Sorting

1. Sorting

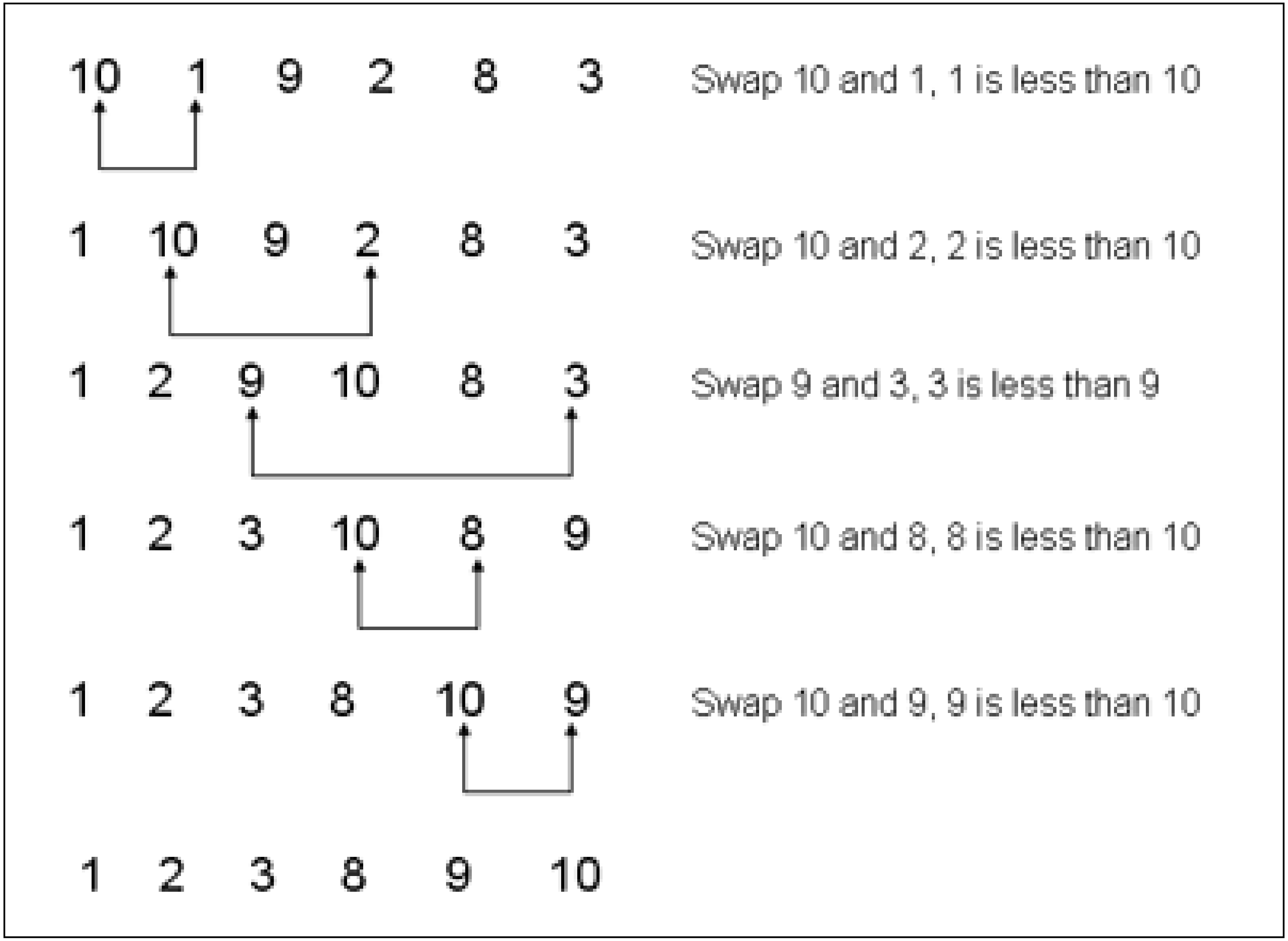
- The most basic technique in programming

