CS2313 Computer Programming

LT6 – Array

Outlines

- 1D and 2D **array** in C++.

Outcomes

- Array definition
- Array initialization
- Updating array elements
- Printing the content of arrays

Syntax Summary

- Punctuators-square brackets
  - [...]

Declaring Array Variables

```
datatype arrayRefVar[arraySize];
```

Example:

```
double myList[10];
```

C++ requires that the array size used to declare an array must be a constant expression. For example, the following code is illegal:

```
int size = 4;
double myList[size]; // Wrong
```

But it would be OK, if size is a constant as follow:

```
const int size = 4;
double myList[size]; // Correct
```

No Bound Checking

C++ does not check array's boundary. So, accessing array elements using subscripts beyond the boundary (e.g., myList[-1] and myList[11]) does not cause syntax errors, but the operating system might report a memory access violation.

Declaring, creating, initializing Using the Shorthand Notation

double myList[4] = {1.9, 2.9, 3.4, 3.5};

This shorthand notation is equivalent to the following statements:

double myList[4];
myList[0] = 1.9;
myList[1] = 2.9;
myList[2] = 3.4;
myList[3] = 3.5;

CAUTION

Using the shorthand notation, you have to declare, create, and initialize the array all in one statement. Splitting it would cause a syntax error. For example, the following is wrong:

```
double myList[4];
myList = {1.9, 2.9, 3.4, 3.5};
```

Implicit Size

C++ allows you to omit the array size when declaring and creating an array using an initilizer. For example, the following declaration is fine:

double myList[] = {1.9, 2.9, 3.4, 3.5};

C++ automatically figures out how many elements are in the array.

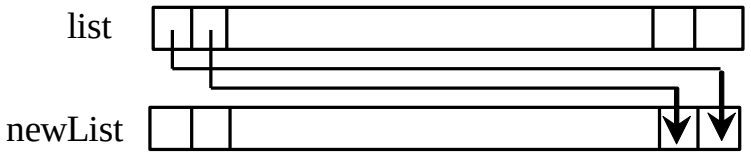
Partial Initialization

C++ allows you to initialize a part of the array. For example, the following statement assigns values 1.9, 2.9 to the first two elements of the array. The other two elements will be set to zero. Note that if an array is declared, but not initialized, all its elements will contain "garbage", like all other local variables.

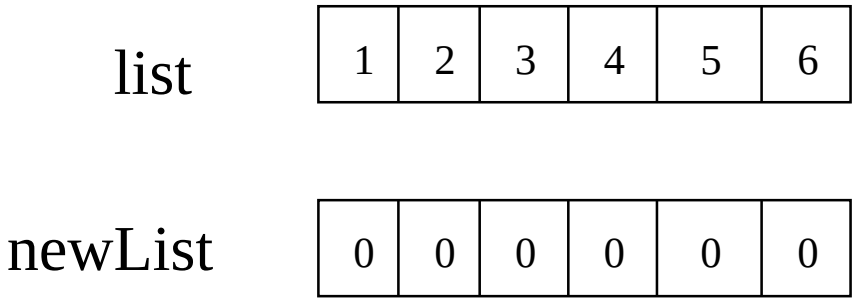
double myList[4] = {1.9, 2.9};

Trace the reverse Function

```
int list1[] = {1, 2, 3, 4, 5, 6};
reverse(list1, list2);
```




```
for (int i = 0, j = size - 1; i < size; i++, j--)
{
  newList[j] = list[i];
}
```



Trace the reverse function, cont.

```
int list1[] = {1, 2, 3, 4, 5, 6};
reverse(list1, list2);
```

i = 0 and j = 5

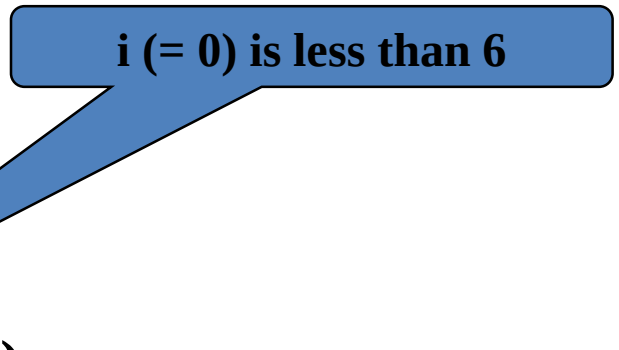
```
for (int i = 0, j = size - 1; i < size; i++, j--)
{
  newList[j] = list[i];
}
```

list	1	2	3	4	5	6

newList	0	0	0	0	0	0

Trace the reverse function, cont.

```
int list1[] = {1, 2, 3, 4, 5, 6};
reverse(list1, list2);
```




```
for (int i = 0, j = size - 1; i < size; i++, j--)
{
  newList[j] = list[i];
}
```

list	1	2	3	4	5	6

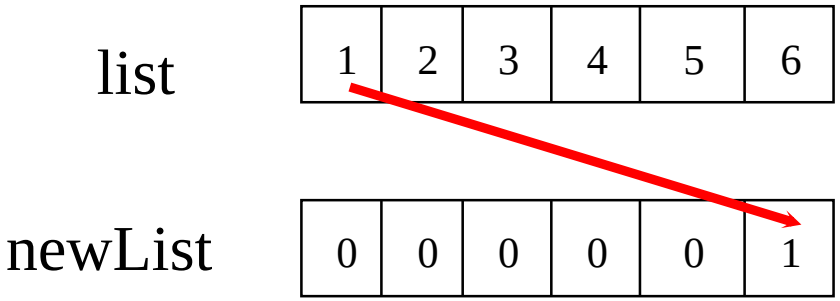
newList	0	0	0	0	0	0

Trace the reverse function, cont.

```
int list1[] = {1, 2, 3, 4, 5, 6};
reverse(list1, list2);
```

```
for (int i = 0, j = size - 1; i < size; i++, j--)
{
  newList[j] = list[i];
}
```

i = 0 and j = 5
Assign list[0] to newList[5]



Trace the reverse function, cont.

```
int list1[] = {1, 2, 3, 4, 5, 6};
reverse(list1, list2);
```

```
for (int i = 0, j = size - 1; i < size; i++, j--)
{
  newList[j] = list[i];
}
```

