



# Linked Lists

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- Each node in the linked list stores the data and a pointer to the next/previous node(s).
- Nodes are created/destroyed as necessary. When adding a new element, a new node is created, and linked into the linked list. When removing an element, the node containing the element is destroyed.



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- A head pointer (pointer to the first node in the list) is usually present (and may be necessary), while a tail pointer is optional.
- Linked lists are better for manipulating data, while array lists are better for storing/accessing data.



## Singly Linked List

- A singly linked list is a version of a linked list where each node *only* has a pointer to the next node (i.e. it is not possible to go back to the previous node). The singly linked list starts from the head pointer.



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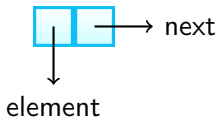
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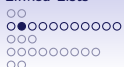
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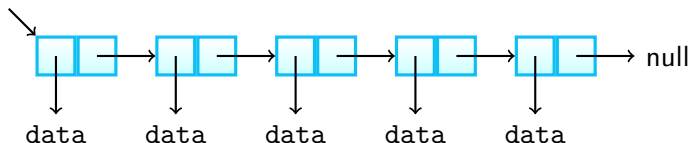


## Singly Linked List

In this course, we refrain from creating "dummy" nodes that lead to null references at the end of a singly linked list. We just have the next reference of the last node point to null.

Example of a singly linked list:

head





## Inserting at the Head

- Allocate a new node with data and next reference.





## Inserting at the Head

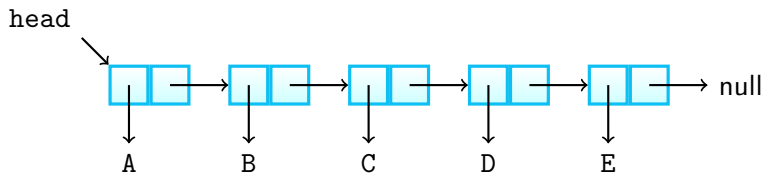
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- Have the new node's next reference point to old head.



## Inserting at the Head

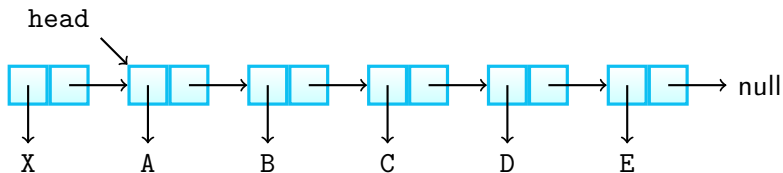
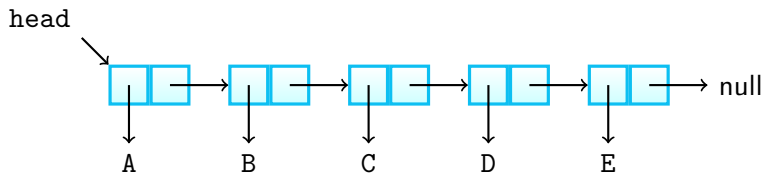
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- Update the head reference to point to new node.

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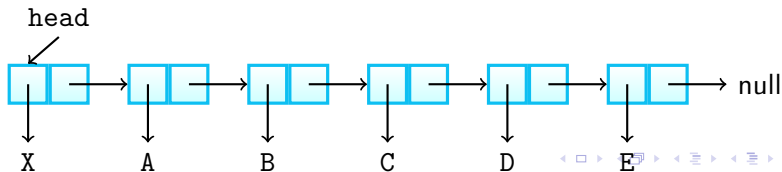
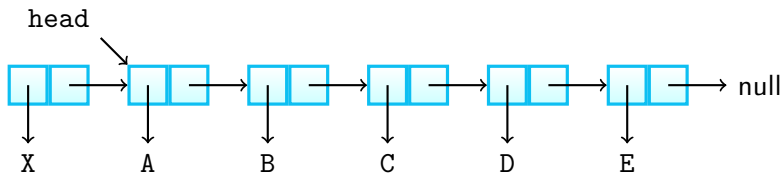
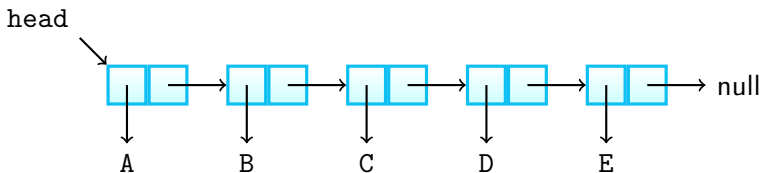




