Data Structure:
List

chap. 4.1-4.2, 4.8

List ADT

- an ordered sequence of element $<A_1, A_2, A_3, \ldots, A_N>$
  - the size of the list is N
  - a list of size 0 is an empty list
  - A_{i+1} follows (succeeds) A_i ($i<N$) and A_{i-1} precedes A_i ($i>1$)
  - the position of an element A_i in a list is i
- operations in the List ADT
  - MakeEmpty (List L): constructor
  - DeleteList (List L): destructor
  - Find (List L, Key K): returns the position of the key
  - Insert (Key K, List L, Position P): insert K after P in L
  - Delete (Key K, List L): delete K from L
  - Concat (List L1, List L2): returns the concatenation of L1 and L2

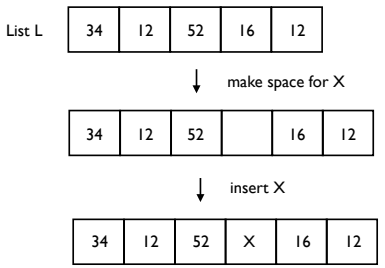
List ADT: an example

- List: L = <34, 12, 52, 16, 12>
  - Find(L, 52): 3
  - Insert(X, L, 3): 34, 12, 52, X, 16, 12
  - Delete(52, L): 34, 12, X, 16, 12

- Find (List L, Key K): returns the position of the key
- Insert (Key K, List L, Position P): insert K after P in L
- Delete (Key K, List L): delete K from L

List ADT: simple implementation with array

Insert X after the key 52 in the list L

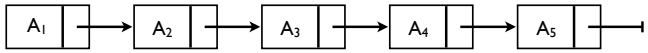


List ADT: simple implementation with array

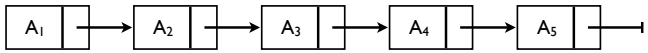
- it is inefficient because . . .
  - an estimate of the maximum size of the list is required
    - it requires overestimating the amount of storage needed for the list
  - it is hard to insert or delete at the beginning or in the middle of the list
    - worst case: O(N)
    - average case: half of the list O(N)
    - building a list by N successive inserts: $O(N^2)$

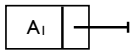
List ADT: linked list

- a linked list consists of a series of structures, which are not necessarily adjacent in memory
- each structure contains an element and a pointer to a structure of its successor
- the last cell's pointer points to NULL

