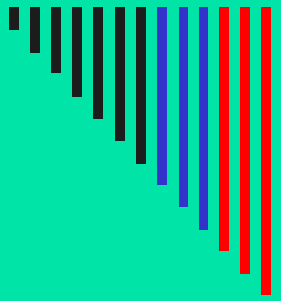


Chapter 5

General Linear Lists

Objectives

Upon completion you will be able to:

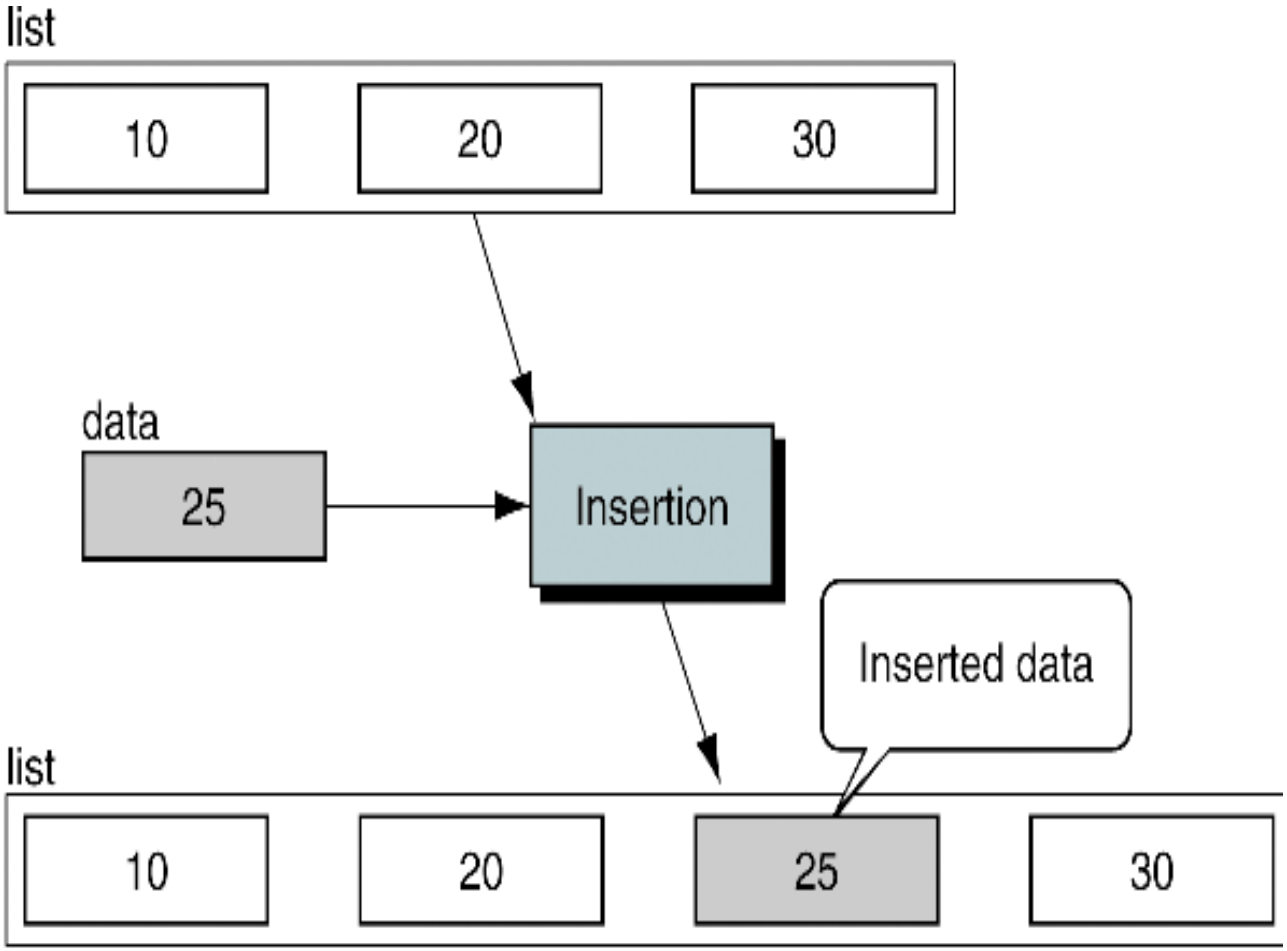
- **Explain the design, use, and operation of a linear list**
- **Implement a linear list using a linked list structure**
- **Understand the operation of the linear list ADT**
- **Write application programs using the linear list ADT**
- **Design and implement different link-list structures**

5-1 Basic Operations

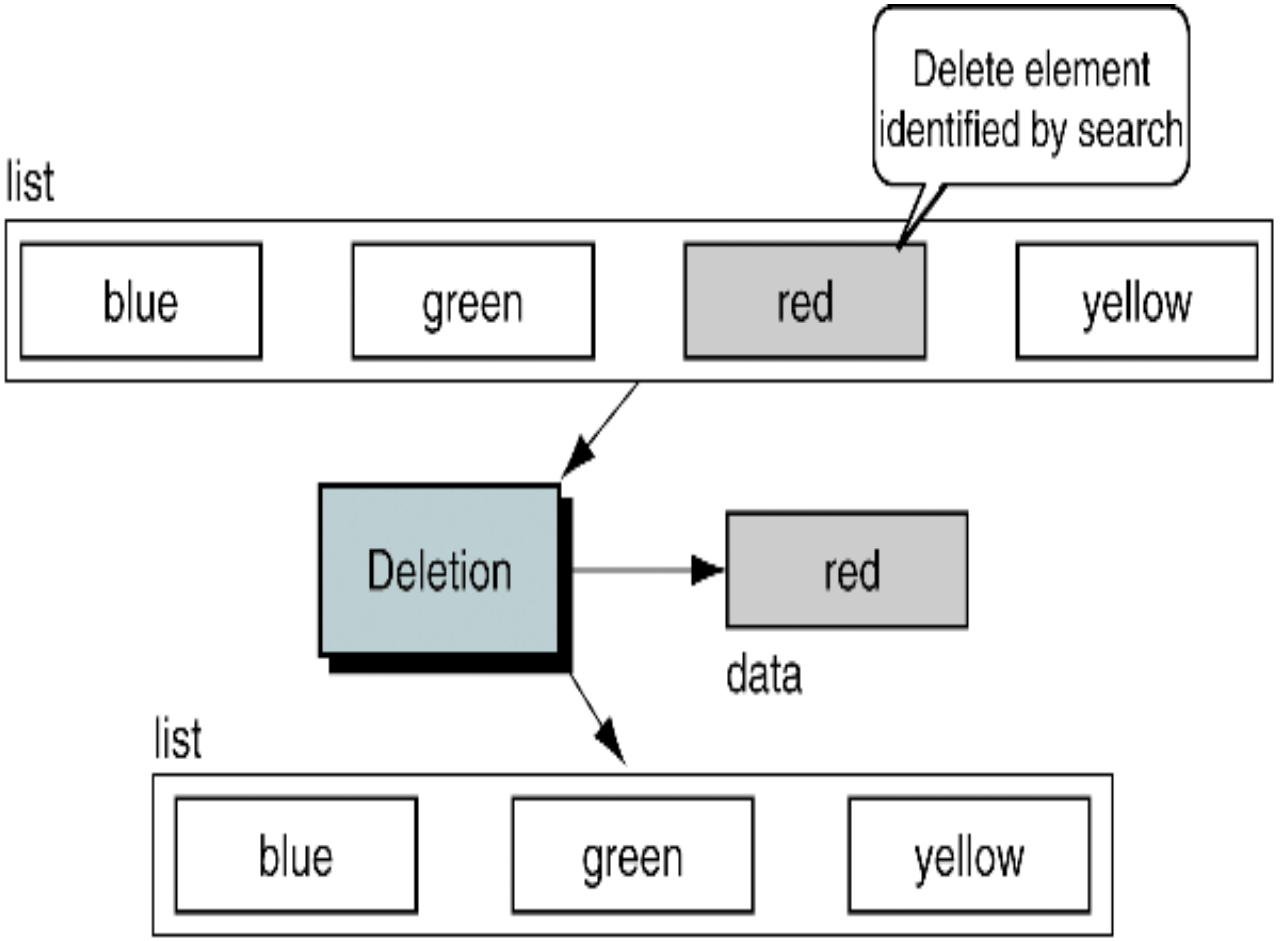
We begin with a discussion of the basic list operations. Each operation is developed using before and after figures to show the changes.

- **Insertion**
- **Deletion**
- **Retrieval**
- **Traversal**

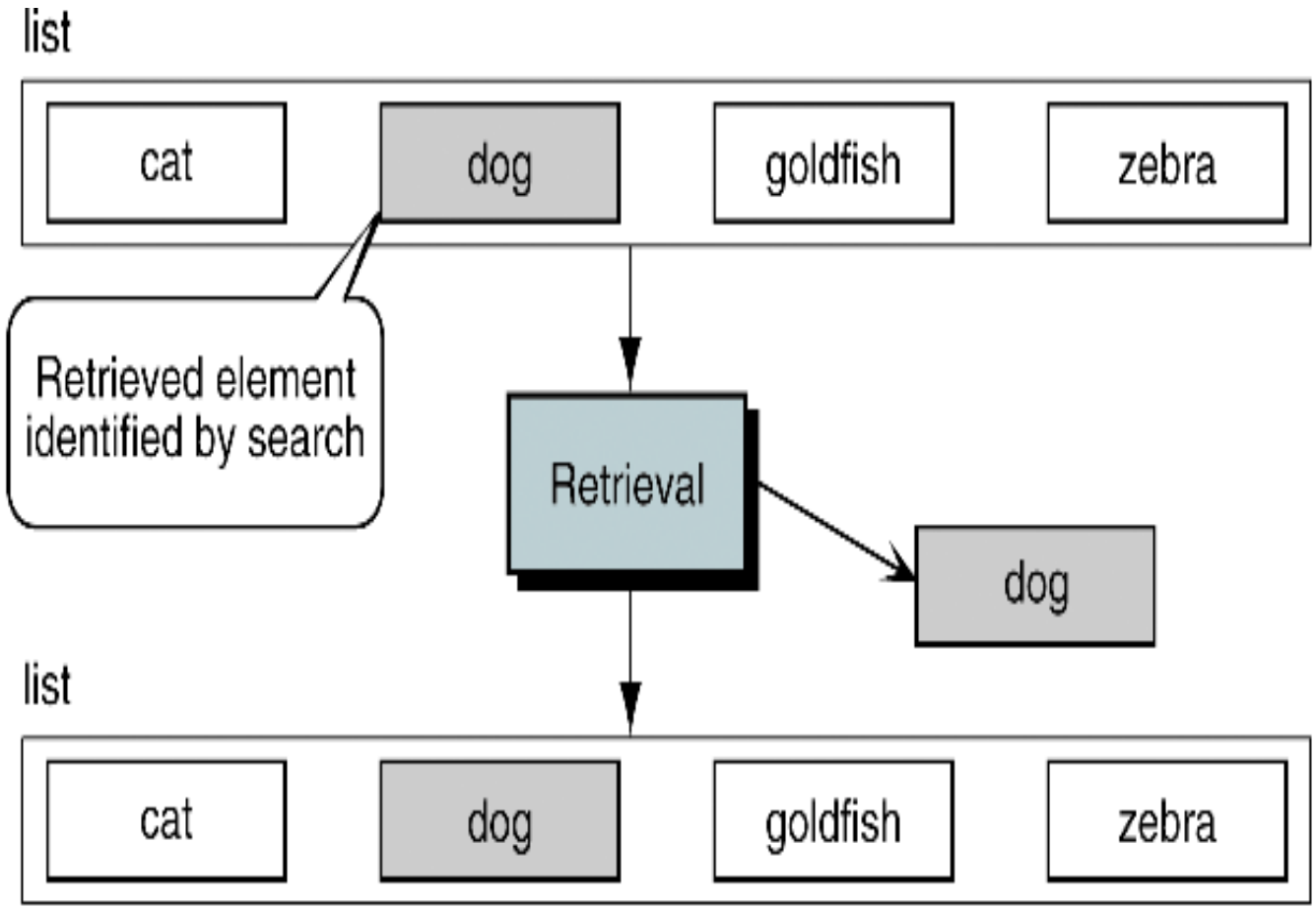
Insertion



Deletion


Delete element identified by search
list
blue
green
red
yellow
Deletion
red
data
list
blue
green
yellow

Retrieval

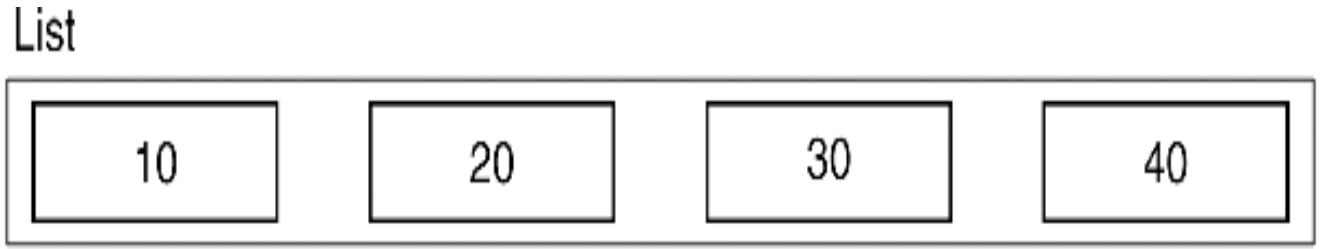

list
cat
dog
goldfish
zebra
Retrieved element identified by search
Retrieval
dog
list
cat
dog
goldfish
zebra

5-2 Implementation

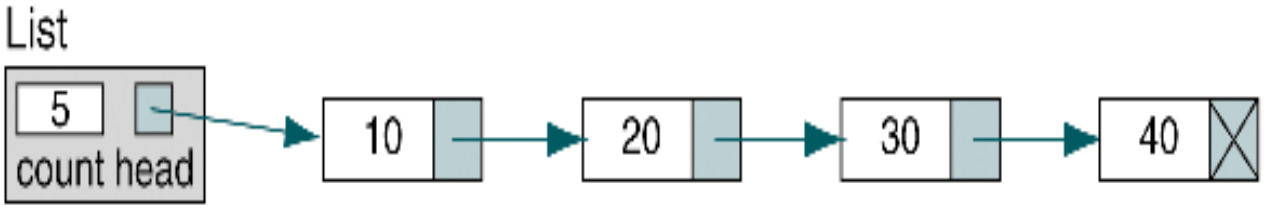
We begin with a discussion of the data structure required to support a list. We then develop the 10 basic algorithms required to build and use a list. In developing the insertion and deletion algorithms, we use extensive examples to demonstrate the analytical steps used in developing algorithms.

