CS2311 Computer Programming

LT6: Arrays

Example 1

- Input the marks for 10 students
- Store the marks in variables
- Compute the average marks
- Print the marks of the students and the average

```
100 30 44 66 50 60 80 75 80 100
The mark of the students are: 100, 30, 44, 66, 50, 60, 80, 75, 80, 100
Average mark=68
```

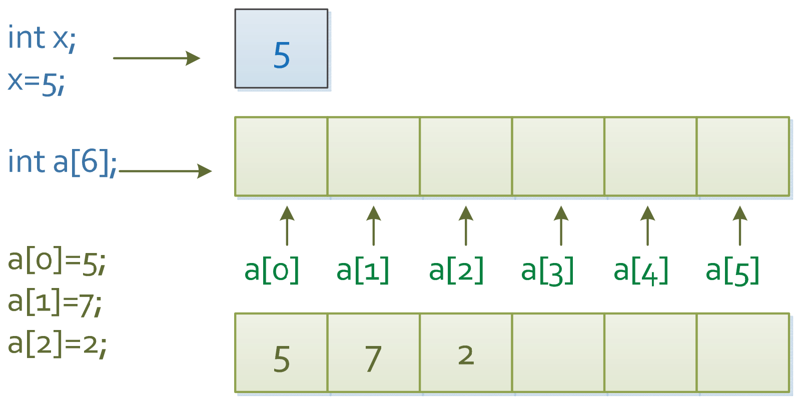
The Program

```
/*define variables for storing 10 students' mark*/
int mark1, mark2, mark3, mark4, mark5,
      mark6, mark7, mark8, mark9, mark10, average;

/*input marks of student*/
cin >> mark1 >> mark2 >> mark3 >> mark4 >>                \\
      mark5 >> mark6 >> mark7 >> mark8 >> mark9 >> mark10;

/*print the marks*/
cout << "The mark of the students are: " << mark1 \\
      << mark2 << mark3 << mark4 << mark5 << mark6 \\
       << mark7 << mark8 << mark9 << mark10 << endl;

average =(mark1+mark2+mark3+mark4+mark5
      +mark6+mark7+mark8+mark9+mark10)/10;

cout << "Average mark"<< average << endl;
```

Is it easy to extend the program to handle more students?

What is an Array?

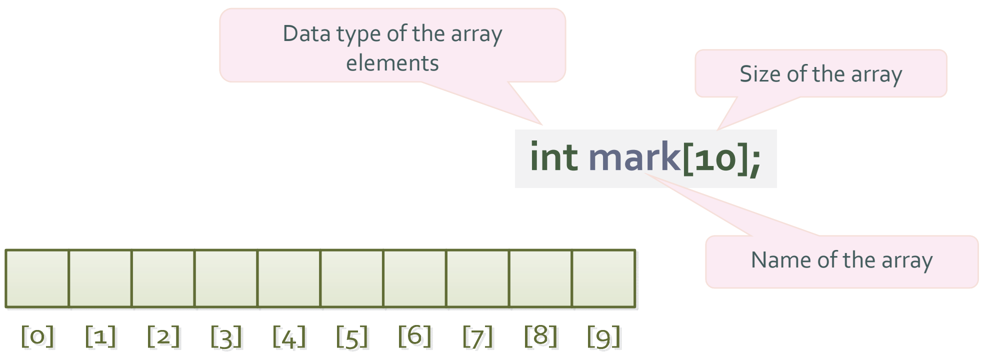
- Sequence of items of the same data type
  - Stored contiguously
  - Can be accessed by index



Outline

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

Array Definition



There are ten elements in this array

mark[0], **mark[1]**, ……, **mark[9]**

The ith array element is **mark[i-1]**.

The range of the subscript **i** is from **0** to **array_size-1**

The location **mark[10]** is invalid. Array out of bound!