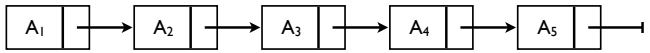


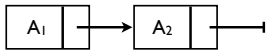
List ADT: linked list



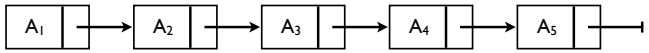


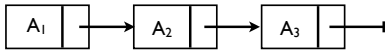
List ADT: linked list

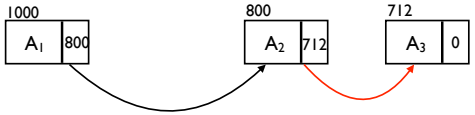




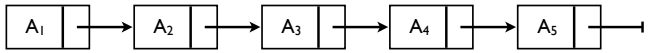
List ADT: linked list

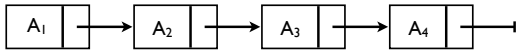


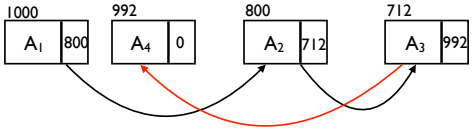




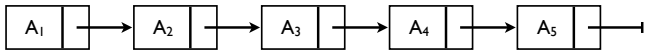
List ADT: linked list

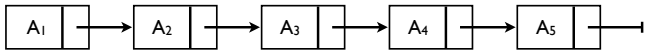


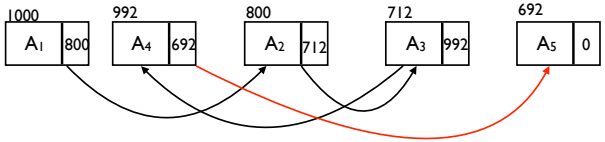




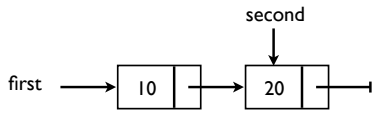
List ADT: linked list



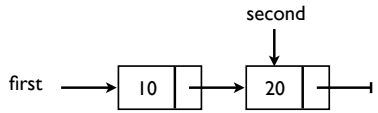




List ADT: example

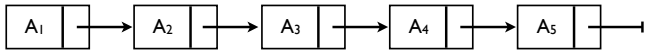


List ADT: example

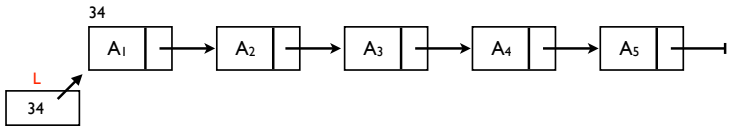



```
typedef struct listNode *listPointer;
typedef struct listNode {
        int data;
        listPointer  link;
};
listPointer create2(){
    listPointer first, second;
    MALLOC(first, sizeof(*first));
    MALLOC(first, sizeof(*second));
    second ->link = NULL;
    second -> data = 20;
    first -> data = 10;
    first->link = second;
    Return first;
    }
```

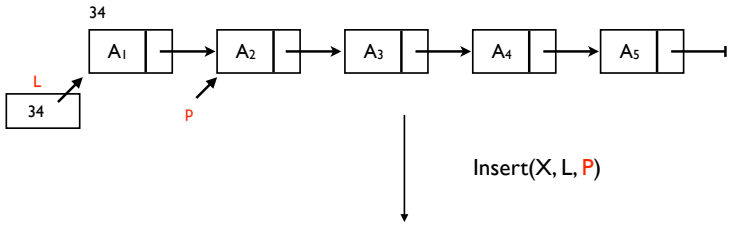
List ADT: insertion



List ADT: insertion

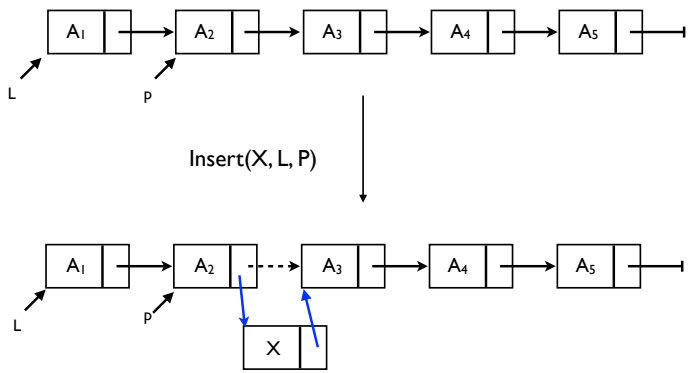


List ADT: insertion

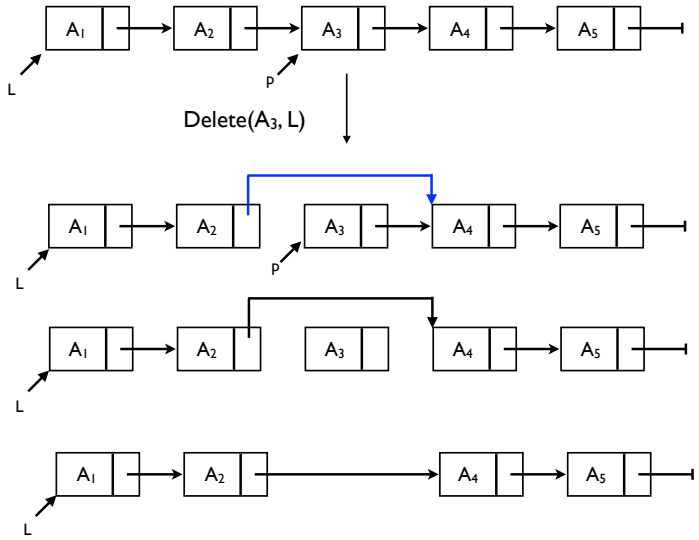


- Insert (Key K, List L, Position P): insert K after P in L

List ADT: insertion



List ADT: deletion



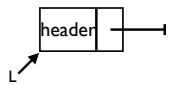
list ADT: type declaration for a linked list

```
typedef struct Node*  PtrToNode;
typedef int ElementType
typedef PtrToNode Position;
typedef PtrToNode List;
struct Node
{
   ElementType    Element;
   Position       Next;
};

List MakeEmpty( List L );
int IsEmpty( List L );
int IsLast( Position P,  List L );
Position Find( ElementType X, List L );
Position FindPrevious ( ElementType X,  List L );
void Delete( ElementType X,  List L );
void Insert ( ElementType X,  List L, Position P );
void DeleteList ( List L );
```

list ADT: MakeEmpty

```
/* create header node  */

List  MakeEmpty( List H )
{
      H = (List)malloc(sizeof(struct Node));
      H->element = header;
      H->next = NULL;
      return H
}
```

