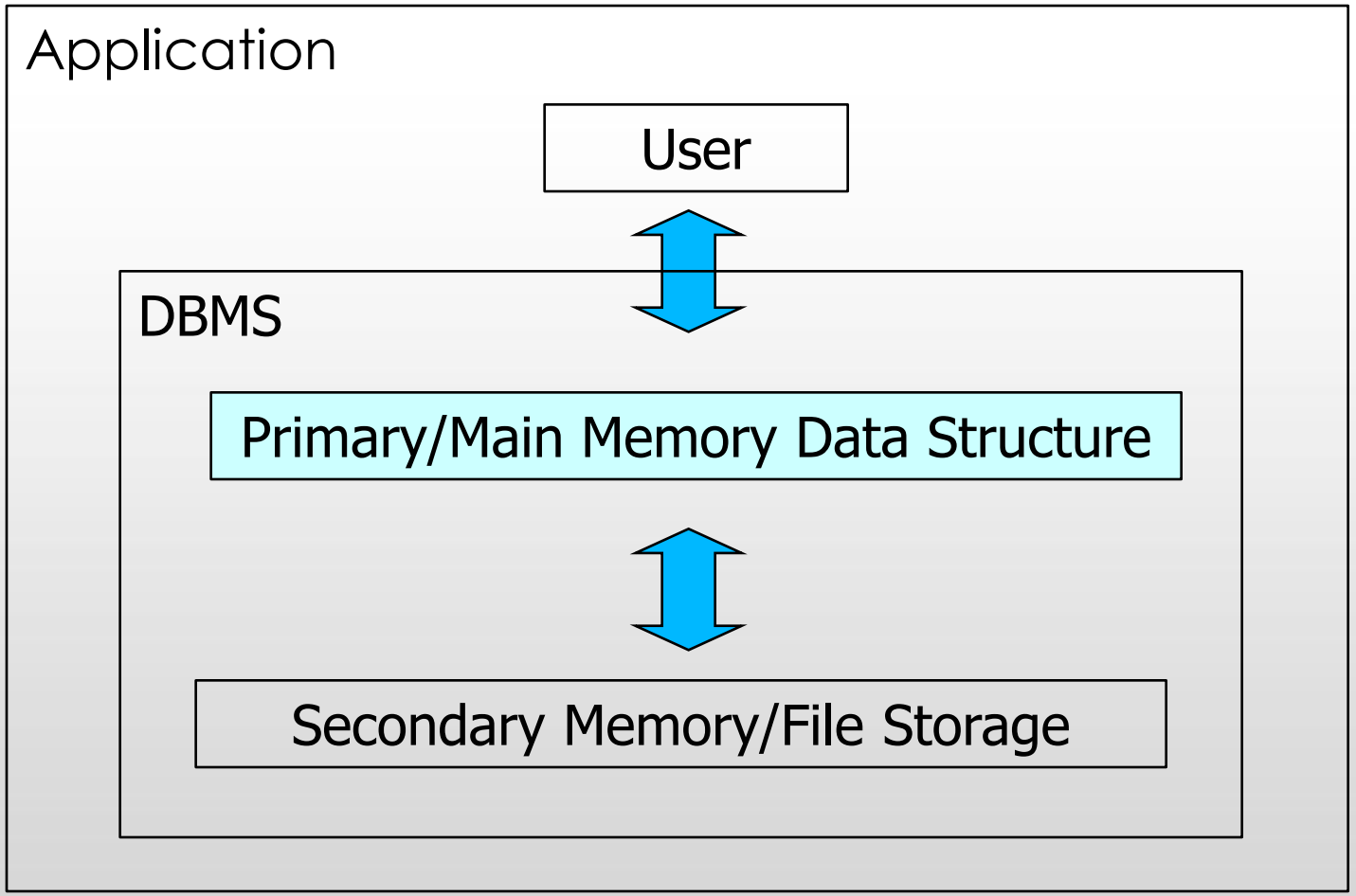
Data Structures

Overview

Overview


Application
User
DBMS
Primary/Main Memory Data Structure
Secondary Memory/File Storage

Definitions

- Data Type – set of values that a variable may assume (e.g. boolean, integer, double, float etc.)

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- Abstract Data Type (ADT) – a mathematical model, together with various operations defined on the model (e.g. Stack, Queue, BST, AVL, Binary Heap, etc.)

Definitions

- Data Structure – collection of variables, possibly of several different data types, connected in various ways (e.g. Array, Record, Singly-linked List, Doubly-linked List, Adjacency Matrix, Adjacency List etc.)

ADT vs. Data Structure

ADT

- Stack and Queue
- Graph

Data Structure

- Array or List Implementation
- Adjacency Matrix or List

1. The List ADT

1.1 Arrays

The List ADT

Definition:

- A sequence of zero or more elements of the same type.
- denoted by: $\mathbf{a_1, a_2, a_3, \ldots, a_n}$

  where n = size of the list and
  i = position of a_i

The List ADT

Operations:

- **insert** (add an element into the list)
- **delete** (remove an element from the list)
- **find** (returns the position of the first occurrence of an element)
- **find kth** (returns the element in the kth position)
- **next**, **previous** (takes as argument a position and returns the position of the successor and predecessor, respectively)
- **print list** (prints all the elements in the list)
- **make null** (delete all elements from the list)

Array Implementation

- Elements are contiguously stored in the main memory
- Fast access to an element
- Size is either fixed at compile time (static array) or at run-time (dynamic array)

```
int A1[5]  vs
int *A2 = (int *)malloc(5 * sizeof(int));
```

Array Implementation

- Indexing
  - first index: zero-based, one-based, n-based
  - bounds checking
  - associative arrays (use of non-integer indices)
  - multi-dimensional arrays

1.1 Arrays

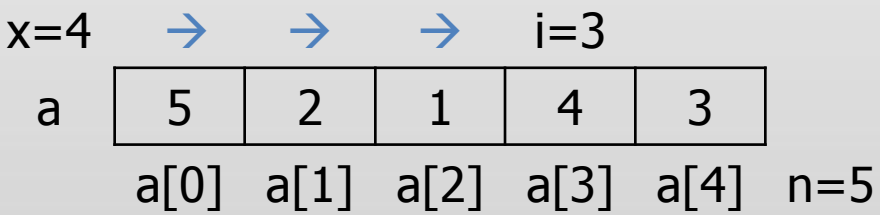
1.1.1 Searching

Linear Search

Linear Search - list is not necessarily sorted

```
int linear_search(int a[], int n, int x){
    int i;
    for(i=0;i<n;i++)
        if (a[i]==x) break; //found x
    return(i<n); //if x is found i<n else i=n
}
```

Case 1: x is in the list, i<n

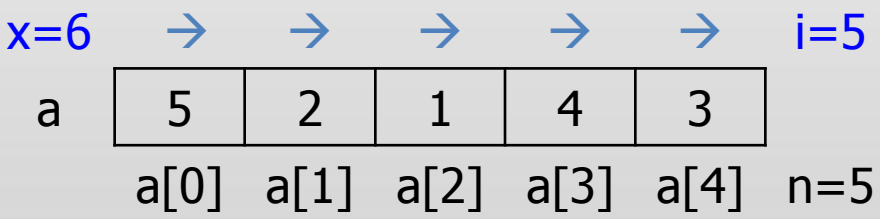


Linear Search

Linear Search - list is not necessarily sorted

```
int linear_search(int a[], int n, int x){
    int i;
    for(i=0;i<n;i++)
        if (a[i]==x) break; //found x
    return(i<n); //if x is found i<n else i=n
}
```

Case 2: x is not in the list, i=n



Binary Search

- Binary Search - list is sorted

```
int binary_search(int a[], int n, int x){
    int lower,upper, middle;
    lower = 0;
    upper = n-1;
    while(lower <= upper){
        middle = (lower + upper)/2;
        if (x > a[middle]) lower = middle+1;
        else if (x < a[middle] upper = middle - 1;
        else return(1);
    }
    return(0);
}
```

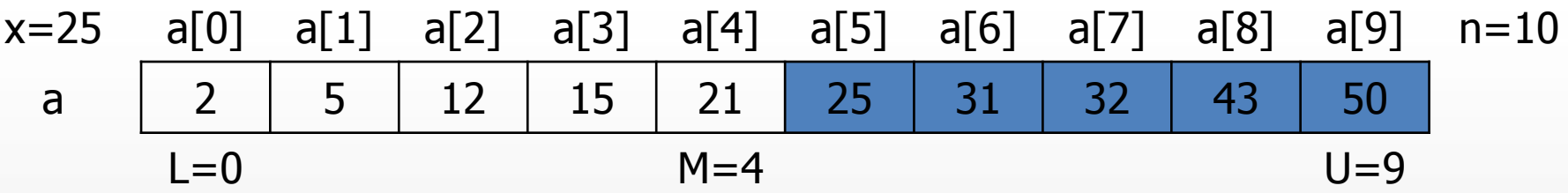
Binary Search

x=25

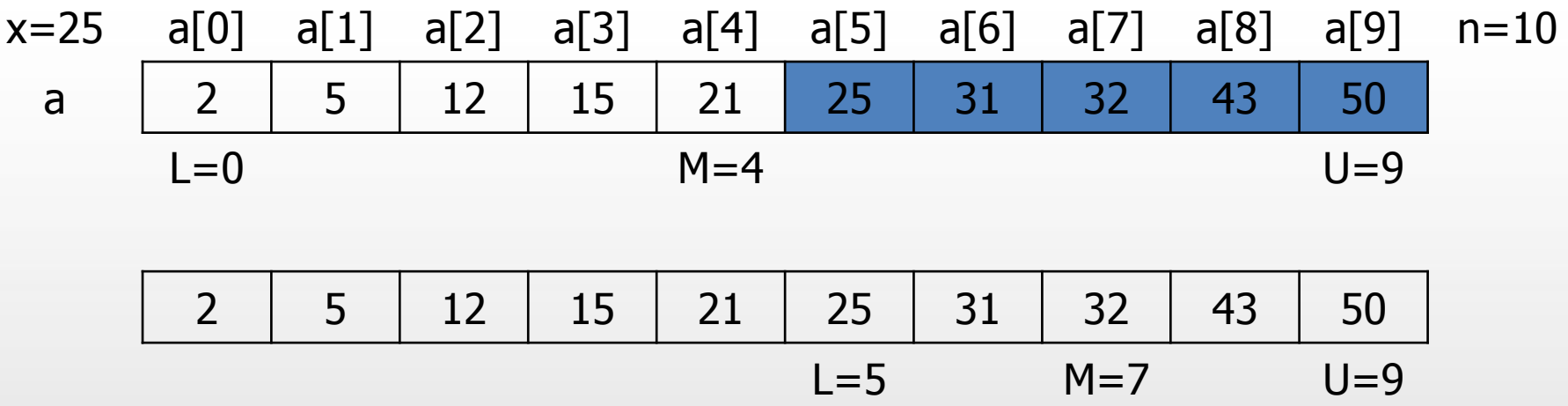
	a[0]	a[1]	a[2]	a[3]	a[4]	a[5]	a[6]	a[7]	a[8]	a[9]
a	2	5	12	15	21	25	31	32	43	50
	L=0				M=4					U=9