- **Data Structure**
- **Algorithms**

Linked List Implementation of List

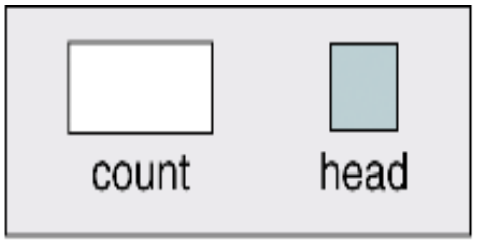


(a) Conceptual view of a list

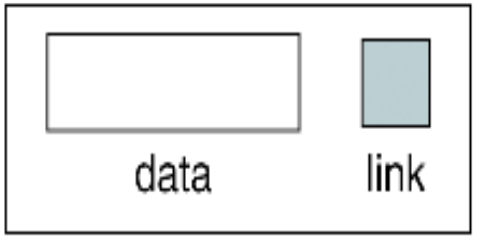


(b) Linked list implementation

Head Node and Data Node



(a) Head structure



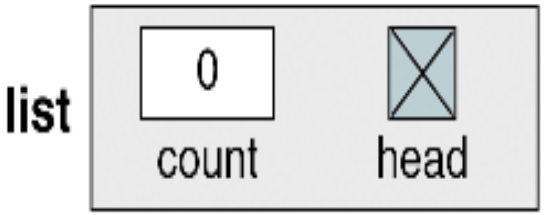
(b) Data node structure

```
list
  count
  head
end list

node
  data
  link
end node
```

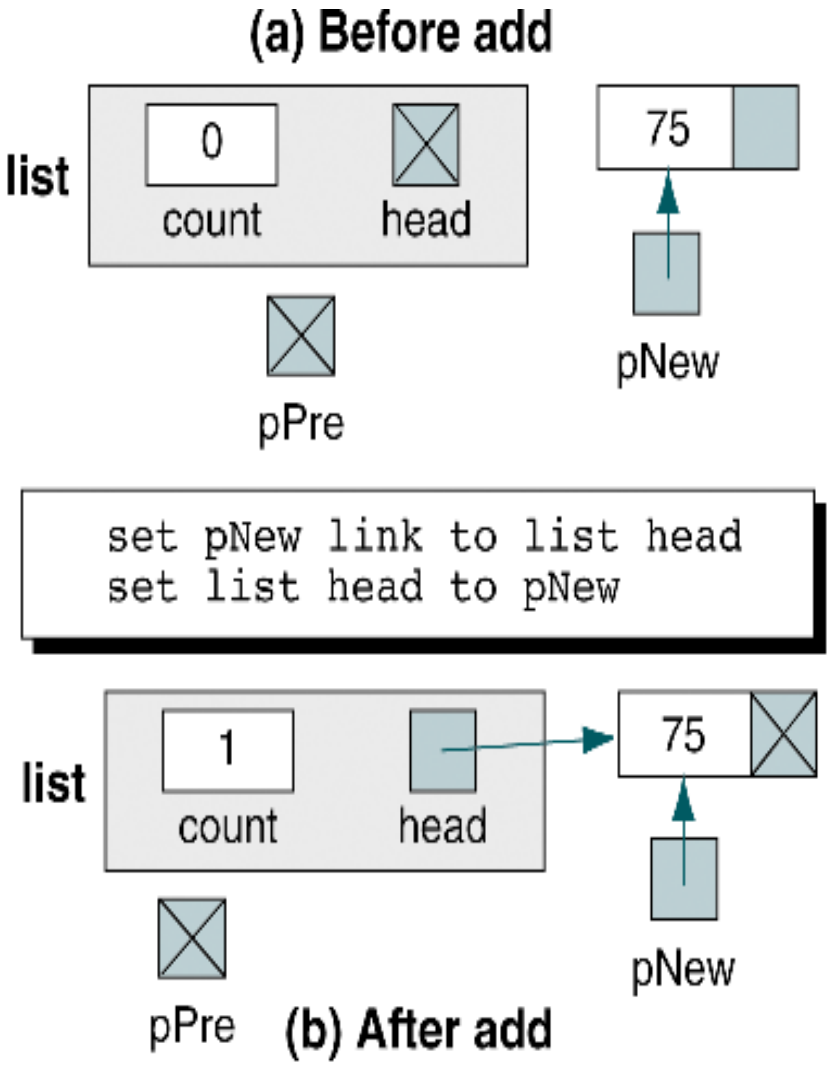
Create List

allocate (list)
set list head to null
set list count to 0

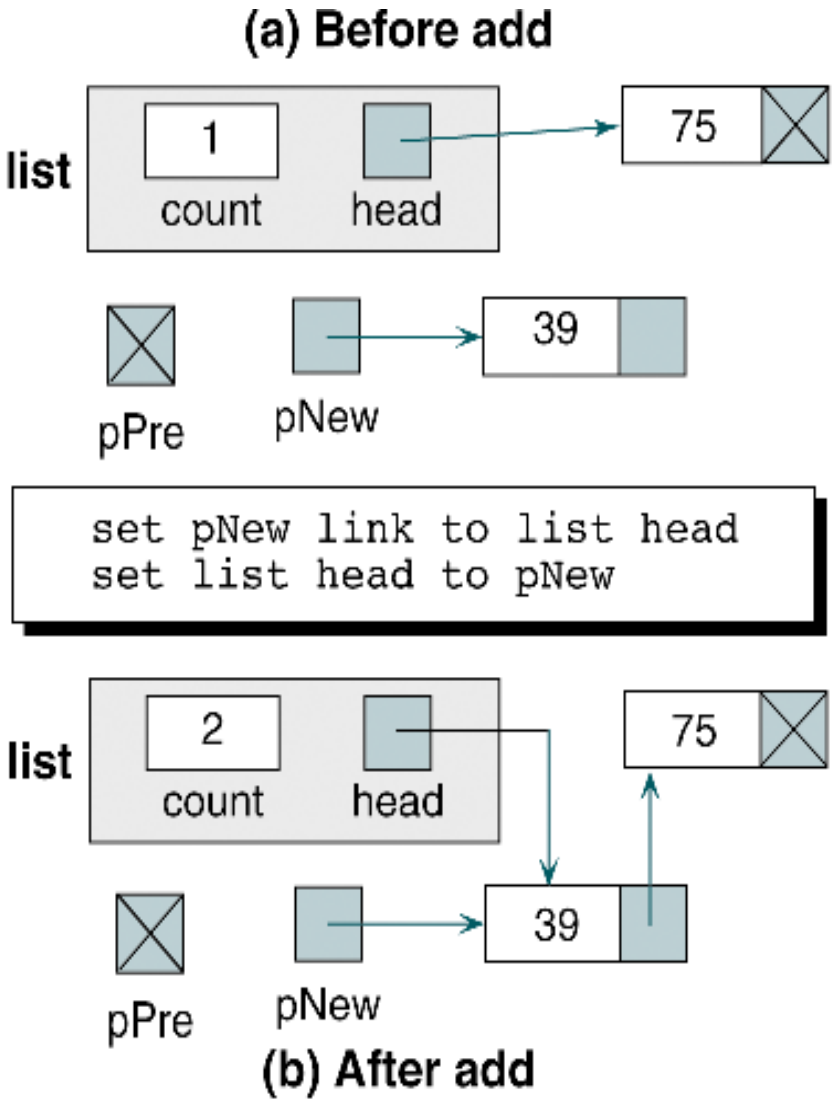



```
Algorithm createList (list)
Initializes metadata for list.
  Pre    list is metadata structure passed by reference
  Post   metadata initialized
1 allocate (list)
2 set list head  to null
3 set list count to 0
end createList
```

