CS 261: Data Structures

Linked Lists
List Stack

Dynamic Array -- Problems

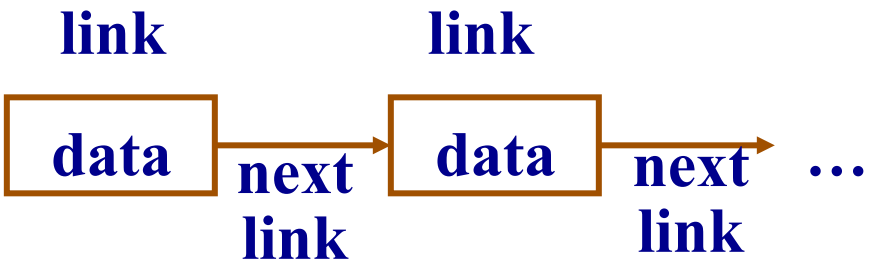
- Data kept in a single large block of memory
- Often more memory used than necessary
  - especially when repeatedly growing and shrinking the dynamic array

Linked List

- A good alternative
- The memory use is always proportional to the number of elements in the collection

Characteristics of Linked Lists

- Elements are held in objects called **Links**
- Links are 1-to-1 with data elements, allocated and released as necessary



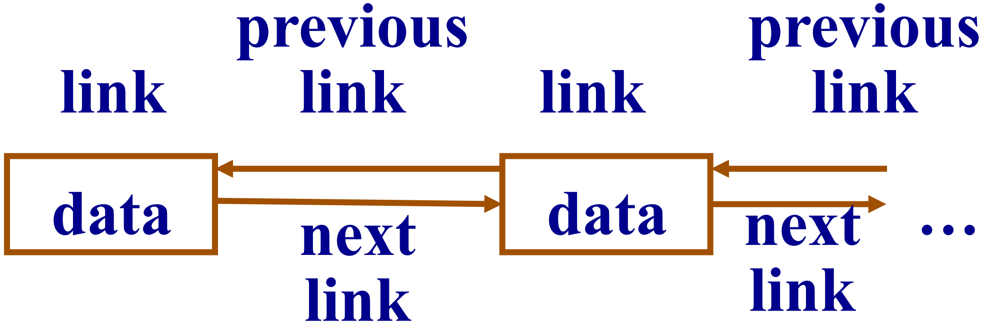
Single and Double Linked Lists

Each link points to

only next link → single linked list

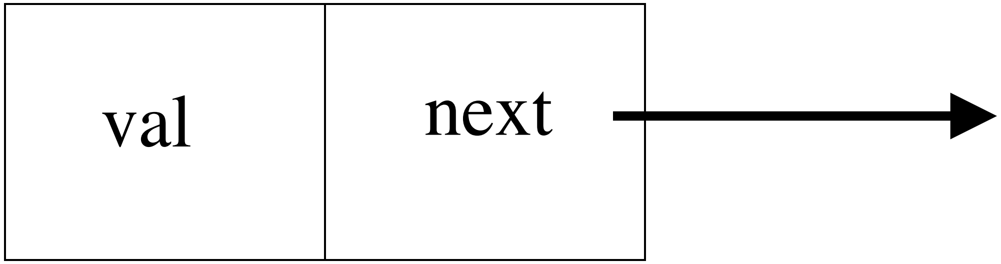
next and previous links → double linked list