n=10

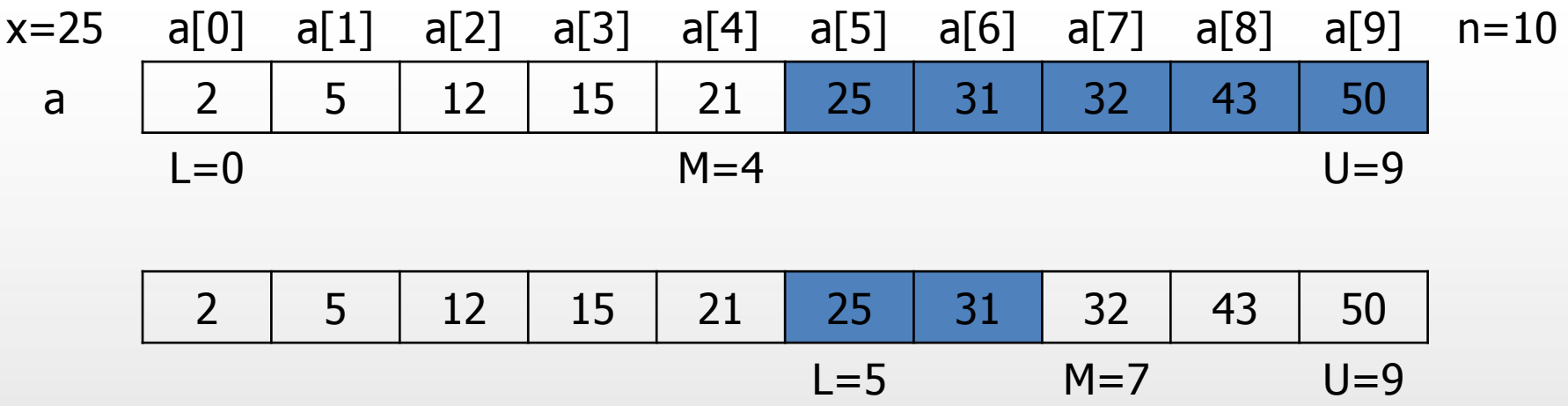
Binary Search



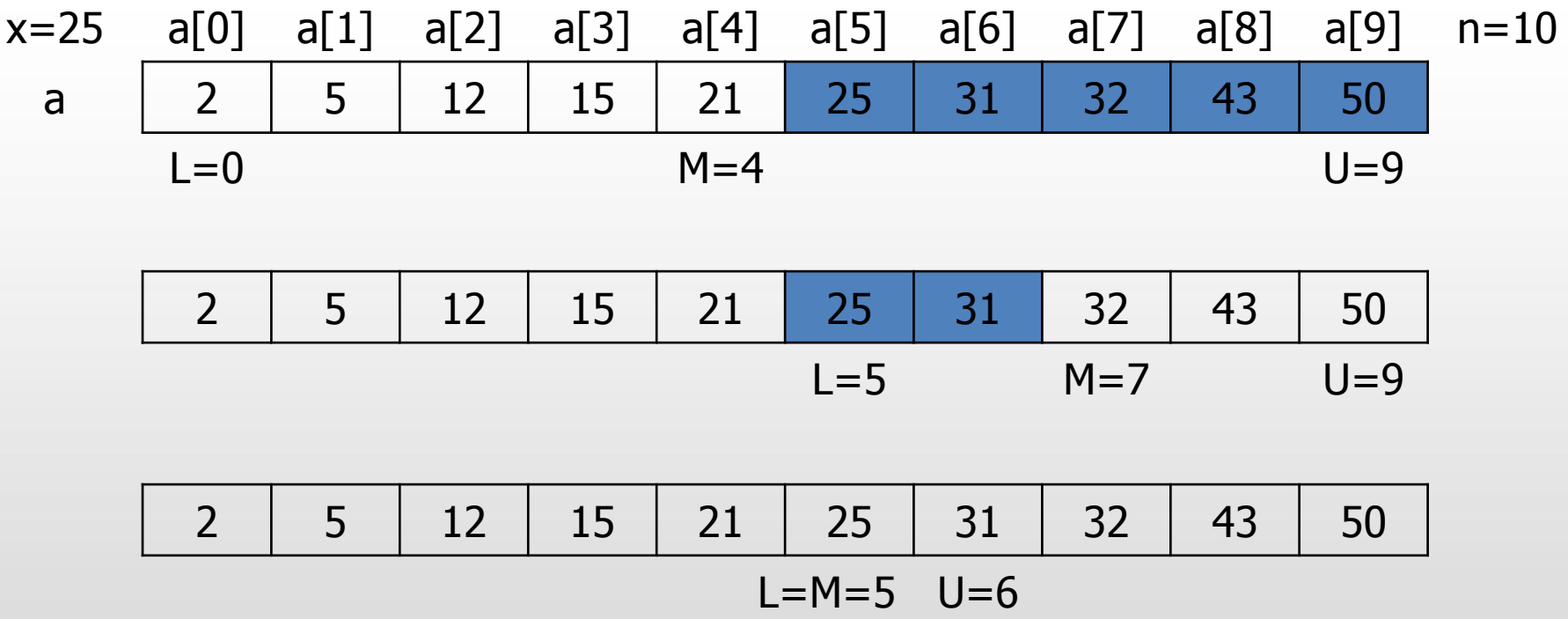
Binary Search



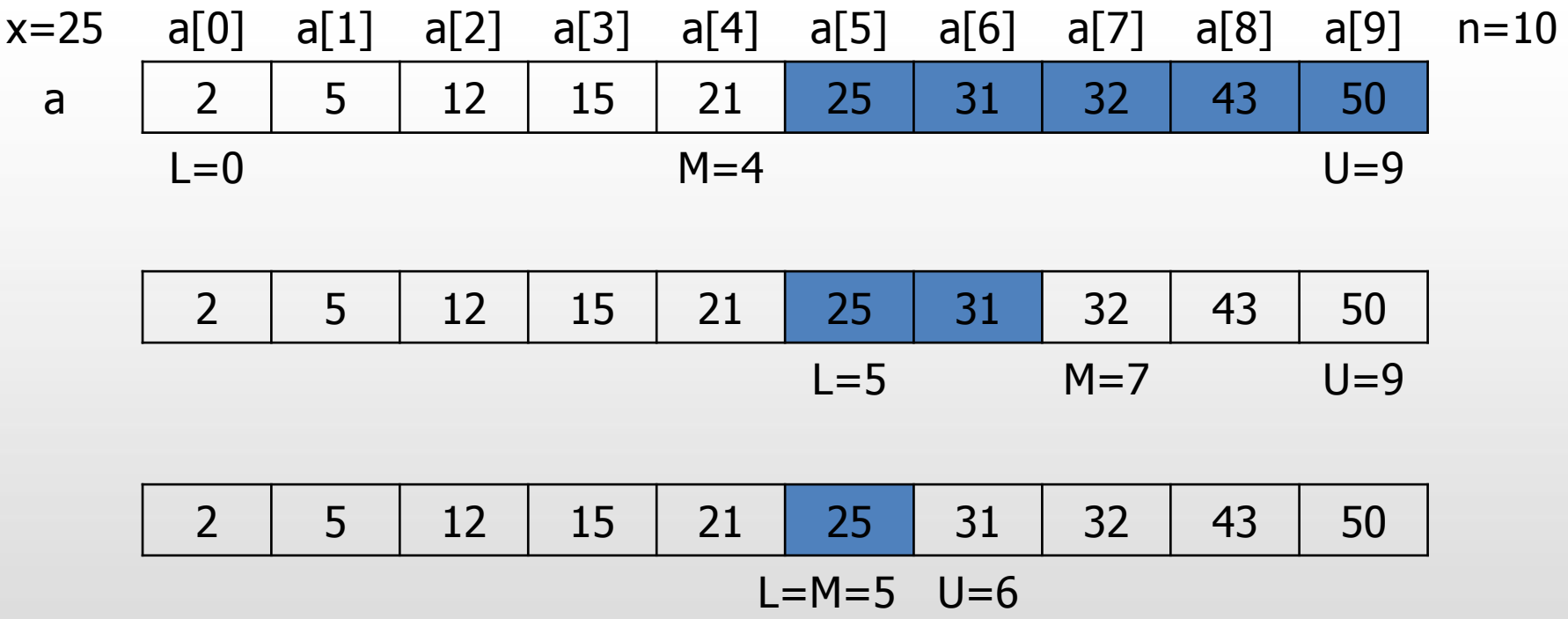
Binary Search



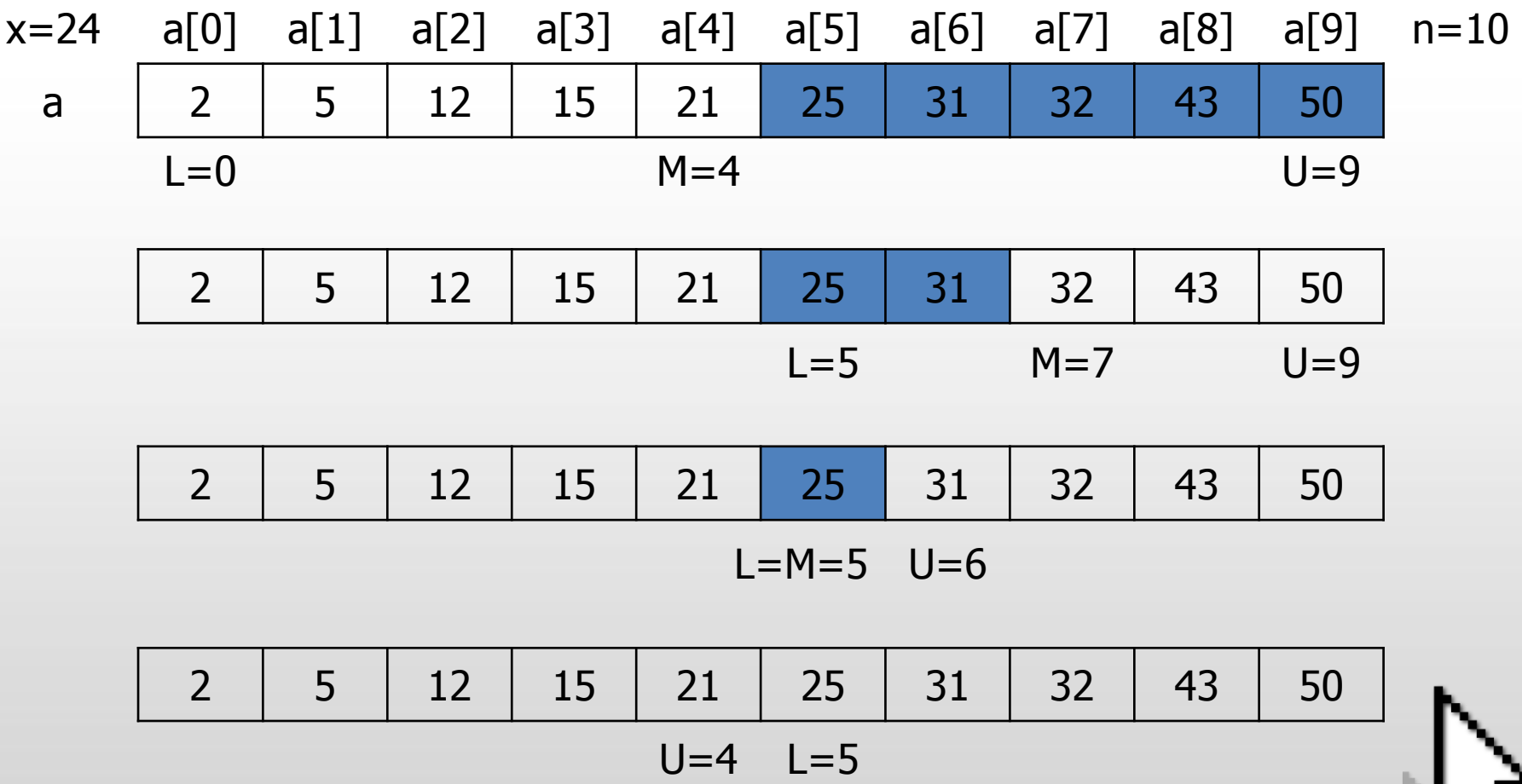
Binary Search



Binary Search



Binary Search



1.1 Arrays

1.1.2 Sorting

Bubble Sort

```
void bubble_sort(int a[], int n){
    int i,j;