- So many solutions for it
  - $O(n^2)$, $O(n\lg n)$, $O(n)$
  - depending on
    - simplicity of mind
    - complexity of insert operation

2. Sorting Algorithms

- Comparison Sort – O(n^2), O($n\lg n$)
  - Insertion sort
  - Merge sort
  - Heap sort
  - Quick sort
  - Counting Sort – O(n)
    - radix sort : extended counting sort
  - Bucket Sort – O(n)
- Why different complexities?
  - use of smart data structure
  - hide cost operations behind

3. Selection Sort



3. Selection Sort – slow

78 84 42 12 56 96 26 32

78 84 42 12 56 96 26 32

3. Selection Sort – the code

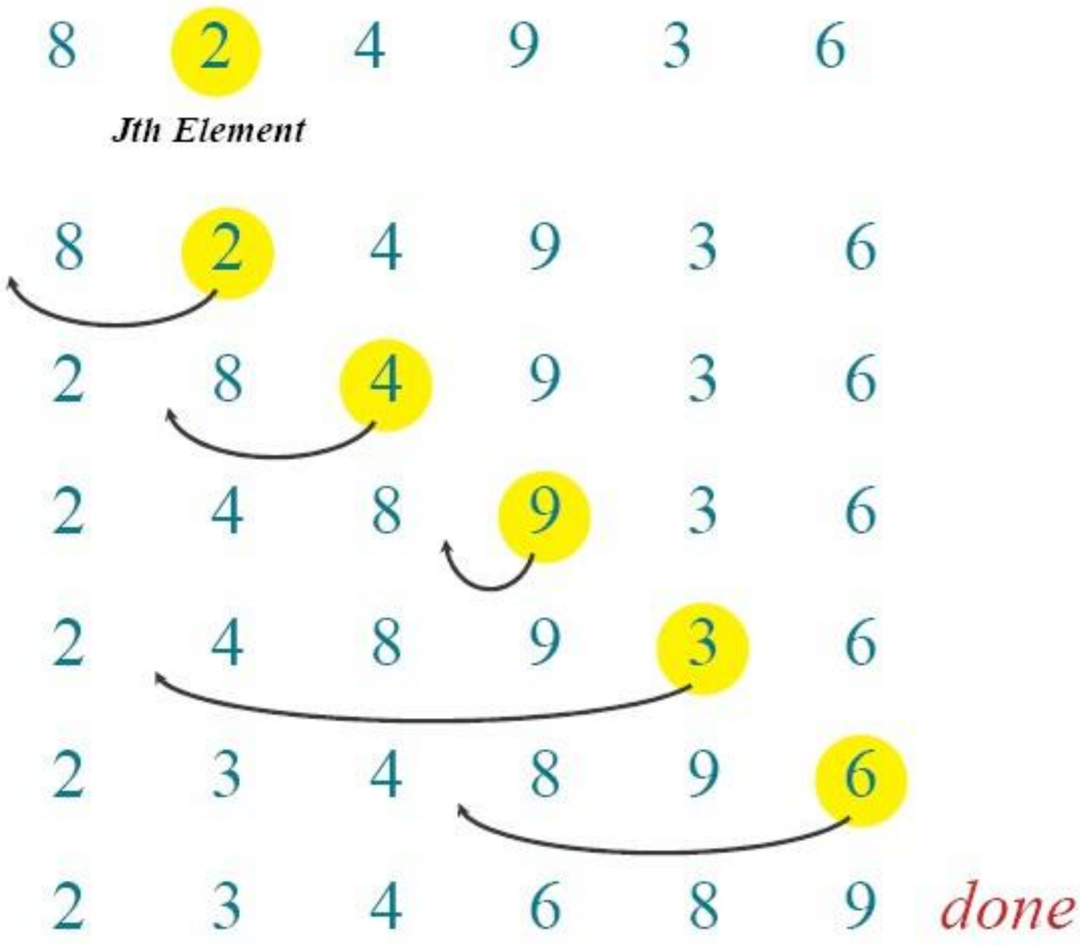
- Pseudocode

```
for i ← 0 to n-2 do
    min ← i
    for j ← (i + 1) to n-1 do
        if A[j] < A[min]
            min ← j
    swap A[i] and A[min]
```

