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Sorting

1) No. of Comparision ↓

2) No. of swap ↓

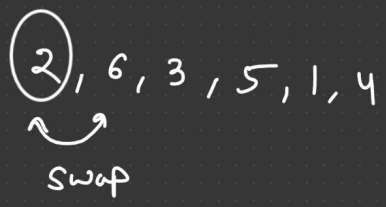
3) Memory usage → In-place ✓
   → x

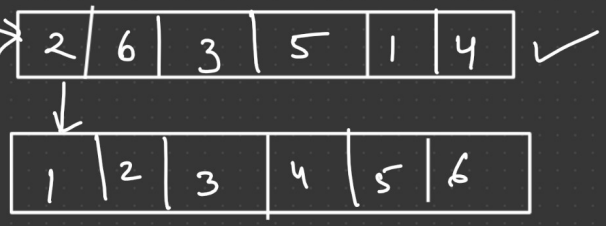
4) Stability :- Maintains relative ordering of duplicate no. ✓

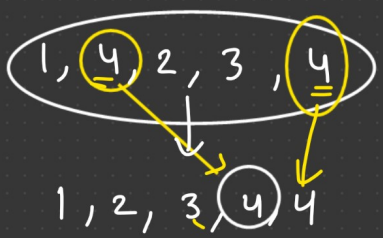
5) Adaptability :- ✓

6) Internal Sort :- RAM

7) External Sort :-







Bubble Sort

I st Iteration :-

2, 8, 3, 5, 9, 8, 12, 11

swap

2, 3, 8, 5, 9, 8, 12, 11

swap

2, 3, 5, 8, 9, 8, 12, 11

swap

2, 3, 5, 8, 8, 9, 12, 11

swap

2, 3, 5, 8, 8, 9, 11 | 12

maximum element now is in right place

II nd Iteration :-

Example:-

I st Iteration:-

23, 4, 1, 22, 10, 5, 11, 19

swap

4, 23, 1, 22, 10, 5, 11, 19

swap

4, 1, 23, 22, 10, 5, 11, 19

swap

4, 1, 22, 23, 10, 5, 11, 19

swap

4, 1, 22, 10, 23, 5, 11, 19

4, 1, 22, 10, 5, 23, 11, 19

swap

4, 1, 22, 10, 5, 11, 23, 19

4, 1, 22, 10, 5, 11, 19 | 23

II nd Iteration:-

1, 4, 22, 10, 5, 11, 19 | 23

swap

1, 4, 10, 22, 5, 11, 19 | 23

swap

1, 4, 10, 5, 22, 11, 19 | 23

swap

1, 4, 10, 5, 11, 22, 19 | 23

swap

1, 4, 10, 5, 11, 19 | 22, 23

swap

III rd Iteration :-

1, 4, 5, 10, 11, 19 | 22, 23 ✓

I → n

II → n-1

III → n-2

⋮

1

Time complexity :-

$n + (n-1) + (n-2) + \dots + 1$

$= \frac{n(n-1)}{2} = O(n^2)$

Radix Sort

$O(n)$

$O(n^2)$ ✓

$O(n \log n)$ ✓

$O(\log n)$ ✗

```
void bubbleSort( int a[] , int n)
{
   int i, j ;
  for( i= n-1 ; i>=0 ; i--)
   {
     for( j= 0 ; j<i ; j++)
     {
        if(a[j] > a[j+1])
        {
           int t = a[j];
               a[j] = a[j+1];
               a[j+1] = t;
        }
     }
} }
```

0, 1, 2, 3, 4, 5

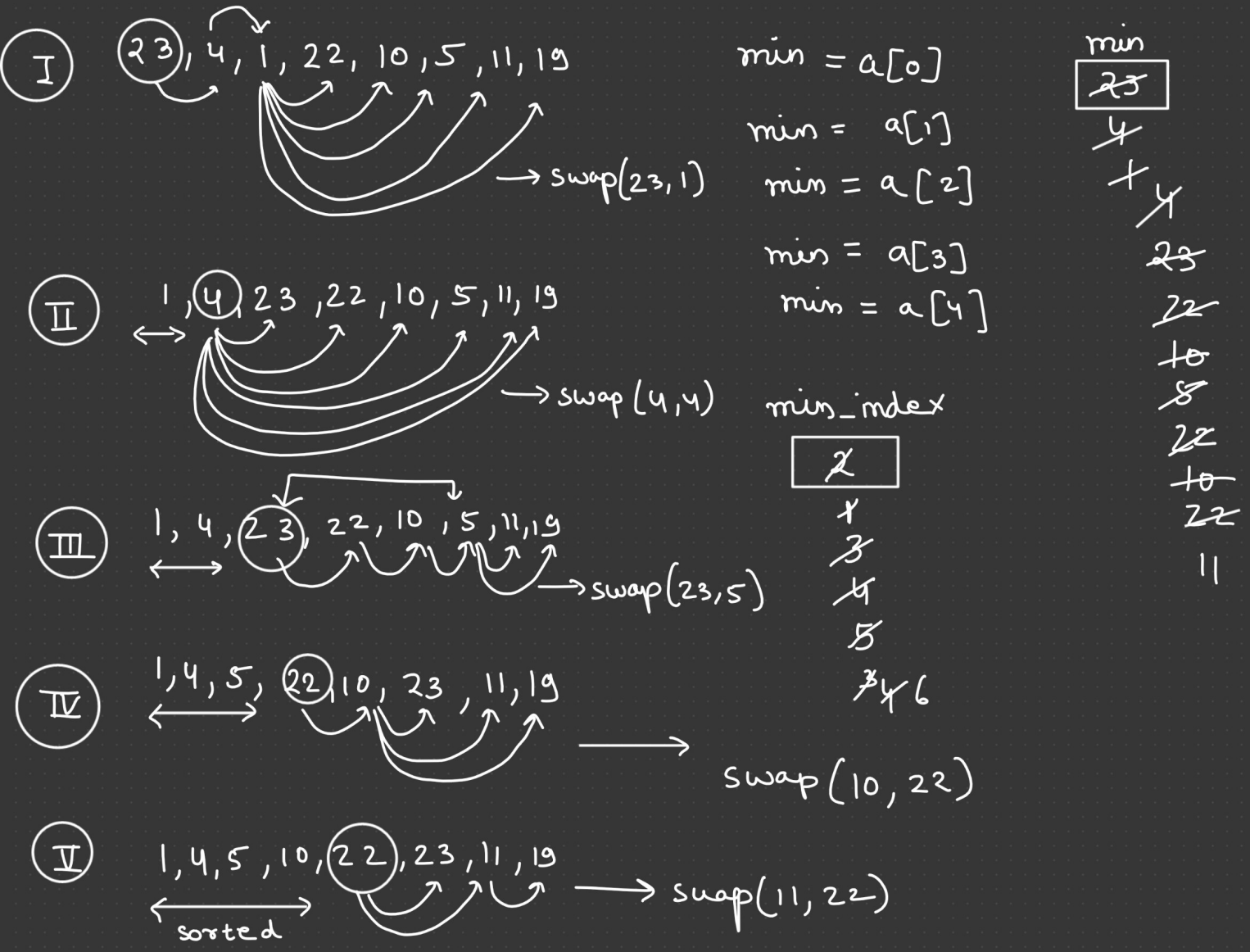
≡ [we can make it adaptable by using flag.]

