Linked Data Structures

Objectives

- Describe linked structures
- Compare linked structures to array-based structures
- Explore the techniques for managing a linked list
- Discuss the need for a separate node class to form linked structures

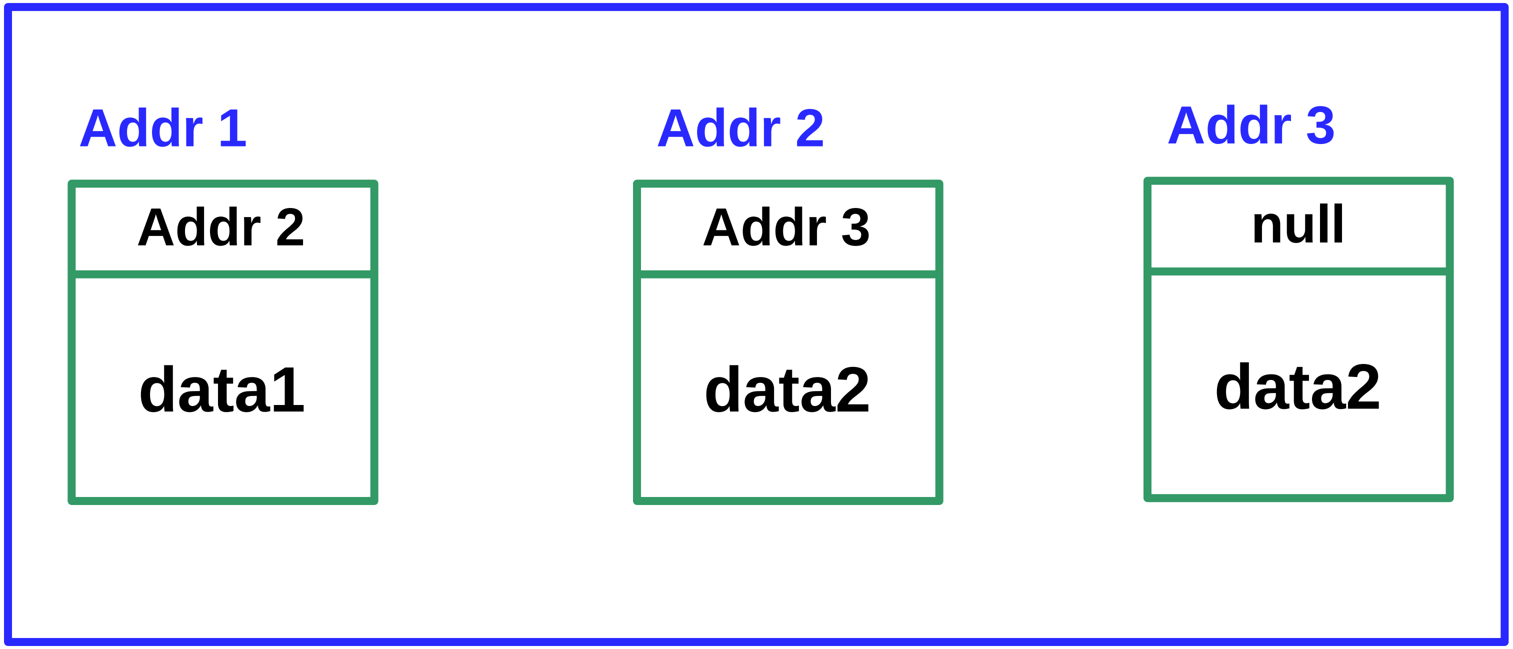
Array Limitations

- What are the limitations of an array, as a data structure?
  - Fixed size
  - Physically stored in consecutive memory locations
  - 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
  - How? each item ***points to*** another item

Memory



Linked Data Structures

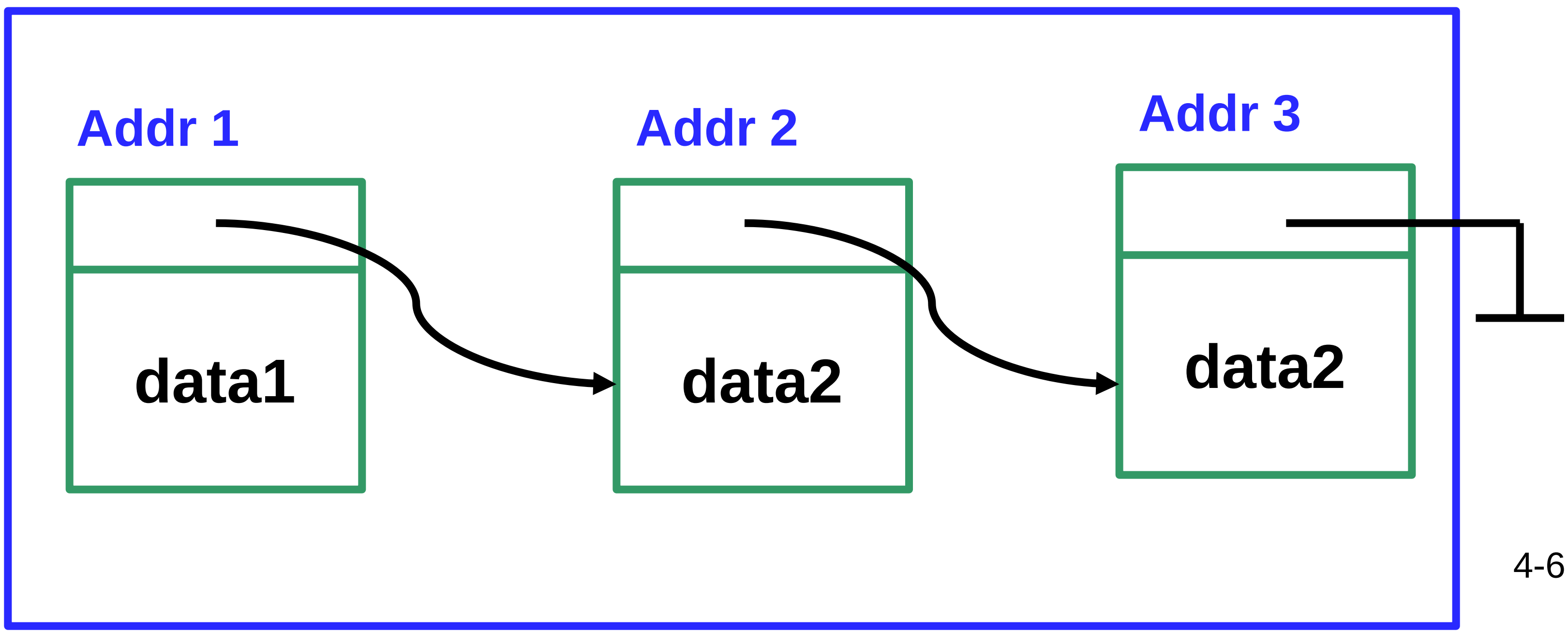
- A ***linked*** data structure consists of items that are linked to other items
  - How? each item ***points to*** another item