Add Node to Empty List

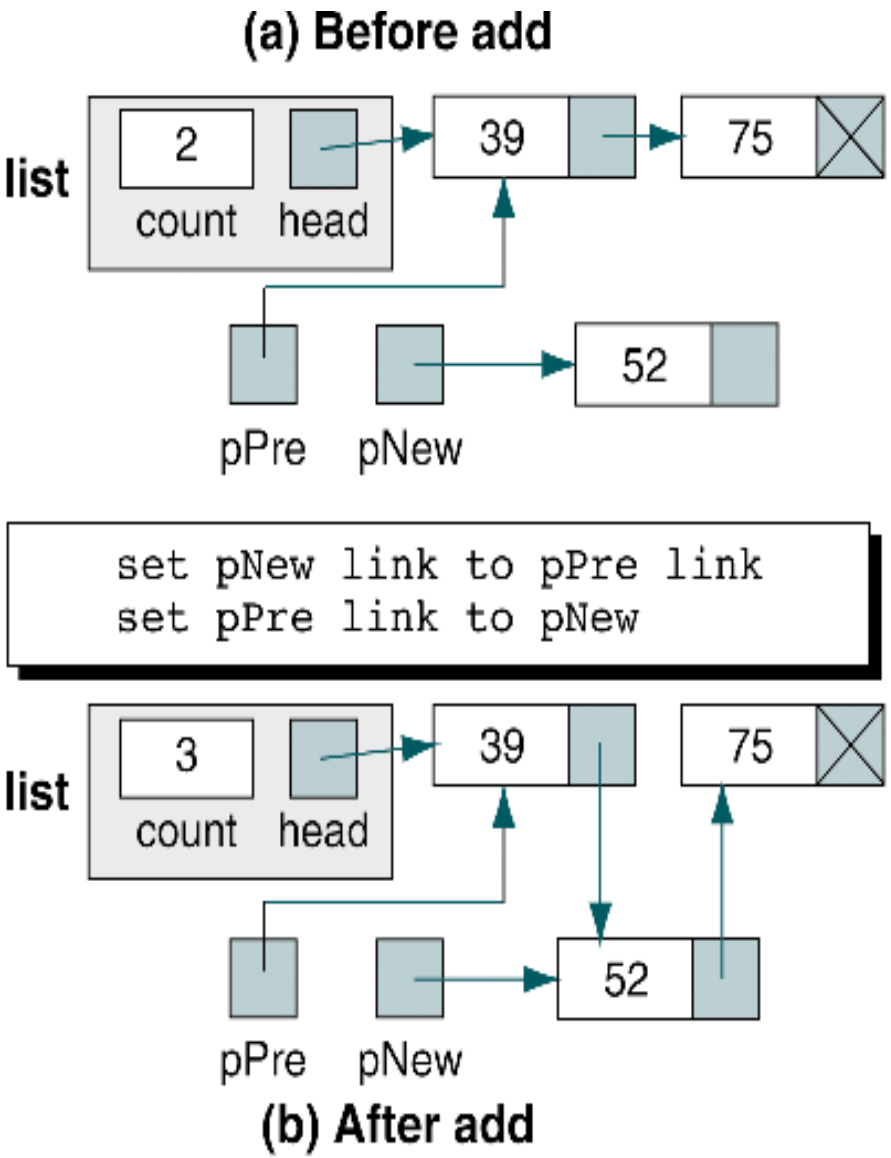


Add Node at Beginning

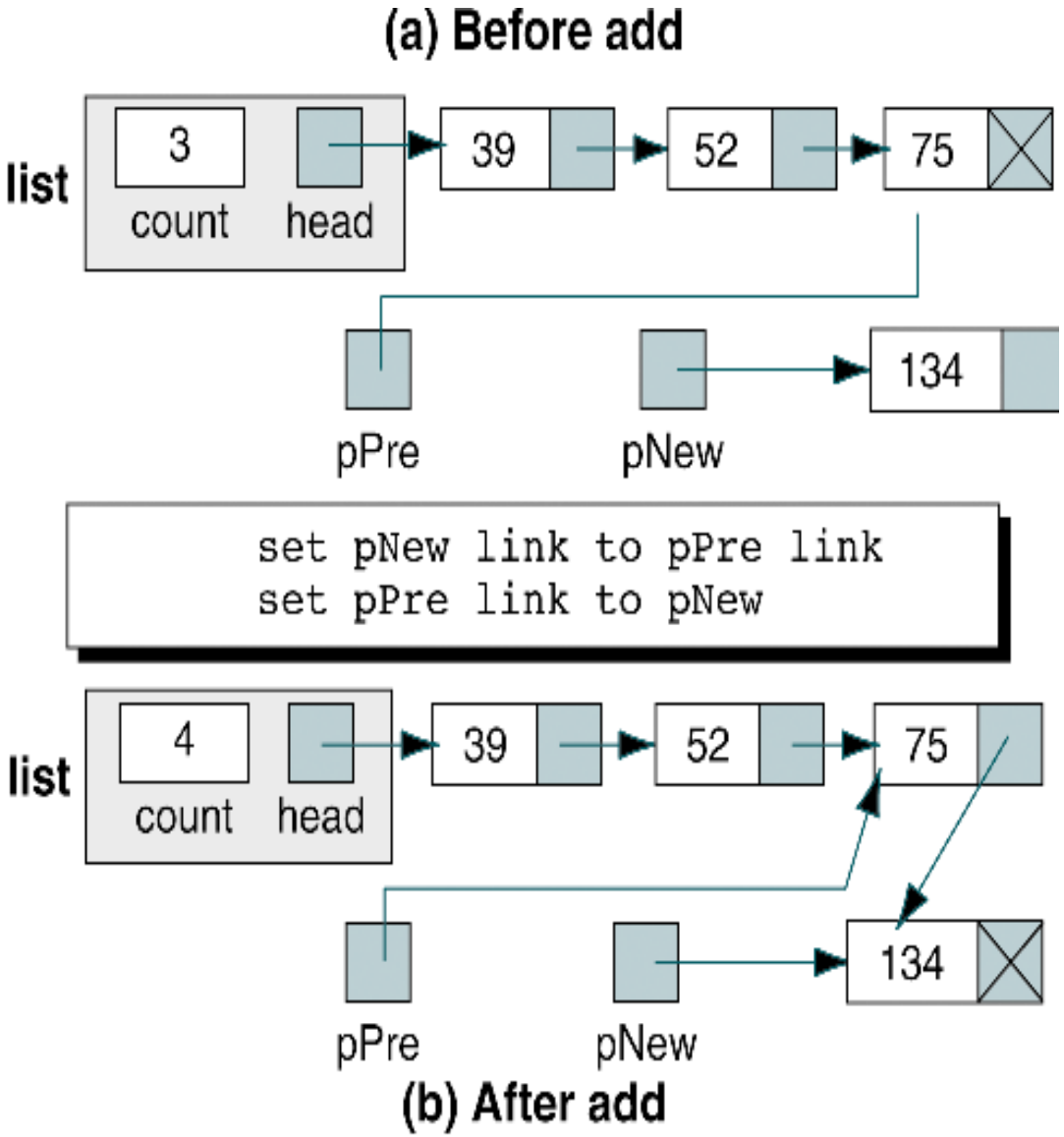


Same as add node to empty list

Add Node in Middle



Add Node at End

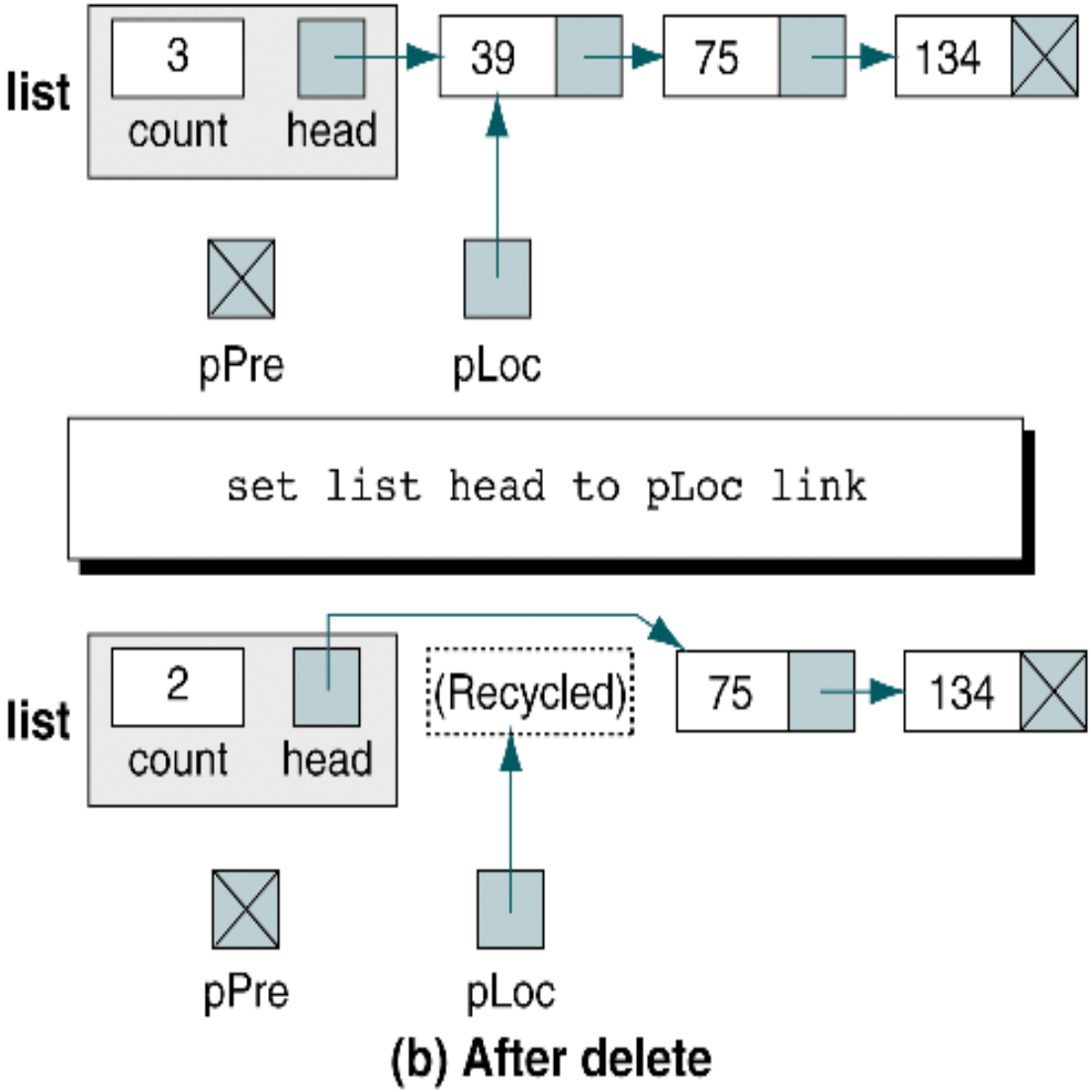


Same as add node in middle

Insert List Node

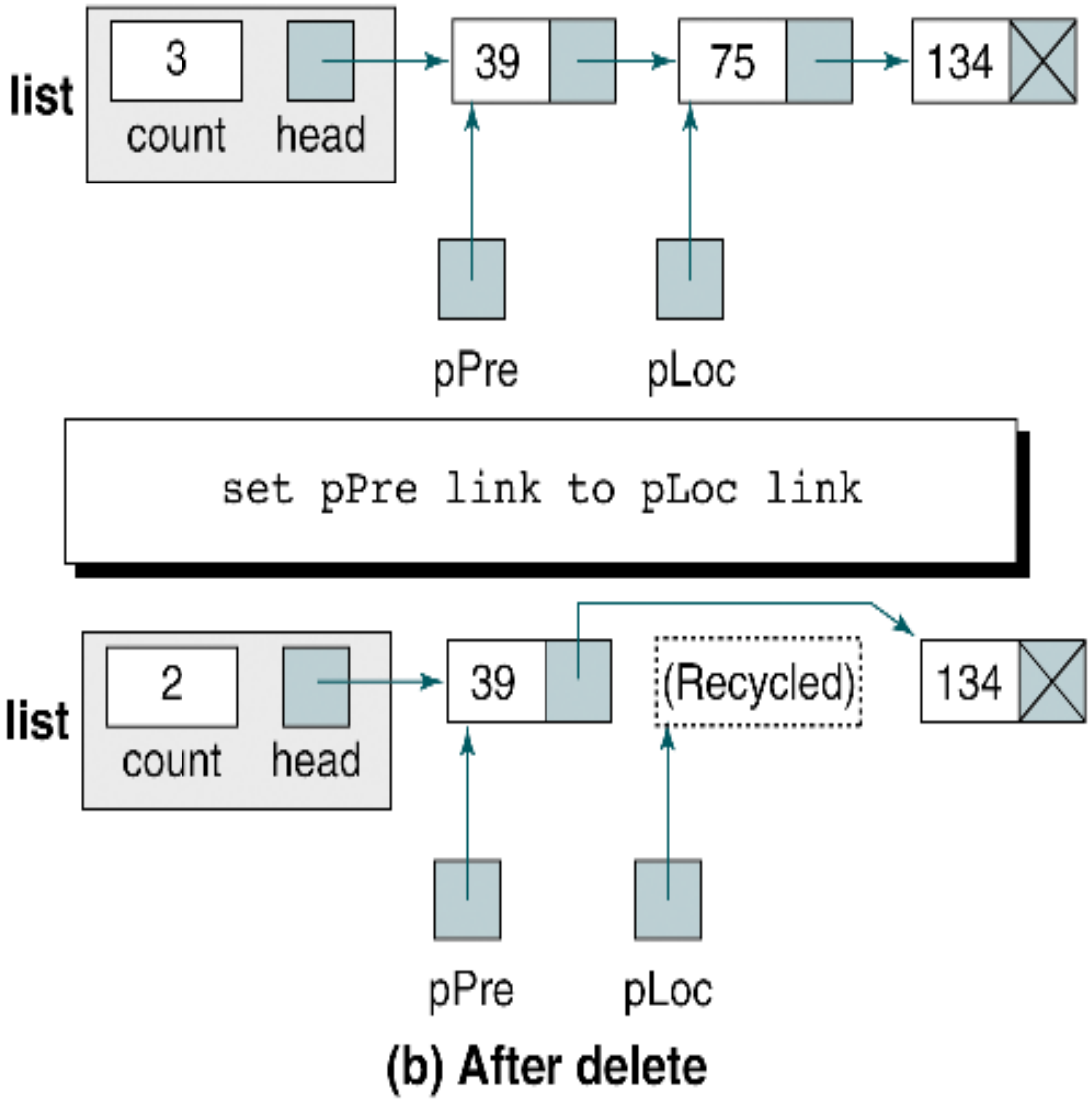
```
Algorithm insertNode (list, pPre, dataIn)
Inserts data into a new node in the list.
  Pre    list is metadata structure to a valid list
         pPre is pointer to data's logical predecessor
         dataIn contains data to be inserted
  Post   data have been inserted in sequence
  Return true if successful, false if memory overflow
1 allocate (pNew)
2 set pNew data to dataIn
3 if (pPre null)
  Adding before first node or to empty list.
  1  set pNew link to list head
  2  set list head to pNew
4 else
  Adding in middle or at end.
  1  set pNew link to pPre link
  2  set pPre link to pNew
5 end if
6 return true
end insertNode
```

Delete First Node



(b) After delete

Delete General Case

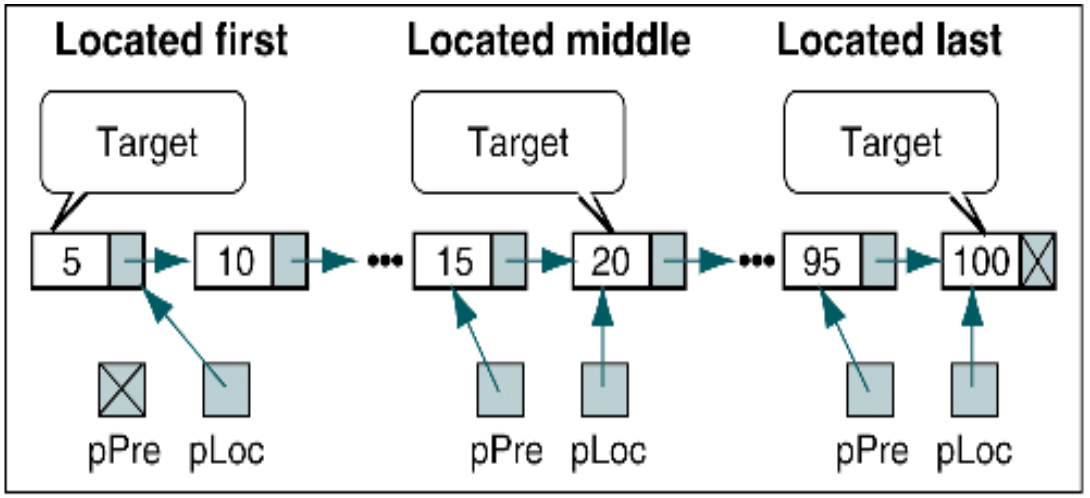


(b) After delete

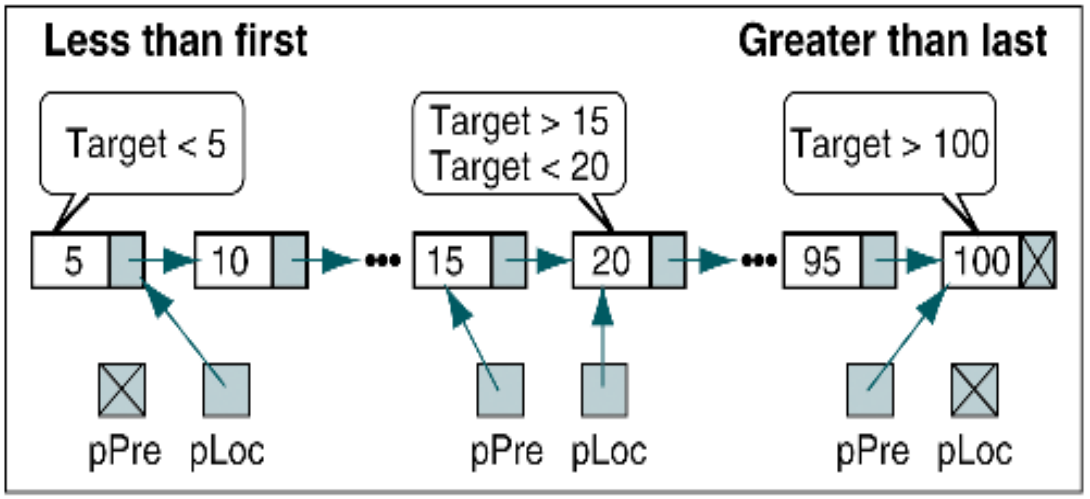
List Delete Node Algorithm

```
Algorithm deleteNode (list, pPre, pLoc, dataOut)
Deletes data from list & returns it to calling module.
  Pre  list is metadata structure to a valid list
       Pre is a pointer to predecessor node
       pLoc is a pointer to node to be deleted
       dataOut is variable to receive deleted data
  Post data have been deleted and returned to caller
1 move pLoc data to dataOut
2 if (pPre null)
  Deleting first node
  1  set list head to pLoc link
3 else
  Deleting other nodes
  1  set pPre link to pLoc link
4 end if
5 recycle (pLoc)
end deleteNode
```

