Analysis and Design of Algorithms
Lecture 4

Sorting Algorithms I

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Sorting Algorithms

- **Sorting Algorithm** is an algorithm made up of a series of instructions that takes an array as input, and outputs a sorted array.

- There are many sorting algorithms, such as:
  - Selection Sort, Bubble Sort, Insertion Sort, Merge Sort, Heap Sort, QuickSort, Radix Sort, Counting Sort, Bucket Sort, ShellSort, Comb Sort, Pigeonhole Sort, Cycle Sort

Bubble Sort

Bubble Sort

- Bubble Sort is the simplest sorting algorithm that works by repeatedly swapping the adjacent elements if they are in wrong order.

Bubble Sort

❑ Algorithm:

- **Step1**: Compare each pair of adjacent elements in the list
- **Step2:** Swap two element if necessary
- **Step3:** Repeat this process for all the elements until the entire array is sorted

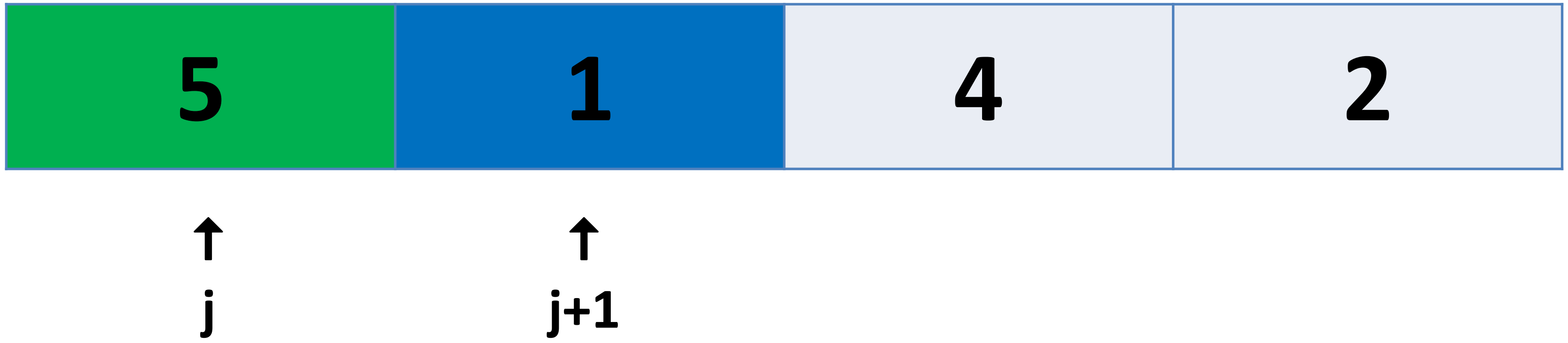
Bubble Sort

- Example 1 Assume the following Array:

5	**1**	**4**	**2**

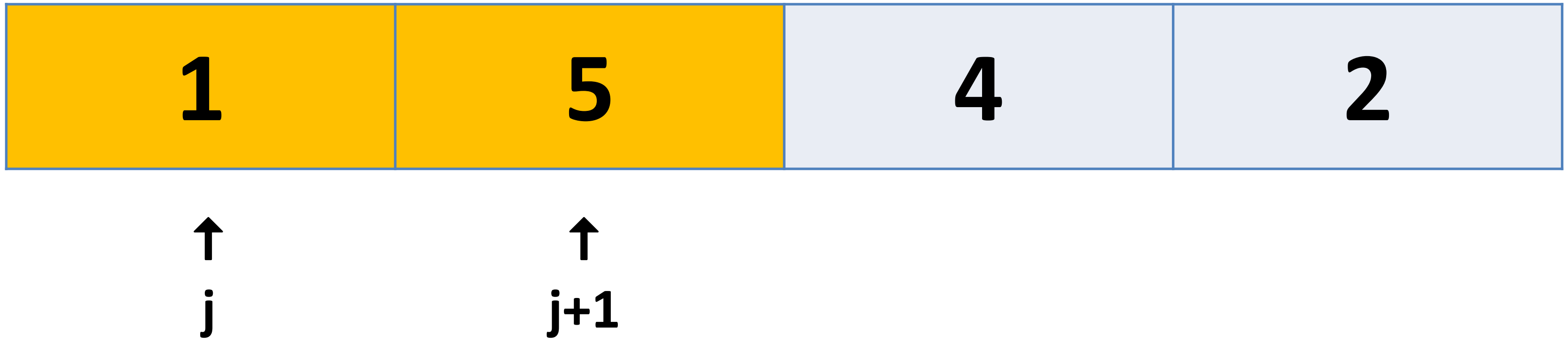
Bubble Sort

- First Iteration:
- Compare



Bubble Sort

- First Iteration:
- Swap

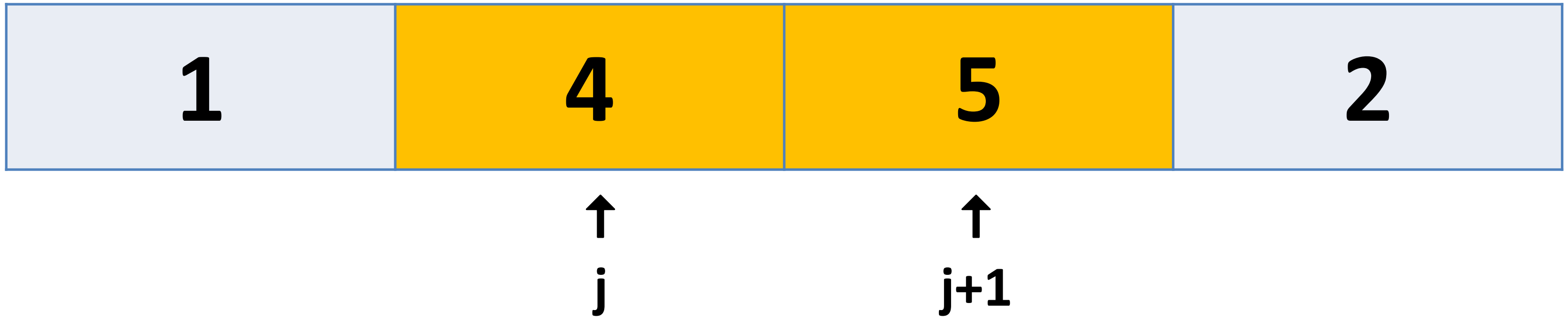


Bubble Sort

- First Iteration:
- Compare

Bubble Sort

- ❑ **First Iteration:**
- ❑ Swap



Bubble Sort

- First Iteration:
- Compare

Bubble Sort

- First Iteration:
- Swap

Bubble Sort

1	4	2	5

Bubble Sort

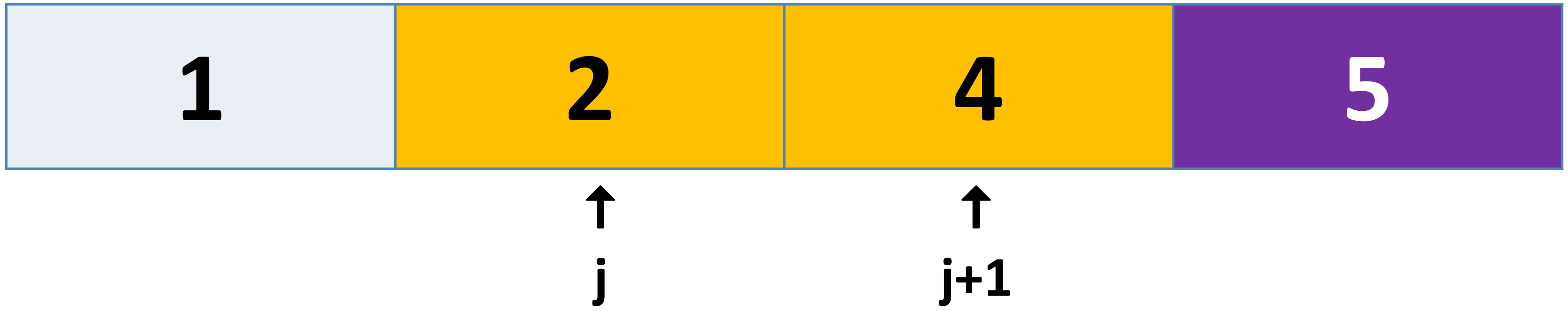
- Second Iteration:
- Compare

Bubble Sort

- Second Iteration:

- Compare

- Second Iteration:
- Swap



Bubble Sort

1	2	4	5

Bubble Sort

- Third Iteration:
- Compare

Bubble Sort

1	2	4	5

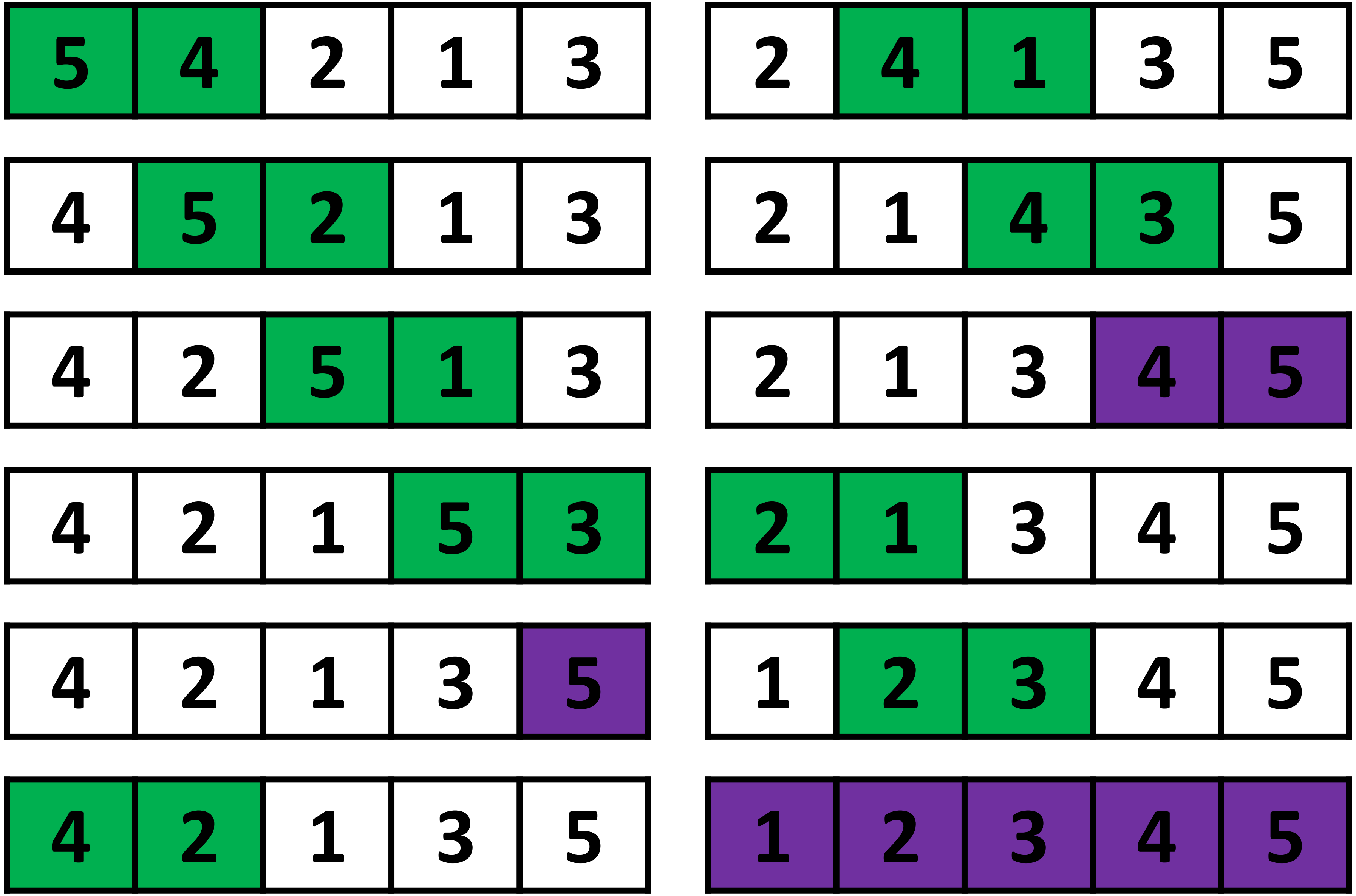
Bubble Sort

- Array is now sorted

1	2	3	4

Bubble Sort

- Example 2:



- What is the output of bubble sort after the 1st iteration given the following sequence of numbers: 13 2 9 4 18 45 37 63
  a) 2 4 9 13 18 37 45 63
  b) 2 9 4 13 18 37 45 63
  c) 13 2 4 9 18 45 37 63
  d) 2 4 9 13 18 45 37 63

Bubble Sort

- What is the output of bubble sort after the 1st iteration given the following sequence of numbers: **13 2 9 4 18 45 37 63**

  a) 2 4 9 13 18 37 45 63

  b) 2 9 4 13 18 37 45 63

  c) 13 2 4 9 18 45 37 63

  d) 2 4 9 13 18 45 37 63

Bubble Sort

- ❑ Python Code

```
def BubbleSort(arr):
    for i in range(len(arr)-1):
        for j in range(len(arr)-i-1):
            if arr[j] > arr[j+1] :
                arr[j], arr[j+1] = arr[j+1], arr[j]
    return arr
```

Bubble Sort

```
arr = [5, 1, 4, 2]
Sortedarr=BubbleSort(arr)
print(Sortedarr)
```

Bubble Sort

- **Time Complexity:** $O(n^2)$ as there are two nested loops

- Example of worst case

5	**4**	**3**	**2**	**1**

Selection Sort

Selection Sort

- The selection sort algorithm sorts an array by repeatedly finding the minimum element (considering ascending order) from unsorted part and putting it at the beginning.

❑ Algorithm:

- **Step1**: Find the minimum value in the list
- **Step2**: Swap it with the value in the current position
- **Step3**: Repeat this process for all the elements until the entire array is sorted

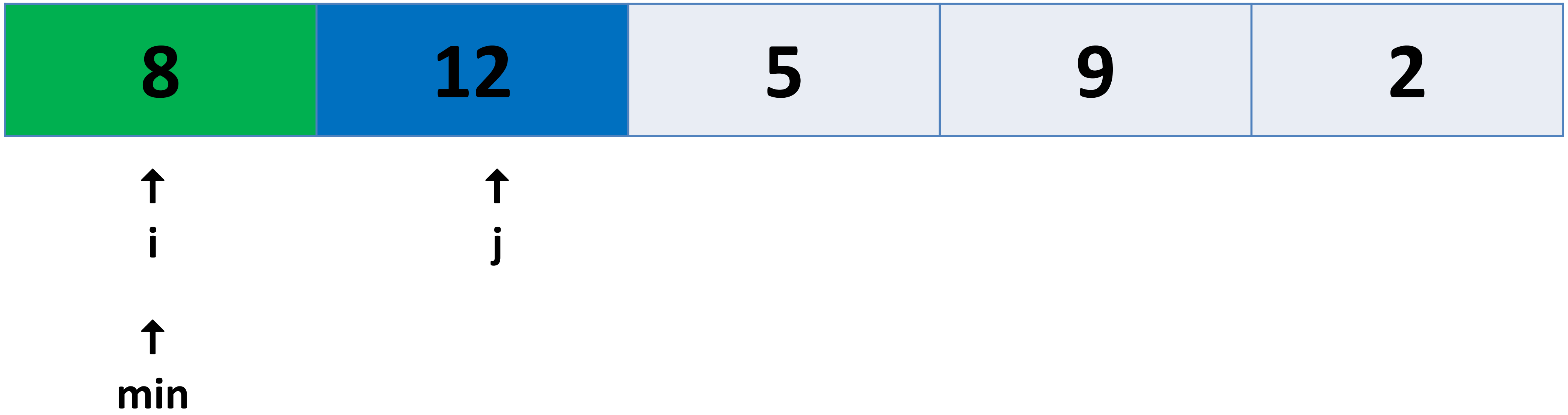
Selection Sort

- Example 1 Assume the following Array:

8	**12**	**5**	**9**	**2**

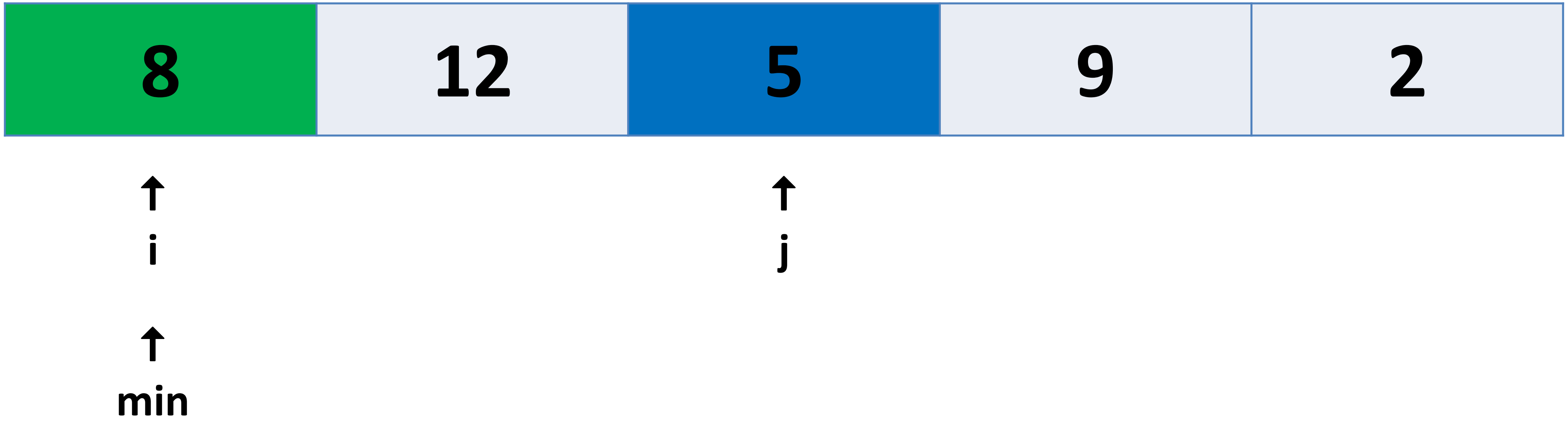
Selection Sort

- Compare

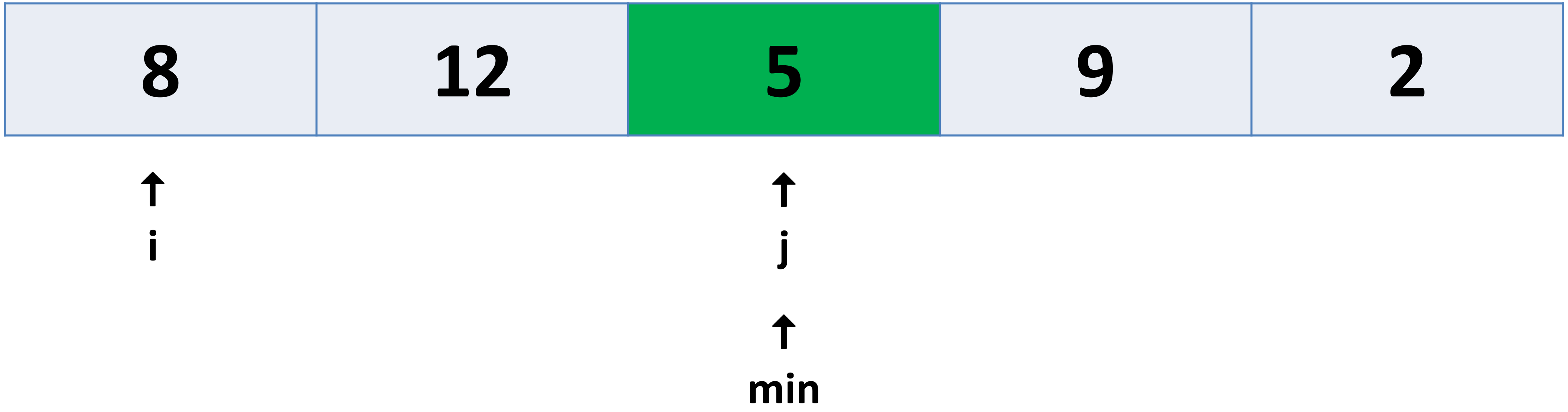


Selection Sort

- Compare

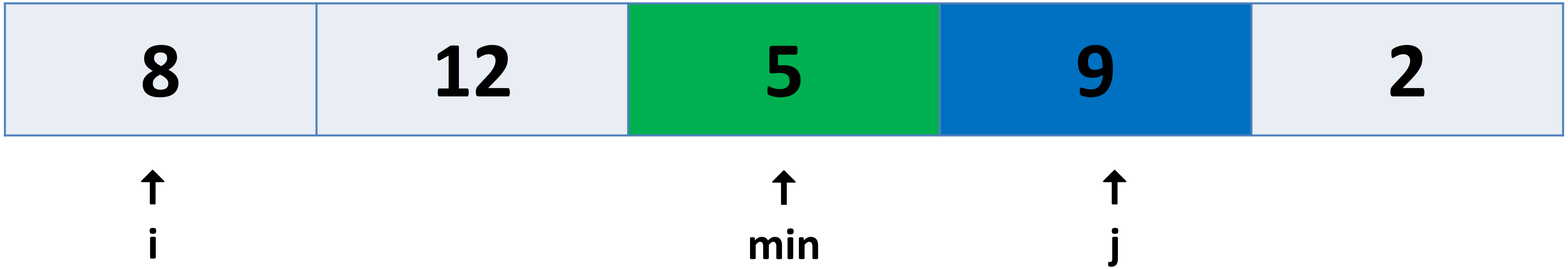


- Move



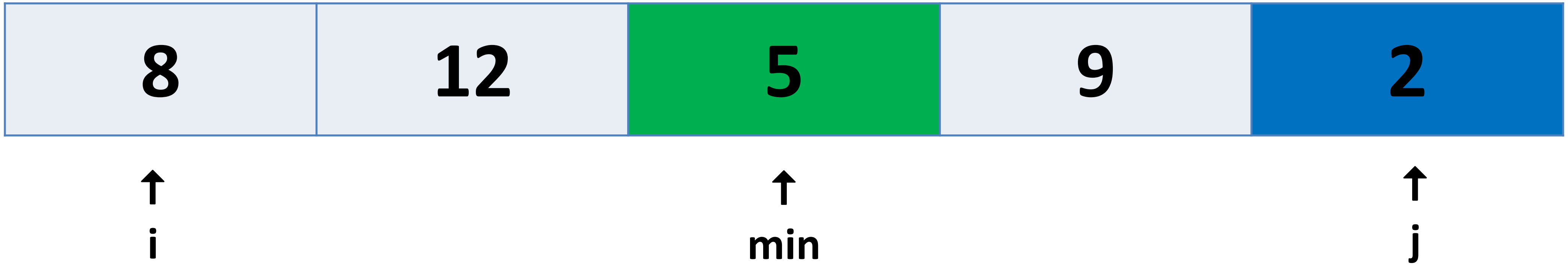
Selection Sort

- Compare



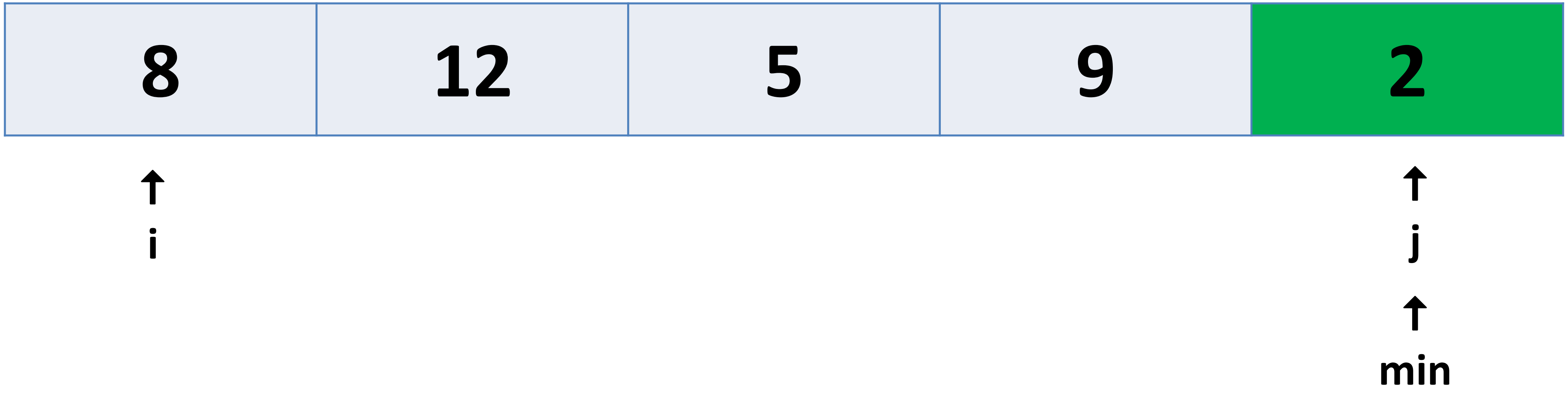
Selection Sort

- Compare



Selection Sort

- Move



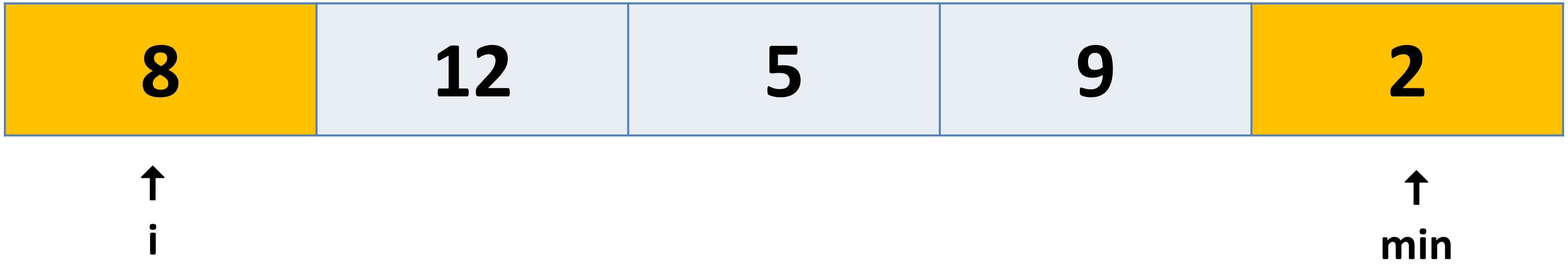
Selection Sort

- ❑ Smallest

8	12	5	9	2
↑ i				↑ min

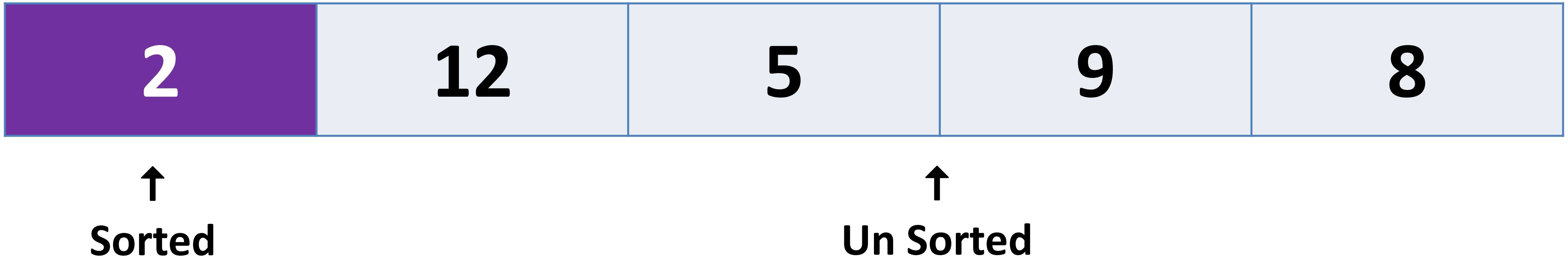
Selection Sort

- Swap



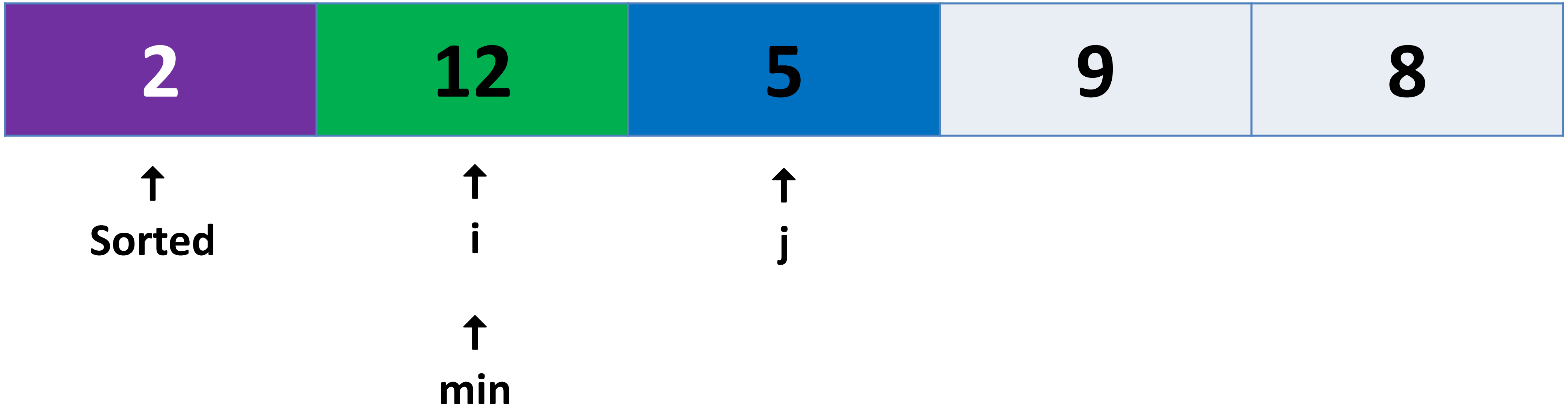
Selection Sort

- Sorted
- Un Sorted



Selection Sort

- ❑ Compare

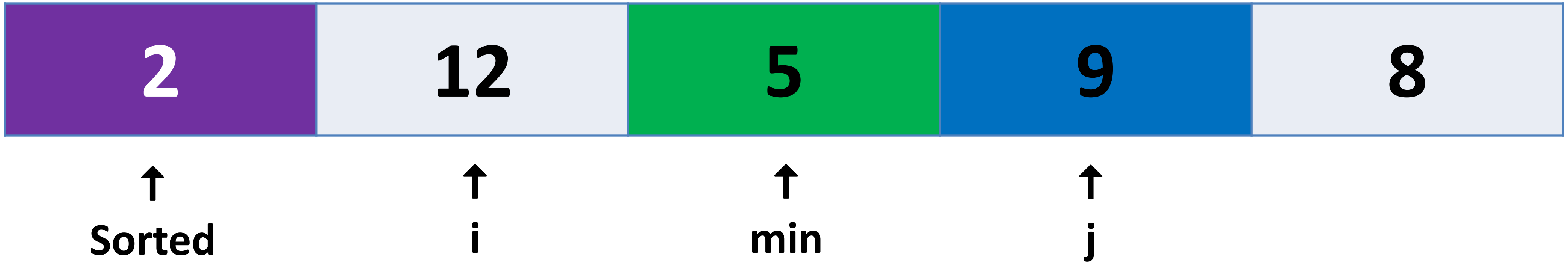


Selection Sort

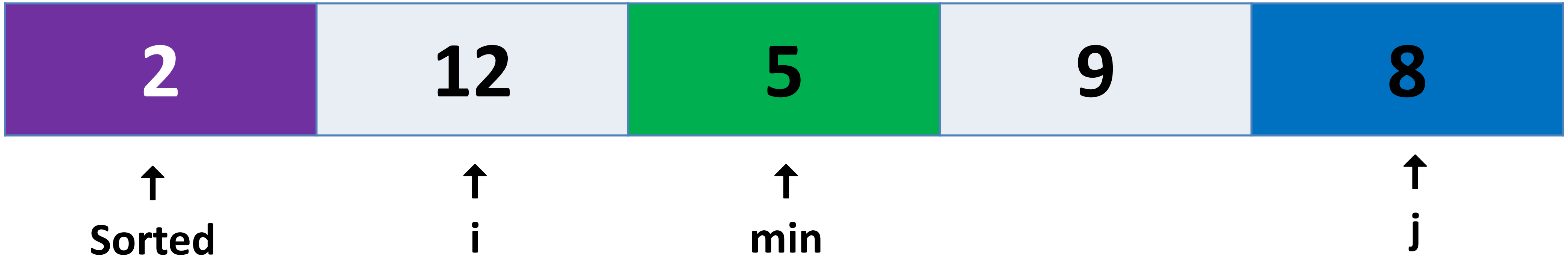
- Move

Selection Sort

- Compare



- Compare



Selection Sort

- Smallest

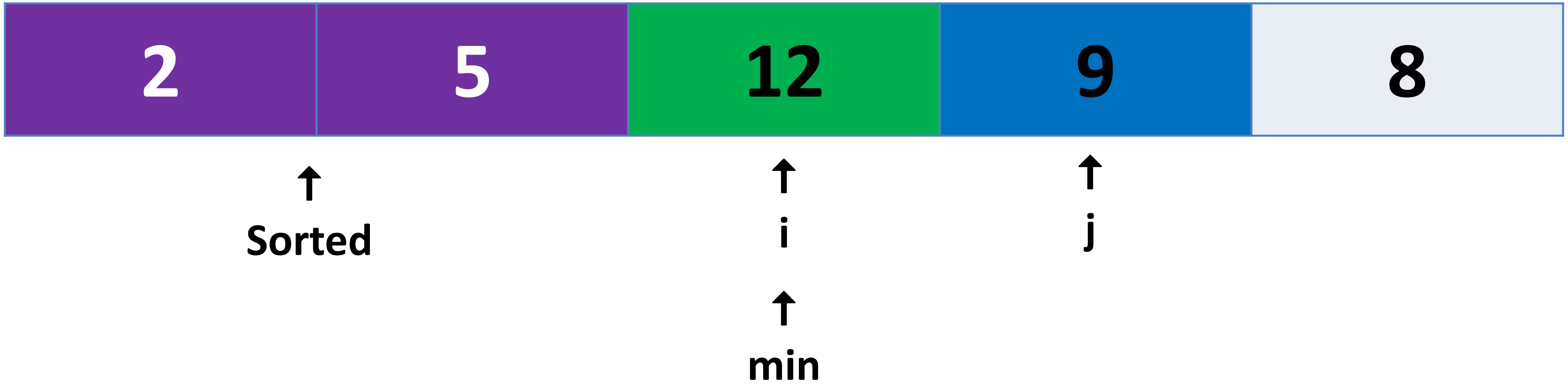
Selection Sort

- Swap

Selection Sort

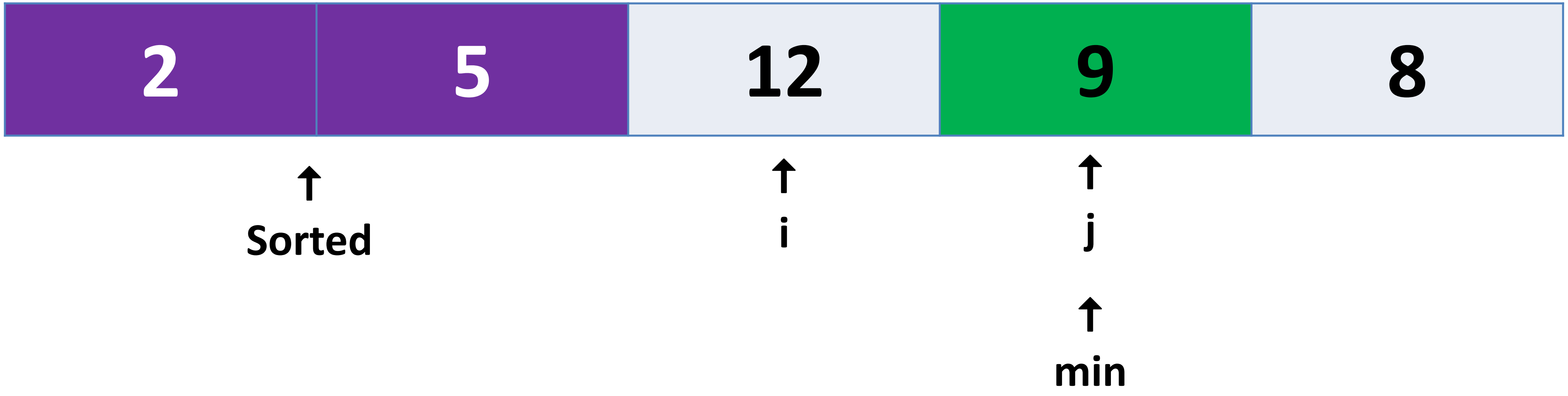
- ❑ Sorted
- ❑ Un Sorted

- Compare



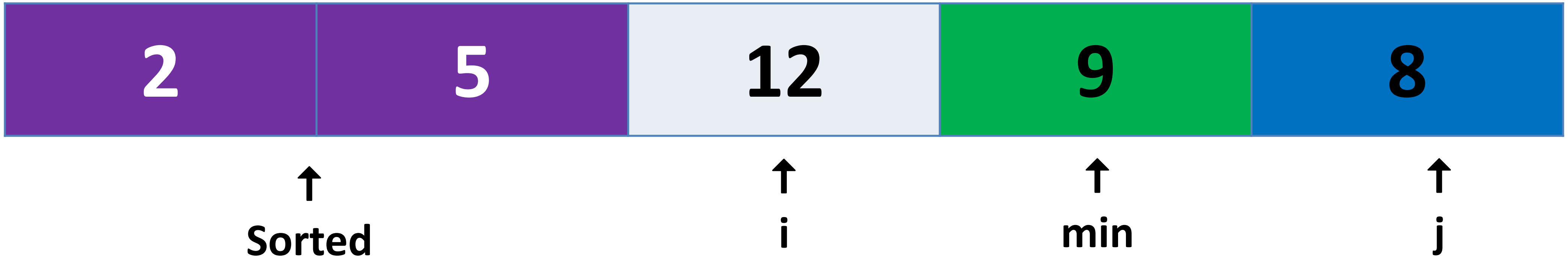
Selection Sort

- Move



