Oregon State University
School of Electrical Engineering and Computer Science

CS 261 – Recitation 4

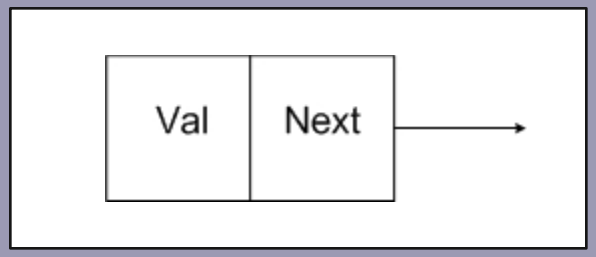
Spring 2016

Outline

- Linked List
- Linked List variations
- Doubly Linked list
- Singly Linked list operations
  - Insert
  - Delete
- Linked List: Stack Implementation
- Linked List: Queue Implementation
- Deque ADT (if time permits!)

Linked List

- a **linked list** is a data structure which consists of nodes linked in a linear fashion.
- Each node in the linked list consists of two fields
  - Data Field
  - Pointer to next node
- Links are 1 – 1 with elements, allocated and released as necessary

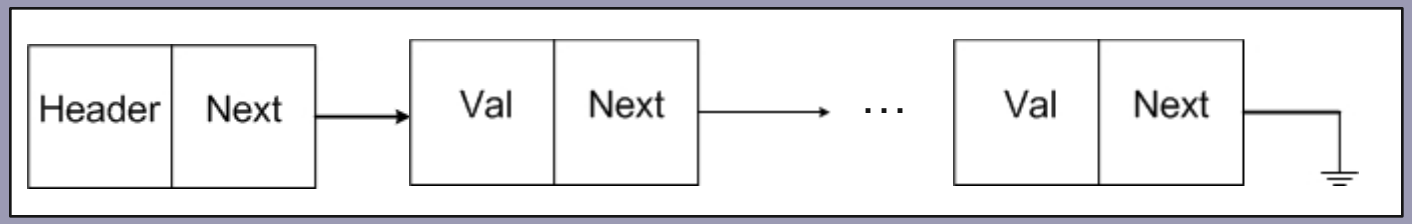


Pictorial Representation
of a node in a linked list

```
struct Link {              /* Single link. */
   TYPE val;               /* Data contained by this link. */
   struct Link *next;      /* Pointer to next link. */
};
```

Linked List variations

- **Singly Linked list with header (special node to denote the start of linked list)**



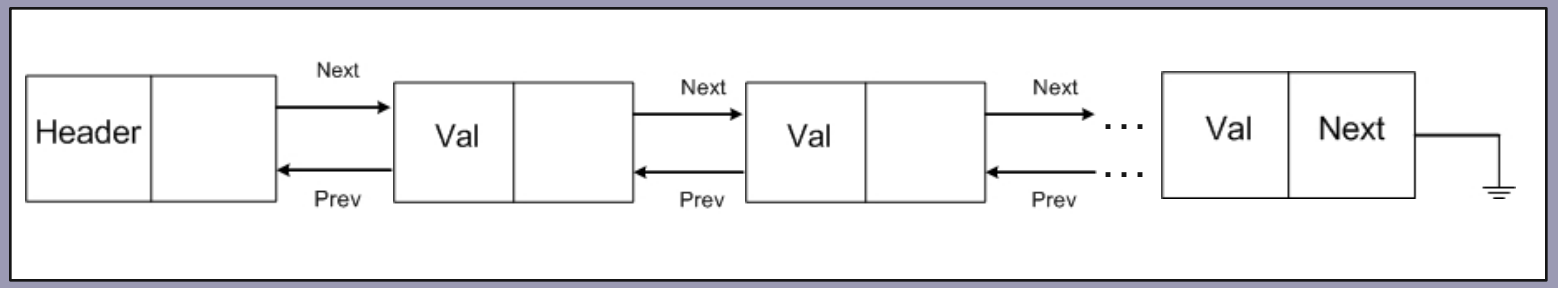
- **Singly linked list with null as terminator**
- **Single linked list with no header**
  - **Use a random value to denote the start of the list.**
- **Singly linked list with a sentinel value for terminating the list**
  - **Use some random value or null data field to denote the end of the list.**
- **Pointer to first element only, or pointer to first and last**
  - **In case of Queue ADT**