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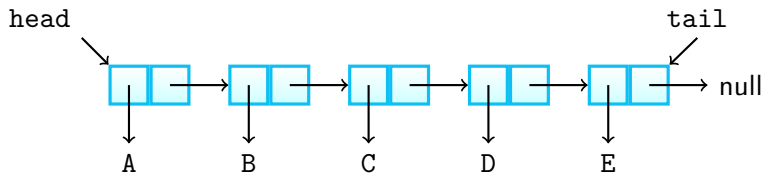


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- Allocate a new node with data and next reference.
- Have new node's next reference point to null.
- Have the last node's next reference point to new node.
- Update tail (if there is a tail pointer) to point to new node.

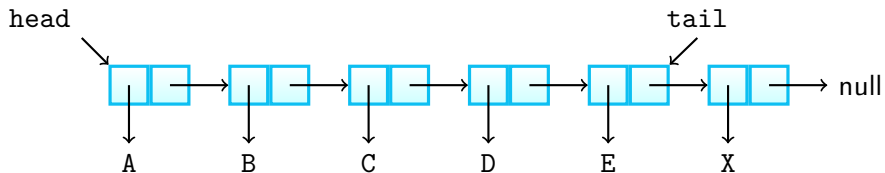
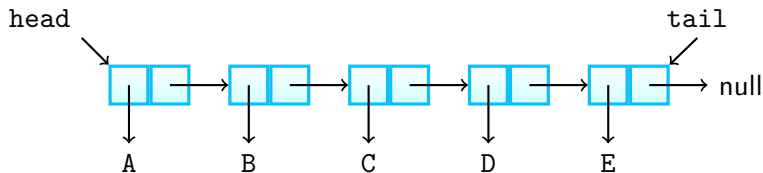


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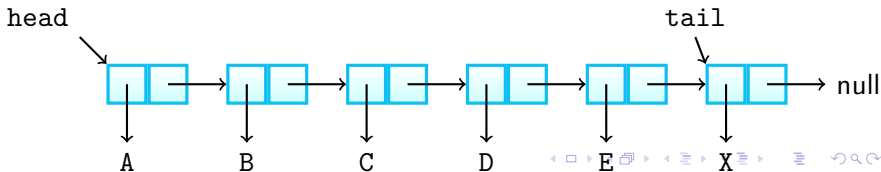
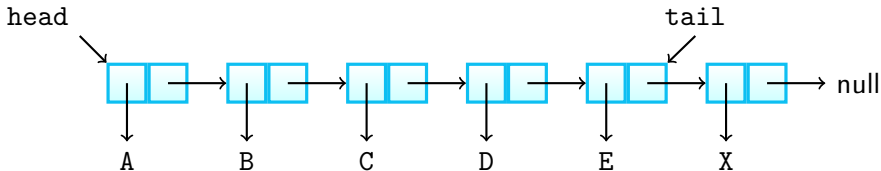
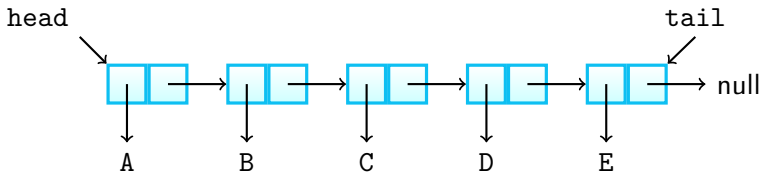


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## Removing at the Head

- Update head to point to the next node in the list.

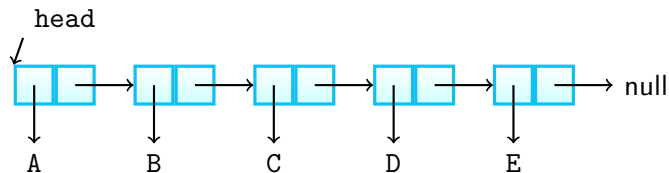


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- Update head to point to the next node in the list.
- Allow garbage collector to reclaim the former first node.

