Insertion Sort

Introduction

The Idea of the insertion sort is similer to the Idea of sorting the Playing cards .

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Insertion Sorting

•It is a simple Sorting algorithm which sorts the array by shifting elements One by one. Following are some of the important characteristics of Insertion Sort.

- It has one of the simplest implementation
- It is efficient for smaller data sets, but very inefficient for larger lists.
- Insertion Sort is adaptive, that means it reduces its total number of steps if given a partially sorted list, hence it increases its efficiency.
- It is better than Selection Sort and Bubble Sort algorithms.
- It is Stable, as it does not change the relative order of elements with equal keys

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5	1	6	2	4	3

Lets take this Array.

5	1	6	2	4	3
1	5	6	2	4	3
1	5	6	2	4	3
1	2	5	6	4	3
1	2	4	5	6	3

(Always we start with the second element as key.)

As we can see here, in insertion sort, we pick up a key, and compares it with elemnts ahead of it, and puts the key in the right place

5 has nothing before it.

1 is compared to 5 and is inserted before 5.

6 is greater than 5 and 1.

2 is smaller than 6 and 5, but greater than 1, so its is inserted after 1.

And this goes on...

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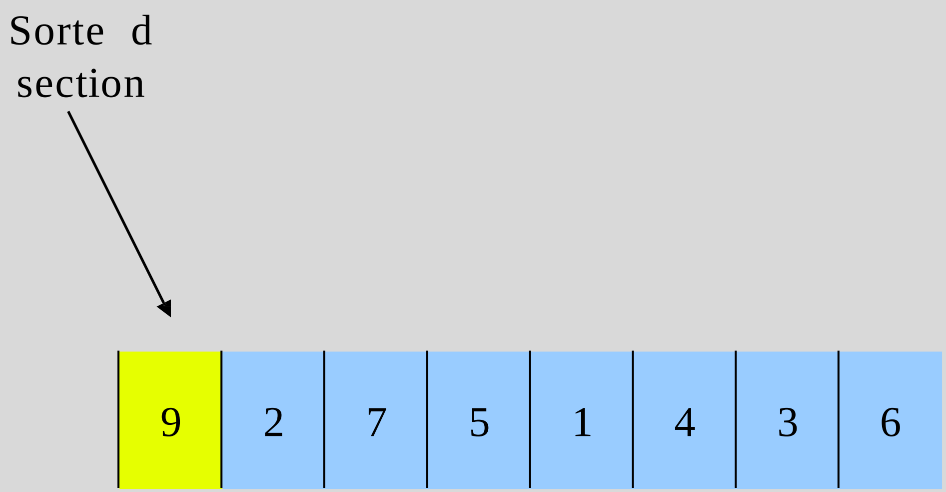
Insertion Sort

Example :

9	2	7	5	1	4	3	6

Insertion Sort



We start by dividing the array in a sorted section and an unsorted section. We put the first element as the only element in the sorted section, and the rest of the array is the unsorted section.

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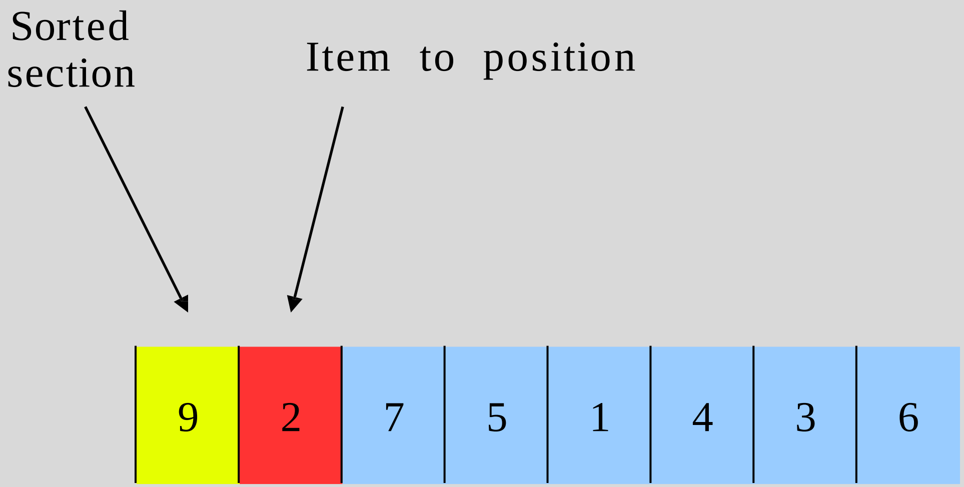

The first element in the unsorted section is the next element to be put into the correct position.

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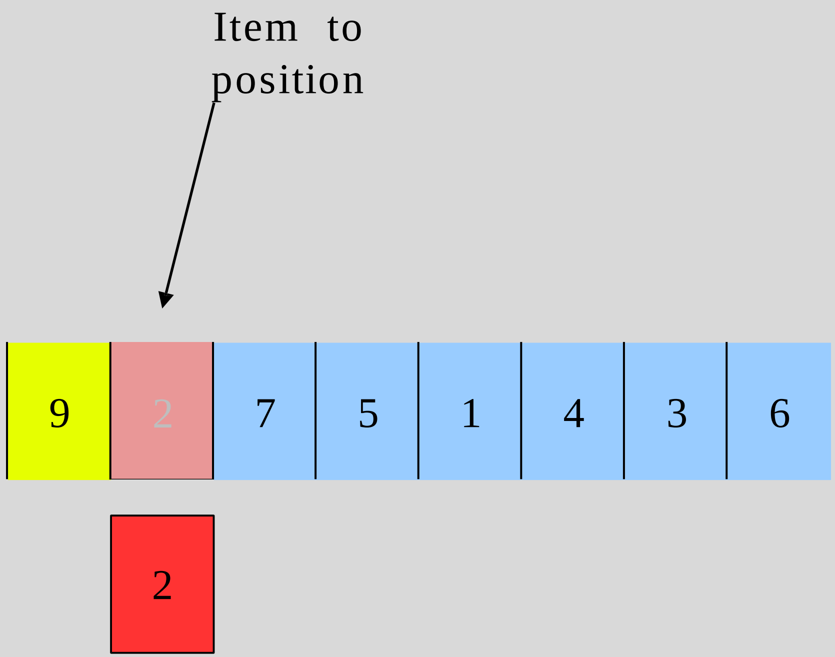

We copy the element to be placed into another variable so it doesn't get overwritten.