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

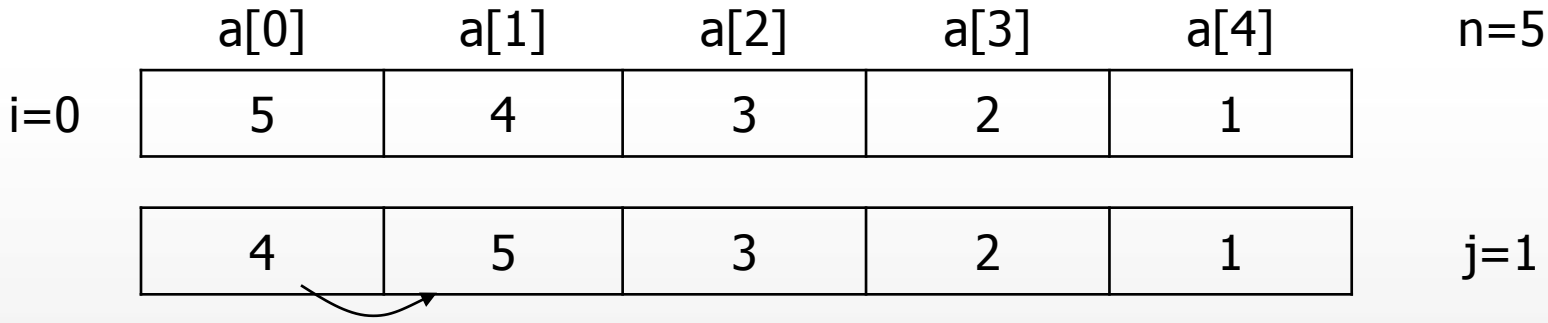
```
void bubble_sort(int a[], int n){
    int i,j;

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

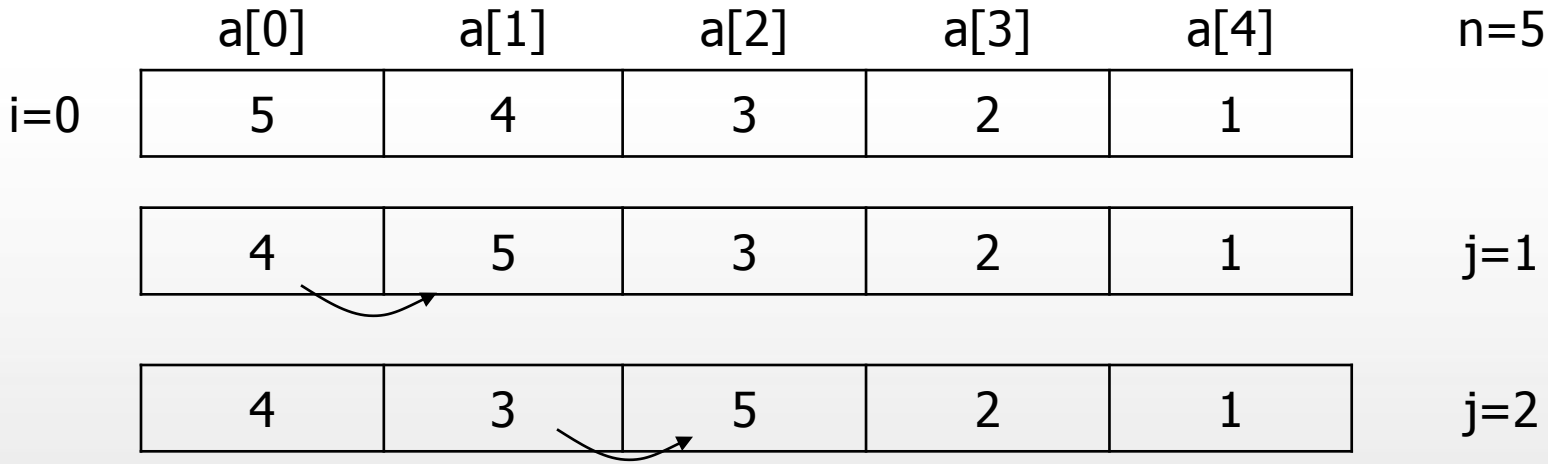
Bubble Sort (inversely sorted input)

	a[0]	a[1]	a[2]	a[3]	a[4]	n=5
i=0	5	4	3	2	1	

Bubble Sort (inversely sorted input)



Bubble Sort (inversely sorted input)