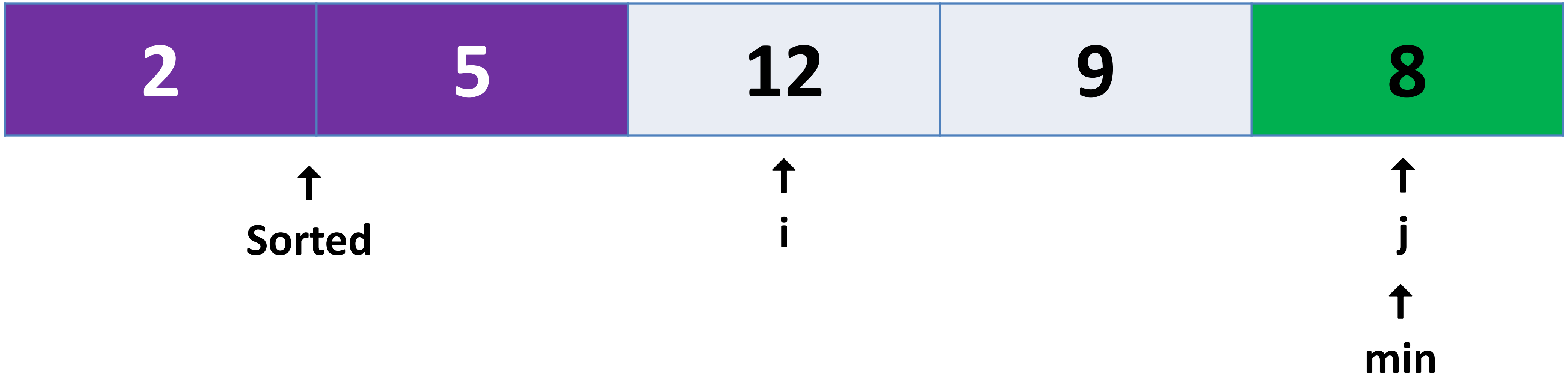
Selection Sort

- Compare



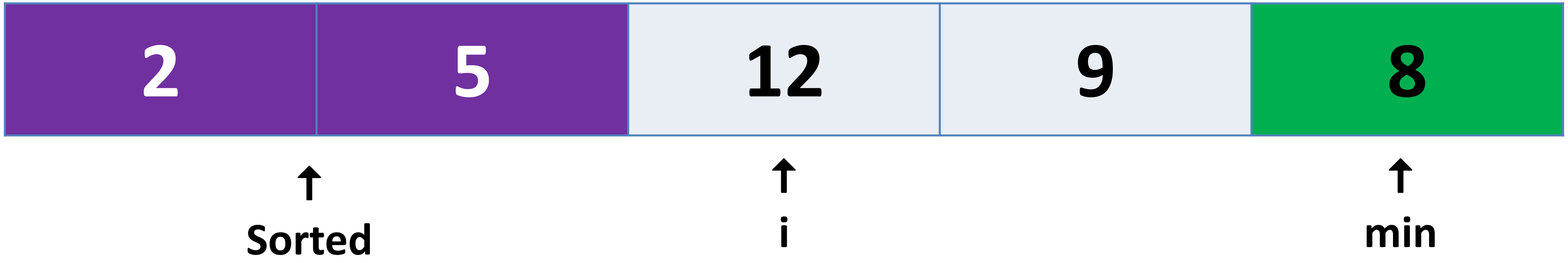
Selection Sort

- ❑ Move

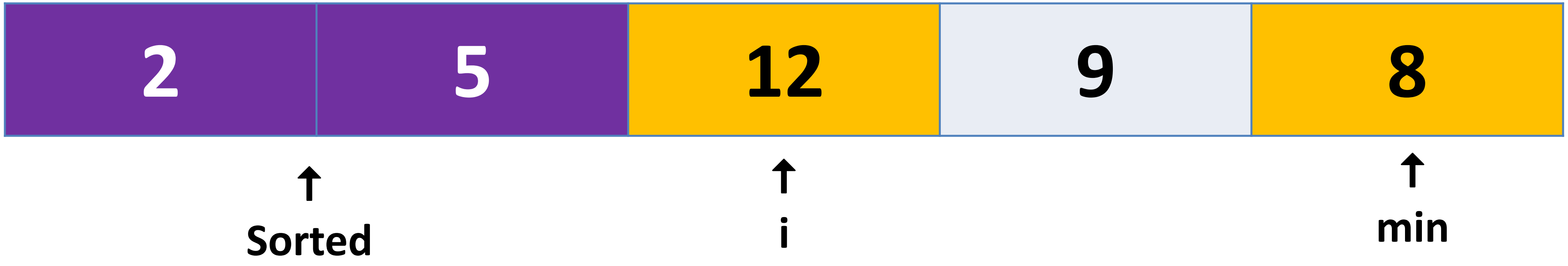


Selection Sort

- Smallest



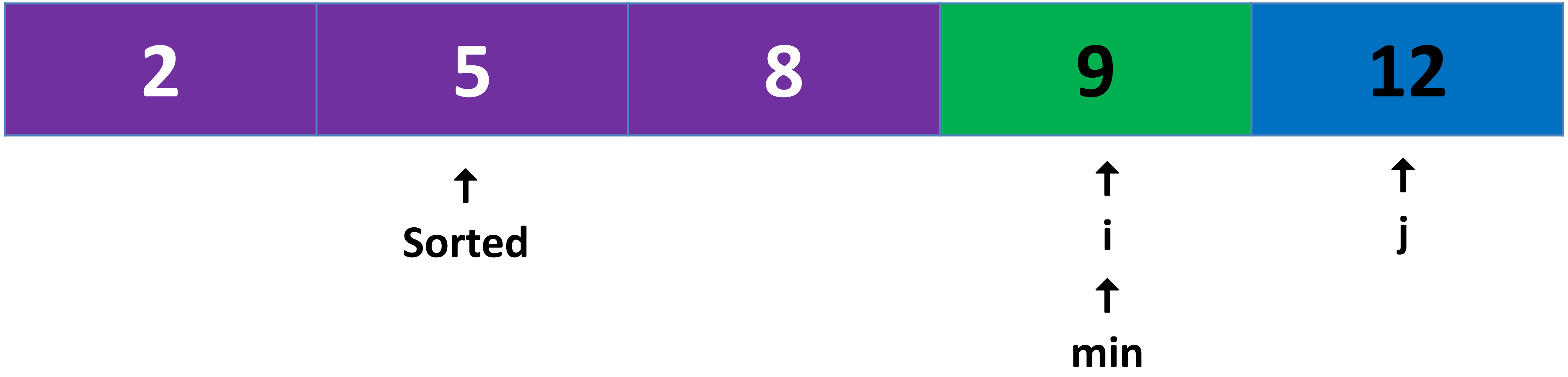
- Swap



- ❑ Sorted
- ❑ Un Sorted

Selection Sort

- Compare

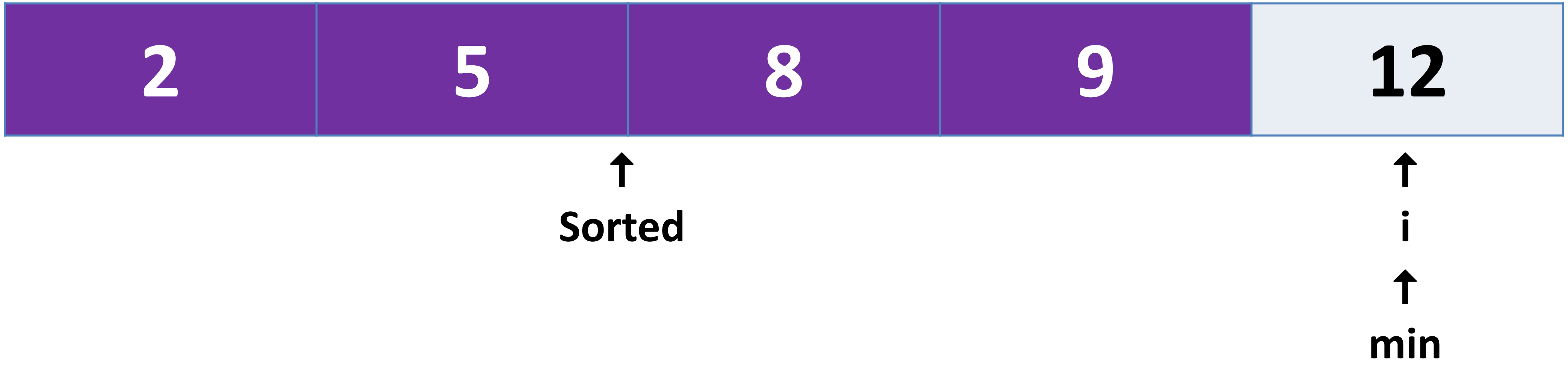


Selection Sort

- ❑ Sorted
- ❑ Un Sorted

Selection Sort

- ❑ Sorted
- ❑ Un Sorted



Selection Sort

- Array is now sorted

2	5	8	9	12

↑
Sorted

Selection Sort

- Example 2:

12	10	16	11	9	7

12	10	16	11	9	7
7	10	16	11	9	12
7	9	16	11	10	12
7	9	10	11	16	12
7	9	10	11	16	12
7	9	10	11	12	16

- What is the output of selection sort after the 2nd iteration given the following sequence of numbers: **13 2 9 4 18 45 37 63**

  a) 2 4 9 13 18 37 45 63

  b) 2 9 4 13 18 37 45 63

  c) 13 2 4 9 18 45 37 63

  d) 2 4 9 13 18 45 37 63

Selection Sort

- What is the output of selection sort after the 2nd iteration given the following sequence of numbers: **13 2 9 4 18 45 37 63**

  a) 2 4 9 13 18 37 45 63