Doubly Linked List

- The doubly linked list consists of data fields and two links – **next** and **previous**

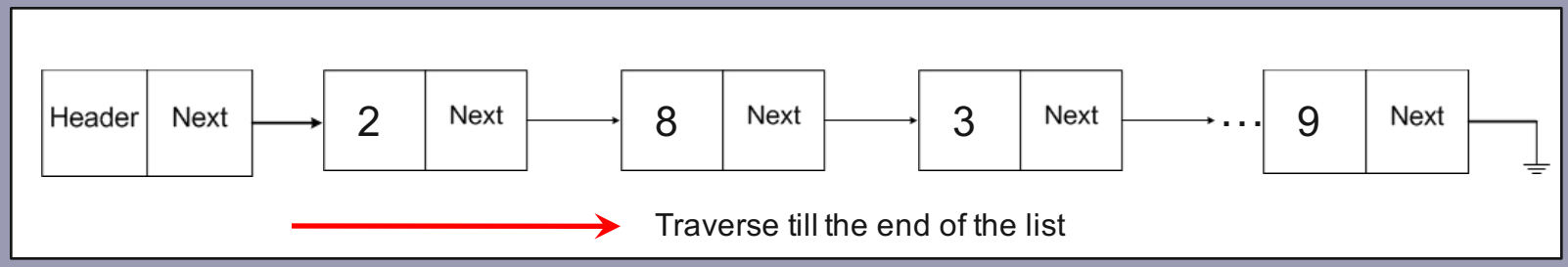
```
struct Link {              /* Double link. */
   TYPE val;               /* Data contained by this link. */
   struct Link *next;      /* Pointer to next node. */
   struct Link *prev;      /* Pointer to previous node. */
};
```

