

Quick Sort

QuickSortLike [Merge Sort](#), **QuickSort** is a [Divide and Conquer algorithm](#). It picks an element as a pivot and partitions the given array around the picked pivot. There are many different versions of quickSort that pick pivot in different ways.

Choosing the pivot

Picking a good pivot is necessary for the fast implementation of quicksort. However, it is typical to determine a good pivot. Some of the ways of choosing a pivot are as follows -

- Pivot can be random, i.e. select the random pivot from the given array.
- Pivot can either be the rightmost element of the leftmost element of the given array.
- Select median as the pivot element.

Working of Quick Sort Algorithm

Now, let's see the working of the Quicksort Algorithm.

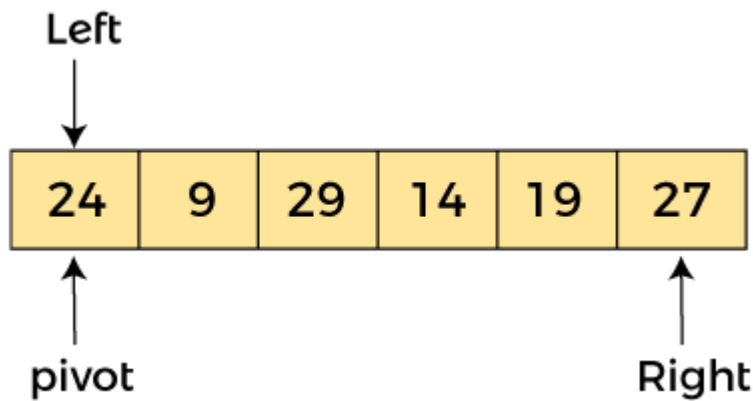
To understand the working of quick sort, let's take an unsorted array. It will make the concept more clear and understandable.

Let the elements of array are -

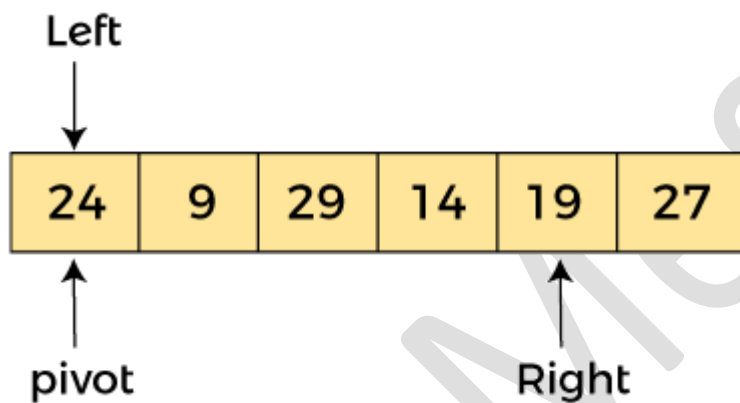
24	9	29	14	19	27
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In the given array, we consider the leftmost element as pivot. So, in this case, $a[\text{left}] = 24$, $a[\text{right}] = 27$ and $a[\text{pivot}] = 24$.

Since, pivot is at left, so algorithm starts from right and move towards left.

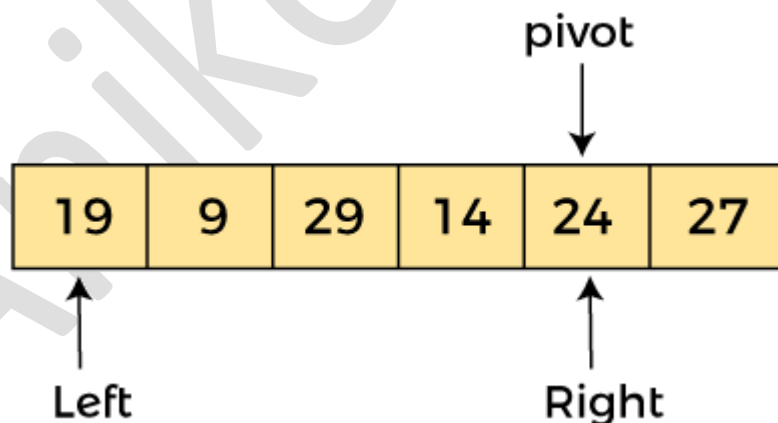


Now, $a[\text{pivot}] < a[\text{right}]$, so algorithm moves forward one position towards left, i.e. -