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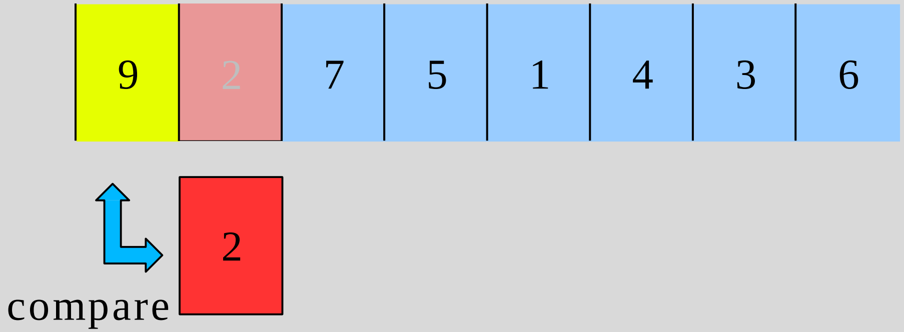

If the previous position is more than the item being placed, copy the value into the next position

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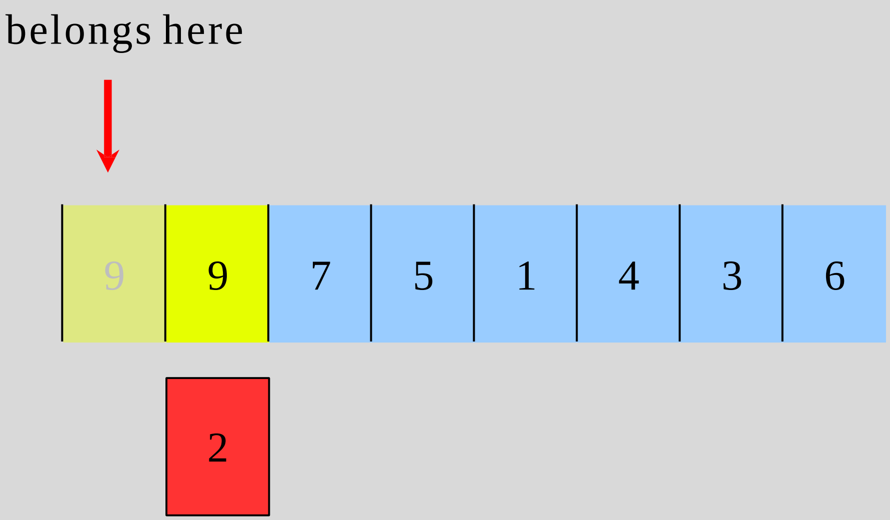

If there are no more items in the sorted section to compare with, the item to be placed must go at the front.

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2	9	7	5	1	4	3	6

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Insertion Sort

2	9	7	5	1	4	3	6

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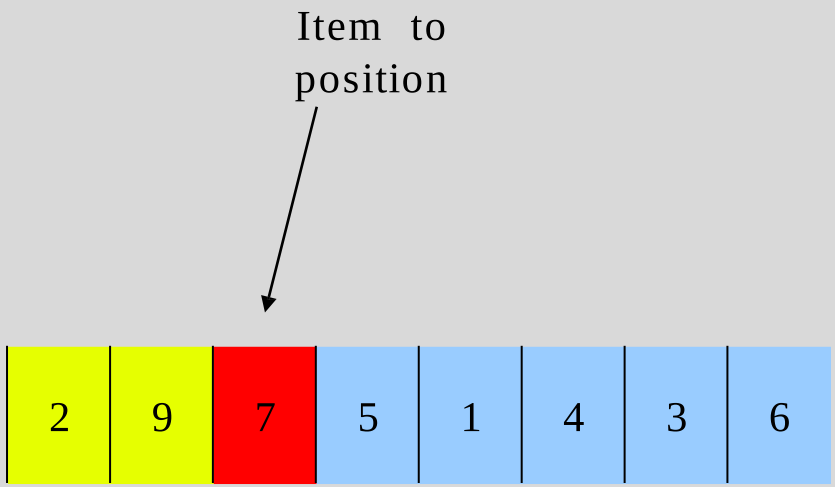
Insertion Sort



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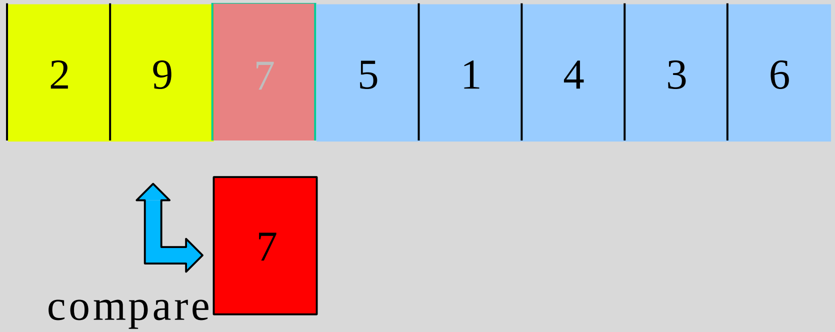

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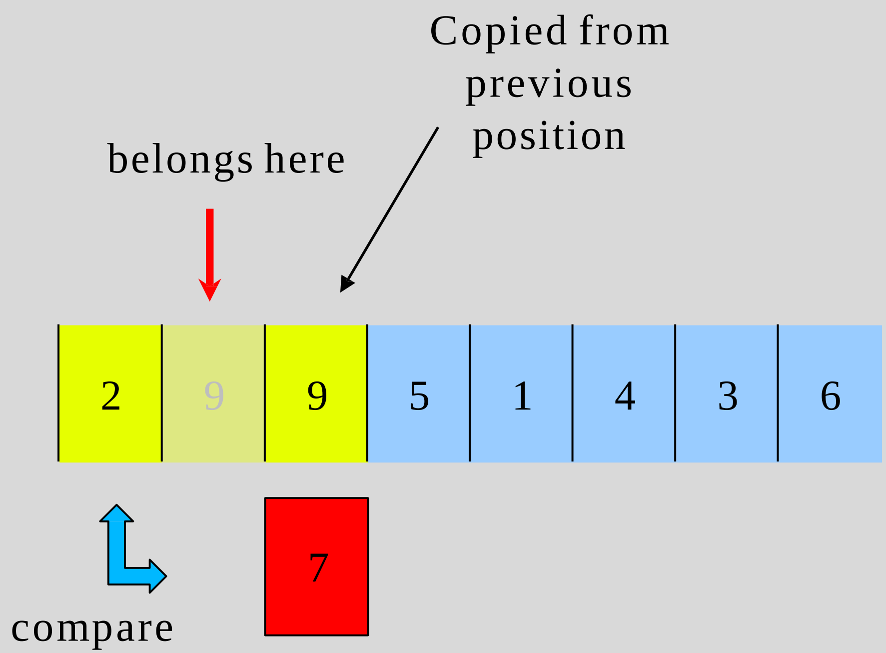

If the item in the sorted section is less than the item to place, the item to place goes *after* it in the array.