Selection Sort

Step:-

1) Find the minimum element in the list.
2) Swap it with value in the current position.
3) Repeat this process for all the elements in the entire array.

Ex :-



VI) 1, 4, 5, 10, 11, (23), 22, 19 — min = a[5]

Sorted ⟷ → swap(23, 19)

min	index
~~23~~	~~5~~
~~22~~	~~6~~
19	7

VII) 1, 4, 5, 10, 11, 19, (22), 23 — min = a[6]

sorted ⟷

min	index
22	6

1, 4, 5, 10, 11, 19, 22, 23 → sorted

Time complexity = $O(n^2)$

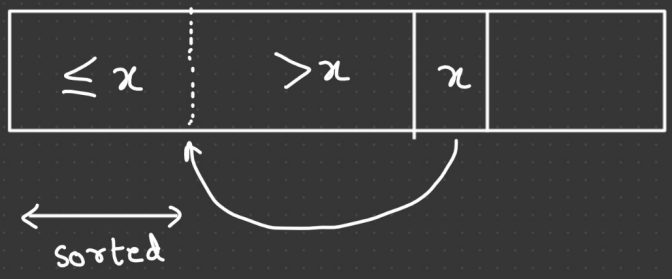
```
void selectionSort( int a[], int n)
{
   int i, j, min, t;
   for(i=0 ; i<n-1; i++)  ⟶ for maintaining the iteration
   {
         min = i;
     for(j=i+1; j<n; j++)
      {
        if(a[min] > a[j])
             min = j;
      }
                          ⟶ swap(a[i], a[min])
       t= a[i];
      a[i] = a[min];
      a[min] = t;
   }
}
```

Insertion Sort

Step:-

1) Select a pivot let say 2nd element of array.

[∵ we assume that 1st element is already sorted]



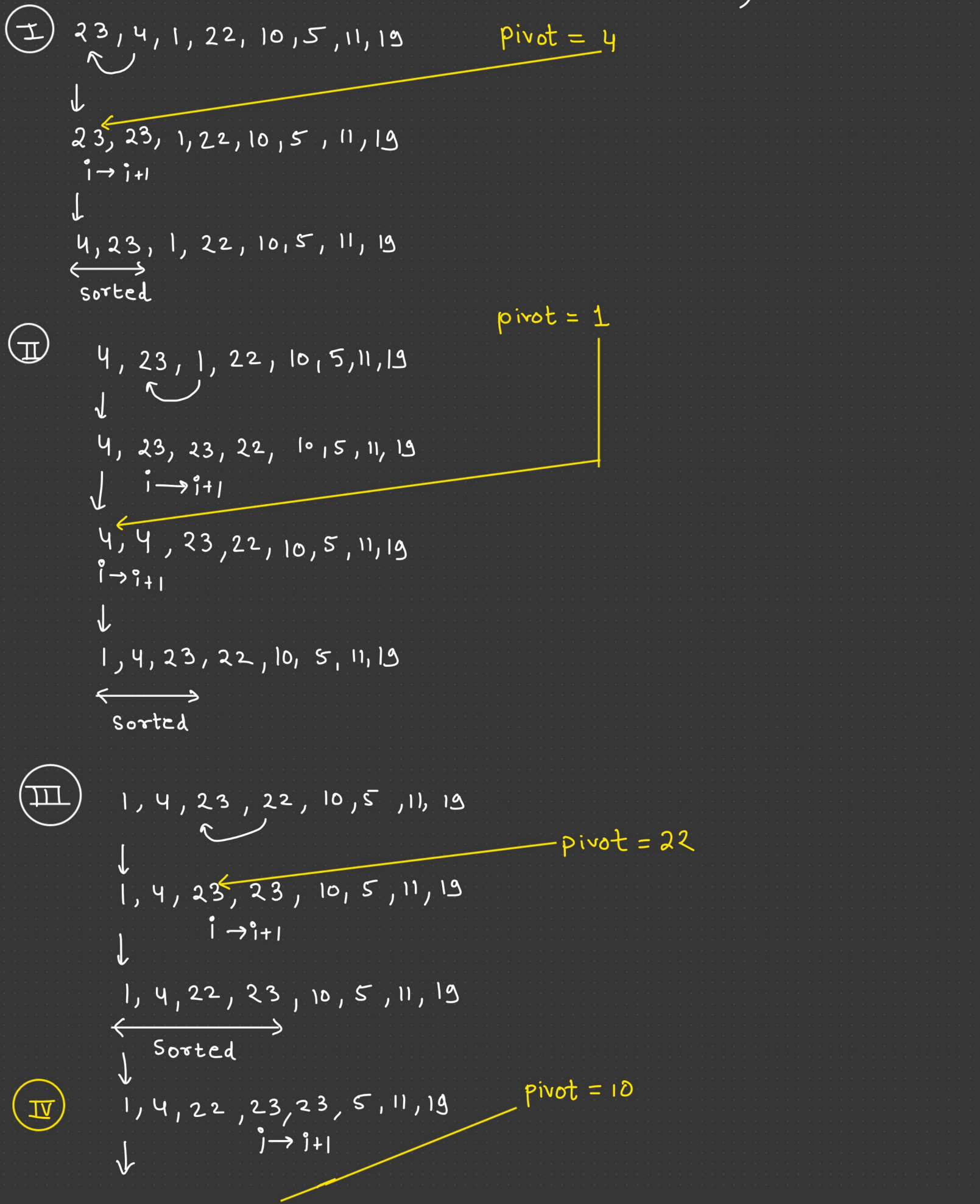
2) we compare pivot with its left sub array and if (pivot < a[i]) then shift a[i] ⟶ a[i+1]