- **Illustration**

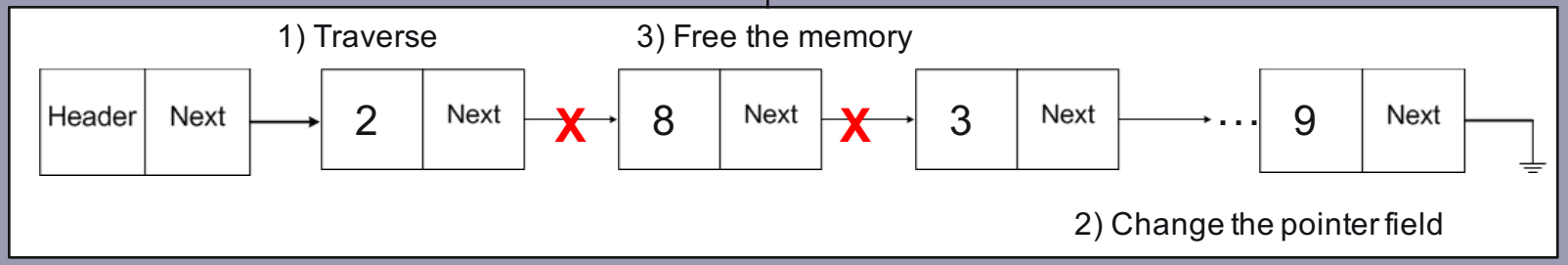


Singly Linked List Operations

- Traverse List

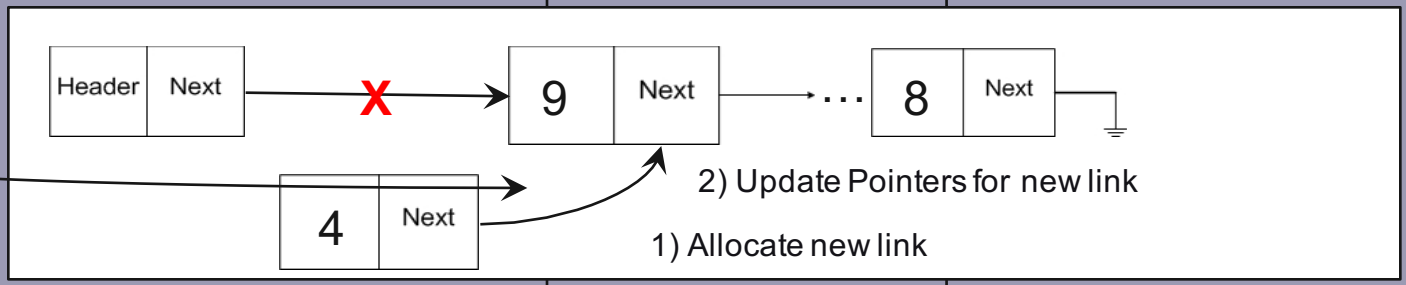


- Delete a specific node
  - Traverse to the node preceding the node to be deleted.
  - Change the pointer field to point the node succeeding the node to be deleted.
  - Free the memory for the deleted node
  - To delete node 8 in the illustration below,