Storing values in array elements

- Suppose the mark for the first student is 30. We can use the notation

```
mark[0] = 30
```

- Reading the marks of the second student

```
cin >> mark[1];
```

- Reading the marks for 10 students from console

```
for (unsigned int i=0; i<10; i++)
    cin >> mark[i];
```

Retrieving Values From An **Array**

- Print the mark of the second student

```
cout << mark[1];
```

- Print and sum the marks of all students

```
for (unsigned int i=0; i<10; i++) {
    cout << mark[i];
    sum += mark[i];
}
```

Summary of Array Declaration and Access

Type	Variable	Array	Variable Access	Array Access
int	int x;	int x[20];	x=1;	x[0]=1

float	float x;	float x[10];	x=3.4;	x[0]=3.4;
				x[9]=1.2;

double	double x;	double x[20];	x=0.7;	x[0]=0.7;
				x[3]=3.4;

char	char x;	char x[5];	x='a';	x[0]='c';
				X[1]='s';

char x[] = "hello";

Array declaration and initialization

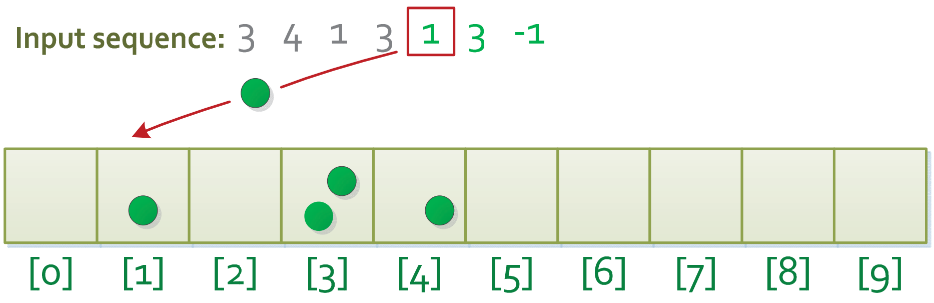
Example 1

(using an integer array with 10 elements)

```
/*define variables for 10 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*/
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 occurrence of each digit
- Use an integer array count of 10 elements
  - count[i] stores the number of occurrence of digit i



The Program: buggy version

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

int main() {
      int count[10];          //number of occurrence of digits
      int digit;              //input digit
      int i;                  //loop index
      //read the digits
      do {
            cin >> digit;
            if (digit >= 0 && digit <= 9)   //necessary to avoid out-of-bound
                  count[digit]++;
      } while (digit != -1);              //stop if the input number is -1
      //print the occurrences
      for (i=0; i<10; i++)
            cout << "Frequency of " << i << " is " << count[i] << endl;
     return 0;
}
```

The actual output (incorrect!)

For some compilers like VS 2015, this program won't run;
for others like g++, this will run with incorrect output

```
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
```

It's a Good Practice to Initialize Arrays

- Otherwise, the values of the elements in the array 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};
```

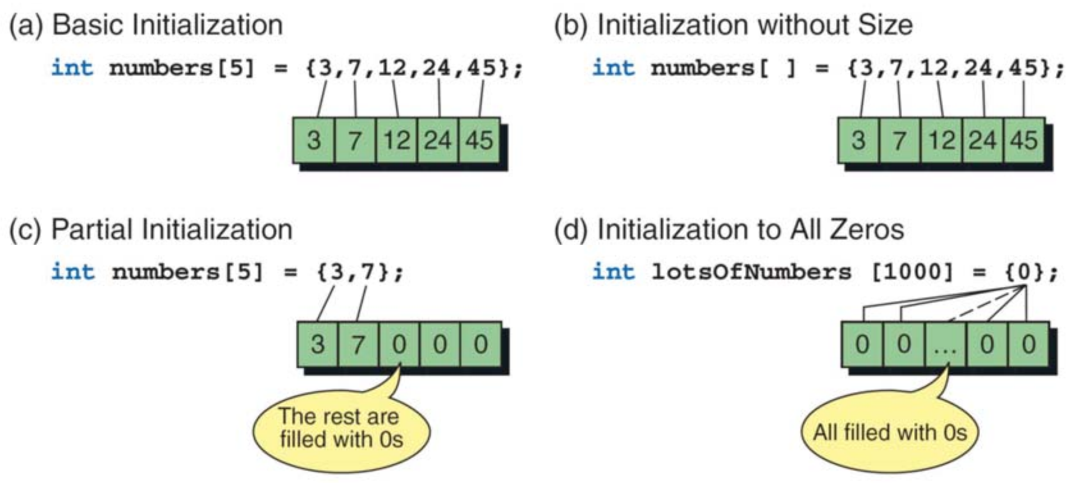
- Define an array of 10 elements, set the 1st element to 100 and the 2nd element to 90
- We list fewer values than the array size (10)
  - The remaining elements are set to 0 by default
- To initialize all elements to 0,

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

Correct program for example 2

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

int main() {
      int count[10] = {0};   //number of occurrence of digits
      int digit;             //input digit
      int i;                 //loop index
      //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 occurrences
      for (i=0; i<10; i++)
            cout << "Frequency of " << i << " is " << count[i] << endl;
     return 0;
}
```

Array Initialization Summary


(a) Basic Initialization
int numbers[5] = {3,7,12,24,45};
3 7 12 24 45
(b) Initialization without Size
int numbers[ ] = {3,7,12,24,45};
3 7 12 24 45
(c) Partial Initialization
int numbers[5] = {3,7};
3 7 0 0 0
The rest are filled with 0s
(d) Initialization to All Zeros
int lotsOfNumbers [1000] = {0};
0 0 ... 0 0
All filled with 0s

- Only fixed-length arrays can be initialized when they are defined.
- Variable length arrays must be initialized by inputting or assigning the values.