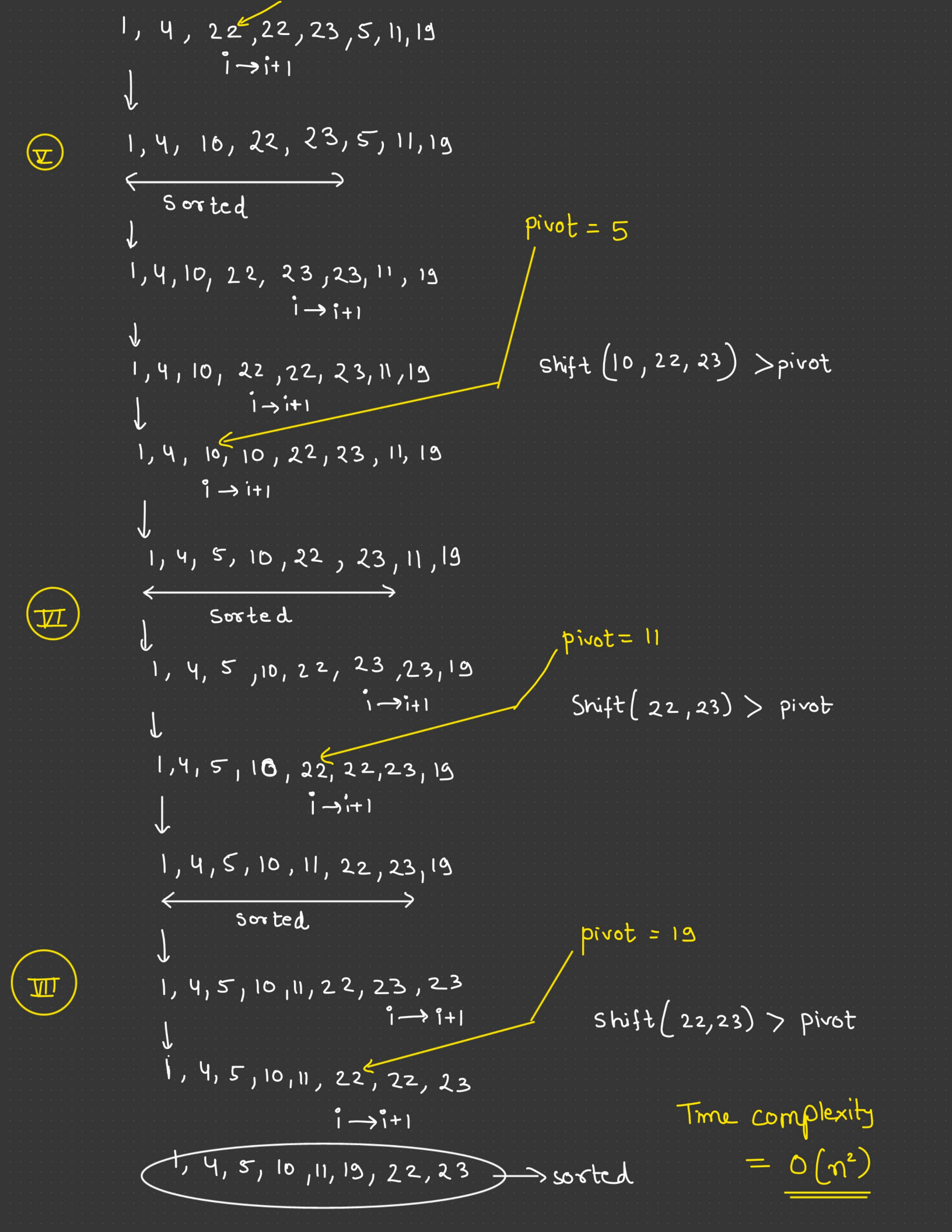
3) Repeat step 2 till the condition satifies.

4) At the end of each iteration, pivot will be placed in its correct position.

5) At the end of all the iteration, Complete array will be sorted.

Example:- (∵ 1st index is already sorted)




1, 4, 22, 22, 23, 5, 11, 19
i → i+1
V
1, 4, 10, 22, 23, 5, 11, 19
Sorted
pivot = 5
1, 4, 10, 22, 23, 23, 11, 19
i → i+1
1, 4, 10, 22, 22, 23, 11, 19
i → i+1
Shift (10, 22, 23) > pivot
1, 4, 10, 10, 22, 23, 11, 19
i → i+1
VI
1, 4, 5, 10, 22, 23, 11, 19
Sorted
pivot = 11
1, 4, 5, 10, 22, 23, 23, 19
i → i+1
Shift (22, 23) > pivot
1, 4, 5, 10, 22, 22, 23, 19
i → i+1
1, 4, 5, 10, 11, 22, 23, 19
sorted
VII
pivot = 19
1, 4, 5, 10, 11, 22, 23, 23
i → i+1
Shift (22, 23) > pivot
1, 4, 5, 10, 11, 22, 22, 23
i → i+1
1, 4, 5, 10, 11, 19, 22, 23
sorted
Time complexity
= O(n²)

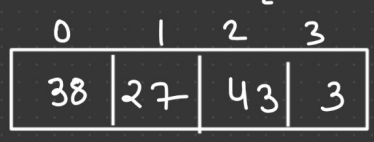
```
void insertionSort(int a[], int n)
{
    for(int i=1; i<n; i++)        ⟶ for selecting the pivot
    {
        int pivot = a[i];
        int j = i-1;
        while(a[j] > pivot && j>=0)
                  C1          C2
        {
            a[j+1] = a[j];
            j--;
        }
        a[j+1] = pivot;
    }
}
```

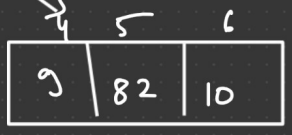
Merge Sort

It is an example Divide & Conquer.