Ordered List Search



(a) Successful searches (return true)



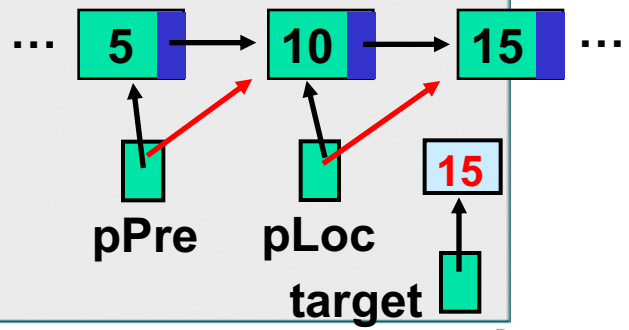
(b) Unsuccessful searches (return false)

List Search Results

Condition	pPre	pLoc	Return
Target < first node	Null	First node	False
Target = first node	Null	First node	True
First < target < last	Largest node < target	First node > target	False
Target = middle node	Node's predecessor	Equal node	True
Target = last node	Last's predecessor	Last node	True
Target > last node	Last node	Null	False

Search List Algorithm

```
Algorithm searchList (list, pPre, pLoc, target)
Searches list and passes back address of node containing
target and its logical predecessor.
  Pre   list is metadata structure to a valid list
        pPre is pointer variable for predecessor
        pLoc is pointer variable for current node
        target is the key being sought
  Post  pLoc points to first node with equal/greater key
        -or- null if target > key of last node
        pPre points to largest node smaller than key
        -or- null if target < key of first node
  Return true if found, false if not found
1 set pPre to null
2 set pLoc to list head
3 loop (pLoc not null AND target > pLoc key)
  1  set pPre to pLoc
  2  set pLoc to pLoc link
4 end loop
5 if (pLoc null)
  Set return value
  1  set found to false
```



Search List Algorithm (cont.)

```
6 else
  1  if (target equal pLoc key)
     1  set found to true
  2  else
     1  set found to false
  3  end if
7 end if
8 return found
end searchList
```

Retrieve List Node Algorithm

```
Algorithm retrieveNode (list, key, dataOut)
Retrieves data from a list.
  Pre    list is metadata structure to a valid list
         key is target of data to be retrieved
         dataOut is variable to receive retrieved data
  Post   data placed in dataOut
          -or- error returned if not found
  Return true if successful, false if data not found
1 set found to searchList (list, pPre, pLoc, key)
2 if (found)
  1  move pLoc data to dataOut
3 end if
4 return found
end retrieveNode
```

Empty List Algorithm

```
Algorithm emtpyList (list)
Returns Boolean indicating whether the list is empty.
  Pre    list is metadata structure to a valid list
  Return true if list empty, false if list contains data
1 if (list count equal 0)
  1  return true
2 else
  1  return false
end emptyList
```

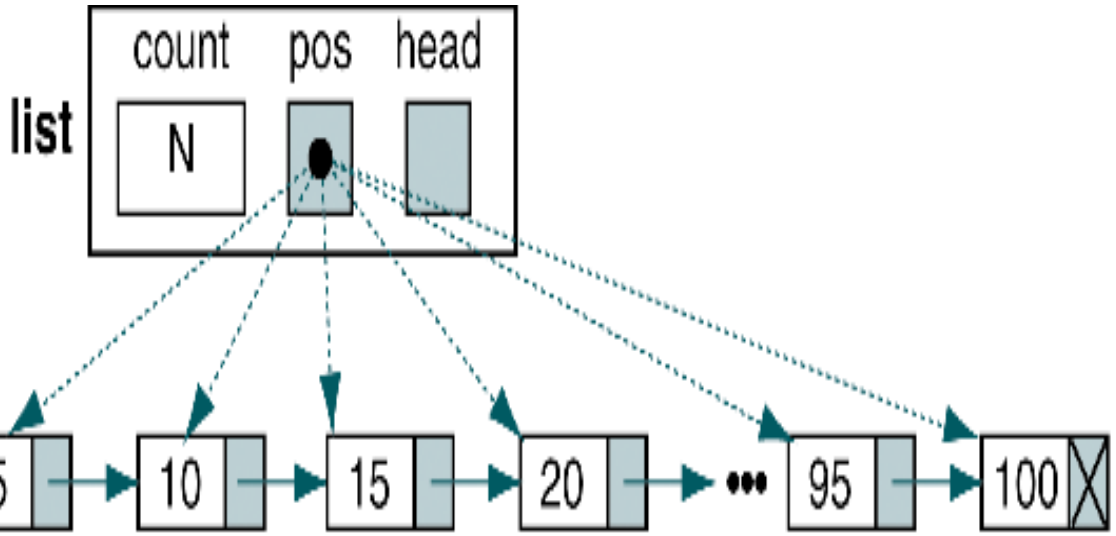
Full List Algorithm

```
Algorithm fullList (list)
Returns Boolean indicating whether or not the list is full.
  Pre    list is metadata structure to a valid list
  Return false if room for new node; true if memory full
1 if (memory full)
  1  return true
2 else
  2  return false
3 end if
4 return true
end fullList
```

List Count Algorithm

```
Algorithm listCount (list)
Returns integer representing number of nodes in list.
  Pre    list is metadata structure to a valid list
  Return count for number of nodes in list
 1 return (list count)
end listCount
```

Traverse List




```
Algorithm getNext (list, fromWhere, dataOut)
Traverses a list. Each call returns the location of an
element in the list.
  Pre    list is metadata structure to a valid list
         fromWhere is 0 to start at the first element
         dataOut is reference to data variable
  Post   dataOut contains data and true returned
         -or- if end of list, returns false
```

Traverse List (cont.)

```
  Return true if next element located
         false if end of list
1 if (empty list)
  1 return false
2 if (fromWhere is beginning)
  Start from first
  1 set list pos to list head
  2 move current list data to dataOut
  3 return true
3 else
  Continue from pos
  1 if (end of list)
    End of List
    1 return false
   2 else
    1 set list pos to next node
    2 move current list data to dataOut
    3 return true
   3 end if
4 end if
end getNext
```

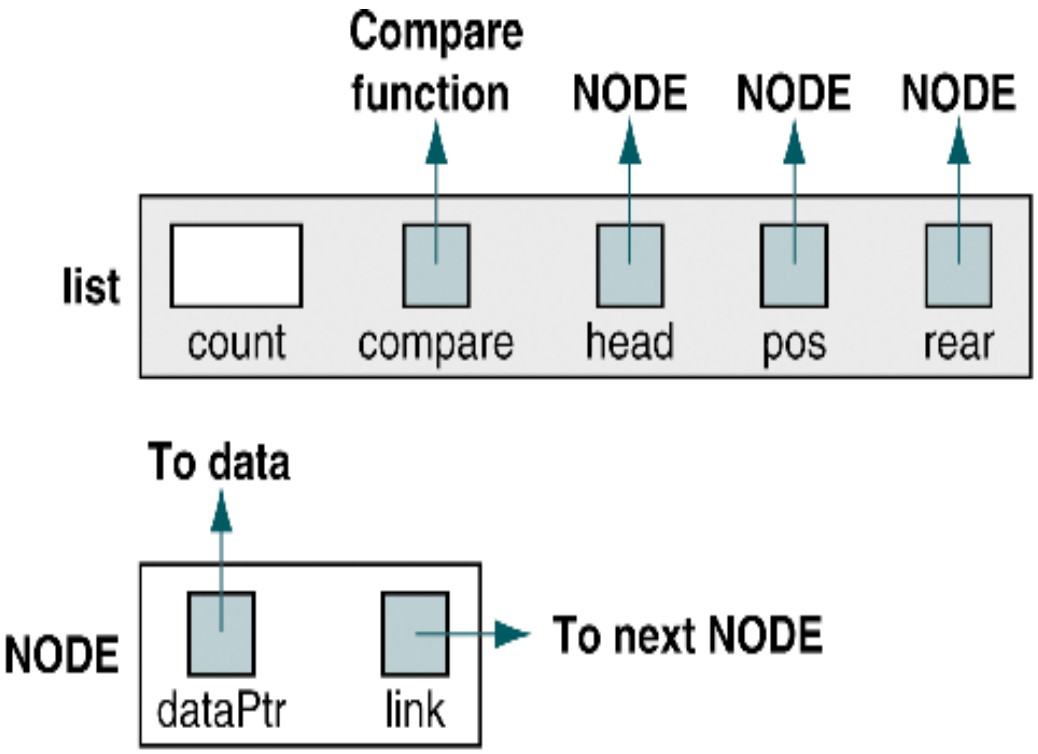
Destroy List

```
Algorithm destroyList (pList)
Deletes all data in list.
  Pre    list is metadata structure to a valid list
  Post   All data deleted
1 loop (not at end of list)
  1  set list head to successor node
  2  release memory to heap
2 end loop
  No data left in list. Reset metadata.
3 set list pos to null
4 set list count to 0
end destroyList
```

5-3 List ADT

We begin with an extensive discussion of the list data structure and the compare function that is required to maintain the list in sequence. We then develop the C functions required to implement the ADT.

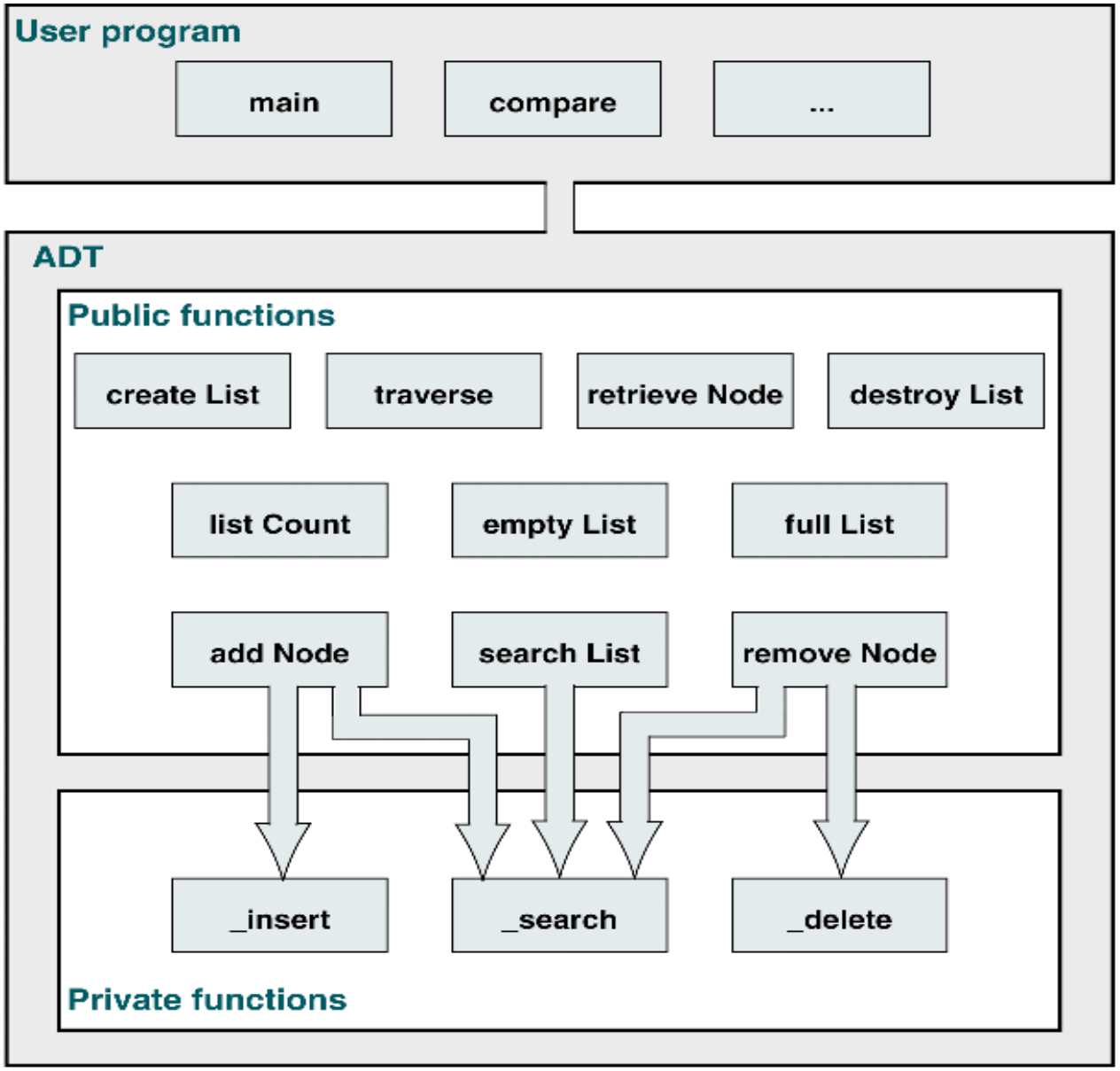
ADT Structure



List ADT Type Definitions

```
1  //List ADT Type Defintions
2    typedef struct node
3       {
4        void*        dataPtr;
5        struct node* link;
6       } NODE;
7
8    typedef struct
9       {
10       int   count;
11       NODE* pos;
12       NODE* head;
13       NODE* rear;
14       int    (*compare) (void* argu1, void* argu2);
15      } LIST;
```

