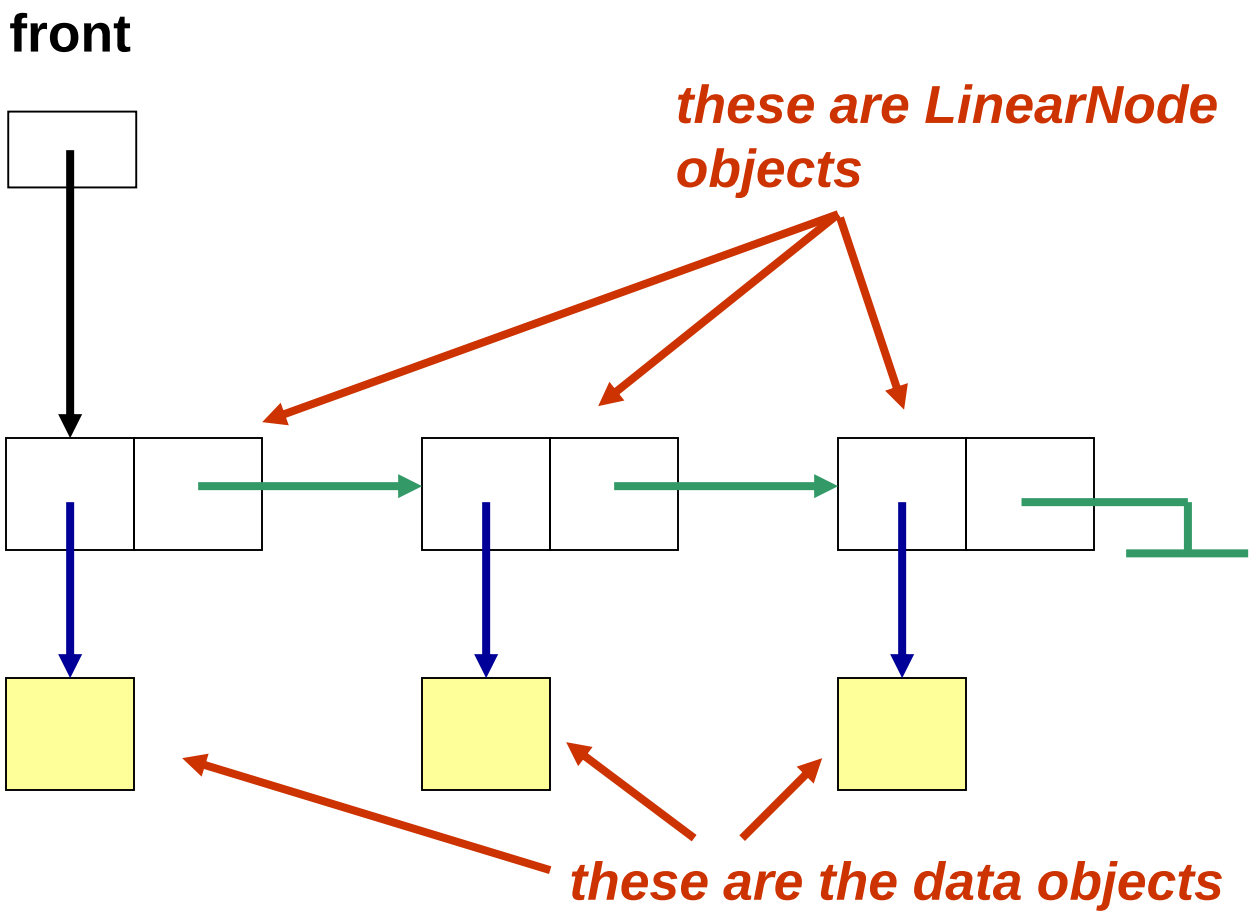
```
Integer intObj = new Integer(7);
LinearNode<Integer> inode =
                    new LinearNode<Integer> (intObj);
```

or

```
LinearNode<Integer> inode =
          new LinearNode<Integer> (new Integer(7));
```

Wrapper class needed because a generic type cannot be primitive

Linked List of Node Objects



Java Class for a Singly Linked List

```
public class SinglyLinkedList<T> {
    private LinearNode<T> front;

    public SinglyLinkedList( ) {
       front = null;
    }
```

Linked List

***Note**: we will hereafter refer to a singly linked list just as a "**linked list**"*

- ***Traversing the linked list***
  - How is the first item accessed?
  - The second?
  - The last?
- What does the last item point to?
  - We call this the ***null link***

Discussion

- How do we get to an item's successor?
- How do we get to an item's predecessor?
- How do we access, say, the 3rd item in the linked list?

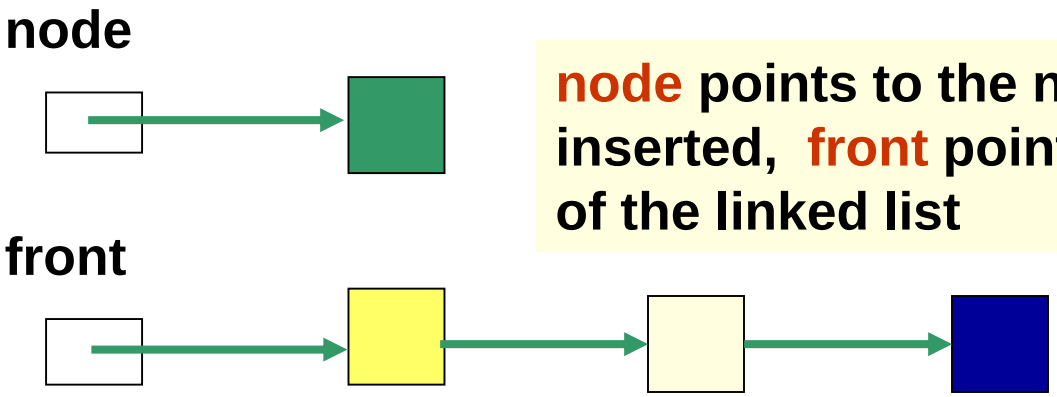
- How does this differ from an array?

