DATA STRUCTURES AND ALGORITHMS

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Quicksort Algorithm

Quicksort is a sorting algorithm based on the divide and conquer approach where

An array is divided into subarrays by selecting a pivot element (element selected from the array).

While dividing the array, the pivot element should be positioned in such a way that elements less than pivot are kept on the left side and elements greater than pivot are on the right side of the pivot.

The left and right subarrays are also divided using the same approach. This process continues until each subarray contains a single element.

At this point, elements are already sorted. Finally, elements are combined to form a sorted array.

Quicksort Algorithm--Working

Step 1: There are different variations of quicksort where the pivot element is selected from different positions. Here, we will be selecting the rightmost element of the array as the pivot element.

Select the Pivot Element

Quicksort Algorithm

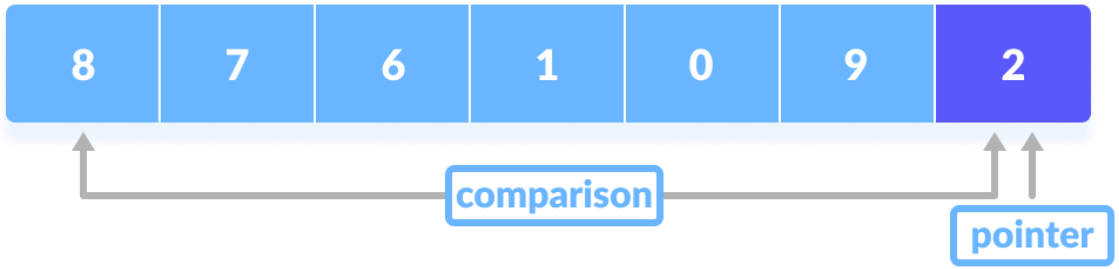
Step 2. Rearrange the Array

Put all the smaller elements on the left and greater on the right of pivot element

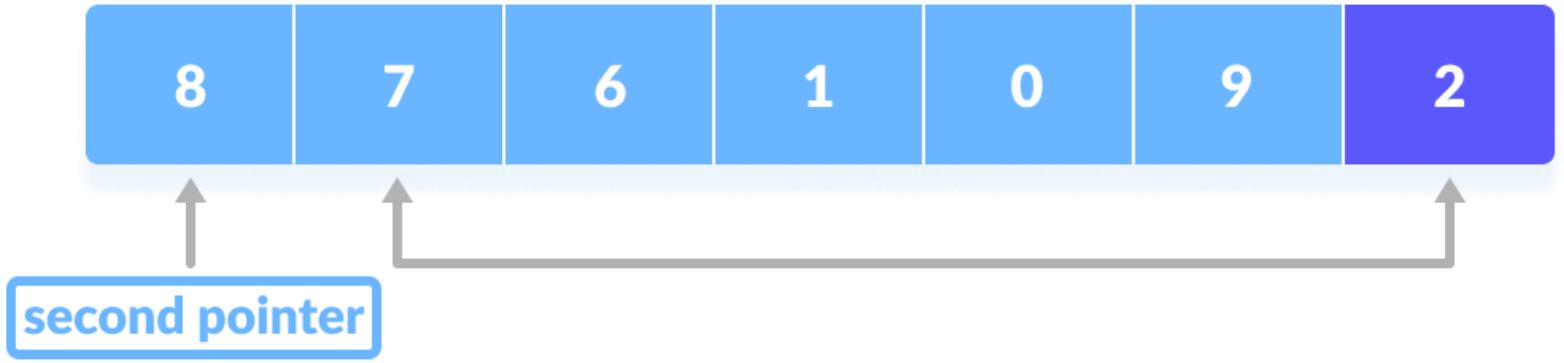
Quicksort Algorithm

Here's how we rearrange the array:

a.A pointer is fixed at the pivot element. The pivot element is compared with the elements beginning from the first index.