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2	7	9	5	1	4	3	6

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Insertion Sort

2	7	9	5	1	4	3	6

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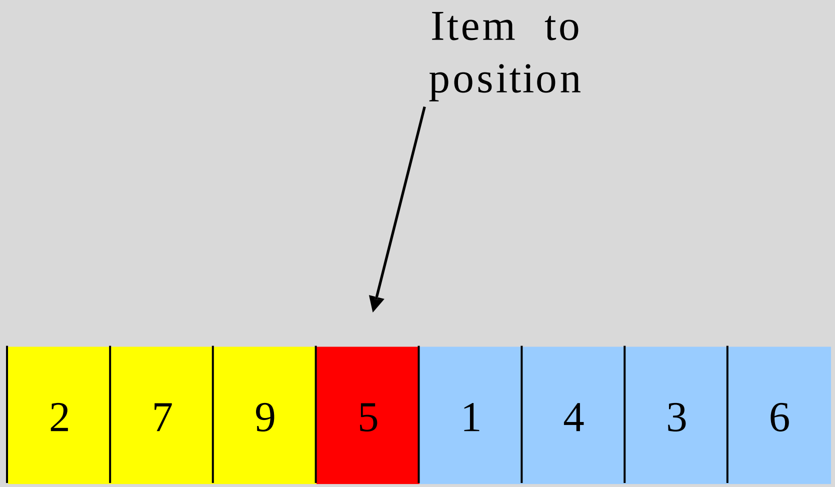

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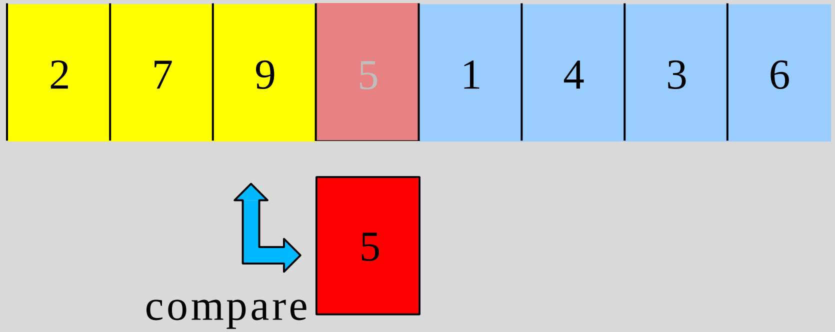

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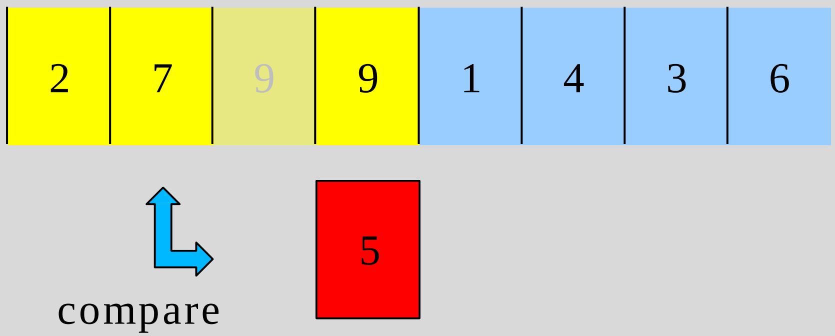

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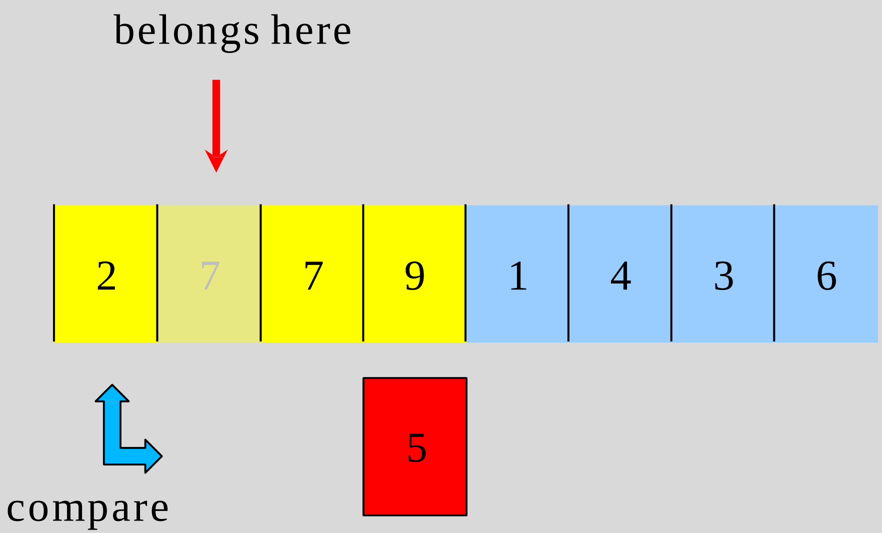