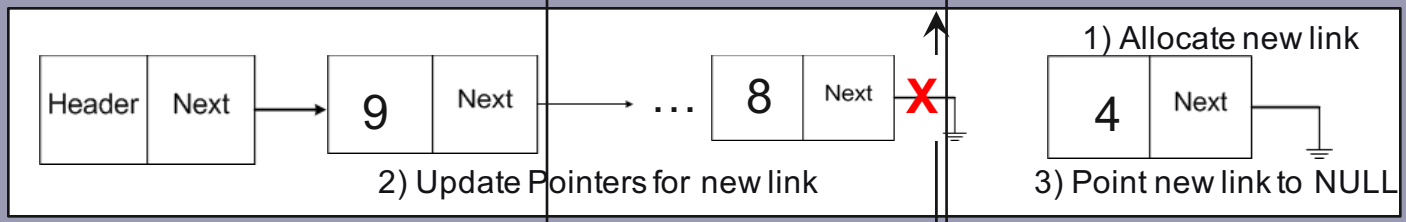


Linked List Operation: Insert

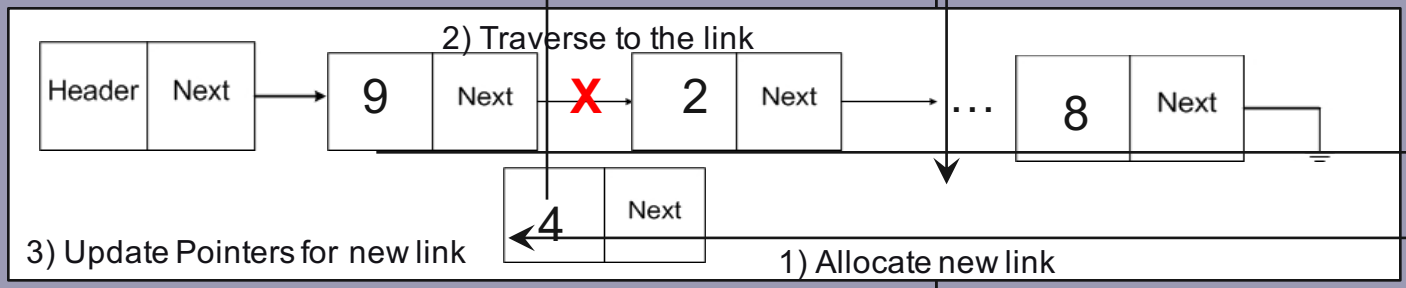
- Insert Beginning of the list



- Insert end of the list



- Insert after a specific node

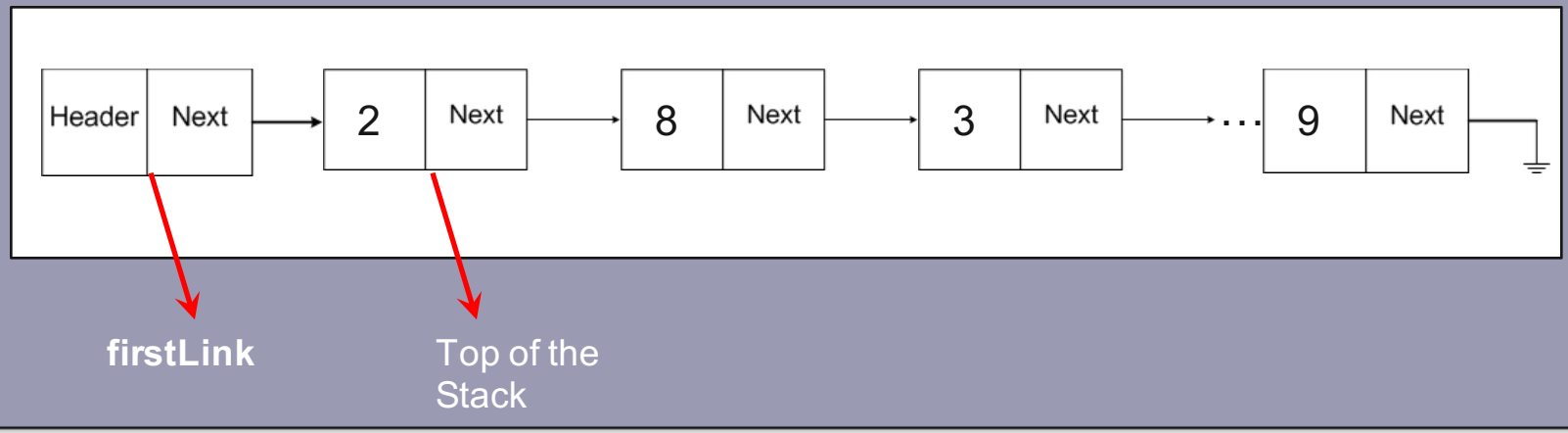


Linked list stack

- **Implementing a stack interface with a linked list:**
  - Header with head reference only: null if empty
  - No sentinel: null terminated
  - Singly linked
  - Elements added or removed from front
  - Only access first element
  - Worksheet 17 deals with this exercise.
- Illustration

```
struct link {
   TYPE value;
   struct link * next;
};

struct linkedListStack {
   struct link *firstLink;
}
```



Linked List Stack: Operations

- **Push**

```
void linkedListStackPush(struct linkedListStack *s, double d){
// Push operation of Stack using Linked list
    struct link * newLink = (struct link *)    malloc(sizeof(struct link));
    assert (newLink != 0);                     //Create new link to store the value
    newLink->value = d;
    newLink->next = s->firstLink;
    s->firstLink = newLink;                //Assign new link immediate to first link
}
```

- **Top of the stack**

```
EleType linkedListStackTop (struct linkedListStack *s) {
//Retrieving element in the top of the stack
    assert (! linkedListStackIsEmpty(s));
    return s->firstLink->value;
}
```

Linked List: Stack Operations (contd…)

- **Pop**

```
void linkedListStackPop (struct linkedListStack *s) {
//Pop operation of the stack
   struct link * lnk = s->firstLink              //Create temporary link
   assert (! linkedListStackIsEmpty(s));
   s->firstLink = lnk->next;
   free(lnk);                                    //Free memory for popped element
}
```

- **isEmpty stack**

```
int linkedListStackIsEmpty (struct linkedListStack *s) {
//To check if stack is empty
   return s->firstLink == 0;
}
```