Linked List Operations

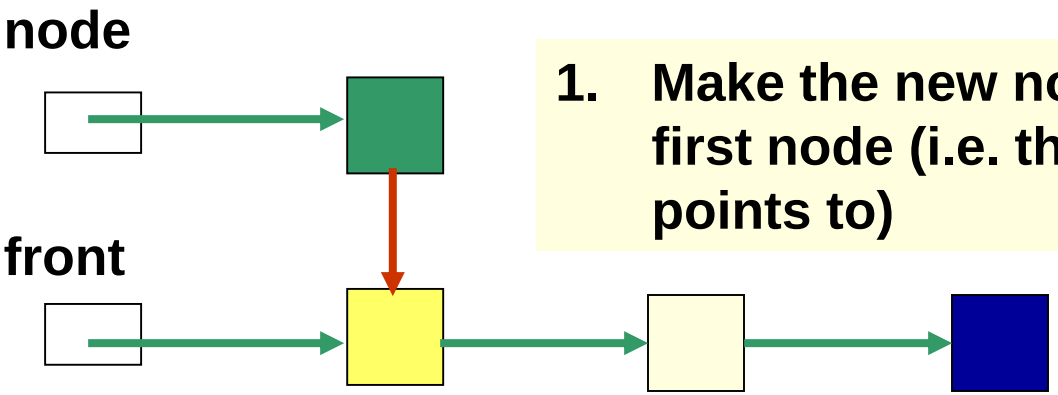
We will now examine linked list operations:

- ***Add*** an item to the linked list
  - We have 3 situations to consider:
    - insert a node at the front
    - insert a node in the middle
    - insert a node at the end

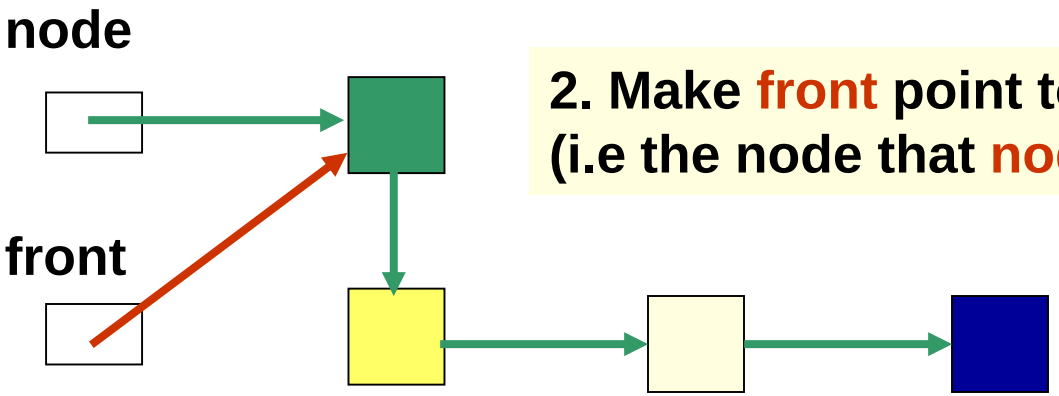
Inserting a Node at the Front



node points to the new node to be inserted, **front** points to the first node of the linked list



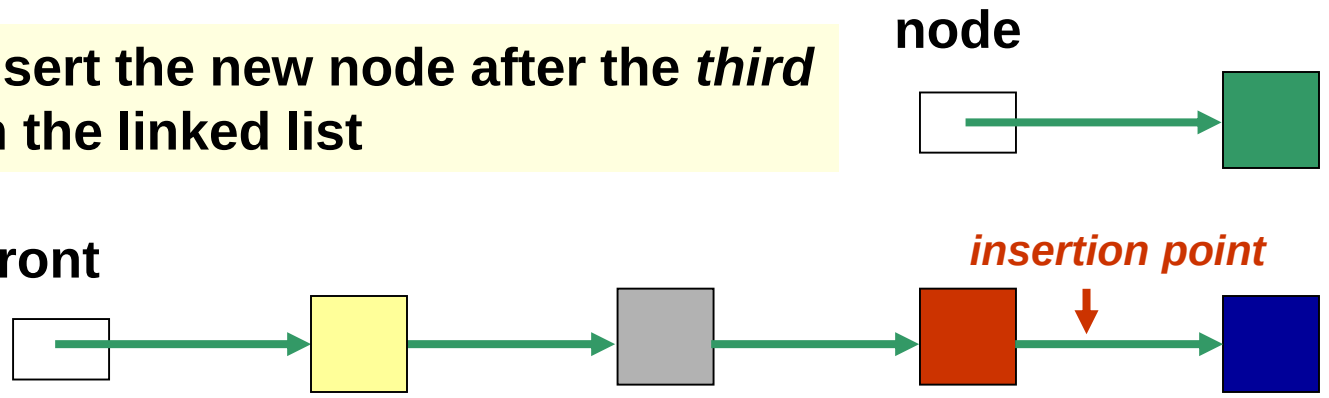
1. Make the new node point to the first node (i.e. the node that **front** points to)