  b) 2 9 4 13 18 37 45 63

  c) 13 2 4 9 18 45 37 63

  d) 2 4 9 13 18 45 37 63

Selection Sort

❑ Python Code

```
def SelectionSort(A):
    for i in range(len(A)):
        minind = i
        for j in range(i+1, len(A)):
            if A[minind] > A[j]:
                minind = j
        A[i], A[minind] = A[minind], A[i]
    return A
```

Selection Sort

```
arr = [8, 12, 5, 9, 2]
Sortedarr=SelectionSort(arr)
print(Sortedarr)
```

Selection Sort

- **Time Complexity:** $O(n^2)$ as there are two nested loops

- Example of worst case

2	**3**	**4**	**5**	**1**

Insertion Sort

- **Insertion sort** is a simple sorting algorithm that works the way we sort playing cards in our hands.

Algorithm:

- **Step1**: Compare each pair of adjacent elements in the list
- **Step2**: Insert element into the sorted list, until it occupies correct position.
- **Step3**: Swap two element if necessary
- **Step4**: Repeat this process for all the elements until the entire array is sorted

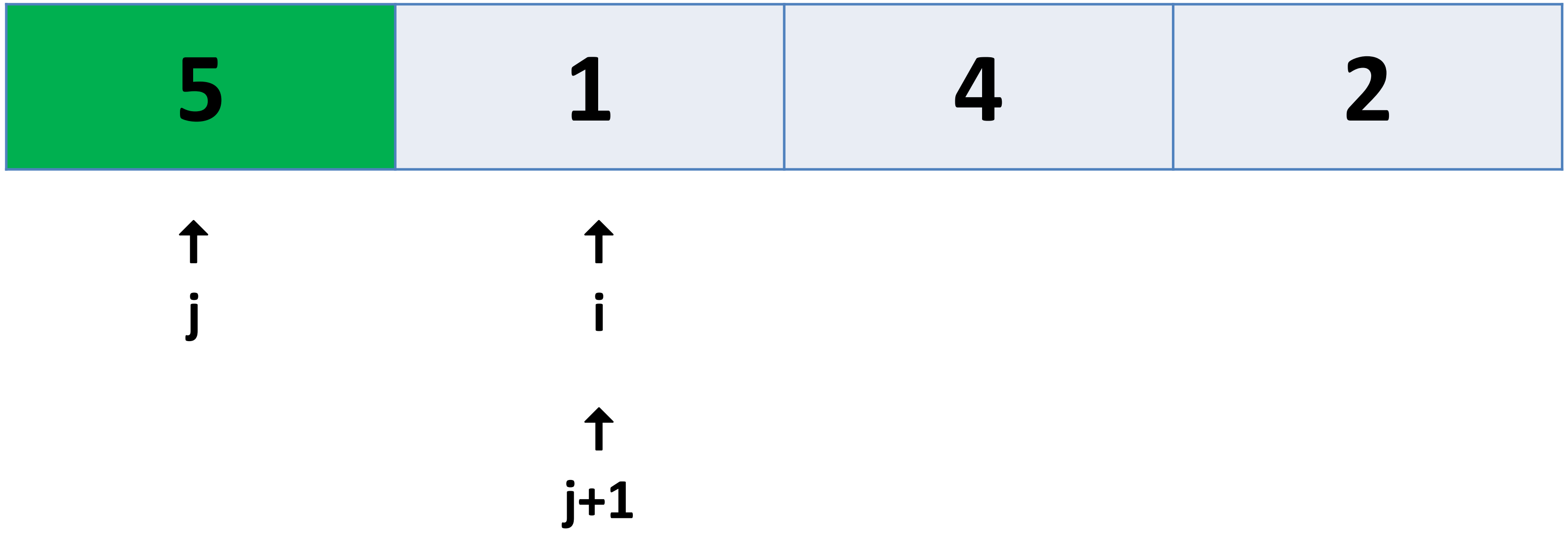
Insertion Sort

- ❑ Assume the following Array:

5	**1**	**4**	**2**

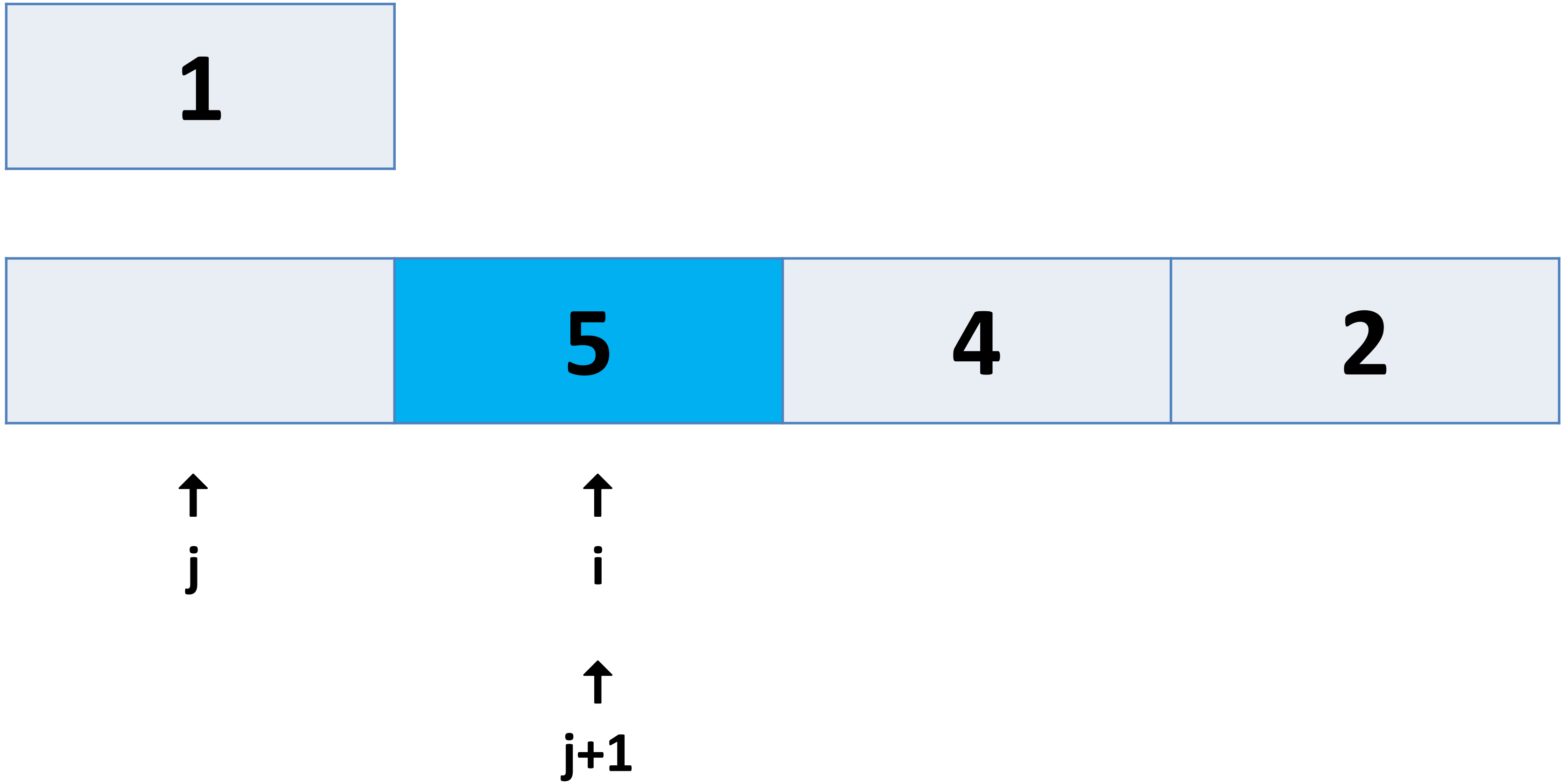
Insertion Sort

- Compare
- Store= 1

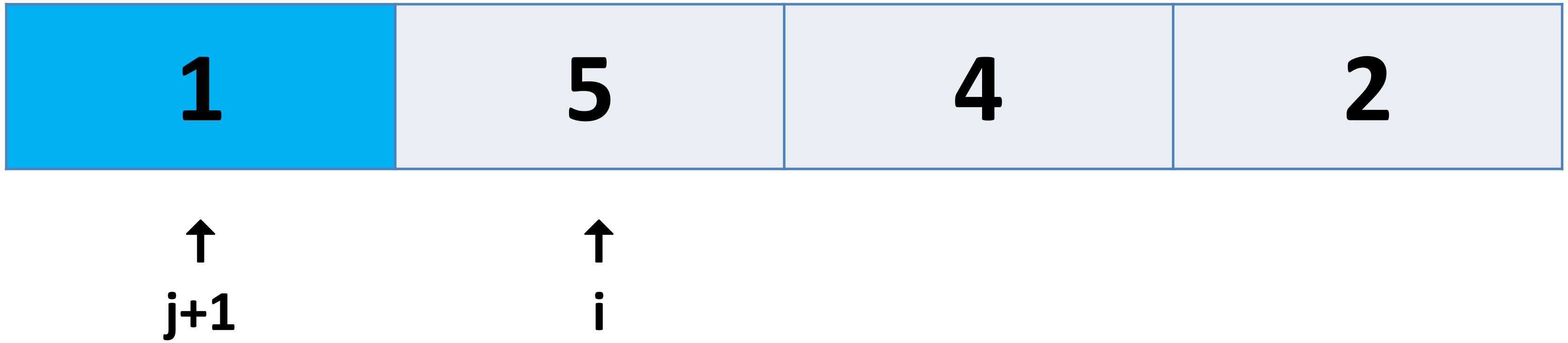


Insertion Sort

- Move
- Store=

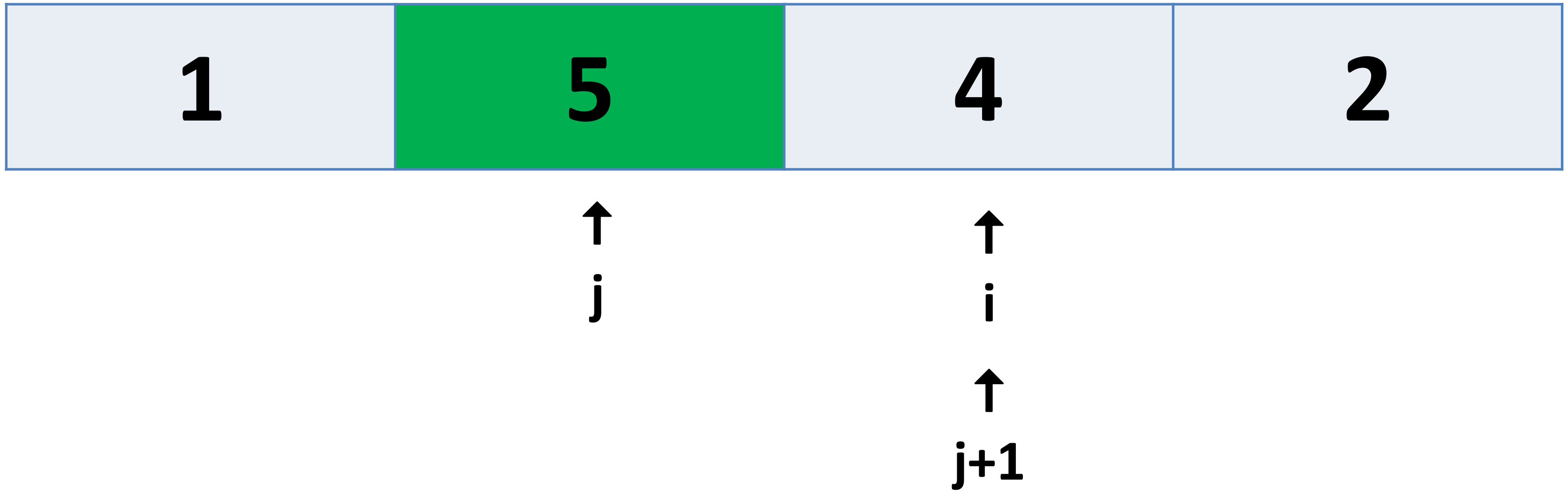


- ❑ Move
- ❑ Store=



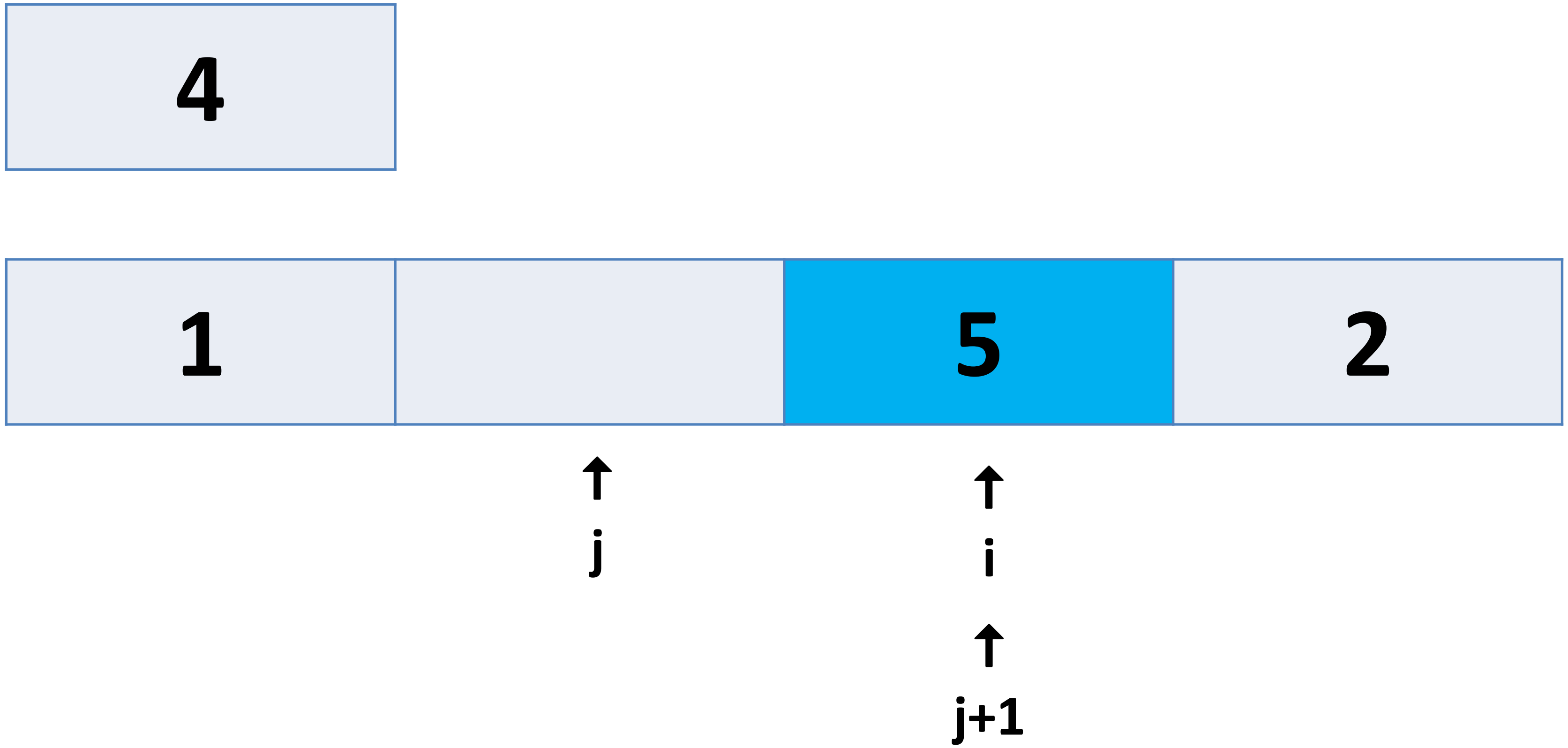
Insertion Sort

- Compare
- Store= 4



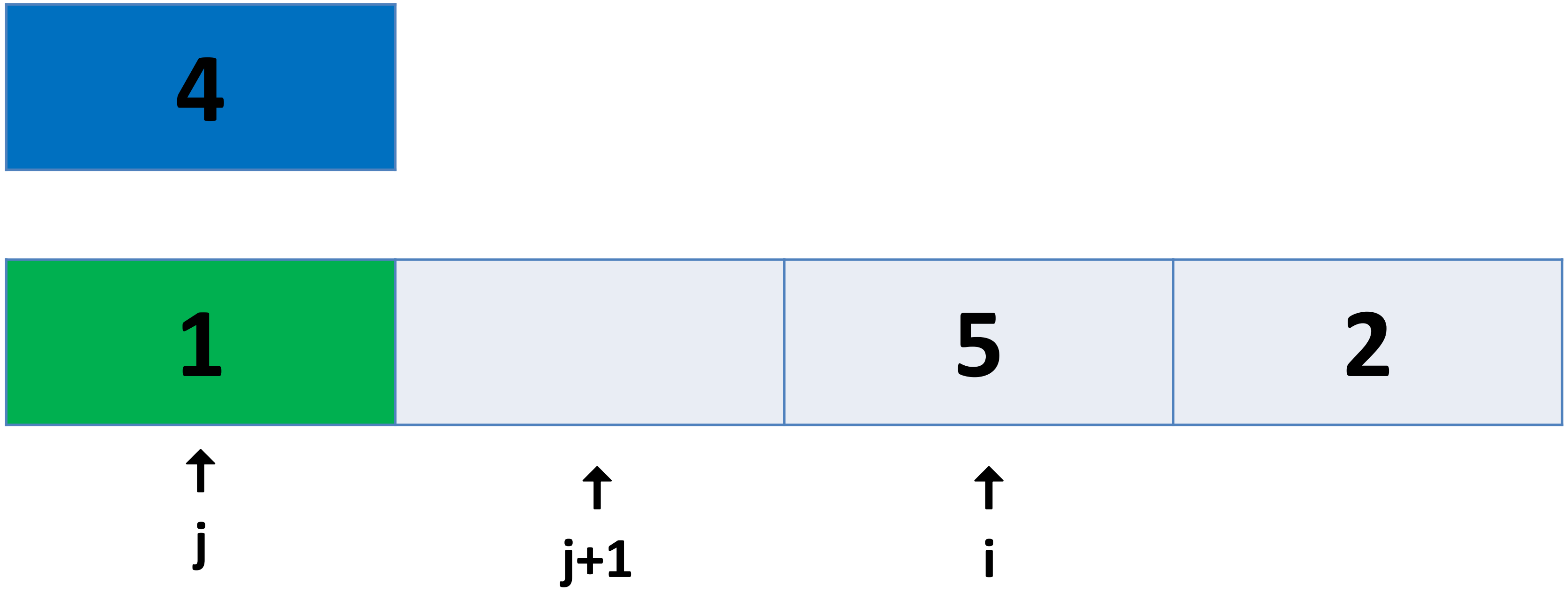
Insertion Sort

- Move
- Store=



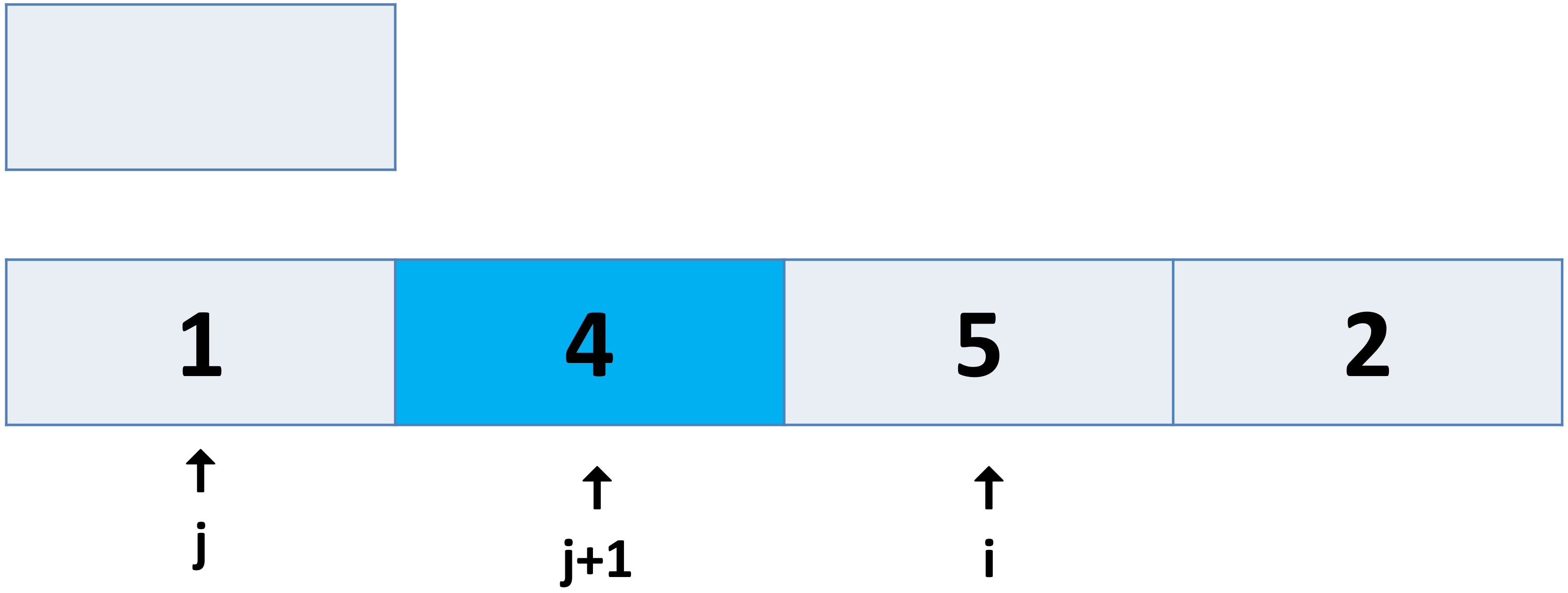
Insertion Sort

- Compare
- Store=



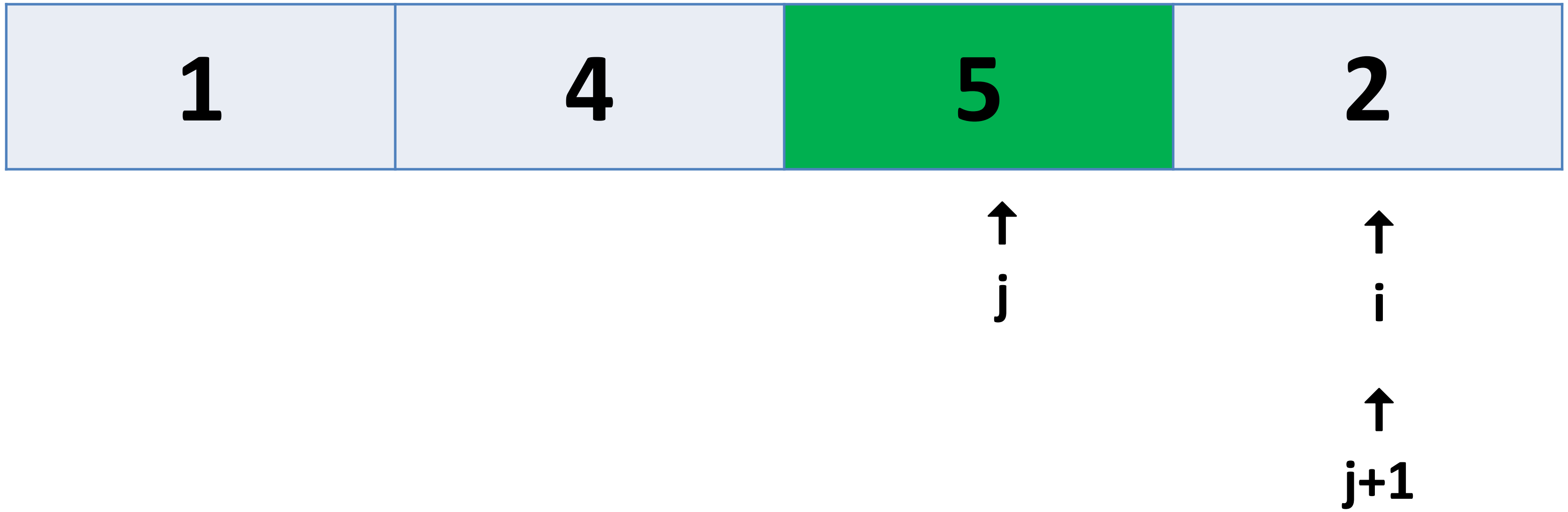
Insertion Sort

- ❑ Move
- ❑ Store=

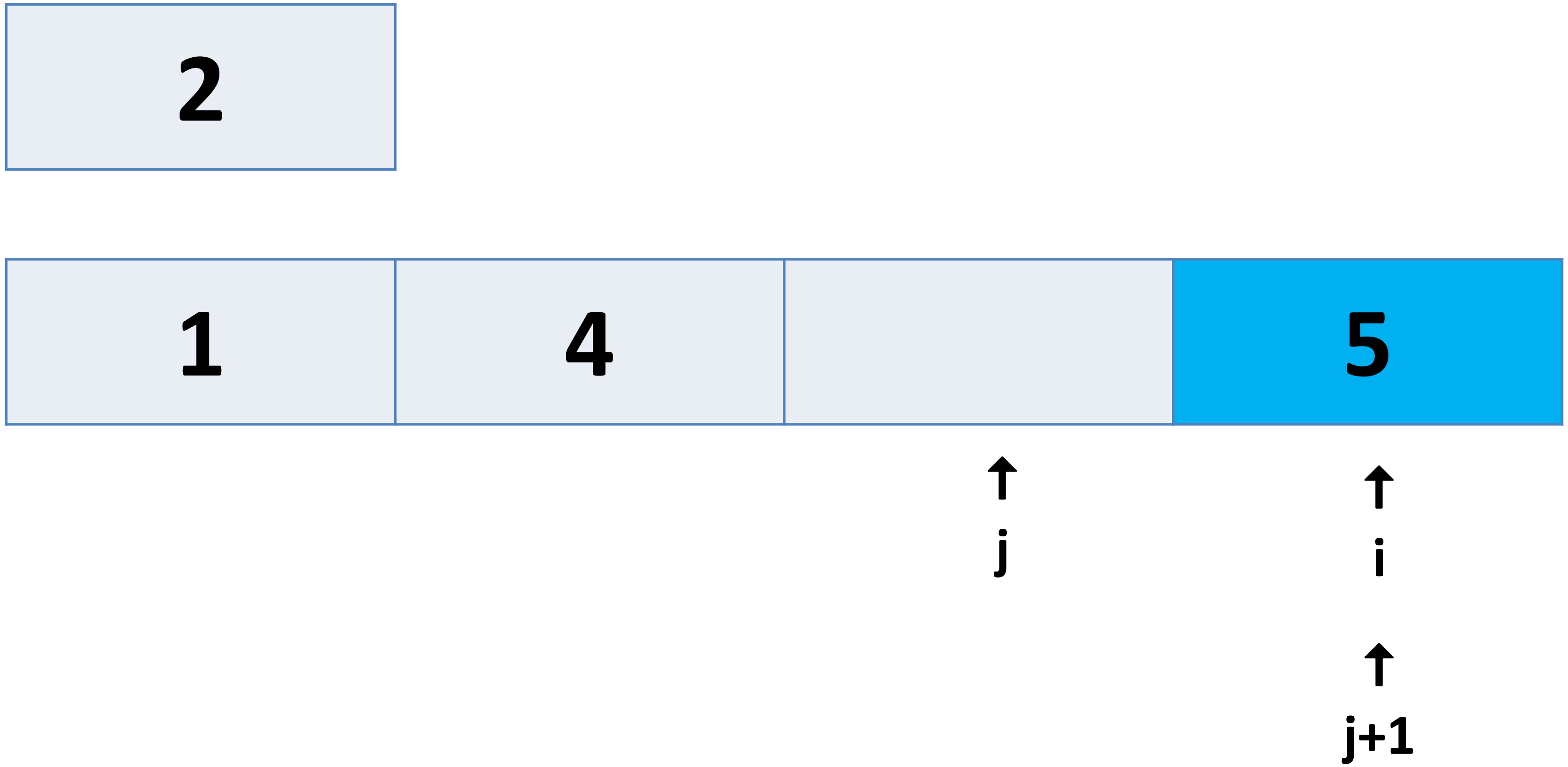


Insertion Sort

- Compare
- Store= 2

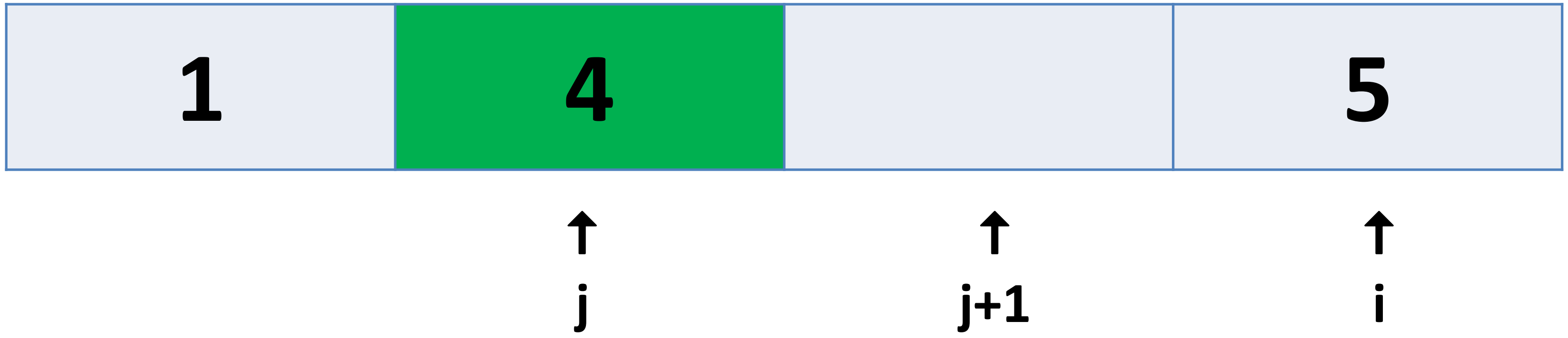


- Move
- Store=



Insertion Sort

- ❑ Compare
- ❑ Store= 2

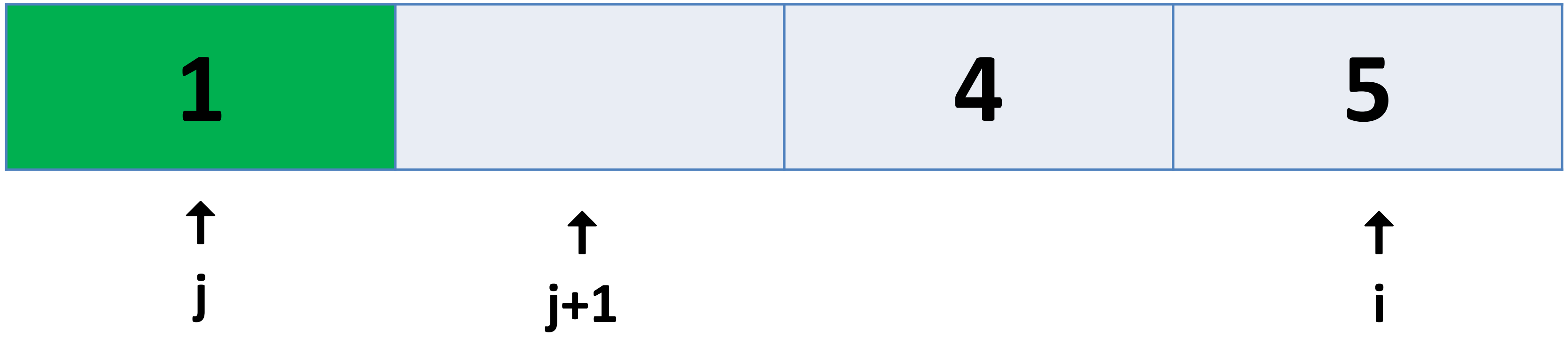


Insertion Sort

- Move
- Store= 2