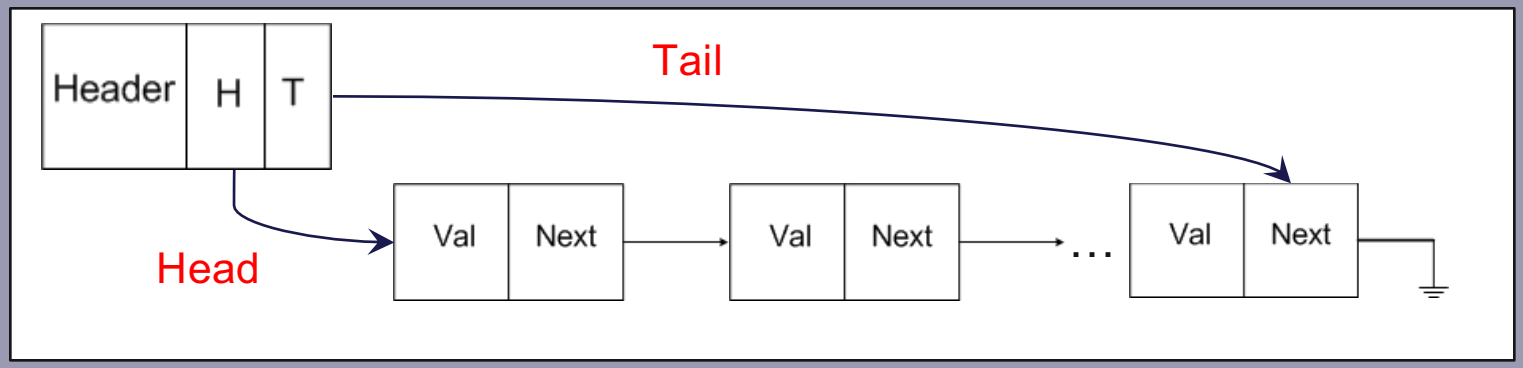
Linked List: Implementation of Queue

- Queue ADT follows a FIFO (First-in-First-out) interface.
- Conceptually similar to a line (queue) of waiting people:
  - A person joins the queue by adding themselves at the end
  - The next person is removed from the front of the queue.

```
struct link {
   TYPE value;
   struct link * next;
};
```

```
struct listQueue {
   struct link *firstLink;
   struct link *lastLink;
};
```

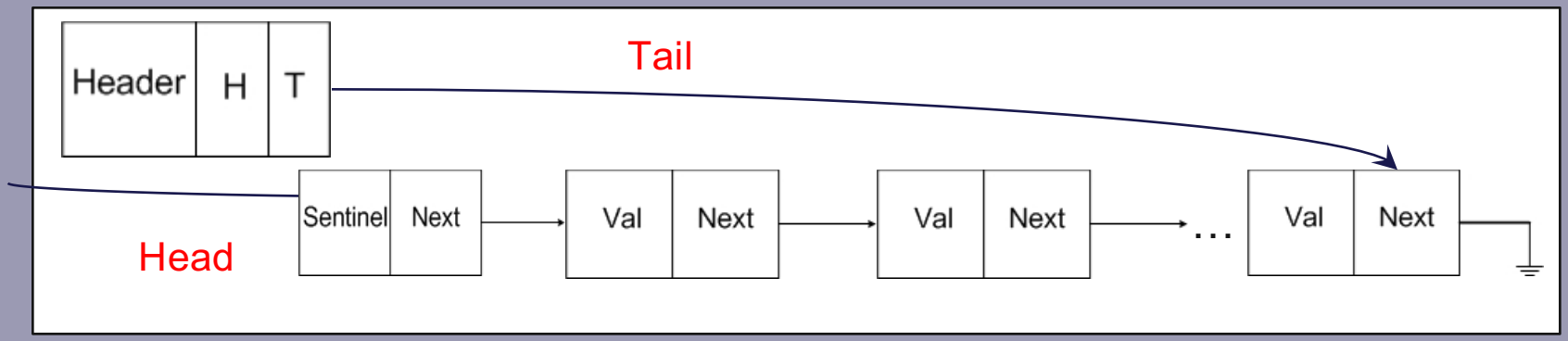
- Illustration



Queue ADT with Sentinels

- A sentinel is a special marker at the front and/or back of the list
- Has no value and never removed
- Helps remove special cases due to null references since it's never null
- An empty list always has a sentinel

- Illustration



Queue ADT: Operations

- Insert Back
  - Insert node at the back of the queue.

```
void listQueueAddBack (struct listQueue *q, TYPE e) {
//Adding new element to the back of the queue
        struct link *lnk = (struct link *) malloc(sizeof(struct slink));
        assert(lnk != 0);                  //Allocate memory for new link
        lnk->value = e;
        lnk->next = 0;
        q->lastLink->next = lnk;      //Make the tail pointer point to the new link
}
```

- Is Queue Empty

```
int listQueueIsEmpty (struct listQueue *q) {
//To check if queue is empty
        return q->firstLink == q->lastLink;
}
```

Queue ADT: Operations (contd…)

- Remove Front
  - Remove node in the front of the queue.