- C Code

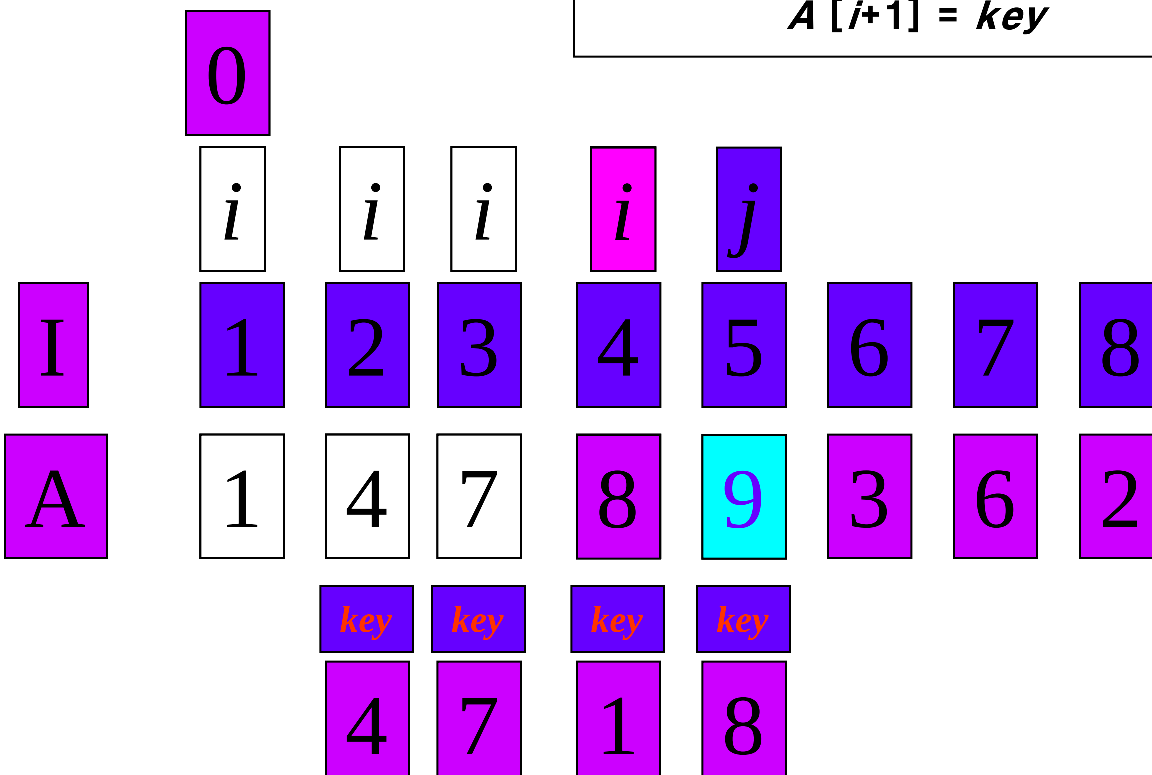
```
selection_sort(int s[], int n)
{
        int i,j;                        /* counters */
        int min;                        /* index of minimum */

        for (i=0; i<n; i++) {
                min=i;
                for (j=i+1; j<n; j++)
                        if (s[j] < s[min]) min=j;
                swap(&s[i],&s[min]);
        }
}
```

4. Insertion Sort



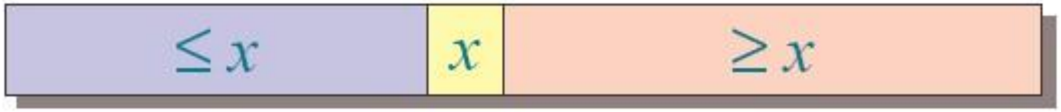
4. Insertion Sort – the code

```
Insertion–Sort (A)
        for each j = 2 to length [A]
        do key = A [j]  //Inserted into Sorted Subarray
                i = j – 1
                while i > 0 & A [i] > key
                        do A [i+1] = A [i]
                            i = i – 1
                A [i+1] = key
```