After this, i becomes 1 and j becomes 4

list	1	2	3	4	5	6

newList	0	0	0	0	0	1

Trace the reverse function, cont.

```
int list1[] = {1, 2, 3, 4, 5, 6};
reverse(list1, list2);
```

i (=1) is less than 6

```
for (int i = 0, j = size - 1; i < size; i++, j--)
{
  newList[j] = list[i];
}
```

list	1	2	3	4	5	6

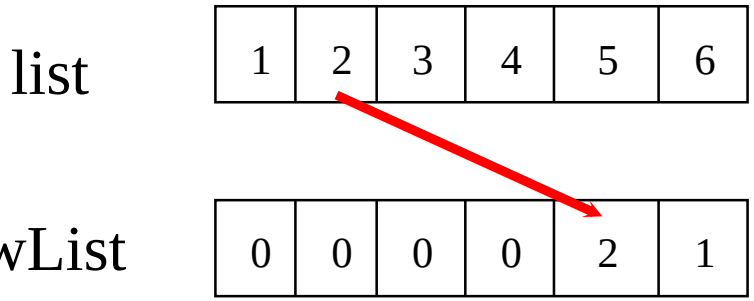
newList	0	0	0	0	0	1

Trace the reverse function, cont.

```
int list1[] = {1, 2, 3, 4, 5, 6};
reverse(list1, list2);
```

```
for (int i = 0, j = size - 1; i < size; i++, j--)
{
  newList[j] = list[i];
}
```

i = 1 and j = 4
Assign list[1] to newList[4]



Trace the reverse function, cont.

```
int list1[] = {1, 2, 3, 4, 5, 6};
reverse(list1, list2);
```

```
for (int i = 0, j = size - 1; i < size; i++, j--)
{
  newList[j] = list[i];
}
```

After this, i becomes 2 and j becomes 3

list	1	2	3	4	5	6

newList	0	0	0	0	2	1

Trace the reverse function, cont.

```
int list1[] = {1, 2, 3, 4, 5, 6};
reverse(list1, list2);
```

```
for (int i = 0, j = size - 1; i < size; i++, j--)
{
  newList[j] = list[i];
}
```

i (=2) is still less than 6

list	1	2	3	4	5	6

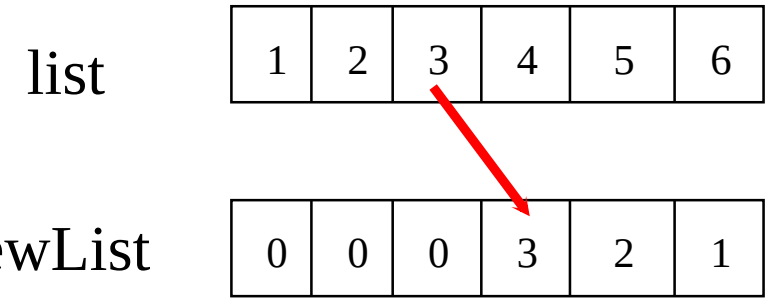
newList	0	0	0	0	2	1

Trace the reverse function, cont.

```
int list1[] = {1, 2, 3, 4, 5, 6};
reverse(list1, list2);
```

```
for (int i = 0, j = size - 1; i < size; i++, j--)
{
  newList[j] = list[i];
}
```

i = 2 and j = 3
Assign list[i] to newList[j]



Trace the reverse function, cont.

```
int list1[] = {1, 2, 3, 4, 5, 6};
reverse(list1, list2);
```

```
for (int i = 0, j = size - 1; i < size; i++, j--)
{
  newList[j] = list[i];
}
```

After this, i becomes 3 and j becomes 2

list	1	2	3	4	5	6

newList	0	0	0	3	2	1

Trace the reverse function, cont.

```
int list1[] = {1, 2, 3, 4, 5, 6};
reverse(list1, list2);
```

```
for (int i = 0, j = size - 1; i < size; i++, j--)
{
  newList[j] = list[i];
}
```

i (=3) is still less than 6

list	1	2	3	4	5	6

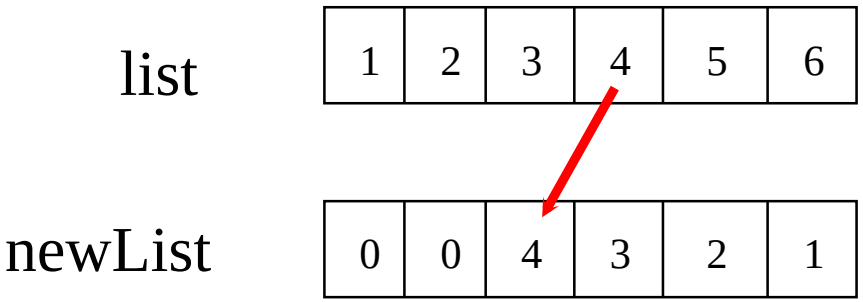
newList	0	0	0	3	2	1

Trace the reverse function, cont.

```
int list1[] = {1, 2, 3, 4, 5, 6};
reverse(list1, list2);
```

```
for (int i = 0, j = size - 1; i < size; i++, j--)
{
  newList[j] = list[i];
}
```

i = 3 and j = 2
Assign list[i] to newList[j]



Trace the reverse function, cont.

```
int list1[] = {1, 2, 3, 4, 5, 6};
reverse(list1, list2);
```

```
for (int i = 0, j = size - 1; i < size; i++, j--)
{
  newList[j] = list[i];
}
```

After this, i becomes 4 and j becomes 1

list	1	2	3	4	5	6

newList	0	0	4	3	2	1

Trace the reverse Function, cont.

```
int list1[] = {1, 2, 3, 4, 5, 6};
reverse(list1, list2);
```

```
for (int i = 0, j = size - 1; i < size; i++, j--)
{
  newList[j] = list[i];
}
```

i (=4) is still less than 6

list	1	2	3	4	5	6

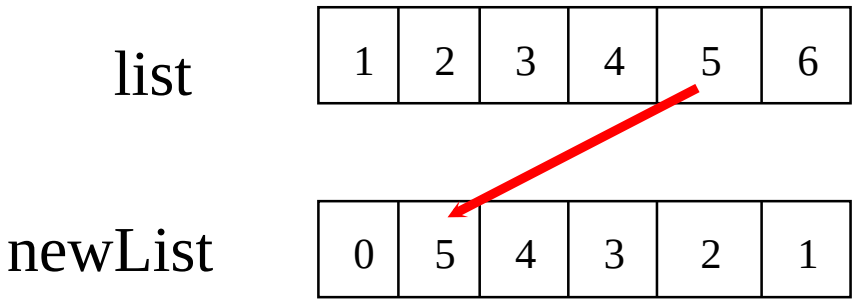
newList	0	0	4	3	2	1

Trace the reverse Function, cont.

```
int list1[] = {1, 2, 3, 4, 5, 6};
reverse(list1, list2);
```

```
for (int i = 0, j = size - 1; i < size; i++, j--)
{
  newList[j] = list[i];
}
```

i = 4 and j = 1
Assign list[i] to newList[j]



