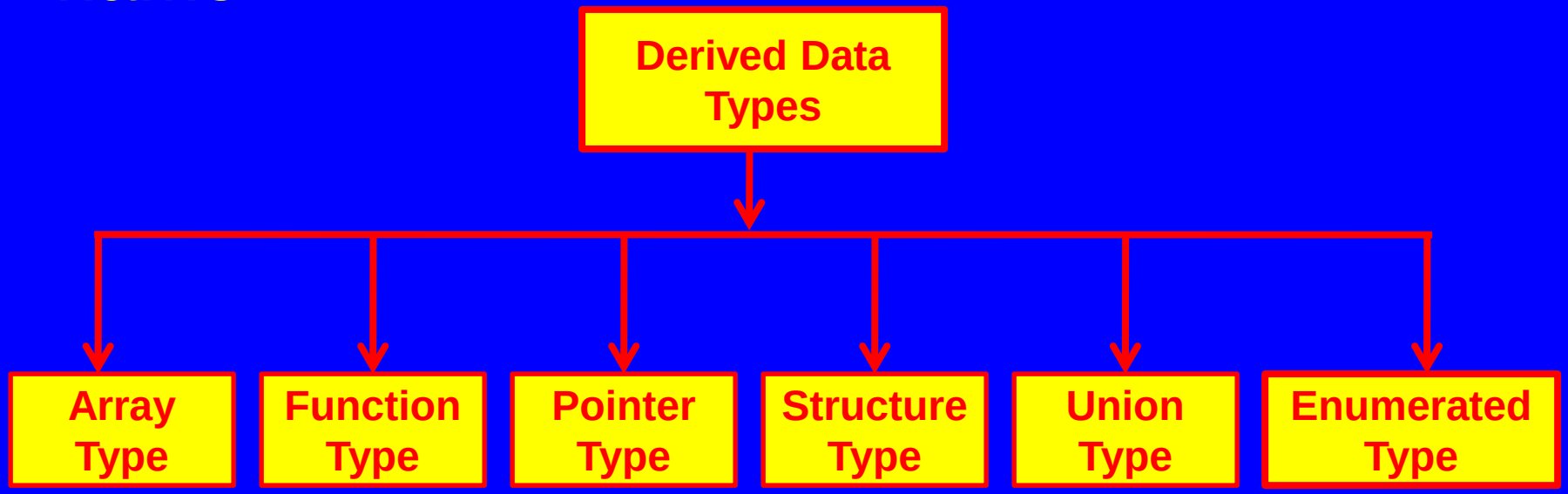
Introduction to Arrays

- ✓One Dimensional Array.
- ✓Two Dimensional Array.
- ✓Inserting Elements in Array.
- ✓Reading Elements from an Array.
- ✓Searching in Array.
- ✓Sorting of an Array.
- ✓Merging of 2 Arrays.

What is an Array?

- ✓An ***array*** is a sequenced collection of elements that share the same data type.
- ✓Elements in an array share the same name



How to Refer Array Elements

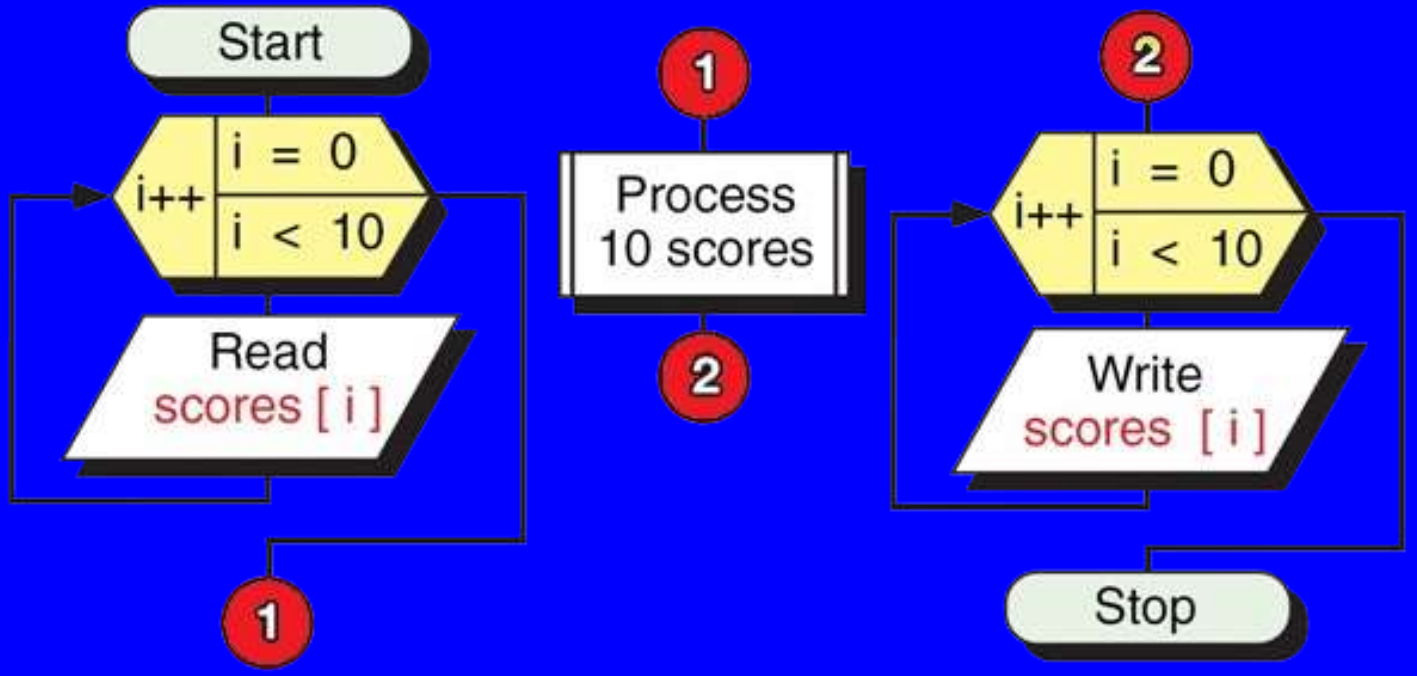
We can reference array elements by using the array's subscript. The first element has a subscript of 0. The last element in an array of length ***n*** has a subscript of ***n-1***.