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

Linked Data Structures

- Singly Linked List

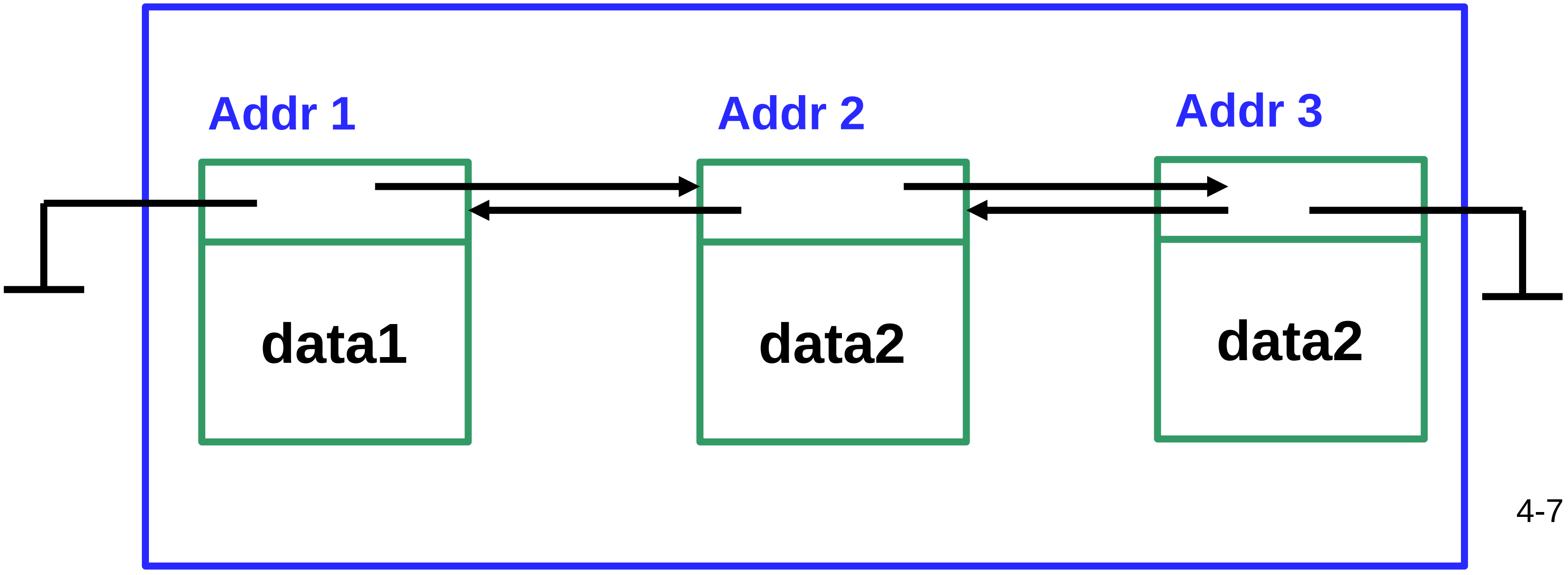
Memory



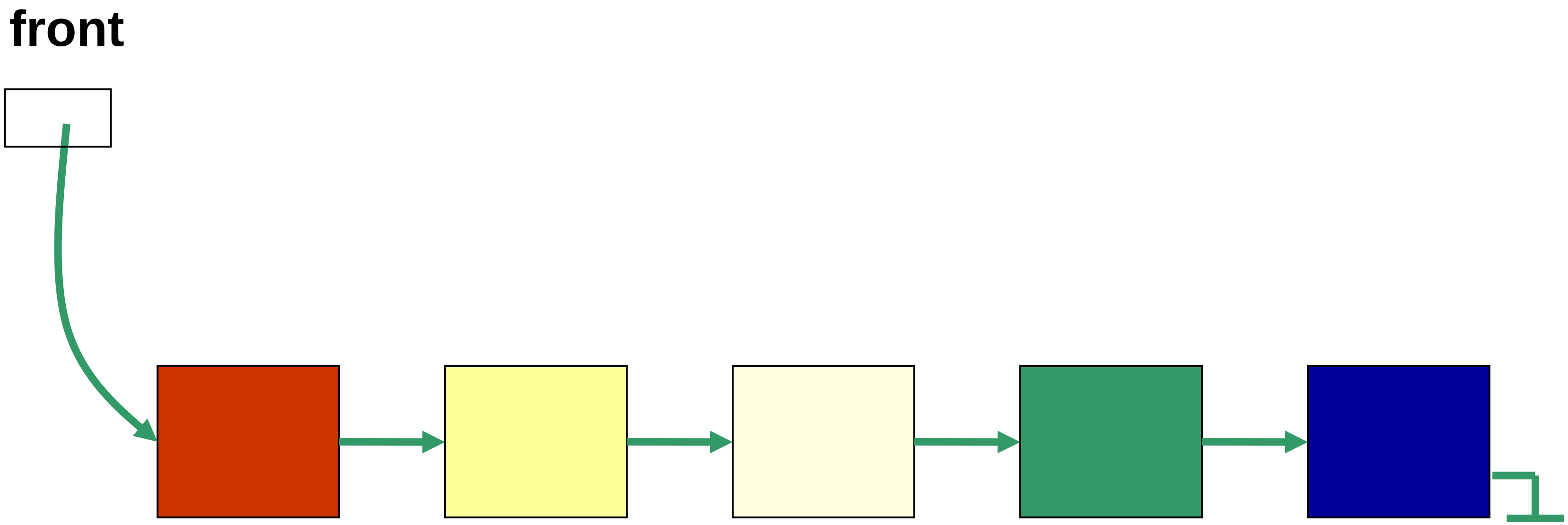
Linked Data Structures

- Doubly Linked List

Memory



Conceptual Diagram of a Singly-Linked List



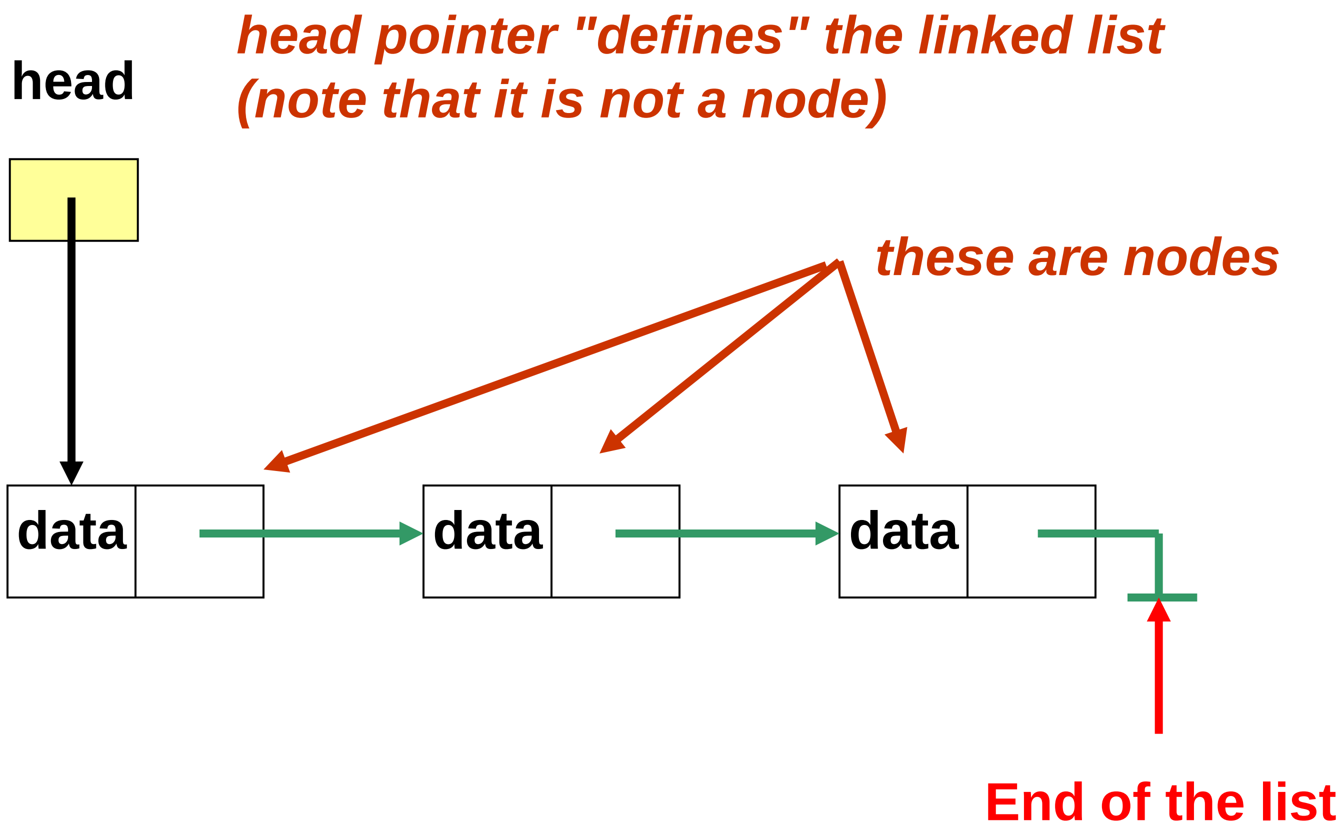
Advantages of Linked Lists

- The items do ***not*** have to be stored in consecutive memory locations: the successor can be anywhere physically
  - So, can insert and delete items without shifting data
  - Can increase the size of the data structure easily
- Linked lists can grow ***dynamically*** (i.e. at run time) – the amount of memory space allocated can grow and shrink as needed

Nodes

- A linked list is an ordered sequence of items called ***nodes***
  - A node is the basic unit of representation in a linked list
- 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
  - The linked list is defined by its head (this is its starting point)

Singly Linked List



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?