in the sequence



Link Structure

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



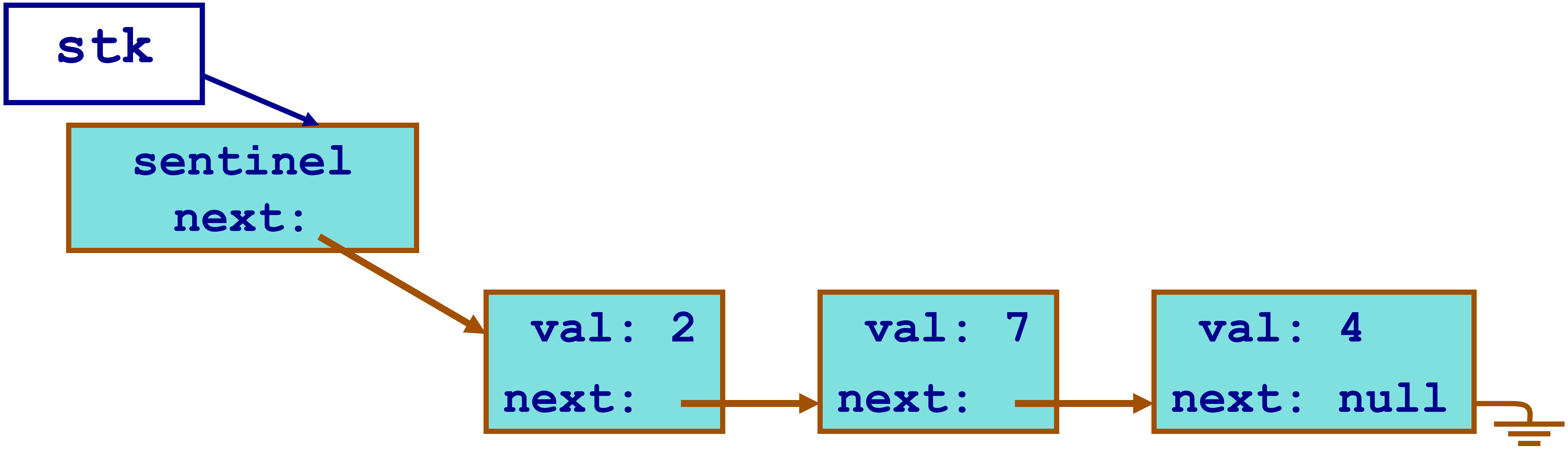
Elements of Linked Lists

- **Sentinel** -- special link for start or end
- Points to
  - first **or** last link only (single linked list)
  - first **and** last link (double linked list)

List Stack

- Sentinel points to the first element
- Sentinel points to NULL if stack empty
- Add or remove elements only from front
- Allow only singly linked list
- Can access only first element