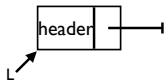
```
struct Node
{
   ElementType    Element;
   Position       Next;
};
```



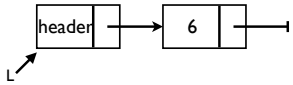
list ADT: IsEmpty

```
/* return true if L is empty  */

int  IsEmpty( List L )
{

}
```

```
struct Node
{
    ElementType    Element;
    Position       Next;
};
```



true

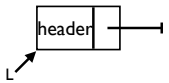


false

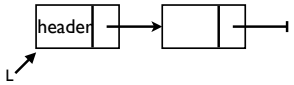
list ADT: IsEmpty

```
/* return true if L is empty  */

int  IsEmpty( List L )
{
    return L->Next == NULL;
}
```

```
struct Node
{
    ElementType    Element;
    Position       Next;
};
```



true

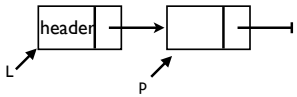


false

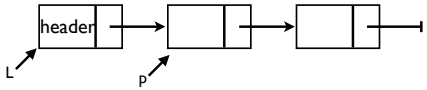
list ADT: IsLast

```
/* return true if P is the last position in list L */

int  IsLast( Position P, List L )
{

}
```

```
struct Node
{
    ElementType    Element;
    Position       Next;
};
```



true

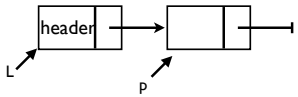


false

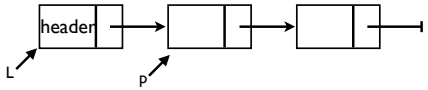
list ADT: IsLast

```
/* return true if P is the last position in list L */

int  IsLast( Position P, List L )
{
    return P->Next == NULL;
}
```

```
struct Node
{
    ElementType    Element;
    Position       Next;
};
```



true

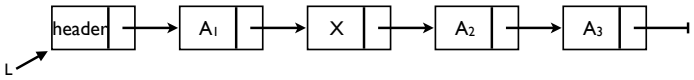


false

list ADT: Find

```
/* return position of X in L; NULL if not found */

Position  Find( ElementType X, List L )
{




}
```

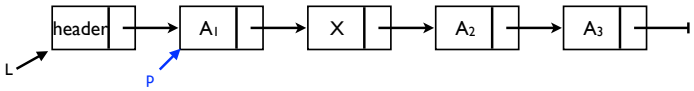
```
struct Node
{
   ElementType    Element;
   Position       Next;
};
```



list ADT: Find

```
/* return position of X in L; NULL if not found */

Position  Find( ElementType X, List L )
{
   Position P;

   P = L->Next;


   return P;
}
```

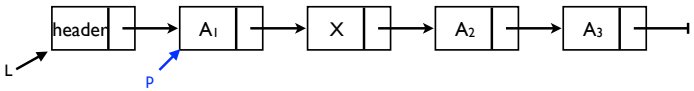
```
struct Node
{
   ElementType    Element;
   Position       Next;
};
```



list ADT: Find

```
/* return position of X in L; NULL if not found */

Position  Find( ElementType X, List L )
{
   Position P;

   P = L->Next;
   while( P != NULL && P->Element != X )


   return P;
}
```

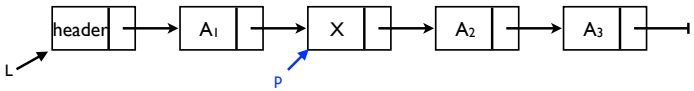
```
struct Node
{
   ElementType    Element;
   Position       Next;
};
```



list ADT: Find

```
/* return position of X in L; NULL if not found */

Position  Find( ElementType X, List L )
{
   Position P;

   P = L->Next;
   while( P != NULL && P->Element != X )
      P = P->Next;

   return P;
}
```