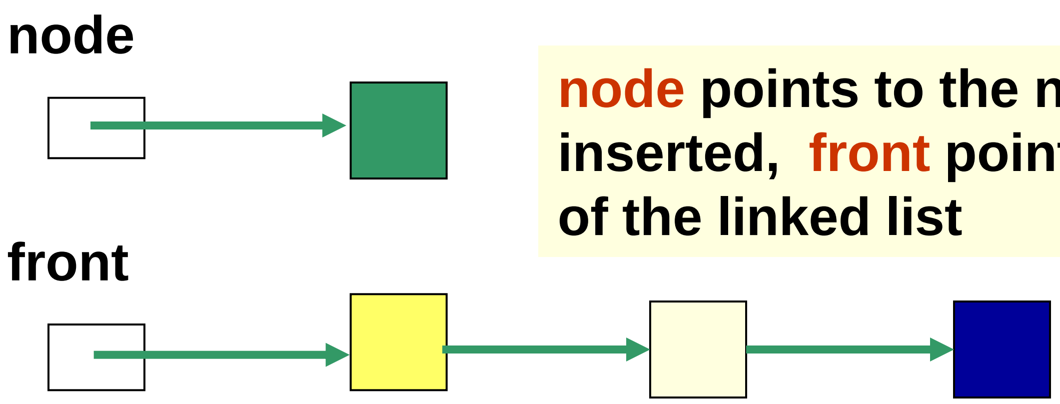
- How does this differ from an array?

Linked List Operations

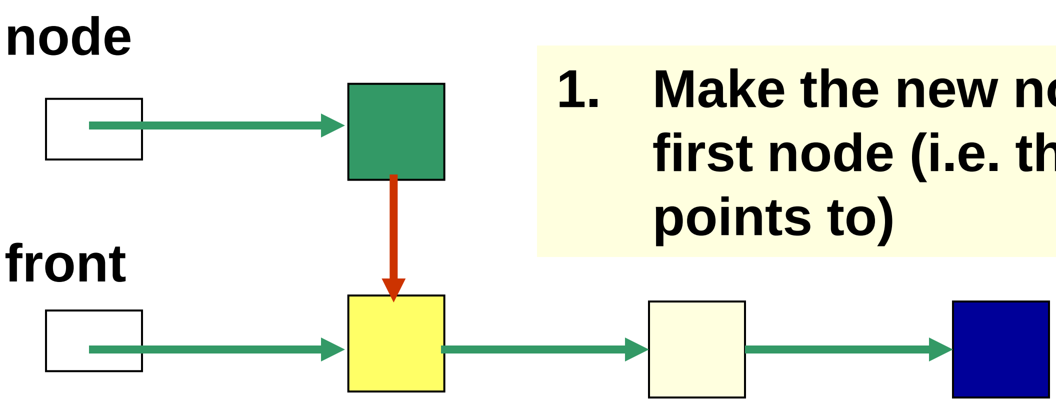
We will now examine linked list operations:

- ***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
- ***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

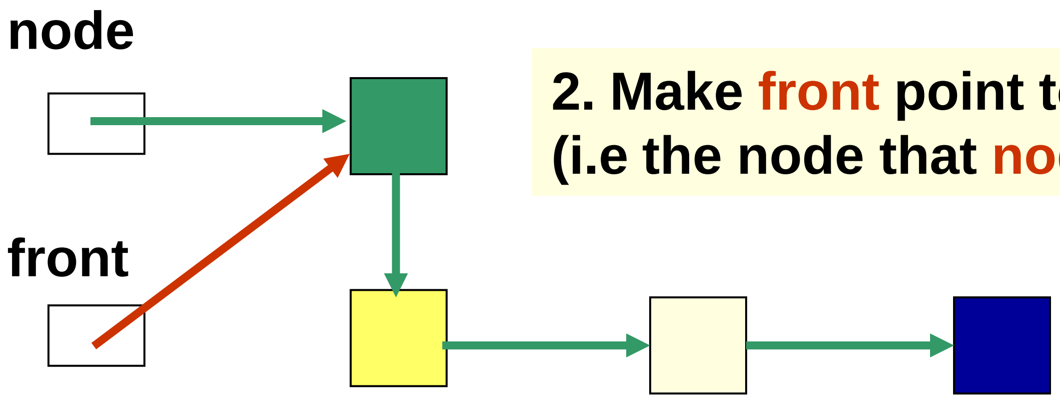
Inserting a Node at the Front



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



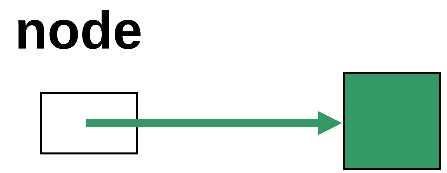
1. **Make the new node point to the first node (i.e. the node that front points to)**

