Linked List

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- Doubly Linked List
- Circular Linked List
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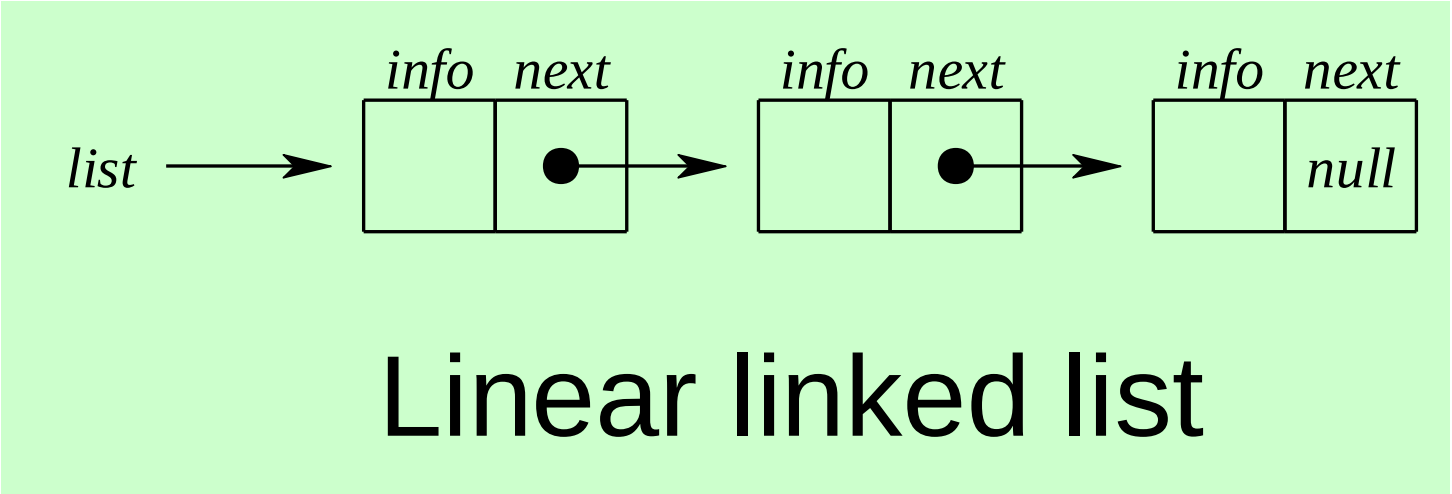
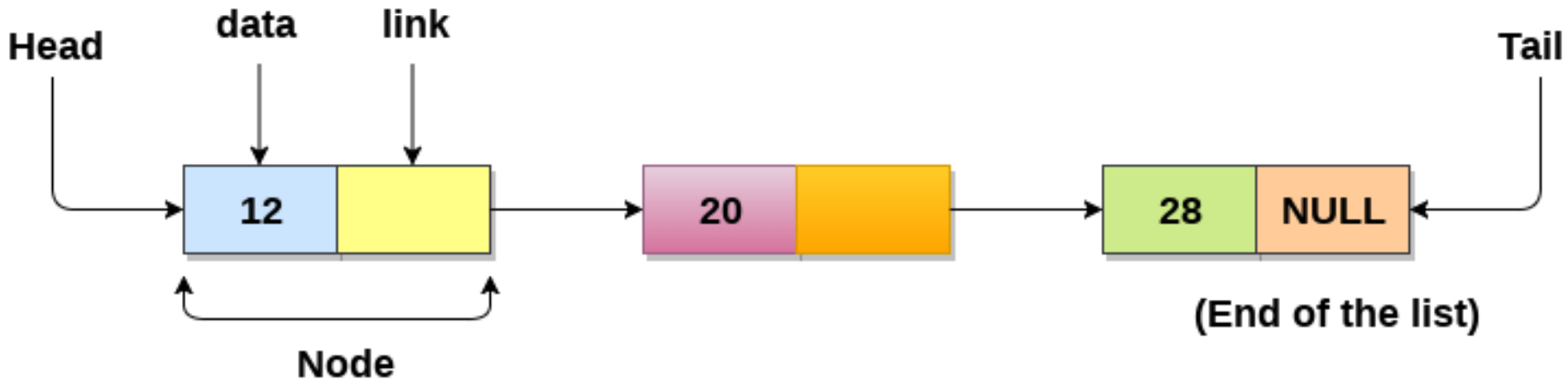
Singly Linked List

- A ***linked list*** is a linear collection of data elements, called ***nodes***, where the linear order is given by means of ***pointers***.
- Each **node** is divided into two parts:
  - The first part contains the ***information*** of the element and
  - The second part contains the address of the next node (***link /next pointer field***) in the list.



Contd.

- Linked List can be defined as collection of objects called **nodes** that are randomly stored in the memory.
- A node contains two fields i.e. data stored at that particular address and the pointer which contains the address of the next node in the memory.
- The last node of the list contains pointer to the null.



Properties

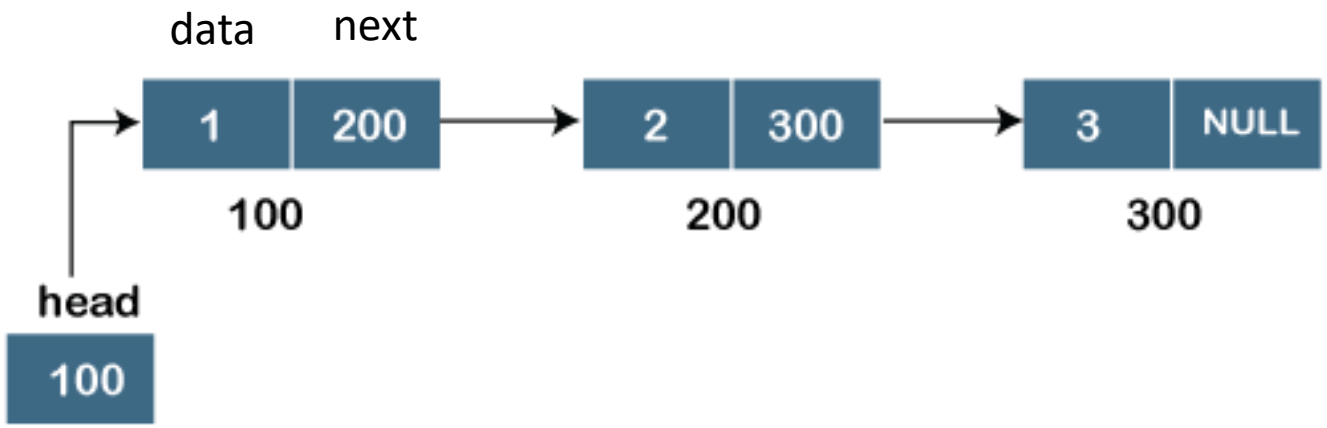
- The list is not required to be contiguously present in the memory. The node can reside any where in the memory and linked together to make a list. This achieves optimized utilization of space.
- list size is limited to the memory size and doesn't need to be declared in advance.
- Empty node can not be present in the linked list.
- We can store values of primitive types or objects in the singly linked list.

Disadvantage of Arrays

1. The size of array must be known in advance before using it in the program.
2. Increasing size of the array is a time taking process. It is almost impossible to expand the size of the array at run time.
3. All the elements in the array need to be contiguously stored in the memory. Inserting any element in the array needs shifting of all its predecessors.

Representation

```
struct node
{
   int data;
   struct node *next;
}
struct node * head;
```



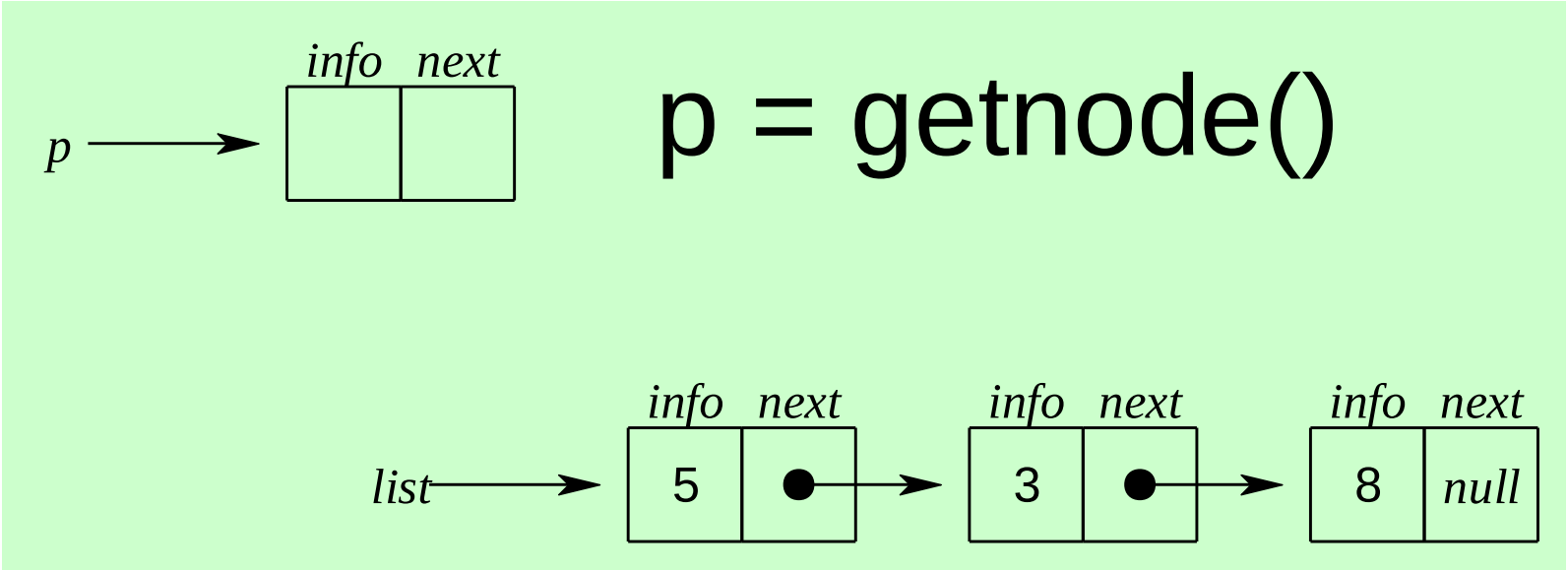
Operations

- Insertion
  - at beginning
  - at end
  - after specified node
- Deletion
  - at beginning
  - at end
  - after specified node
- Traversing
- Searching

Basic Code

```
#include<stdio.h>
#include<stdlib.h>
struct node
{
    int data;
    struct node *next;
};
struct node *head;
```

