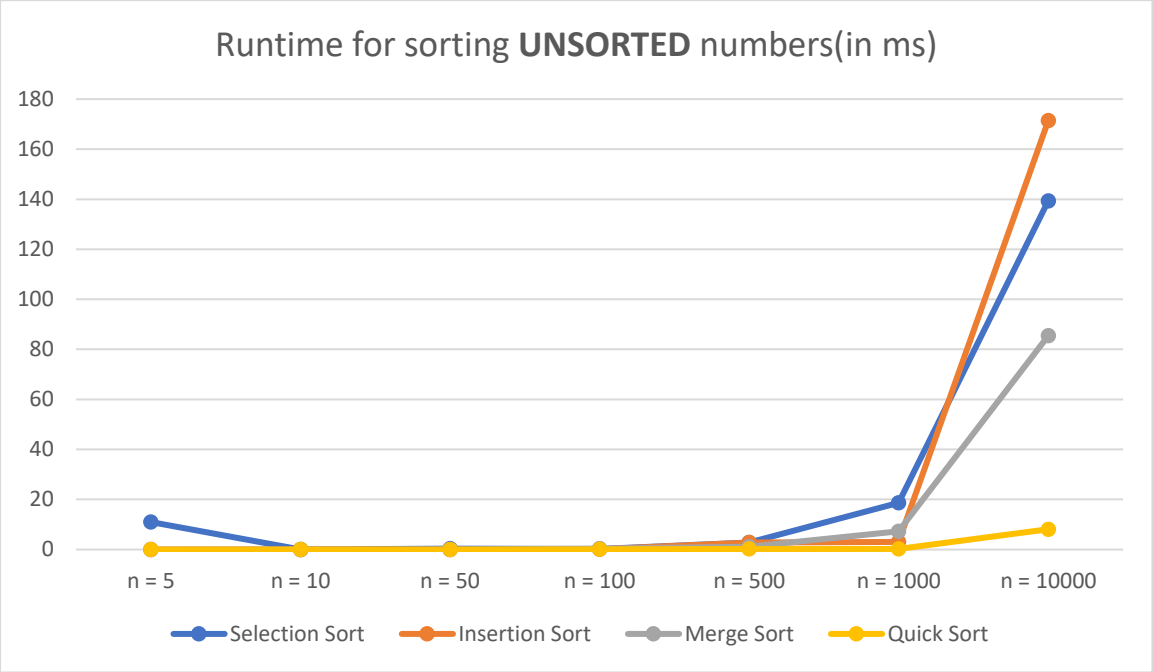
Runtime for **UNSORTED** numbers (in milliseconds):

Algorithm	n = 5	n = 10	n = 50	n = 100	n = 500	n = 1000	n = 10000
Selection Sort	10.9309	0.0058	0.3417	0.2719	2.8320	18.6658	139.3359
Insertion Sort	0.00680	0.0044	0.0248	0.1072	2.8399	3.01470	171.3940
Merge Sort	0.01110	0.0090	0.0345	0.3305	1.1216	7.31120	85.46060
Quick Sort	0.00860	0.0057	0.0194	0.0701	0.2457	0.20200	8.099500