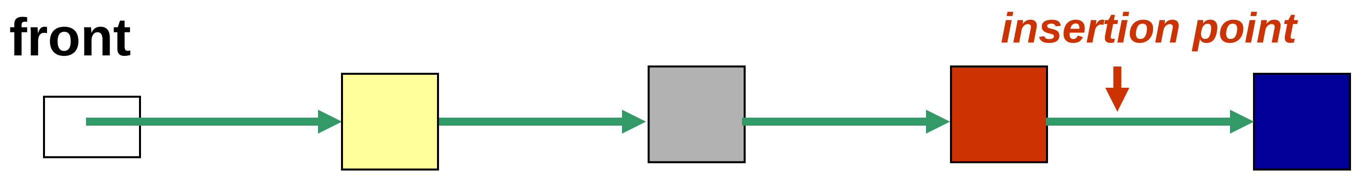


2. Make front point to the new node (i.e the node that node points to)

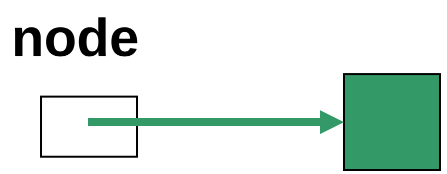
Inserting a Node in the Middle

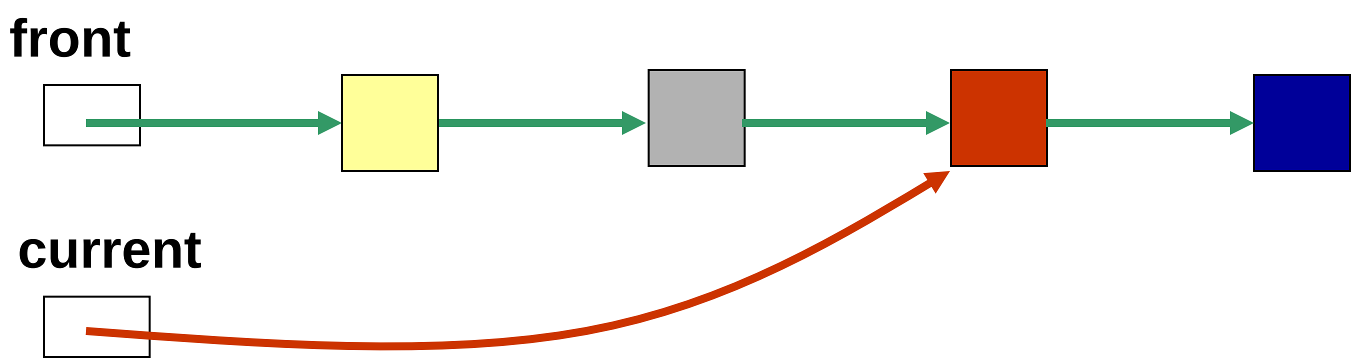
Let's insert the new node after the *third* node in the linked list