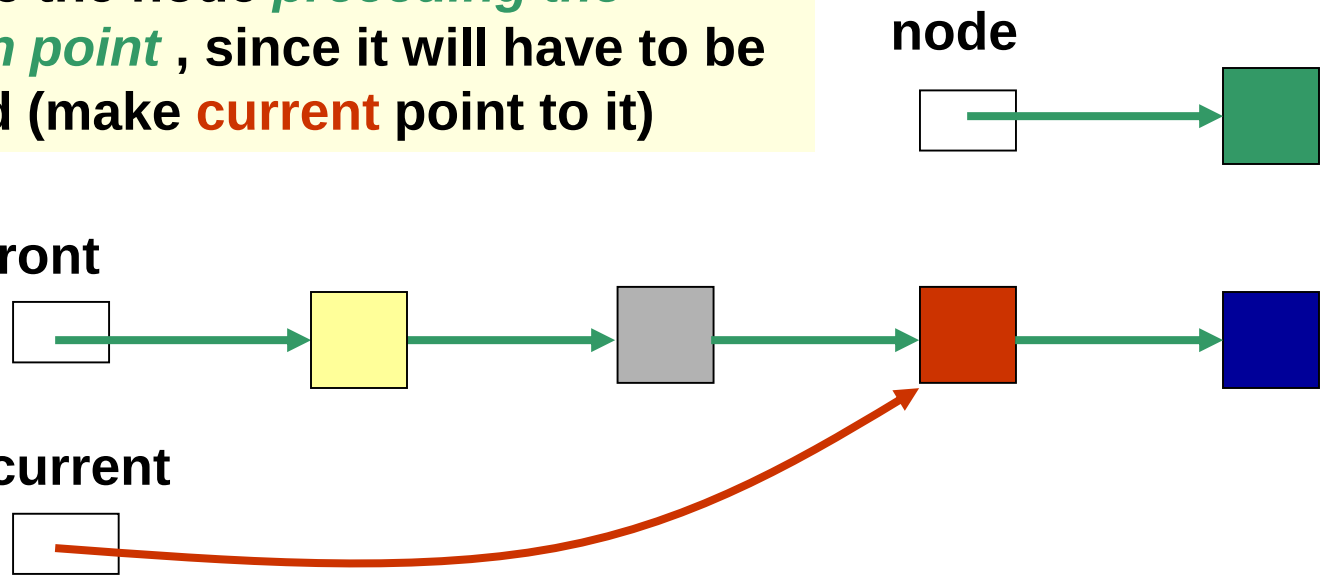
2. Make front point to the new node (i.e the node that node points to)

Inserting a Node in the Middle

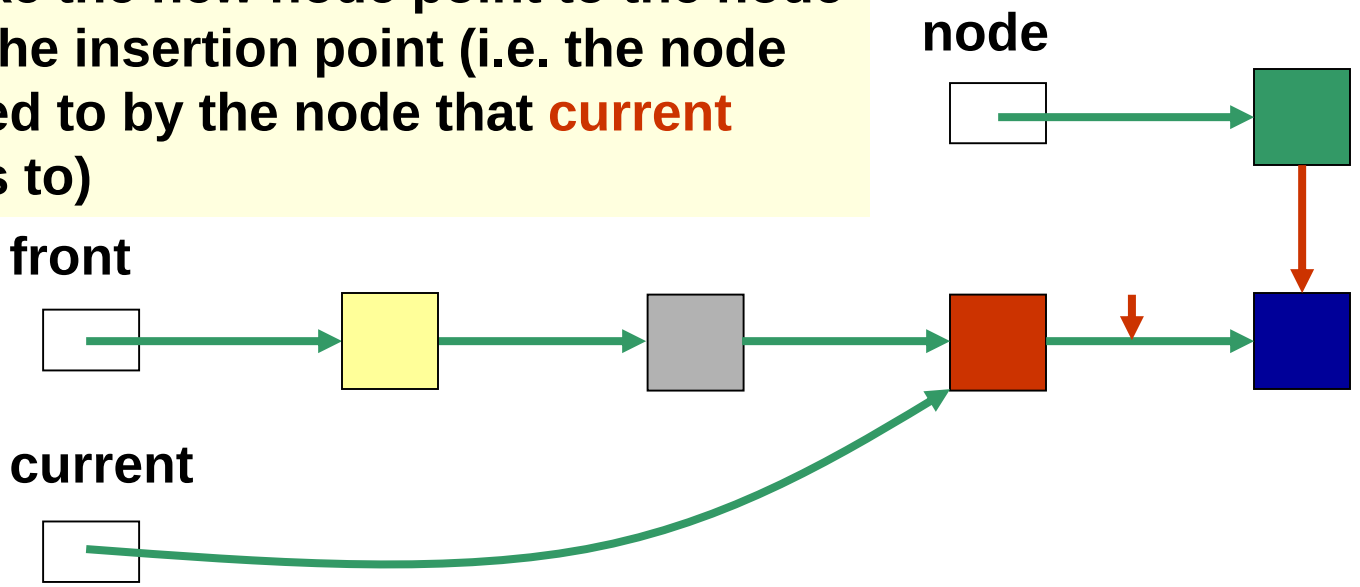
Let's insert the new node after the *third* node in the linked list



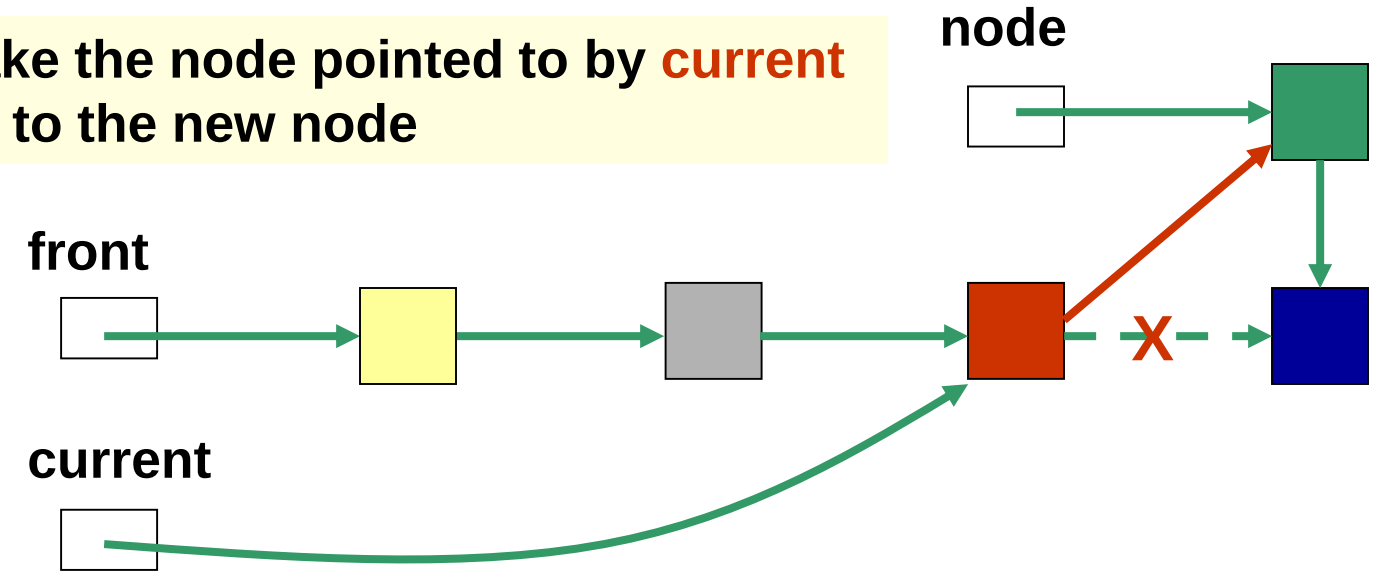
1. Locate the node *preceding the insertion point* , since it will have to be modified (make current point to it)