Insert at the beginning



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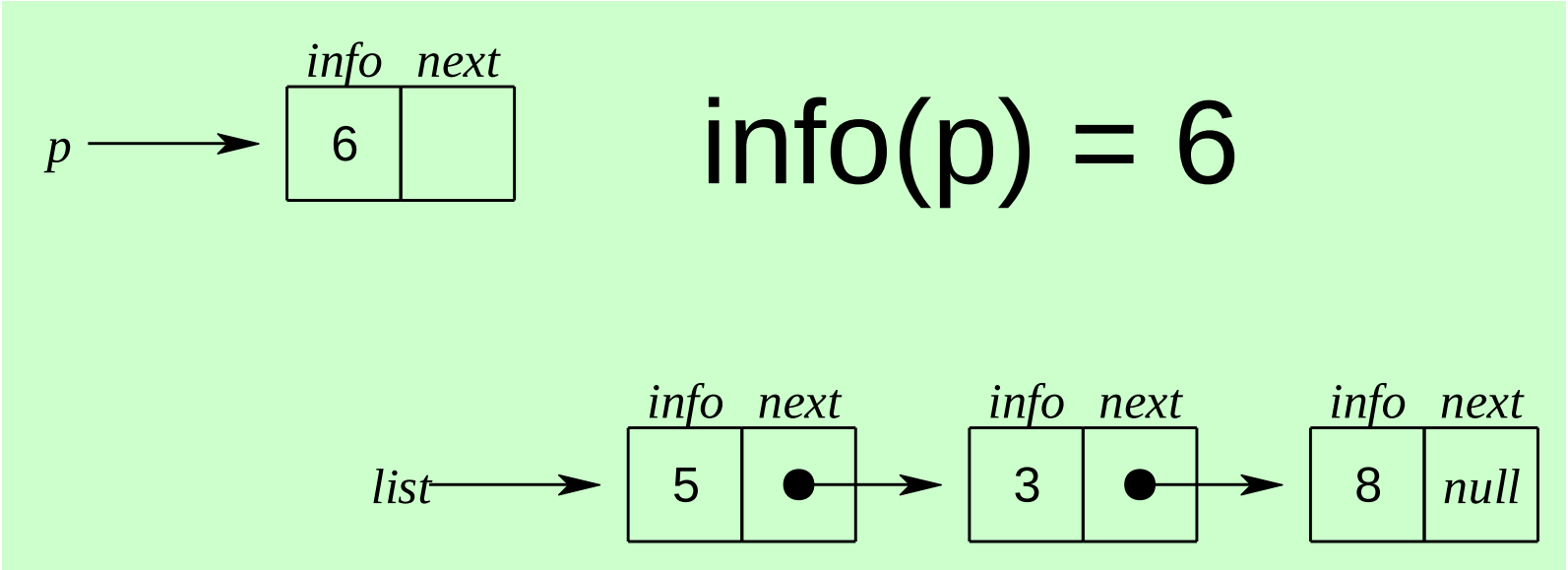
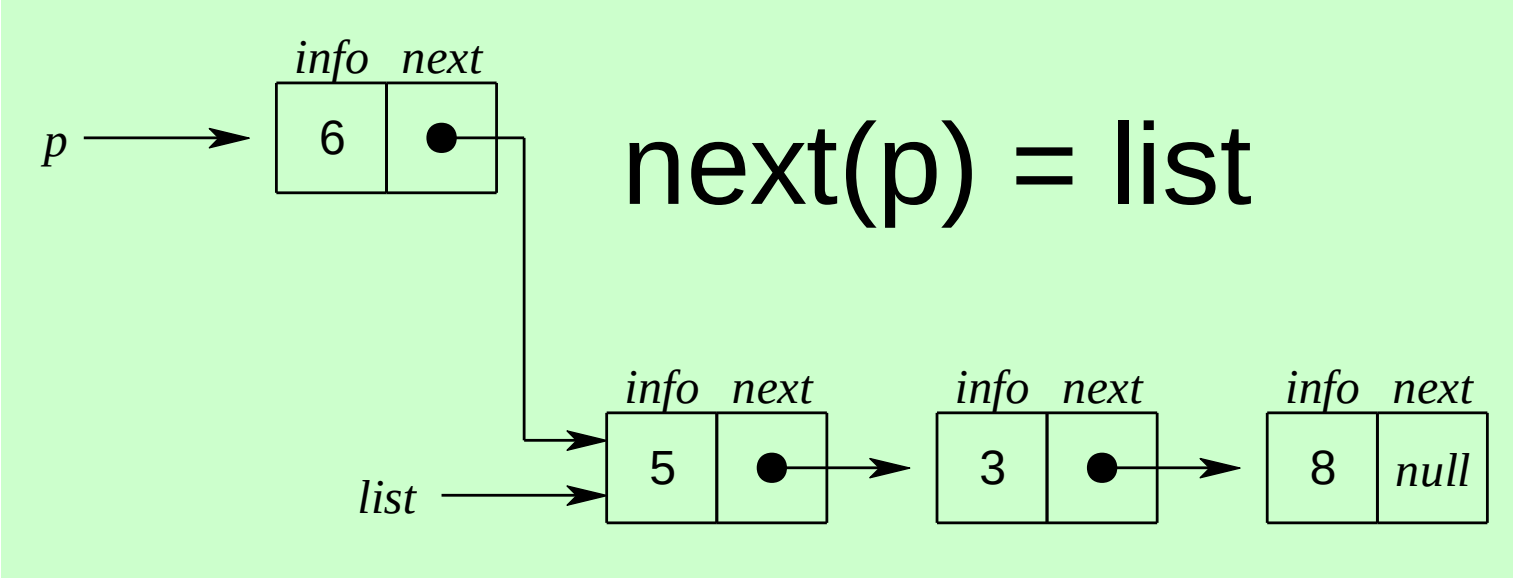
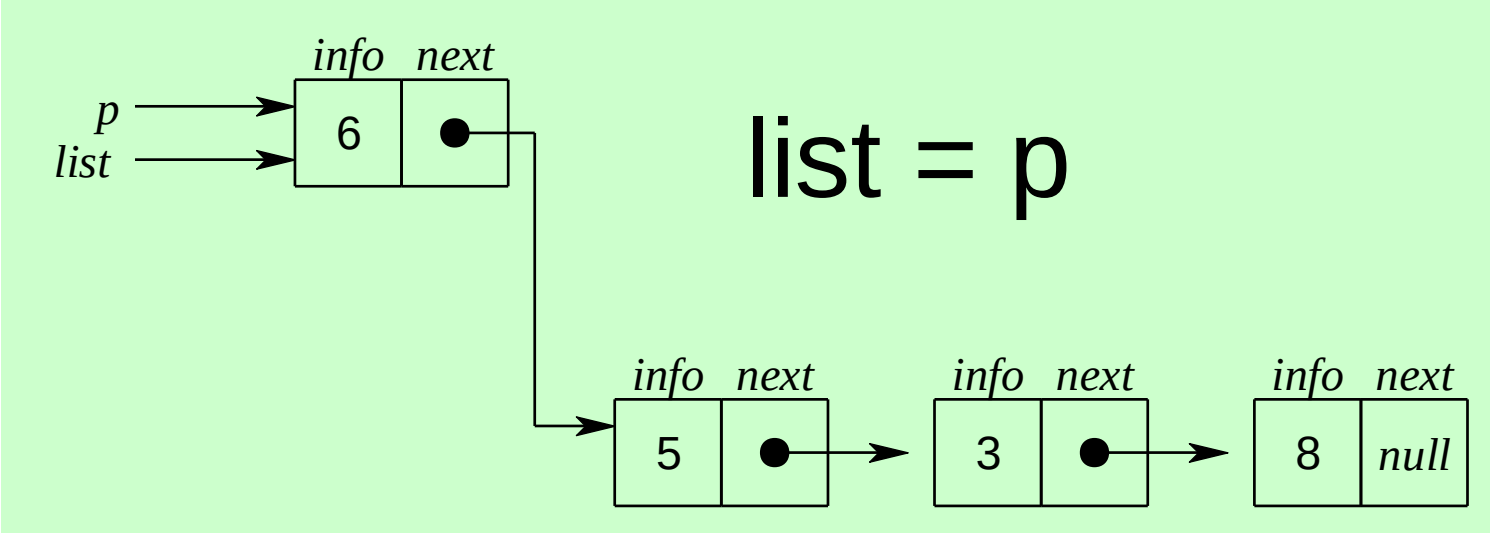

info next
p
6
info(p) = 6
info next
info next
info next
list
5
3
8
null

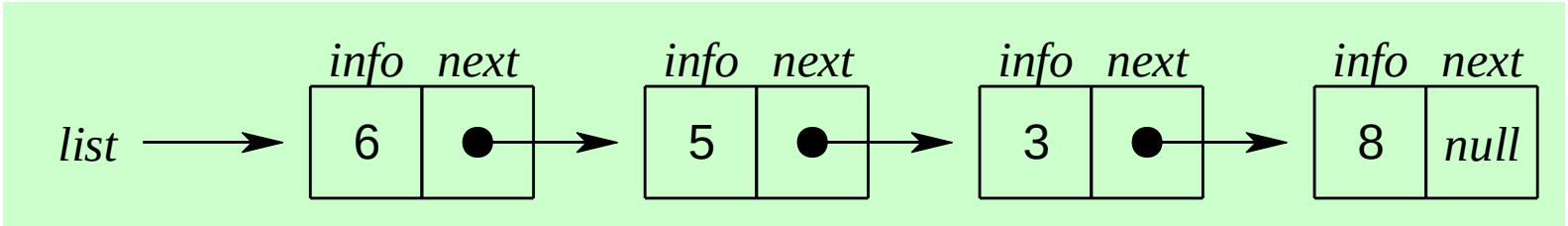
Contd.


info next
p
6
next(p) = list
info next
info next
info next
5
3
8
null
list

Contd.


info next
p
list
6
list = p
info next
5
info next
3
info next
8
null

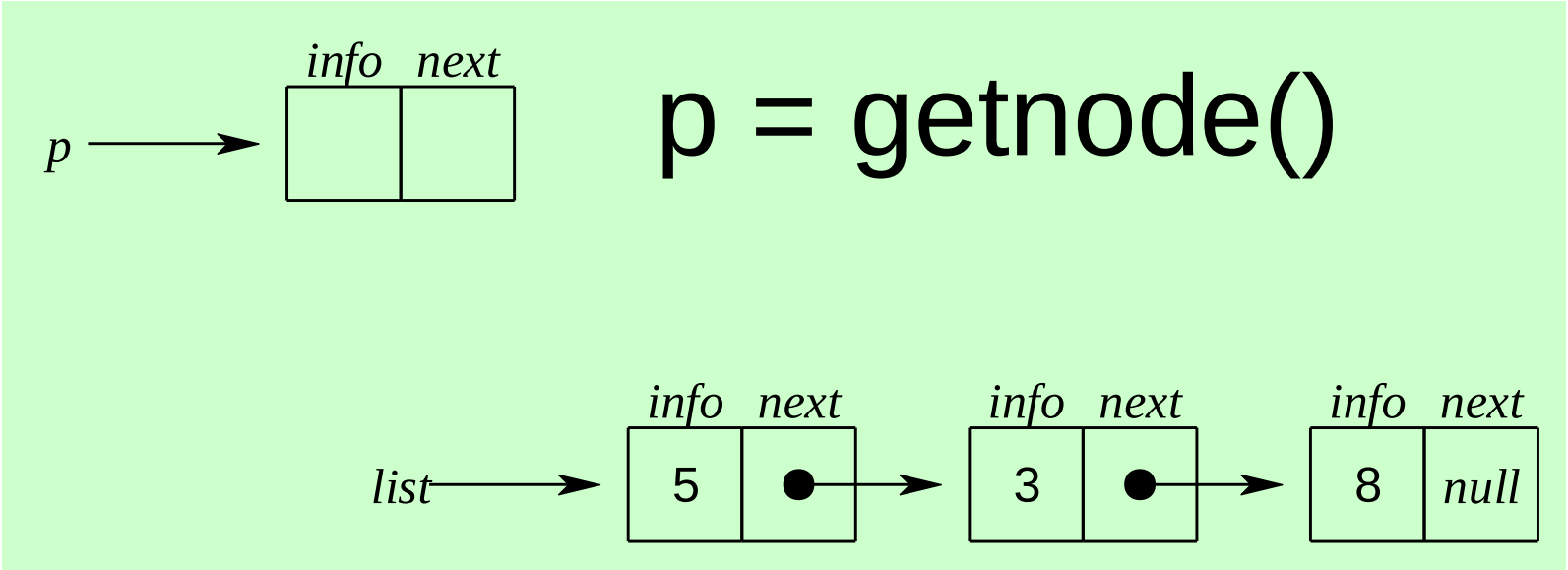
Contd.