Trace the reverse Function, cont.

```
int list1[] = {1, 2, 3, 4, 5, 6};
reverse(list1, list2);
```

```
for (int i = 0, j = size - 1; i < size; i++, j--)
{
  newList[j] = list[i];
}
```

After this, i becomes 5 and j becomes 0

list

1	2	3	4	5	6

newList

0	5	4	3	2	1

Trace the reverse Function, cont.

```
int list1[] = {1, 2, 3, 4, 5, 6};
reverse(list1, list2);
```

```
for (int i = 0, j = size - 1; i < size; i++, j--)
{
  newList[j] = list[i];
}
```

i (=5) is still less than 6

list	1	2	3	4	5	6

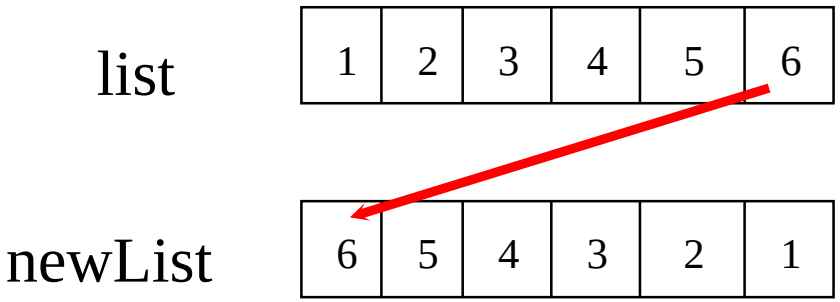
newList	0	5	4	3	2	1

Trace the reverse Function, cont.

```
int list1[] = {1, 2, 3, 4, 5, 6};
reverse(list1, list2);
```

```
for (int i = 0, j = size - 1; i < size; i++, j--)
{
  newList[j] = list[i];
}
```

i = 5 and j = 0
Assign list[i] to newList[j]



Trace the reverse Function, cont.

```
int list1[] = {1, 2, 3, 4, 5, 6};
reverse(list1, list2);
```

```
for (int i = 0, j = size - 1; i < size; i++, j--)
{
  newList[j] = list[i];
}
```

After this, i becomes 6 and j becomes -1

list	1	2	3	4	5	6

newList	6	5	4	3	2	1

Trace the reverse function, cont.

```
int list1[] = {1, 2, 3, 4, 5, 6};
reverse(list1, list2);
```

```
for (int i = 0, j = size - 1; i < size; i++, j--)
{
  newList[j] = list[i];
}
```

i (=6) < 6 is false. So exit the loop.

list	1	2	3	4	5	6

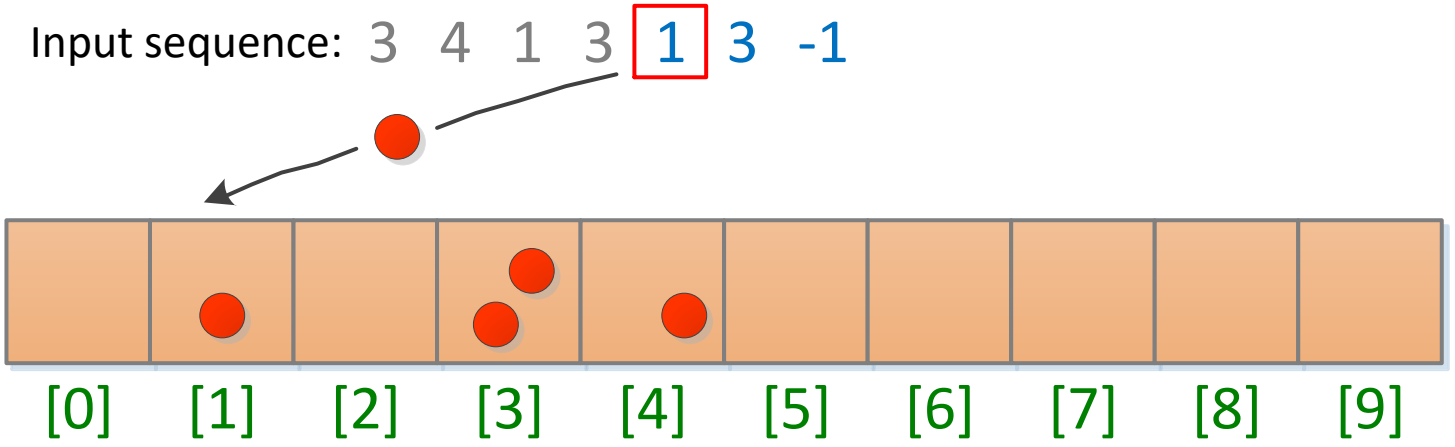
newList	6	5	4	3	2	1

Example 1 - Using An Integer Array

```
/*define variables for storing10 students' mark*/
int marks[10], sum=0, average;
int i;

/*input marks of student*/
for (i=0; i<10; i++)
    cin >> mark[i];

/*print the marks and sum all the marks*/
cout << "The mark of the students are:";
for (i=0; i<10; i++) {
    cout << mark[i];
    sum = sum + mark[i];
}

/*compute and print the average*/
average = sum/10;
cout << "Average mark=" << average << endl;
```

Example 2 - Counting Digits

- Input a sequence of digits `{0, 1, 2, …, 9}`, which is terminated by `-1`.
- Count the frequency of occurrence of each digit.
- Use an integer array `count` of `10` elements.
  - `count[i]` stores the frequency of occurrence of digit `i`.



The Program - Buggy Version

```
#include <iostream>
using namespace std;

void main(){
    int count[10];  //frequency of occurrence of digits
    int digit;      //input digit.
    int i;      //loop counter

    //read the digits
    do {
        cin >> digit;
        if (digit>=0 && digit<=9)
            count[digit]++;
    } while(digit != -1); //stop if the input number is -1

    //print the frequency
    for (i=0; i<10; i++){
        cout << "Frequency of " << i << " is " << count[i] << endl;
    }
}
```

The Possible Actual Output - Incorrect!

```
3 4 1 3 1 3 -1
Frequency of 0 is 2089878893
Frequency of 1 is 2088886165
Frequency of 2 is 1376256
Frequency of 3 is 3
Frequency of 4 is 1394145
Frequency of 5 is 1245072
Frequency of 6 is 4203110
Frequency of 7 is 1394144
Frequency of 8 is 0
Frequency of 9 is 1310720
```

Always Good Practice to Initialize Arrays

- Otherwise, the values of the array elements is **unpredictable**.

- A common way to **initialize** an array is to set all the elements to zero.

```
for (i=0; i<10; i++)
    count[i]=0;
```

Array Initializer

```
int mark [10]={100, 90};
```

- Define an array of `10` elements, set the `1st` element to `100` and the `2nd` element to `90`.
- We list fewer values than the array size (10). The remaining elements are set to `0` by default.