2. Make the new node point to the node after the insertion point (i.e. the node pointed to by the node that current points to)

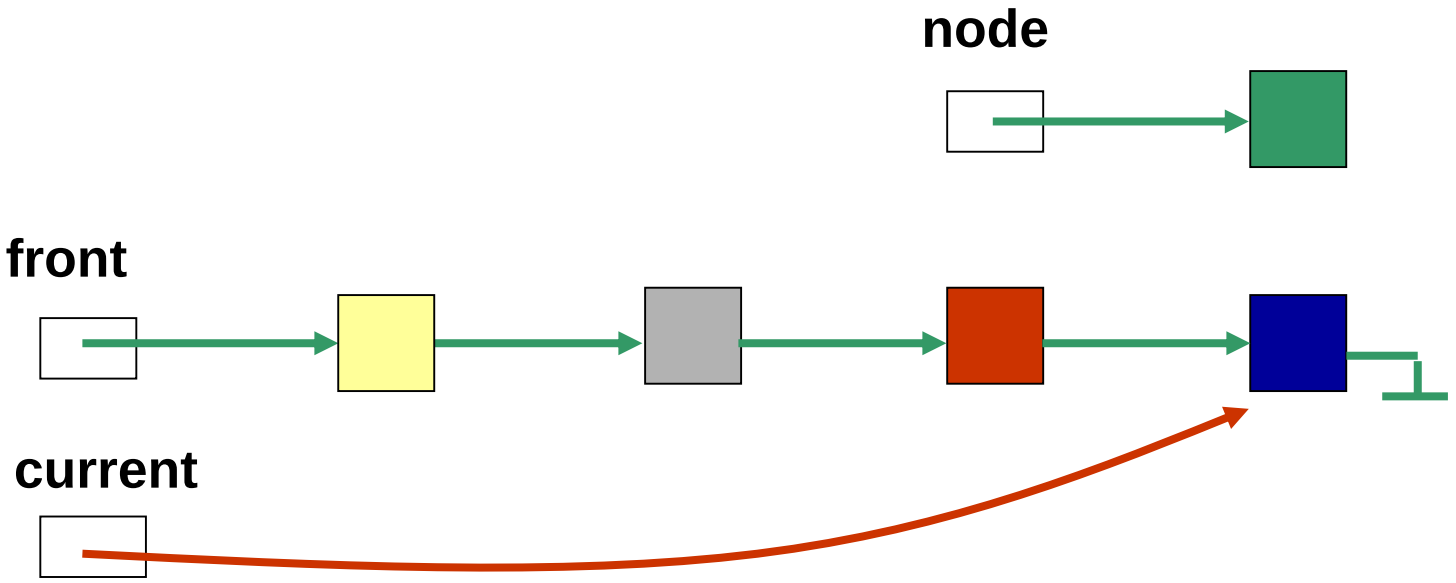


3. Make the node pointed to by current point to the new node



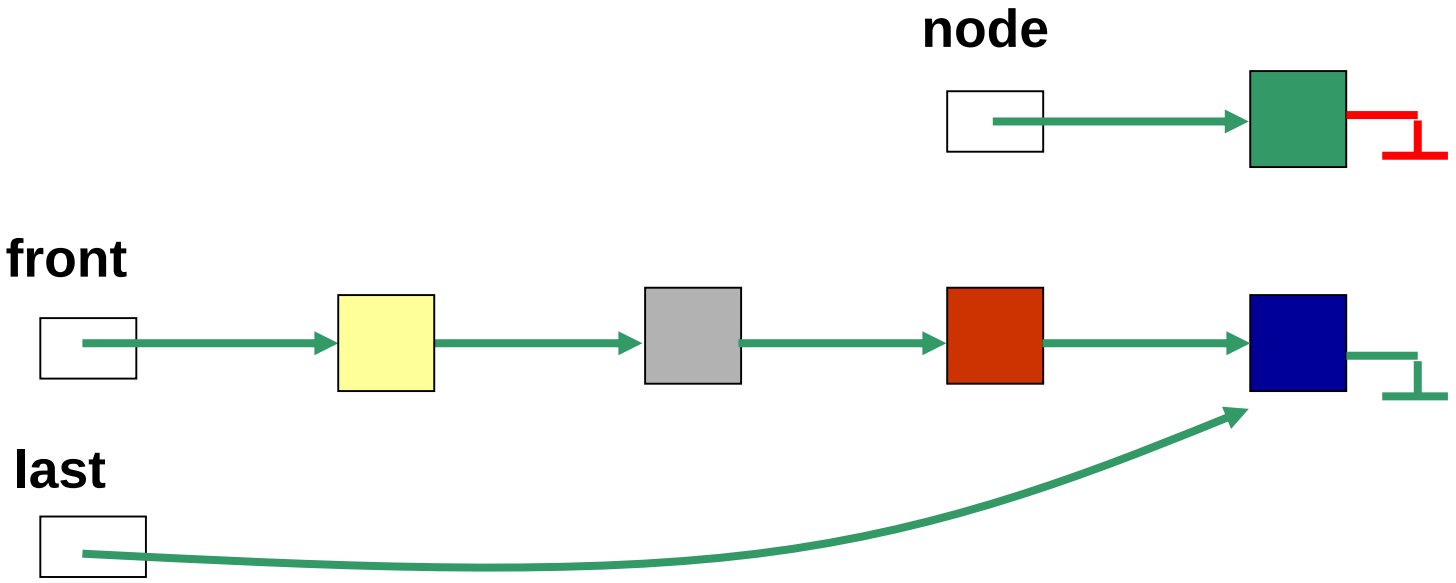
Inserting a Node at the End

1. Locate the last node



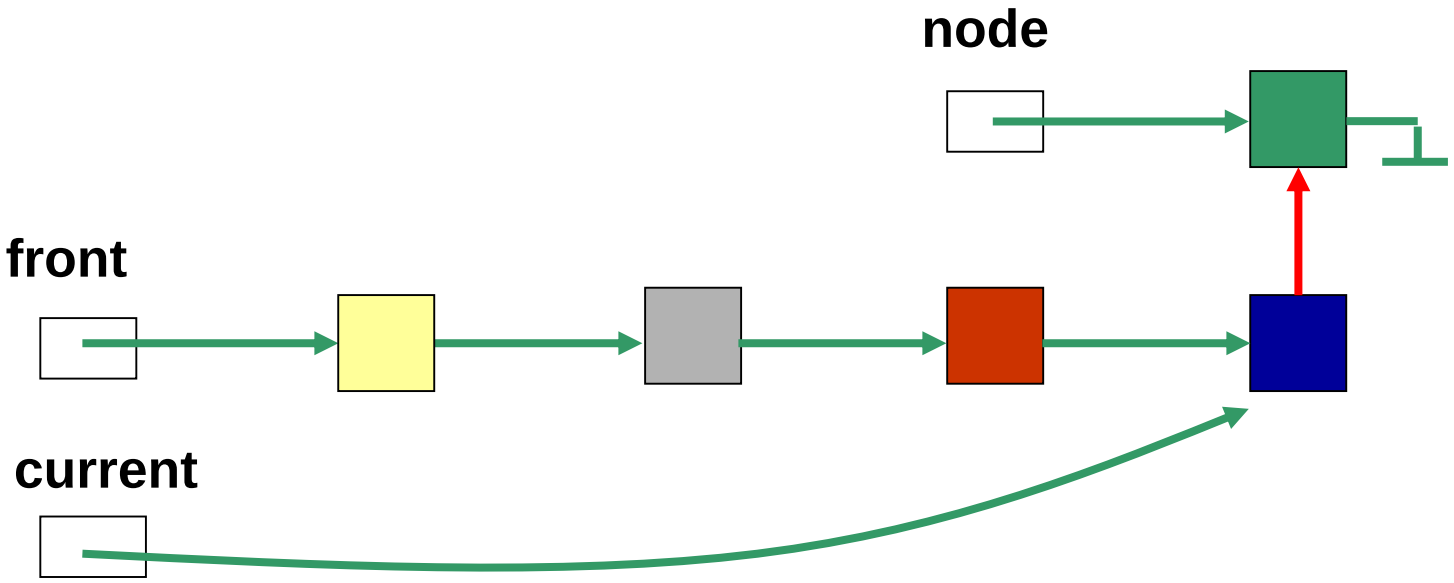
Inserting a Node at the End

2. Make new node point to null



Inserting a Node at the End

3. Make last point to new node



Discussion

- Inserting a node at the front is a special case; why?
- Is inserting a node at the end a special case?

Algorithm for inserting a node in a singly linked list

Algorithm insert (*newNode*, *predecessor*)
In: New node to be inserted after *predecessor*.
Out: {Insert *newNode* in linked list after *predecessor*; *newNode* must be inserted at the front of the list if predecessor is null.}