Code

```
void beginsert()
{
    struct node *ptr;
    int item;
    ptr = (struct node *)
malloc(sizeof(struct node *));
    if(ptr == NULL)
    {
        printf("\nOVERFLOW");
    }
else
    {
        printf("\nEnter value\n");
        scanf("%d",&item);
        ptr->data = item;
        ptr->next = head;
        head = ptr;
        printf("\nNode inserted");
    }
}
```

Insert at the end



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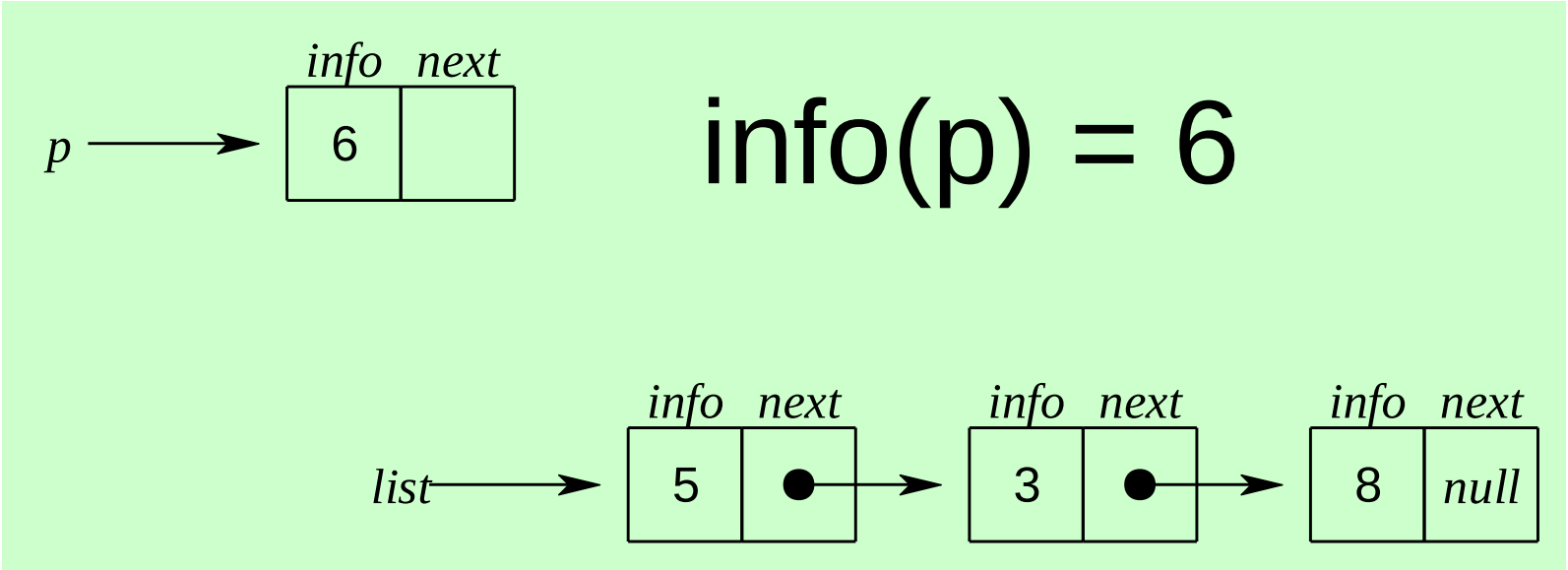
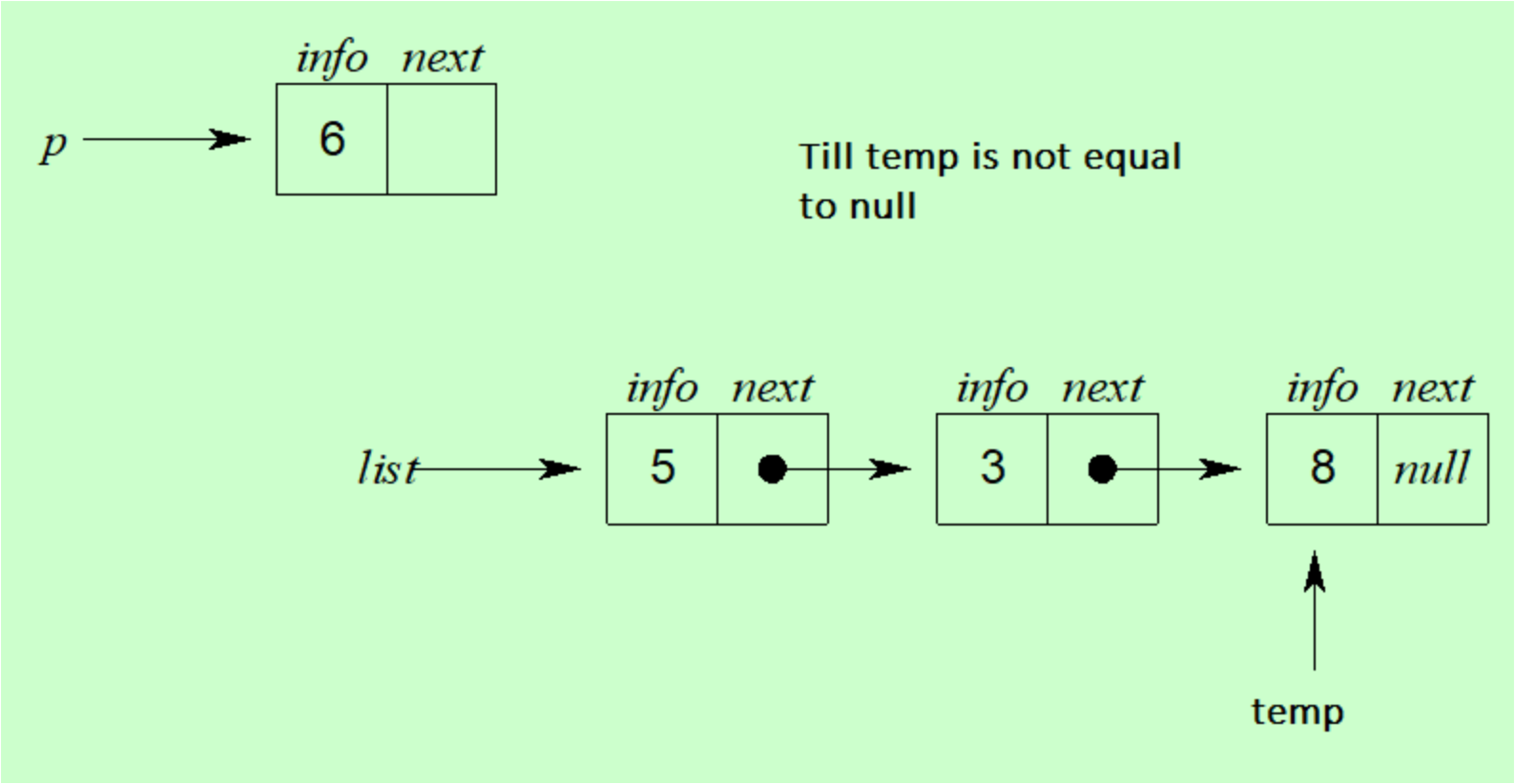
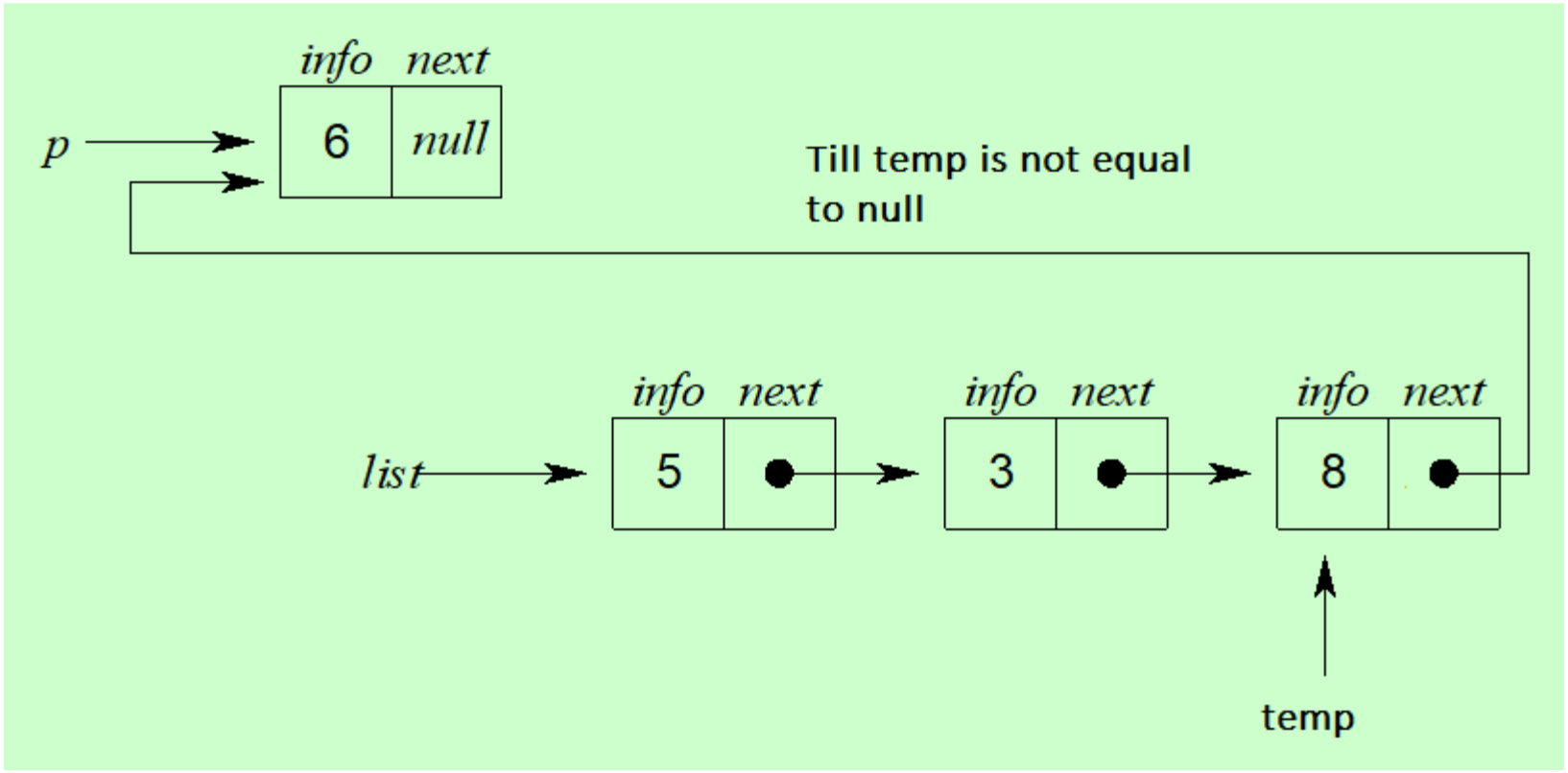

info next
p
6
info(p) = 6
info next
info next
info next
list
5
3
8
null

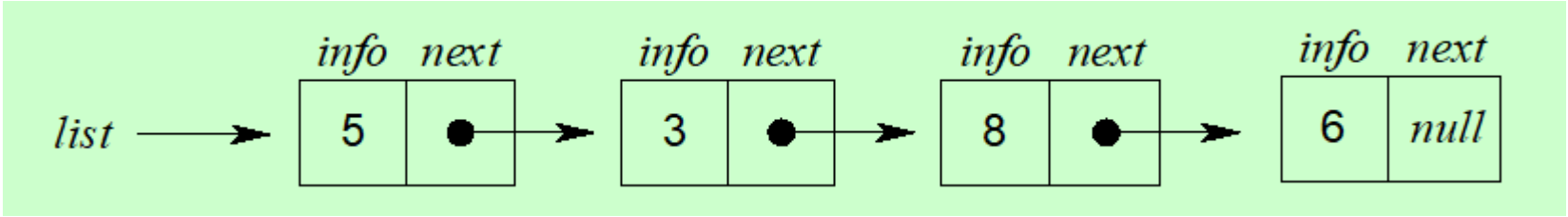
Contd.


info next
p
6
Till temp is not equal
to null
info next
info next
info next
list
5
3
8
null
temp

Contd.


info next
p
6
null
Till temp is not equal
to null
info next
info next
info next
list
5
3
8
temp

Contd.