$$mid = \frac{start + end}{2}$$

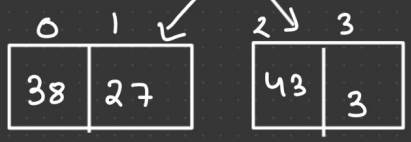
$$= \frac{0+6}{2} = 3$$

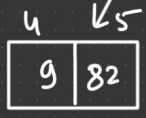


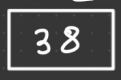


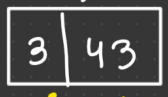
$$mid = \frac{0+3}{2} = 1$$

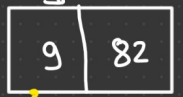
$$mid = \frac{4+6}{2} = 5$$











3<27

27<43

38<43

3<9 1

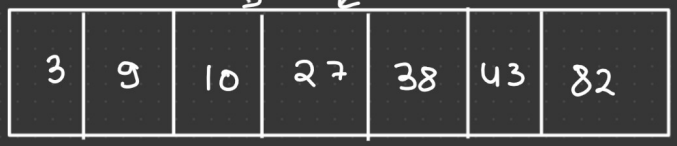
9<27 2

10<27 3

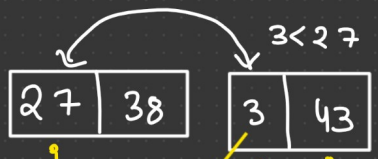
27<82 4

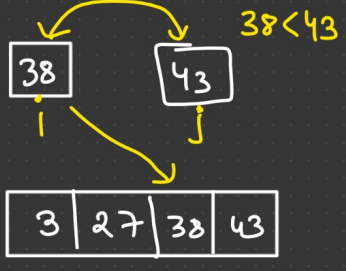
38<82 5

43<82 6

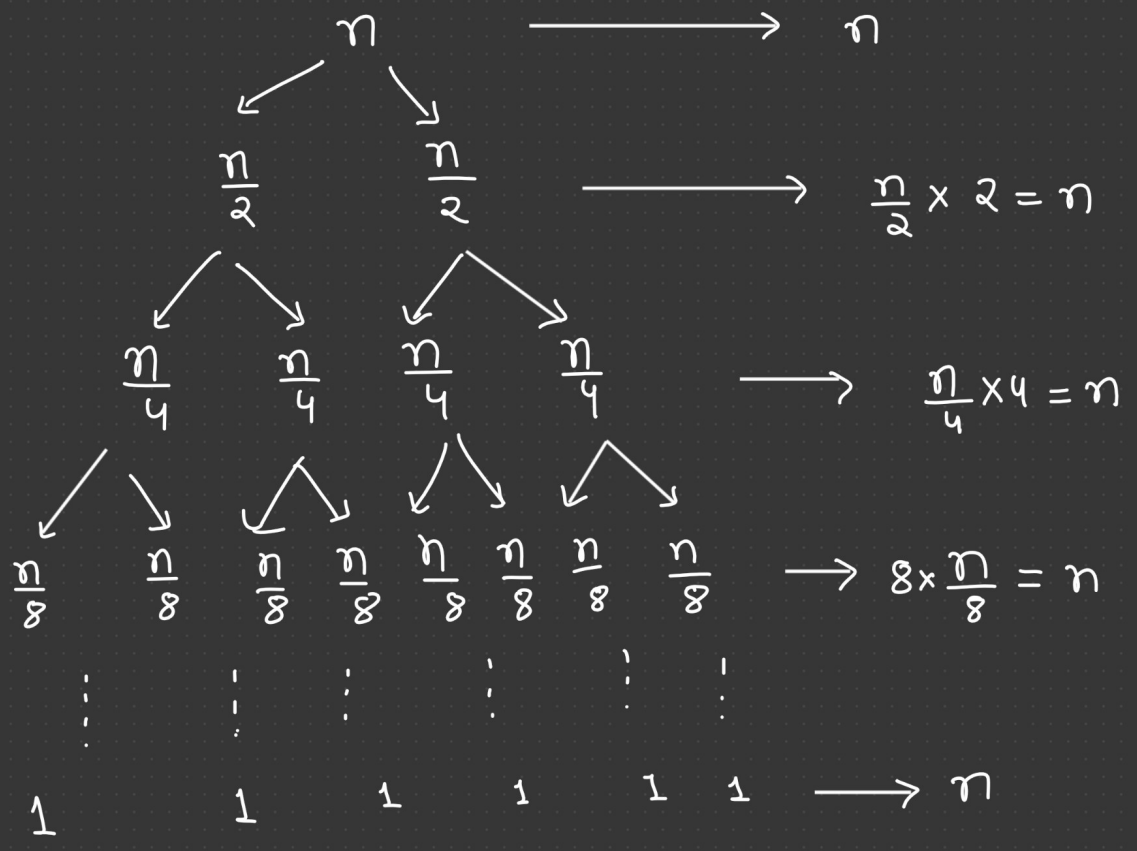


Sorted





Time Complexity:-



Time Complexity :- $n + n + n + \ldots$ (upto height of tree)

$\because$ Height of Tree $= \log n$

$= n(\log n) \Rightarrow O(n \log n)$

$n + n + n = n(1+1+1) = n \times 3$

$n + n + n + n = n(1+1+1+1) = n \times 4$

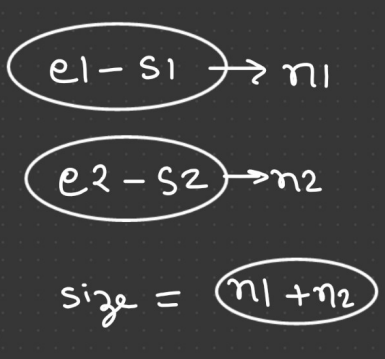
$n + n + \ldots$ $\log n$ time $= n(1 + 1 + 1 + \ldots \log n \text{ times}) = n \times \log n$

```
void mergesort( int a[], int i, int j)
{
    int mid = (i+j)/2;

    if (i< j)
    {
        mergesort(a, i, mid);
        mergesort(a, mid+1, j);
        merge(a, i, mid, mid+1, j);
    }
}
```


```
void merge( int a[], int s1, int e1, int s2, int e2)
{
    int temp[50], i=s1, j=s2, k=0;

    while( i<=e1 && j<=e2)
    {
        if(a[i] < a[j])
        {
            temp[k] = a[i];
            i++, k++;
        }
        else
        {
            temp[k]=a[j];
            j++, k++;
        }
    }
```



```
    while (i <= e1)
    {
        temp[k] = a[i];
        i++, k++;
    }
    while (j<=e2)
    {
        temp [k] = a[j];
        j++, k++;
    }
for (k=0, i = s1 ; i<=e2   ; i++, k++)
{
    a[i] = temp[k];
}
}
```