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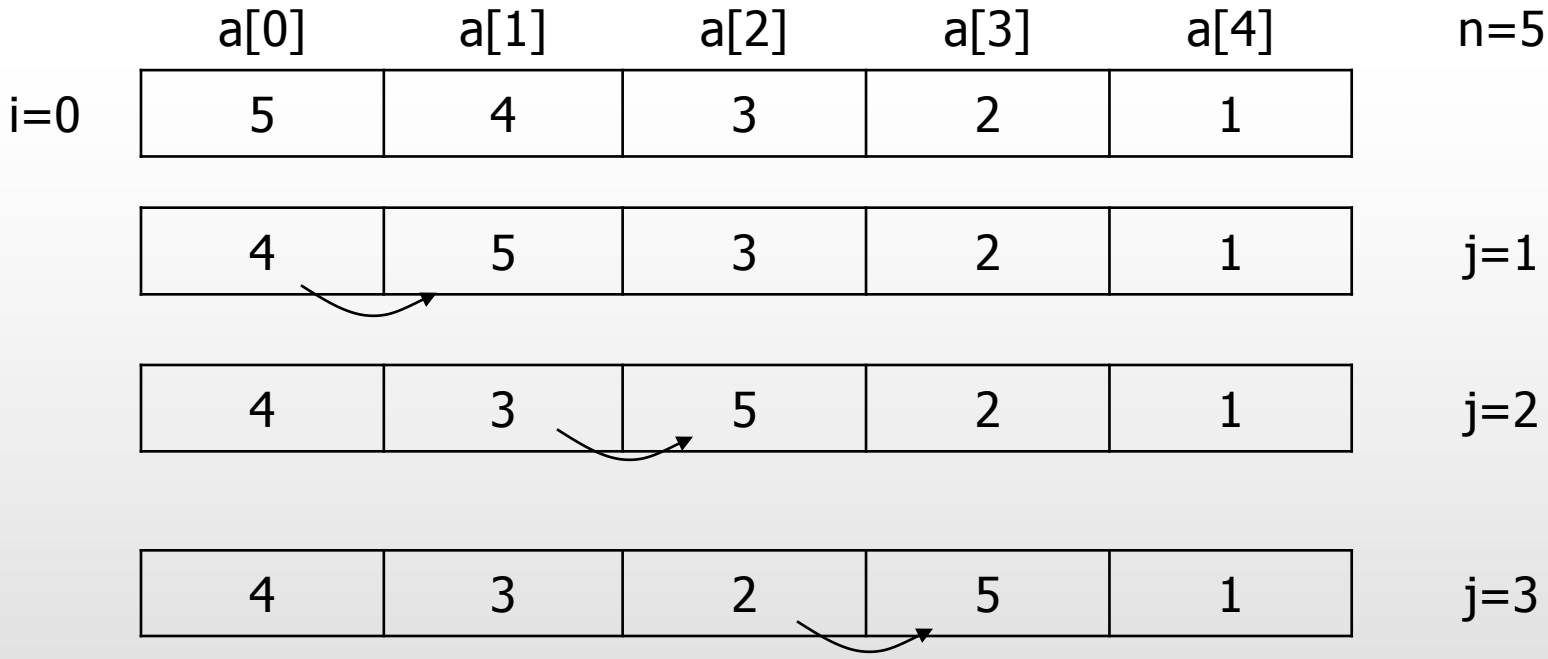
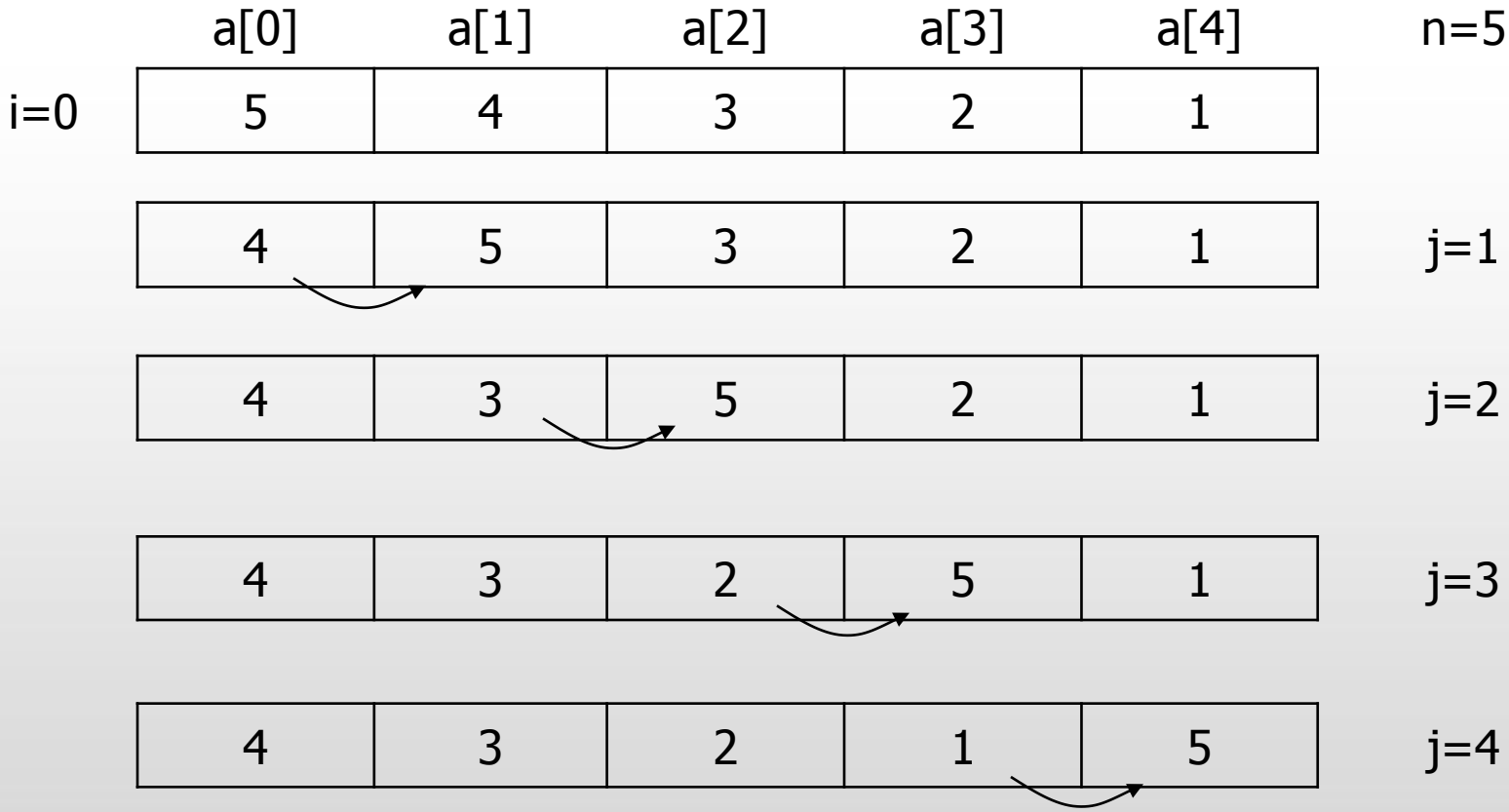
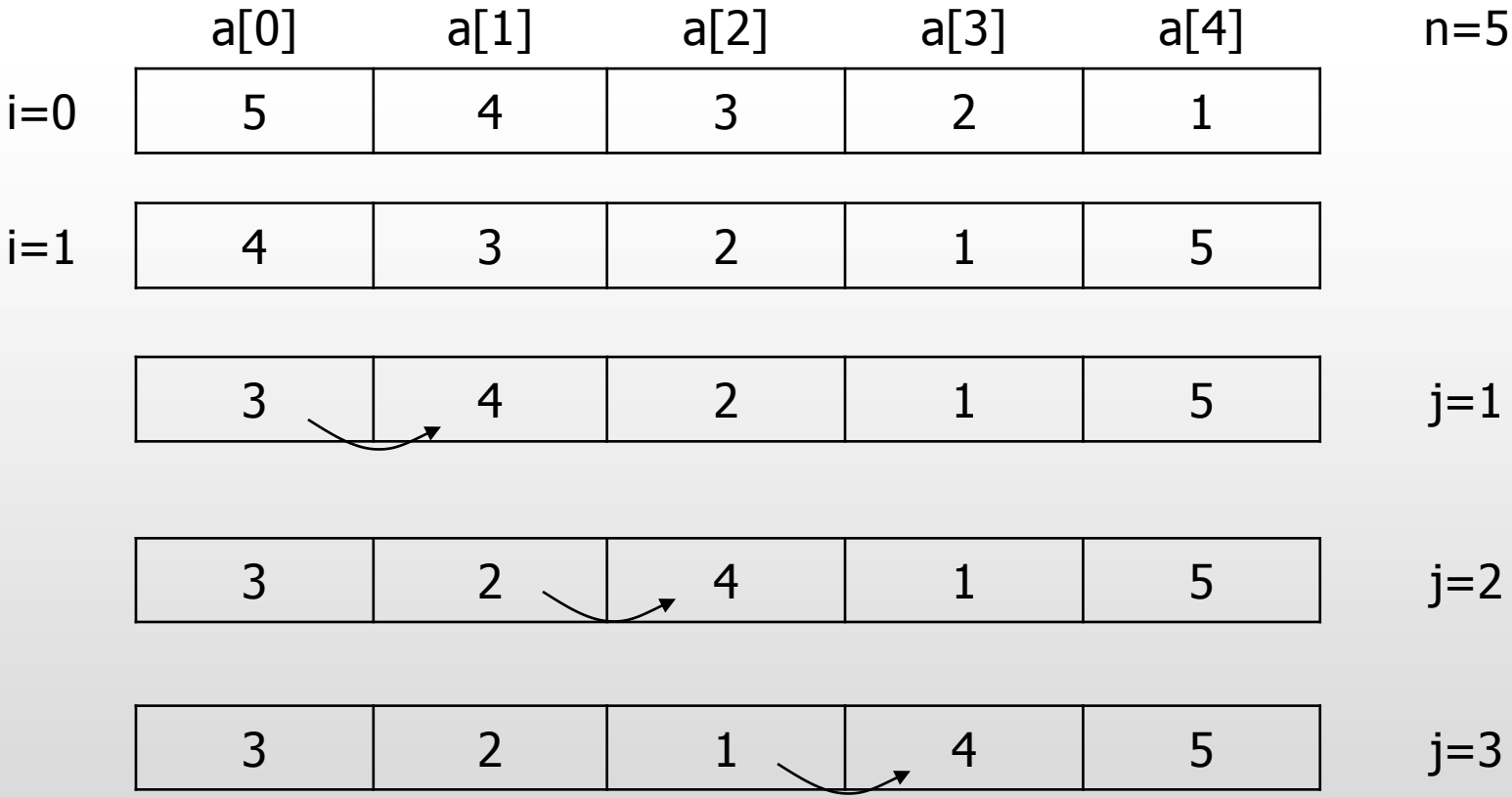