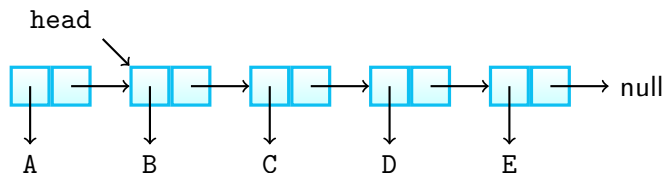
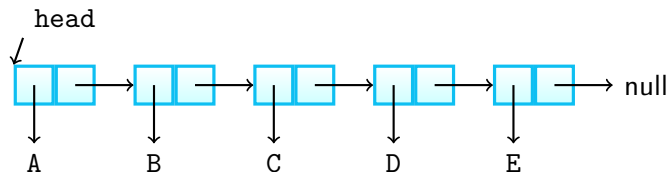


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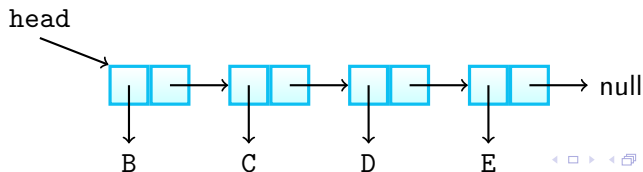
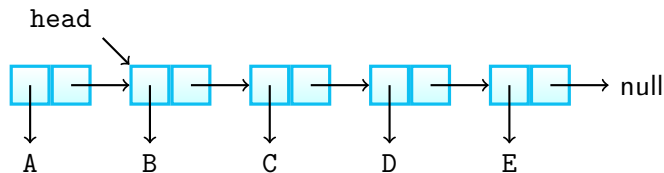
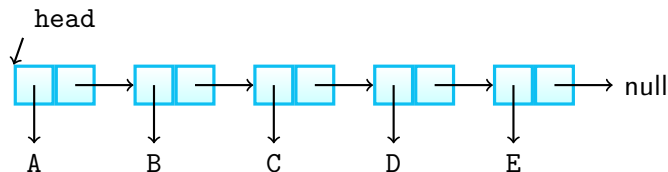


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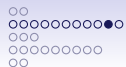
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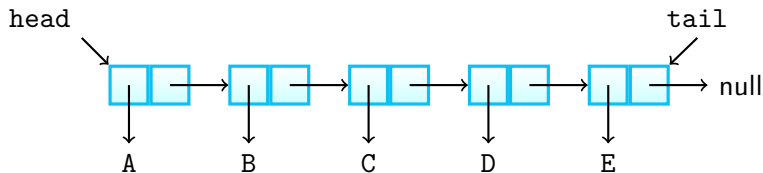


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- Iterate to the node before the last node.
- Update tail (if there is a tail pointer).
- Set the current node's next reference to null

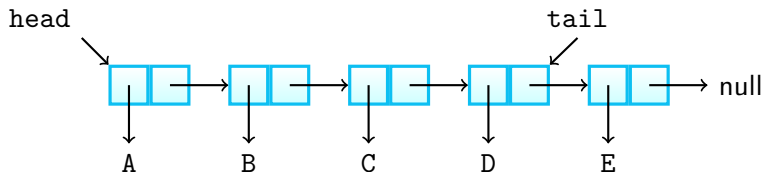
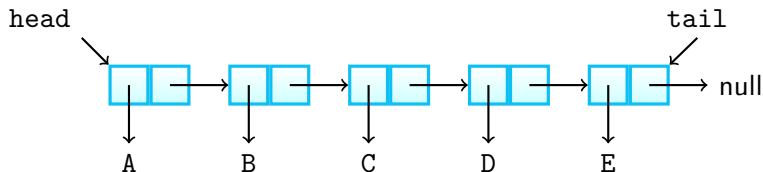


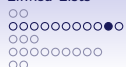
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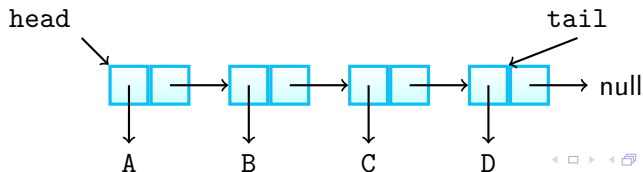
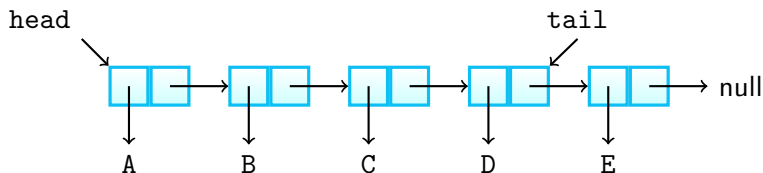
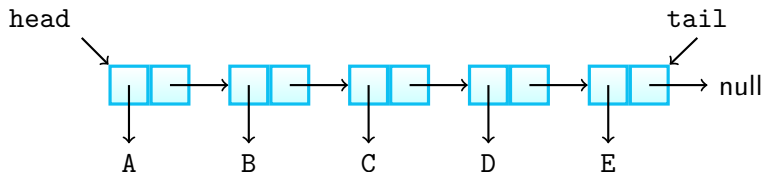