List Stack



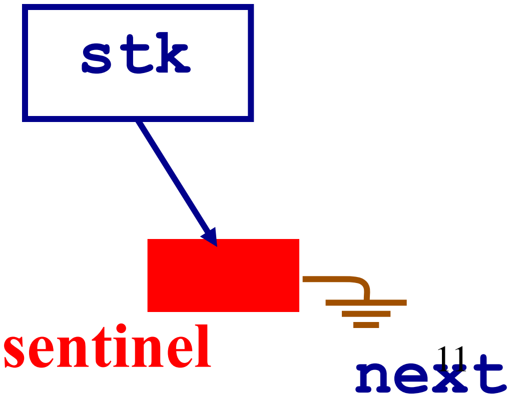
Implementation of List Stack

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

struct ListStack {
   struct Link * sentinel;
};
```

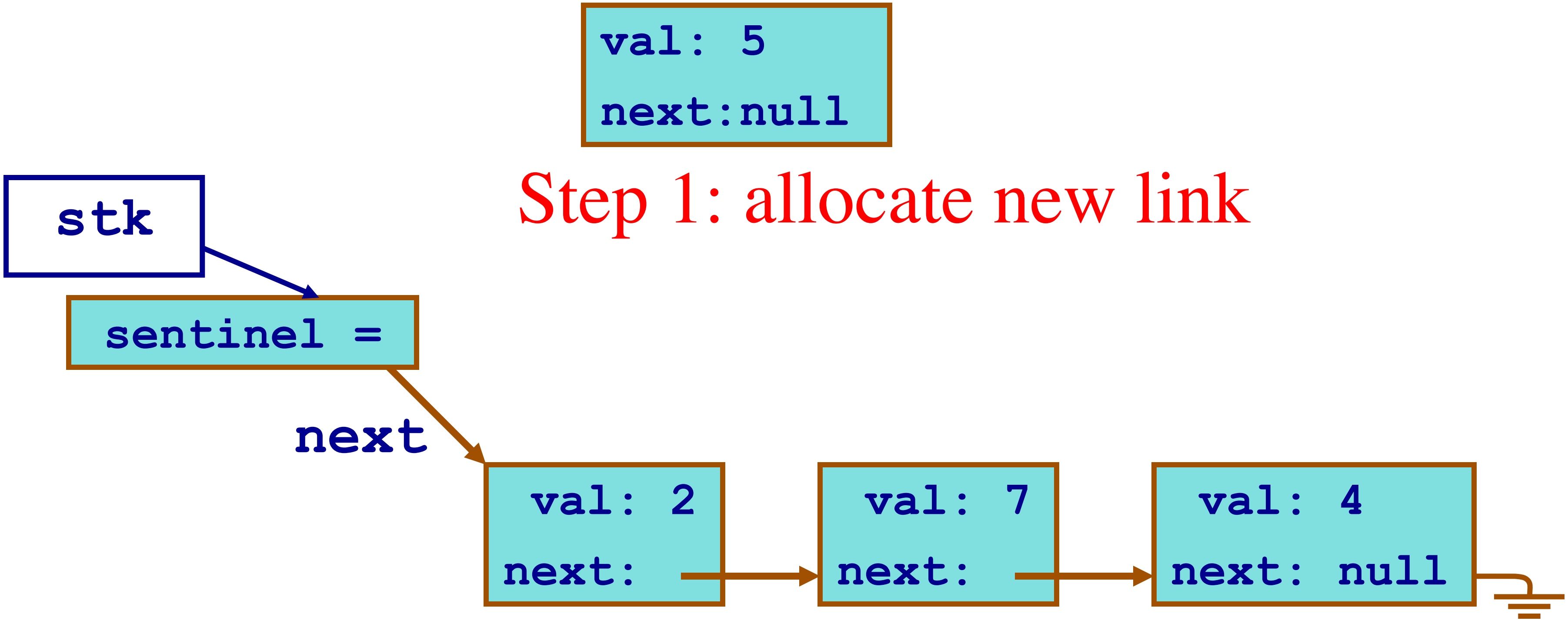
How to initialize List Stack?

InitStack

```
void InitStack(struct ListStack * stk){
   /*initialize the sentinel*/
   struct Link *sentinel =
       (struct Link *)malloc(sizeof(struct Link));

    assert(sentinel != 0);