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Insertion Sort

2	5	7	9	1	4	3	6

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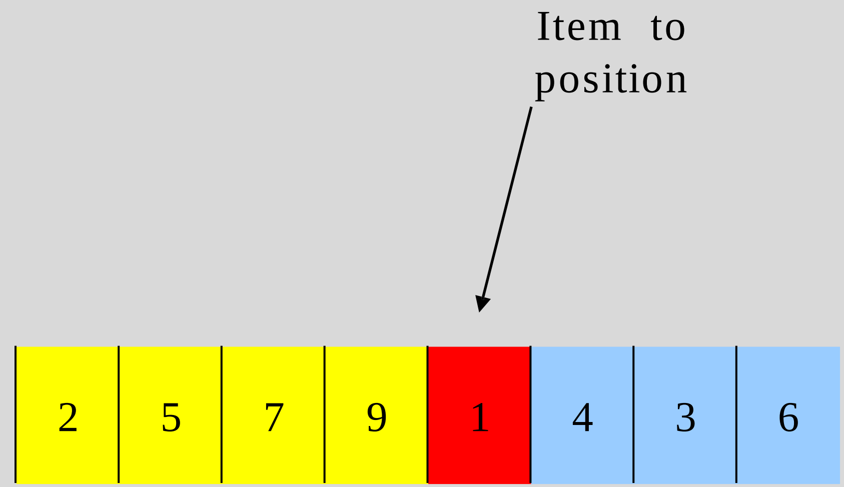

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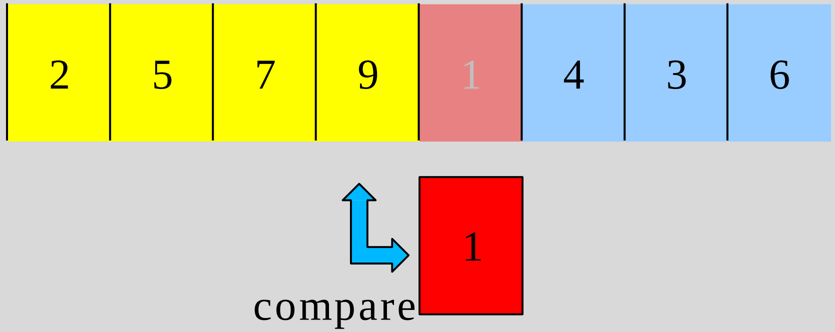

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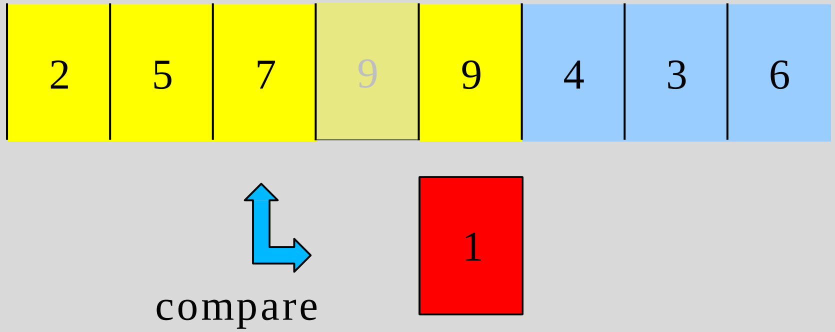

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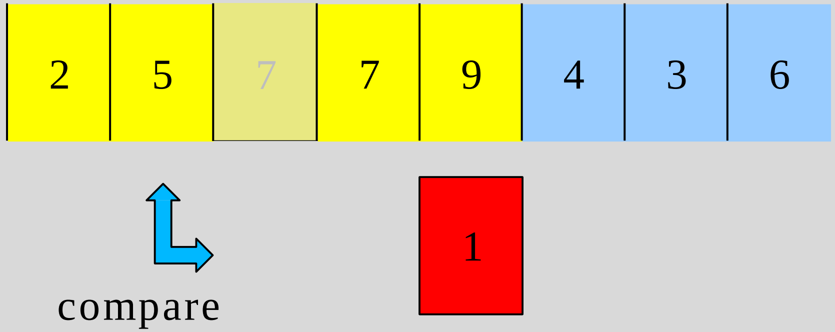

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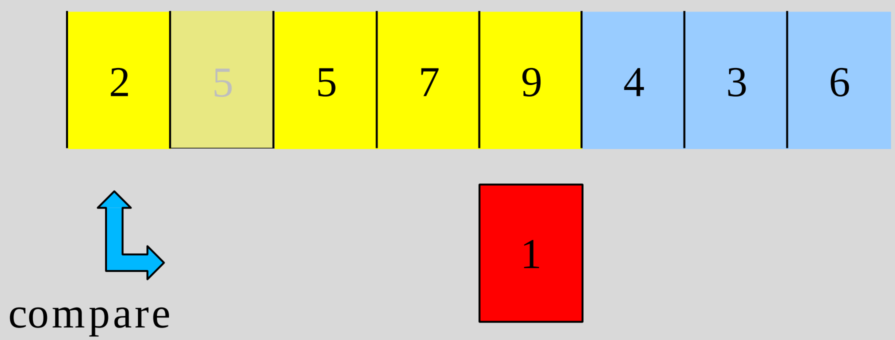

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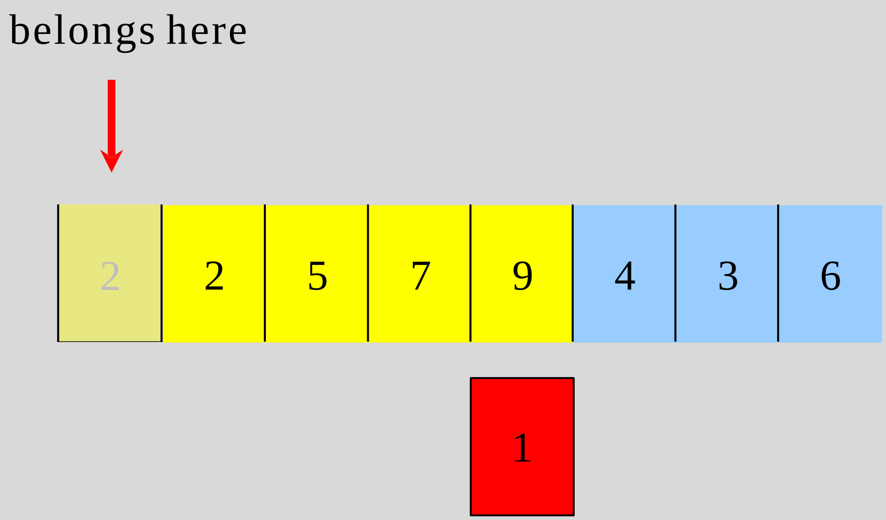