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- In addition to inserting/removing at the head/tail, you can add items at any location in the linked list.



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- Examples of these are shown for doubly-linked lists.



## Pseudocode For Inserting/Removing

**procedure** ADDFIRST(*e*)

*node*  $\leftarrow$  Create a new Node object, and have its data be *e*,  
and the next node be *head*

*head*  $\leftarrow$  *node*

**if** list is empty **then**

*tail*  $\leftarrow$  *node*

**end if**

*size*  $\leftarrow$  *size* + 1

**end procedure**



## Pseudocode For Inserting/Removing

**procedure** ADDLAST(*e*)

*node*  $\leftarrow$  Create a new Node object, and have its data be *e*

**if** list is empty **then**

*head*  $\leftarrow$  *node*

**else**

*tail.next*  $\leftarrow$  *node*

**end if**

*tail*  $\leftarrow$  *node*

*size*  $\leftarrow$  *size* + 1

**end procedure**



## Pseudocode For Inserting/Removing

```
procedure REMOVEFIRST(e)  
    node  $\leftarrow$  head  
    head  $\leftarrow$  head.next  
    size  $\leftarrow$  size - 1  
    return node  
end procedure
```



## Doubly Linked List

- A doubly linked list is a version of a linked list where each node has a pointer to the next node *and* a pointer to the previous node.
- Doubly linked lists can be traversed forward and backward.



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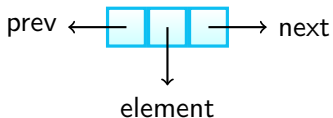
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## Generic Code For Doubly Linked List Node

```

public class DoublyLinkedList<Type> {
    private class Node<Type> {
        private Type data;
        private Node<Type> next;
        private Node<Type> prev;

        private Node(Type data, Node<Type> next,
            Node<Type> prev) {
            this.data = data;
            this.next = next;
            this.prev = prev;
        }
    }
}

```

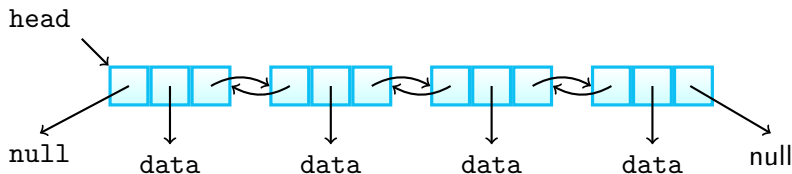


## Generic Code For Doubly Linked List Node

```
// Node constructor chaining
private Node(Type data) {
    this(data, null, null)
// this.data = data
// this.next = null
// this.prev = null
}
```

## Doubly Linked List

Example of a doubly linked list:



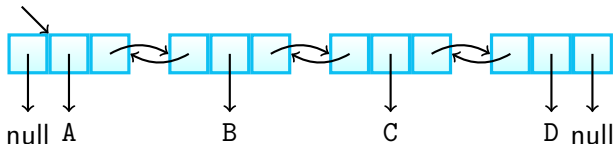
Notice that prev reference of the first node points to null, as does the next reference of the last node



## Insertion

Create new node X. Insert a new node, X, between node C and node D. Set new node's prev reference to C and next reference to D.