```
if predecessor is null then {
        newNode.setNext(front)
        front = newNode
}
else {
        succ = predecessor.getNext()
        newNode.setNext(succ)
        predecessor.setNext(newNode)
}
```

Java implementation of algorithm for inserting a node in a singly linked list

```
public void insert (LinearNode<T> newNode,
                    LinearNode<T> predecessor) {
    if (predecessor == null) {
        newNode.setNext(front);
        front = newNode;
    }
    else {
        LinearNode<T> succ = predecessor.getNext();
        newNode.setNext(succ);
        predecessor.setNext(newNode);
    }
}
```

Linked List Operations

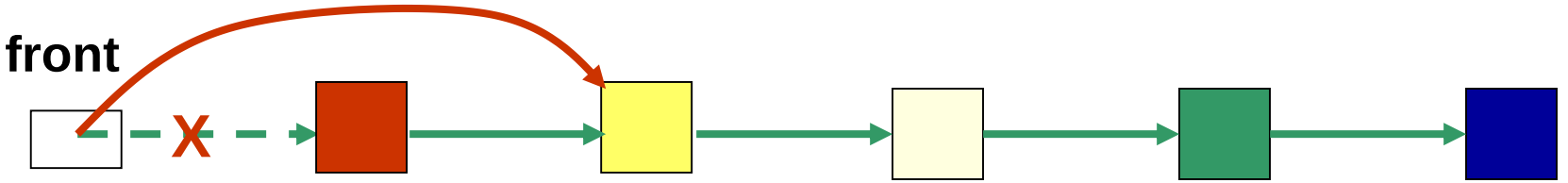
- ***Delete*** an item from the linked list

  - We have 3 situations to consider:
    - delete the node at the front
    - delete an interior node
    - delete the last node