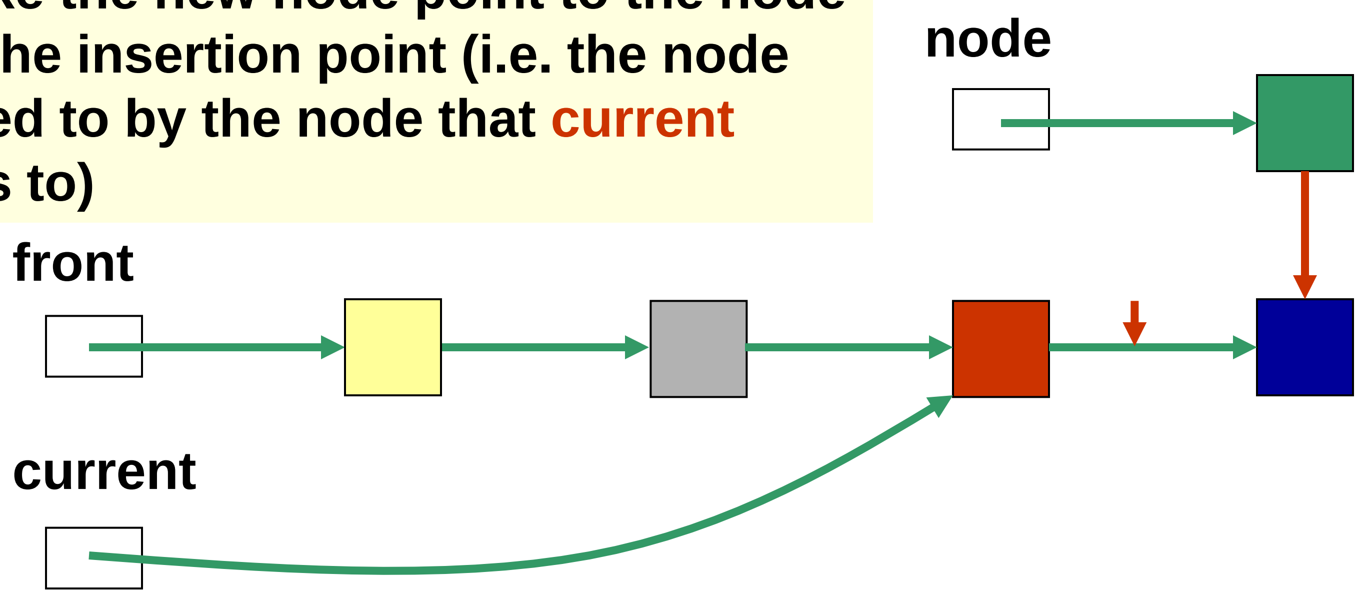


1. Locate the node *preceding the insertion point* , since it will have to be modified (make current point to it)

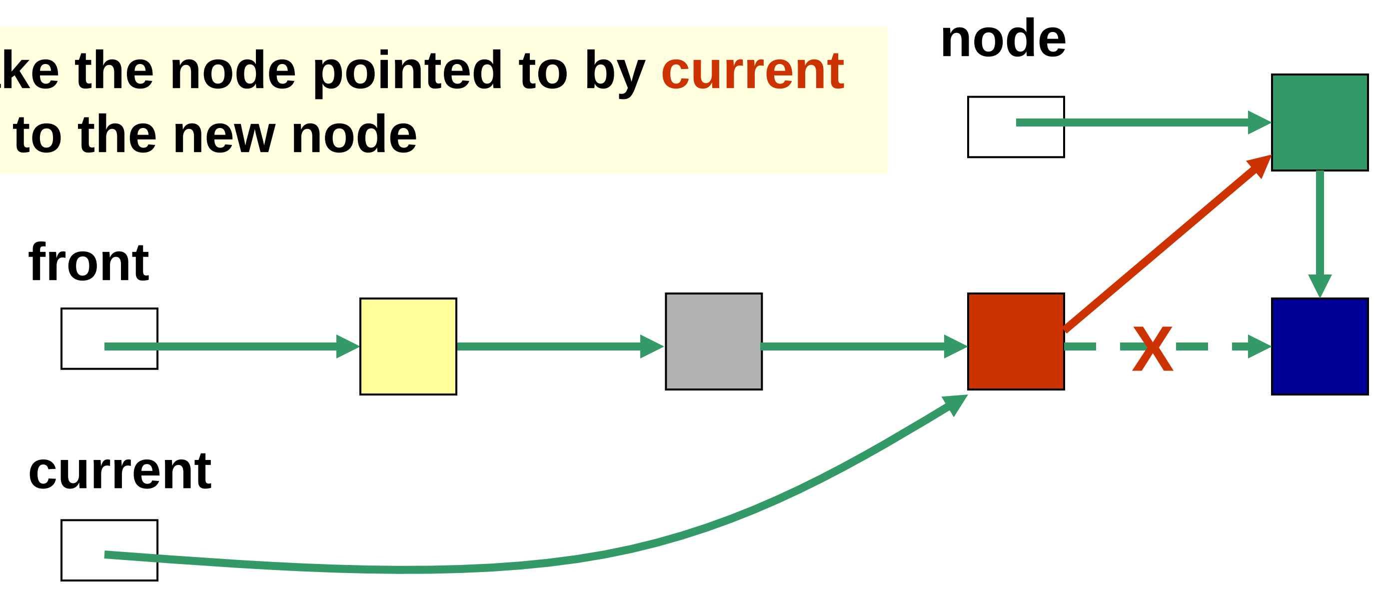




2. Make the new node point to the node after the insertion point (i.e. the node pointed to by the node that current points to)