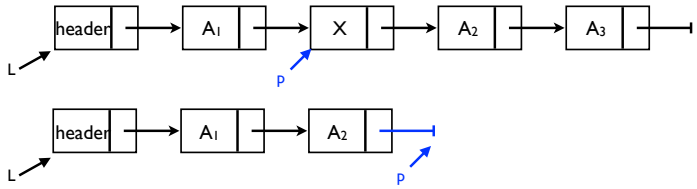
```
struct Node
{
   ElementType    Element;
   Position       Next;
};
```



list ADT: Find

```
/* return position of X in L; NULL if not found */

Position  Find( ElementType X, List L )
{
   Position P;

   P = L->Next;
   while( P != NULL && P->Element != X )
      P = P->Next;

   return P;
}
```

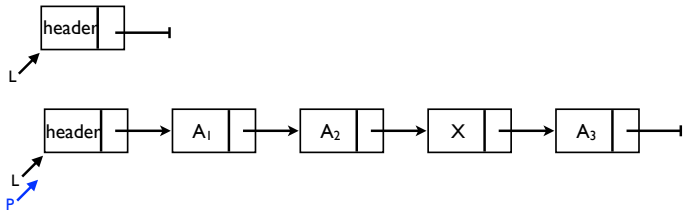
```
struct Node
{
   ElementType    Element;
   Position       Next;
};
```



list ADT: FindPrevious

```
Position  FindPrevious( ElementType X, List L )
{
   Position P;

   P = L;
   while( P->Next != NULL &&                    )
      P = P->Next;
   return P;
}
```

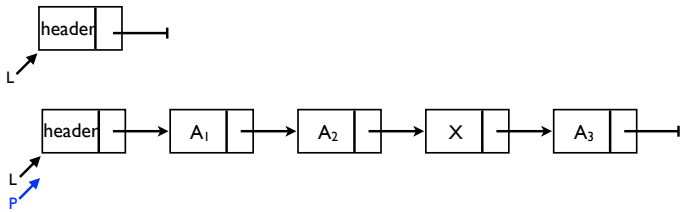
```
struct Node
{
   ElementType    Element;
   Position       Next;
};
```



list ADT: FindPrevious

```
Position  FindPrevious( ElementType X, List L )
{
   Position P;

   P = L;
   while( P->Next != NULL && P->Next->Element != X )
      P = P->Next;
   return P;
}
```

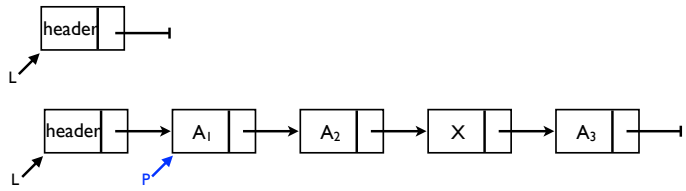
```
struct Node
{
   ElementType    Element;
   Position       Next;
};
```



list ADT: FindPrevious

```
Position  FindPrevious( ElementType X, List L )
{
   Position P;

   P = L;
   while( P->Next != NULL && P->Next->Element != X )
      P = P->Next;
   return P;
}
```

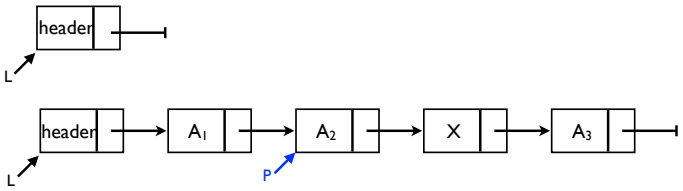
```
struct Node
{
   ElementType    Element;
   Position       Next;
};
```



list ADT: FindPrevious

```
Position  FindPrevious( ElementType X, List L )
{
   Position P;

   P = L;
   while( P->Next != NULL && P->Next->Element != X )
      P = P->Next;
   return P;
}
```

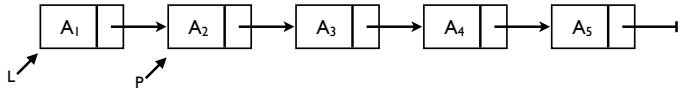
```
struct Node
{
   ElementType    Element;
   Position       Next;
};
```



List ADT: Insert

```
void  Insert( ElementType X,  List L,  Position P )
{




}
```