5. Quick Sort

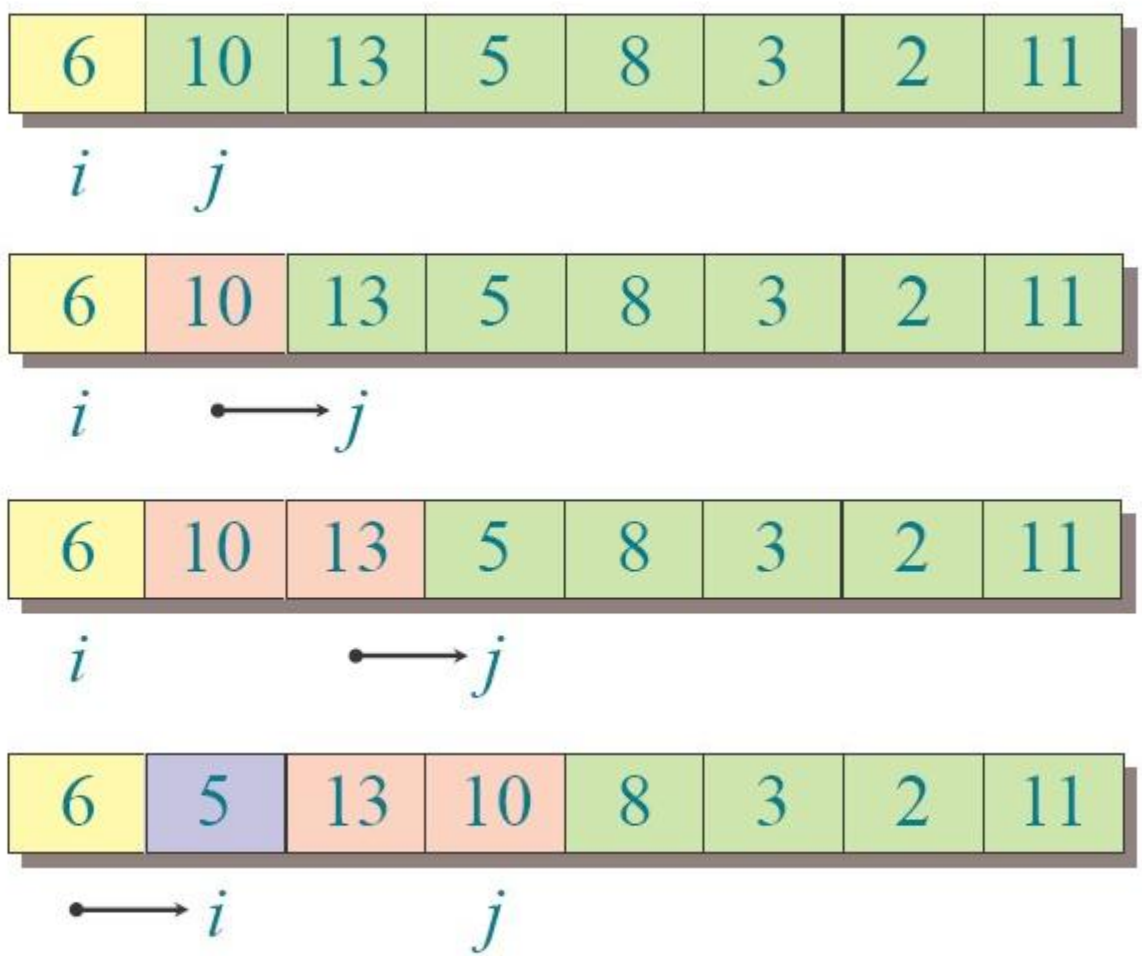
- Divide-and-Conquer
  - Divide
    - the array into two parts