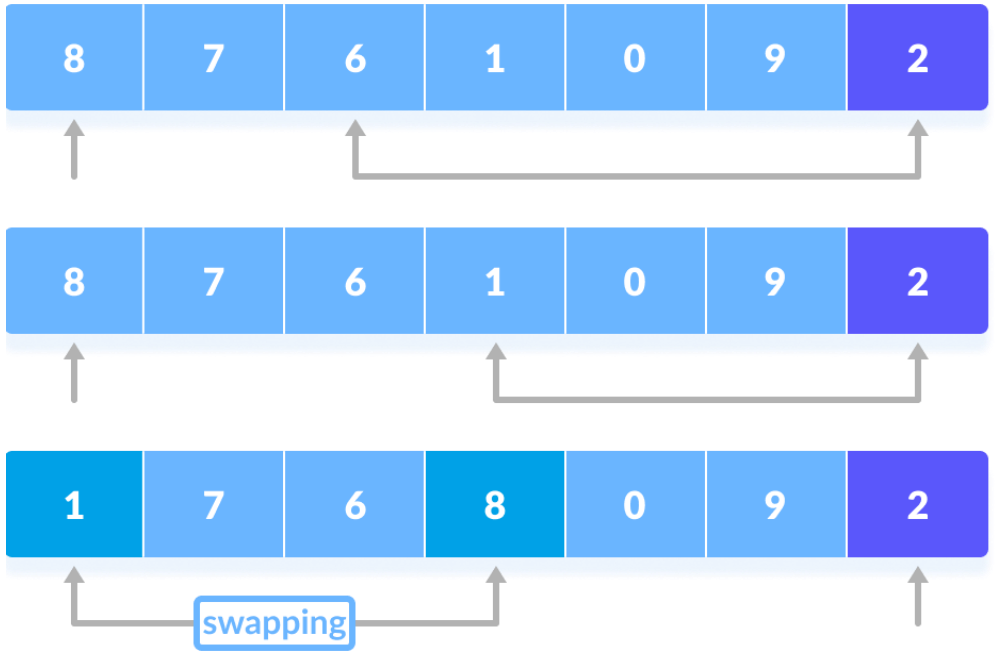
Quicksort Algorithm



If the element is greater than the pivot element, a second pointer is set for that element.