   /*linked list is empty*/
    sentinel->next = NULL;
    stk->sentinel = sentinel;
}
```



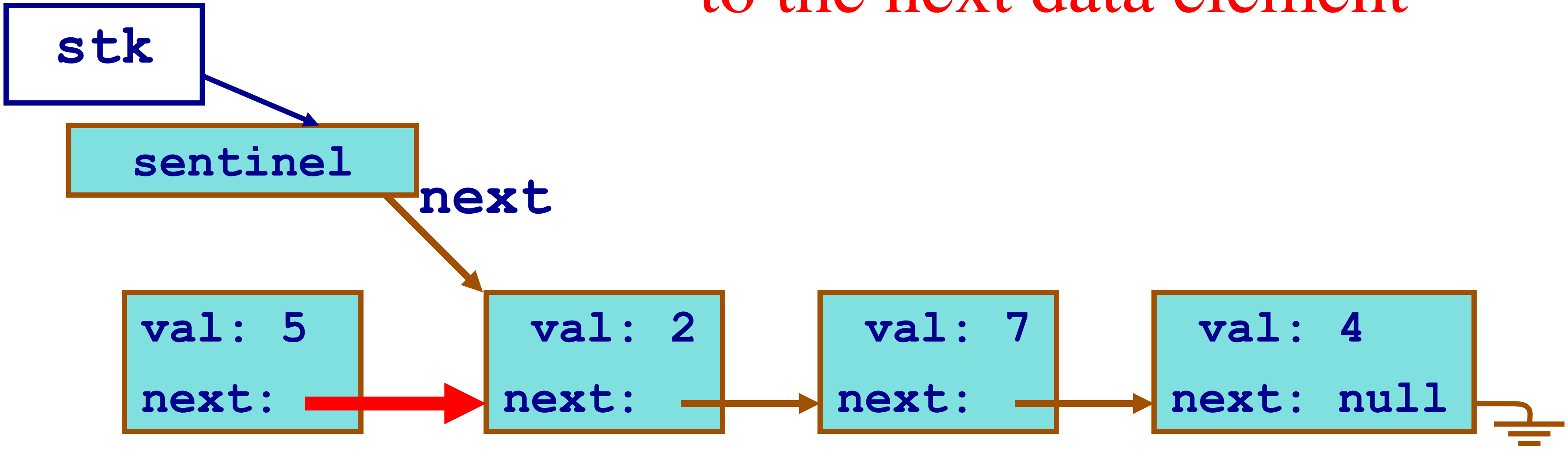
Push List Stack: 3 Steps



Step 1: allocate new link

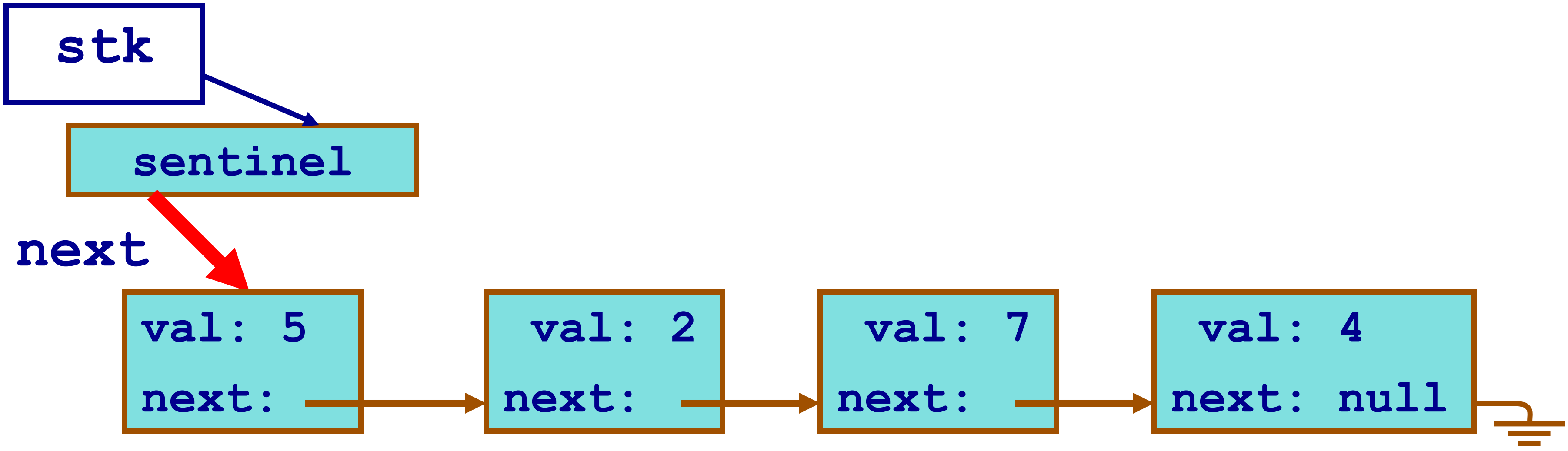
Push List Stack: 3 Steps

Step 2: link the new element to the next data element



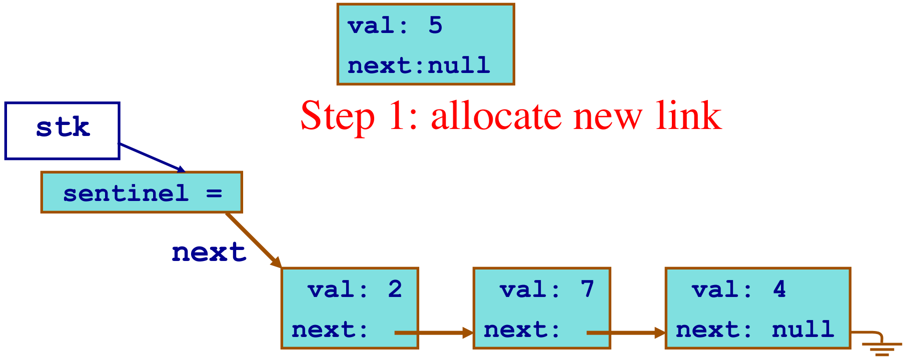
Push List Stack: 3 Steps

Step 3: add the new element to the top



Push List Stack: 3 Steps