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Insertion Sort

1	2	5	7	9	4	3	6

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Insertion Sort

1	2	5	7	9	4	3	6

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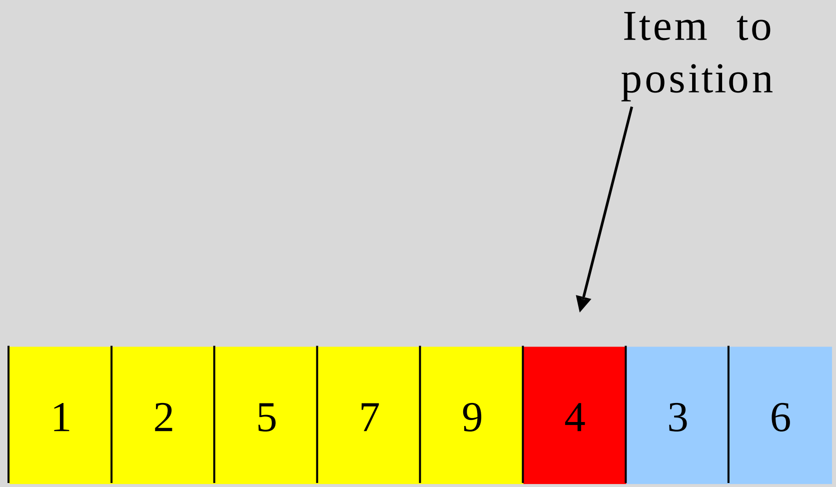
Insertion Sort



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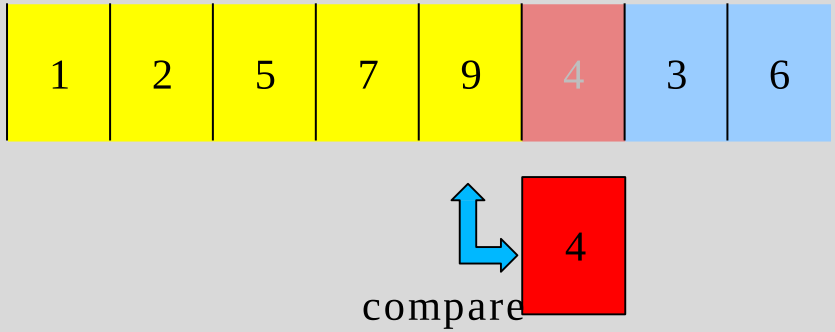

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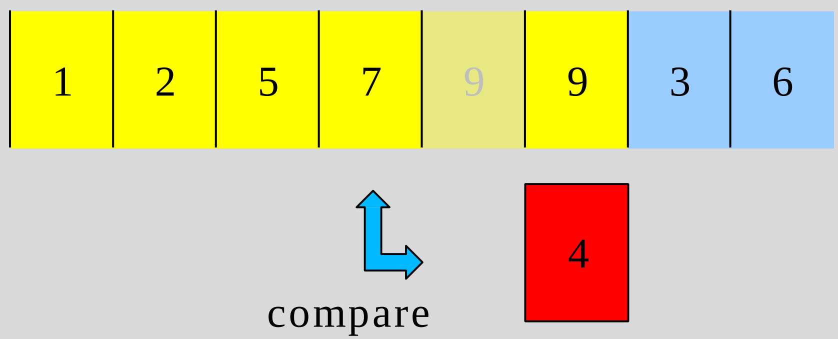

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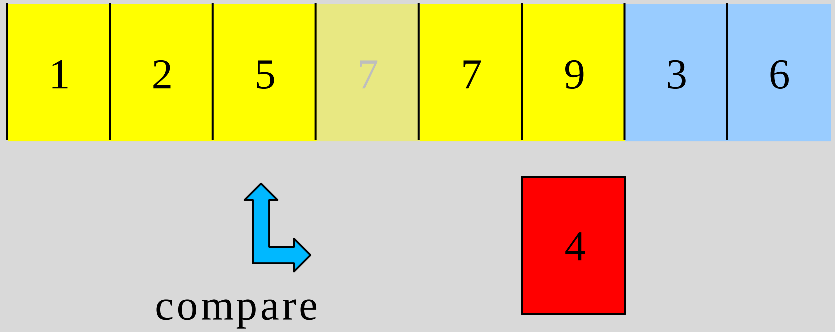

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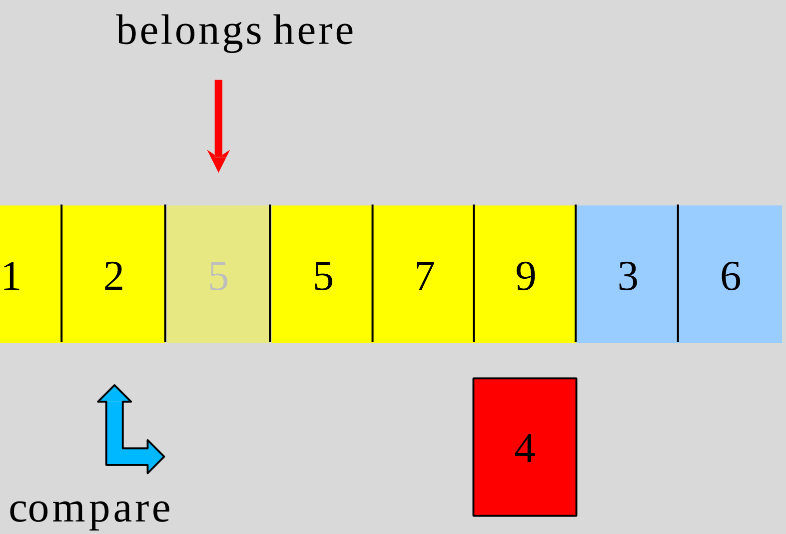

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Insertion Sort

1	2	4	5	7	9	3	6

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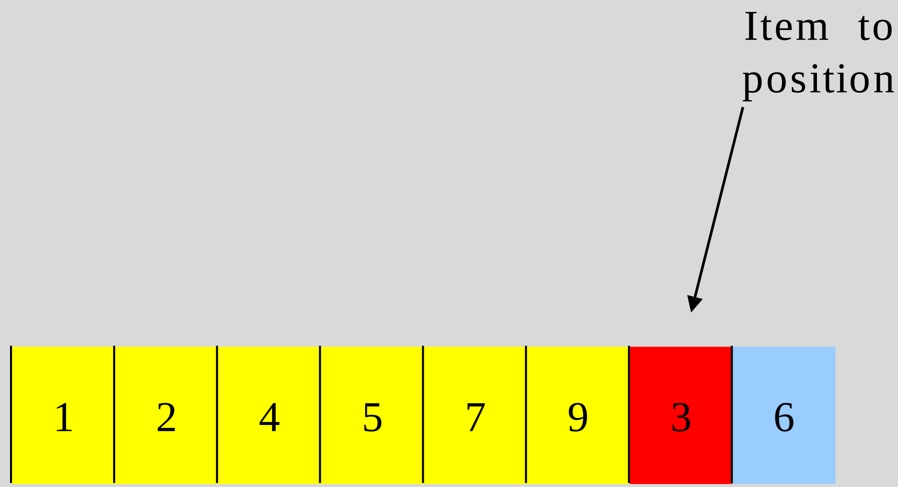
Insertion Sort