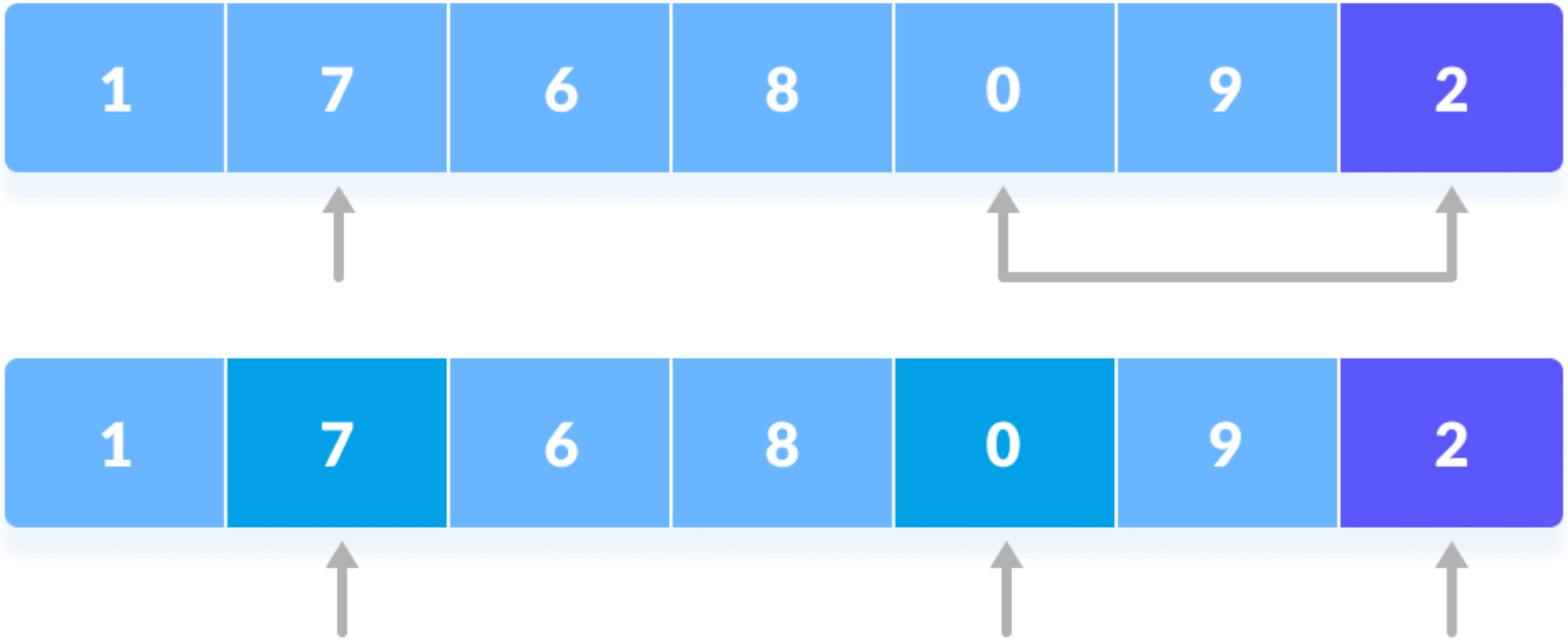
Quicksort Algorithm

Now, pivot is compared with other elements. If an element smaller than the pivot element is reached, the smaller element is swapped with the greater element found earlier.



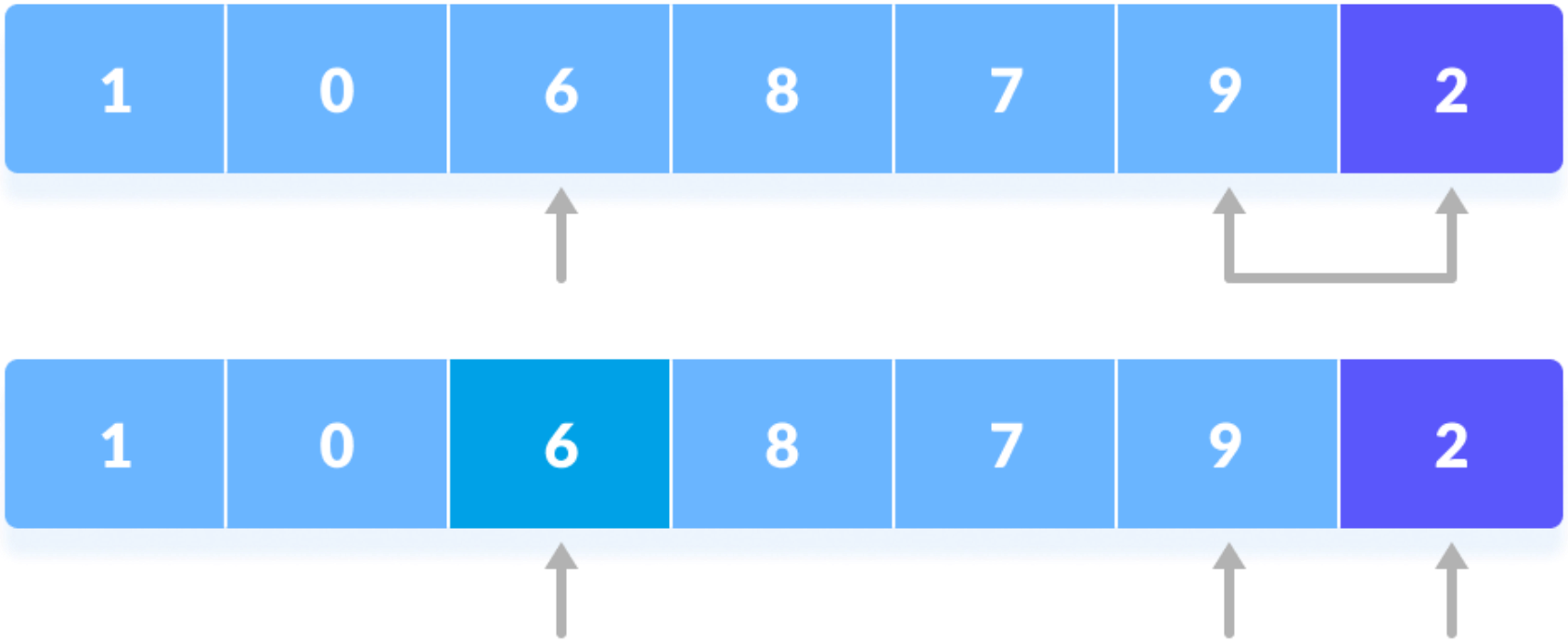
Quicksort Algorithm

Again, the process is repeated to set the next greater element as the second pointer. And, swap it with another smaller element.



