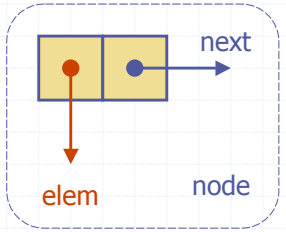
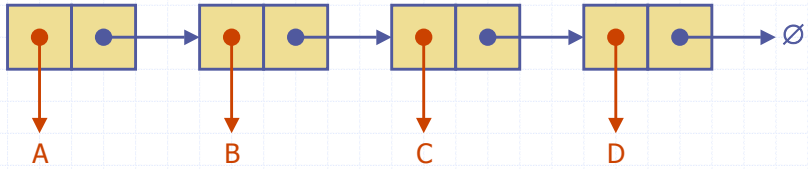
Linked Lists

Singly Linked List (§ 4.4.1)

- A singly linked list is a concrete data structure consisting of a sequence of nodes
- Each node stores
  - element
  - link to the next node



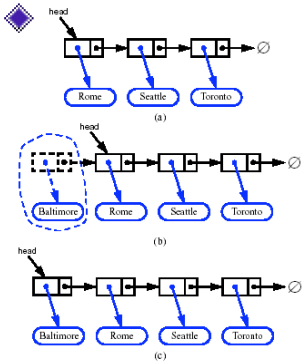


Linked List node in Java

```
public class ListNode {
    Object elem;
    ListNode next;
    public ListNode (ListNode next, Object elem)
        {this.next = next; this.elem = elem; }
    public Object getElem() {return elem; }
    public void setElem(Object elem) {this.elem = elem; }
    public ListNode getNext() {return next; }
    public void setNext(ListNode next) {this.next = next; }
    }
```

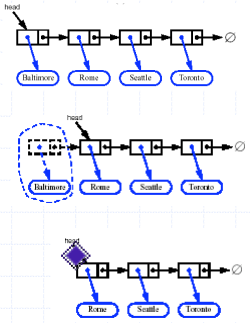

Inserting at the Head

1. Allocate a new node
2. Insert new element
3. Have new node point to old head
4. Update head to point to new node



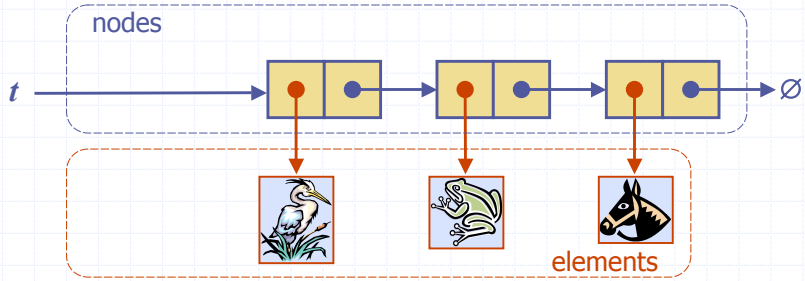
Removing at the Head

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



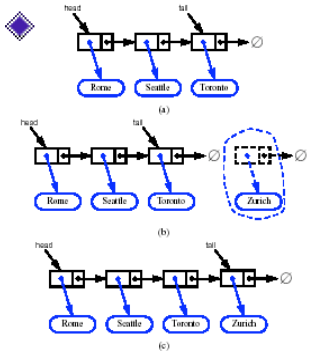
Stack with a Singly Linked List

- We can implement a stack with a singly linked list
- The top element is stored at the first node of the list
- The space used is $O(n)$ and each operation of the Stack ADT takes $O(1)$ time



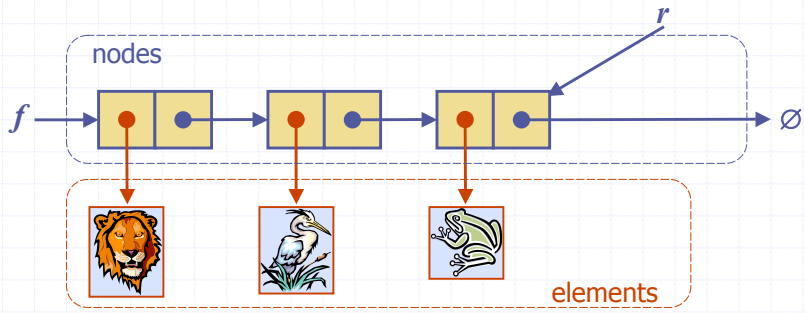
Inserting at the Tail

1. Allocate a new node
2. Insert new element
3. Have new node point to null
4. Have old last node point to new node
5. Update tail to point to new node



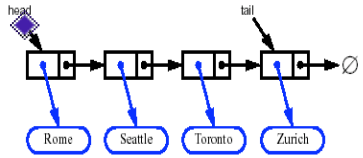
Queue with a Singly Linked List

- We can implement a queue with a singly linked list
  - The front element is stored at the first node
  - The rear element is stored at the last node
- The space used is $O(n)$ and each operation of the Queue ADT takes $O(1)$ time



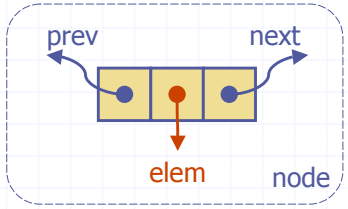
Removing at the Tail

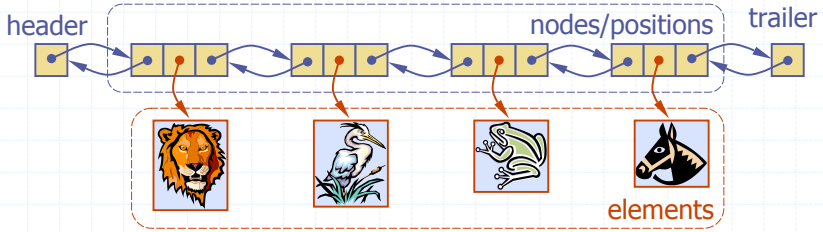
- Removing at the tail of a singly linked list is not efficient!
- There is no constant-time way to update the tail to point to the previous node



Doubly Linked List

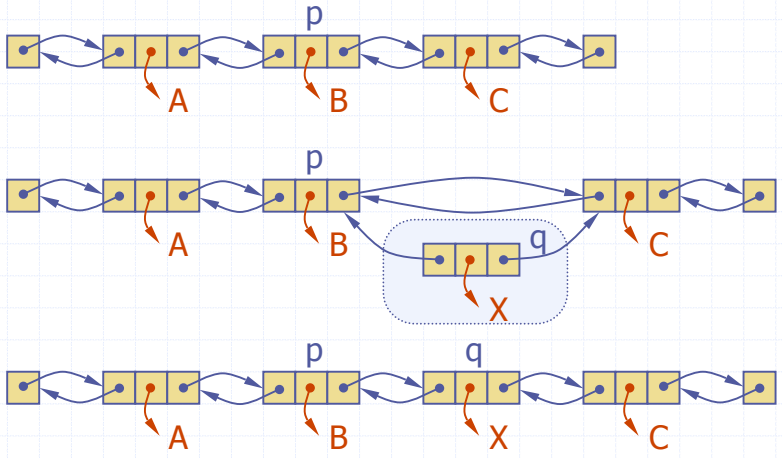
- A doubly linked list is a more complex type of list that allows insertion in the middle
- Nodes store:
  - element (sometimes combined into the node instead of a reference)
  - link to the previous node
  - link to the next node
- Special trailer and header nodes





Insertion

- We visualize operation insertAfter(p, X), which returns position q



Deletion

- We visualize remove(p), where p = last()