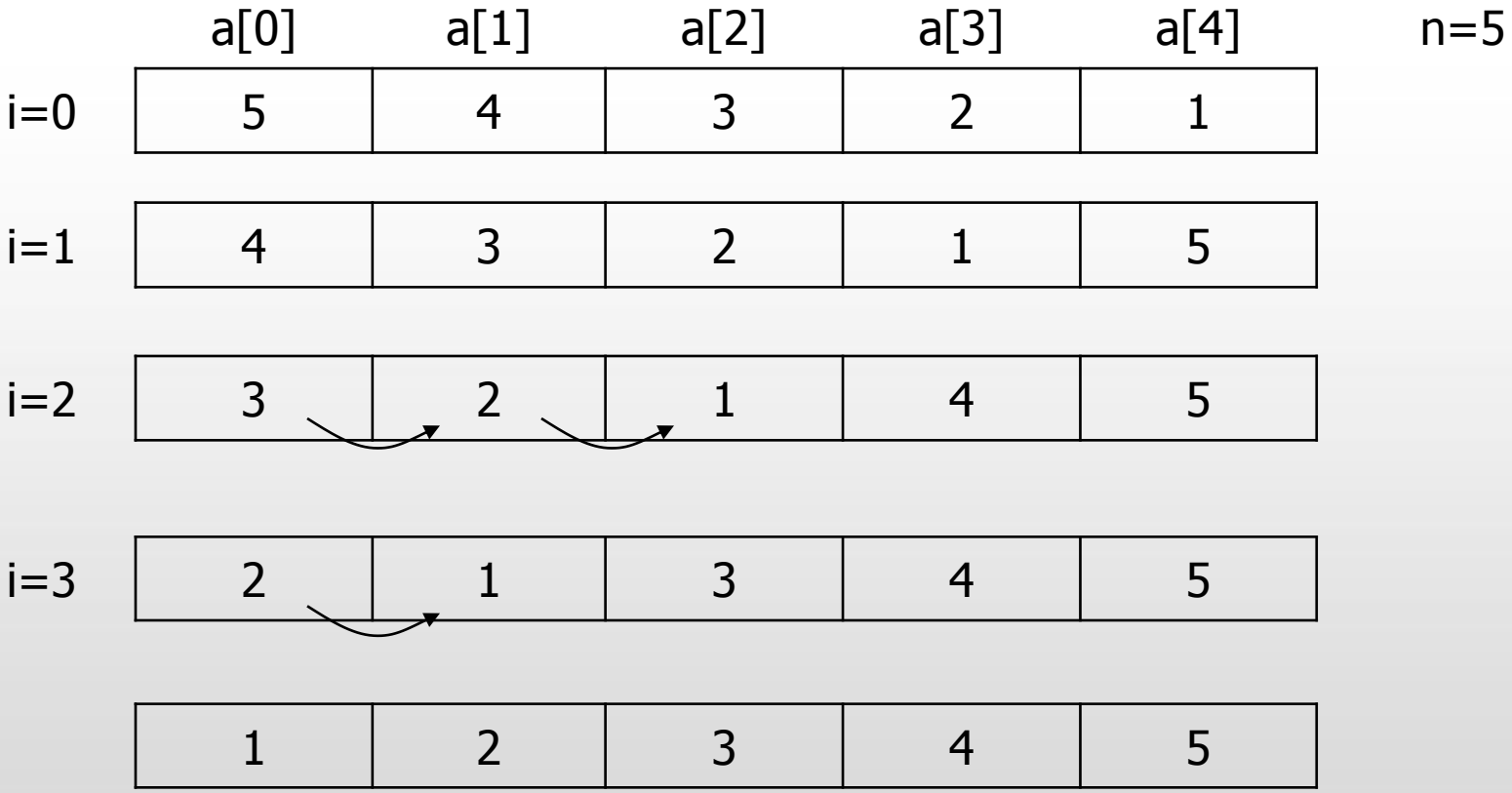
Bubble Sort (inversely sorted input)



Bubble Sort (inversely sorted input)



Bubble Sort (inversely sorted input)



Bubble Sort

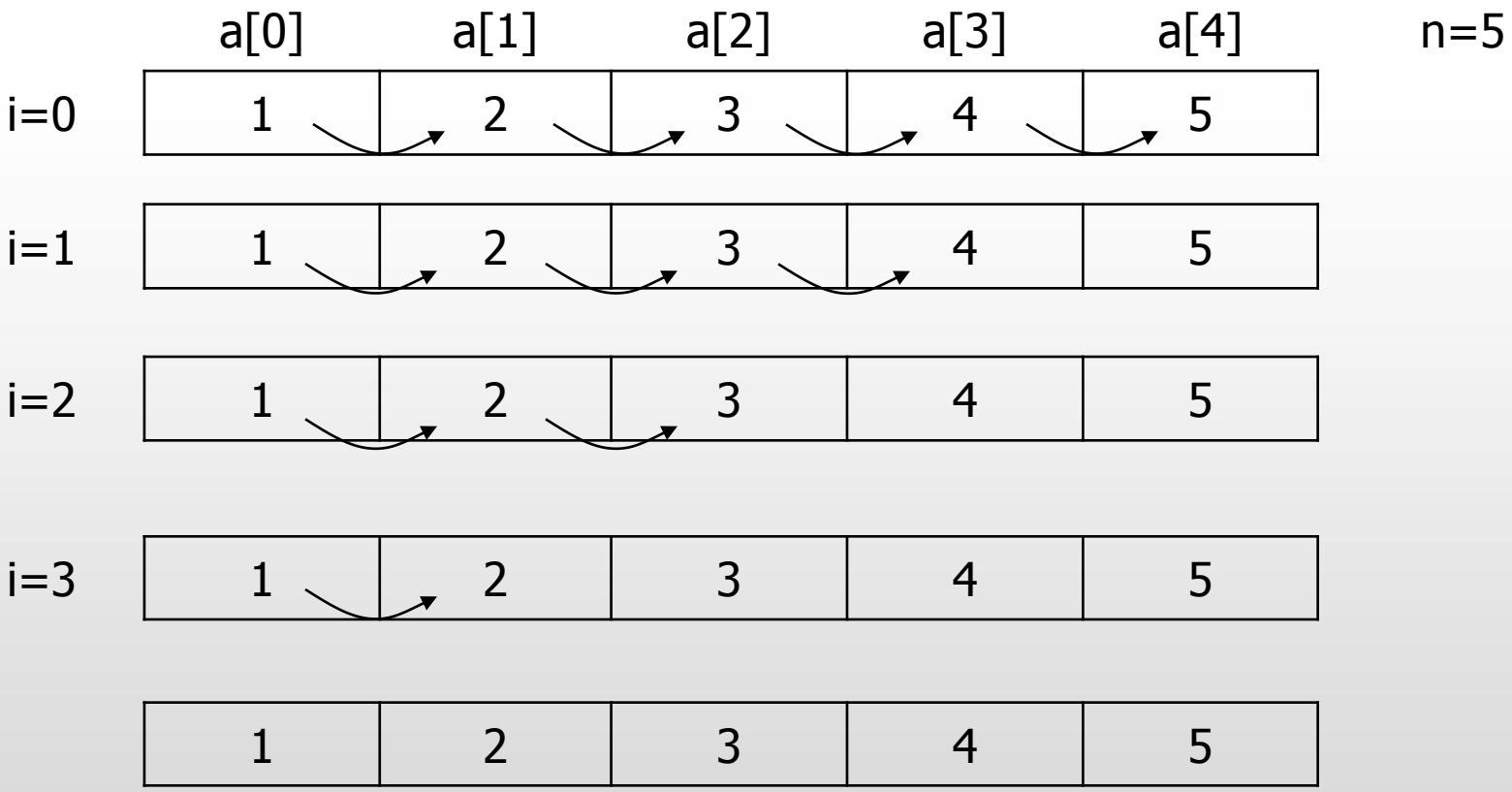
```
void bubble_sort(int a[], int n){
    int i,j;

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

```
void bubble_sort(int a[], int n){
    int i,j;

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

Bubble Sort (pre-sorted input)