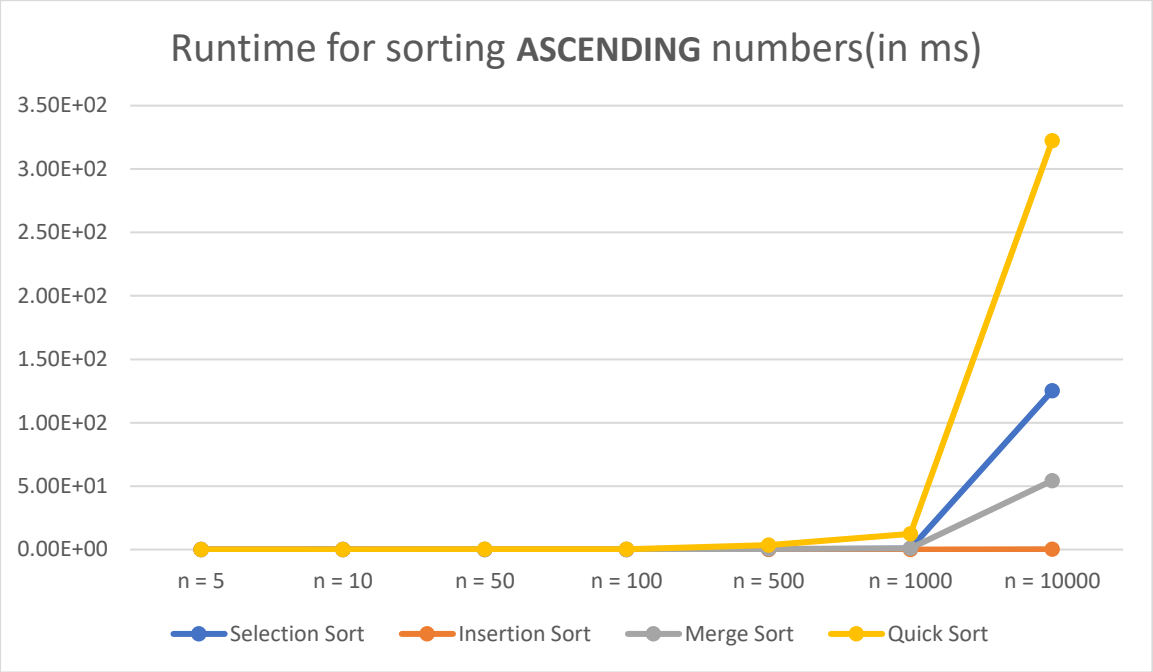
Chart - 1



Runtime for **ASCENDING** numbers (in milliseconds):

Algorithm	n = 5	n = 10	n = 50	n = 100	n = 500	n = 1000	n = 10000
Selection Sort	6.0E-4	7.0E-4	0.0029	0.0400	0.2210	0.5938	125.0601
Insertion Sort	0.0372	0.0532	0.0336	0.0525	0.0243	0.0591	0.19880
Merge Sort	0.0039	0.0059	0.0266	0.0567	0.3813	1.0779	54.3279
Quick Sort	0.0031	0.0042	0.1350	0.1299	3.3800	12.4442	322.2035

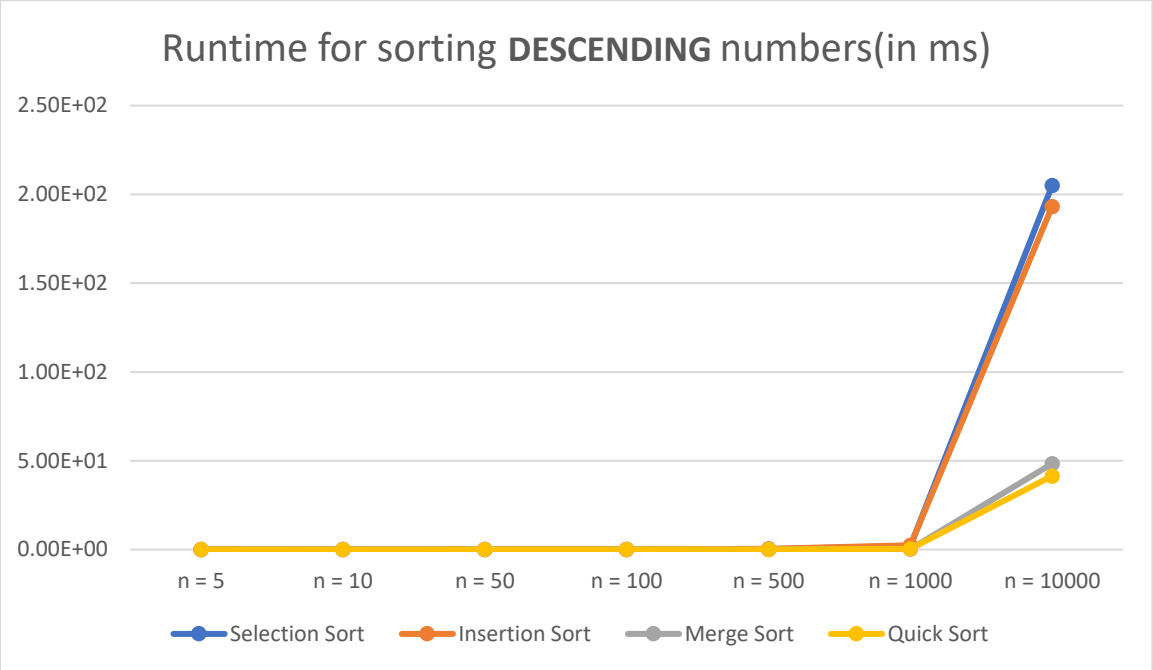
Chart - 2



Runtime for **DESCENDING** numbers (in milliseconds):

Algorithm	n = 5	n = 10	n = 50	n = 100	n = 500	n = 1000	n = 10000
Selection Sort	9.0E-4	0.0010	0.0058	0.0140	0.2645	1.9458	205.0326
Insertion Sort	7.0E-4	0.0010	0.0061	0.0188	0.3984	2.3863	193.2124
Merge Sort	0.0013	0.0032	0.0055	0.0114	0.1085	0.3040	48.348
Quick Sort	0.0083	0.0018	0.0035	0.0072	0.1152	0.4320	41.400

Chart - 3



Discussion

Selection Sort:

Since the time complexity of selection sort is $O(N^2)$, as we can see from Chart-1, for smaller values of *n*, selection sort performs less efficiently than other algorithms, the running time dramatically increases as *n* increases.