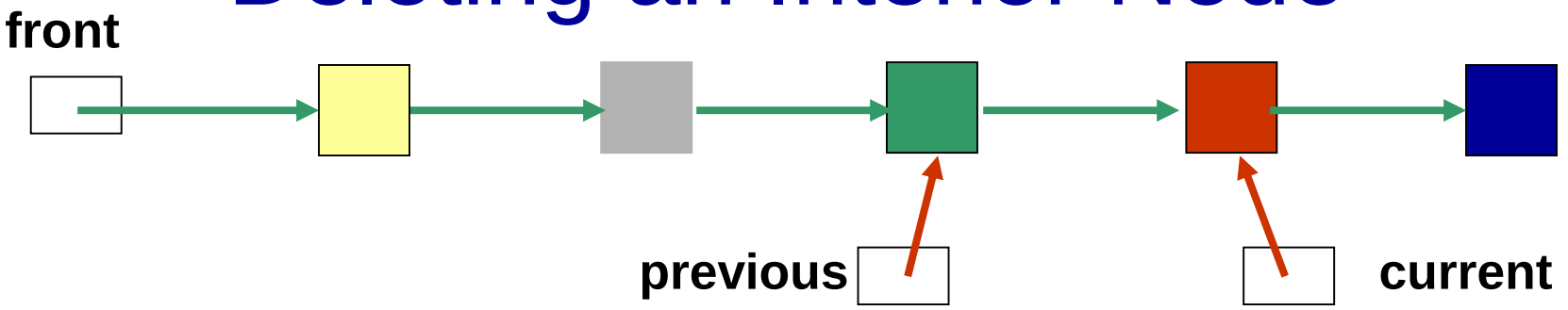
Deleting the First Node

front points to the first node in the linked list, which points to the second node

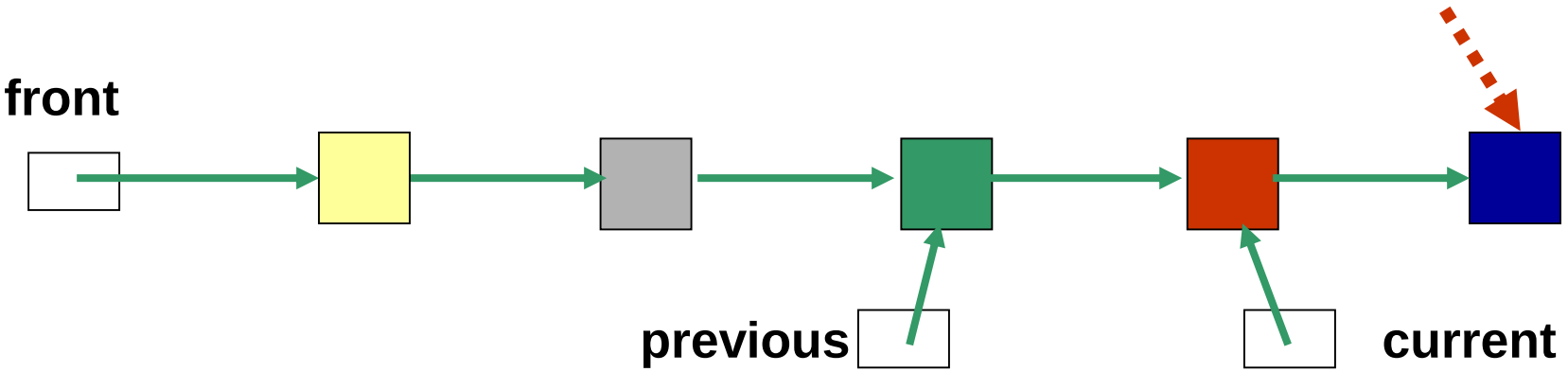
Make front point to the second node (i.e. the node pointed to by the first node)



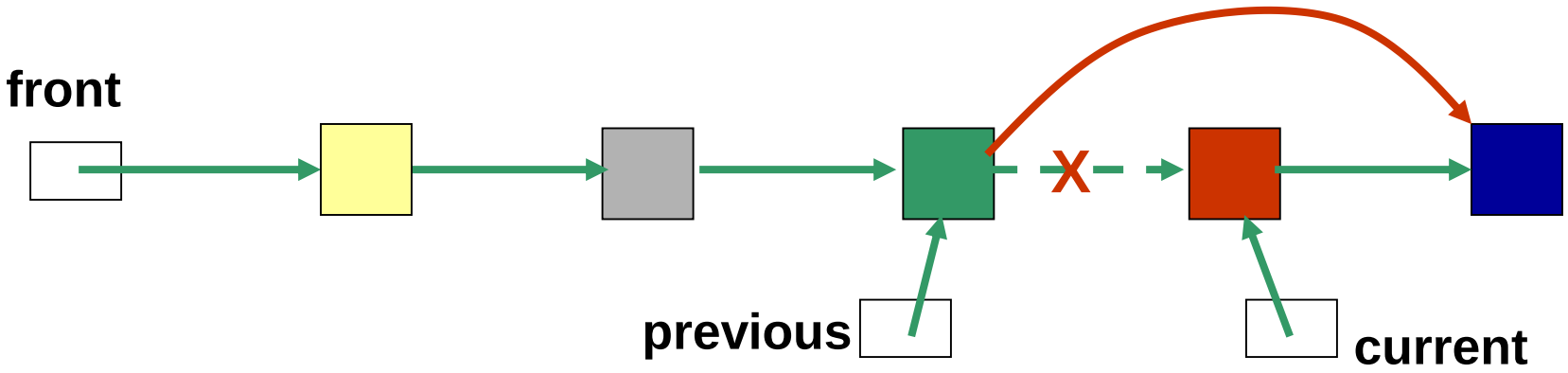
Deleting an Interior Node



1. Traverse the linked list so that current points to the node to be deleted and previous points to the node prior to the one to be deleted



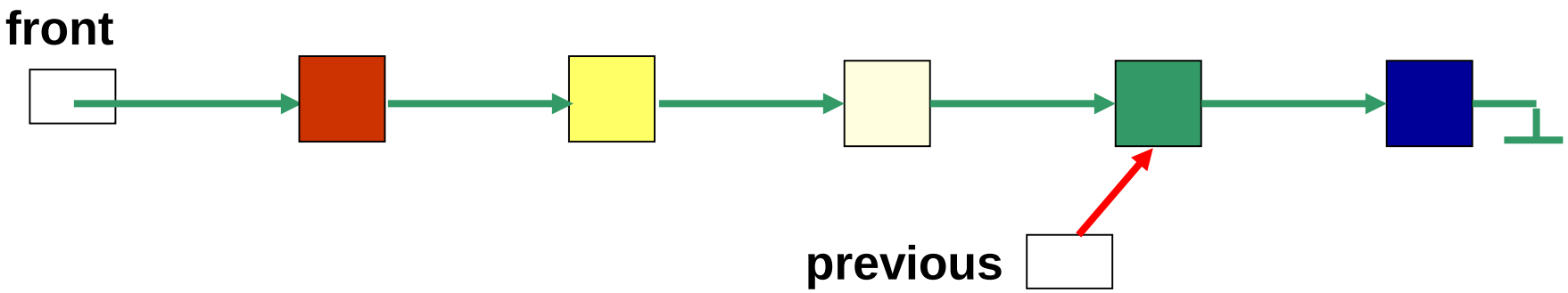
2. We need to get at the node *following the one to be deleted* (i.e. the node pointed to by the node that current points to)