When we write a program, we refer to an *individual* array element using *indexing*. To index a subscript, use the array name and the subscript in a pair of square brackets:

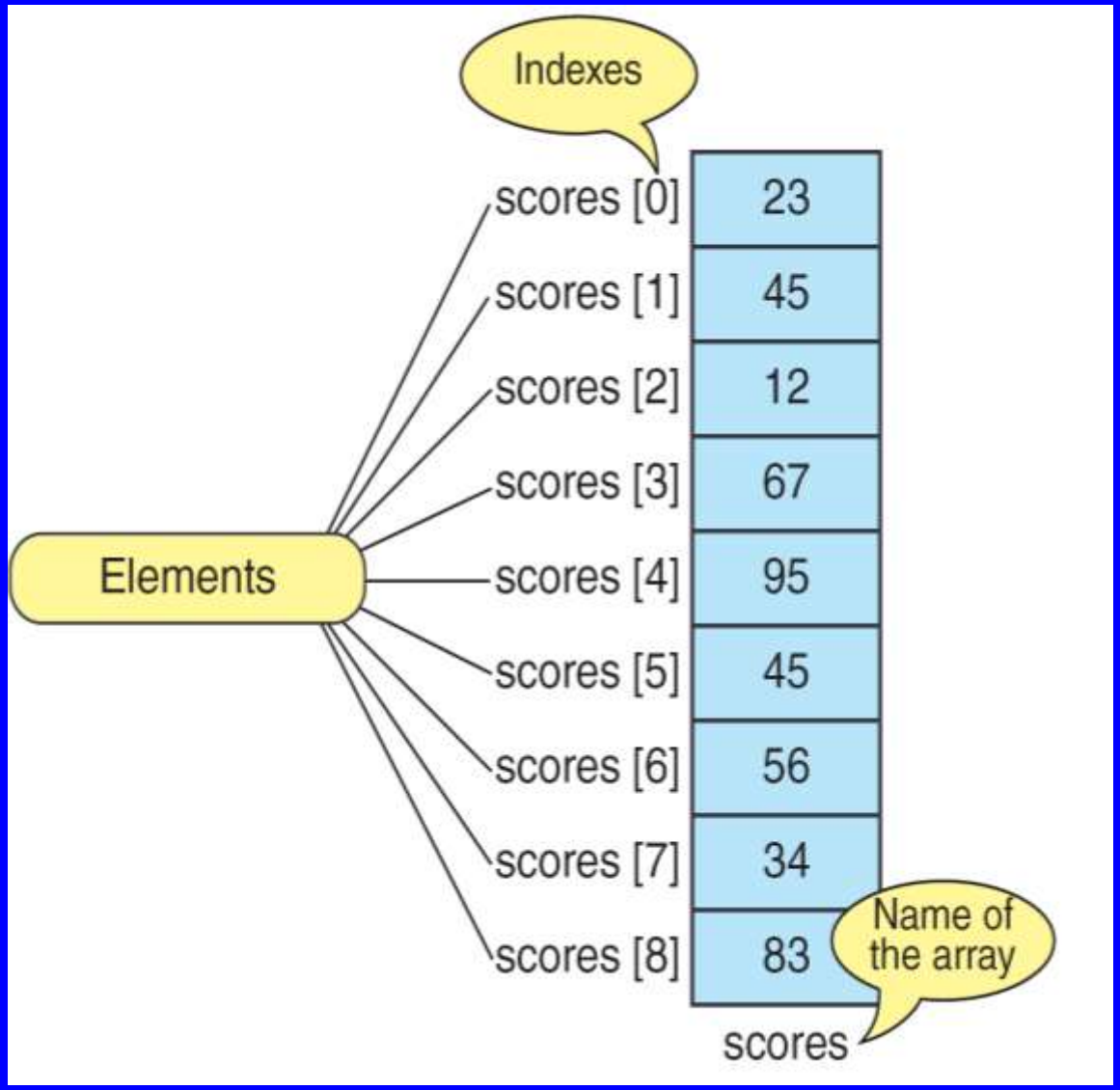
```
a[12];
```

Arrays and Loops

Since we can refer to individual array elements using numbered indexes, it is very common for programmers to use **for** loops when processing arrays.



Example : scores Array



Array Types in C++

C++ supports two types of arrays:

- ✓***Fixed Length Arrays*** – The programmer "hard codes" the length of the array, which is fixed at run-time.

- ✓***Variable-Length Arrays*** – The programmer doesn't know the array's length until run-time.

Declaring an Array

- To declare an array, we need to specify its data type, the array's identifier and the size:

- **type arrayName [arraySize];**

- The **arraySize** can be a constant (for fixed length arrays) or a variable (for variable-length arrays).

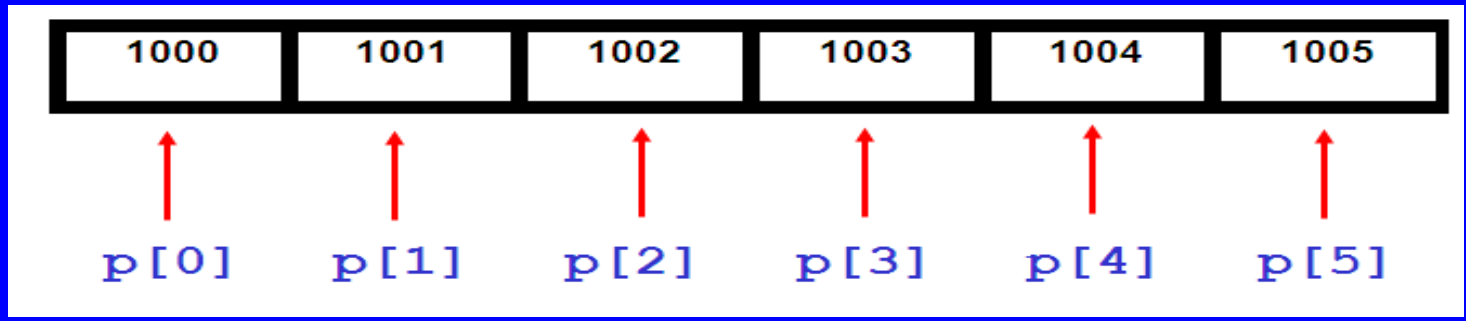
- Before using an array (even if it is a variable-length array), we must declare and initialize it!