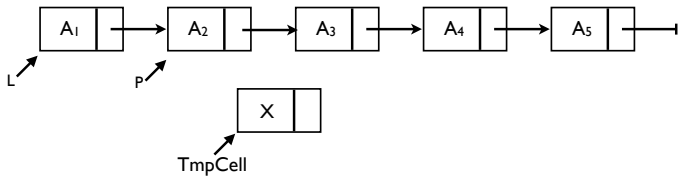
```
struct Node
{
   ElementType    Element;
   Position       Next;
};
```



List ADT: Insert

```
void  Insert( ElementType X,  List L,  Position P )
{
   Position TmpCell;

   TmpCell = malloc( sizeof( struct Node ) );
   if ( TmpCell == NULL )
      FatalError( "Out of space!!!" );

   TmpCell->Element = X;



}
```

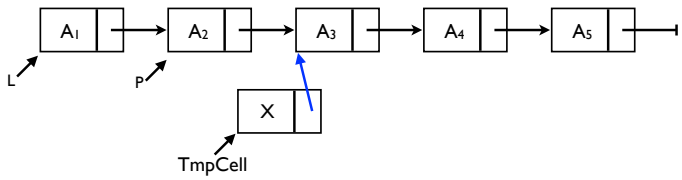
```
struct Node
{
   ElementType    Element;
   Position       Next;
};
```



List ADT: Insert

```
void  Insert( ElementType X,  List L,  Position P )
{
   Position TmpCell;

   TmpCell = malloc( sizeof( struct Node ) );
   if ( TmpCell == NULL )
      FatalError( "Out of space!!!" );

   TmpCell->Element = X;
   TmpCell->Next = P->Next;

}
```

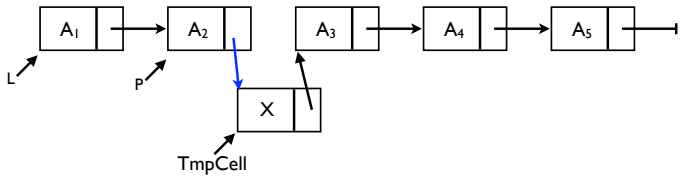
```
struct Node
{
   ElementType    Element;
   Position       Next;
};
```



List ADT: Insert

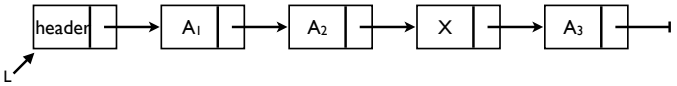
```
void  Insert( ElementType X,  List L,  Position P )
{
   Position TmpCell;

   TmpCell = malloc( sizeof( struct Node ) );
   if ( TmpCell == NULL )
      FatalError( "Out of space!!!" );

   TmpCell->Element = X;
   TmpCell->Next = P->Next;
   P->Next = TmpCell;
}
```

```
struct Node
{
   ElementType    Element;
   Position       Next;
};
```



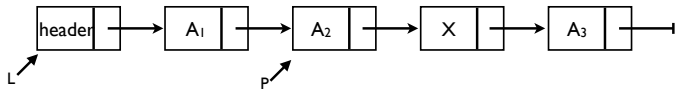
list ADT: Delete

```
void   Delete( ElementType X, List L )
{




}
```



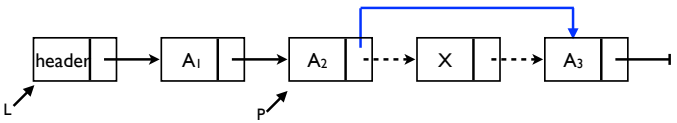
list ADT: Delete

```
void   Delete( ElementType X, List L )
{
   Position P,  TmpCell;

   P = FindPrevious( X, L );




}
```



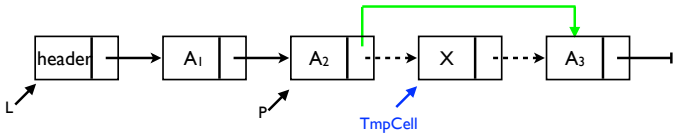
list ADT: Delete

```
void   Delete( ElementType X, List L )
{
   Position P,  TmpCell;

   P = FindPrevious( X, L );
   if ( !IsLast( P, L ) )                /*  Assumption of header use  */
   {                                     /*  X is found; delete it  */

      P->Next = ???;     /*  Bypass deleted cell  */

   }
}
```