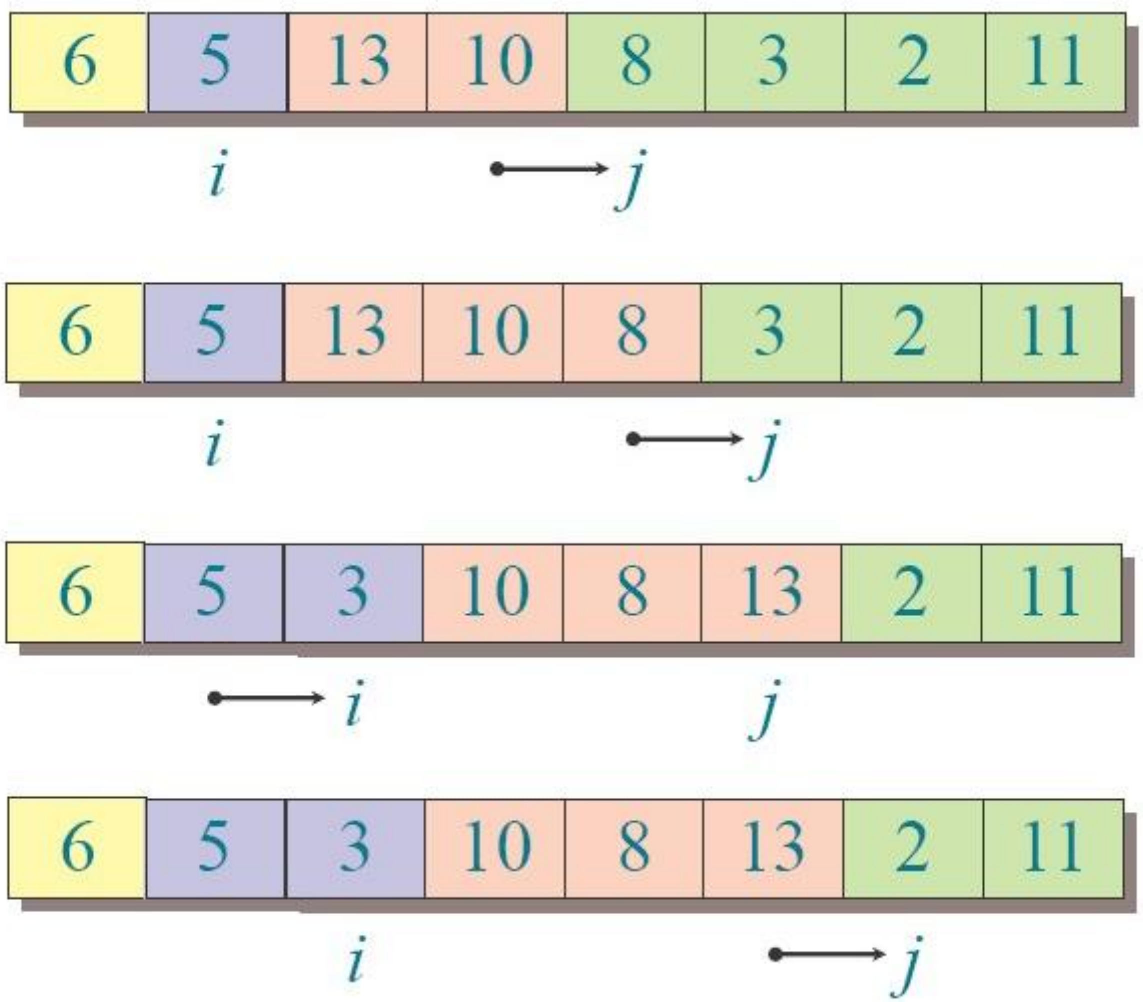


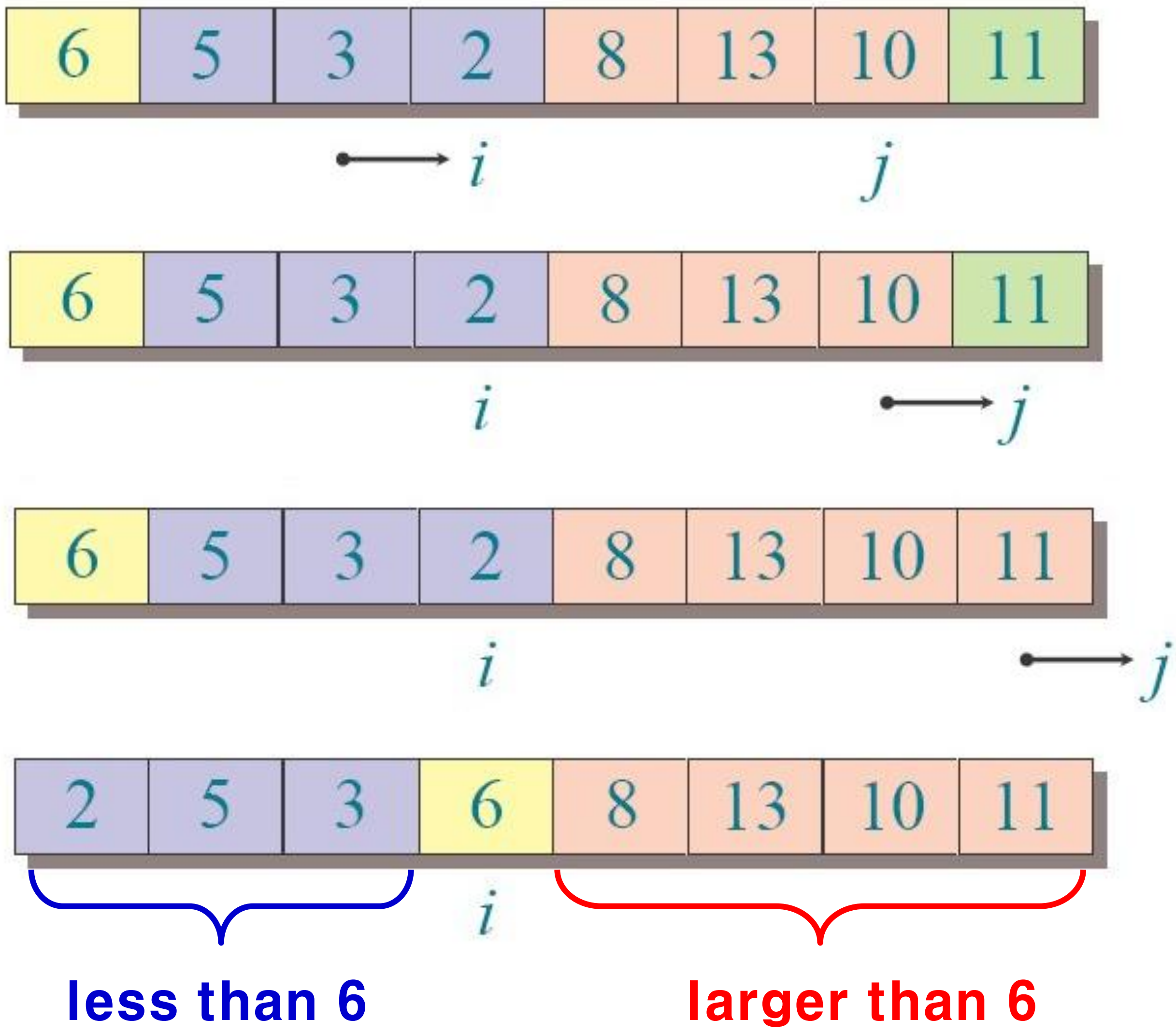
    - the value of x? pivot
  - Conquer
    – do the same to each divided subarray
  - Combine