- To initialize all elements to 0:

```
int mark[10]={0};
int count[10]={0};
```

```
for (i=0; i<10; i++)
    count[i]=0;
```

Buggy Version

```
#include <iostream>
using namespace std;

void main(){
    int count[10]; //frequency of occurrence  of digits
    int digit; //input digit
    int i; //loop counter

    //read the digits
    do {
        cin >> digit;
        if (digit>=0 && digit<=9)
            count[digit]++;
    } while(digit != -1); //stop if the input number is -1

    //print the frequency
    for (i=0; i<10;i++){
        cout << "Frequency of " << i << " is " << count[i] << endl;
   }
}
```

Correct Program

```
#include<iostream>
using namespace std;
void main(){
    int count[10]; //frequency of occurrence  of digits
    int digit; //input digit.
    int i; //loop counter

    //initialization
    for (i=0;i<10;i++){
        count[i]=0;
    }

    //read the digits
    do {
        cin >> digit;
        if (digit>=0 && digit<=9)
        count[digit]++;
    } while(digit != -1); //stop if the input number is -1

    //print the frequency
    for (i=0; i<10;i++){
        cout << "Frequency of " << i << " is " << count[i] << endl;
    }
}
```

Array Initialization Summary

(a) Basic Initialization

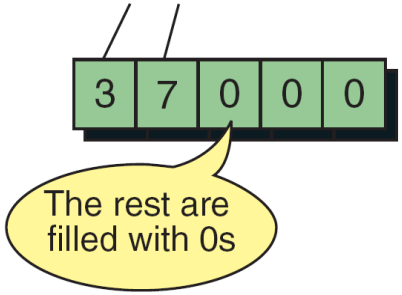
```
int numbers[5] = {3,7,12,24,45};
```

(b) Initialization without Size

```
int numbers[ ] = {3,7,12,24,45};
```

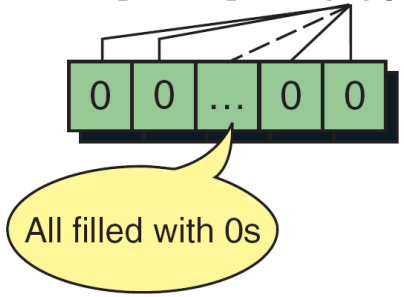
(c) Partial Initialization

```
int numbers[5] = {3,7};
```



(d) Initialization to All Zeros

```
int lotsOfNumbers [1000] = {0};
```



Example 3: Comparing Two Arrays

- We have two integer arrays, each with 5 elements:

```
int array1[5]={10, 5, 3, 5, 1};
int array2[5];
```

- The user input the values of `array2`.
- Compare whether all the elements in `array1` and `array2` are the same.

Array Equality

- Note that you have to compare array element **one by one**.
- The following code generates **incorrect** results:

```
if (array1 == array2)
    cout << "The arrays are equal ";
else
    cout << "The arrays are not equal ";
```

The Program

```
#include <iostream>
using namespace std;
void main(){
     int array1[5]={10, 5, 3, 5, 1};
     int array2[5];
     int i;
     bool arrayEqual=true;

     cout << "Input 5 numbers\n";
     for (i=0;i<5;i++)
          cin >> array2[i];

     for (i=0; i<5 && arrayEqual; i++){
          if (array1[i]!=array2[i]){
               arrayEqual=false;
          }
     }

     if (arrayEqual)
          cout << "The arrays are equal";
     else
          cout << "The arrays are not equal";
}
```

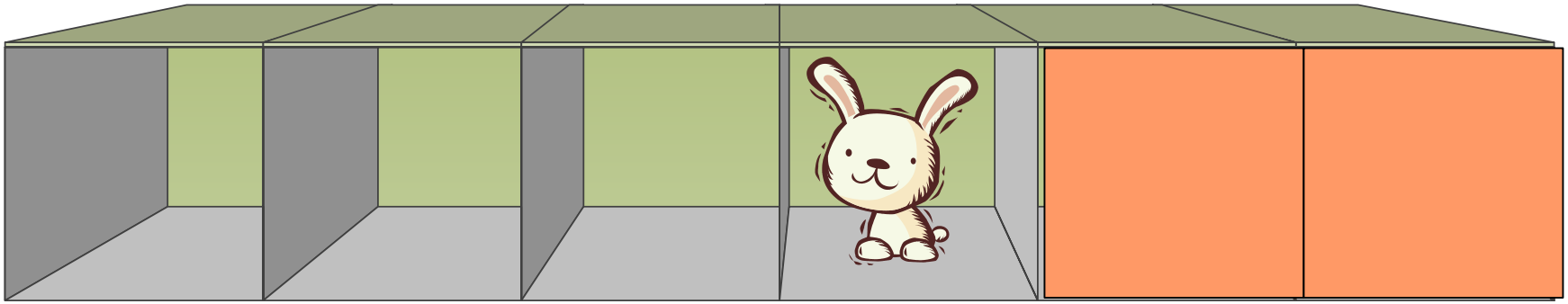
```
Input 5 numbers
10 5 3 5 1
The arrays are equal
```

```
Input 5 numbers
10 4 3 5 2
The arrays are not equal
```

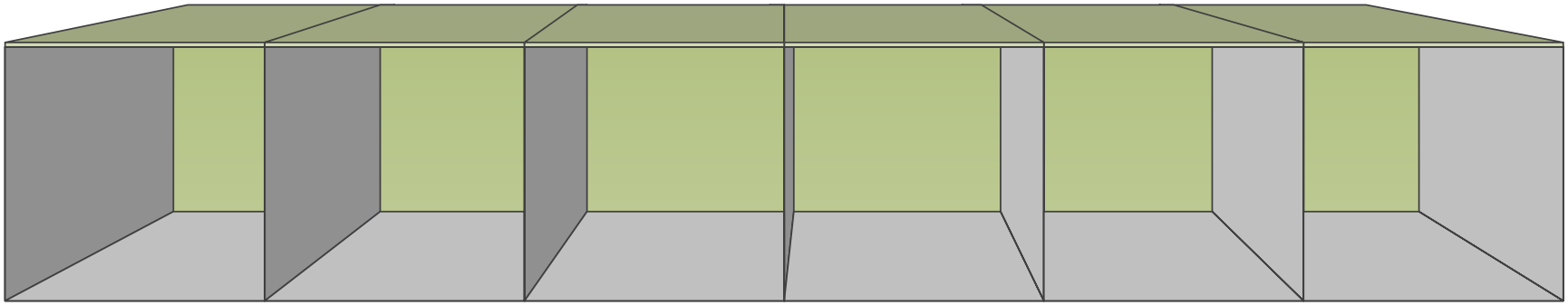
Example 4: Searching

- Read `10` numbers from the user and store them in an array.
- User input another number `x`.
- The program checks if `x` is an element of the array
  - If yes, output the index of the element.
  - If no, output `-1`.