```
void pushStack (struct listStack *stk, TYPE val){
   struct Link * new =
       (struct Link *) malloc(sizeof(struct Link));
   assert (new != 0);
   new->value = val;



}
```

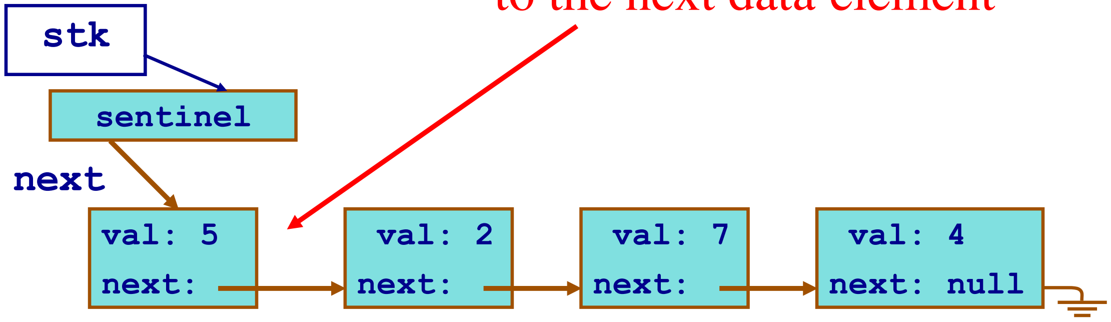


Step 1: allocate new link

Push List Stack: 3 Steps

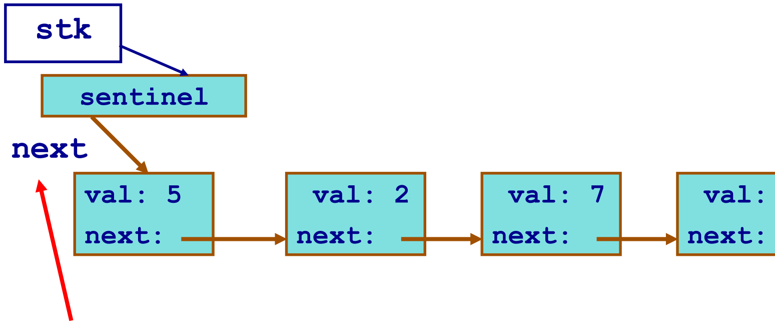
```
void pushStack (struct listStack *stk, TYPE val){
   struct Link * new =
        (struct Link *) malloc(sizeof(struct Link));
   assert (new != 0);
   new->value = val;
   new->next =  stk->sentinel->next;








}
```

Step 2: link the new element to the next data element



Push List Stack: 3 Steps

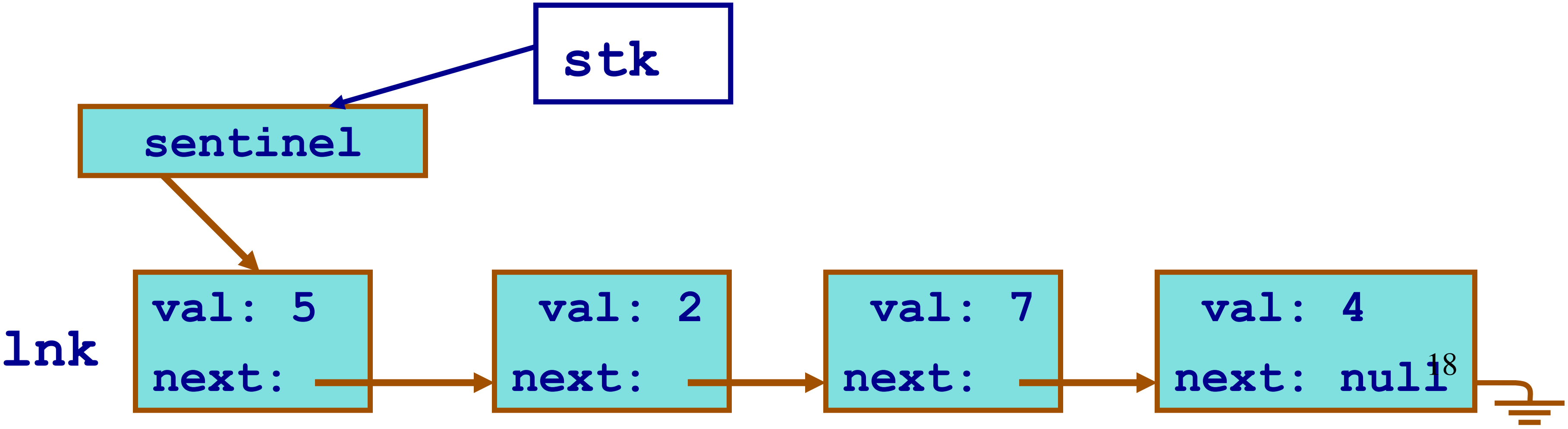
```
void pushStack (struct listStack *stk, TYPE val){
    struct Link * new =
         (struct Link *) malloc(sizeof(struct Link));
    assert (new != 0);
    new->value = val;
    new->next =  stk->sentinel->next;
    stk->sentinel->next = new;
}
```



Step 3: add the new element to the top

PopStack