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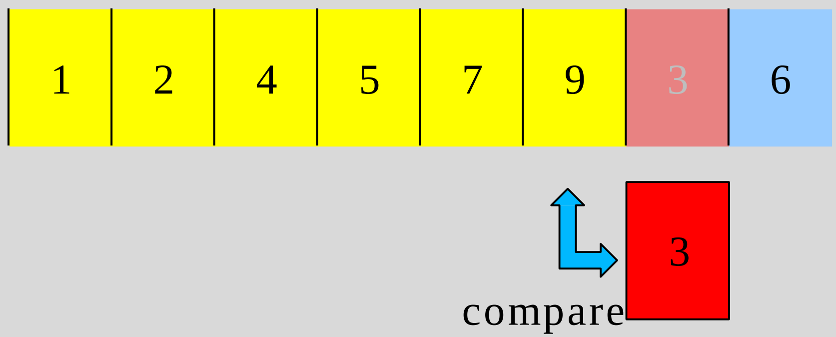

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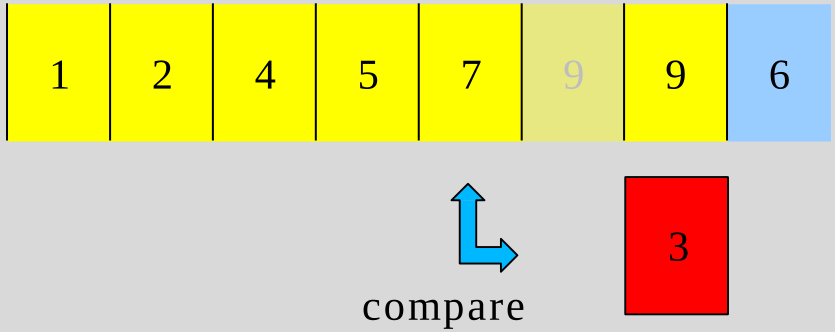

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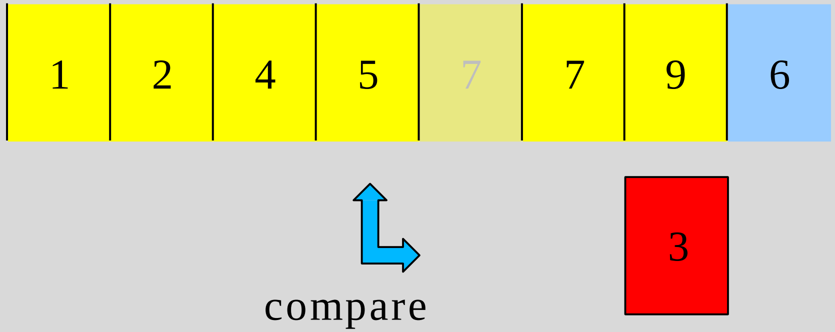

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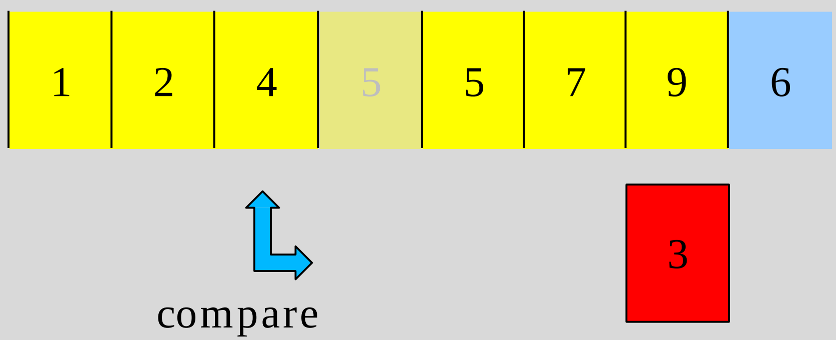

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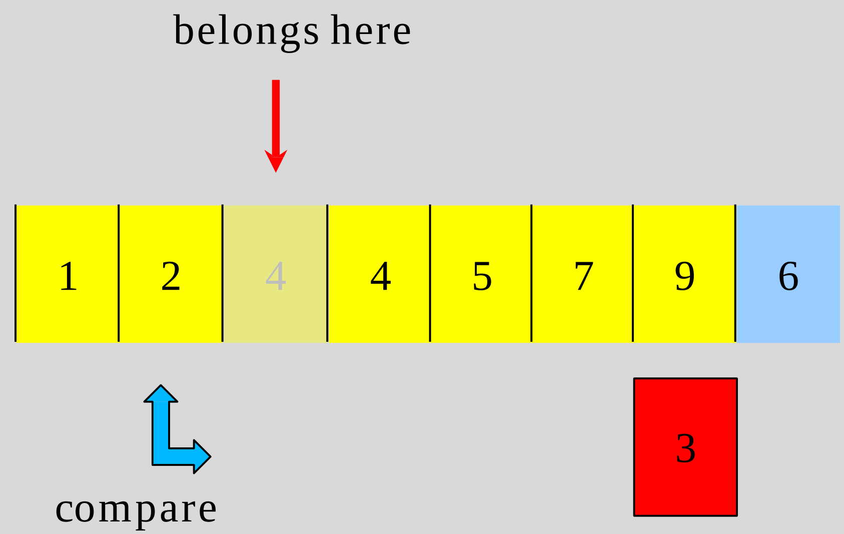