Code

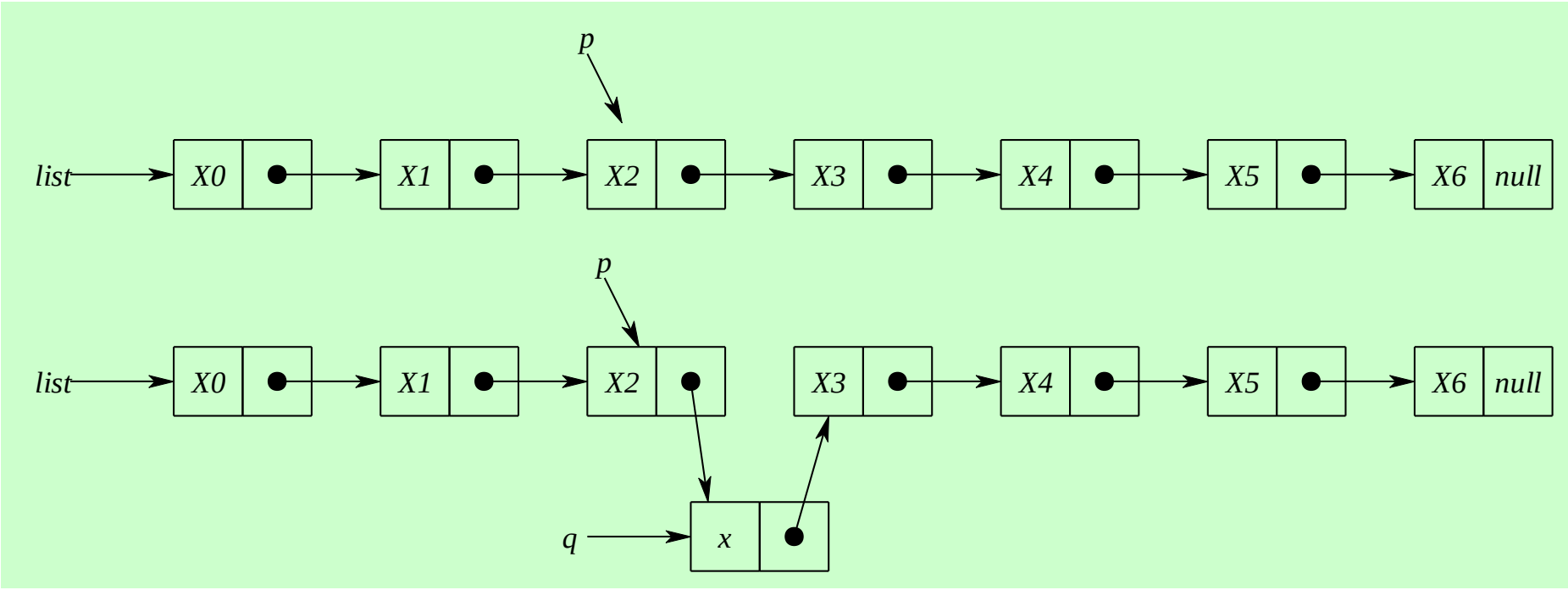
```
void lastinsert()
{
   struct node *ptr,*temp;
   int item;
   ptr = (struct node*)malloc(sizeof(struct node));
   if(ptr == NULL)
   {
      printf("\nOVERFLOW");
   }
```

Code

```
else
   {
      printf("\nEnter value?\n");
      scanf("%d",&item);
      ptr->data = item;
      if(head == NULL)
      {
         ptr -> next = NULL;
            head = ptr;
         printf("\nNode inserted");
      }
```

```
      else
      {
         temp = head;
         while (temp -> next != NULL)
         {
            temp = temp -> next;
         }
         temp->next = ptr;
         ptr->next = NULL;
         printf("\nNode inserted");

      }
   }
}
```

Insert after location



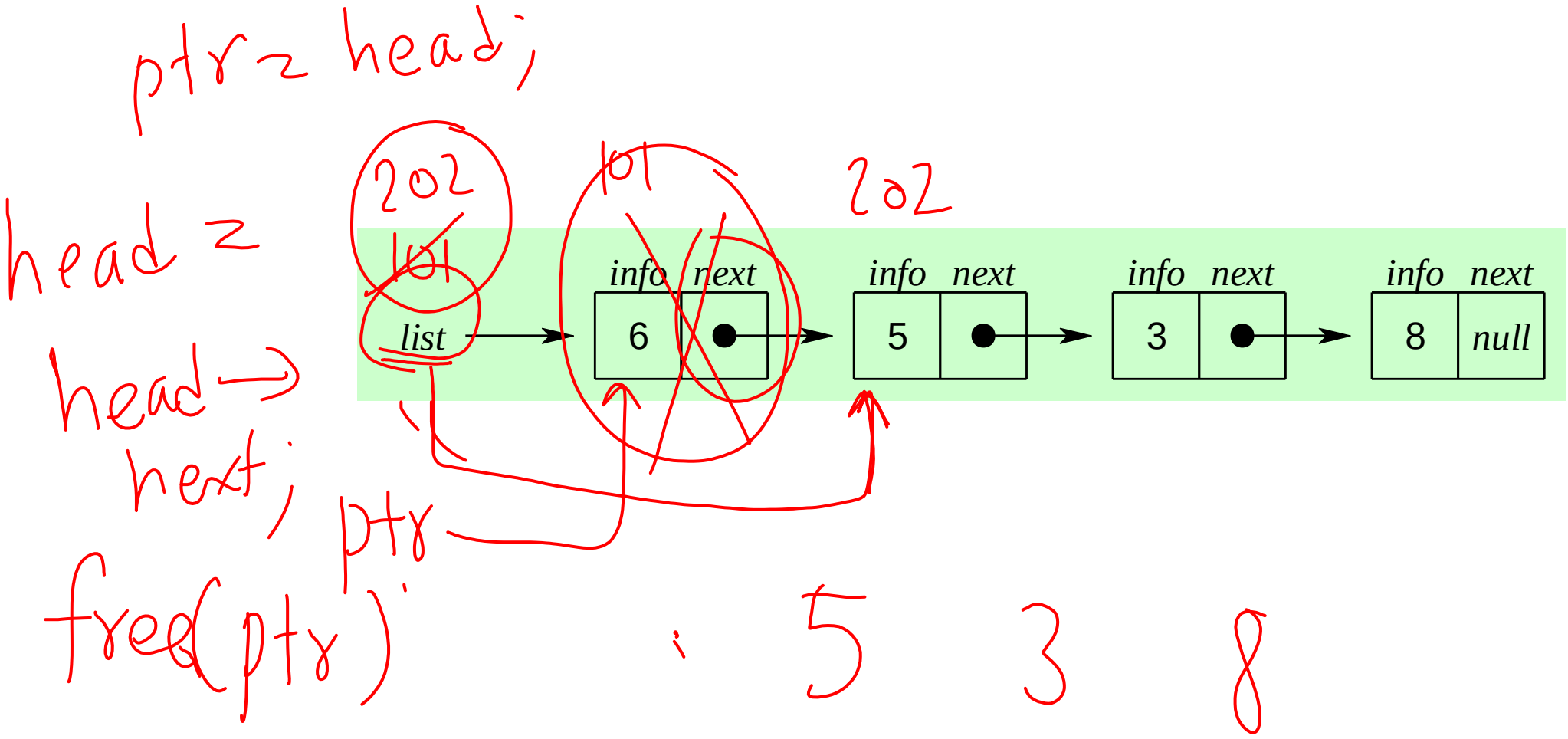
Code

```
void randominsert()
{
   int i,loc,item;
   struct node *ptr, *temp;
   ptr = (struct node *) malloc (sizeof(struct node));
   if(ptr == NULL)
   {
      printf("\nOVERFLOW");
   }
   else
   {
      printf("\nEnter element value");
      scanf("%d",&item);
      ptr->data = item;
      printf("\nEnter the location after wh
ich you want to insert ");
      scanf("\n%d",&loc);
      temp=head;
      for(i=0;i<loc;i++)
      {
         temp = temp->next;
         if(temp == NULL)
         {
            printf("\ncan't insert\n");
            return;
         }
```

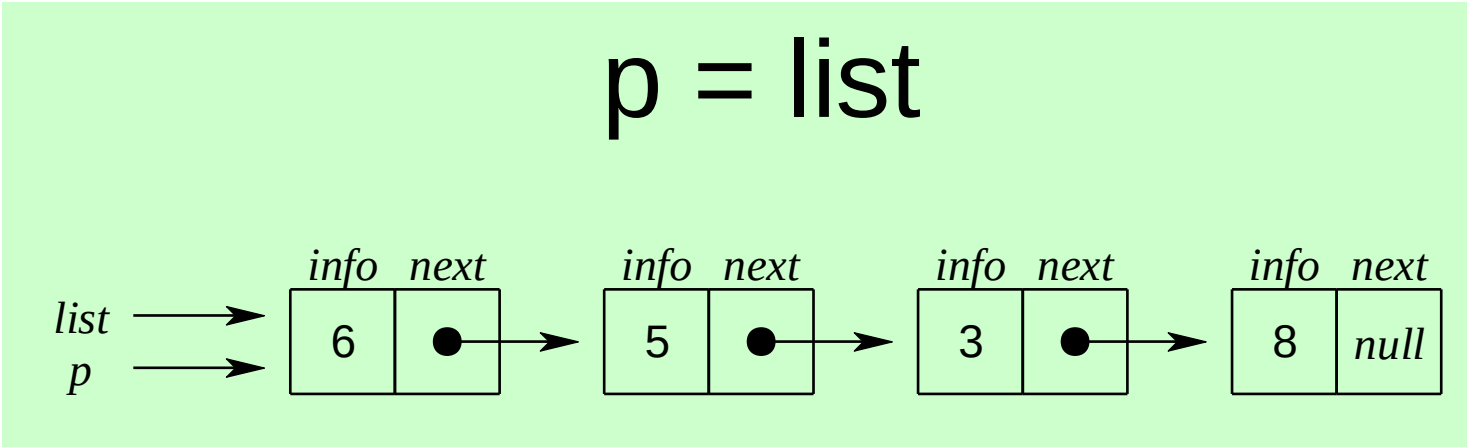
Contd.

```
 }
        ptr ->next = temp ->next;
        temp ->next = ptr;
        printf("\nNode inserted");
    }
}
```

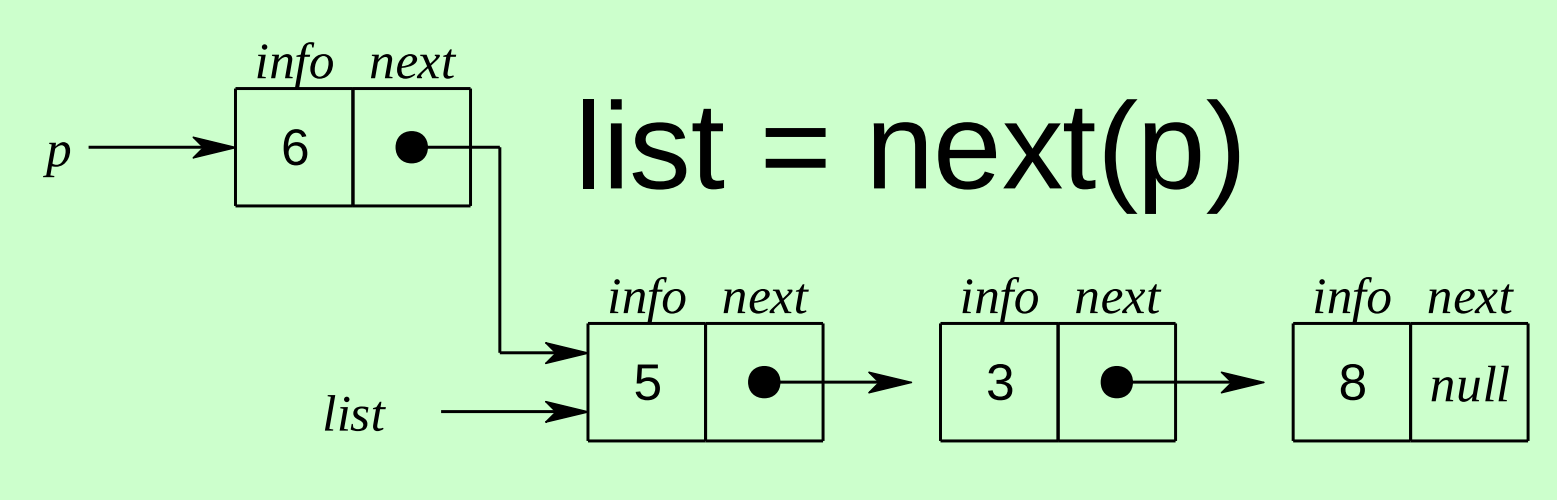
Deletion from beginning



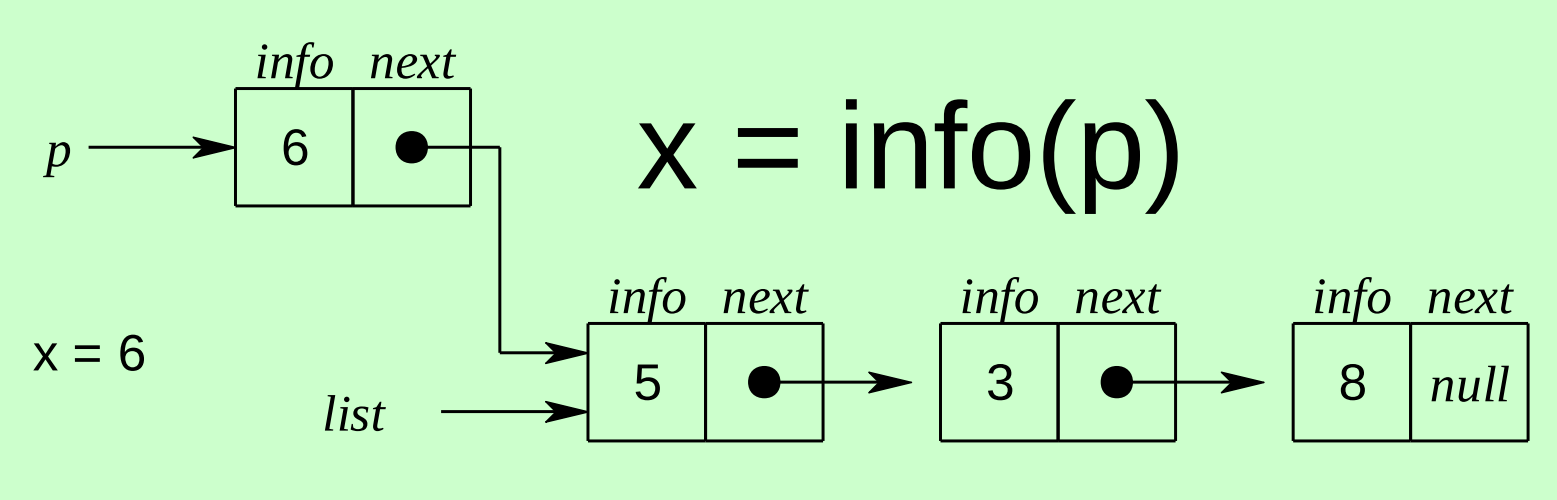
Contd.