```
/*move the top to the next element*/
void PopStack (struct ListStack *stk) {
   struct Link * lnk = stk->sentinel->next;
   if(lnk!=NULL){ /*the top element exists*/



}
```



stk

sentinel

lnk

val: 5
next:

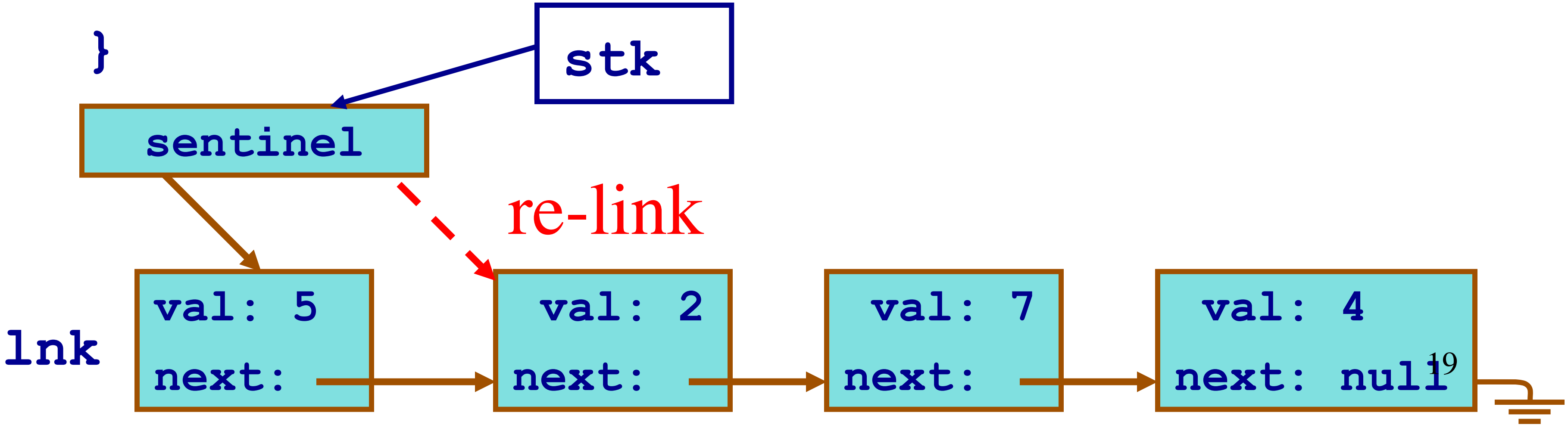
val: 2
next:

val: 7
next:

val: 4
next: null

PopStack