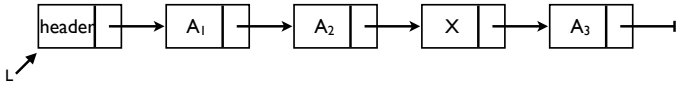
list ADT: Delete

```
void   Delete( ElementType X, List L )
{
   Position P,  TmpCell;

   P = FindPrevious( X, L );
   if ( !IsLast( P, L ) )                /*  Assumption of header use  */
   {                                     /*  X is found; delete it  */
      TmpCell = P->Next;
      P->Next = TmpCell->Next;     /*  Bypass deleted cell  */
      free( TmpCell );
   }
}
```



list ADT: DeleteList

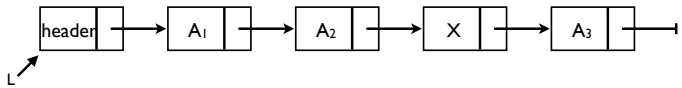
```
void  DeleteList( List L )
{




}
```



list ADT: DeleteList

```
void  DeleteList( List L )
{
   Position P;

   P = L->Next;   /*  Header assumed  */
   L->Next = NULL;
   while( P != NULL )
   {
      free( P );
      P = P->Next;
   }
}
```

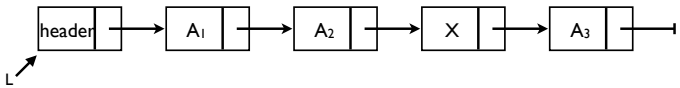
Is it okay?



list ADT: DeleteList

```
void  DeleteList( List L )
{
   Position P;

   P = L->Next;   /*  Header assumed  */
   L->Next = NULL;
   while( P != NULL )
   {
      free( P );
      P = P->Next;
   }
}
```

```
void DeleteList( List L )
{
   Position P, Tmp;

   P = L->Next;   /*  Header assumed  */
   L->Next = NULL;
   while( P != NULL )
   {
      Tmp = P->Next;
      free( P );
      P = Tmp;
   }
}
```

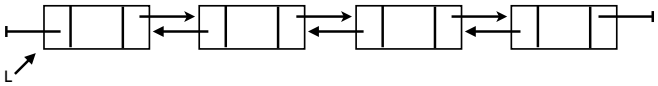


Doubly Linked List

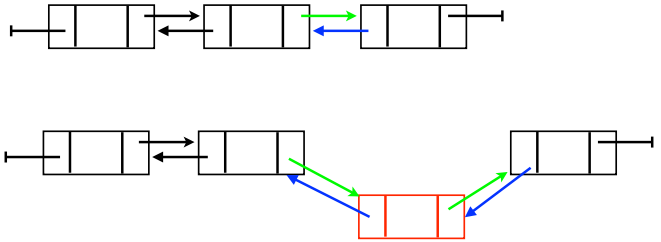
- a list that contains links to next and previous nodes

```
struct Node
{
    ElementType    Element;
    Position       Next;
    Position       Prev;
};
```

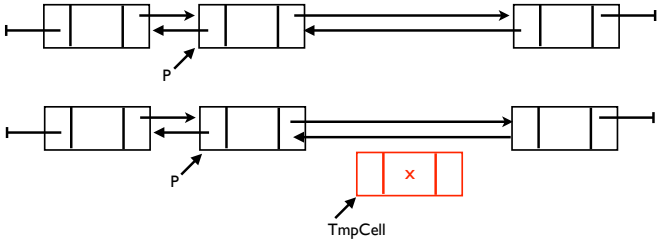
- FindPrevious() in singly linked list is not necessary



Doubly Linked List: insert



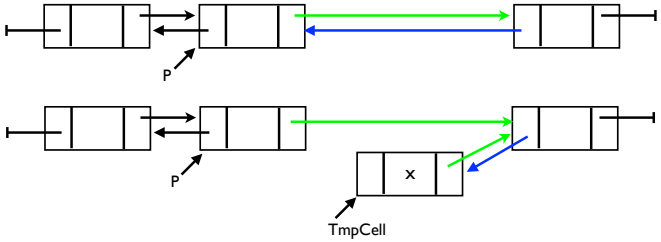
Doubly Linked List: insert




```
void  Insert( ElementType X,  List L,  Position P )
{
    Position TmpCell;

    TmpCell = malloc( sizeof( struct Node ) );
    if ( TmpCell == NULL )
        FatalError( "Out of space!!!" );

    TmpCell->Element = X;


}
```

```
struct Node
{
    ElementType    Element;
    Position       Next;
    Position       Prev;
};
```