Searching for the Rabbit (Case I)



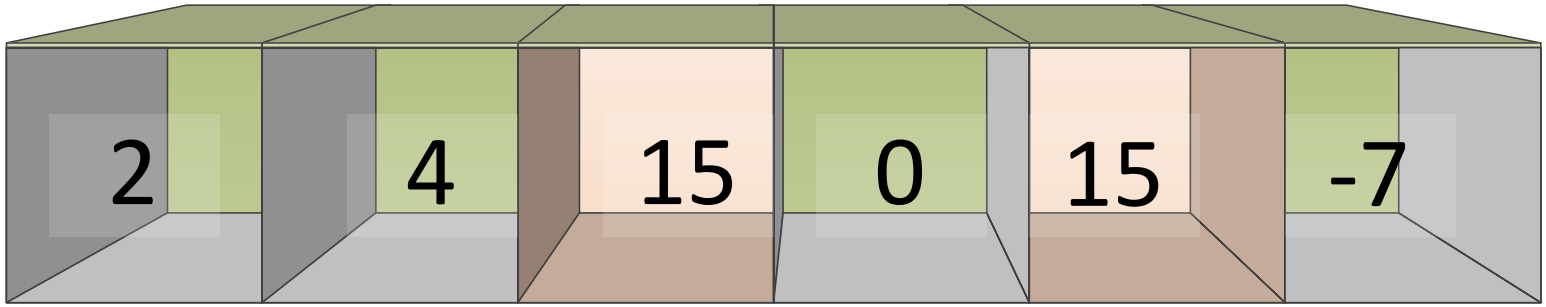
Searching for the Rabbit (Case II)



Searching for `x=15` (Case 1)

Suppose `N=6`

i=1
a[i]!=x

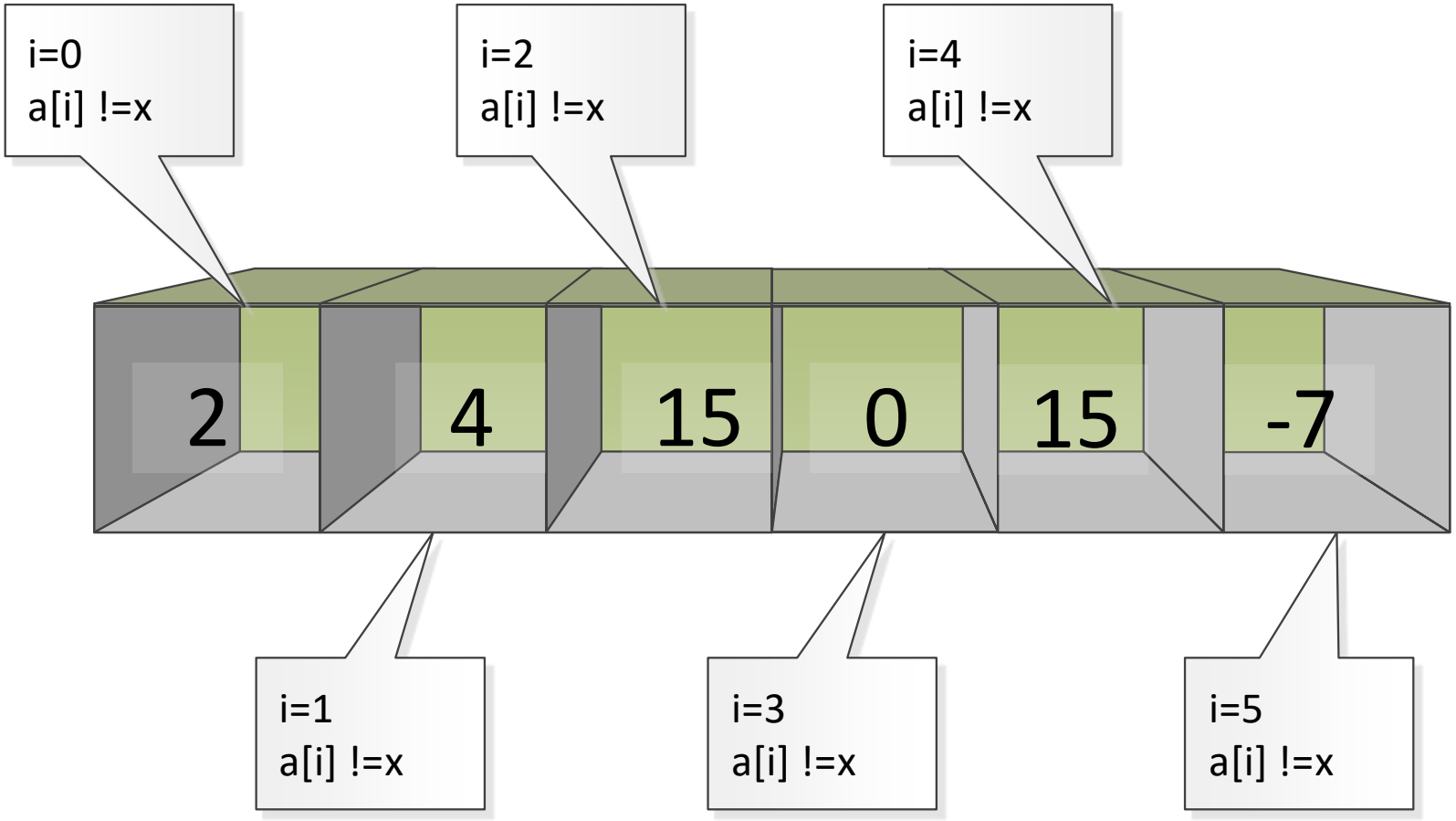


i=0
a[i]!=x

i=2
a[i]==x

Output i=2
break out of the loop

Searching for x=8 (Case 2)



Output -1

The Program

```
#include <iostream>
using namespace std;
#define N 10

void main() {
    int a[N], i, x, position;

    for (i=0; i<N; i++)
        cin >> a[i];
    cout << "Input your target: ";
    cin >>x;
    for (i=0, position=-1; i<N; i++){
        if (a[i]==x) {
            position=i;
            break;
        }
    }
    if (position == -1)
        cout << "Target not found!\n");
    else
        cout << "Target found at position" << position << endl;
}
```

Example 5: Sorting

- One of the most common applications in CS is sorting
  - arranging data by their values: {1, 5, 3, 2} → {1, 2, 3, 5}.