List ADT Functions



List ADT Prototype Declarations

```
1  //Prototype Declarations
2    LIST* createList   (int (*compare)
3                        (void* argu1, void* argu2));
4    LIST* destroyList  (LIST* list);
5
6    int   addNode   (LIST* pList, void* dataInPtr);
7
8    bool  removeNode   (LIST*  pList,
9                        void*  keyPtr,
10                       void** dataOutPtr);
11
12   bool  searchList   (LIST*  pList,
13                       void*  pArgu,
14                       void** pDataOut);
```

List ADT Prototype Declarations (cont.)

```
15
16    bool  retrieveNode (LIST*  pList,
17                        void*  pArgu,
18                        void** dataOutPtr);
19
20    bool  traverse     (LIST*  pList,
21                        int    fromWhere,
22                        void** dataOutPtr);
23
24    int   listCount    (LIST*  pList);
25    bool  emptyList    (LIST*  pList);
26    bool  fullList     (LIST*  pList);
27
28    static int _insert   (LIST* pList,
29                          NODE* pPre,
30                          void* dataInPtr);
31
32    static void _delete  (LIST*  pList,
33                          NODE*  pPre,
34                          NODE*  pLoc,
35                          void** dataOutPtr);
36    static bool _search  (LIST*  pList,
37                          NODE** pPre,
38                          NODE** pLoc,
39                          void*  pArgu);
40  //End of List ADT Definitions
```

Create List in C

```
1  /*============== createList =============
2    Allocates dynamic memory for a list head
3    node and returns its address to caller
4       Pre    compare is address of compare function
5              used to compare two nodes.
6       Post   head has allocated or error returned
7       Return head node pointer or null if overflow
```

Create List in C (cont.)

```
 8  */
 9  LIST* createList
10       (int (*compare) (void* argu1, void* argu2))
11  {
12  //Local Definitions
13    LIST* list;
14
15  //Statements
16    list = (LIST*) malloc (sizeof (LIST));
17    if (list)
18       {
19        list->head    = NULL;
20        list->pos     = NULL;
21        list->rear    = NULL;
22        list->count   = 0;
23        list->compare = compare;
24       } // if
25
26    return list;
27  } // createList
```

Internal Insert Function in C

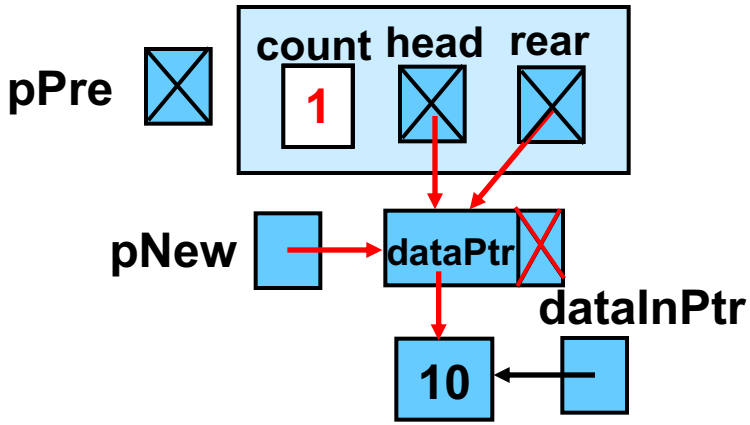
```
1  /*==================== _insert ==================
2    Inserts data pointer into a new node.
3       Pre    pList pointer to a valid list
4              pPre  pointer to data's predecessor
5              dataInPtr data pointer to be inserted
6       Post   data have been inserted in sequence
7       Return boolean, true  if successful,
8                       false if memory overflow
```

Internal Insert Function *(continued)*

```
9  */
10 static bool _insert (LIST* pList, NODE* pPre,
11                       void* dataInPtr)
12 {
13 //Local Definitions
14   NODE* pNew;
```

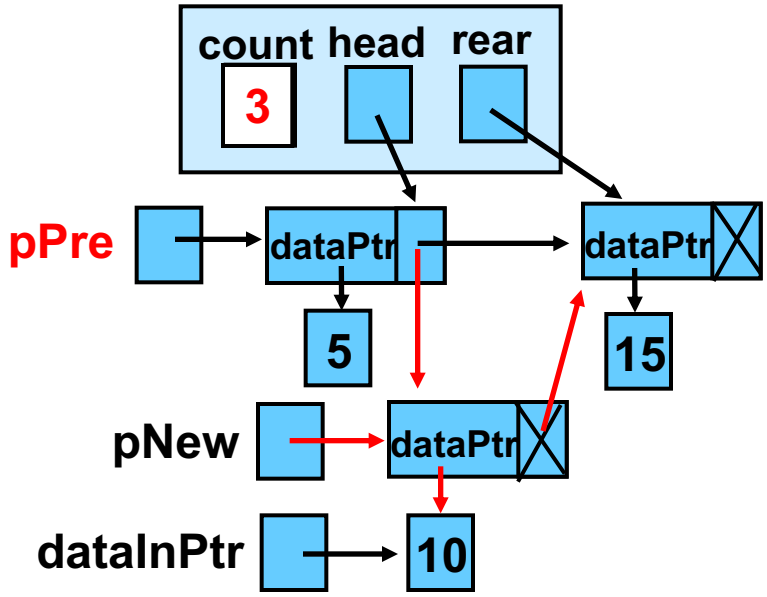
Internal Insert Function in C (cont.)

```
16  //Statements
17    if (!(pNew = (NODE*) malloc(sizeof(NODE))))
18       return false;
19
20    pNew->dataPtr    = dataInPtr;
      pNew->link       = NULL;
22
23    if (pPre == NULL)
24       {
25        // Adding before first node or to empty list.
26        pNew->link       = pList->head;
27        pList->head      = pNew;
28        if (pList->count == 0)
29         // Adding to empty list. Set rear
30           pList->rear = pNew;
31       } // if pPre
```



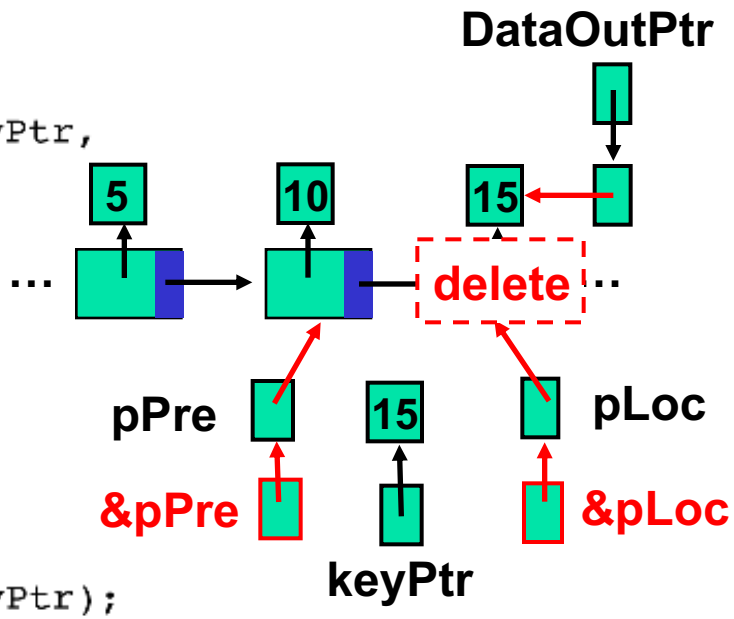
Internal Insert Function (cont.)

```
32    else
33       {
34        // Adding in middle or at end
35        pNew->link  = pPre->link;
36        pPre->link  = pNew;
37
38       // Now check for add at end of list
39        if (pNew->link     == NULL)
40             pList->rear   =  pNew;
41       } // if else
42
43    (pList->count)++;
44    return true;
45 } // _insert
```



Remove Node in C

```
1  /*================== removeNode ================
2    Removes data from list.
3       Pre     pList pointer to a valid list
4               keyPtr pointer to key to be deleted
5               dataOutPtr pointer to data pointer
6       Post    Node deleted or error returned.
7       Return false not found; true deleted
8  */
9  bool removeNode   (LIST*  pList, void*  keyPtr,
10                     void** dataOutPtr)
11 {
12 //Local Definitions
13   bool found;
14
15   NODE* pPre;
16   NODE* pLoc;
17
18 //Statements
19   found = _search (pList, &pPre, &pLoc, keyPtr);
20   if (found)
21      _delete (pList, pPre, pLoc, dataOutPtr);
22
23   return found;
24 } // removeNode
```

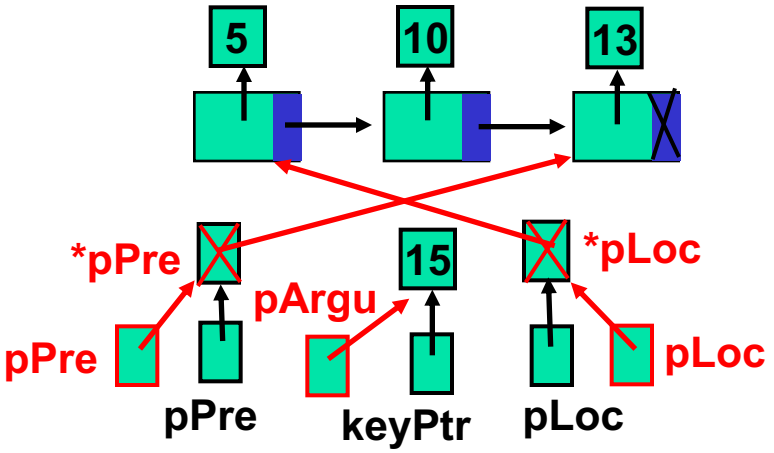


Internal Search Function in C

```
1  /*================== _search ================
2    Searches list and passes back address of node
3    containing target and its logical predecessor.
4       Pre    pList pointer to initialized list
5              pPre  pointer variable to predecessor
6              pLoc  pointer variable to receive node
7              pArgu pointer to key being sought
8       Post   pLoc points to first equal/greater key
9         -or- null if target > key of last node
10             pPre points to largest node < key
11        -or- null if target < key of first node
12       Return boolean true found; false not found
13
14 */
15 bool _search (LIST*  pList, NODE** pPre,
16               NODE** pLoc,  void*  pArgu)
17 {
18 //Macro Definition
19 #define COMPARE \
20   ( ((* pList->compare) (pArgu, (*pLoc)->dataPtr)) )
```

Internal Search Function in C (cont.)

```
21
22  #define COMPARE_LAST \
23    ((* pList->compare) (pArgu, pList->rear->dataPtr))
24
25  //Local Definitions
26    int result;
27
28  //Statements
29    *pPre  = NULL;
30    *pLoc  = pList->head;
31    if (pList->count == 0)
32        return false;
33
34    // Test for argument > last node in list
35    if ( COMPARE_LAST > 0)
36       {
37        *pPre = pList->rear;
38        *pLoc = NULL;
39        return false;
40       } // if
```

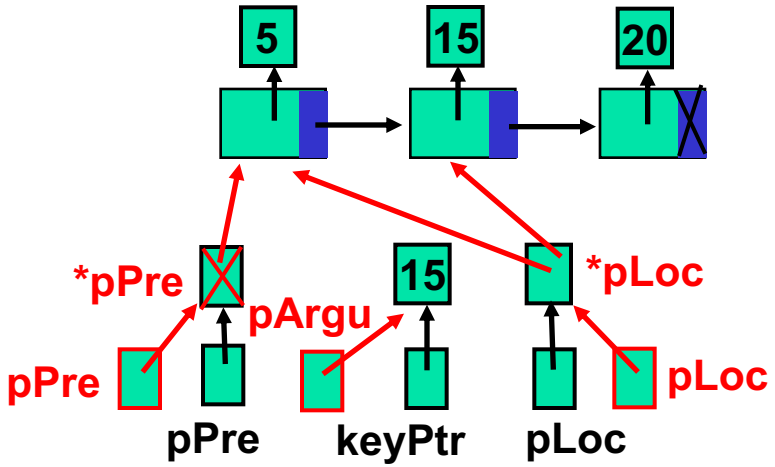


Internal Search Function in C (cont.)