Example 3: Comparing 2 arrays

- We have two integers arrays, each with 5 elements
  int array1[5] = {10, 5, 3, 5, 1};
  int array2[5];
- The user inputs the values of **array2**
- Compare whether all of 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

```
int 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";
    return 0;
}
```

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

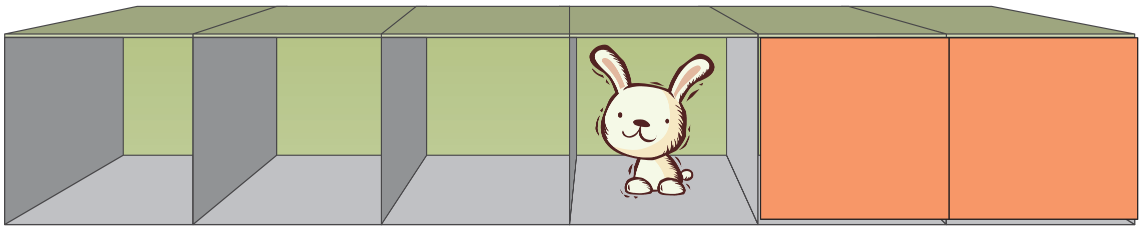
```
Input 5 numbers
10 4 3 5 2
The arrays are not equal
```

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**

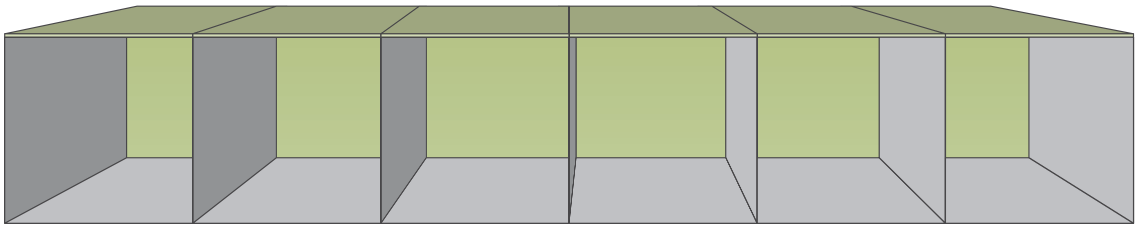
Searching for the Rabbit (Case I)

Search sequentially



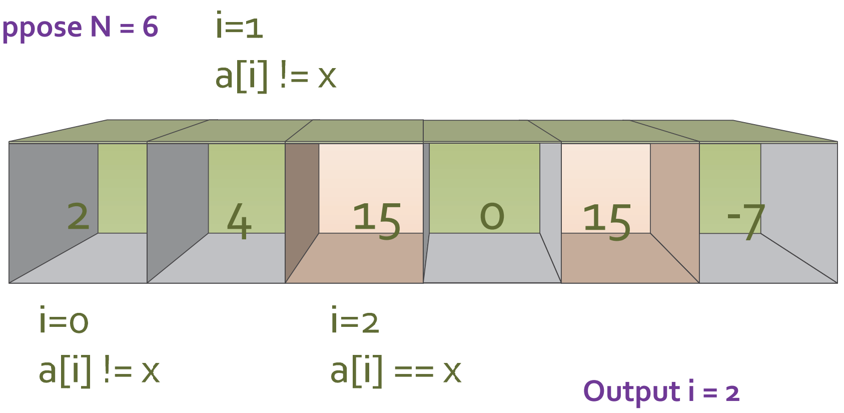
If found, skip the rest

Searching for the Rabbit (Case II)