Declaring an Array

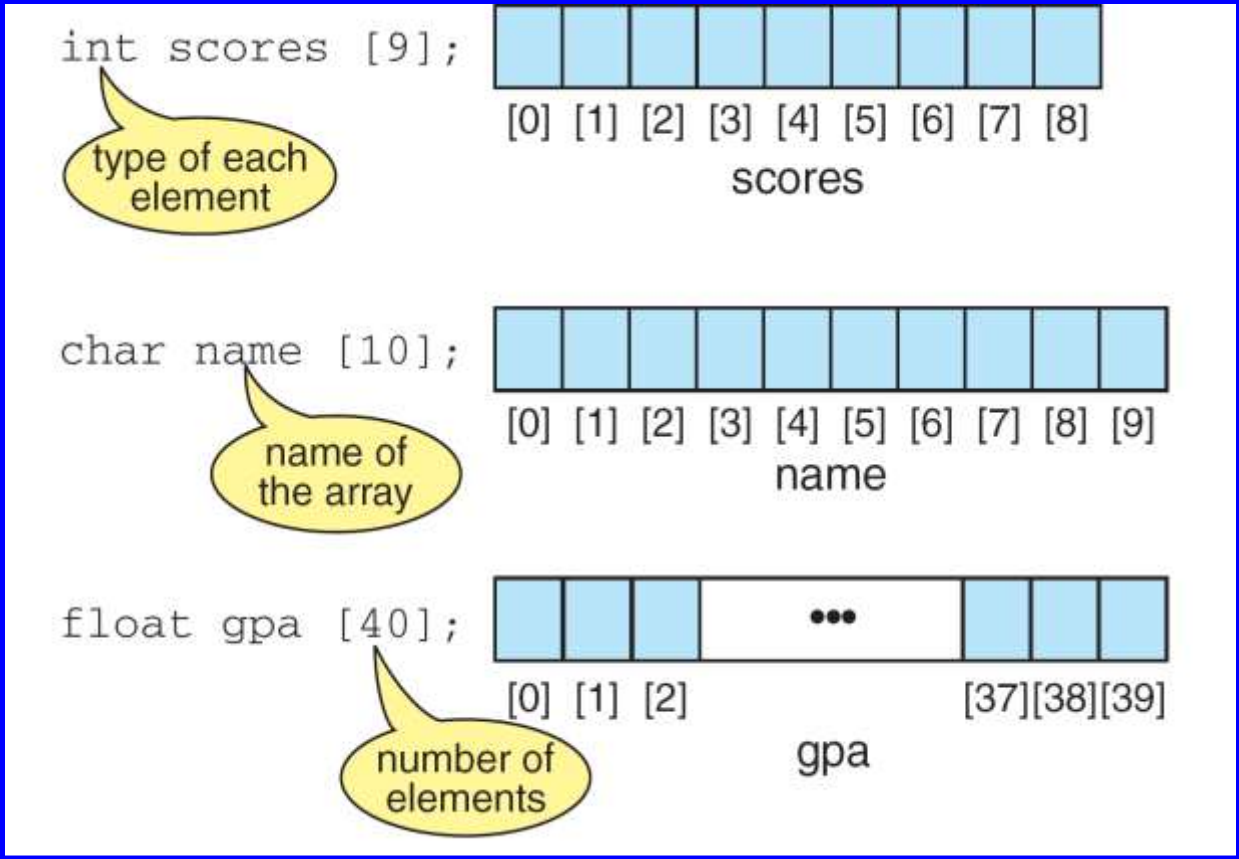
- So what is actually going on when you set up an array?

Memory

- Each element is held in the next location along in memory
- Essentially what the PC is doing is looking at the **FIRST** address (which is **pointed** to by the variable **p)** and then just counts along.



Declaration Examples



Accessing Elements

✓To access an array's element, we need to provide an integral value to identify the index we want to access.

✓We can do this using a constant: **scores[0];**
✓We can also use a variable:

```
for(i = 0; i < 9; i++)
{
        scoresSum += scores[i];
}
```

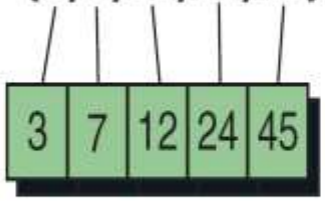
Accessing Elements

- ✓ We can initialize fixed-length array elements when we define an array.
- ✓ If we initialize fewer values than the length of the array, C++ assigns zeroes to the remaining elements.

Array Initialization Examples

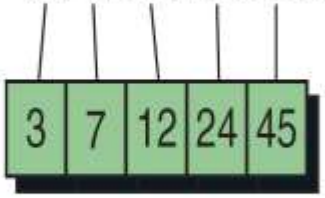
(a) Basic Initialization

```
int numbers[5] = {3,7,12,24,45};
```



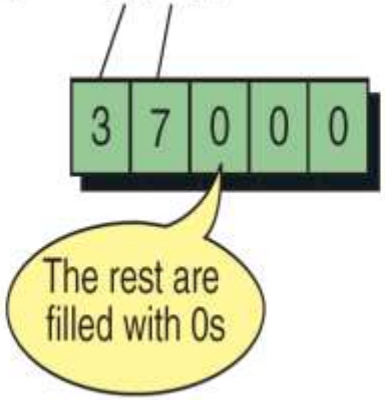
(b) Initialization without Size

```
int numbers[ ] = {3,7,12,24,45};
```



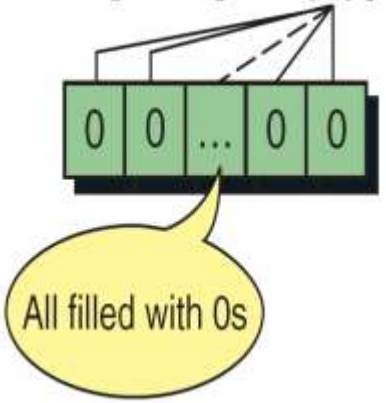
(c) Partial Initialization

```
int numbers[5] = {3,7};
```



(d) Initialization to All Zeros

```
int lotsOfNumbers [1000] = {0};
```



Inserting Values using a *for* Loop

✓Once we know the length of an array or the size of the array, we can input values using a **for** loop:

```
arrayLength = 9;

for (j = 0; j < arrayLength; j++)
{
        cin>> scores[j];
}//end for
```

Assigning Values to Individual array Elements

✓We can assign any value that reduces to an array's data type:

```
scores[5] = 42;
scores[3] = 5 + 13;
scores[8] = x + y;
scores[0] = pow(7, 2);
```

Copying Entire Arrays

✓We **cannot** directly copy one array to another, even if they have the same length and share the same data type.
Instead, we can use a **for** loop to copy values:

```
for(m = 0; m < 25; m++)

{
        a2[m] = a1[m];
}//end for
```

Swapping Array Elements

✓To swap (or exchange) values, we **must** use a temporary variable. A common novice's mistake is to try to assign elements to one another:

```
/*The following is a logic error*/
numbers[3] = numbers[1];
numbers[1] = numbers[3];

/*A correct approach …*/
temp = numbers[3];
numbers[3] = numbers[1];
numbers[1] = temp;
```

Printing Array Elements

✓To print an array's contents, we would use a **for** loop:

```
for(k = 0; k < 9; k++)
{
        cout<<scores[k];
}//end for
```

Range Checking

- ✓Unlike some other languages, C++ does not provide built-in range checking. Thus, it is possible to write code that will produce “out-of-range” errors, with unpredictable results.