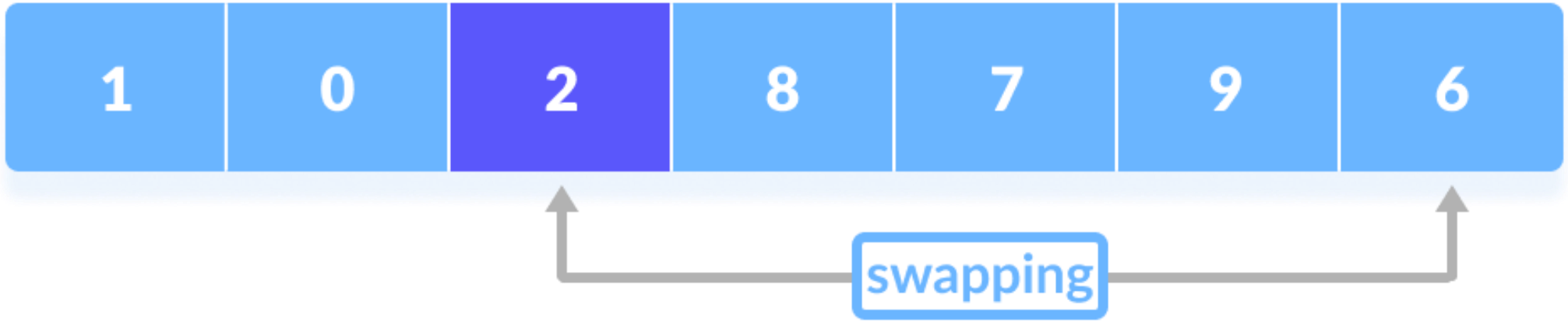
Quicksort Algorithm

The process goes on until the second last element is reached.