3. Make the node that previous points to, point to the node following the one to be deleted

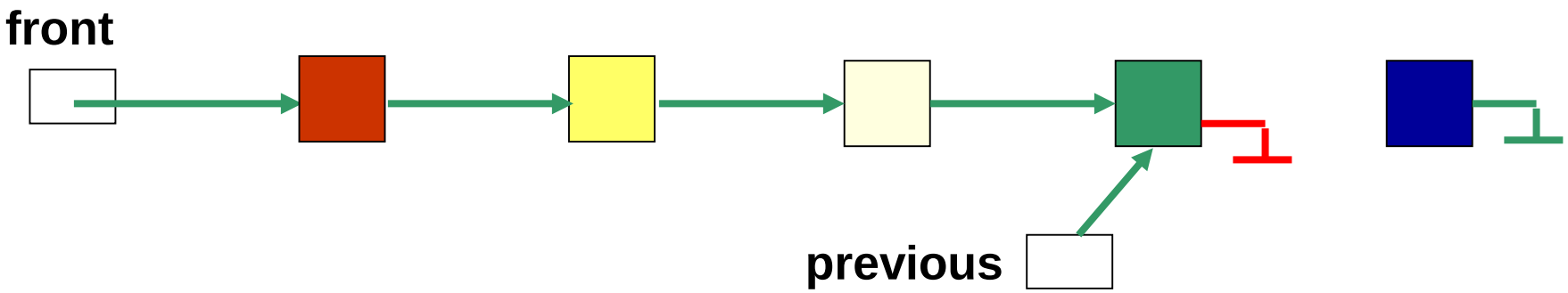
Deleting the Last Node

1. Find the previous to the last node in the linked list



Deleting the Last Node

1. Make previous point to null



Discussion

- Deleting the node at the front is a special case; why?
- Is deleting the last node a special case?

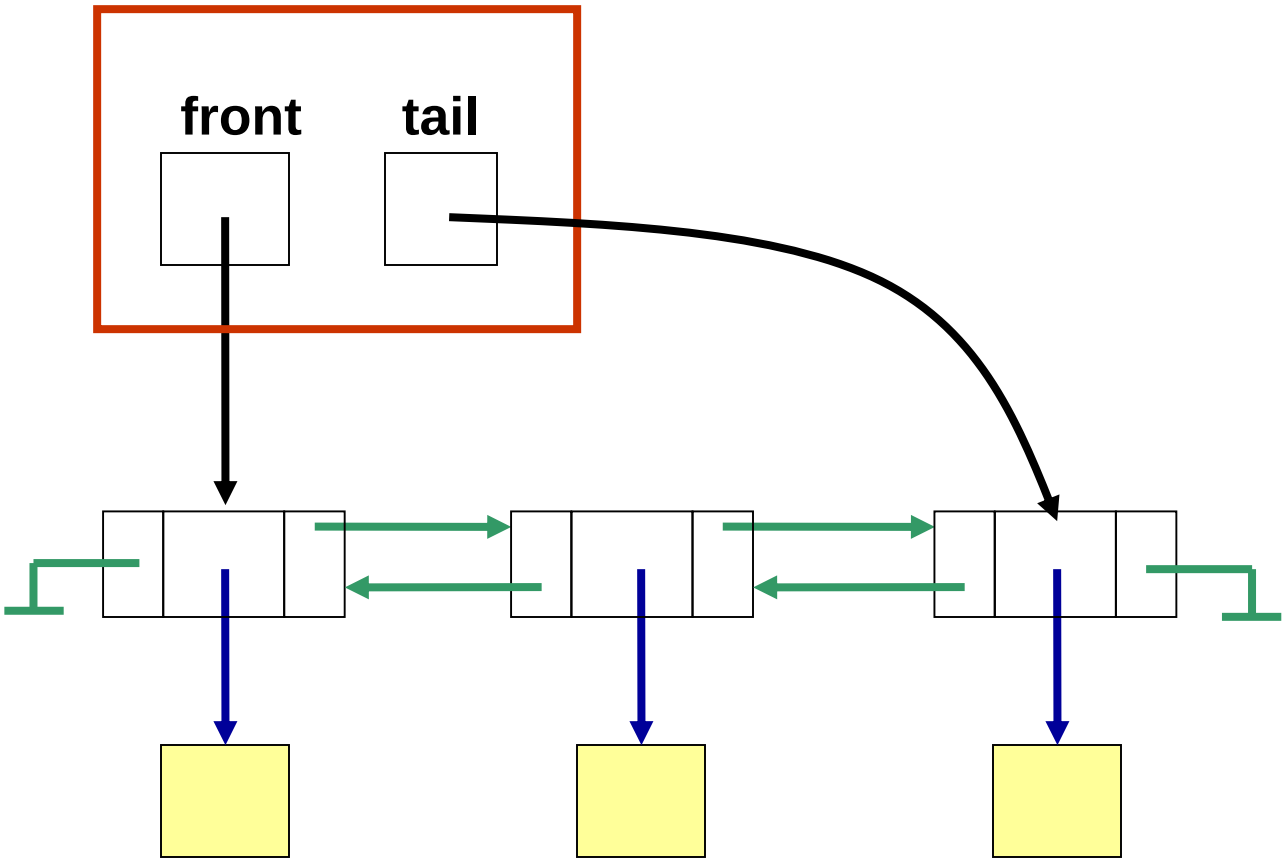
Algorithm delete (*nodeToDelete*)
In: node to delete
Out: *true* if the node was deleted, *false* otherwise

```
current = front
predecessor = null
while (current ≠ null) and (current ≠ nodeToDelete) do {
        predecessor = current
        current = current.getNext()
}
if current is null then return false
else {
        if predecessor ≠ null then
                predecessor.setNext(current.getNext())
        else front = front.getNext()
        return true
}
```