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



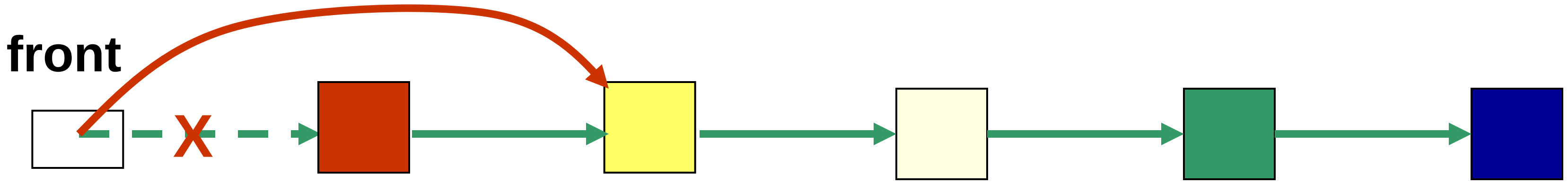
Discussion

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

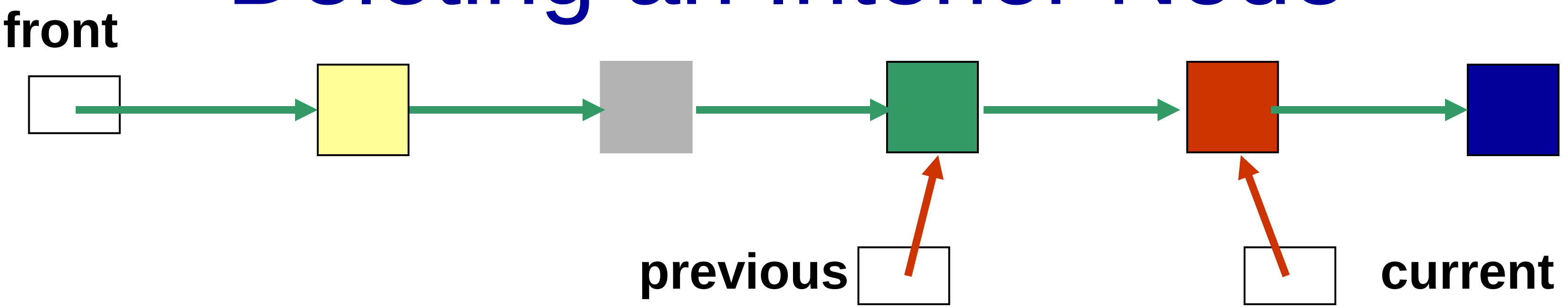
Deleting the First Node

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

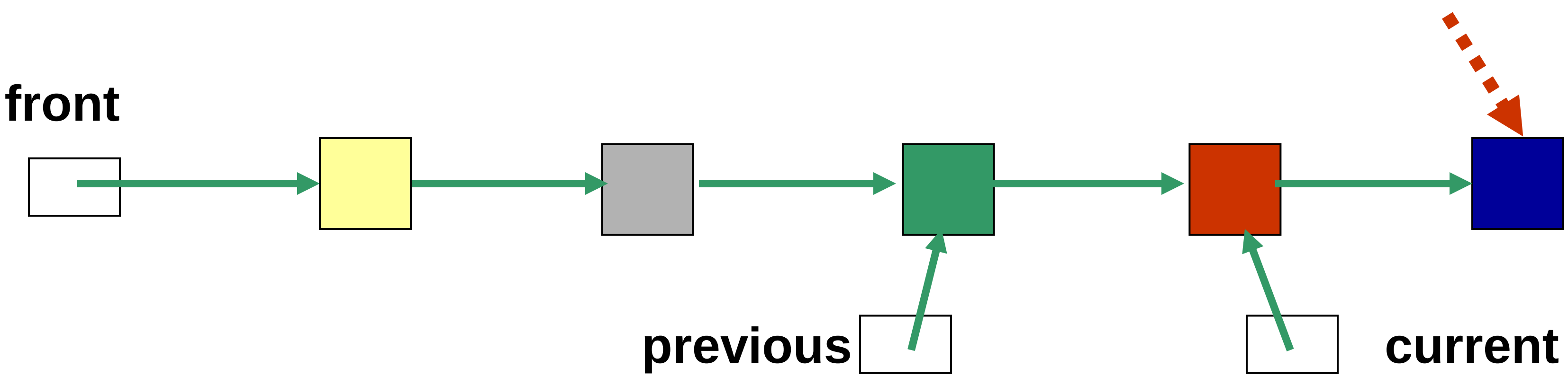
Make front point to the second node (i.e. the node pointed to by the first node)