Note:

```
#define COMPARE \
  ( ((* pList->compare) (pArgu, (*pLoc)->dataPtr)) )
```

```
41
42    while ( (result = COMPARE) > 0 )
43       {
44        // Have not found search argument location
45        *pPre = *pLoc;
46        *pLoc = (*pLoc)->link;
47       } // while
48
49    if (result == 0)
50       // argument found--success
51       return true;
52    else
53       return false;
54 } // _search
```

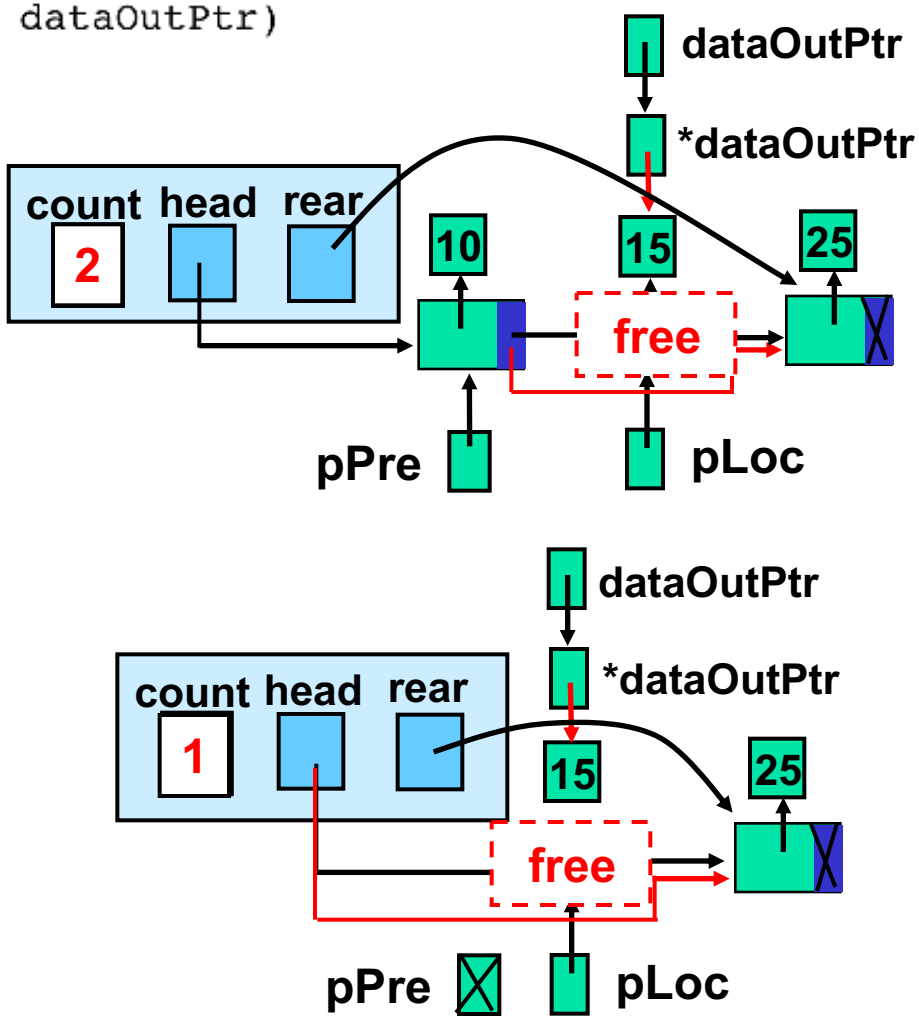


Internal Delete Function in C

```
1  /*================ _delete ================
2    Deletes data from a list and returns
3    pointer to data to calling module.
4       Pre    pList pointer to valid list.
5              pPre  pointer to predecessor node
6              pLoc  pointer to target node
7              dataOutPtr pointer to data pointer
```

Internal Delete Function in C (cont.)

```
10  */
11  void _delete (LIST* pList, NODE*  pPre,
12                NODE* pLoc,  void** dataOutPtr)
13  {
14  //Statements
15    *dataOutPtr = pLoc->dataPtr;
16    if (pPre == NULL)
17       // Deleting first node
18       pList->head = pLoc->link;
19    else
20       // Deleting any other node
21       pPre->link = pLoc->link;
22
23    // Test for deleting last node
24    if (pLoc->link == NULL)
25        pList->rear = pPre;
26
27    (pList->count)--;
28    free (pLoc);
29
30    return;
31  } // _delete
```



Search User Interface in C

```
1  /*================== searchList ================
2    Interface to search function.
3       Pre    pList pointer to initialized list.
4              pArgu pointer to key being sought
5       Post   pDataOut contains pointer to found data
6         -or- NULL if not found
7       Return boolean true successful; false not found
8  */
```

Search User Interface in C (cont.)

```
 9  bool searchList (LIST*  pList, void* pArgu,
10                   void** pDataOut)
11  {
12  //Local Definitions
13    bool  found;
14
15    NODE* pPre;
16    NODE* pLoc;
17
18  //Statements
19    found = _search (pList, &pPre, &pLoc, pArgu);
20    if (found)
21        *pDataOut = pLoc->dataPtr;
22    else
23        *pDataOut = NULL;
24    return found;
25  } // searchList
```

Retrieve Node in C

```
 1  /*================== retrieveNode ================
 2    This algorithm retrieves data in the list without
 3    changing the list contents.
 4       Pre    pList pointer to initialized list.
 5              pArgu pointer to key to be retrieved
 6       Post   Data (pointer) passed back to caller
 7       Return boolean true success; false underflow
 8  */
 9  static bool retrieveNode (LIST*  pList,
10                            void*  pArgu,
11                            void** dataOutPtr)
12  {
13  //Local Definitions
14    bool  found;
15
16    NODE* pPre;
17    NODE* pLoc;
18
19  //Statements
20    found = _search (pList, &pPre, &pLoc, pArgu);
21    if (found)
22       {
23        *dataOutPtr = pLoc->dataPtr;
24        return true;
25       } // if
26
27    *dataOutPtr = NULL;
28    return false;
29  } // retrieveNode
```

Empty List in C

```
1  /*================= emptyList ================
2    Returns boolean indicating whether or not the
3    list is empty
4       Pre    pList is a pointer to a valid list
5       Return boolean true empty; false list has data
6  */
7  bool emptyList (LIST* pList)
8  {
9  //Statements
10   return (pList->count == 0);
11 } // emptyList
```

Full List in C

```
 1  /*================== fullList ================
 2    Returns boolean indicating no room for more data.
 3    This list is full if memory cannot be allocated for
 4    another node.
 5       Pre    pList pointer to valid list
 6       Return boolean true if full
 7                      false if room for node
 8  */
 9  bool fullList (LIST* pList)
10  {
11  //Local Definitions
12  NODE* temp;
13
14  //Statements
15    if ((temp = (NODE*)malloc(sizeof(*(pList->head)))))
16       {
17        free (temp);
18        return false;
19       } // if
21   // Dynamic memory full
22   return true;
23
24  } // fullList
```

List Count in C

```
1  /*================== listCount ==================
2    Returns number of nodes in list.
3       Pre    pList is a pointer to a valid list
4       Return count for number of nodes in list
5  */
6  int listCount(LIST* pList)
7  {
8  //Statements
9
10   return pList->count;
11
12 } // listCount
```

Traverse List in C

Traverse List

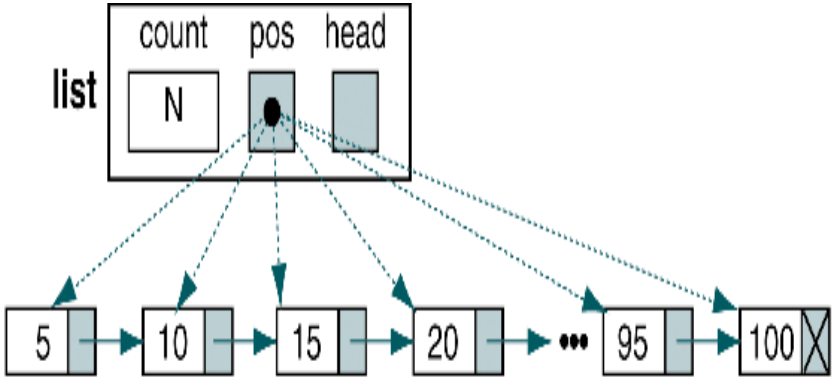
```
 1  /*================== traverse ================
 2    Traverses a list. Each call either starts at the
 3    beginning of list or returns the location of the
 4    next element in the list.
 5       Pre    pList       pointer to a valid list
 6              fromWhere   0 to start at first element
 7              dataPtrOut  address of pointer to data
```

Traverse List *(continued)*

```
 9       Return true node located; false if end of list
10  */
11  bool traverse (LIST*  pList,
12                 int    fromWhere,
```

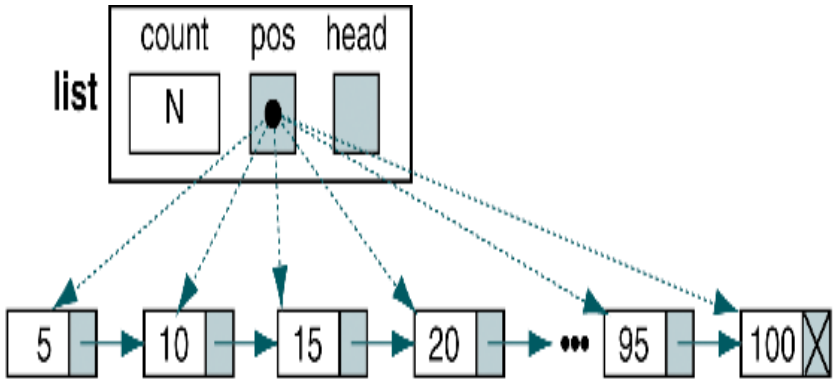
Traverse List in C (cont.)

```
15  //Statements
16    if (pList->count == 0)
17        return false;
18
19    if (fromWhere == 0)
20       {
21        // Start from first node
22        pList->pos  = pList->head;
23        *dataPtrOut = pList->pos->dataPtr;
24        return true;
25       } // if fromwhere
```



Traverse List in C (cont.)

```
26    else
27       {
28        // Start from current position
29        if (pList->pos->link == NULL)
30            return false;
31        else
32           {
33            pList->pos  = pList->pos->link;
34            *dataPtrOut = pList->pos->dataPtr;
35            return true;
36           } // if else
37       } // if fromwhere else
38 } // traverse
```



Destroy List in C

```
 1  /*=================== destroyList ================
 2    Deletes all data in list and recycles memory
 3       Pre    List is a pointer to a valid list.
 4       Post   All data and head structure deleted
 5       Return null head pointer
 6  */
 7  LIST* destroyList (LIST* pList)
 8  {
 9  //Local Definitions
10    NODE* deletePtr;
11
12  //Statements
13    if (pList)
14       {
15        while (pList->count > 0)
16           {
```

Destroy List in C (cont.)

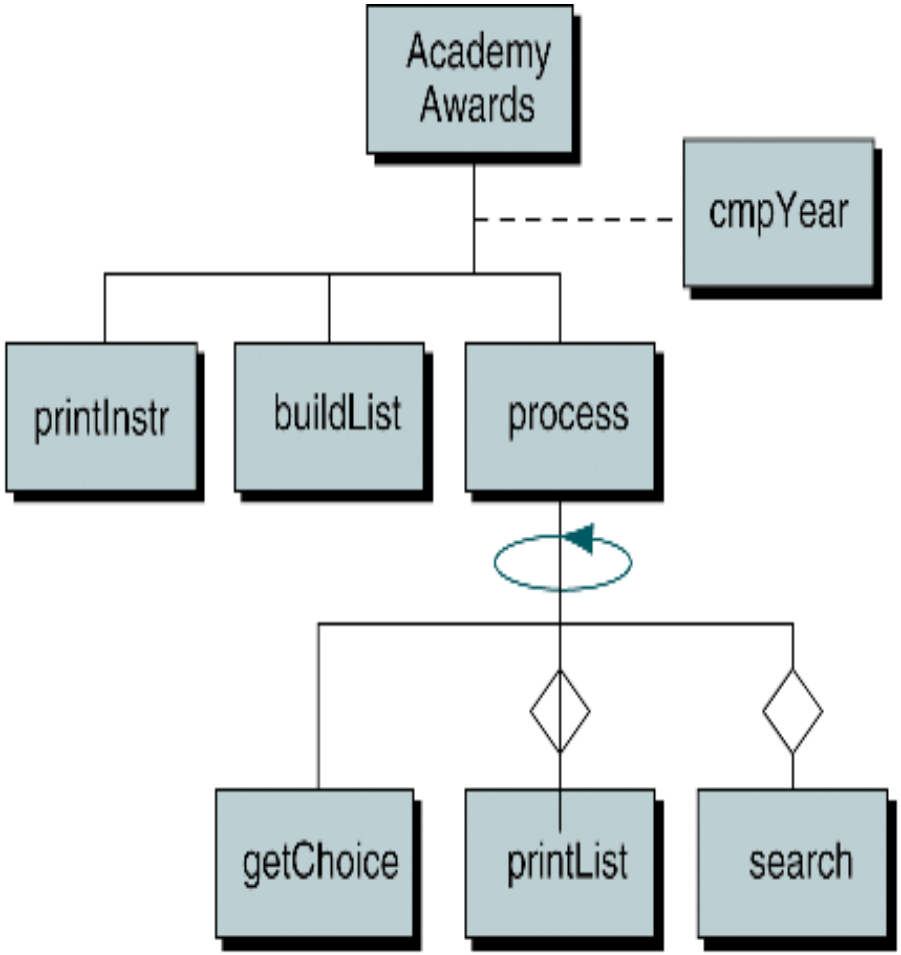
```
17              // First delete data
18              free (pList->head->dataPtr);
19
20              // Now delete node
21              deletePtr    = pList->head;
22              pList->head  = pList->head->link;
23              pList->count--;
24              free (deletePtr);
25            } // while
26          free (pList);
27        } // if
28    return NULL;
29  } // destroyList
```

5-4 Application

To demonstrate how easily we can implement a list once we have an abstract data type, we implement a list of award-winning pictures and their directors. We then develop eight functions to implement the application. We conclude with a discussion of the basic steps required to test a list implementation.