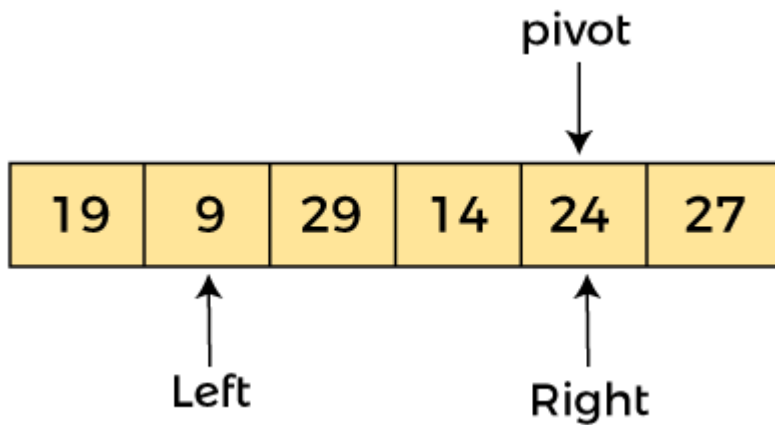
Now, $a[\text{left}] = 24$, $a[\text{right}] = 19$, and $a[\text{pivot}] = 24$.

Because, $a[\text{pivot}] > a[\text{right}]$, so, algorithm will swap $a[\text{pivot}]$ with $a[\text{right}]$, and pivot moves to right, as -

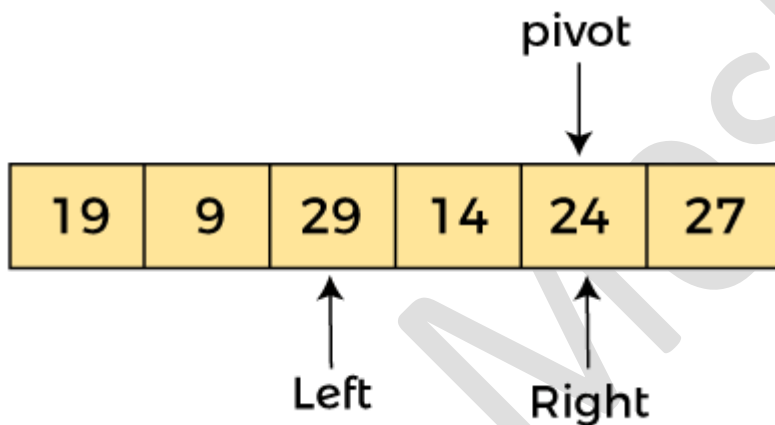


Now, $a[\text{left}] = 19$, $a[\text{right}] = 24$, and $a[\text{pivot}] = 24$. Since, pivot is at right, so algorithm starts from left and moves to right.

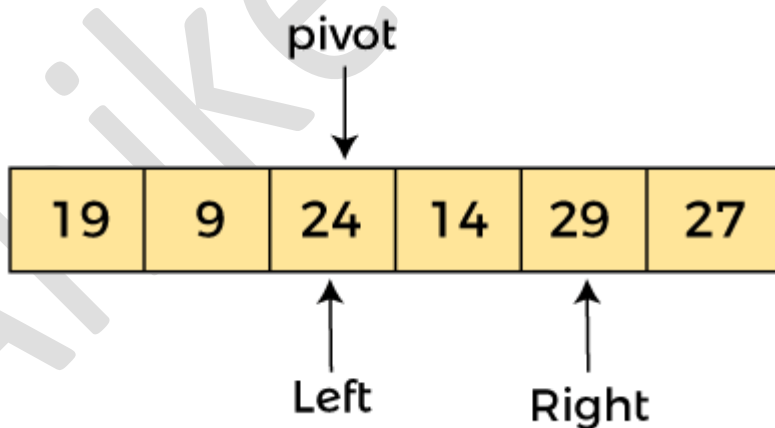
As $a[\text{pivot}] > a[\text{left}]$, so algorithm moves one position to right as -