```
/*move the top to the next element*/
void PopStack (struct ListStack *stk) {
   struct Link * lnk = stk->sentinel->next;
   if(lnk!=NULL){ /*the top element exists*/
     stk->sentinel->next = lnk->next;
     free(lnk);
   }
}
```



topStack, isEmpty...

- Should be done on your own
- Worksheet 17

List Stack vs. Dyn. Array Stack

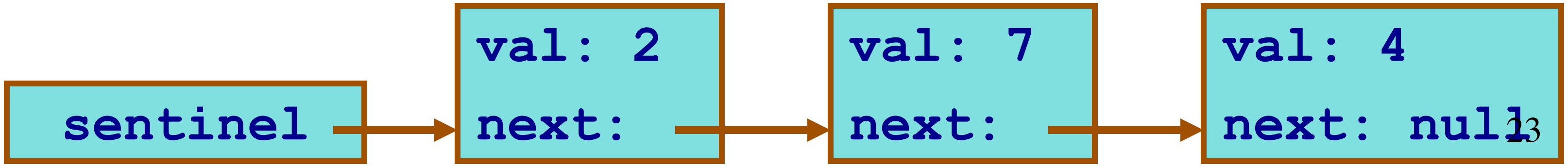
	List	Dyn. Array
pushStack	O(1)	O(1)
popStack	O(1)	O(1)
topStack	O(1)	O(1)

List Bag

- Init, Add operations are similar to List Stack
- Contains and Remove operations are tricky
- How to patch up links after removing an element?

Remove

```
void removeListBag(struct ListBag *b, TYPE val) {















}
```



sentinel

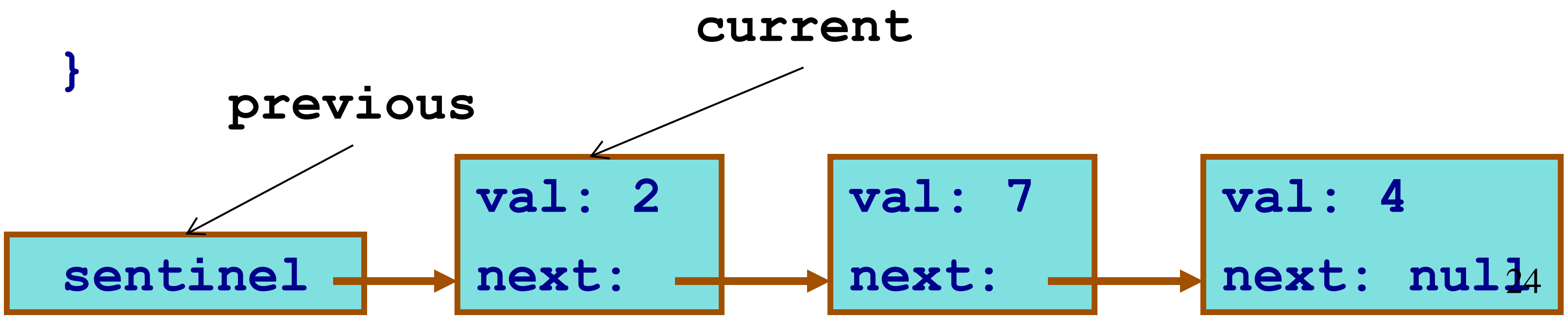
val: 2
next:

val: 7
next:

val: 4
next: null

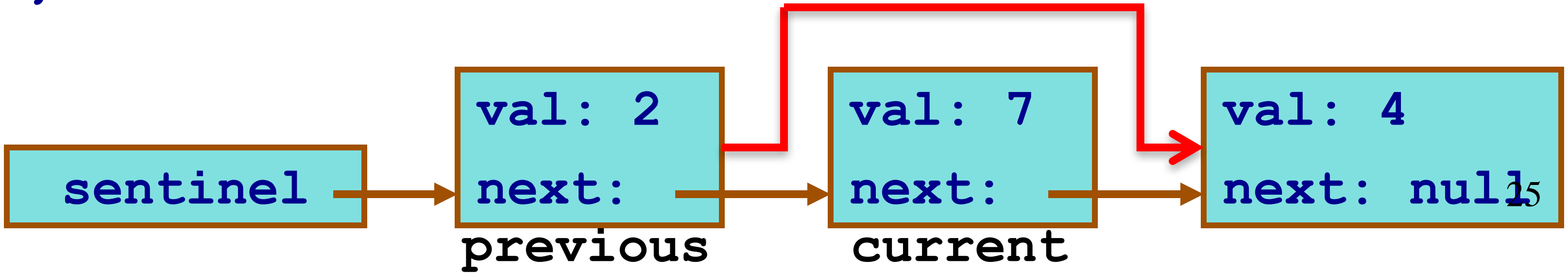
Remove