head

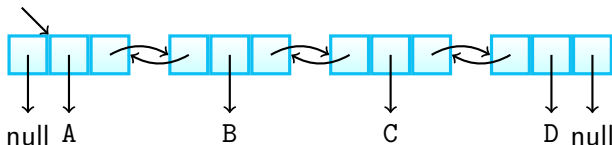




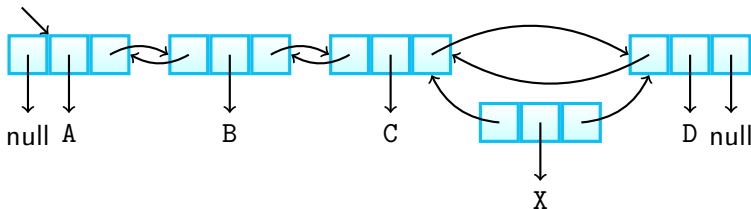
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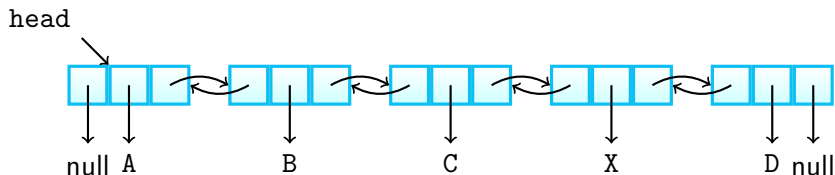


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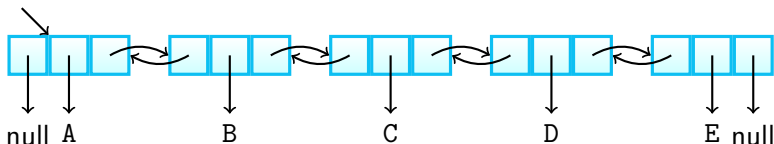
Once node X is connected, set Node C's next reference to node X, and Node D's prev reference to node X.



## Deletion

Remove node D, between nodes C and E. The order in which you redirect references is important so you do not lose your linked list.

head



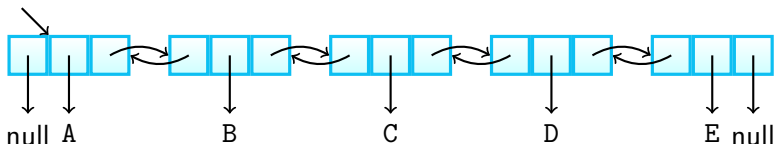




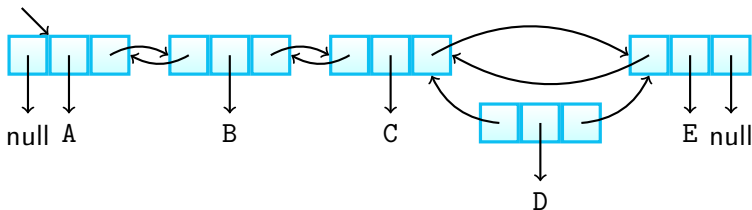
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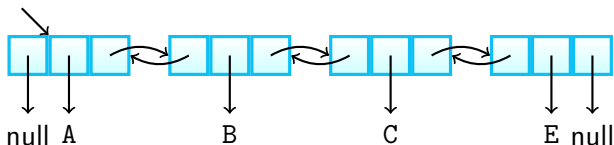




## Deletion

Set node C's next reference to node E, and node E's prev reference to C. Node D will be garbage collected.

head





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- Doubly linked lists are used in browser history, scroll bars or forward/back buttons





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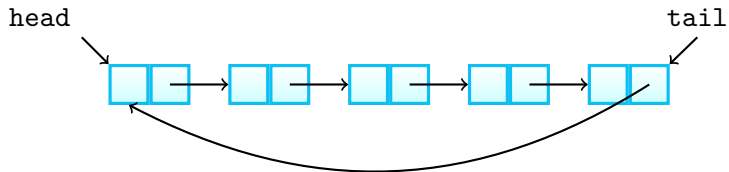
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- Depending on single or double links, adding or removing is the same as for the type of link
- Applications that use circular linked lists are gifs, music playlists; round-robin scheduling algorithms for operating systems



## Circular Linked Lists

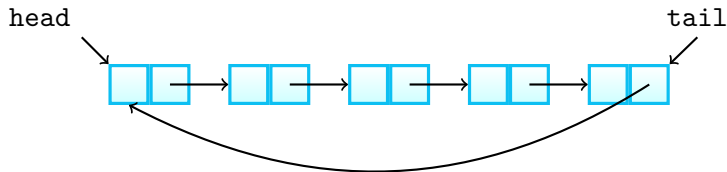
Example of Singly Circular Linked List





## Circular Linked Lists

Example of Singly Circular Linked List



Example of Doubly Circular Linked List