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Insertion Sort

1	2	3	4	5	7	9	6

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Insertion Sort

1	2	3	4	5	7	9	6

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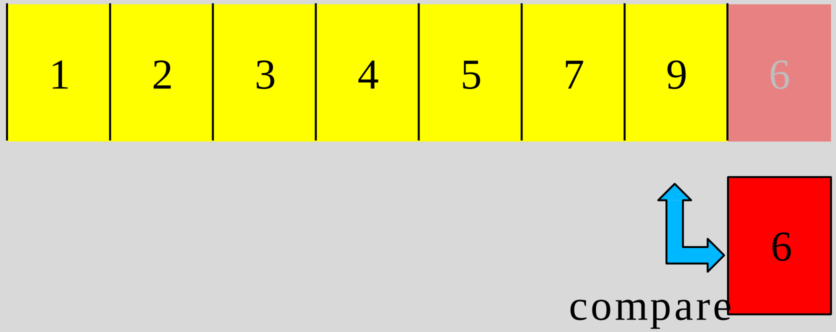
Insertion Sort

Insertion Sort



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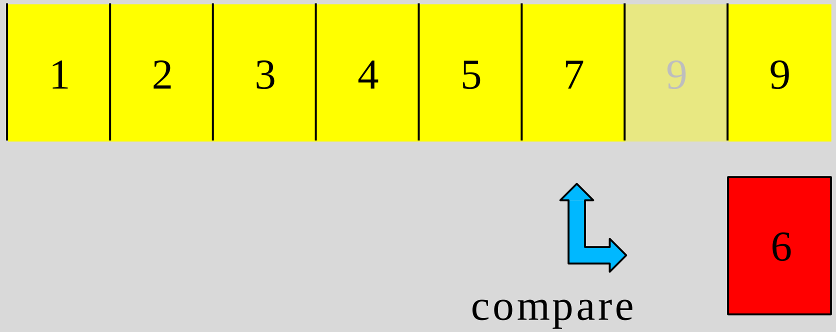

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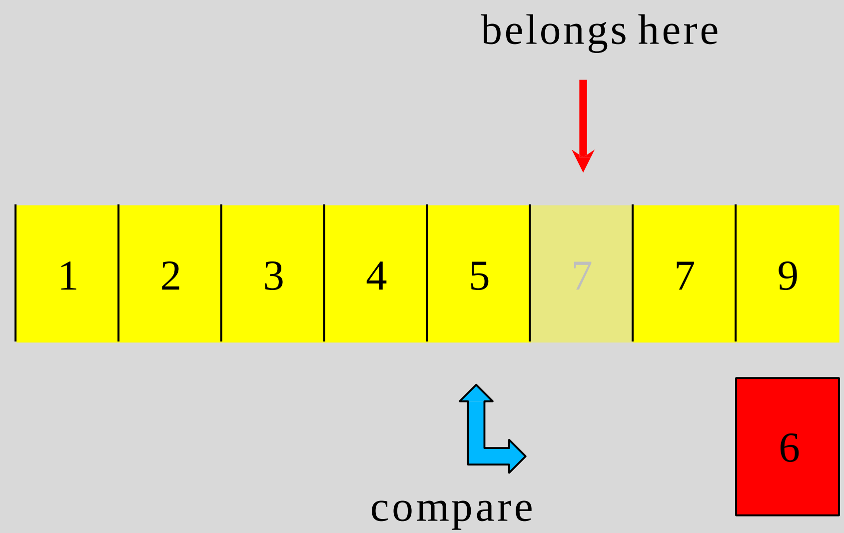

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Insertion Sort

1	2	3	4	5	6	7	9

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Insertion Sort

1	2	3	4	5	6	7	9

SORTED!

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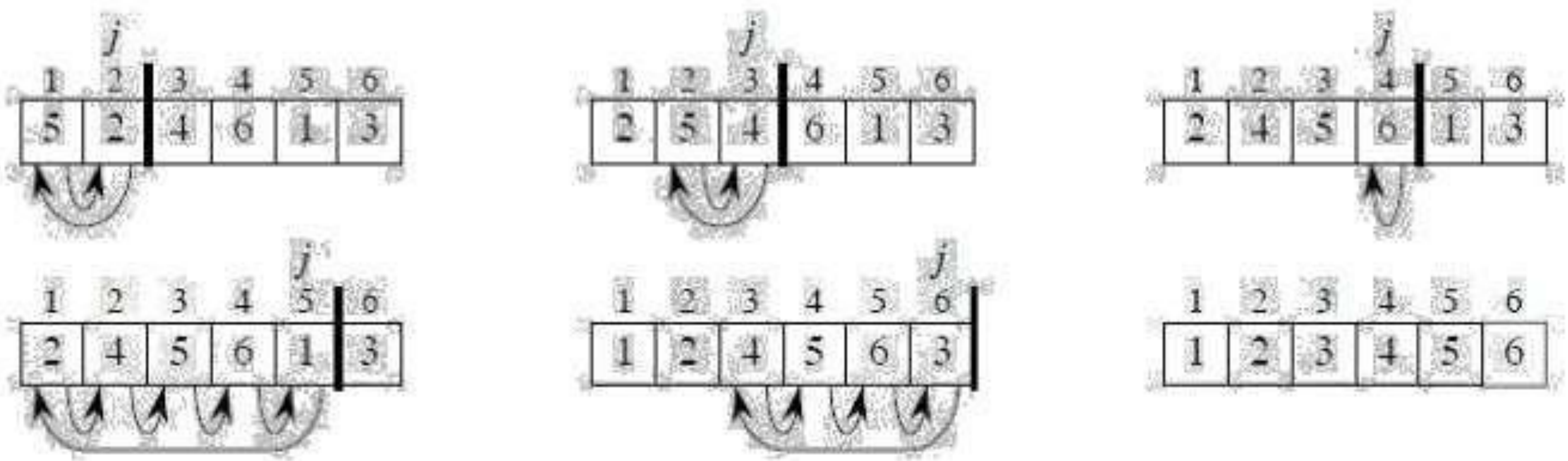
--* (Way of working) *-*-*

Select – Compare – Shift - Insert



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Pseudo Code

- **for i = 0 to n – 1**

```
j = 1
while j > 0 and A[j] < A[j – 1]
        swap(A[j], A[j-1])
        j = j - 1
```

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CODE OF INSERTION SORT

```
void insertion_sort (int arr[ ], int length)
{
        int i, j, temp;

        for (i = 0; i < length; i++)
        {
                j = i;

          while (j > 0 && arr[j] < arr[j-1])
            {
                temp = arr[j];
                arr[j] = arr[j-1];
                arr[j-1] = temp;
                j--;
            }
        }
}
```

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Best Times to Use Insertion Sort

- When the data sets are relatively small.
  - ➢Moderately efficient
- When you want a quick easy implementation.
  - ➢Not hard to code Insertion sort.
- When data sets are mostly sorted already.
  - ➢(1,2,4,6,3,2)

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Worst Times to Use Insertion Sort

- When the data sets are relatively large.