It's the best case if the array is already sorted in ascending order when selection sort is called, since the algorithm doesn't have to do swap operation after each comparison, but it's still $O(N^2)$, the two loops still execute the same number of times, regardless of whether the array is sorted or not, so the run time is not going to improve much. (shows in Chart-2)

The worst case is that sorting a reversely sorted array, since the algorithm has to do swap operation after each comparison, consumes more time. (shows in Char-3)

Insertion Sort:

The time complexity of insertion sort is $O(N^2)$ as well, as Chart-1 shows, the running time dramatically increases as *n* increases. For smaller values of *n*, insertion sort performs efficiently like other algorithms.

It's the best case when the array is already sorted in ascending order, since the number of searches and swaps are reduced maximally. In this case, insertion sort performs more efficiently than the other algorithms. (shows in Chart-2)

It's the worst case when the array is already sorted in descending order, since on each iteration of its outer loop, insertion sort has to traverse all elements to find the correct place to insert the next item. (shows in Char-3)

Merge Sort:

The time complexity of merge sort is $O(N \log N)$, it's a stable algorithm, for smaller values of *n*, merge sort performs efficiently like other algorithms, the running time slowly increases as *n* increases. It shows stable characteristics in unsorted, ascending and descending all three cases.

Quick Sort:

The time complexity of quick sort in practice is $O(N \log N)$, for smaller values of *n*, quick sort performs efficiently like other algorithms, in unsorted and descending cases, the running time slowly increases as *n* increases, and performs most efficiently in all four algorithms. (shows in Chart-1, Chart-3)

It's the worst case when the array is already sorted in ascending order, since in this case, the pivot is the smallest, the calls is from a linear tree rather a balanced binary tree. The time complexity of quick sort in worst case is $O(N^2)$, the running time dramatically increases as *n* increases, and performs least efficiently in all four algorithms. (shows in Chart-2)

Source Code:

```
import java.util.Arrays;
import java.util.Collections;
import java.util.Random;

public class TimeAlgorithms {
    private Integer[] unsorted;
    private Integer[] ascending;
    private Integer[] descending;

    public void generateArrays(int n, String s) {
        Random num =  new Random();
        Integer[] temp = new Integer[n];
        for (int i = 0; i < n; ++i) {
            temp[i] = num.nextInt(n);
        }
        if (s.equals("unsorted")) {
            unsorted = new Integer[n];
            unsorted = temp;
        } else if (s.equals("ascending")) {
            Arrays.sort(temp);
            ascending = new Integer[n];
            ascending = temp;
        } else {
            Arrays.sort(temp, Collections.reverseOrder());
            descending = new Integer[n];
            descending = temp;
        }
    }

    public void runTest(int n, Integer[] array) {
        System.out.printf("n = %d%n", n);

        // test for Selection Sort
        Integer[] arrayS = new Integer[n];
        System.arraycopy(array, 0, arrayS, 0, n);
        long startS = System.nanoTime();
        SortingAlgorithms.selectionSort(arrayS, false);
        long endS = System.nanoTime();
        double timeS = (endS - startS) / 1000000.0;
        System.out.println("Selection Sort Runtime: " + timeS + " ms");

        // test for Insertion Sort
        Integer[] arrayI = new Integer[n];
        System.arraycopy(array, 0, arrayI, 0, n);
        long startI = System.nanoTime();
        SortingAlgorithms.insertionSort(arrayI, false);
        long endI = System.nanoTime();
        double timeI = (endI - startI) / 1000000.0;
        System.out.println("Insertion Sort Runtime: " + timeI + " ms");

        // test for Merge Sort
        Integer[] arrayM = new Integer[n];
        System.arraycopy(array, 0, arrayM, 0, n);
        long startM = System.nanoTime();
        SortingAlgorithms.mergeSort(arrayM, false);
        long endM = System.nanoTime();
        double timeM = (endM - startM) / 1000000.0;
```

```
        System.out.println("Merge Sort Runtime: " + timeM + " ms");

        // test for Quick Sort
        Integer[] arrayQ = new Integer[n];
        System.arraycopy(array, 0, arrayQ, 0, n);
        long startQ = System.nanoTime();
        SortingAlgorithms.quickSort(arrayQ, false);
        long endQ = System.nanoTime();
        double timeQ = (endQ - startQ) / 1000000.0;
        System.out.println("Quick Sort Runtime: " + timeQ + " ms");
    }

    public static void main(String[] args) {
        int[] cases = {5, 10, 50, 100, 500, 1000, 10000};
        TimeAlgorithms test = new TimeAlgorithms();

        System.out.println("********** test for unsorted numbers **********");
        for (int i = 0; i < 7; ++i) {
            test.generateArrays(cases[i], "unsorted");
            test.runTest(cases[i], test.unsorted);
        }

        System.out.println("********** test for ascending numbers **********");
        for (int i = 0; i < 7; ++i) {
            test.generateArrays(cases[i], "ascending");
            test.runTest(cases[i], test.ascending);
        }

        System.out.println("********** test for descending numbers **********");
        for (int i = 0; i < 7; ++i) {
            test.generateArrays(cases[i], "descending");
            test.runTest(cases[i], test.descending);
        }
    }
}
```