- There are many algorithms for sorting.
  - Selection Sort
  - Bubble Sort
  - Insertion Sort
  - Quick Sort
  - Quicker Sort
  - Merge Sort
  - Heap Sort

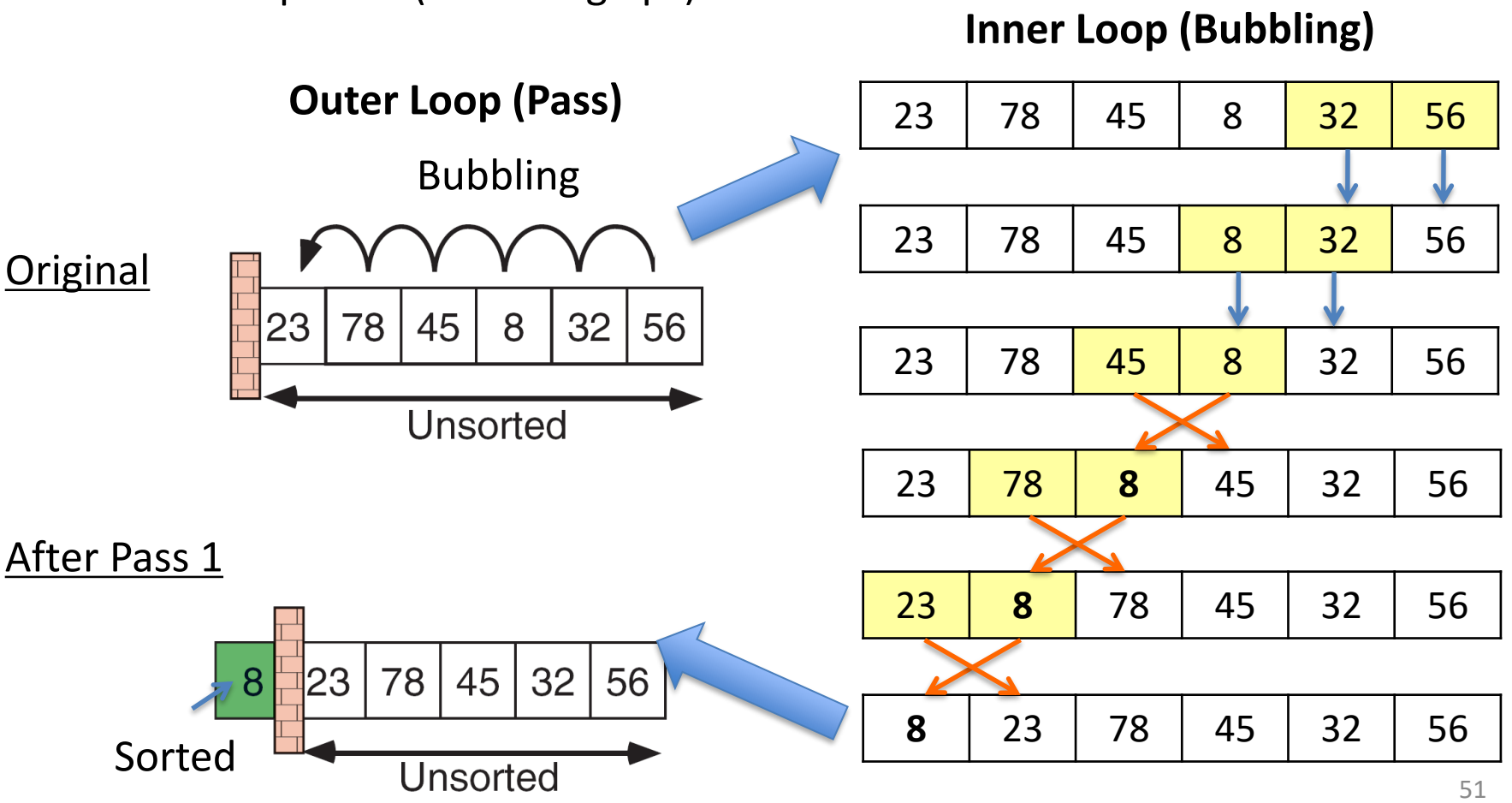
  "Classic" sorting algorithms

  Faster, more complex sorting algorithms

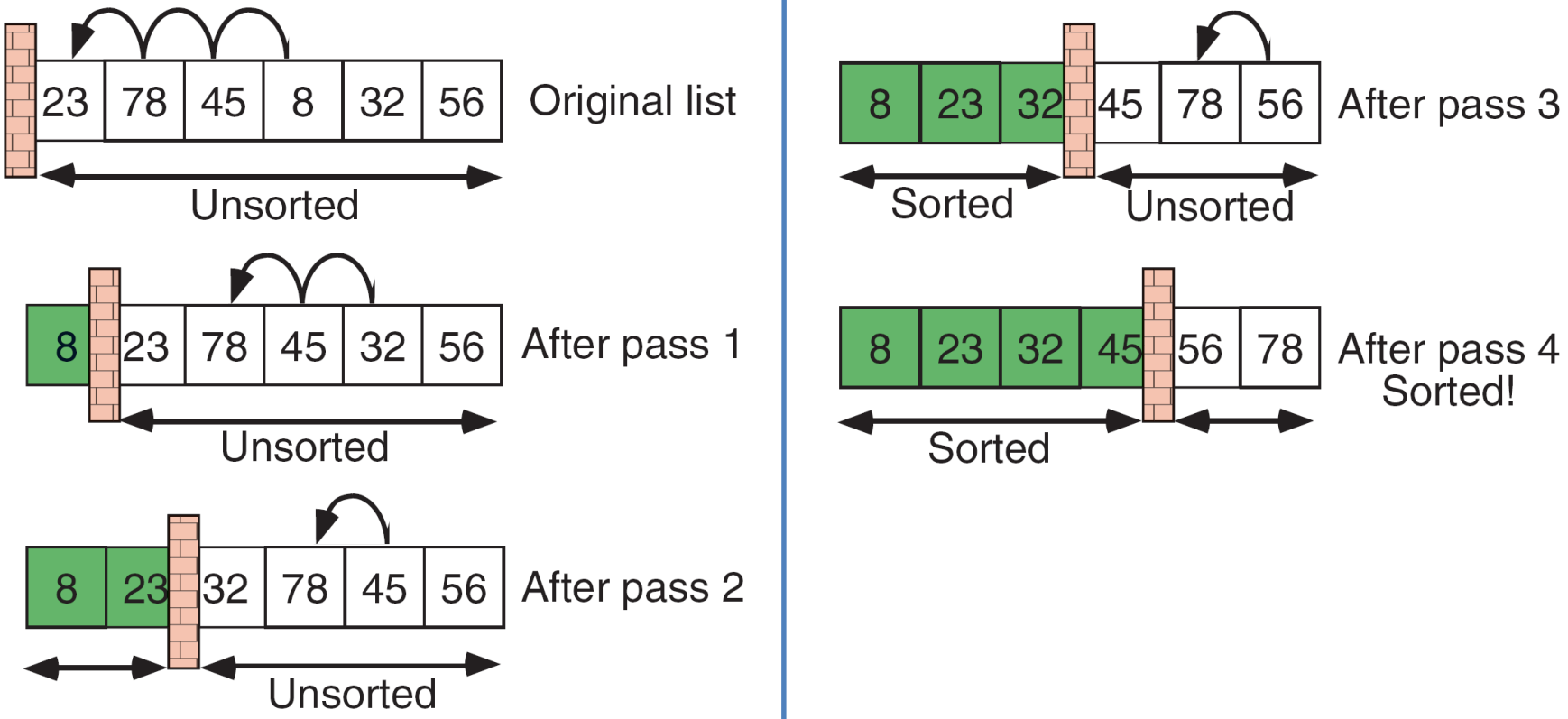
- Based on iteratively swapping two elements in the array so that eventually the array is ordered.
  - The algorithms differ in how they choose the two elements.