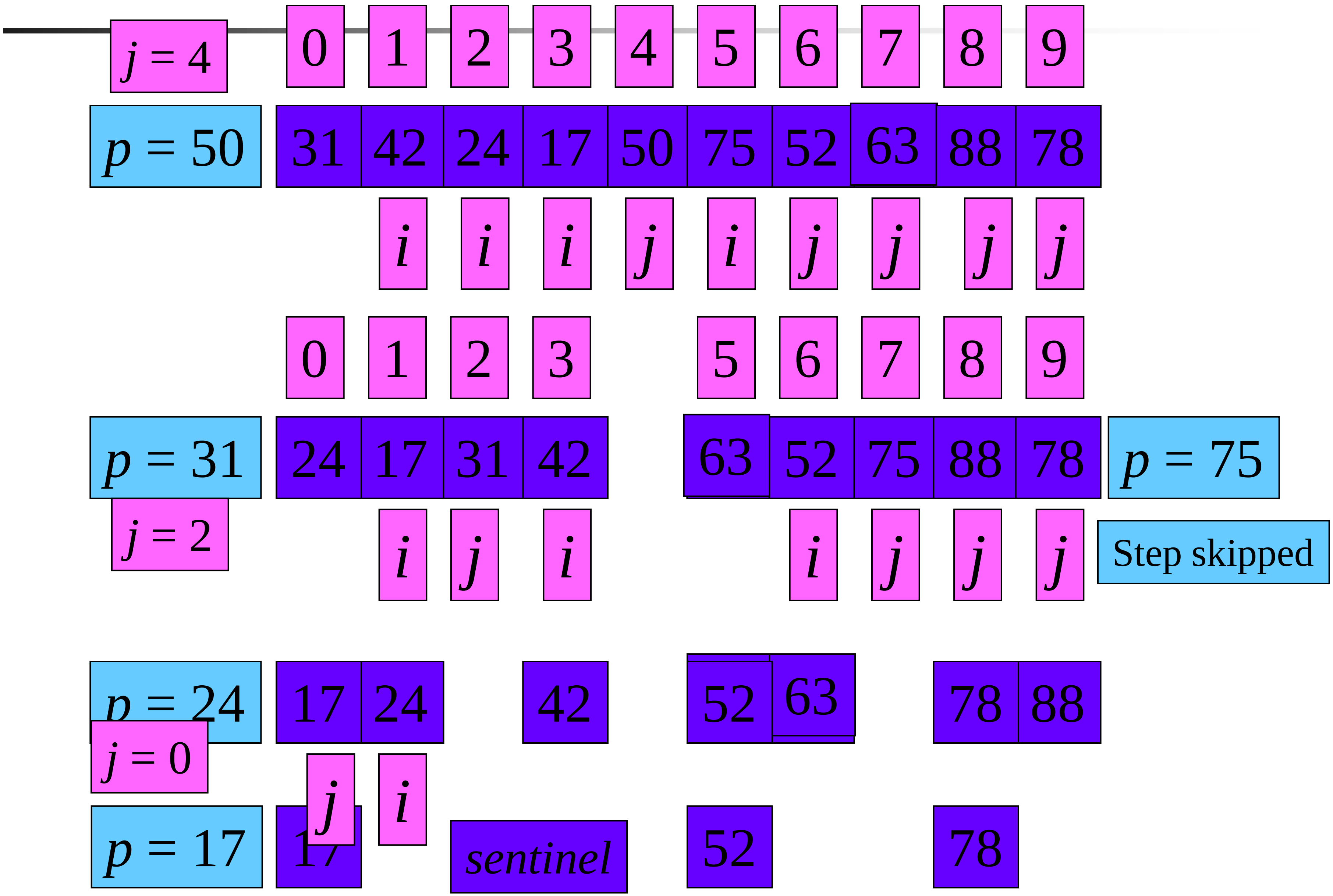
5. Quick Sort Example

- pivot: 6




6 5 13 10 8 3 2 11
i j
6 5 13 10 8 3 2 11
i j
6 5 3 10 8 13 2 11
i j
6 5 3 10 8 13 2 11
i j


6 5 3 2 8 13 10 11
i j
6 5 3 2 8 13 10 11
i j
6 5 3 2 8 13 10 11
i j
2 5 3 6 8 13 10 11
i
less than 6
larger than 6


j = 4
0 1 2 3 4 5 6 7 8 9
p = 50
31 42 24 17 50 75 52 63 88 78
i i i j i j j j j
0 1 2 3 5 6 7 8 9
p = 31
24 17 31 42
63 52 75 88 78
p = 75
j = 2
i j i
i j j j
Step skipped
p = 24
17 24
42
52 63
78 88
j = 0
j i
p = 17
17
sentinel
52
78