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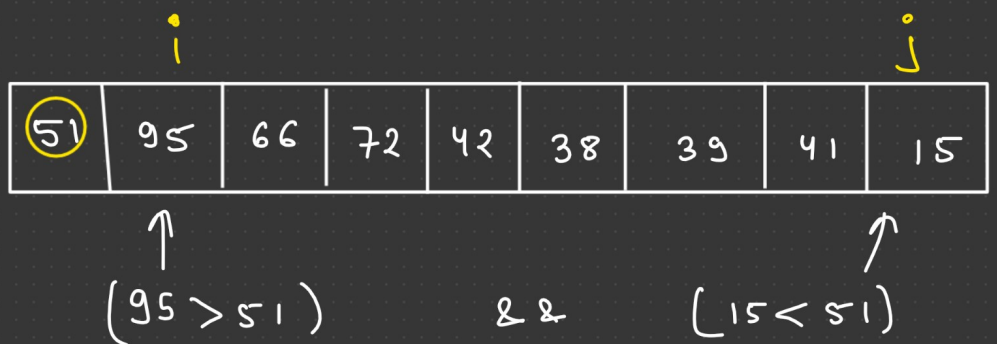
Quick Sort

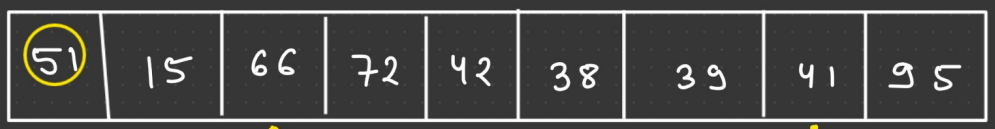
pivot = 51

if(a[i] > pivot && a[j] < pivot)
Swap(a[i], a[j])
i++, j--



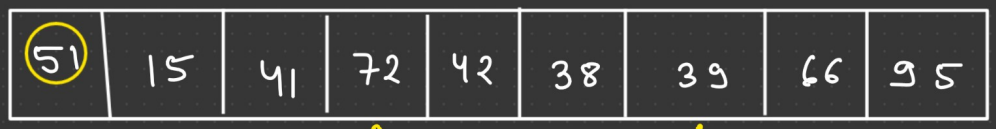
(95 > 51) && (15 < 51)

swap(95, 15)



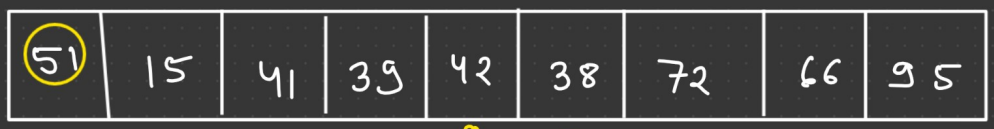
i (66 > 51) && (41 < 51) j

swap(66, 41)



i j

(72 > 51) && (39 < 51) swap(72, 39)



i j

No swap

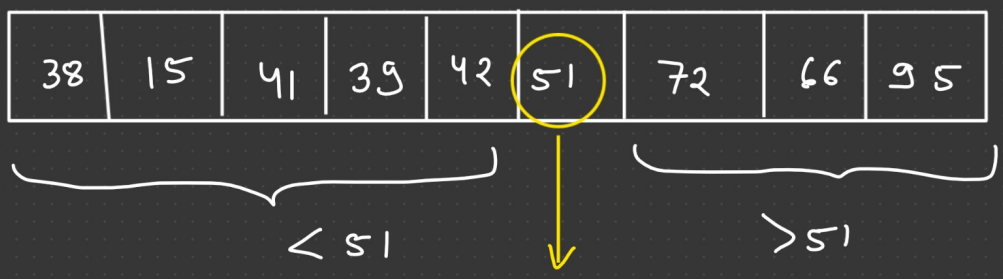
① i > p j < p

② i < p → i++

③ j > p → j--

(42 < 51) && (38 < 51)

Swap(51, 38)

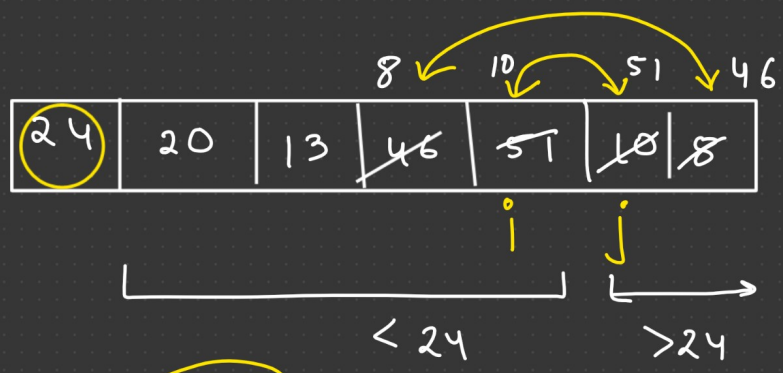


Now 51 is at correct position.