Bubble Sort

- The array is divided into two parts: sorted and unsorted.
- In each pass, start at the end, and swap neighboring elements if they are out of sequence ("bubbling up").



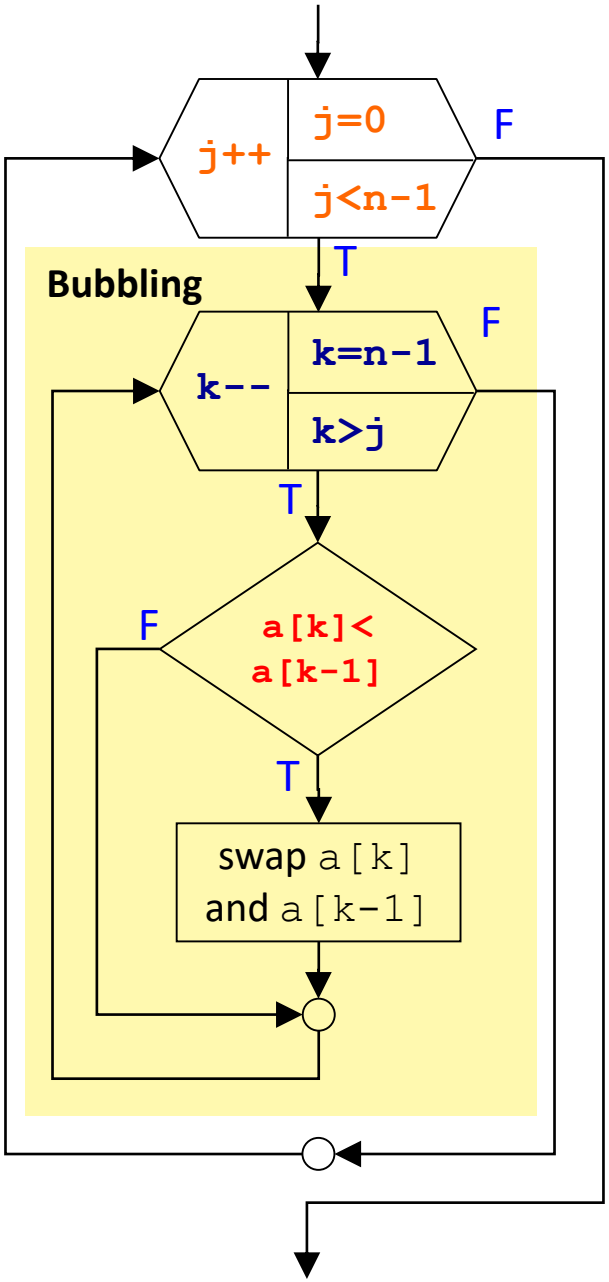
Bubble Sort



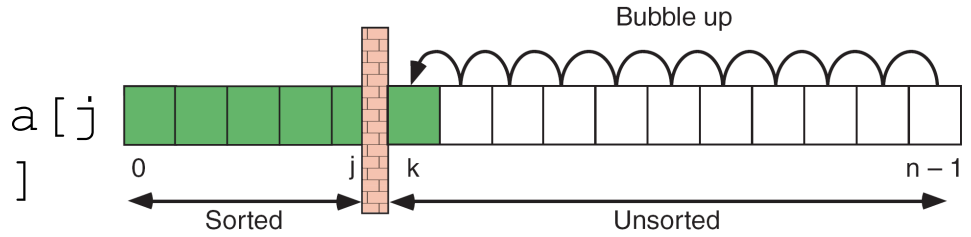
bubble-sort dance: http://youtu.be/lyZQPjUT5B4
insert-sort dance: http://youtu.be/ROalU379l3U

Bubble Sort

Demo!




```
#include <iostream>
using namespace std;
#define n 10
void main() {
  int a[n], j, k, tmp;

  cout <<"Input" << n <<" numbers: ";
  for (j=0; j<n; j++)
    cin >> a[j];

  for(j=0; j<n-1; j++)    // outer loop
    for(k=n-1; k>j; k--) // bubbling
      if (a[k]<a[k-1]) {
        tmp    = a[k];   // swap neighbors
        a[k]   = a[k-1];
        a[k-1] = tmp;
      }

  cout << "Sorted: ";
  for(j=0; j<n; j++)
    cout << a[j];
}
```