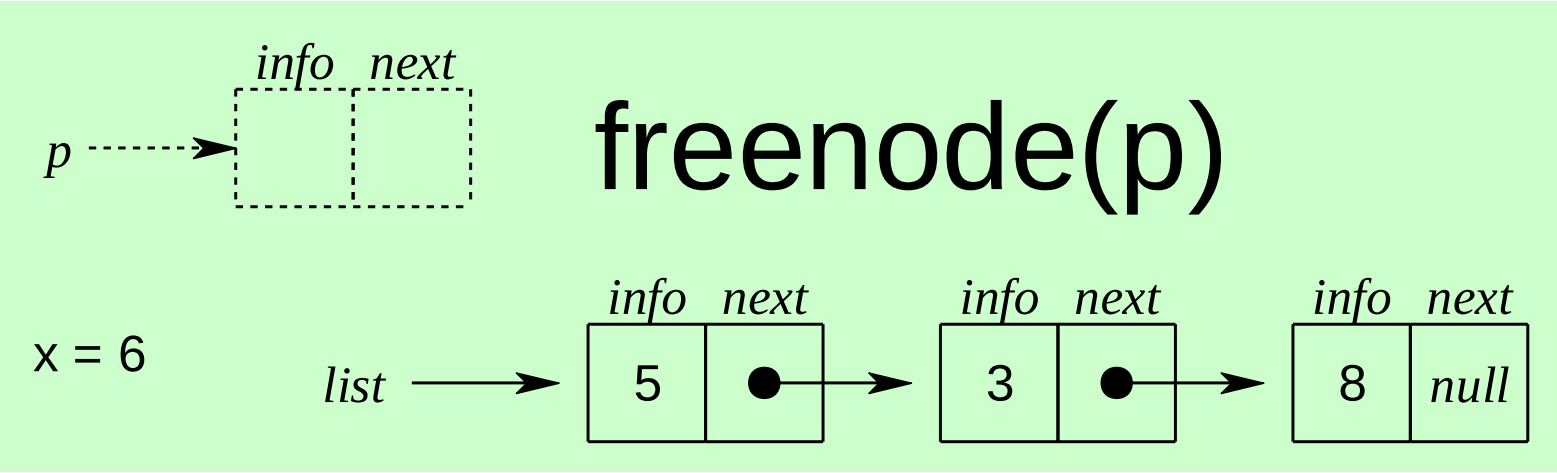
Contd.


info next
p
6
list = next(p)
info next
info next
info next
5
3
8
null
list

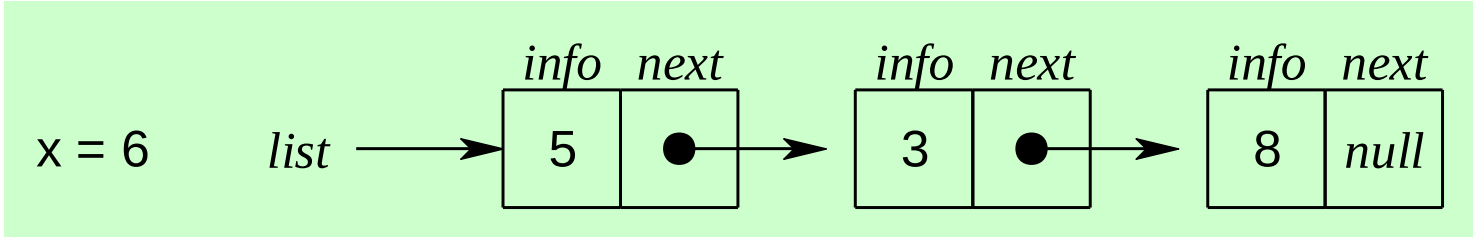
Contd.


info next
p
6
x = info(p)
info next
info next
info next
x = 6
5
3
8
null
list

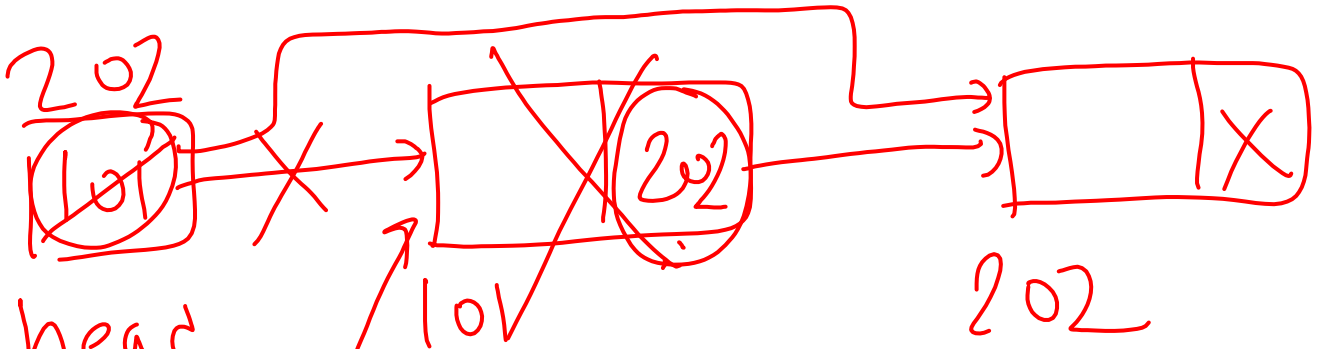
Contd.


info next
p
freenode(p)
x = 6
info next
info next
info next
list
5
3
8
null

Contd.



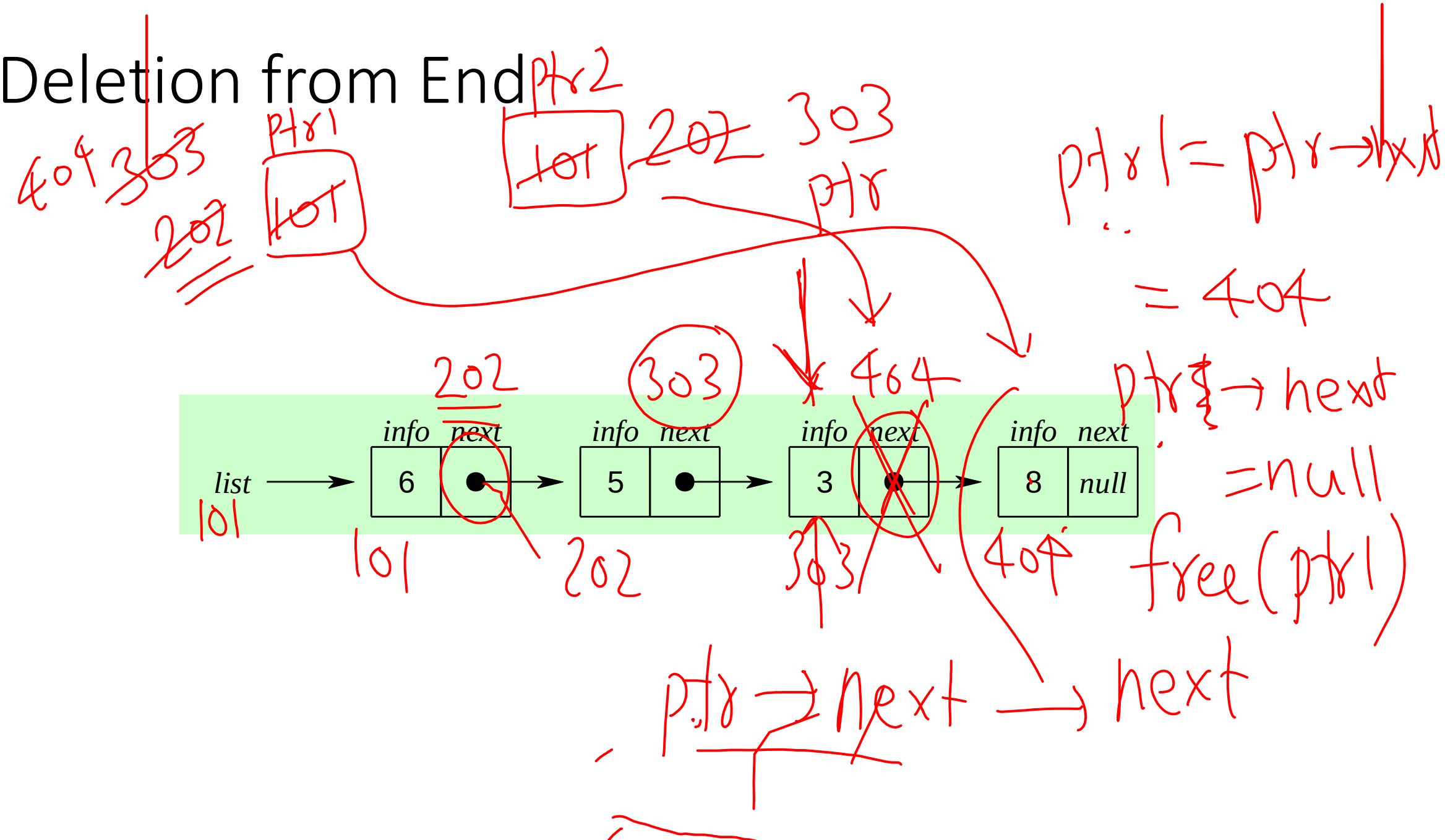
Code



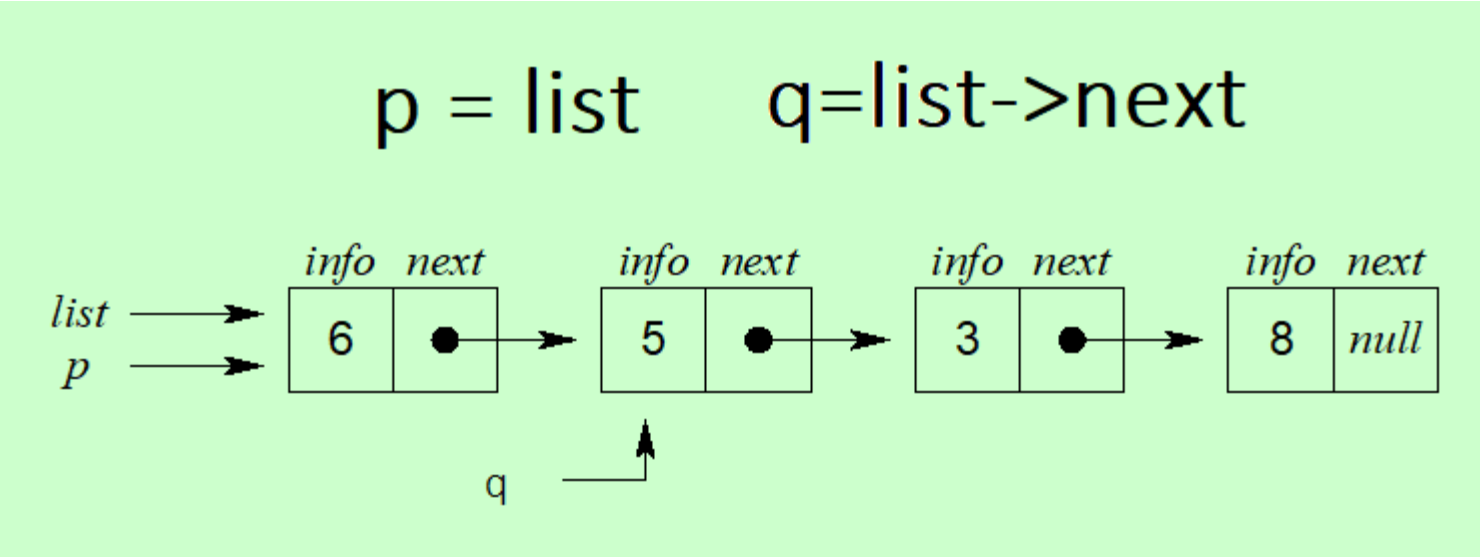

```
void begin_delete()
{
    struct node *ptr;
    if(head == NULL)
    {
        printf("\nList is empty\n");
    }
    else
    {
        ptr = head;
        head = ptr->next;
        free(ptr);
        printf("\nNode deleted from
the begining ...\n");
    }
}
```