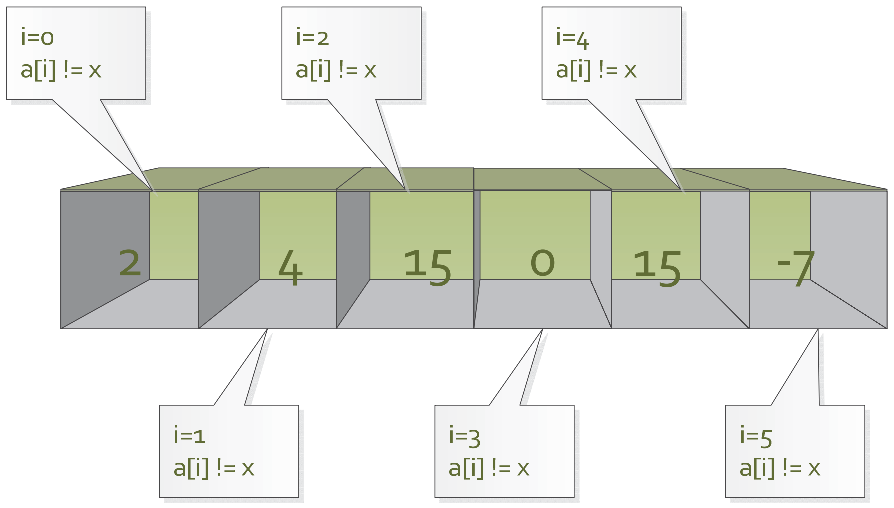
Searching for **x=15** (Case 1)

Suppose N = 6



Output i = 2
break out of the loop

Searching for **x=8** (Case 2)



Output -1

The Program

```
int main() {
    const int N = 6;
    int a[N], i, x, position = -1;

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

Example 5: Sorting

- One of the most common applications 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**

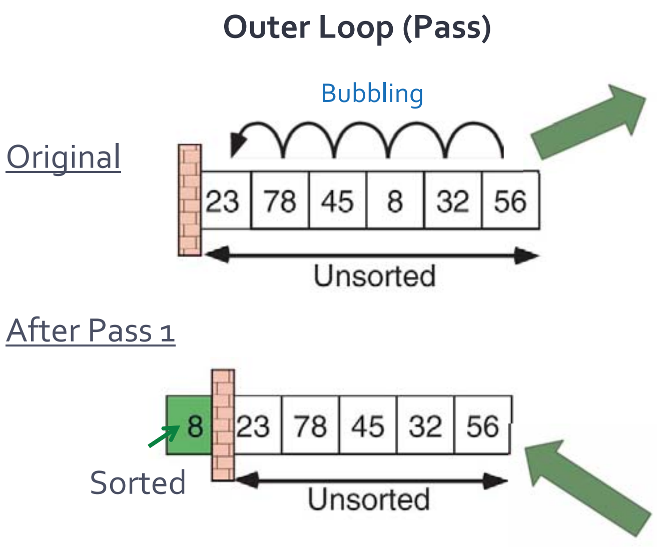
"Classic" sorting algorithms

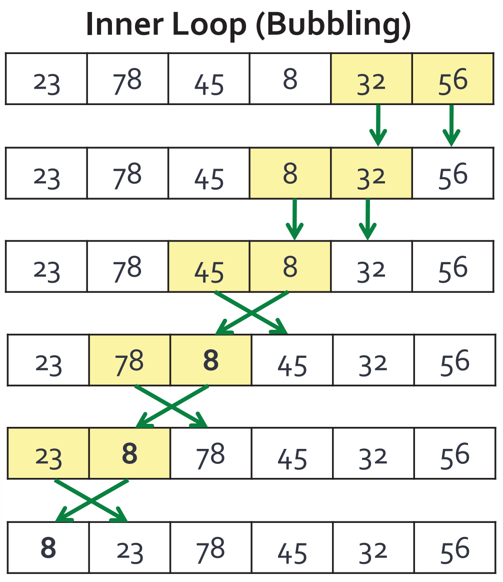
Faster, more complex sorting algorithms

- 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.

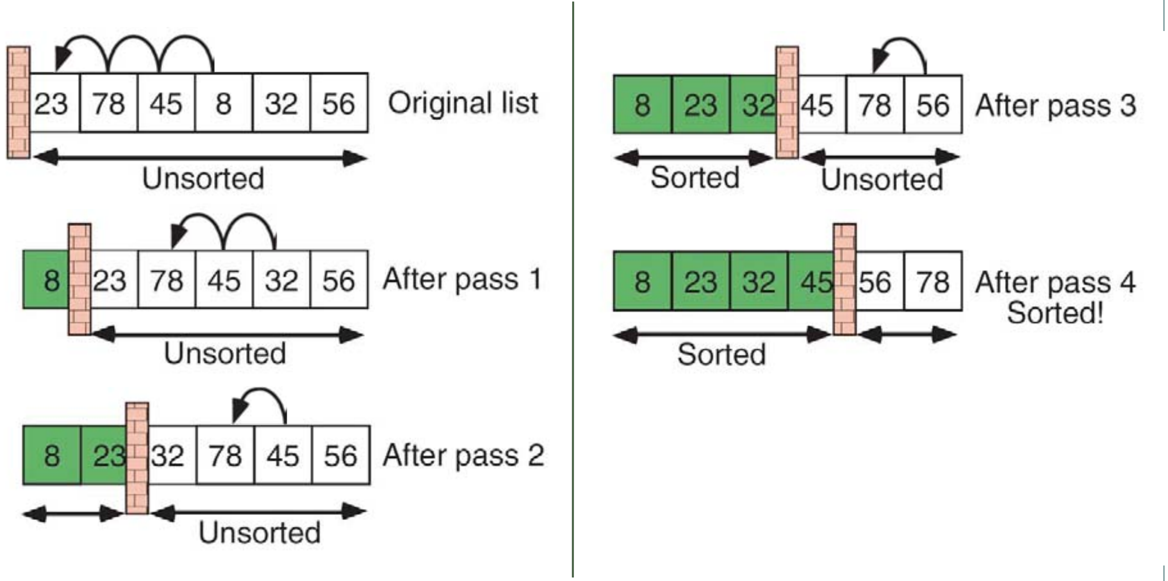
Bubble Sort

- In each pass, start at the end, and swap neighboring elements if they are out of sequence ("bubbling up").
- After i passes, the first i elements are sorted.





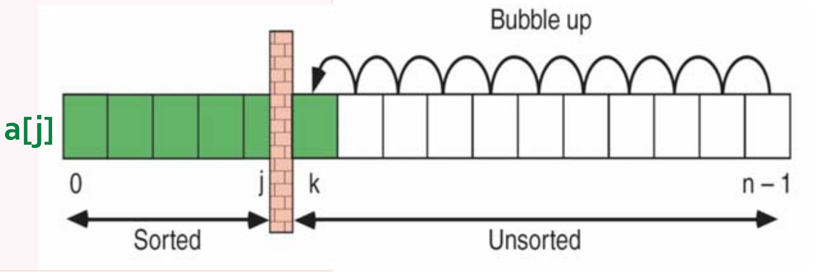
Bubble Sort



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

Bubble Sort