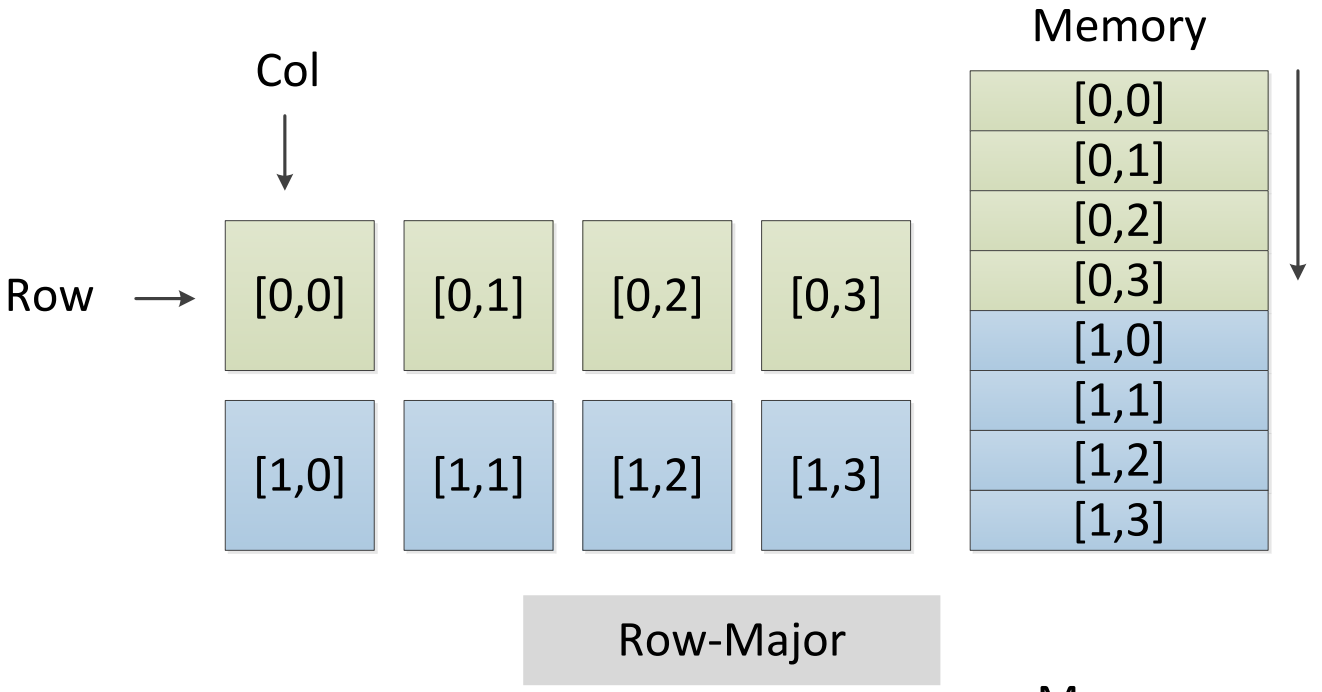
Multi-Dimensional Array

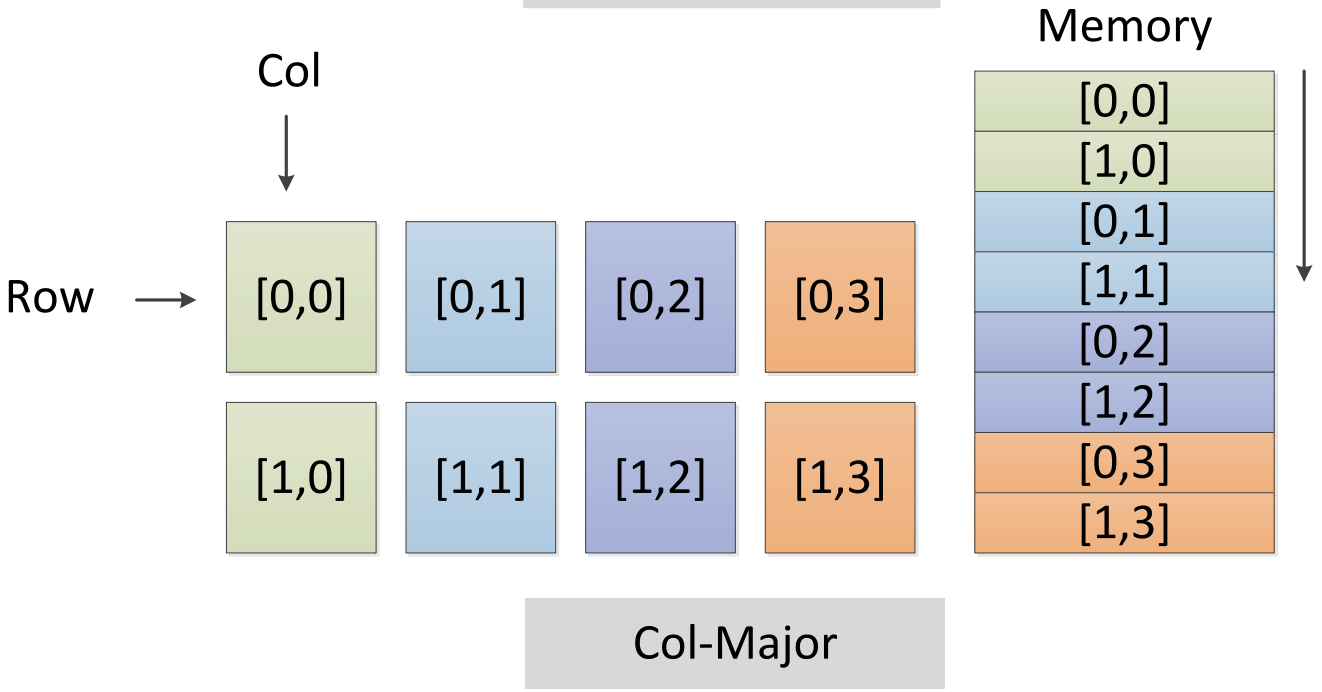
- Multi-dimensional array refers to an array with more than one index. It is a logical representation. On physical storage, the multi-dimensional array is same as single dimensional array (*stored contiguously* in memory space).

- To define a two-dimensional array, we specify the size of each dimension as follows:

```
int page [30][100]; //[row][column]
```

- In C++, the array will be stored in the "row-major" order, i.e. first block of memory will be used to store page [0][0] to page [0][99], the next block for page [1][0] to page [1][99]


Memory
Col
Row
[0,0]
[0,1]
[0,2]
[0,3]
[1,0]
[1,1]
[1,2]
[1,3]
Row-Major


Memory
Col
Row
[0,0]
[0,1]
[0,2]
[0,3]
[1,0]
[1,1]
[1,2]
[1,3]
Col-Major

Multi-Dimensional Array

- To access an element of the array, we specify an index for each dimension:

```
cin >> page [i][j];   //[row][column]
```

- The above statement will input an integer into row `i` and column `j` of the array.

BMI Program

```
#include <iostream>
using namespace std;
#define N 10

void main() {
    float data[N][2]; // N records, each record holds two values (weight and height)
    int i, count , position;
    do {
        cout <<"Number of record (max: 10):";
        cin >> count;
        if (count >10)
            cout << "Maximum number of record is 10, please enter again:" << endl;
    }while (count >10);
    for (i=0; i<count; i++){
        cout << "Weight(kg) Height(m) (" << i+1 << "):";
        cin >> data[i][0];
        cin >> data[i][1];
    }
    for (i=0; i<count; i++){
    cout << "BMI for " << i+ 1 << ": "  << data[i][0]/(data[i][1]*data[i][1]);
    cout << endl;
    }
}
```

Summary

- Array is a sequence of variables of the **same** data type.
- Array elements are **indexed** and can be **accessed** by using subscripts, e.g. `arrayName[1]`, `arrayName[4]`.
- Array elements are **stored contiguously** in memory space.
- Array declaration, initialization, searching, and sorting.
- Array can be multi-dimensional, e.g. 1D , 2D.