head = head→next,

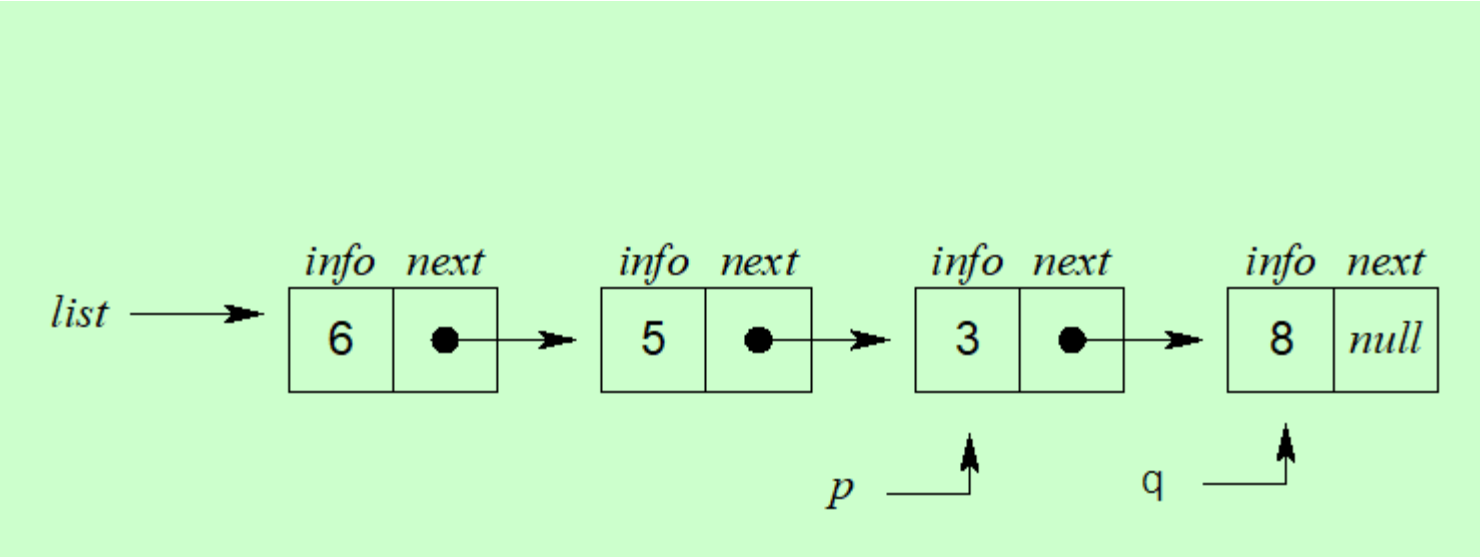
Deletion from End



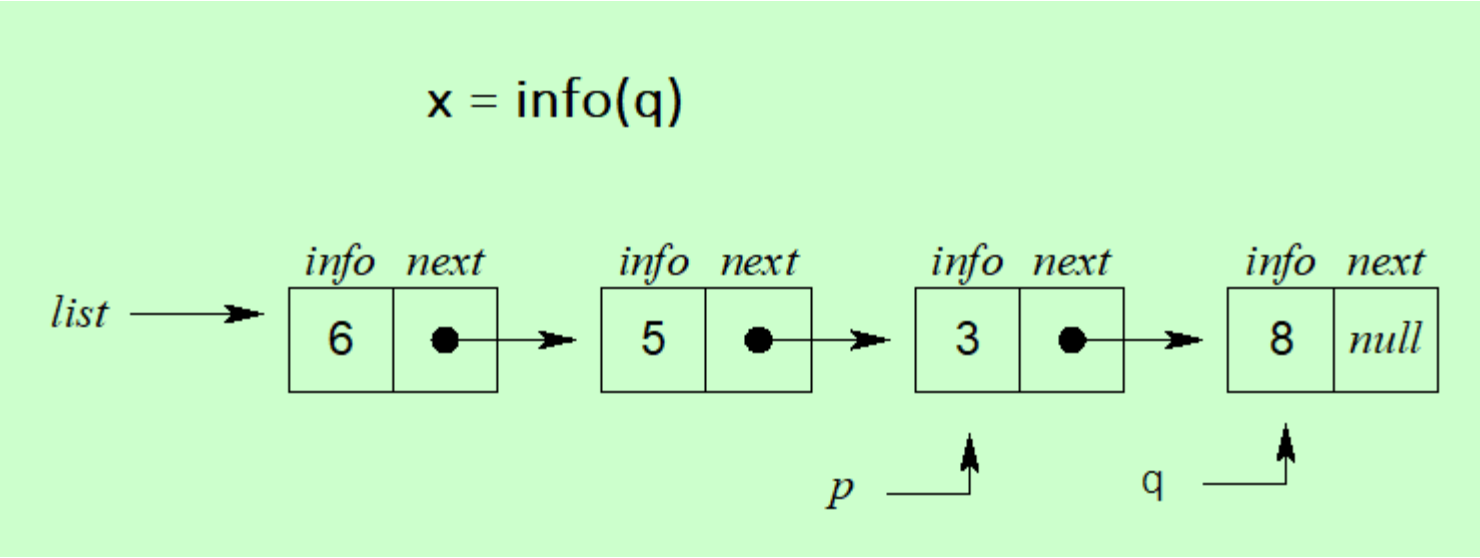
Contd.


p = list
q=list->next
info
next
info
next
info
next
info
next
list
p
6
5
3
8
null
q

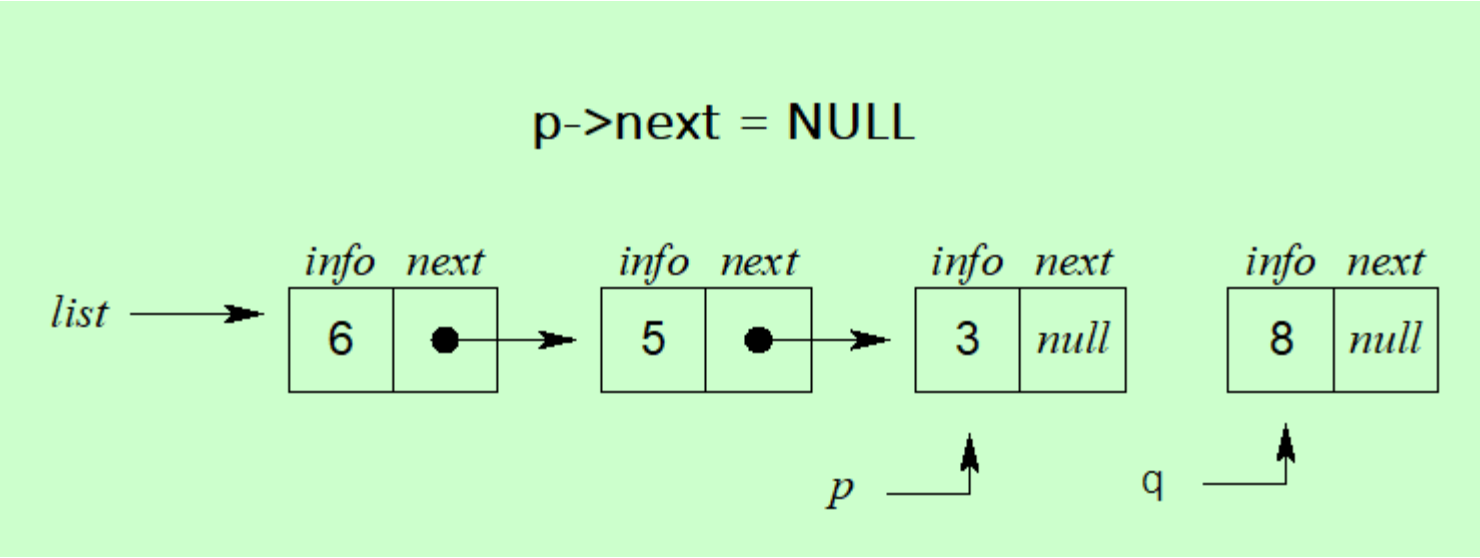
Contd.



Contd.

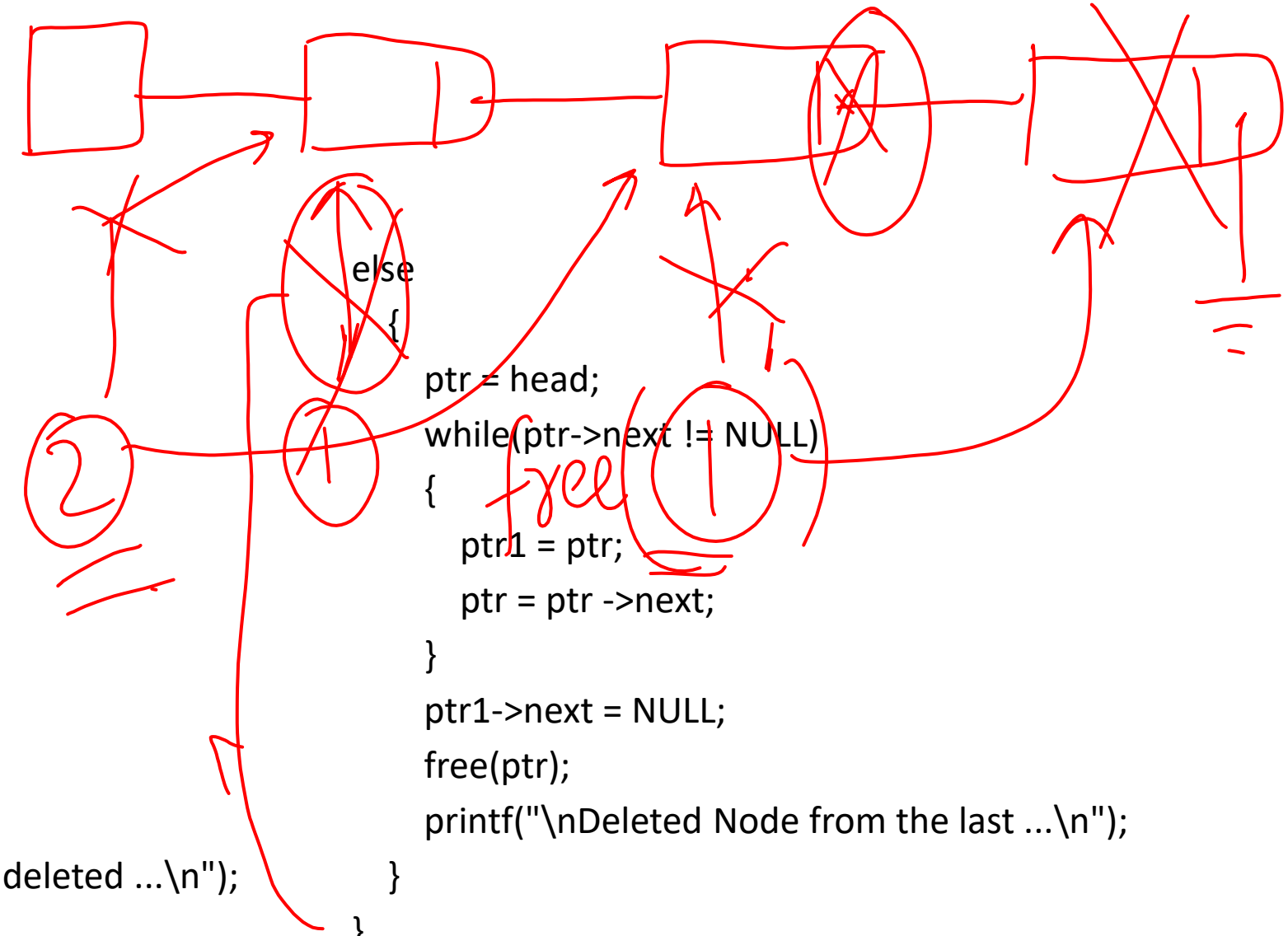

x = info(q)
list
info next
6
info next
5
info next
3
info next
8
null
p
q

Contd.