- **Data Structure**
- **Application Functions**
- **Testing Insert and Delete Logic**

Academy Awards List Design



Data Structure for Academy Awards

```
1  /*Data Structure for Academy Awards
2       Written by:
3       Date:
4  */
5
6  const short STR_MAX = 41;
7
8  typedef struct
9    {
10    short   year;
11    char    picture [STR_MAX];
12    char    director[STR_MAX];
13   } PICTURE;
```

Machine for Academy Awards

```
 1  /*This program maintains and displays a list of
 2    Academy Awards Motion Pictures.
 3       Written by:
 4       Date:
 5  */
 6  #include <stdio.h>
 7  #include <stdlib.h>
 8  #include <cType.h>
 9  #include <stdbool.h>
10  #include "P5-16.h"              // Data Structure
11  #include "linkListADT.h"
12
13  //Prototype Declarations
14    void  printInstr (void);
15    LIST* buildList  (void);
16    void  process    (LIST* list);
17    char  getChoice  (void);
18    void  printList  (LIST* list);
19    void  search     (LIST* list);
20
```

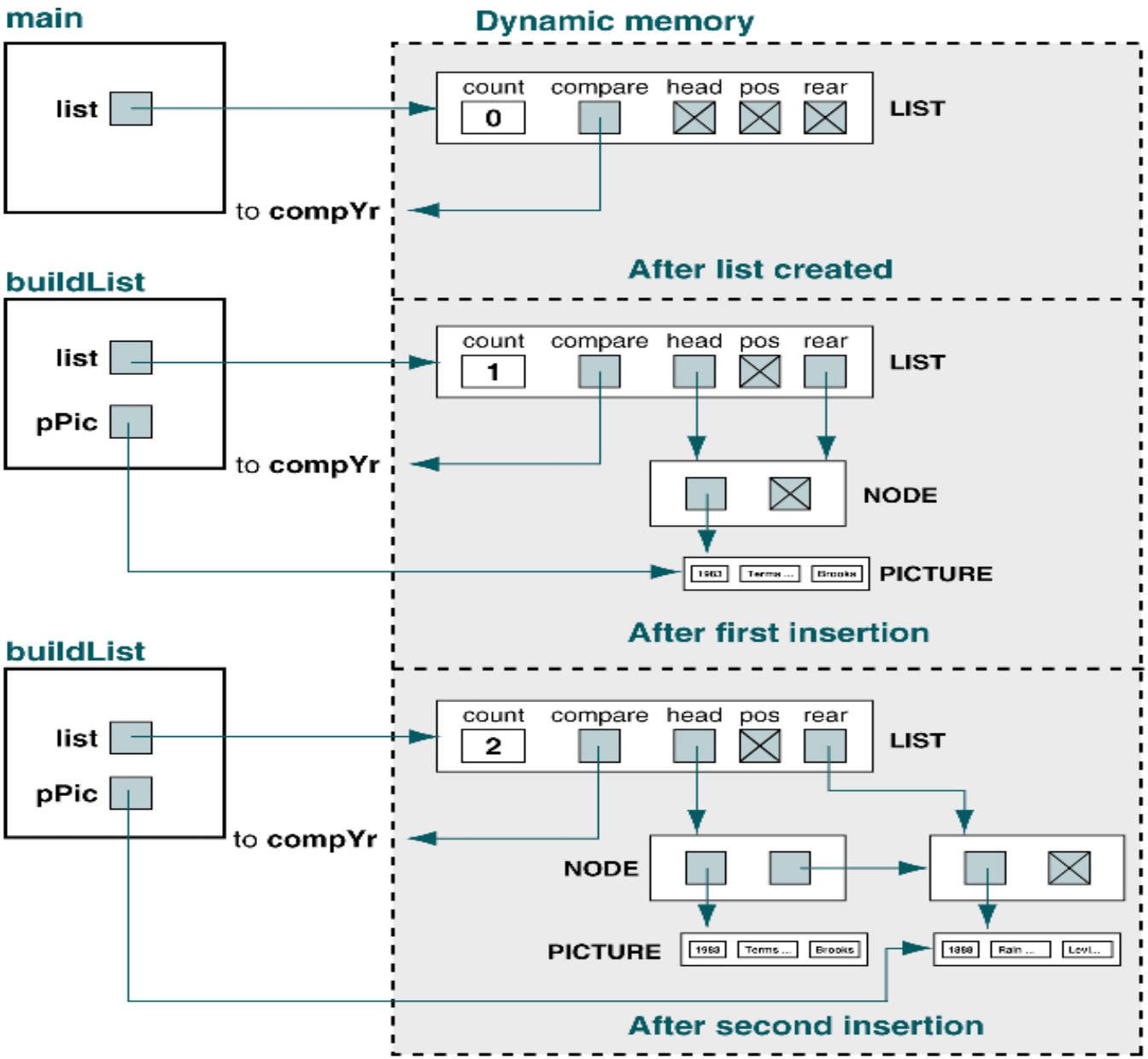
Machine for Academy Awards (cont.)

```
21    int   cmpYear    (void* pYear1, void* pYear2);
22
23  int main (void)
24  {
25  // Local Definitions
26     LIST* list;
27
28  // Statements
29     printInstr ();
30     list = buildList ();
31     process (list);
32
33     printf("End Best Pictures\n"
34            "Hope you found your favorite!\n");
35     return 0;
36  }  // main
```

Print Instructions for User

```
1  /*================== printInstr ================
2    Print instructions to user.
3       Pre    nothing
4       Post   instructions printed
5  */
6  void printInstr (void)
7  {
8  //Statements
9    printf("This program prints the Academy Awards \n"
10     "Best Picture of the Year and its director.\n"
11     "Your job is to enter the year; we will do\n"
12     "the rest. Enjoy.\n");
13   return;
14 } // printInstr
```

Build List Status after 2nd Insert



Build List

```
 1  /*==================== buildList ====================
 2    Reads a text data file and loads the list
 3    Pre    file exists in format: yy \t 'pic' \t 'dir'
 4    Post   list contains data
 5           -or- program aborted if problems
 6  */
 7  LIST* buildList (void)
 8  {
 9  //Local Definitions
10    FILE* fpData;
11    LIST* list;
12
13    short  yearIn;
14    int    addResult;
15
16    PICTURE* pPic;
17
18  //Statements
19    list   = createList (cmpYear);
20    if (!list)
21        printf("\aCannot create list\n"),
22                exit (100);
23    fpData = fopen("pictures.dat", "r");
24    if (!fpData)
25        printf("\aError opening input file\n"),
26                exit (110);
```

Build List (cont.)

```
27    while (fscanf(fpData, " %hd", &yearIn) == 1)
28        {
29         pPic = (PICTURE*) malloc(sizeof(PICTURE));
30         if (!(pPic))
31             printf("\aOut of Memory in build list\n"),
32                    exit (100);
33         pPic->year = yearIn;
34
35         // Skip tabs and quote
36         while ((fgetc(fpData)) != '\t')
37            ;
38         while ((fgetc(fpData)) != '"')
39            ;
40         fscanf(fpData, " %40[^\"], %*c", pPic->picture);
41         while ((fgetc(fpData)) != '\t')
42            ;
43         while ((fgetc(fpData)) != '"')
44            ;
```

Build List (cont.)

```
45          fscanf(fpData, " %40[^\"], %*c", pPic->director);
46
47          // Insert into list
48          addResult = addNode (list, pPic);
49          if (addResult != 0)
50              if (addResult == -1)
51                printf("Memory overflow adding movie\a\n"),
52                          exit (120);
53              else
54                 printf("Duplicate year %hd not added\n\a",
55                          pPic->year);
56          while (fgetc(fpData) != '\n')
57                ;
58        } // while
59     return list;
60  } // buildList
```

Process user Choices

```
1  /*=================== process ==================
2    Process user choices
3    Pre    list has been created
4    Post   all of user's choice executed
5  */
6  void process (LIST* list)
7  {
8  //Local Definitions
9    char choice;
10
11 //Statements
12   do
13      {
14       choice = getChoice ();
15
16       switch (choice)
17          {
18           case 'P': printList (list);
19                     break;
20           case 'S': search (list);
21           case 'Q': break;
22          } // switch
23      } while (choice != 'Q');
24   return;
25 }  // process
```

Get User's Choice

```
1  /*================== getChoice ==================
2    Prints the menu of choices.
3       Pre    nothing
4       Post   menu printed and choice returned
5  */
6  char getChoice (void)
7  {
```

Get user's Choice (cont.)

```
 8  //Local Definitions
 9    char choice;
10    bool valid;
11
12  //Statements
13    printf("======== MENU ======= \n"
14           "Here are your choices:\n"
15           "  S: Search for a year\n"
16           "  P: Print all years  \n"
17           "  Q: Quit             \n\n"
18           "Enter your choice: ");
19    do
20       {
21        scanf(" %c", &choice);
22        choice = toupper(choice);
23        switch (choice)
24           {
25            case 'S':
26            case 'P':
27            case 'Q': valid = true;
28                      break;
29            default:  valid = false;
30                      printf("\aInvalid choice\n"
31                             "Please try again: ");
32                      break;
33           } // switch
34       } while (!valid);
35    return choice;
36  } // getChoice
```

Print List

```
1  /*================== printList ==================
2    Prints the entire list
3       Pre    list has been created
4       Post   list printed
5  */
6  void printList (LIST* list)
```

Print List (cont.)

```
 7  {
 8  //Local Definitions
 9    PICTURE* pPic;
10
11  //Statements
12
13    // Get first node
14    if (listCount (list) == 0)
15       printf("Sorry, nothing in list\n\a");
16    else
17       {
18        printf("\nBest Pictures List\n");
19       traverse (list, 0, (void**)&pPic);
20        do
21          {
22           printf("%hd %-40s %s\n",
23                  pPic->year,      pPic->picture,
24                  pPic->director);
25          } while (traverse (list, 1, (void**)&pPic));
26       } // else
27    printf("End of Best Pictures List\n\n");
28  } // printList
```

Search List

```
 1  /*====================== search =====================
 2    Searches for year and prints year, picture, and
 3    director.
 4       Pre     list has been created
 5               user has selected search option
 6       Post    year printed or error message
 7  */
 8  void search (LIST* list)
 9  {
10  //Local Definitions
11    short     year;
12    bool      found;
13
14    PICTURE   pSrchArgu;
15    PICTURE* pPic;
16
17  //Statements
18    printf("Enter a four digit year: ");
19    scanf ("%hd", &year);
20    pSrchArgu.year = year;
21
22    found = searchList (list, &pSrchArgu,
23                        (void**)&pPic);
24
25    if (found)
26        printf("%hd %-40s %s\n",
27               pPic->year, pPic->picture, pPic->director);
28    else
29        printf("Sorry, but %d is not available.\n", year);
30    return;
31  } // search
```

Compare Year Function

```
1  /*=================== cmpYear ===================
2    Compares two years in PICTURE structures
3       Pre  year1 is a pointer to the first structure
4            year2 is a pointer to the second structure
5       Post two years compared and result returned
6    Return -1 if year1 less; 0 if equal; +1 greater
7  */
8  int cmpYear (void* pYear1, void* pYear2)
9  {
10 //Local Definitions
11   int   result;
12   short year1;
13   short year2;
14
```

Compare Year Function (cont.)

```
15  //Statements
16    year1 = ((PICTURE*)pYear1)->year;
17    year2 = ((PICTURE*)pYear2)->year;
18
19    if (year1 < year2)
20        result = -1;
21    else if (year1 > year2)
22        result = +1;
23    else
24        result = 0;
25    return result;
26  } // cmpYear
```

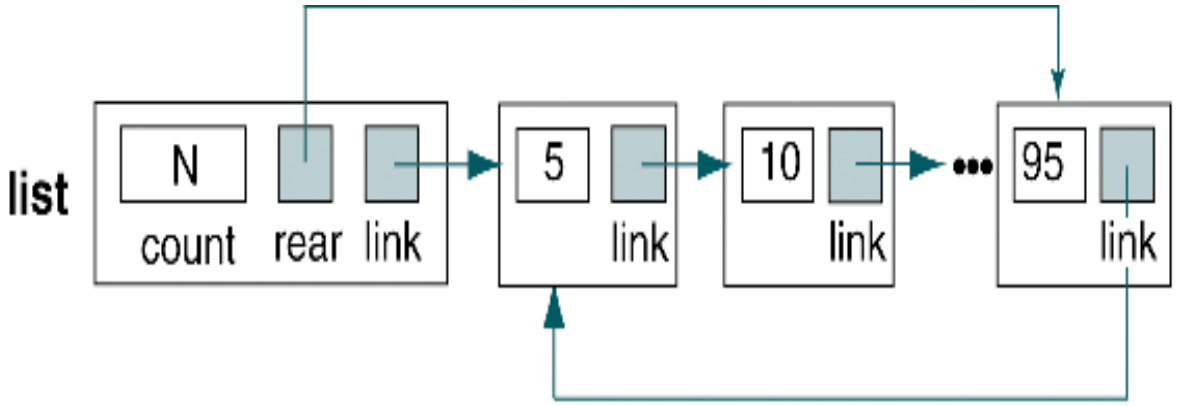
5-4 Complex Implementations

The implementation we have used to this point is known as a single linked list. In this section we introduce three other useful implementation. They are not fully developed. To be included in the list ADT, they would need additional structures, such as a pointer to a compare function and a position pointer as well as functions