Quick Sort

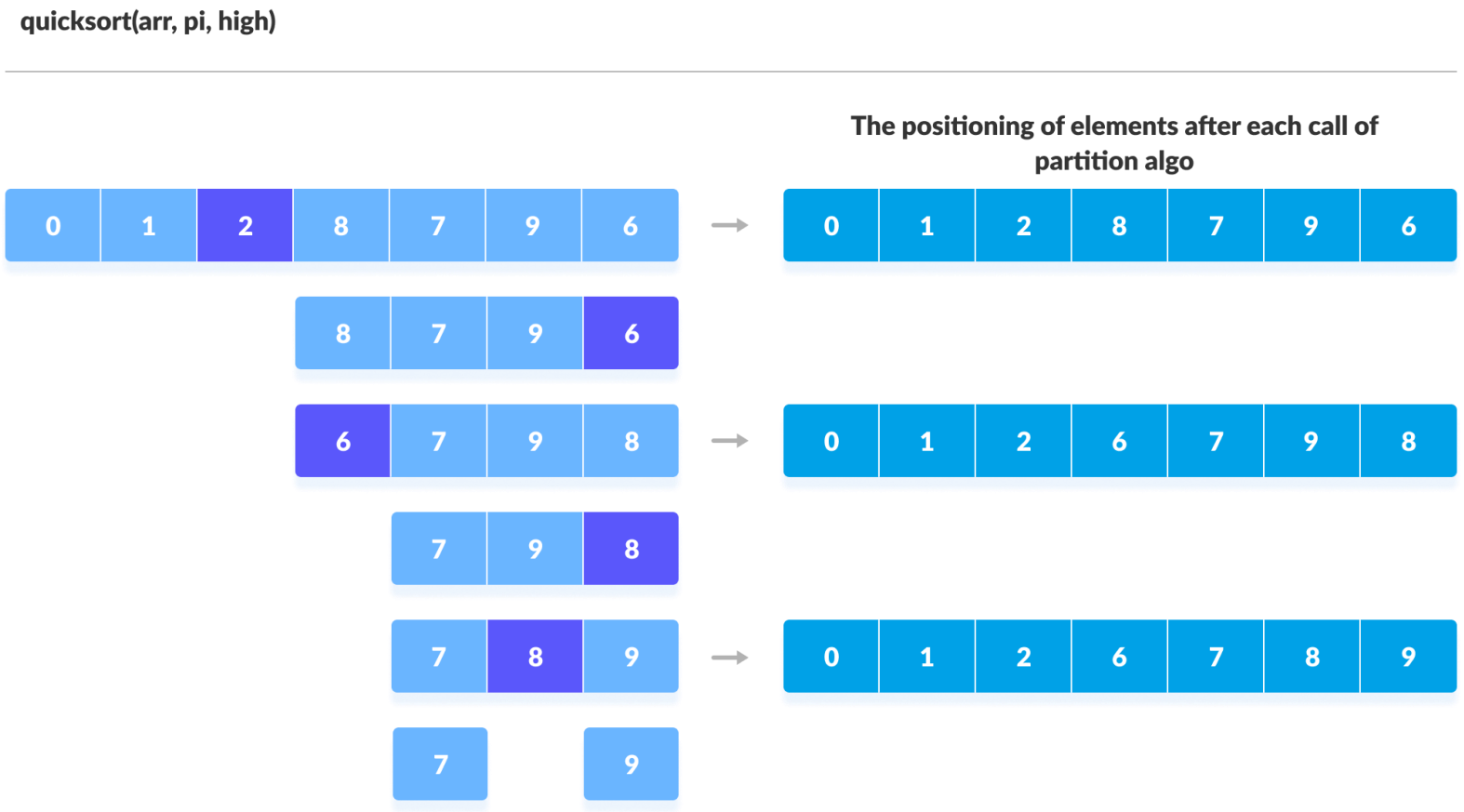
Finally, the pivot element is swapped with the second pointer.



Quick Sort

Step 3: Divide Subarrays

Pivot elements are again chosen for the left and the right sub-parts separately. And, **step 2** is repeated.