- ✓Common Error (array length is 9):

```
for(j = 1; j <= 9; j++)
{
        cin>>scores[j]);
}//end for
```

Passing Elements to Functions

So long as an array element's data type matches the data type of the formal parameter to which we pass that element, we may pass it directly to a function:

```
AnyFunction(myArray[4]);
…
void AnyFunction(int anyValue)
{
        …
}
```

Passing Elements to Functions

✓We may also pass the address of an element:

```
anyFunction(&myArray[4]);
…
void anyFunction(int* anyValue)
{
        *anyValue = 15;
}
```

Arrays are Passed by Reference

✓Unlike individual variables or elements, which we pass by value to functions, C++ passes arrays to functions by reference.

✓The array's name identifies the address of the array's first element.

✓To reference individual elements in a called function, use the indexes assigned to the array in the calling function.

Passing a Fixed-Length Array

- ✓When we pass a fixed-length array to a function, we need only to pass the array's name:

AnyFunction(myArray);

- ✓In the called function, when can declare the formal parameter for the array using empty brackets (preferred method):

void AnyFunction(int passArray[ ]);

- ✓or, we can use a pointer:

void AnyFunction(int* passArray);

Passing a Variable-Length Array

- ✓When we pass a variable-length we must define and declare it as variable length. In the function declaration, we may use an asterisk as the array size or we me use a variable name:

void AnyFunction(int size, int passArray[*]);

- ✓In the function definition, we **must** use a variable (that is within the function's scope) for the array size:

void AnyFunction(int size, int passArray[size]);

Searching

&

Sorting Techniques

Searching

- ***Searching*** is the process of finding the location of a target value within a list.
- C++ supports type basic algorithms for searching arrays:

  - The **Sequential Search** (may use on an unsorted list)

  - The **Binary Search** (must use only on a sorted list)

Sequential Search

✓We should only use the sequential search on small lists that aren't searched very often.

✓The sequential search algorithm begins searching for the target at the first element in an array and continues until (1) it finds the target or (2) it reaches the end of the list without finding the target

Sequential Search Program

```
Found=0;
for(i=0; i<size; i++)
{
If (a[i]==SKey)
Found=1; pos=i;
}
If(Found)
cout<<“Element is found @ position ” <<pos+1;
else
cout<< “Element Not exists in the list”;
```

Binary Search

✓We should use the binary search on large lists (>50 elements) that are sorted.

✓The binary search divides the list into two halves.

✓First, it searches for the target at the midpoint of the list. It can then determine if the target is in the first half of the list or the second, thus eliminating half of the values.

✓With each subsequent pass of the data, the algorithm re-calculates the midpoint and searches for the target.

✓With each pass, the algorithm narrows the search scope by half.

✓The search always needs to track three values – the midpoint, the first position in the scope and the last position in the scope.

Binary Search- needs sorted list

```
beg=1;
end=n;
mid=(beg+end)/2;                    // Find Mid Location of
   Array
while(beg<=end && a[mid]!=item)
{
   if(a[mid]<item)       beg=mid+1;
   else                  end=mid-1;
   mid=(beg+end)/2;
}
if(a[mid]==item)
   {     cout<<"\nData is Found at Location : "<<mid;    }
else  {          cout<<"Data is Not Found“;                  }
```

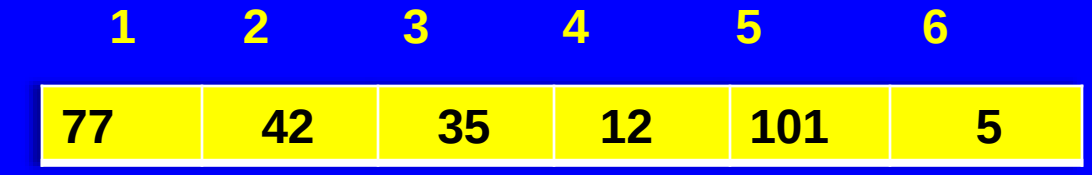
Sorting Techniques

Objectives

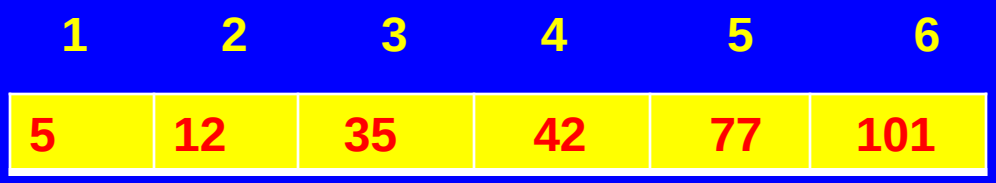
1. What is sorting?
2. Various types of sorting technique.
3. Selection sort
4. Bubble sort
5. Insertion sort
6. Comparison of all sorts
7. CBSE questions on sorting
8. Review
9. Question hour

Sorting

- ✓ Sorting takes an unordered collection and makes it an ordered one i.e. either in ascending or in descending order.



(UNSORTED ARRAY)



(SORTED ARRAY)

Sorting

- ✓Sorting is the “process through which data are arranged according to their values.”
- ✓Sorted lists allow us to search for data more efficiently.
- ✓Sorting algorithms depend heavily on swapping elements – **remember, to swap elements, we need to use a temporary variable!**
- ✓We’ll examine three sorting algorithms – the Selection Sort, the Bubble Sort and the Insertion Sort.

Types of Sorting algorithms

There are many, many different types of sorting algorithms, but the primary ones are:

- ✓ Bubble Sort
- ✓ Selection Sort
- ✓ Insertion Sort
- ✓ Merge Sort
- ✓ Shell Sort
- ✓ Heap Sort
- ✓Quick Sort
- ✓Radix Sort
- ✓Swap sort

Selection Sort

- ✓ Divide the list into two sublists: sorted and unsorted, with the sorted sublist preceding the unsorted sublist.
- ✓ In each pass,
- ✓ Find the smallest item in the unsorted sublist
- ✓ Exchange the selected item with the first item in the sorted sublist.
- ✓ Thus selection sort is known as exchange selection sort that requires single array to work with.