Insertion Sort

- Compare
- Store= 2



Insertion Sort

- Compare
- Store=

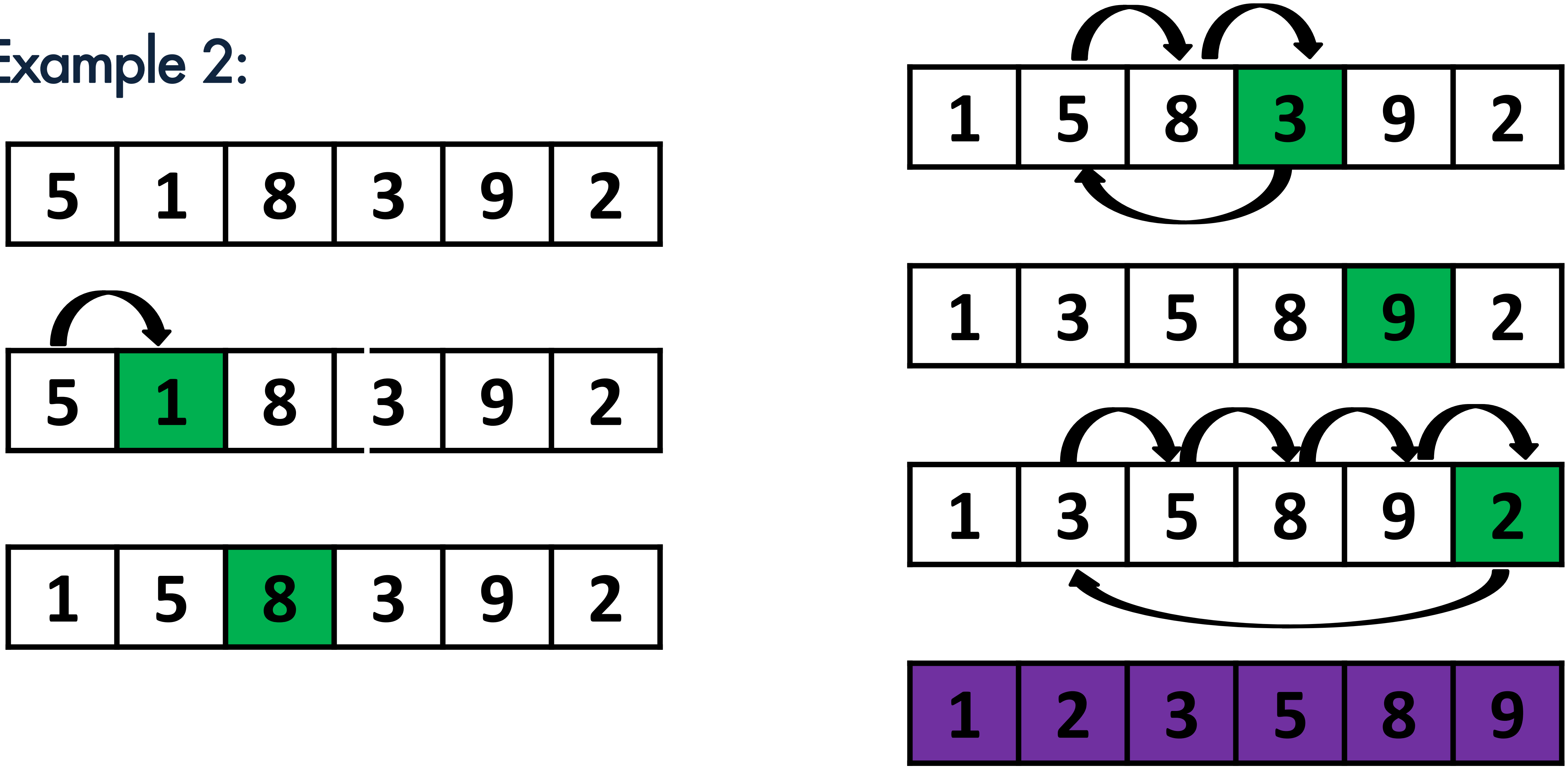
Insertion Sort

- Array is now sorted

1	2	4	5

Selection Sort

- Example 2:



Insertion Sort

- What is the output of insertion sort after the 1st iteration given the following sequence of numbers: 7 3 5 1 9 8 4 6

  a) 3 7 5 1 9 8 4 6

  b) 1 3 7 5 9 8 4 6

  c) 3 4 1 5 6 8 7 9

  d) 1 3 4 5 6 7 8 9

Insertion Sort

- What is the output of insertion sort after the 1st iteration given the following sequence of numbers: 7 3 5 1 9 8 4 6

   a) 3 7 5 1 9 8 4 6

   b) 1 3 7 5 9 8 4 6

   c) 3 4 1 5 6 8 7 9

   d) 1 3 4 5 6 7 8 9

Insertion Sort

- What is the output of insertion sort after the 2nd iteration given the following sequence of numbers: 7 3 5 1 9 8 4 6

  a) 3 5 7 1 9 8 4 6

  b) 1 3 7 5 9 8 4 6

  c) 3 4 1 5 6 8 7 9

  d) 1 3 4 5 6 7 8 9

Insertion Sort

- What is the output of insertion sort after the 2nd iteration given the following sequence of numbers: 7 3 5 1 9 8 4 6

  a) 3 5 7 1 9 8 4 6

  b) 1 3 7 5 9 8 4 6

  c) 3 4 1 5 6 8 7 9

  d) 1 3 4 5 6 7 8 9

Insertion Sort

❑ Python Code

```
def InsertionSort(arr):
    for i in range(1, len(arr)):
        store = arr[i]
        j = i-1
        while j >=0 and store < arr[j] :
                arr[j+1] = arr[j]
                j -= 1
        arr[j+1] = store
    return arr
```

Insertion Sort

```
arr = [12, 6, 5, 14, 3]
Sortedarr=InsertionSort(arr)
print(Sortedarr)
```

Insertion Sort

- Time Complexity: $O(n^2)$

- Example of worst case

5	**4**	**3**	**2**	**1**

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THANKS FOR YOUR TIME