5. Quick Sort Algorithm

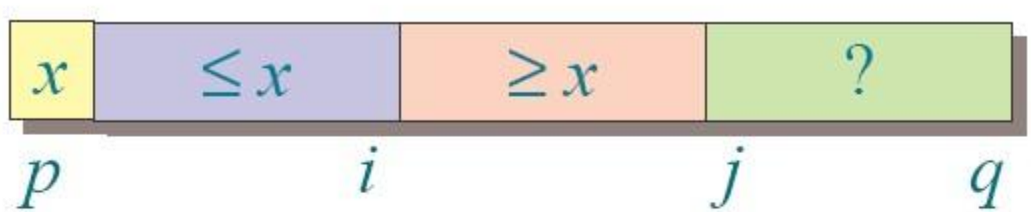
QUICKSORT(A, p, r)
  if $p < r$
    then $q \leftarrow$ PARTITION(A, p, r)
      QUICKSORT(A, p, $q-1$)
      QUICKSORT(A, $q+1$, r)

Initial call: QUICKSORT(A, 1, n)

Details

```
PARTITION(A, p, q)  ◁ A[p . . q]
    x ← A[p]            ◁ pivot = A[p]
    i ← p
    for j ← p + 1 to q
        do if A[j] ≤ x
              then  i ← i + 1
                    exchange A[i] ↔ A[j]
    exchange A[p] ↔ A[i]
    return i
```

Running time $= O(n)$ for n elements.



the code

```
quicksort(int s[], int l, int h)
{
    int p;          /* 분할을 위한 인덱스 */

    if ((h-l)>0)) {
        p = partition(s, l, h);
        quicksort(s, l, p-1);
        quicksort(s, p+1, h);
    }
}
```

```
int partition(int s[], int l, int h)
{
    int i;              /* counter */
    int p;              /* 피벗 원소의 인덱스 */
    int firsthigh;      /* 피벗을 위한 디바이더 위치 */

    p = l;
    firsthigh = l;
    for (i=l; i<h; i++)
        if (s[i] < s[p]) {
                swap(&s[i], &s[firsthigh]);
                firsthigh++;
        }
    swap(&s[p], &s[firsthigh]);

    return(firsthigh);

}
```

What if p=h?

Library

```
#include <stdlib.h>

void qsort(void *base, size_t nel, size_t width,
        int (*compare) (const void *, const void *));
```

- array: base
- number of elements: nel
- size of each element: width bytes
- you should provide compare function

```
int mycompare(int *i, int *j)
   {
        if (*i > *j) return (1);
        elseif (*i < *j) return (-1);
        else return (0);
   }
```

Library

- bsearch (key, (char *) a, cnt, sizeof(int), intcompare)
  - search the key value in the given sorted array

- C++

```
void sort(RandomAccessIterator bg, RandomAccessIterator end)
void sort(RandomAccessIterator bg, RandomAccessIterator end,
          BinaryPredicate op)
```

```
void stable_sort(RandomAccessIterator bg, RandomAccessIterator end)
void stable_sort(RandomAccessIterator bg, RandomAccessIterator end,
          BinaryPredicate op)
```

Vito's Family

The input consists of several test cases. The first line contains the number of test cases.
For each test case you will be given the integer number of relatives r ($0 < r < 500$) and the street numbers (also integers) $s_1, s_2, \ldots, s_i, \ldots, s_r$ where they live ($0 < s_i < 30,000$). Note that several relatives might live at the same street number.

For each test case, your program must write the minimal sum of distances from the optimal Vito's house to each one of his relatives. The distance between two street numbers s_i and s_j is $d_{ij} = |s_i - s_j|$.

Sample Input

```
2
2 2 4
3 2 4 6
```

Sample Output

```
2
4
```