Selection sort program

```
void selectionSort(int a[ ], int N)
{
    int i, j, small;
     for (i = 0; i < (N - 1); i++)
     {
         small = a[i];
      // Find the index of the minimum element
      for (int j = i + 1; j < N; j++)
      {          if (a[j] < small)
              {  small=a[j];
                 minIndex = j;
               }
      }
      swap(a[i], small);
}  }
```

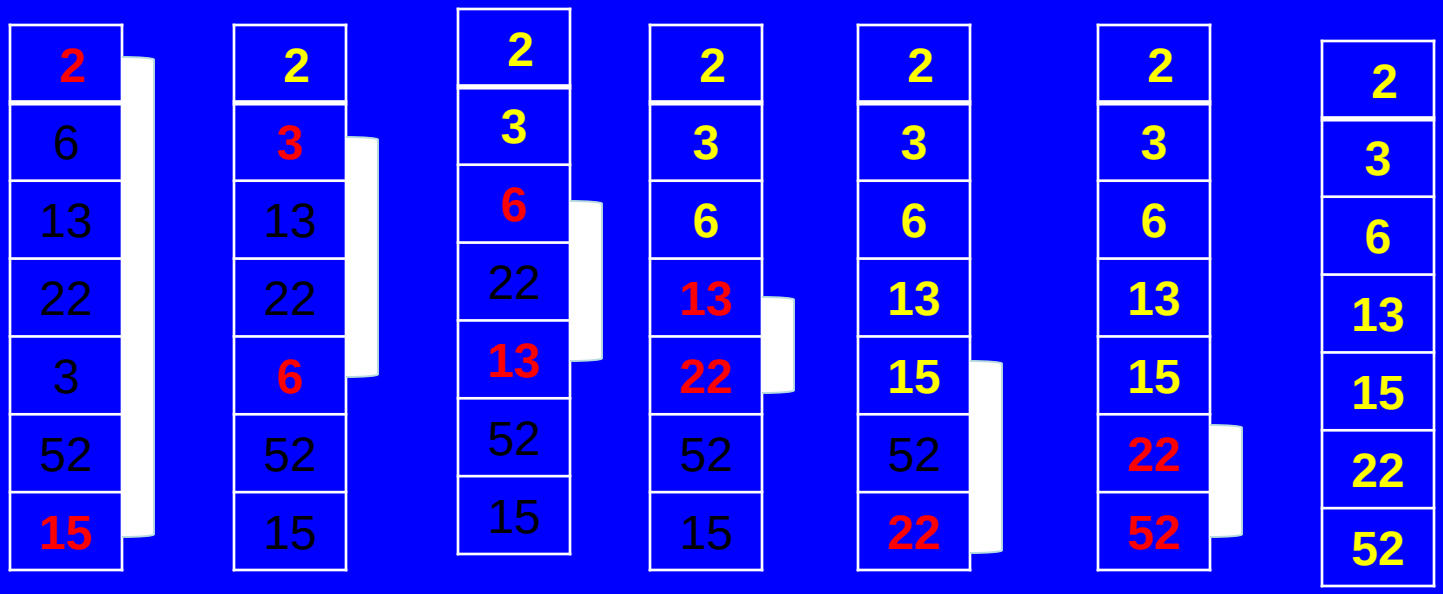
Selection sort example

Array **numlist** contains

15	6	13	22	3	52	2

Smallest element is 2. Exchange 2 with element in 1st array position (*i.e.* element 0) which is 15

Step 1 **Step 2** **Step 3** **Step 4** **Step 5** **Step 6** **Step 7**



Observations about Selection sort

Advantages:

1. Easy to use.
2. The efficiency DOES NOT depend on initial arrangement of data
3. Could be a good choice over other methods when data moves are costly but comparisons are not.

Disadvantages:

1. Performs more transfers and comparison compared to bubble sort.
2. The memory requirement is more compared to insertion & bubble sort.

Bubble Sort

Basic Idea:-

- ✓ Divide list into sorted the unsorted sublist is "bubbled" up into the sorted sublist.
- ✓ Repeat until done:

  1. Compare adjacent pairs of records/nodes.

  2. If the pair of nodes are out of order, exchange them, and continue with the next pair of records/nodes.

  3. If the pair is in order, ignore and unsorted sublists.

- ✓ Smallest element in them and continue with the next pair of nodes.

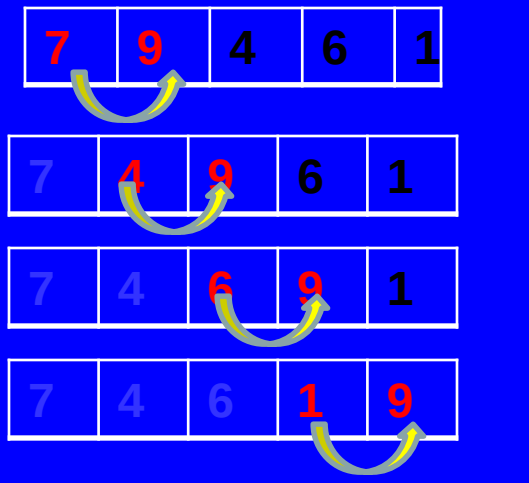
Bubble Sort Program

```
void BubbleSort(int a[],int N)
{
   int  i , j , tmp;
   for (i=0;i<N; i++)
   {
     for(j=0 ; j < (N-1)-i ; j++)
     {
         if (a[j]>a[j+1])      //swap the values if previous is greater
         {                      // than ext one
            tmp=a[j];
            a[j]=a[j+1];
           a[j+1]=tmp;
         }
      }      }
```

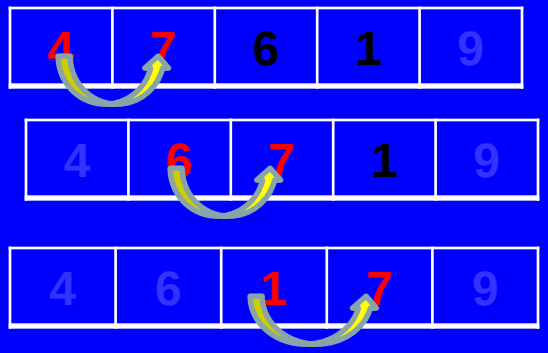
Bubble sort example

Initial array elements

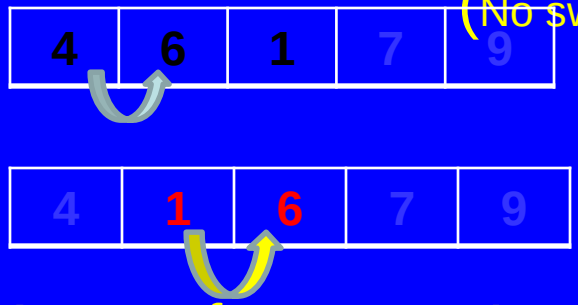
Array after pass-1



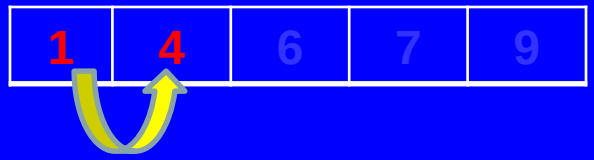
Array after pass-2



Array after pass-3 (No swap)



Array after pass-4



Final sorted array

Observations about Bubble Sort

Advantages:

1. Easy to understand & implement.
2. Requires both comparison and swapping.
3. Lesser memory is required compared to other sorts.