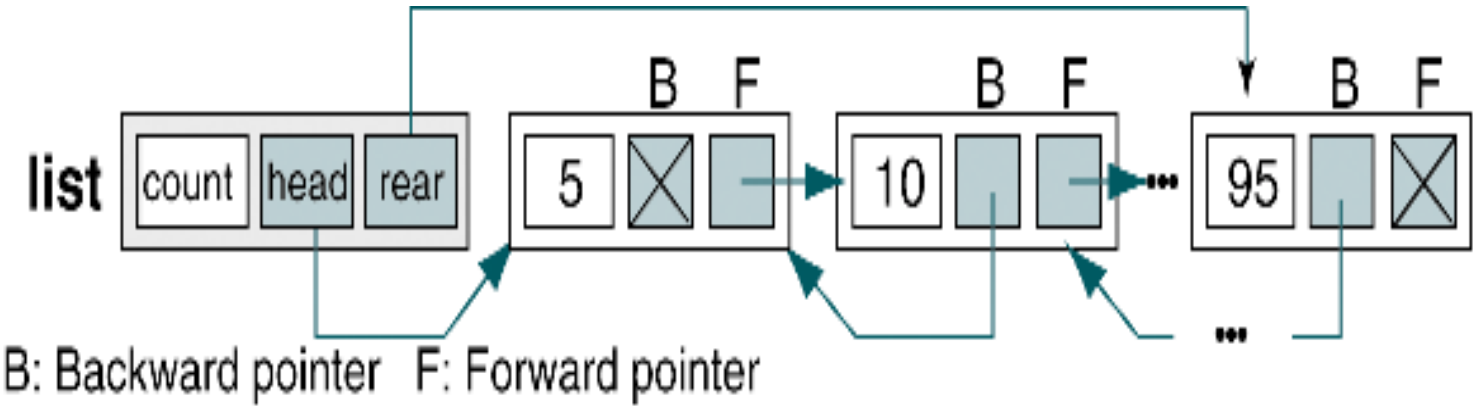
- **Circularly Linked list**
- **Double Linked List**
- **Multilinked List**

Circularly Linked List

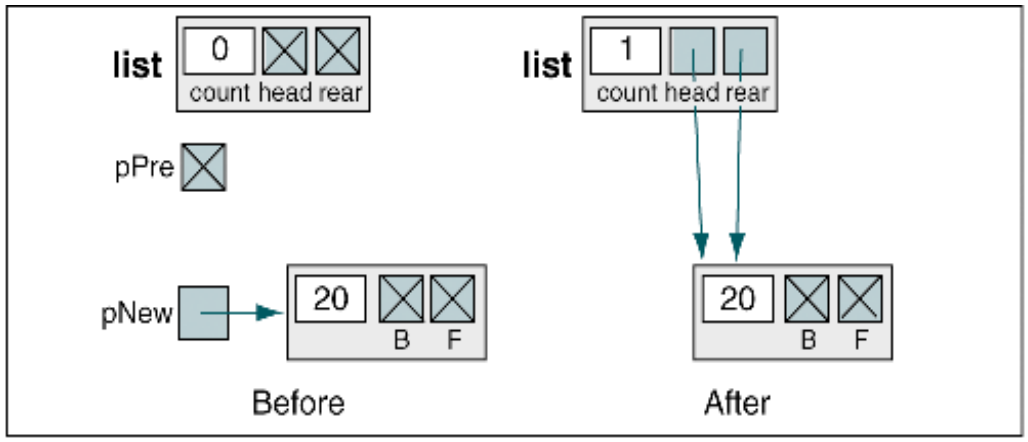
- Circularly linked list are used to allow access to nodes in the middle of the list without starting at the beginning
- If the search target lies before the current node
  - Single linked list: search completes as end of the list is reached
  - Circular list: search continues from the beginning of the list
- If the target does not exist
  - Single linked list: stop search as end of the list is reached
  - Circular list: save the starting node's address and stop search when we have circles around to it



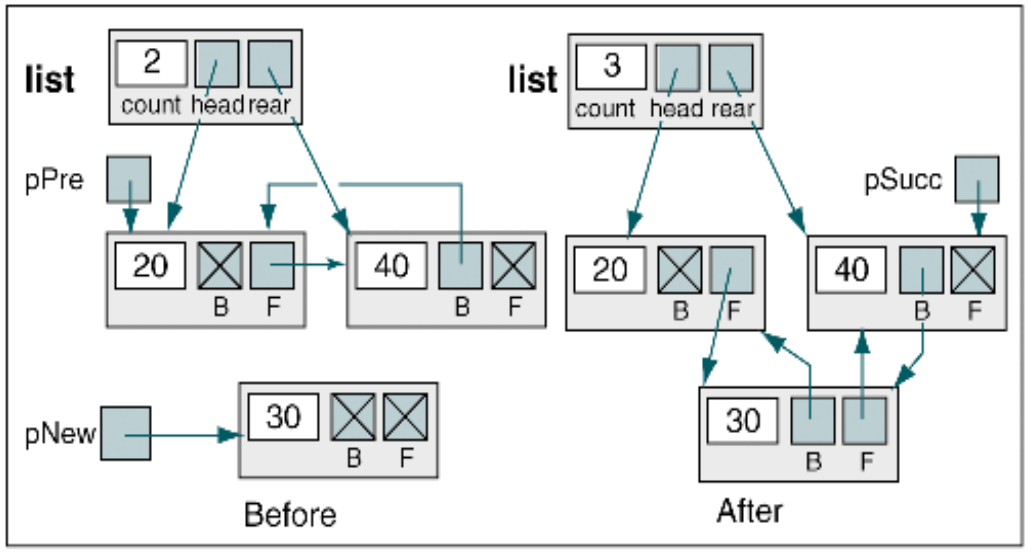
Double Linked List



Double Linked List Insertion



(a) Insert into null list or before first node



(b) Insert between two nodes

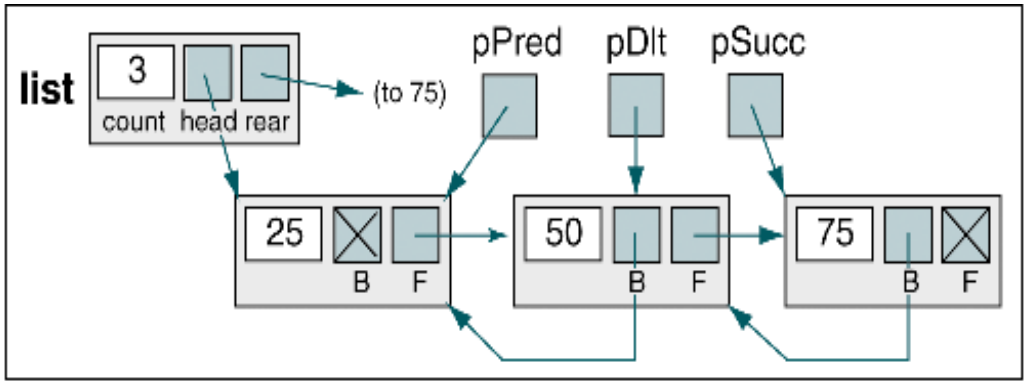
Double Linked List Insert Algorithm

```
Algorithm insertDbl (list, dataIn)
This algorithm inserts data into a doubly linked list.
  Pre    list is metadata structure to a valid list
         dataIn contains the data to be inserted
  Post   The data have been inserted in sequence
  Return 0: failed--dynamic memory overflow
         1: successful
         2: failed--duplicate key presented
1 if (full list)
  1  return 0
2 end if
  Locate insertion point in list.
3 set found to searchList
       (list, predecessor, successor, dataIn key)
4 if (not found)
  1  allocate new node
  2  move dataIn to new node
  3  if (predecessor is null)
     Inserting before first node or into empty list
     1  set new node back pointer to null
     2  set new node fore pointer to list head
     3  set list head to new node
  4  else
       Inserting into middle or end of list
     1  set new node fore pointer to predecessor fore pointer
     2  set new node back pointer to predecessor
```

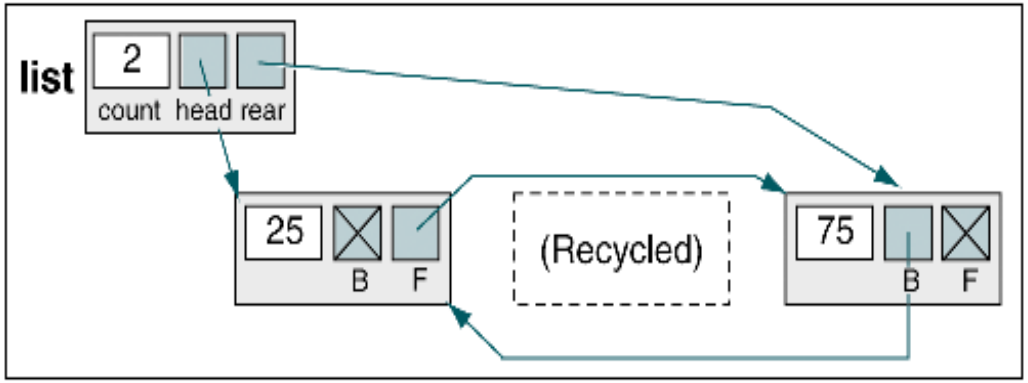
Double Linked List Insert (cont.)

```
  5  end if
     Test for insert into null list or at end of list
  6  if (predecessor fore null)
       Inserting at end of list--set rear pointer
     1  set list rear to new node
  7  else
       Inserting in middle of list--point successor to new
     1  set successor back to new node
  8  end if
  9  set predecessor fore to new node
  10 return 1
 5 end if
   Duplicate data. Key already exists.
 6 return 2
end insertDbl
```

Double Linked List Delete



(a) Before delete



(b) After deleting 50

Double Linked List Delete Algorithm

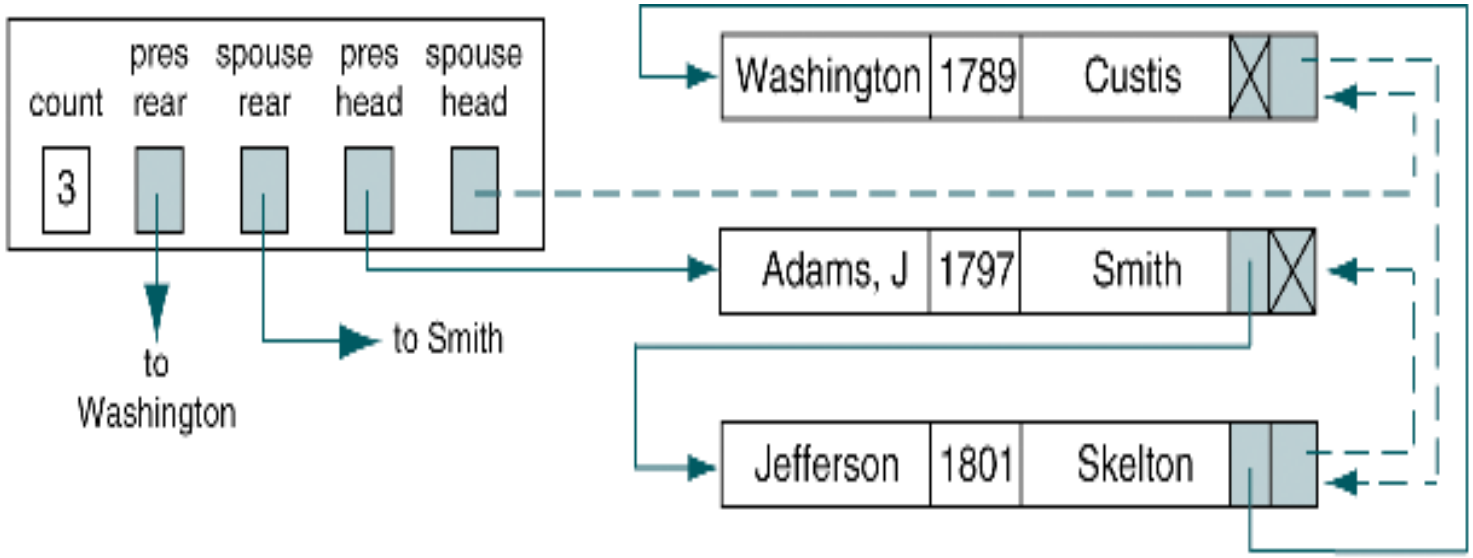
```
Algorithm deleteDbl (list, deleteNode)
This algorithm deletes a node from a doubly linked list.
   Pre    list is metadata structure to a valid list
          deleteNode is a pointer to the node to be deleted
   Post   node deleted
 1 if (deleteNode null)
   1  abort ("Impossible condition in delete double")
 2 end if
 3 if (deleteNode back not null)
   Point predecessor to successor
   1  set predecessor      to deleteNode back
   2  set predecessor fore to deleteNode fore
 4 else
   Update head pointer
   1  set list head to deleteNode fore
 5 end if
 6 if (deleteNode fore not null)
   Point successor to predecessor
   1  set successor      to deleteNode fore
   2  set successor back to deleteNode back
 7 else
   Point rear to predecessor
   1  set list rear to deleteNode back
 8 end if
 9 recycle (deleteNode)
end deleteDbl
```

Multilinked List Implementation of Presidents List

President	Year	First lady
Washington, George	1789	Custis, Martha Dandridge
Adams, John	1797	Smith, Abigail
Jefferson, Thomas	1801	Skelton, Martha Wayles
Madison, James	1809	Todd, Dorothy Payne
Monroe, James	1817	Kortright, Elizabeth
Adams, John Quincy	1825	Johnson, Louisa Catherine
Jackson, Andrew	1829	Robards, Rachel Donelson
Van Buren, Martin	1837	Hoes, Hannah
Harrison, William H.	1841	Symmes, Anna
Tyler, John	1841	Christian, Letitia

Multilinked List Implementation of Presidents List (cont.)

- In multilinked list the same set of data can be processed in multiple sequence, while the data are not replicated
- In the following example, two logical lists in the one physical list: one for president and one for the spouse



Multilinked List Add Node