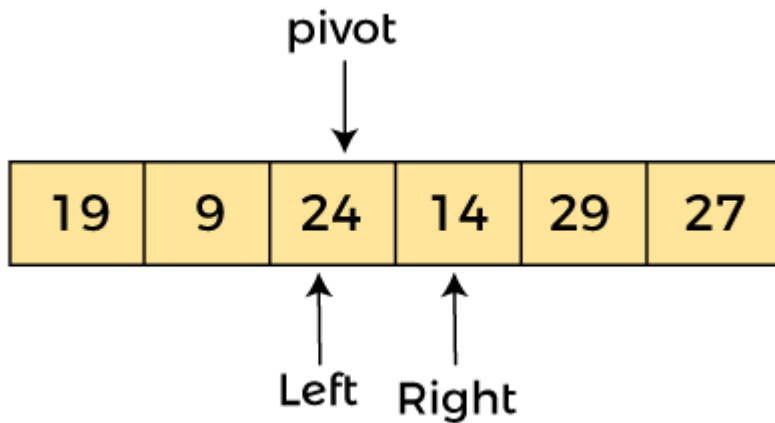
Now, $a[\text{left}] = 9$, $a[\text{right}] = 24$, and $a[\text{pivot}] = 24$. As $a[\text{pivot}] > a[\text{left}]$, so algorithm moves one position to right as -



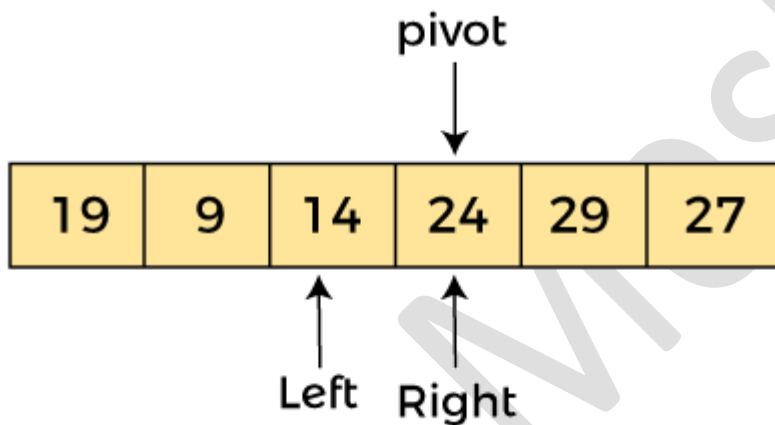
Now, $a[\text{left}] = 29$, $a[\text{right}] = 24$, and $a[\text{pivot}] = 24$. As $a[\text{pivot}] < a[\text{left}]$, so, swap $a[\text{pivot}]$ and $a[\text{left}]$, now pivot is at left, i.e. -



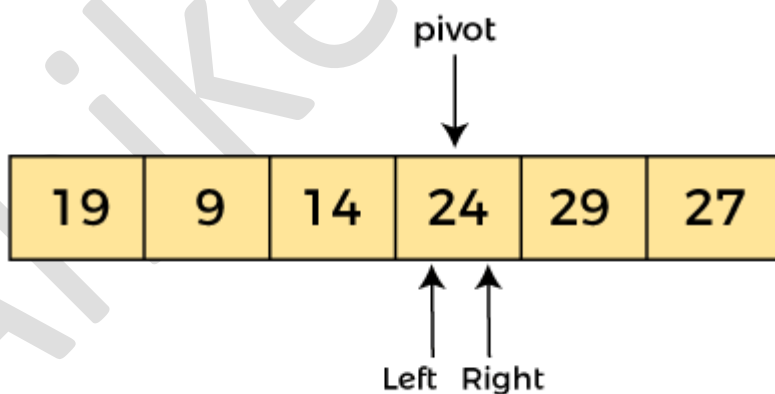
Since, pivot is at left, so algorithm starts from right, and move to left. Now, $a[\text{left}] = 24$, $a[\text{right}] = 29$, and $a[\text{pivot}] = 24$. As $a[\text{pivot}] < a[\text{right}]$, so algorithm moves one position to left, as -