Quick Sort Algorithm

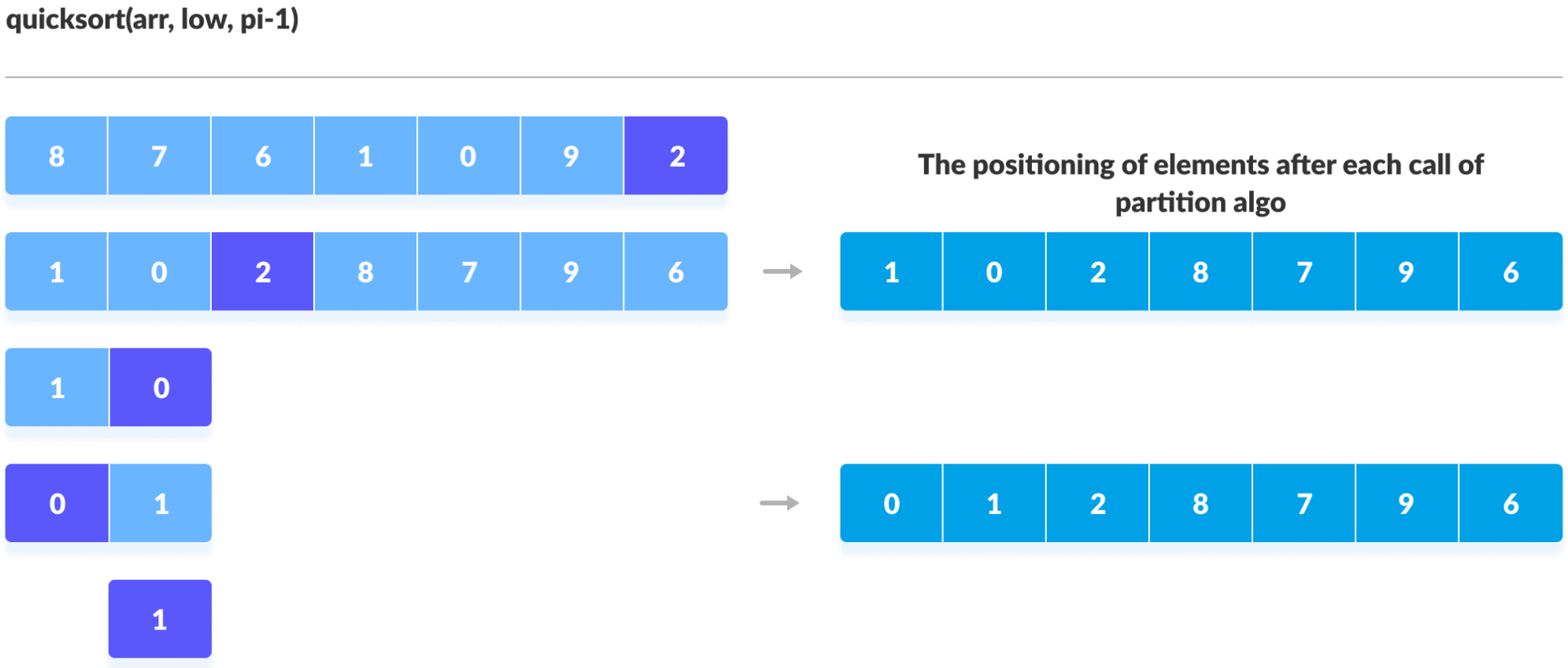
```
quickSort(array, leftmostIndex, rightmostIndex)
 if (leftmostIndex < rightmostIndex)
     pivotIndex <- partition(array,leftmostIndex, rightmostIndex)
     quickSort(array, leftmostIndex, pivotIndex - 1)
     quickSort(array, pivotIndex, rightmostIndex)

partition(array, leftmostIndex, rightmostIndex)
     set rightmostIndex as pivotIndex
     storeIndex <- leftmostIndex
     for i <- leftmostIndex + 1 to rightmostIndex
        if element[i] < pivotElement
             swap element[i] and element[storeIndex]
             storeIndex++
     swap pivotElement and element[storeIndex+1]
return storeIndex + 1
```