Selection Sort

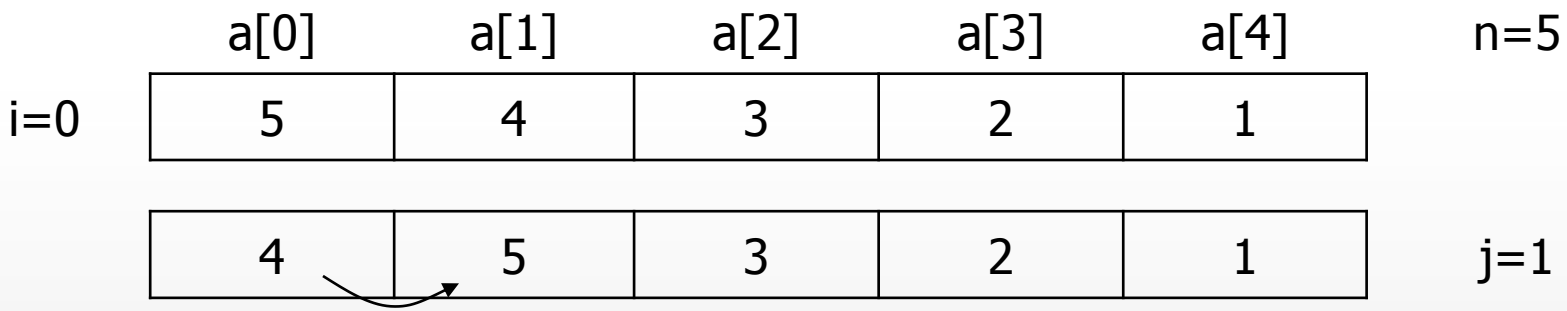
```
void selection_sort(int a[], int n){
    int i,j;

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

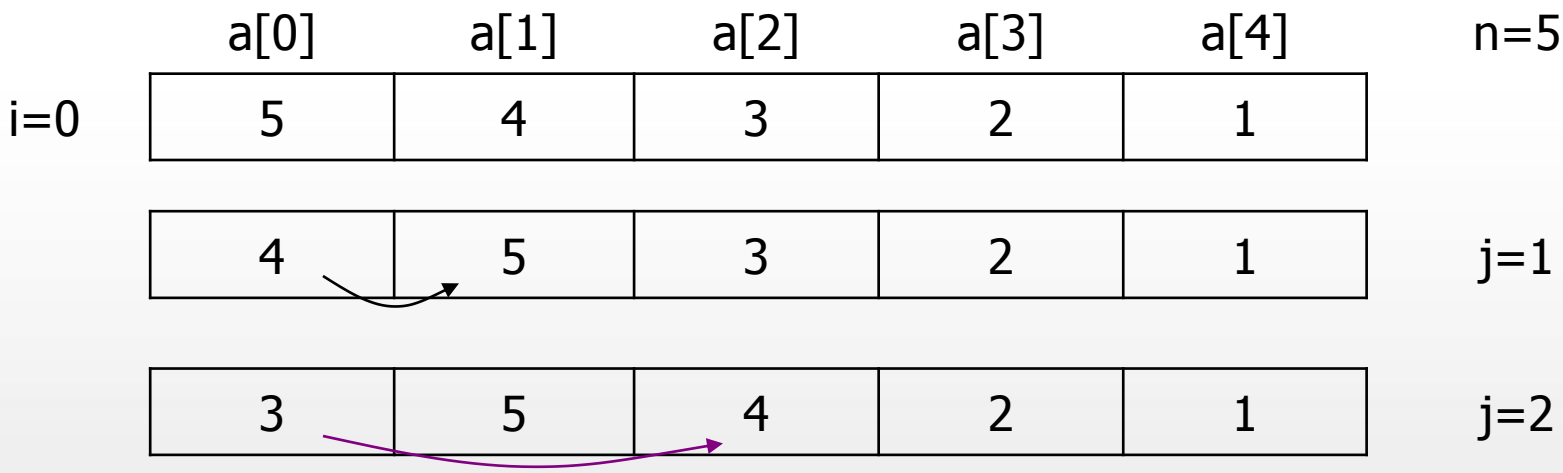
Selection Sort (inversely sorted input)

	a[0]	a[1]	a[2]	a[3]	a[4]	n=5
i=0	5	4	3	2	1	

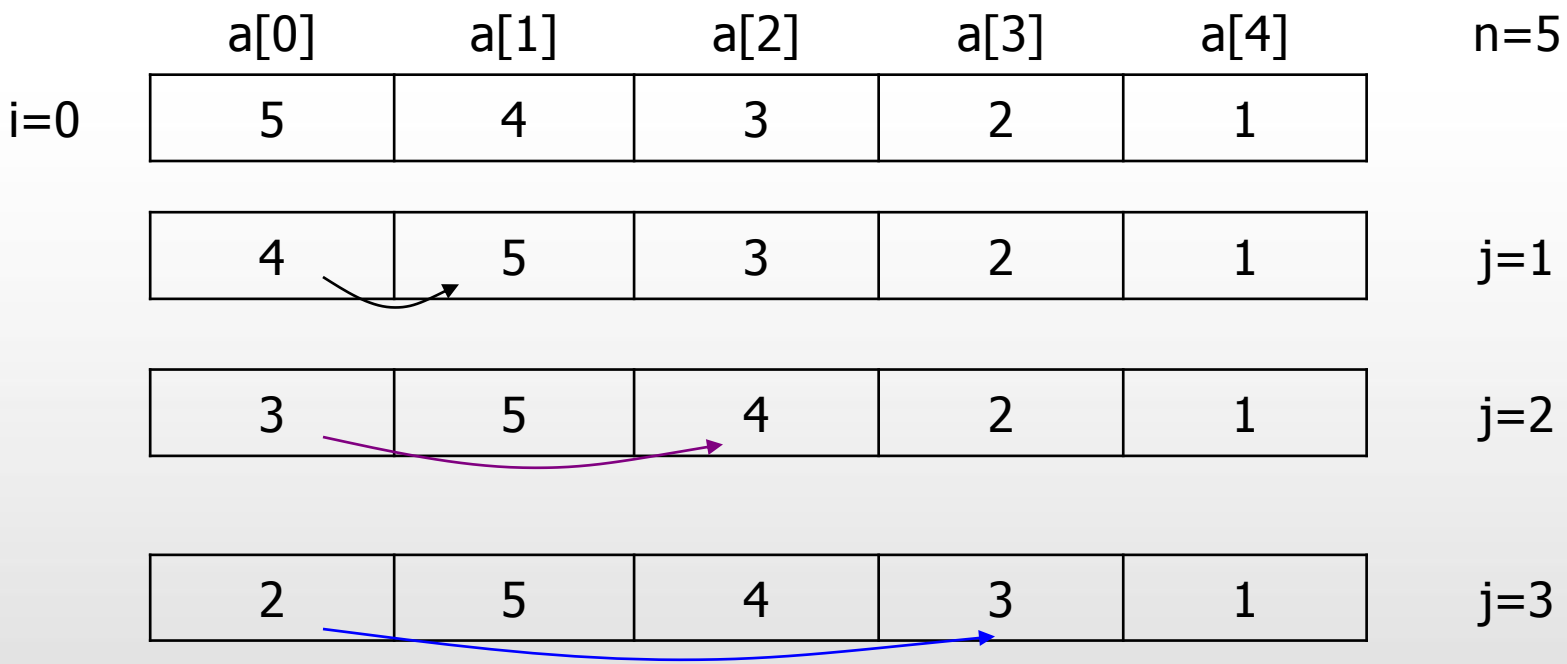
Selection Sort (inversely sorted input)



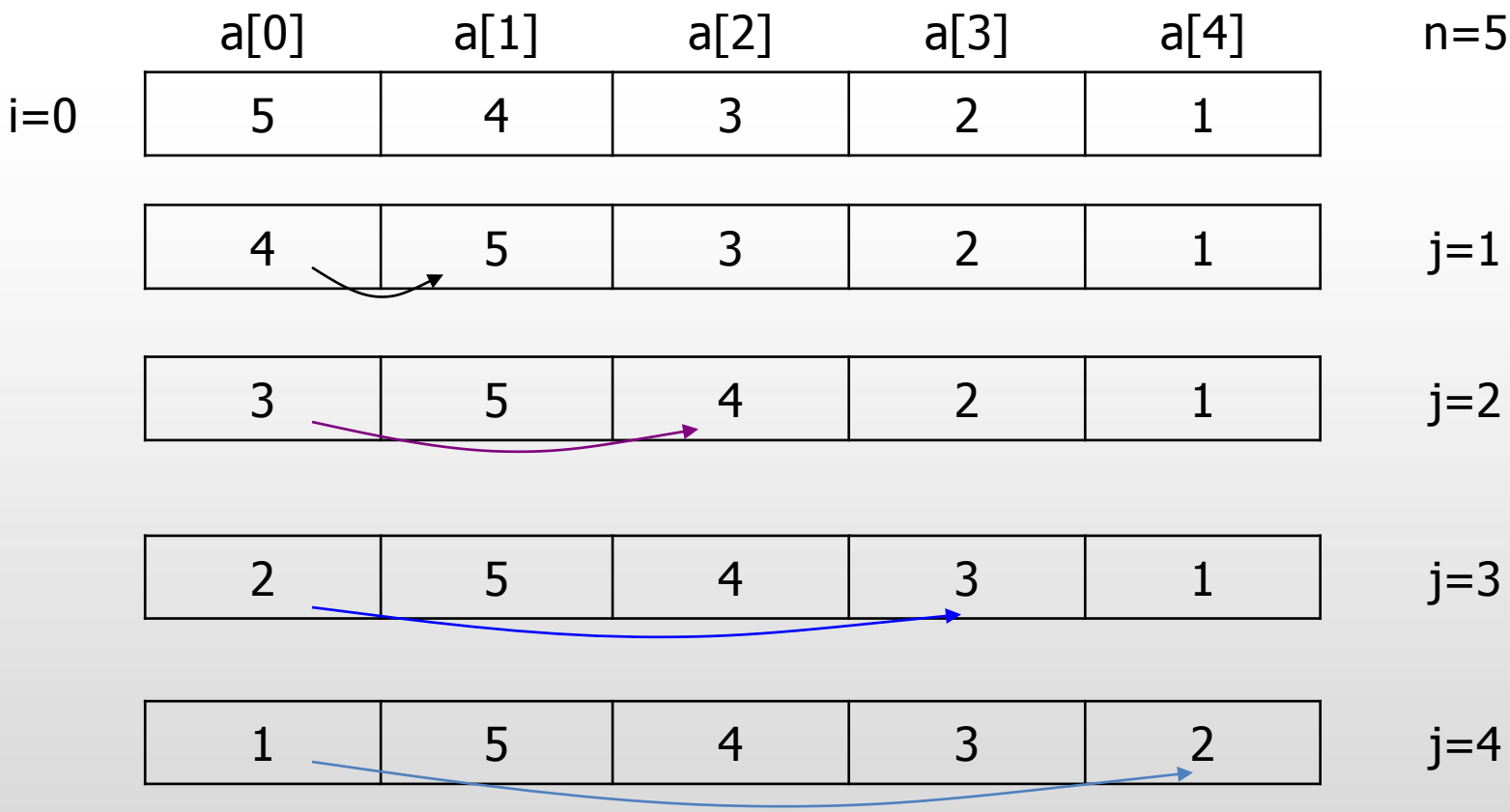
Selection Sort (inversely sorted input)