15	38	41	39	42	51	72	66	95

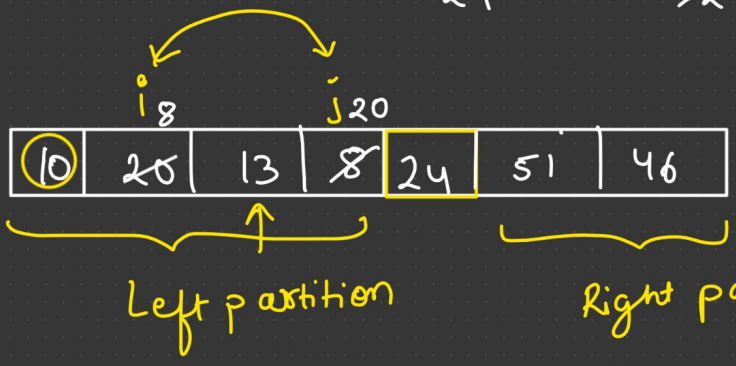
15	38	41	39	42	51	72	66	95

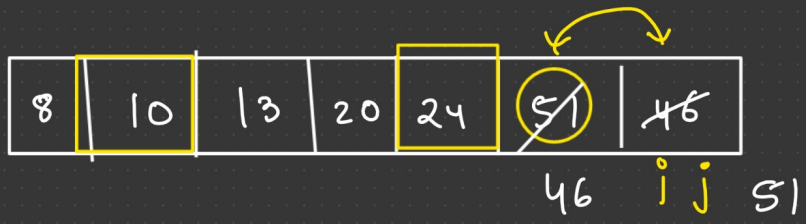
Ex:-

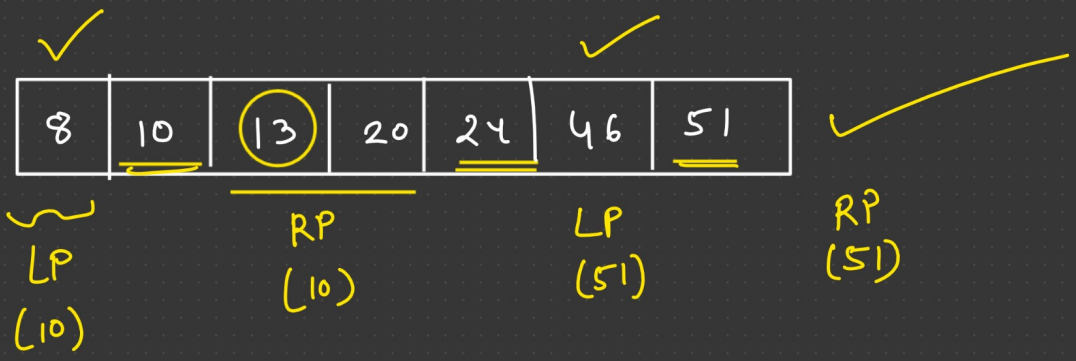


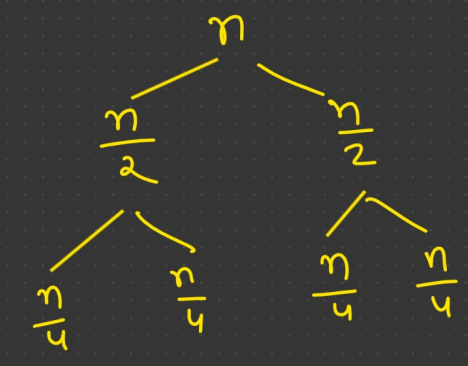
i<P → i++

j>P → j--

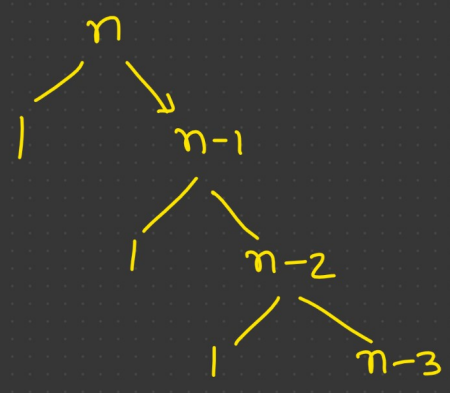








Best = $\Omega(n \log n)$

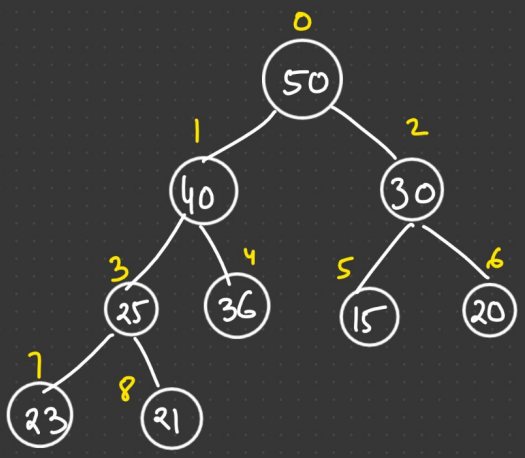


worst case

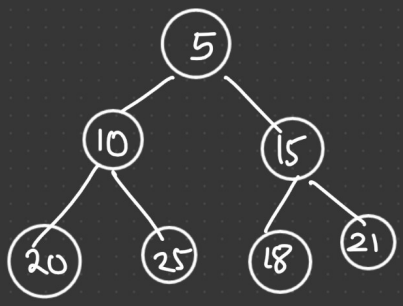
$n + (n-1) + (n-2) + \cdots + 1 = O(n^2)$

