

	Insertion	Selection	Merge	Quick
Best case time	already sorted $\Theta(n)$	$\Theta(n^2)$	$\Theta(n \lg(n))$	$\Theta(n \lg(n))$
Worst case time	reverse sorted $\Theta(n^2)$	$\Theta(n^2)$	$\Theta(n \lg(n))$	$\Theta(n^2)^* \text{ avg } O(n \lg(n))$
Key operations	swap(a, j, j-1) (until in the right place)	swap(a, i, indexOfMin) (after finding minimum value)	l = copy(a, 0, len/2) r = copy(a, len/2, len) ls = sort(l) rs = sort(r) merge(ls, rs)	p = partition(a, l, h) sort(a, l, p) sort(a, p + 1, h)

```

import java.util.Arrays;
public class Sort {
    static void selectionSort(int[] arr) {
        for(int i = 0; i < arr.length; i += 1) {
            int minIndex = i;
            for(int j = i; j < arr.length; j += 1) {
                if(arr[minIndex] > arr[j]) { minIndex = j; }
            }
            int temp = arr[i];
            arr[i] = arr[minIndex];
            arr[minIndex] = temp;
        }
    }

    static void insertionSort(int[] arr) {
        for(int i = 0; i < arr.length; i += 1) {
            for(int j = i; j > 0; j -= 1) {
                if(arr[j] < arr[j-1]) {
                    int temp = arr[j-1];
                    arr[j-1] = arr[j];
                    arr[j] = temp;
                }
                else { break; } // new! exit inner loop early
            }
        }
    }
}

```

↑
stop at
first pair of
ordered elts

3 (5) (6) (8) 10

Best case?

- A: Array in decreasing order
- B: Array in increasing order
- C: Array of all equal elements
- D: Something else

Divide and Conquer

```

import java.util.Arrays;
public class SortFaster {

    static int[] combine(int[] p1, int[] p2) {...}

    static int[] mergeSort(int[] arr) {
        int len = arr.length
        if(len <= 1) { return arr; }
        else {
            int[] p1 = Arrays.copyOfRange(arr, 0, len / 2);
            int[] p2 = Arrays.copyOfRange(arr, len / 2, len);
            int[] sortedPart1 = mergeSort(p1);
            int[] sortedPart2 = mergeSort(p2);
            int[] sorted = combine(sortedPart1, sortedPart2);
            return sorted;
        }
    }
}

```

Pivot ideas:

- random
- middle index
- average of k

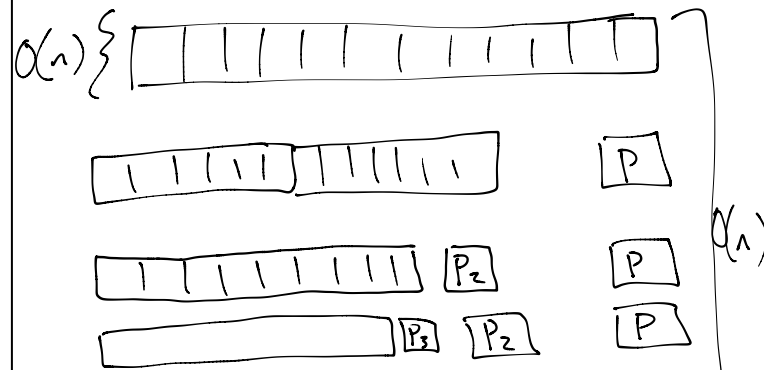
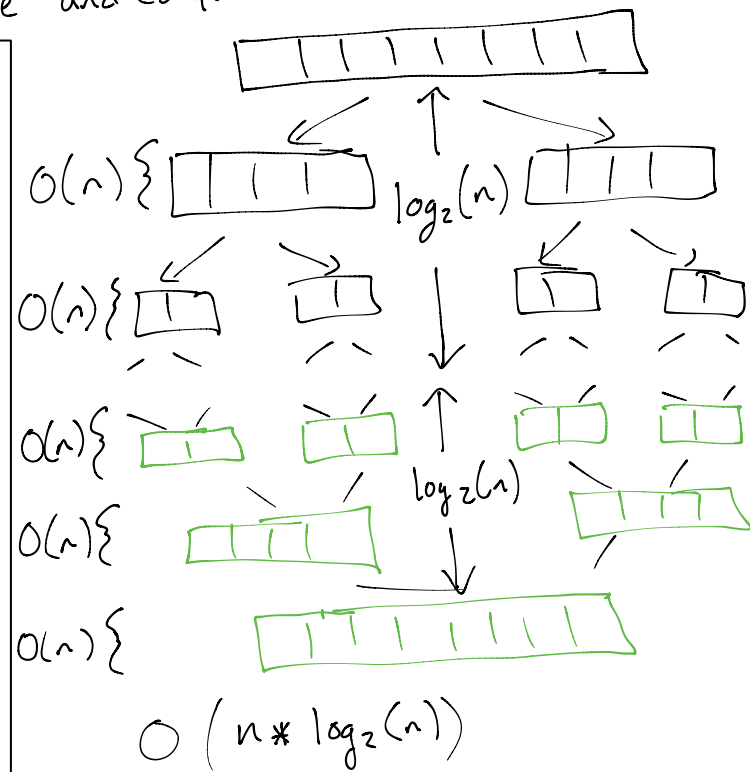
```

static int partition(String[] array, int l, int h) {...}

static void qsort(String[] array, int low, int high) {
    if(high - low <= 1) { return; }
    int splitAt = partition(array, low, high);
    qsort(array, low, splitAt);
    qsort(array, splitAt + 1, high);
}

public static void sort(String[] array) {
    qsort(array, 0, array.length);
}
}

```



Worst case: Pivot value is extreme - $O(n^2)$

```

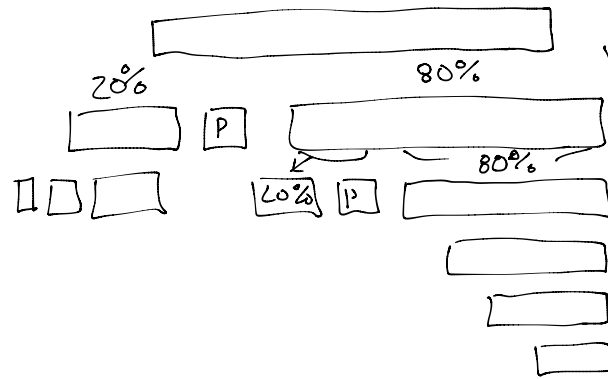
interface Map<Key, Value> {

```

```

}

```



Randomized /
Approximation
Algorithms

$$1 * 0.8$$

$$\log_{\frac{1}{0.8}}(n)$$

$$n * 0.5$$

$$\log_2(n)$$