Selection Sort (inversely sorted input)



Selection Sort (inversely sorted input)



Selection Sort (inversely sorted input)

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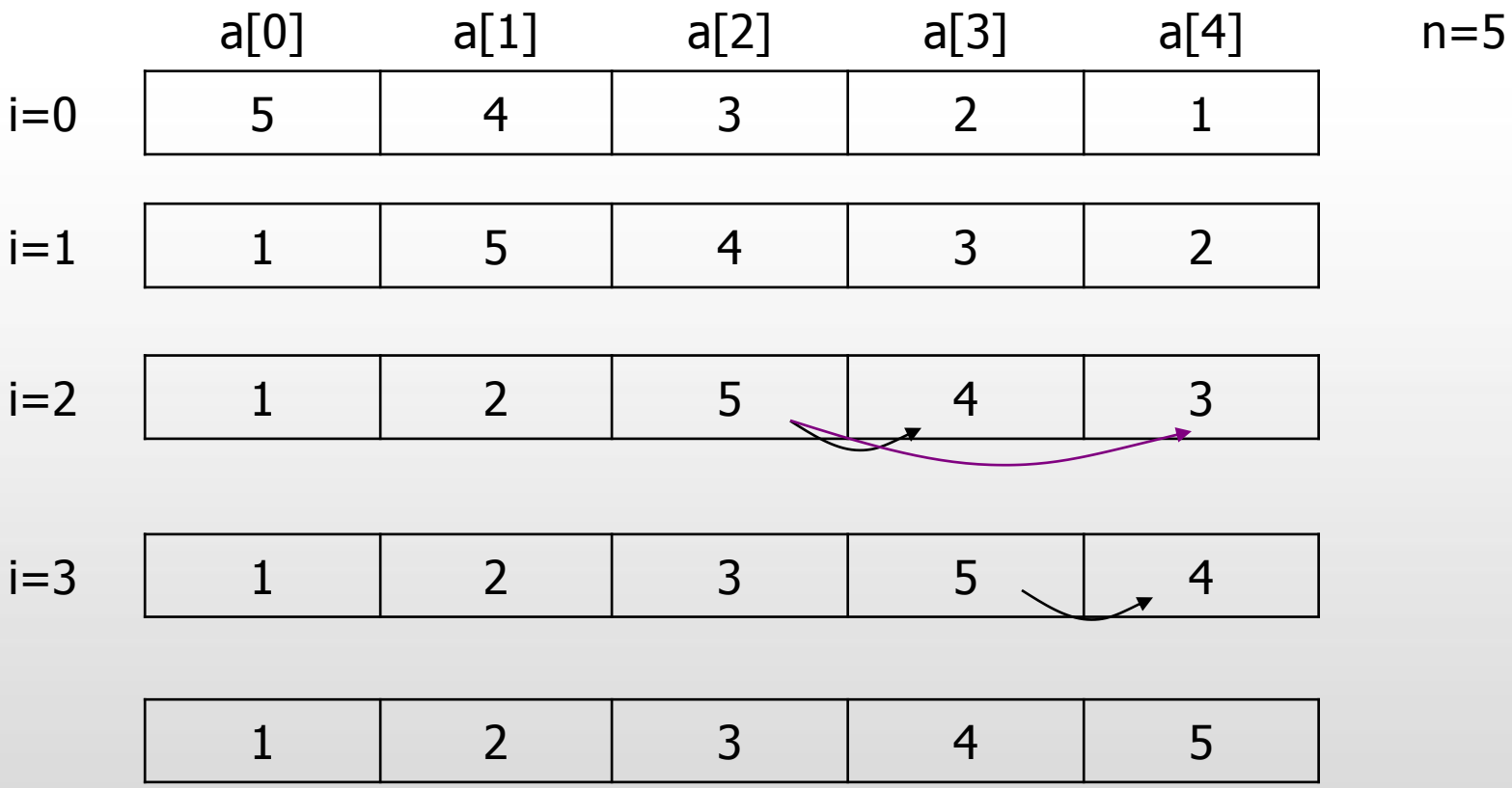
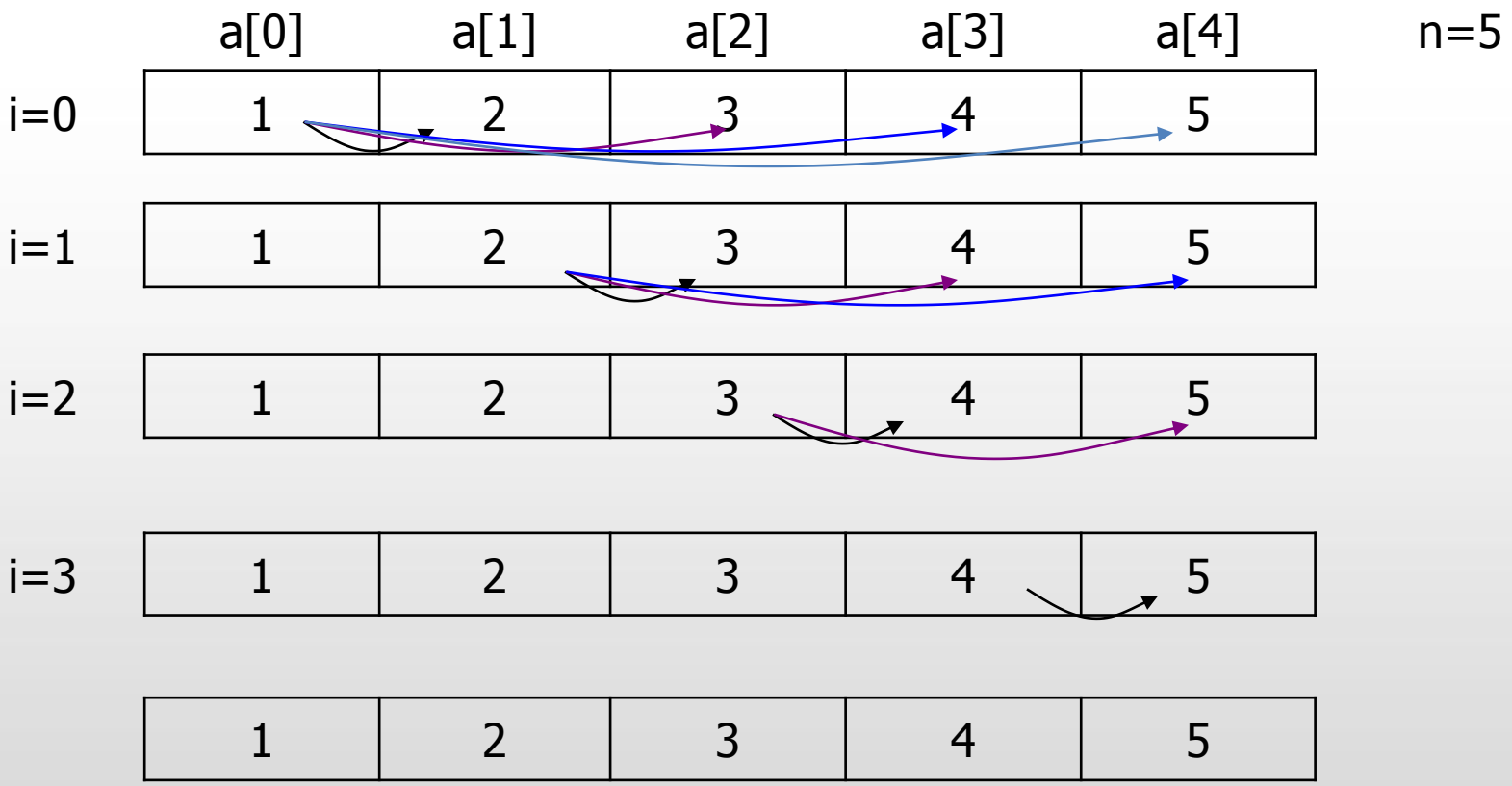


Selection Sort (pre-sorted input)

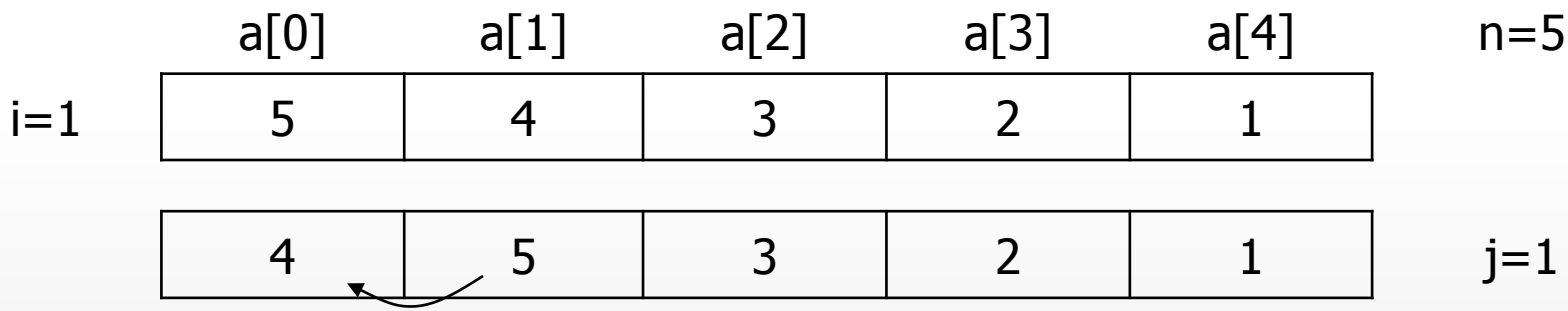


Insertion Sort

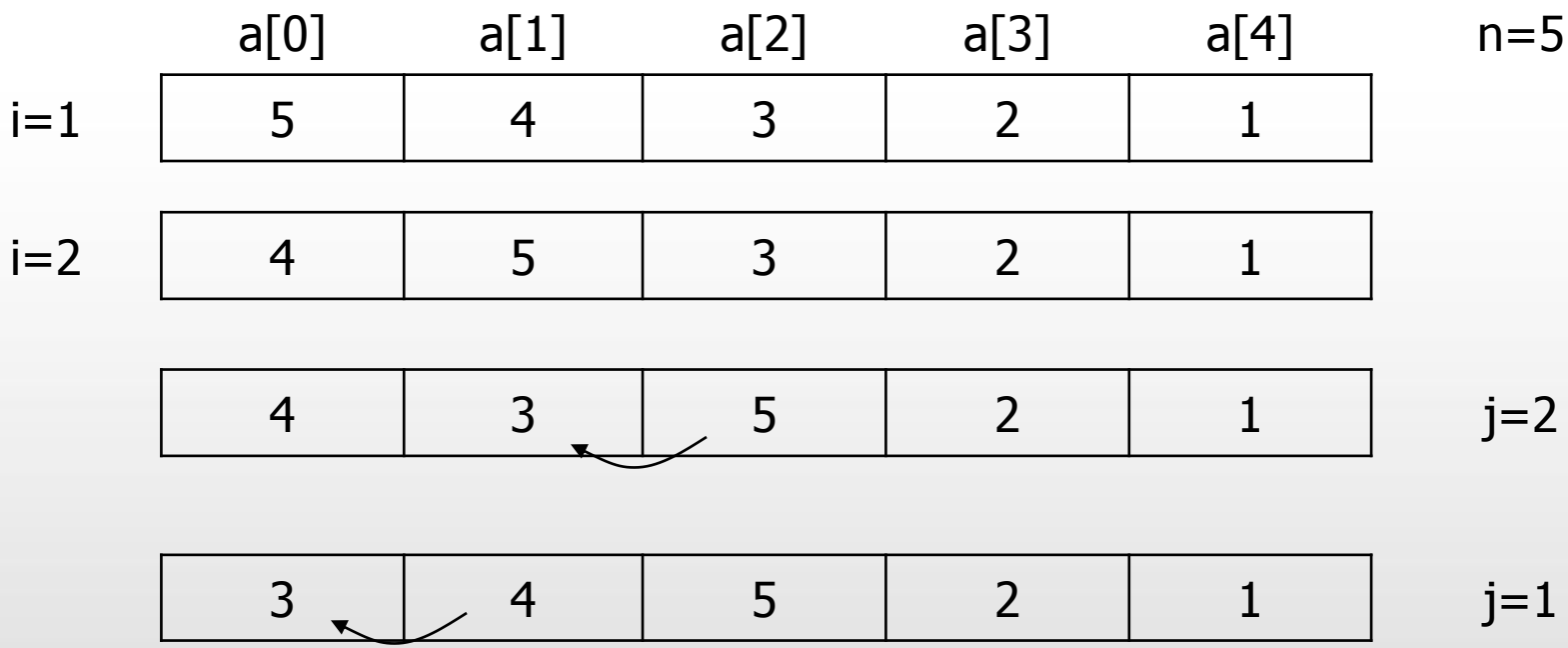
```
void insertion_sort(int a[], int n){
    int i,j;