Heap Sort

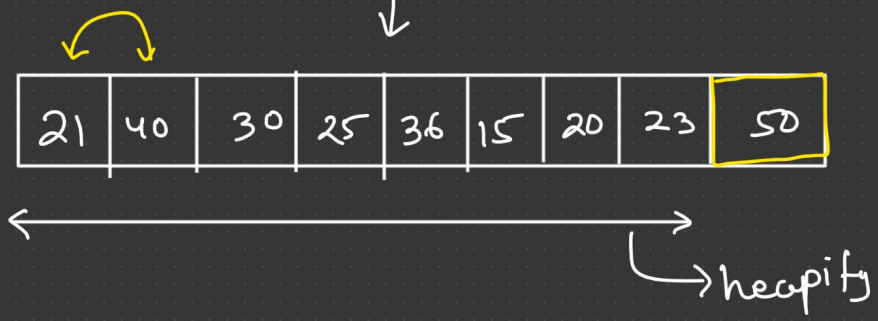
Max Heap

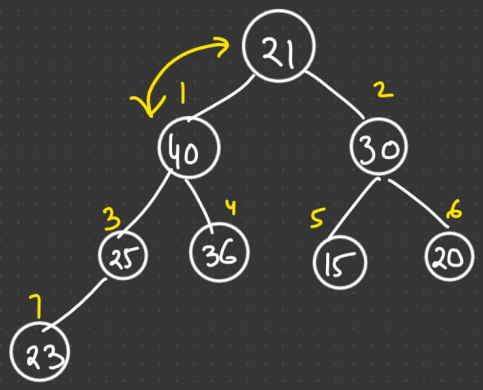


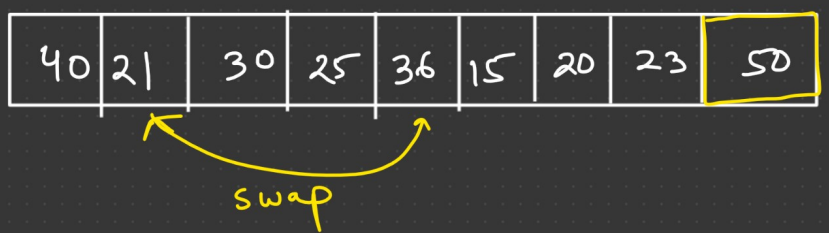
Min Heap

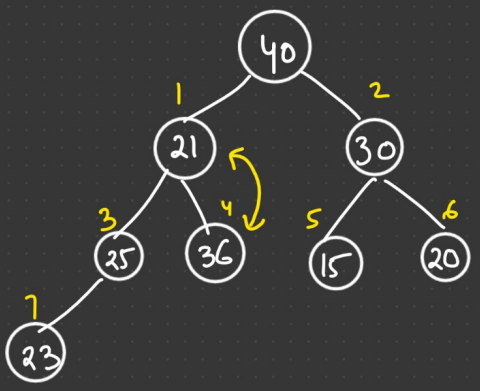


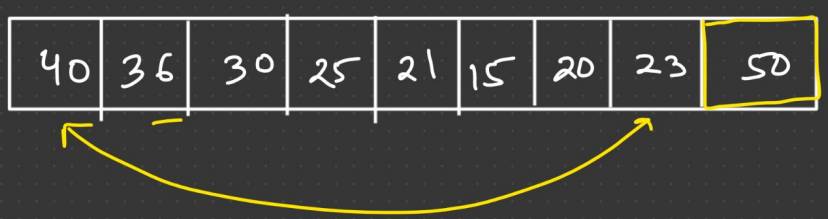
It must be complete tree

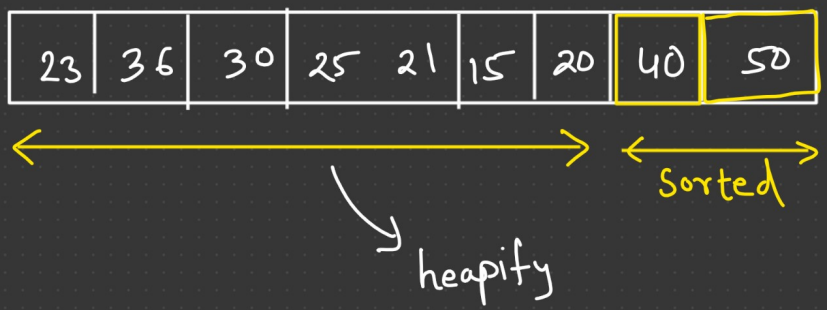








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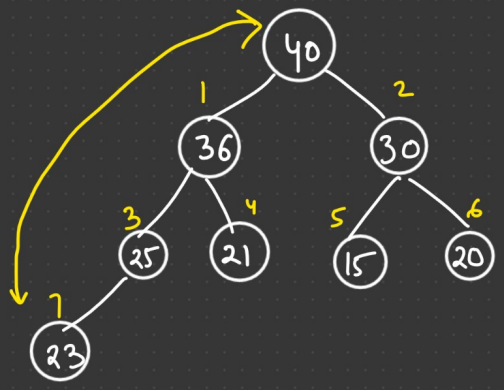
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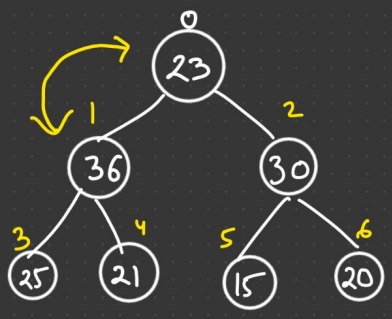
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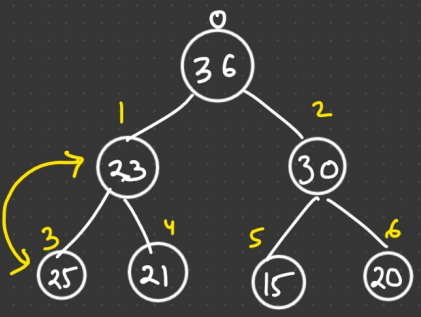
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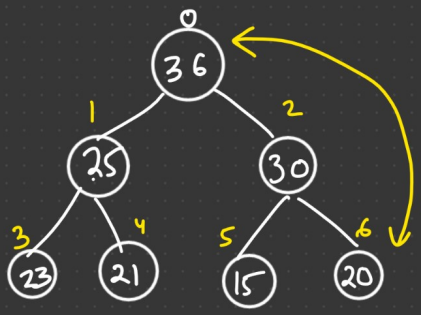
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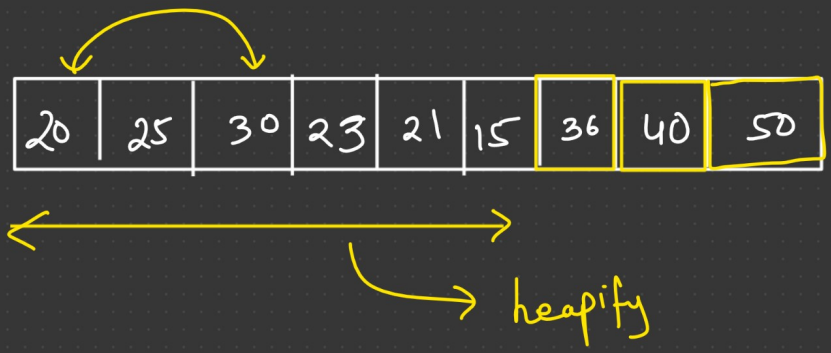
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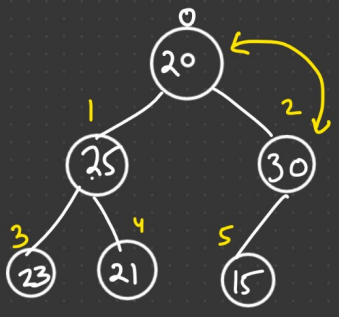
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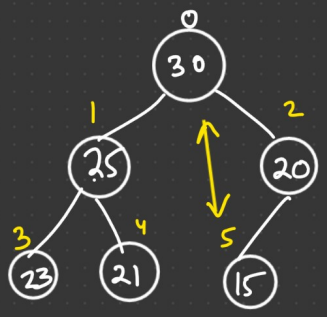
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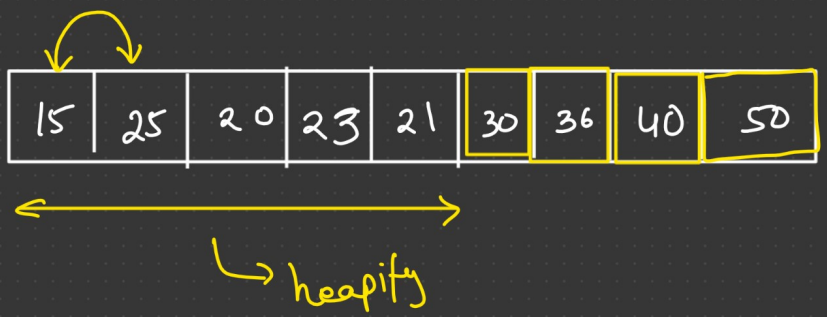
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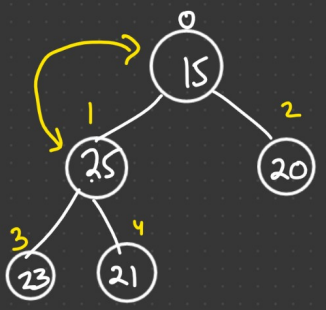