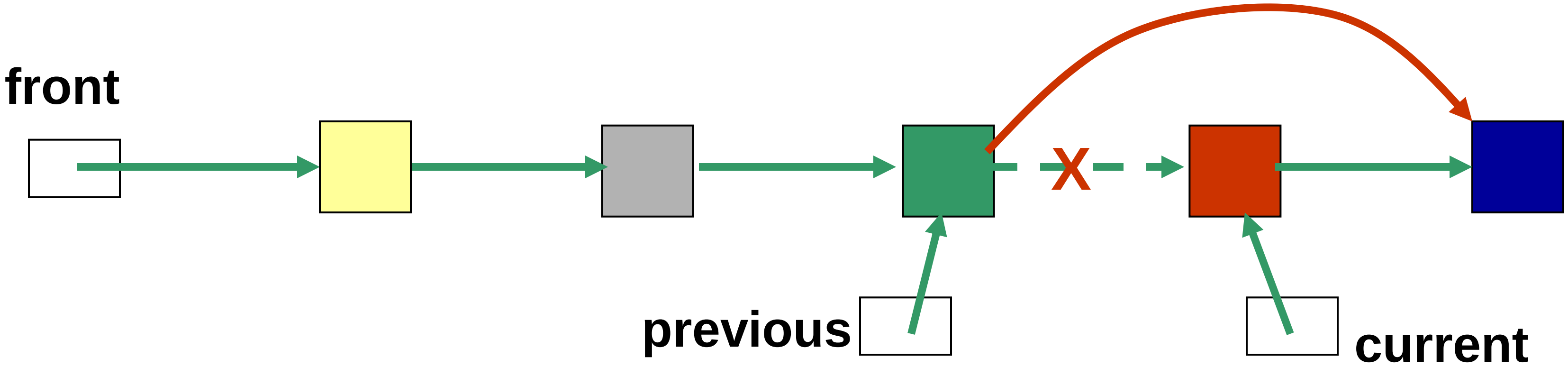
Deleting an Interior Node



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

Discussion

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

References As Links

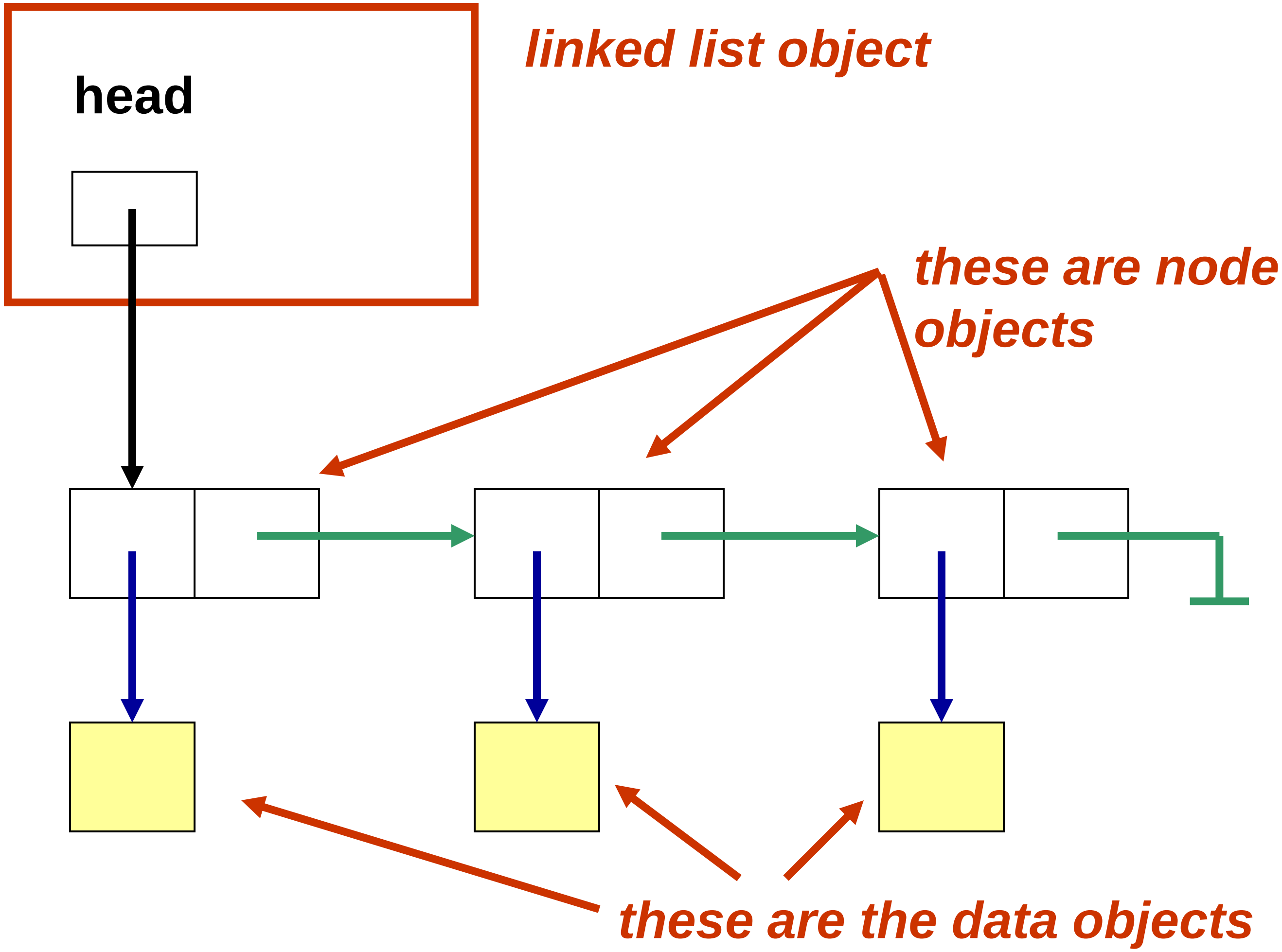
- Recall that in Java, a reference variable contains a reference or ***pointer*** to an object
  - We can show a reference variable **obj** as ***pointing to*** an object:

- A linked structure uses ***references*** to link one object to another

Implementation of Linked List

- In Java, a linked list is a list of ***node objects***, each of which consists of two references:
  - A reference to the ***data object***
  - A reference to the ***next node object***
- The ***head pointer*** is the reference to the linked list, ***i.e.*** to the first node object in the linked list
- The last node has the **null** value as its reference to the “next” node object

Linked List of Node Objects

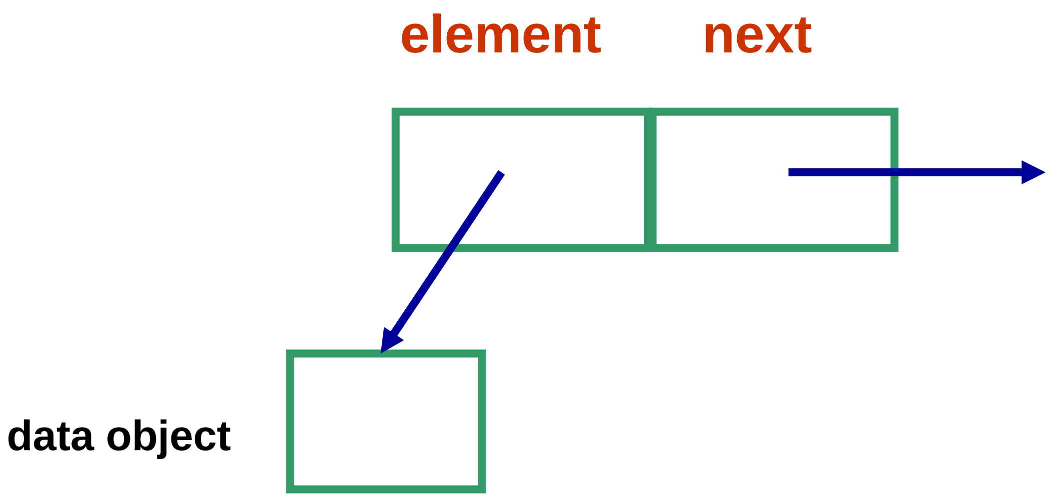


Node Objects

- For our linked list implementations, we will define a class called LinearNode to represent a node
  - It will be defined for the generic type T
- Why is it a good idea to have separate node class?
- *Note that it is called "**LinearNode**" to avoid confusion with a different class that will define nodes for non-linear structures later*

The **LinearNode** Class

- Attributes (instance variables):
  - ***element***: a reference to the data object
  - ***next*** : a reference to the next node
    - so it will be of type LinearNode



The LinearNode Class

- Methods: we only need
  - Getters
  - Setters

```java
public class LinearNode<T>
 {
   private LinearNode<T> next;
   private T element;

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

   public LinearNode (T elem){
      next = null;
      element = elem;
   }                           // cont'd..
```

LinearNode.java

LinearNode.java (cont'd)

```
    public LinearNode<T> getNext( ){
      return next;
  }
    public void setNext (LinearNode<T> node){
      next = node;
  }
    public T getElement( ){
      return element;
  }
    public void setElement (T elem) {
      element = elem;
  }
}
```

Example: Create a LinearNode Object

- Example: create a node that contains the integer 7

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

or

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

Exercise: Build a Linked List

- Exercise: create a linked list that contains the integers 1, 2, 3, …, 10

Doubly Linked Lists

- In a ***doubly linked list***, each node has two links:
  - A reference to the ***next node*** in the list
  - A reference to the ***previous node*** in the list
    - What is the "previous" reference of the first node in the list?
- What is the advantage of a doubly linked list?
- What is a disadvantage?

Doubly Linked List