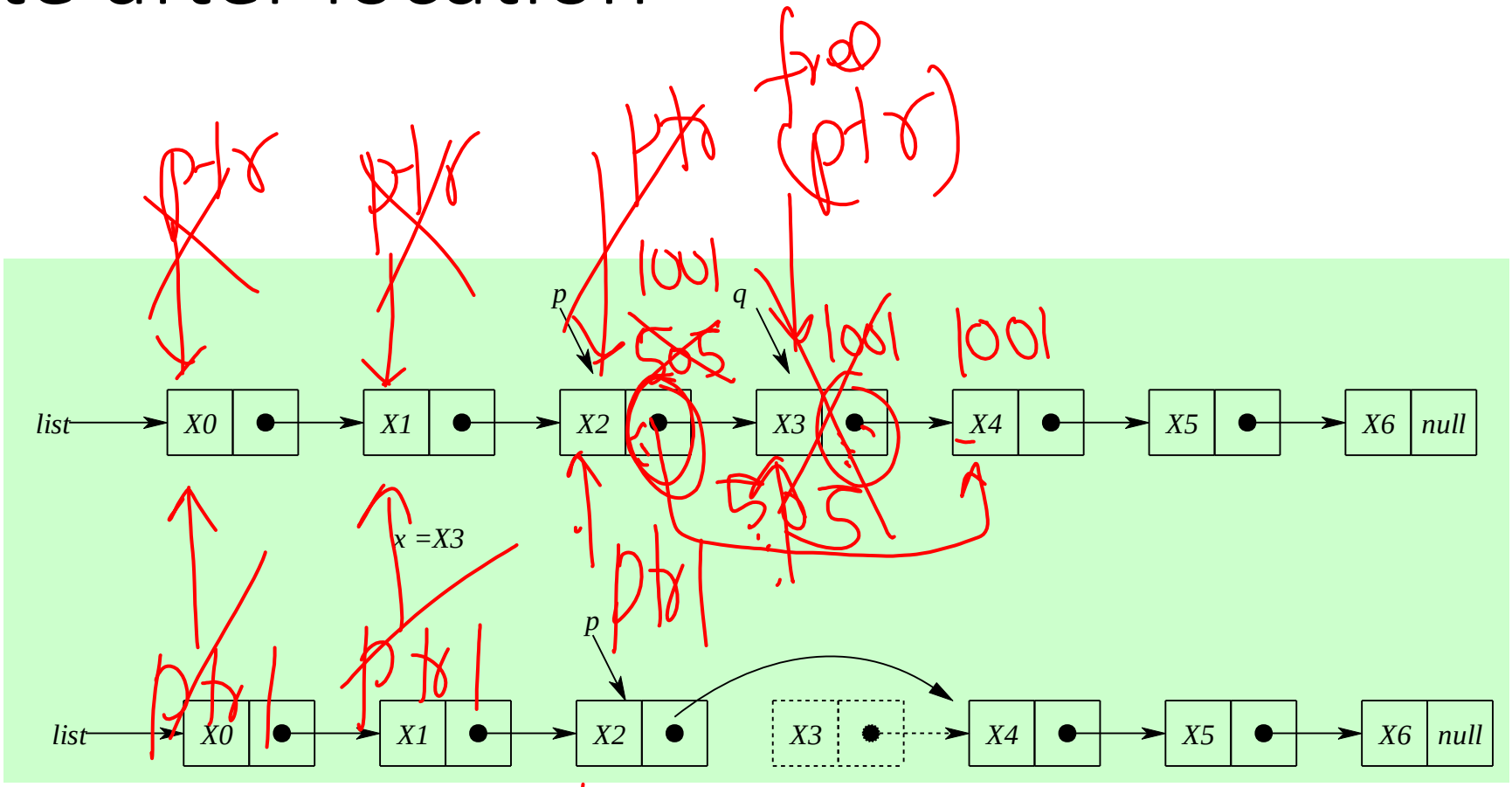


Code

```
void last_delete()
{
   struct node *ptr,*ptr1;
   if(head == NULL)
   {
      printf("\nlist is empty");
   }
   else if(head -> next == NULL)
   {
      free(head);
      head = NULL;
      printf("\nOnly node of the list deleted ...\n");
   }
   else
   {
      ptr = head;
      while(ptr->next != NULL)
      {
         ptr1 = ptr;
         ptr = ptr ->next;
      }
      ptr1->next = NULL;
      free(ptr);
      printf("\nDeleted Node from the last ...\n");
   }
}
```

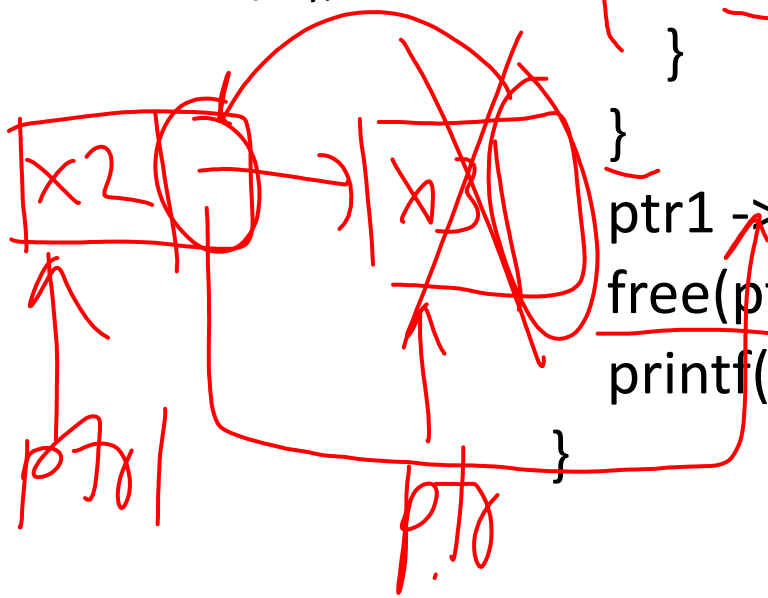


Delete after location



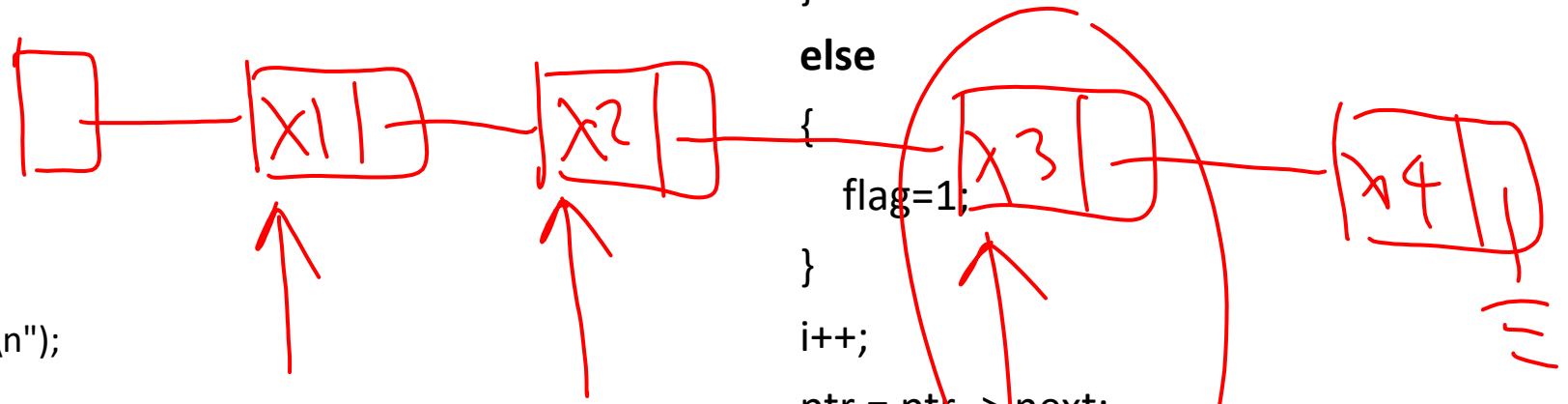
Code

```
void random_delete()
{
    struct node *ptr,*ptr1;
    int loc,i;
    printf("\n Enter the location of the node after which you want to perform deletion \n");
    scanf("%d",&loc);
    ptr=head;
    for(i=0;i<loc;i++)
    {
        ptr1 = ptr;
        ptr = ptr->next;
        if(ptr == NULL)
        {
            printf("\nCan't delete");
            return;
        }
    }
    ptr1 ->next = ptr ->next;
    free(ptr);
    printf("\nDeleted node %d ",loc+1);
}
```



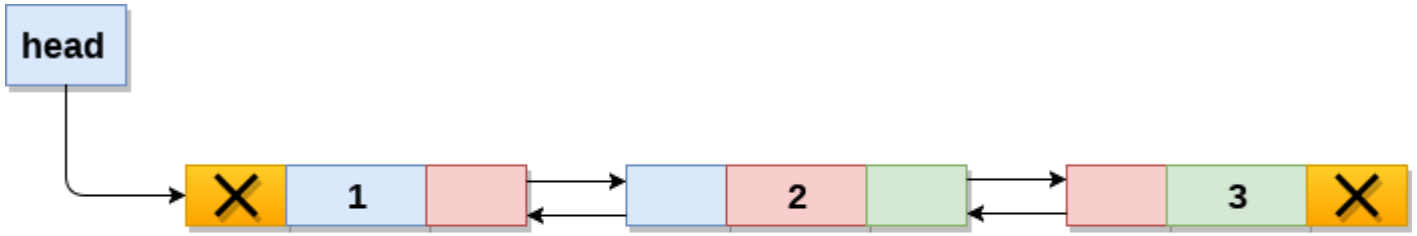
Searching

```
void search()
{
   struct node *ptr;
   int item,i=0,flag;
   ptr = head;
   if(ptr == NULL)
   {
      printf("\nEmpty List\n");
   }
   else
   {
      printf("\nEnter item which you want to search?\n");
      scanf("%d",&item);
      while (ptr!=NULL)
      {
         if(ptr->data == item)
         {
            printf("item found at location %d ",i+1);
            flag=0;
         }
         else
         {
            flag=1;
         }
         i++;
         ptr = ptr -> next;
      }
      if(flag==1)
      {
         printf("Item not found\n");
      }
   }
}
```



Doubly Linked List: Representation

```
struct node
{
    struct node *prev;
    int data;
    struct node *next;
}
```



Doubly Linked List

Operations

- Insertion
  - at beginning
  - at end
  - after specified node
- Deletion
  - at beginning
  - at end
  - after specified node
- Traversing
- Searching