Now, $a[\text{pivot}] = 24$, $a[\text{left}] = 24$, and $a[\text{right}] = 14$. As $a[\text{pivot}] > a[\text{right}]$, so, swap $a[\text{pivot}]$ and $a[\text{right}]$, now pivot is at right, i.e. -



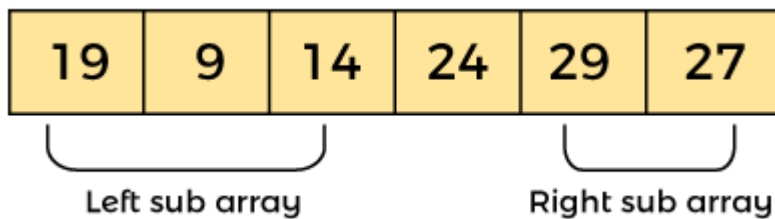
Now, $a[\text{pivot}] = 24$, $a[\text{left}] = 14$, and $a[\text{right}] = 24$. Pivot is at right, so the algorithm starts from left and move to right.



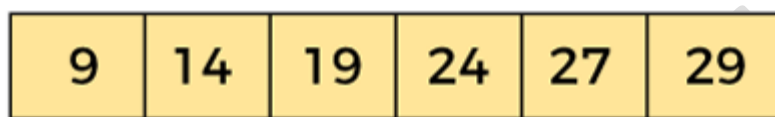
Now, $a[\text{pivot}] = 24$, $a[\text{left}] = 24$, and $a[\text{right}] = 24$. So, pivot, left and right are pointing the same element. It represents the termination of procedure.

Element 24, which is the pivot element is placed at its exact position.

Elements that are right side of element 24 are greater than it, and the elements that are left side of element 24 are smaller than it.



Now, in a similar manner, quick sort algorithm is separately applied to the left and right sub-arrays. After sorting gets done, the array will be -



Quicksort complexity

Now, let's see the time complexity of quicksort in best case, average case, and in worst case. We will also see the space complexity of quicksort.

1. Time Complexity

Case	Time Complexity
Best Case	$O(n \cdot \log n)$
Average Case	$O(n \cdot \log n)$
Worst Case	$O(n^2)$

- **Best Case Complexity** - In Quicksort, the best-case occurs when the pivot element is the middle element or near to the middle element. The best-case time complexity of quicksort is **$O(n \cdot \log n)$** .
- **Average Case Complexity** - It occurs when the array elements are in jumbled order that is not properly ascending and not properly descending. The average case time complexity of quicksort is **$O(n \cdot \log n)$** .
- **Worst Case Complexity** - In quick sort, worst case occurs when the pivot element is either greatest or smallest element. Suppose, if the

pivot element is always the last element of the array, the worst case would occur when the given array is sorted already in ascending or descending order. The worst-case time complexity of quicksort is **$O(n^2)$** .

Though the worst-case complexity of quicksort is more than other sorting algorithms such as **Merge sort** and **Heap sort**, still it is faster in practice. Worst case in quick sort rarely occurs because by changing the choice of pivot, it can be implemented in different ways. Worst case in quicksort can be avoided by choosing the right pivot element.

2. Space Complexity

Space Complexity	$O(n \cdot \log n)$
Stable	NO

- The space complexity of quicksort is $O(n \cdot \log n)$.

Quick sort

```
import java.util.Arrays;

public class Solution {
    public static void main (String[] args) {
        int[] arr = {3,7,4,5,1,2};
        sort(arr, 0, arr.length-1);
        System.out.println(Arrays.toString(arr));
    }

    public static void sort(int[] arr, int low, int high) {
        int start = low;
        int end = high;
        int mid = start + (end - start)/2;
        int pivot = arr[mid];

        if (low >= high) {
            return;
        }
        while (start <= end) {
            while(pivot < arr[end]) {
                end--;
            }

            while(pivot > arr[start]) {
                start++;
            }

            if (start <= end) {
                int temp = arr[start];
                arr[start] = arr[end];
                arr[end] = temp;
                start++;
                end--;
            }
        }
        sort(arr, low, end);
        sort(arr, start, high);
    }
}
```