```
void removeListBag(struct ListBag *b, TYPE val) {
    struct Link *previous = b->sentinel;
    struct Link *current = b->sentinel->next;
    while (current != NULL){




    }
}
```



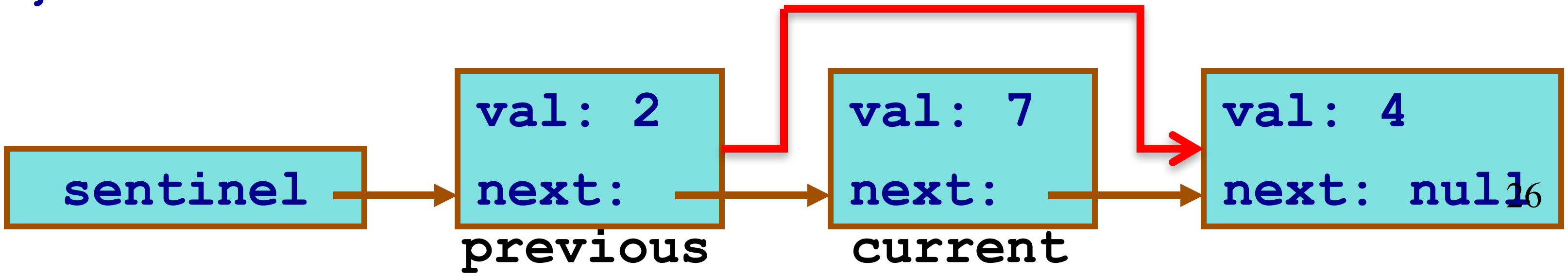
Remove

```
void removeListBag(struct ListBag *b, TYPE val) {
   struct Link *previous = b->sentinel;
   struct Link *current = b->sentinel->next;
   while (current != NULL){
     if (EQ(current->value,val)) {
       previous->next = current->next;





     }
   }
}
```



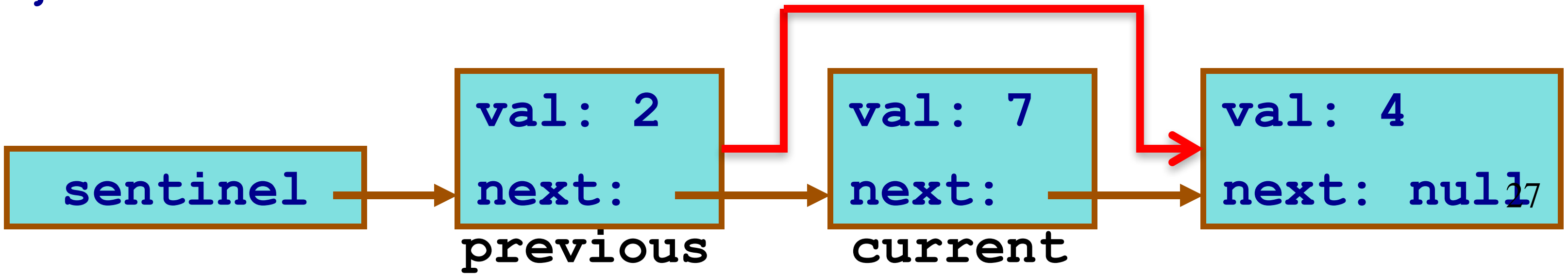
Remove – First Occurrence

```
void removeListBag(struct ListBag *b, TYPE val) {
   struct Link *previous = b->sentinel;
   struct Link *current = b->sentinel->next;
   while (current != NULL){
     if (EQ(current->value,val)) {
       previous->next = current->next;
       free(current);
       return; /*removes only the first occurrence*/
     }
     previous = current;
     current = current->next;
   }
}
```



Remove -- All Occurrences

```
void removeListBag(struct ListBag *b, TYPE val) {
   struct Link *previous = b->sentinel;
   struct Link *current = b->sentinel->next;
   while (current != NULL){
     if (EQ(current->value,val)) {
       previous->next = current->next;
       free(current);
       current = previous; → next
     }
     previous = current;
     current = current->next;
   }
}
```



When you find it

- When you find the element to be deleted, what does previous point to?

- What if the element to be deleted is at the front of the list? Does this matter?