Disadvantages:

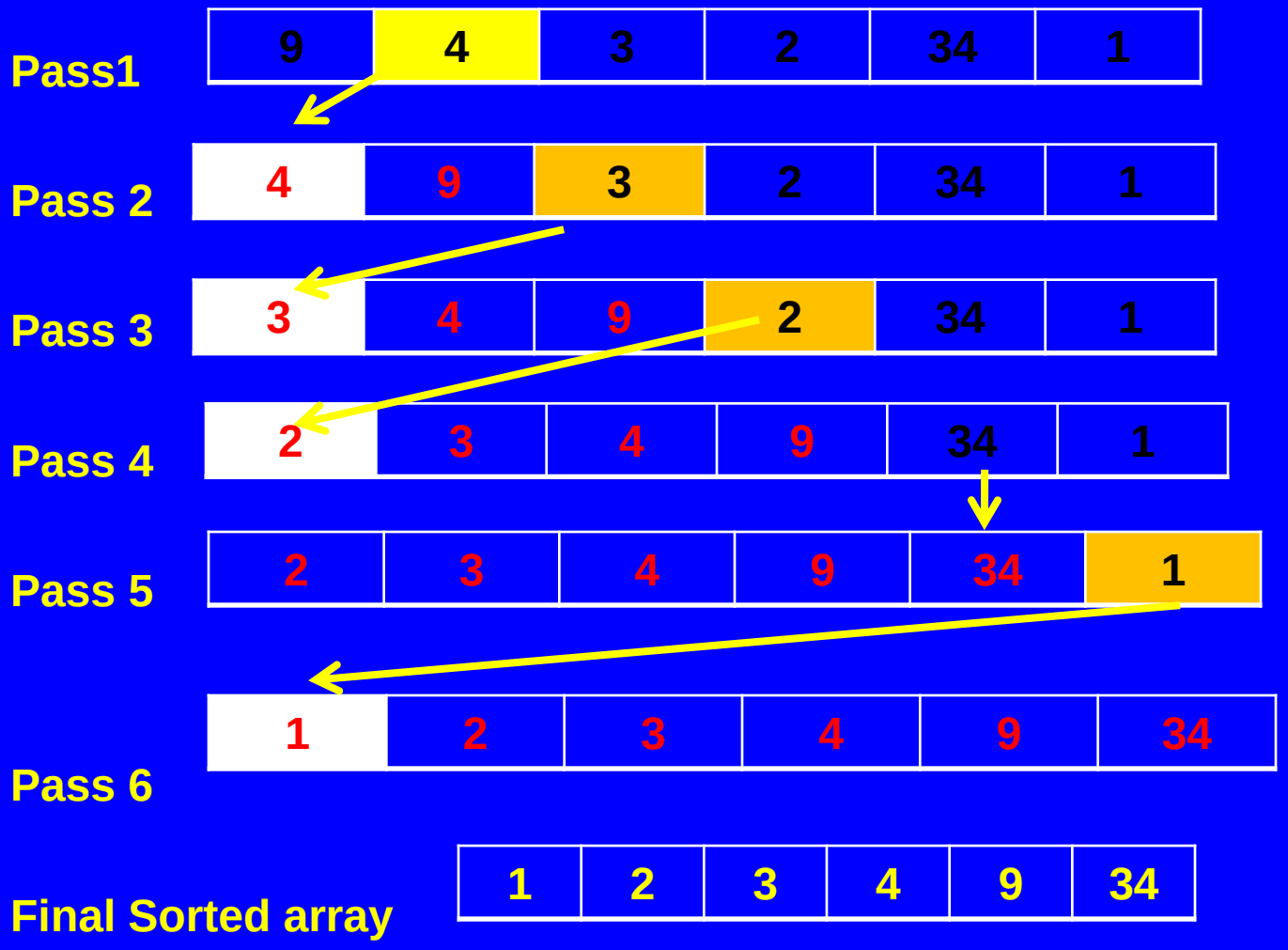
1. As the list grows larger the performance of bubble sort get reduced dramatically.
2. The bubble sort has a higher probability of high movement of data.

Insertion sort

- ✓ Commonly used by card players: As each card is picked up, it is placed into the proper sequence in their hand.
- ✓ Divide the list into a sorted sublist and an unsorted sublist.
- ✓ In each pass, one or more pieces of data are removed from the unsorted sublist and inserted into their correct position in a sorted sublist.

Insertion sort program

Initially array contents are (9,4,3,2,34,1)



Insertion sort program

```
void insertionSort(int a[ ], int N)
{
    int temp,i, j;
    a[0]=INT_MIN;
   for(i=1;i<N ; i++)
   {
      temp=a[i]; j=i-1;
      while(temp < AR[j])
       {  a[j+1]=a[j];
          j--;
       }
a[j+1]=temp;
}
}
```

Observations about insertion sort

Advantages:

1. Simplicity of the insertion sort makes it a reasonable approach.
2. The programming effort in this techniques is trivial.
3. With lesser memory available insertion sort proves useful.

Disadvantage:

1. The sorting does depend upon the distribution of element values.
2. For large arrays -- it can be extremely inefficient!

Merging of two sorted arrays into third array in sorted order

- ✓ Algorithm to merge arrays a[m](sorted in ascending order) and b[n](sorted in descending order) into third array C [n + m] in ascending order.

```
Merge(int a[ ], int m, int b[n], int c[ ])
{
int i=0; //    i points to the smallest element of the array a
    which is at index 0

int j=n-1;// j points to the smallest element of the array b
//which is at the index m-1 since b is sorted in
    //descending order
```

Merging of two sorted arrays into third array in sorted order

```
int k=0;  //k points to the first element of the array c
while(i<m&&j>=0)
      {
          if(a[i]<b[j])
         c[k++]=a[i++]; // copy from array a into array c and
                                then increment i and k
       else

          c[k++]=b[j--]; // copy from array b into array c and
                                then decrement j and increment k
      }
```

Merging of two sorted arrays into third array in sorted order

```
while(i<m)        //copy all remaining elements of array a

    c[k++]=a[i++];

while(j>=0)       //copy all remaining elements of array b

    c[k++]=b[j--];
}  // end of Function.
```

Merging of two sorted arrays into third array in sorted order

```
void main()
{
int a[5]={2,4,5,6,7},m=5; //a is in ascending order
int b[6]={15,12,4,3,2,1},n=6; //b is in descending order
int c[11];
merge(a, m, b, n, c);
cout<<”The merged array is :\n”;
for(int i=0; i<m+n; i++)
    cout<<c[i]<”, “;
}
```

Output is

The merged array is:

1, 2, 2, 3, 4, 4, 5, 6, 7, 12, 15

CBSE Questions on Sorting

1.Consider the following array of integers

42,29,74,11,65,58, use insertion sort to sort them in ascending order and indicate the sequence of steps required.