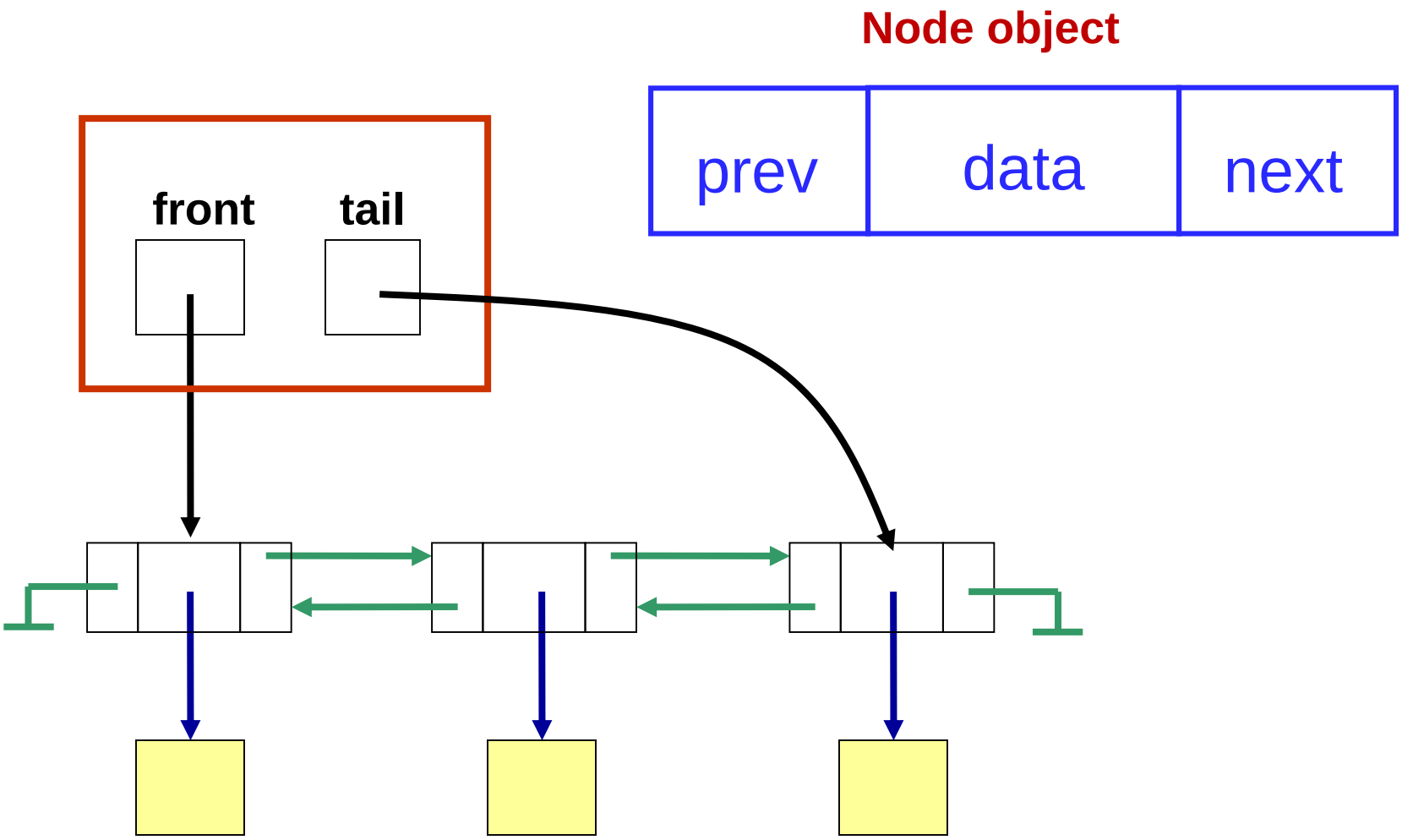
Java Implementation of Above Algorithm

```
public boolean delete (LinearNode<T> nodeToDelete) {
    LinearNode<T> current, predecessor;
    current = front;
    predecessor = null;
    while ((current != null) && (current != nodeToDelete)) {
        predecessor = current;
        current = current.getNext();
    }
    if (current == null) return false;
    else {
        if (predecessor != null)
            predecessor.setNext(current.getNext());
        else front = front.getNext();
        return true;
    }
}
```

Doubly Linked List



Doubly Linked List



Java Class for a Node of a Doubly Linked List

```
public class LinearNodeDLL<T> {
    private LinearNodeDLL<T> next;
      private LinearNodeDLL<T> prev;
    private T dataItem;


    public LinearNodeDLL( ) {
       next = null;
       prev = null;
       dataItem = null;
    }


    public LinearNodeDLL (T value) {
       next = null;
       prev = null;
       dataItem = value;
    }
```

```
    public LinearNodeDLL<T> getNext( ) {
      return next;
    }
     public void setNext (LinearNodeDLL<T> node) {
      next = node;
    }
 public LinearNodeDLL<T> getPrev( ) {
      return prev;
    }
     public void setPrev (LinearNodeDLL<T> node) {
      prev = node;
    }
     public T getDataItem( ) {
      return dataItem;
    }
     public void setDataItem (T value) {
      dataItem = value;
    }
}
```

Java Class for a Doubly Linked List

```
public class DoublyLinkedList<T> {
    private LinearNodeDLL<T> front;
    private LinearNodeDLL<T> tail;

    public DoublyLinkedList( ) {
       front = null;
       tail = null;
    }
   …
}
```

Write algorithms to add a new node to a doubly linked list and to remove a node from a doubly linked list.