- When data sets are completely unsorted
  - Absolute worst case would be reverse ordered. (9,8,7,6,5,4)

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- Advantages
  - Good running time for "almost sorted" arrays $\Theta(n)$
  - Simple implementation.
  - Stable, i.e. does not change the relative order of elements with equal keys

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Disadvantages

It is less efficient on list containing more number of elements.
As the number of elements increases the performance of the program would be slow.
Insertion sort needs a large number of element shifts.

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Insertion sort analysis

Best Case of Insertion Sort

10, 20, 30, 40,

		Comparison	Swap
Pass 1.	10	0	0
Pass 2.	10 | 20	1	0
Pass 3.	10 | 20 | 30	1	0
Pass 4.	10 | 20 | 30 | 40	1	0
		⋮	
		1	0
		$n-1$	0

$\therefore n-1+0$

$\Rightarrow O(n)$

If array is almost sorted, then insertion sort is best algo.

10	20	30	40	50	60	70	80	90	5
0	1	1	1	1	1	1	1	1	n

$2n$

$O(n)$

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Worst case

i/p: 50 40 30 20 10

		Linear search: Comparison	Swap
Pass ①	[50]	→ 0	0
Pass ②	[50 | 40] ⇒ [40 | 50]	→ 1	1
Pass ③	[40 | 50 | 30] $x = 30$ 2 Right Shift ⇓ [30 | 40 | 50]	→ 2	2
Pass ④	[30 | 40 | 50 | 20] $x = 20$ 3 Right Shift (∵ 3 failure) ⇓ [20 | 30 | 40 | 50]	→ 3	3

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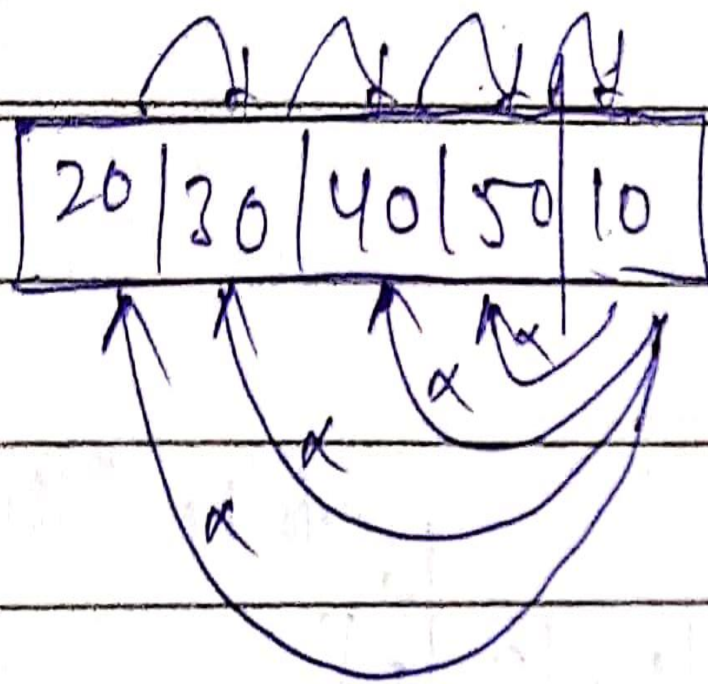
L.S

Date______



$x = 10$

4 failure

4 right shift

C	S
$n-1$	$n-1$
$O(n^2)$	$O(n^2)$

$$\Downarrow$$

10	20	30	40	50

$2n^2$

$\therefore O(n^2)$

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- **Average case**

the order of growth =0(N^2)

the no of comparison and shift/swap is less than the selection and bubble sort.

- **Hence it is better than selection and bubble sort.**

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Important Points

Date

Note ① Insertion Sort Algo will take Best case (n-1) comparison and 0 swap.

∴ Best Case time Complexity = $O(n)$

② If array is almost sorted, insertion sort is preferable.

③ If array size is very less, insertion sort is preferable (no divide and no conquer, no combine).

Comparisons

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Comparison with Bubble Sort:

- **In it we set the largest element at the end in each iteration**
- **Time Complexity:**
- **Worst case: we have to do n comparisons for 1st iteration, n-1 for next and n-2 for next until we reach at 1.**

Time complexity= $O(n^2)$

•Best Case: when the list is already sorted

Time Complexity= $O(n)$

- **Average Case:**

Time Complexity=$O(n^2)$

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Comparison with Selection Sort:

- In selection sort minimum element n the whole list will be placed at rightmost
- Worst case: Time complexity= $O(n^2)$ because we have to traverse the whole list
- Best Case: Time complexity= $O(n^2)$ because swaping will must happen at least one time
- Average Case: Time complexity= $O(n^2)$

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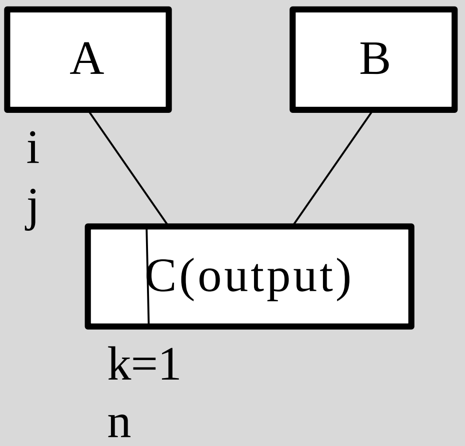
Comparison with Merge Sort:

- Divide and Conquer Rule
- We divide the array recursively until it reach to one element and then it get sorted according to comparisons and then merged again

```
for k=1 to n
     if(A[i]<B[j])
          C[k]=A[i];
           i++;
     else if(A[i]>B[j])
            C[k]=B[j]
             j++
```



Time Complexity:

- Best Case:

  Time Complexity= O(nlogn)
- Worst Case:

  Time Complexity= O(nlogn)
- Average Case:
- Time Complexity= O(nlogn)

Because we are dividing the array in this case, e.g if we have 32 elements in array then we will have to divide 5 times….so it will take logn times for dividing and n times for merging…. Total=nlogn

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Any Questions ?