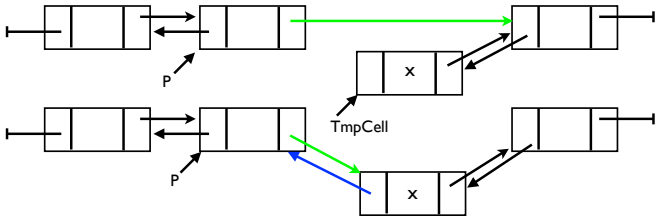
Doubly Linked List: insert




```
void  Insert( ElementType X,  List L,  Position P )
{
    Position TmpCell;

    TmpCell = malloc( sizeof( struct Node ) );
    if ( TmpCell == NULL )
        FatalError( "Out of space!!!" );

    TmpCell->Element = X;
    TmpCell->Next = P->Next;
    TmpCell->Next->Prev = TmpCell;
}
```

```
struct Node
{
    ElementType    Element;
    Position       Next;
    Position       Prev;
};
```

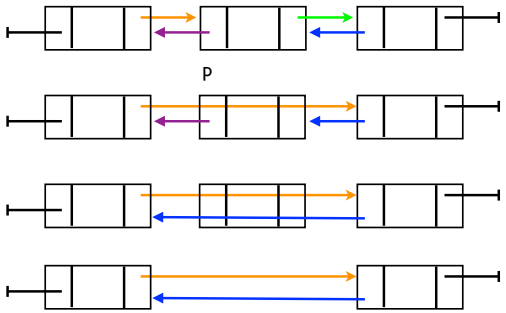
Doubly Linked List: insert



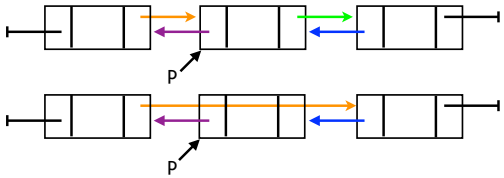

```
void  Insert( ElementType X,  List L,  Position P )
{
    Position TmpCell;

    TmpCell = malloc( sizeof( struct Node ) );
    if ( TmpCell == NULL )
        FatalError( "Out of space!!!" );

    TmpCell->Element = X;
    TmpCell->Next = P->Next;
    TmpCell->Next->Prev = TmpCell;
    P->Next = TmpCell;
    TmpCell->Prev = P
}
```

```
struct Node
{
    ElementType    Element;
    Position       Next;
    Position       Prev;
};
```

Doubly Linked List: delete

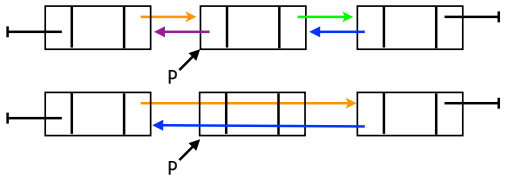


Doubly Linked List: delete



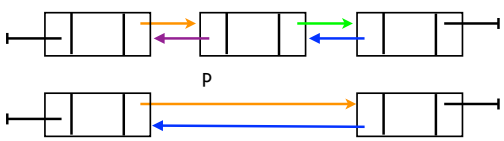

```
void  Delete( ElementType X,  List L)
{
    Position P;
    P = Find(X, L);

    P->Prev->Next = P->Next;


}
```

Doubly Linked List: delete




```
void  Delete( ElementType X,  List L)
{
    Position P;
    P = Find(X, L);

    P->Prev->Next = P->Next;
    P->Next->Prev = P->prev;

}
```

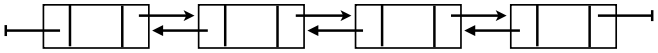
Doubly Linked List: delete




```
void  Delete( ElementType X,  List L)
{
   Position P;
   P = Find(X, L);

   P->Prev->Next = P->Next;
   P->Next->Prev = P->prev;
   free(P);
}
```

Circularly Linked List

- Doubly Linked List



- Circularly Linked List