2. The following array of integers is to arranged in ascending order using the bubble sort technique : 26,21,20,23,29,17. Give the contents of array after each iteration.

3. Write a C++ function to arrange the following Employee structure in descending order of their salary using bubble sort. The array and its size is required to be passed as parameter to the function. Definition of Employee structure

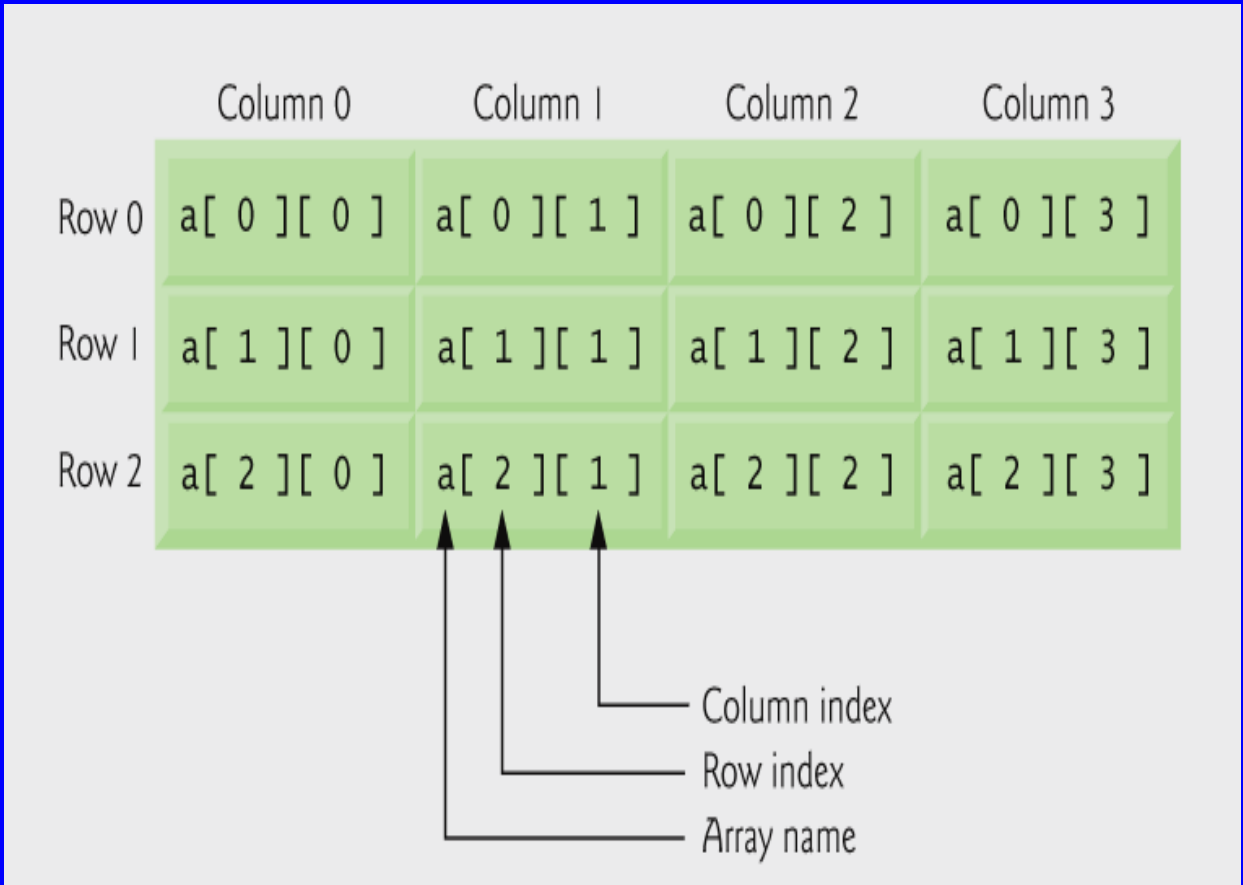
```
struct Employee {  int Eno;
                   char Name[20];
                   float salary;    };
```

Revision

1. In selection sort, algorithm continuous goes on finding the smallest element and swap that element with appropriate position element.
2. In bubble sort, adjacent elements checked and put in correct order if unsorted.
3. In insertion sort, the exact position of the element is searched and put that element at its particular position.

2D Array Definition

- ✓ To define a fixed-length two-dimensional array:
  int table[5][4];
- ✓ 2-D Array a[m][n];m Rows and n columns - int a[3][4];



Implementation of 2-D Array in memory

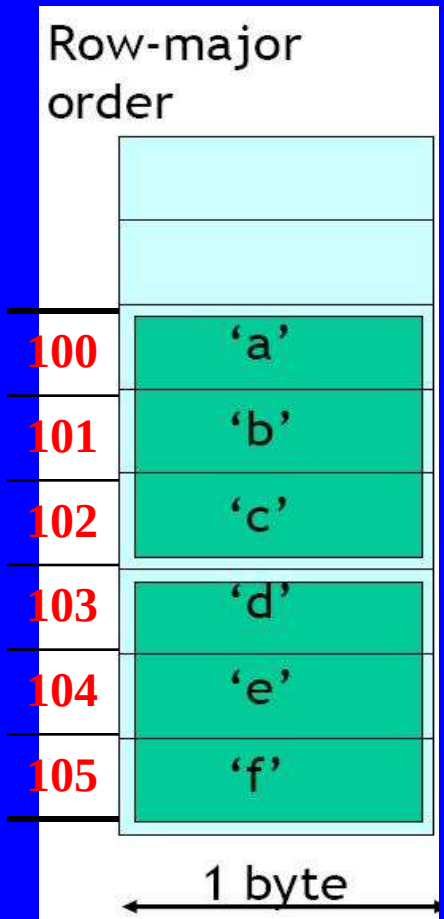
The elements of 2-D array can be stored in memory by two-Linearization method :