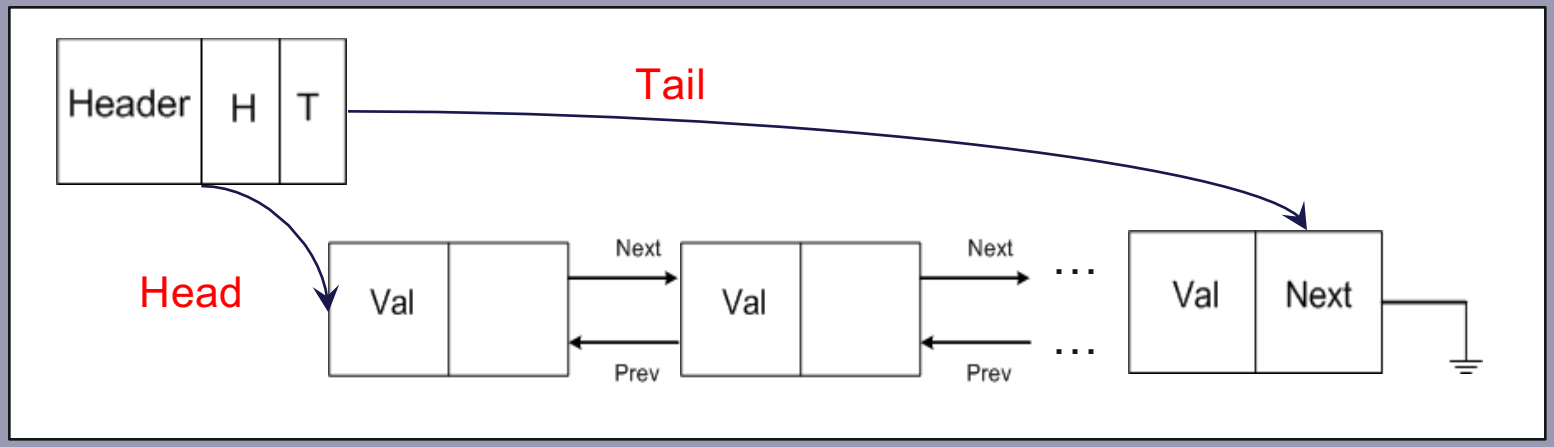
```
void listQueueRemoveFront (struct listQueue *q) {
//To remove front element from the queue
struct link * lnk = q->firstLink->next;
assert ( ! listQueueIsEmpty(q));
        q->firstLink->next = lnk->next;
free (lnk);
}
```

- Front of the queue
  - Retrieve the element in front of the queue.

```
TYPE listQueueFront (struct listQueue *q) {
//Retrieve front element in the queue
assert (! listQueueIsEmpty(q));
return q->lastLink->value;
}
```

Deque ADT

- What if we want to add and remove elements from both front and back?
- Need to use links going both forward and backwards
- Makes adding a new link harder, as must maintain both forward and backward links.
- Illustration



- Deque can be implemented with sentinels.

Deque ADT: Operations

- Insert Last
  - Insert the new node to the end of the deque.
- Insert Front
  - Insert the new node to the beginning of the deque.
- Remove Last
  - Remove the last node from the deque.
- Remove Front
  - Remove the first node from the deque.
- Traverse
  - Move through the nodes in the deque.

Deque ADT Operations: Insert

- Insert Back
  - Update the tail pointer to point the newly added node.
  - Update the prev pointer of the newly added node to point the old last node.
  - Update the next pointer of the newly added node to null.
  - Update the next pointer of the old last node to point the newly added node.
- Insert Front
  - Update the head pointer to point the newly added node.
  - Update the prev pointer of the newly added node to point the header node.
  - Update the next pointer of the newly added node to the old first node.
  - Update the prev pointer of the old first node to point the newly added node.

Deque ADT Operations: Delete

- Delete Back
  - Update the tail pointer to point the node previous to the removed node.
  - Update the next pointer of the node previous to the removed node to null.
- Delete Front
  - Update the head pointer to point the node next to the removed node.
  - Update the prev pointer of the node next to the removed node to point the header node.