Quick Sort

Visual Illustration of Quicksort Algorithm

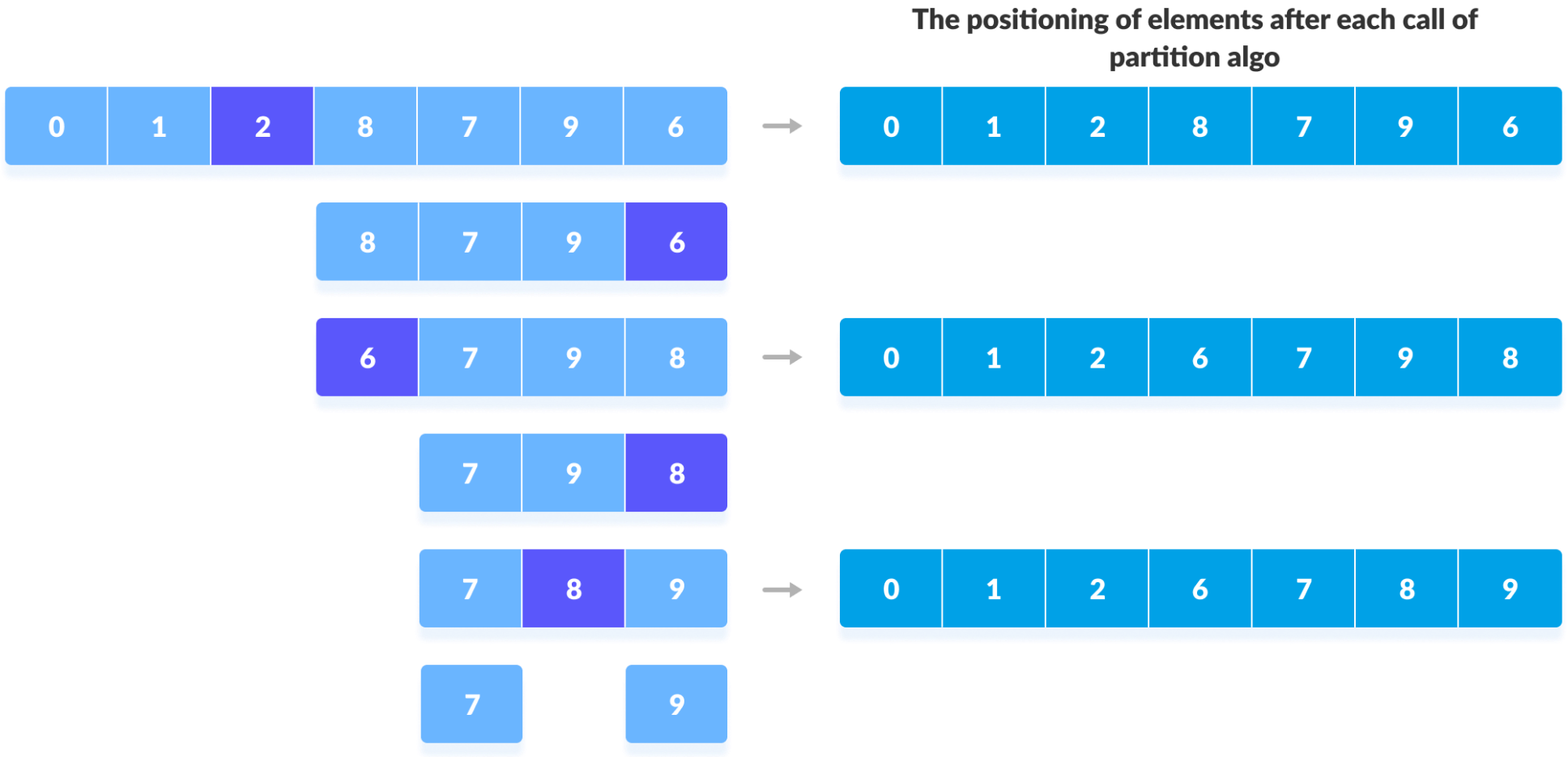
You can understand the working of quicksort algorithm with the help of the illustrations below.



Sorting the elements on the left of pivot using recursion

Quick Sort

quicksort(arr, pi+1, high)



Quick Sort

```
void swap(int *a, int *b) {
  int t = *a;
  *a = *b;
  *b = t;
}
// function to print the array
void printArray(int array[], int size) {
  int i;
  for (i = 0; i < size; i++)
    cout << array[i] << " ";
  cout << endl;
}
// function to rearrange array (find the partition point)
int partition(int array[], int low, int high) {
   // select the rightmost element as pivot
  int pivot = array[high];

  // pointer for greater element
  int i = (low - 1);

  // traverse each element of the array
  // compare them with the pivot
  for (int j = low; j < high; j++) {
    if (array[j] <= pivot) {

      // if element smaller than pivot is found
      // swap it with the greater element pointed by i
      i++;

      // swap element at i with element at j
      swap(&array[i], &array[j]);
    }
  }

  // swap pivot with the greater element at i
  swap(&array[i + 1], &array[high]);

  // return the partition point
  return (i + 1);
}
```

Quick Sort

```
void quickSort(int array[], int low, int high) {
  if (low < high) {

    // find the pivot element such that
    // elements smaller than pivot are on left of pivot
    // elements greater than pivot are on righ of pivot
    int pi = partition(array, low, high);

    // recursive call on the left of pivot
    quickSort(array, low, pi - 1);

    // recursive call on the right of pivot
    quickSort(array, pi + 1, high);
  }
}
```

Quick Sort

Quicksort Complexity

Time Complexity	
Best	O(n*log n)
Worst	$O(n^2)$
Average	O(n*log n)

Quick Sort

Time Complexities

- **Worst Case Complexity [Big-O]**: $O(n^2)$

It occurs when the pivot element picked is either the greatest or the smallest element.

This condition leads to the case in which the pivot element lies in an extreme end of the sorted array.
One sub-array is always empty and another sub-array contains $n - 1$ elements. Thus, quicksort is called only on this sub-array.

However, the quicksort algorithm has better performance for scattered pivots.