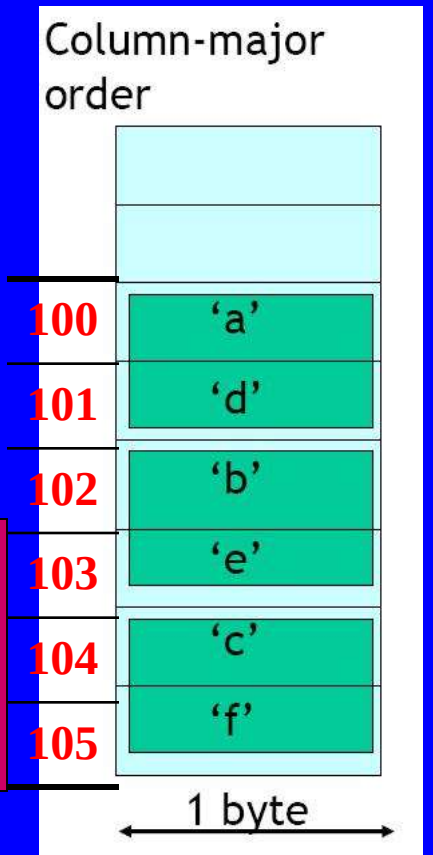
1. **Row Major**
2. **Column Major**

Here is a 2x3 array of characters to be stored:

'a' 'b' 'c'
'd' 'e' 'f'

'a', 'b', 'c', 'd', 'e', 'f'





Therefore,the memory address calculation will be different in both the methods.

Implementation of 2-D Array in memory

1. Row Major Order for a[m][n] or a[0…m-1][0…n-1]

Address of a[I, J] element = B + w(N_c ($I-L_r$)+($J-L_c$)

2.Column Major Order- a[m][n] or a[0…m-1][0…n-1]

Address of a[I, J] element = B + w(N_r ($J-L_c$)+($I-L_r$)

B = Base Address, I = subscript (row), J = subscript (column), N_c = No. of column, N_r = No. of rows, L_r = row lower bound(0) , L_c = column lower bound (0), U_c=column upper bound(n-1) ,U_r =row upper bound (m-1), w = element size.

Implementation of 2-D Array in memory

1. Row Major Order for a[m][n] or a[0…m-1][0…n-1]

Address of a[I, J] element = B + w(N_c ($I-L_r$)+($J-L_c$)

2.Column Major Order- a[m][n] or a[0…m-1][0…n-1]

Address of a[I, J] element = B + w(N_r ($J-L_c$)+($I-L_r$)

B = Base Address, I = subscript (row), J = subscript (column), N_c = No. of column, N_r = No. of rows, L_r = row lower bound(0) , L_c = column lower bound (0), U_c=column upper bound(n-1) ,U_r =row upper bound (m-1), w = element size.

Memory Address Calculation

1. Row Major Order formula

$$X = B + W * [I * C + J]$$

2. Column Major Order formula

$$X = B + W * [I + J * R]$$

Memory Address Calculation

- ✓ An array S[10][15] is stored in the memory with each element requiring 4 bytes of storage. If the base address of S is 1000, determine the location of S[8][9] when the array is S stored by CBSE 1998 OUTISDE DELHI 3
- ✓ (i) Row major (ii) Column major.

ANSWER

- ✓ Let us assume that the Base index number is [0][0].
- ✓ Number of Rows = R = 10
- ✓ Number of Columns = C = 15 Size of data = W = 4
- Base address = B = S[0][0] = 1000 Location of S[8][9] = X

Memory Address Calculation

(i) When S is stored by Row Major

X = B + W * [8 * C + 9]

= 1000 + 4 * [8 * 15 + 9]

= 1000 + 4 * [120 + 9]

= 1000 + 4 * 129

= 1516

(ii) When S is stored by Column Major

X = B + W * [8 + 9 * R]

= 1000 + 4 * [8 + 9 * 10]

= 1000 + 4 * [8 + 90]

= 1000 + 4 * 98

= 1000 + 392

= 1392

Programs on 2D Arrays

1. sum of rows a[3][2]

```
for(row=0;row<3;row++)
{ sum=0;
for(col=0;col<2;col++)
sum+=a[row][col];
cout<<"sum is "<<sum; }
```

2. sum of columns a[2][3]

```
for(col=0;col<3;col++)
{sum=0;
 for(row=0;row<2;row++)
sum+=a[row][col];
cout<<"column sum is"<<sum;}
```

Programs on 2D Arrays

3. sum of left diagonals a[3][3]

```
sum=0;
for(row=0;row<3;row++)
sum+=a[row][row]
```

4. sum of right diagonals a[3][3]

```
sum=0;
for(row=0,col=2;row<3;row++,col--)
sum+=a[row][col]
```

5. Transpose of a matrix a[3][2] stored in b[2][3]

```
for(row=0;row<3;row++)
for(col=0;col<2;col++)
b[col][row]=a[row][col];
```

Programs on 2D Arrays

6. **Display the lower half** a[3][3]

```
for(row=0;row<3;row++)
for(col=0;col<3;col++)
if(row<col)
cout<<a[row][col];
```

7. **Display the Upper Half** a[3][3]

```
for(row=0;row<3;row++)
for(col=0;col<3;col++)
if(row>col)
cout<<a[row][col];
```

Programs on 2D Arrays

8. **ADD/Subtract matrix**

```
a[2][3]+/-b[2][3]=c[2][3]
for(row=0;row<2;row++)
for(col=0;col<3;col++)
c[row][col]=a[row][col]+/- b[row][col]
```

9. **Multiplication** a[2][3]*b[3][4]=c[2][4]

```
for(row=0;row<2;row++)
for(col=0;col<4;col++)
{c[row][col]=0;
 for(k=0;k<3;k++)
c[row][col]+=a[row][k]*b[k][col]  }
```

Programs on 1D Arrays

1. **Reversing an array**

```
j=N-1;
for(i=0;i<N/2;i++)
{     temp=a[i];
      a[i]=a[j];
      a[j]=temp;    j--;  }
```

2. **Exchanging first half with second half** (array size is even)

```
      for(i=0,j=N/2;i<N/2;i++,j++)
      {         temp=a[i];
                 a[i]=a[j];
                a[j]=temp;  }
```

Programs on 1D Arrays

3. **Interchanging alternate locations**

(size of the array will be even)

```
for(i=0;i<N;i=i+2)
{ temp= a[i]; //swapping the alternate
   a[i]=a[i+1]; //locations using third
   a[i+1]=temp;} //variable
```