Codes

Insertion_at_beg.txt

Insertion_at_end.txt

Insertion_specified.txt

Search.txt

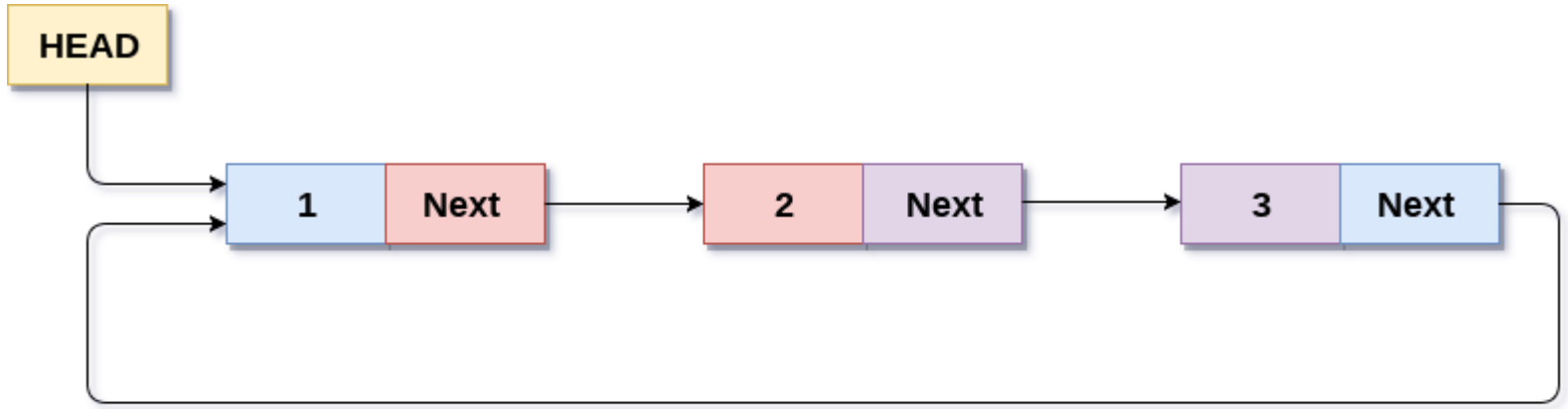
Deletion_beg.txt

Deletion_end.txt

Deletion_specified.txt

Circular Linked List: Representation

```
struct node
{
   int data;
   struct node *next;
}
struct node * head;
```



Circular Singly Linked List

Operations

- Insertion
  - at beginning
  - at end
- Deletion
  - at beginning
  - at end
- Traversing
- Searching

Codes

Insertion_circular_at_beg.txt

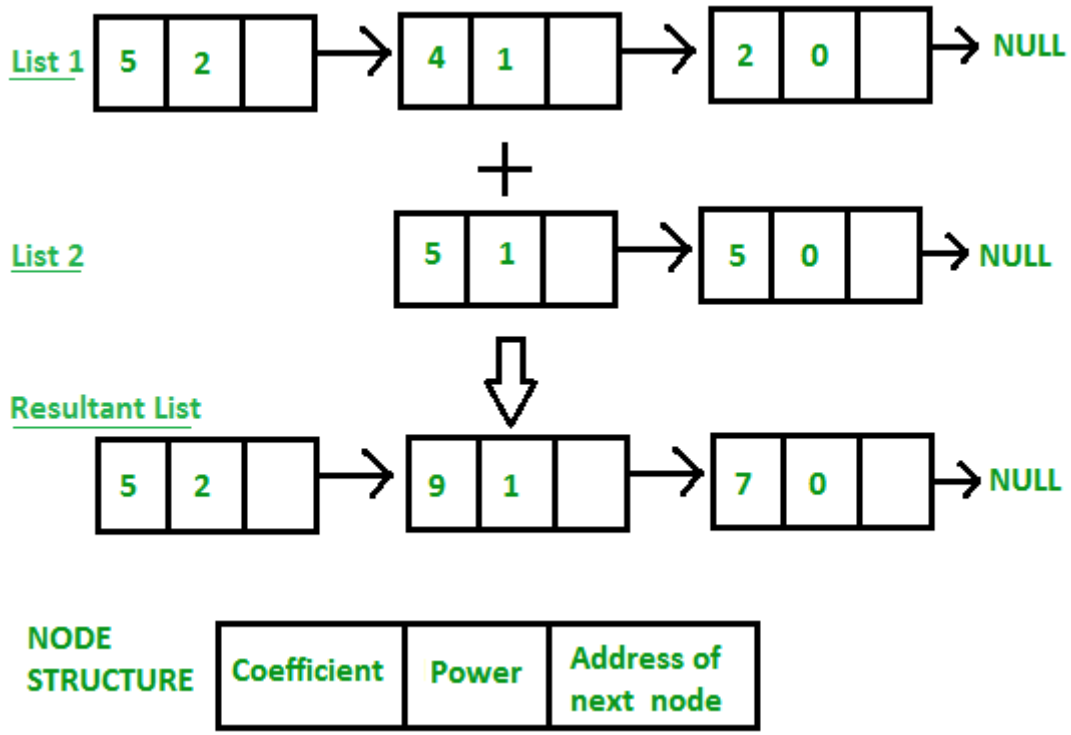
Insertion_circular_at_end.txt

Search_circular.txt

Deletion_circular_at_beg.txt

Deletion_circular_at_end.txt

Adding two polynomials



Code

```
// Node structure containing power and coefficient of
// variable
struct Node {
    int coeff;
    int pow;
    struct Node* next;
};
```

Node Creation

```
// Function to create new node
void create_node(int x, int y, struct Node** temp)
{
    struct Node *r, *z;
    z = *temp;
    if (z == NULL) {
        r = (struct Node*)malloc(sizeof(struct Node));
        r->coeff = x;
        r->pow = y;
        *temp = r;
        r->next = (struct Node*)malloc(sizeof(struct
Node));
        r = r->next;
        r->next = NULL;
}
    else {
        r->coeff = x;
        r->pow = y;
        r->next = (struct
Node*)malloc(sizeof(struct Node));
        r = r->next;
        r->next = NULL;
    }
}
```

Polynomial Add

```
// Function Adding two polynomial numbers
void polyadd(struct Node* poly1, struct Node* poly2,
             struct Node* poly)
{
    while (poly1->next && poly2->next) {
        // If power of 1st polynomial is greater then 2nd,
        // then store 1st as it is and move its pointer
        if (poly1->pow > poly2->pow) {
            poly->pow = poly1->pow;
            poly->coeff = poly1->coeff;
            poly1 = poly1->next;
        }
```

Contd.

```
            // If power of 2nd polynomial is greater then 1st,
        // then store 2nd as it is and move its pointer
        else if (poly1->pow < poly2->pow) {
            poly->pow = poly2->pow;
            poly->coeff = poly2->coeff;
            poly2 = poly2->next;
        }
```

```
// If power of both polynomial numbers is same then
        // add their coefficients
        else {
            poly->pow = poly1->pow;
            poly->coeff = poly1->coeff + poly2->coeff;
            poly1 = poly1->next;
            poly2 = poly2->next;
        }
```

Contd.

```
// Dynamically create new node
        poly->next
            = (struct Node*)malloc(sizeof(struct Node));
        poly = poly->next;
        poly->next = NULL;
    }
```

Contd.

```
while (poly1->next || poly2->next) {
    if (poly1->next) {
        poly->pow = poly1->pow;
        poly->coeff = poly1->coeff;
        poly1 = poly1->next;
    }
    if (poly2->next) {
        poly->pow = poly2->pow;
        poly->coeff = poly2->coeff;
        poly2 = poly2->next;
    }
    poly->next
        = (struct
Node*)malloc(sizeof(struct Node));
    poly = poly->next;
    poly->next = NULL;
  }
}
```

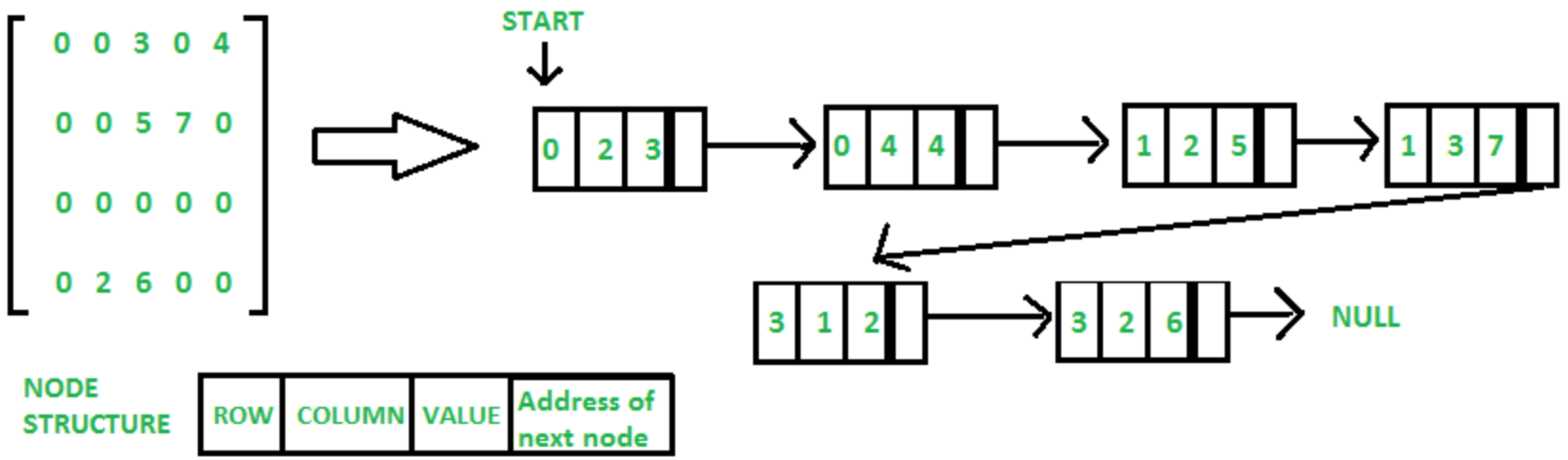
Contd.

```
// Display Linked list
void show(struct Node* node)
{
    while (node->next != NULL) {
        printf("%dx^%d", node->coeff, node->pow);
        node = node->next;
        if (node->coeff >= 0) {
            if (node->next != NULL)
                printf("+");
        }
    }
}
```

Driver Code

```
// Driver code
int main()
{
    struct Node *poly1 = NULL, *poly2 = NULL, *poly = NULL;

    // Create first list of 5x^2 + 4x^1 + 2x^0
    create_node(5, 2, &poly1);
    create_node(4, 1, &poly1);
    create_node(2, 0, &poly1);

    // Create second list of -5x^1 - 5x^0
    create_node(-5, 1, &poly2);
    create_node(-5, 0, &poly2);

    printf("1st Number: ");
    show(poly1);

    printf("\n2nd Number: ");
    show(poly2);

    poly = (struct Node*)malloc(sizeof(struct Node));

    // Function add two polynomial numbers
    polyadd(poly1, poly2, poly);

    // Display resultant List
    printf("\nAdded polynomial: ");
    show(poly);

    return 0;
}
```

Sparse Matrix Representation



Code

```
// C program for Sparse Matrix Representation
// using Linked Lists
#include<stdio.h>
#include<stdlib.h>

// Node to represent sparse matrix
struct Node
{
    int value;
    int row_position;
    int column_postion;
    struct Node *next;
};
```

Contd.

```
// Function to create new node
void create_new_node(struct Node** start, int non_zero_element,
                     int row_index, int column_index )
{
   struct Node *temp, *r;
   temp = *start;
   if (temp == NULL)
   {
      // Create new node dynamically
      temp = (struct Node *) malloc (sizeof(struct Node));
      temp->value = non_zero_element;
      temp->row_position = row_index;
      temp->column_postion = column_index;
      temp->next = NULL;
      *start = temp;

   }
```

```
else
   {
      while (temp->next != NULL)
         temp = temp->next;

      // Create new node dynamically
      r = (struct Node *) malloc (sizeof(struct Node));
      r->value = non_zero_element;
      r->row_position = row_index;
      r->column_postion = column_index;
      r->next = NULL;
      temp->next = r;

   }
}
```

Contd.

```
// This function prints contents of linked list
// starting from start
void PrintList(struct Node* start)
{
    struct Node *temp, *r, *s;
    temp = r = s = start;

    printf("row_position: ");
    while(temp != NULL)
    {

        printf("%d ", temp->row_position);
        temp = temp->next;
    }
    printf("\n");
    printf("column_postion: ");
    while(r != NULL)
    {
        printf("%d ", r->column_postion);
        r = r->next;
    }
    printf("\n");
    printf("Value: ");
    while(s != NULL)
    {
        printf("%d ", s->value);
        s = s->next;
    }
    printf("\n");
}
```

Contd.

```
// Driver of the program
int main()
{
  // Assume 4x5 sparse matrix
   int sparseMatric[4][5] =
   {
      {0 , 0 , 3 , 0 , 4 },
      {0 , 0 , 5 , 7 , 0 },
      {0 , 0 , 0 , 0 , 0 },
      {0 , 2 , 6 , 0 , 0 }
   };

   /* Start with the empty list */
   struct Node* start = NULL;
```

```
   for (int i = 0; i < 4; i++)
      for (int j = 0; j < 5; j++)

         // Pass only those values which
are non - zero
         if (sparseMatric[i][j] != 0)
            create_new_node(&start,
sparseMatric[i][j], i, j);

   PrintList(start);

   return 0;
}
```