    for(i=1;i<n;i++)
        for(j=i;j>0;j--)
            if (a[j]<a[j-1])
                swap(&a[j-1],&a[j]);
            else
                break;
}
```

Insertion Sort (inversely sorted input)



Insertion Sort (inversely sorted input)



Insertion Sort (inversely sorted input)

Insertion Sort (pre-sorted input)

Merge Sort

```
void merge_sort(int a[], int lower, int upper){
    int mid;

    if (upper-lower>0) {
        mid=(lower+upper)/2
        merge_sort(a, lower, mid);
        merge_sort(a, mid+1, upper);
        merge(a, lower, mid, upper);
    }
}
```

Merge Sort

a[0]	a[1]	a[2]	a[3]	a[4]	a[5]	a[6]	a[7]
8	1	5	3	7	2	6	4

Merge Sort

a[0]	a[1]	a[2]	a[3]	a[4]	a[5]	a[6]	a[7]
8	1	5	3	7	2	6	4

Merge Sort

a[0]	a[1]	a[2]	a[3]	a[4]	a[5]	a[6]	a[7]
8	1	5	3	7	2	6	4

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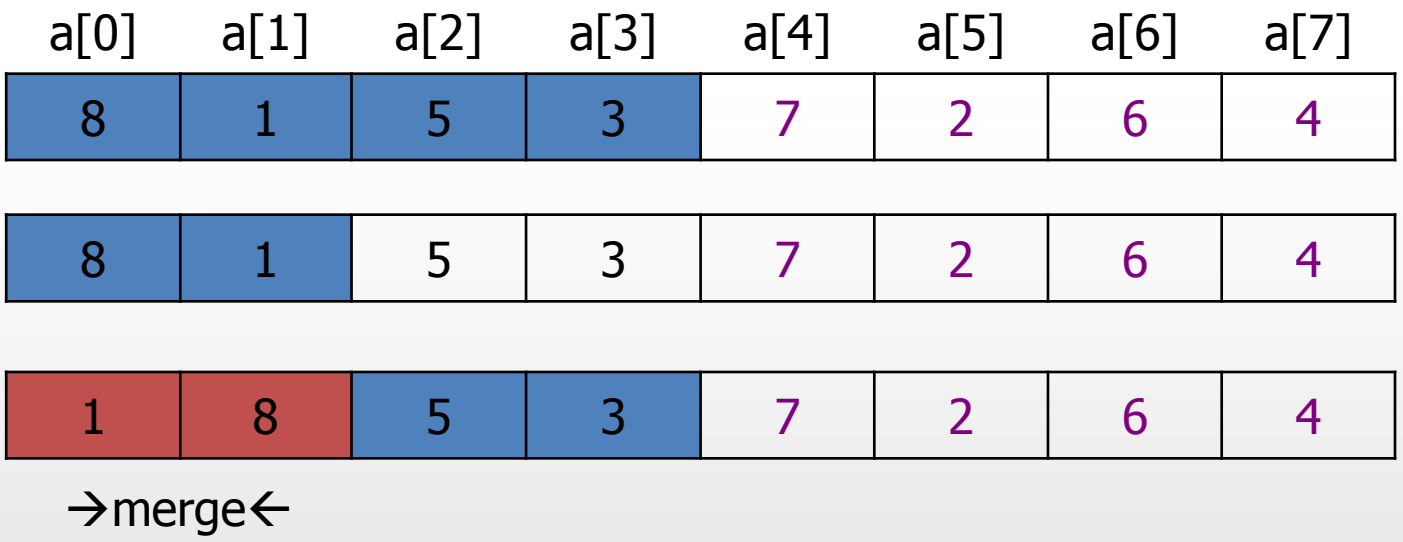
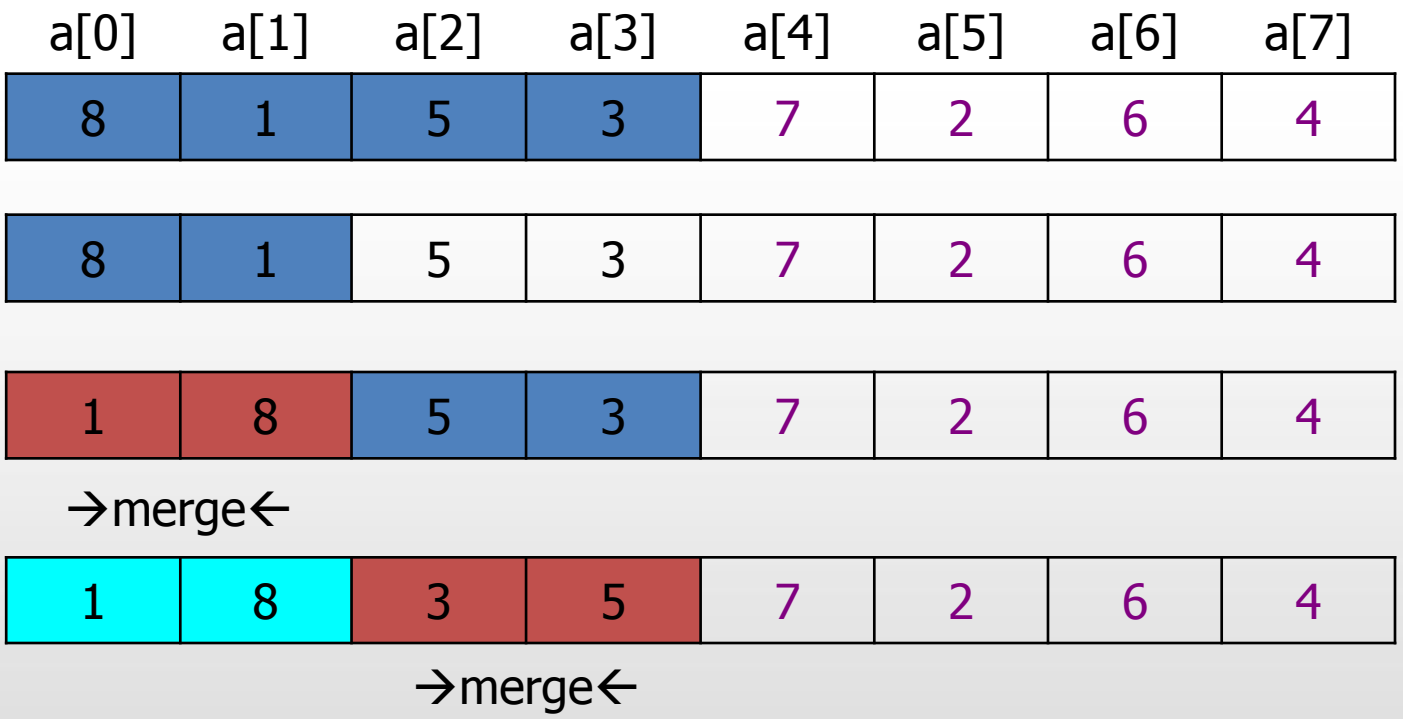
Merge Sort



Merge Sort


a[0] a[1] a[2] a[3] a[4] a[5] a[6] a[7]
8 1 5 3 7 2 6 4
8 1 5 3 7 2 6 4
1 8 5 3 7 2 6 4
→merge←
1 8 3 5 7 2 6 4
→merge←

Merge Sort


a[0] a[1] a[2] a[3] a[4] a[5] a[6] a[7]
8 1 5 3 7 2 6 4
8 1 5 3 7 2 6 4
1 8 5 3 7 2 6 4
→merge←
1 8 3 5 7 2 6 4
→merge←
1 3 5 8 7 2 6 4
→ merge ←

Merge Sort


a[0] a[1] a[2] a[3] a[4] a[5] a[6] a[7]
1 3 5 8 7 2 6 4
1 3 5 8 2 7 6 4
→merge←
1 3 5 8 2 7 4 6
→merge←
1 3 5 8 2 4 6 7
→ merge ←
1 2 3 4 5 6 7 8
→ merge ←

Merge

```
void merge (int a[], int lower, int mid, int upper){
    int *temp,i,j,k;

    temp=(int *)malloc((upper-lower+1)*sizeof(int));

    for(i=0,j=lower,k=mid+1; j<=mid || k<=upper; i++)
        temp[i]=(j<=mid && (k>upper || a[j]<a[k]))?
                    a[j++]:a[k++];
    for(i=0,j=lower;j<=upper; i++, j++)
        a[j]=temp[i];

    free(temp);
}
```

Merge

	[0]	[1]	[2]	[3]	[4]	[5]	[6]	[7]	
a	1	3	5	8	2	4	6	7	j++
temp	1								i=0
a	1	3	5	8	2	4	6	7	k++
temp	1	2							i=1
a	1	3	5	8	2	4	6	7	j++
temp	1	2	3						i=2
a	1	3	5	8	2	4	6	7	k++
temp	1	2	3	4					i=3

Merge

	[0]	[1]	[2]	[3]	[4]	[5]	[6]	[7]	
a	1	3	5	8	2	4	6	7	j++
temp	1	2	3	4	5				i=4
a	1	3	5	8	2	4	6	7	k++
temp	1	2	3	4	5	6			i=5
a	1	3	5	8	2	4	6	7	k++
temp	1	2	3	4	5	6	7		i=6
a	1	3	5	8	2	4	6	7	j++
temp	1	2	3	4	5	6	7	8	i=7