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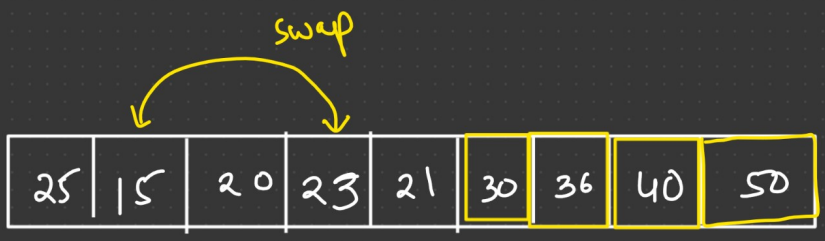
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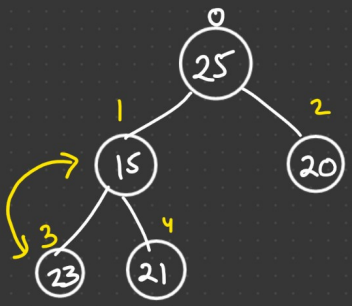
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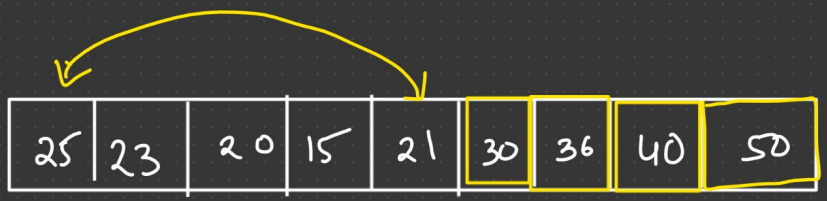
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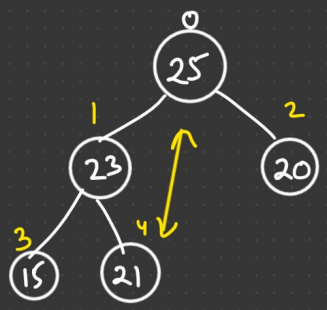
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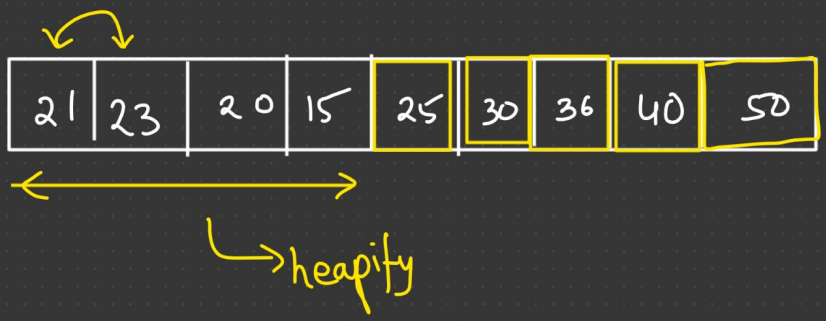
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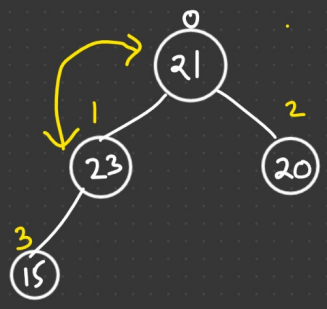
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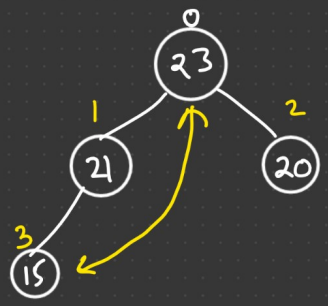
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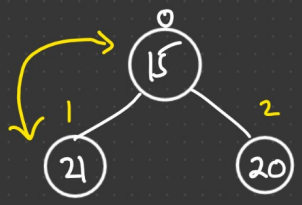
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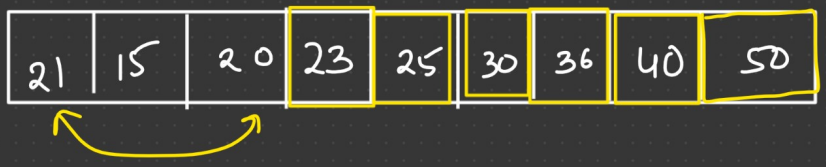
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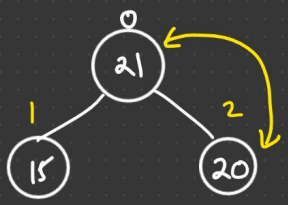
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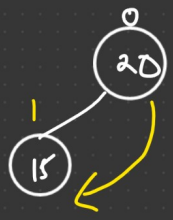
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