```
int main() {
    const int n = 10;
    int a[n], tmp;
    cout <<"Input" << n <<" numbers: ";
    for (int j=0; j<n; j++)
        cin >> a[j];
    for(int j=0; j<n-1; j++)            // outer loop
        for(int 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(int j=0; j<n; j++)
        cout << a[j];
    return 0;
}
```



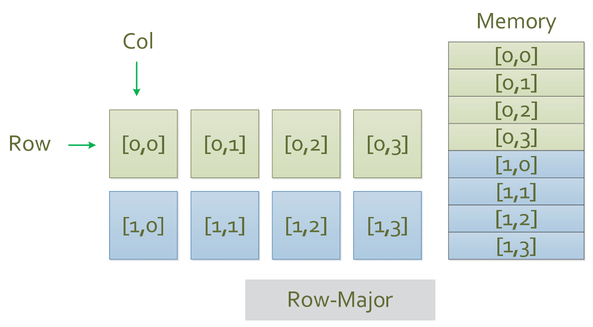
Multi-dimensional Array

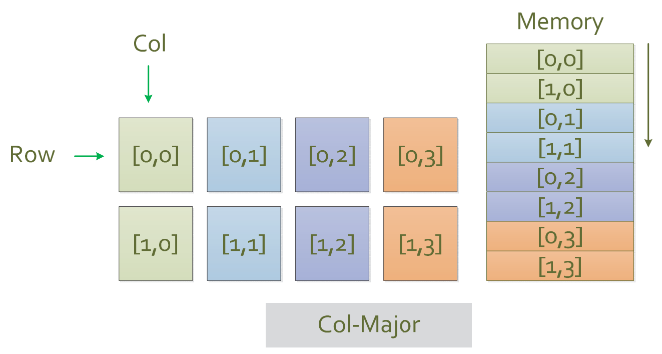
- Multi-dimensional array refers to an array with more than one index. It is a logical representation. On physical storage, the multi-dimensional array is same as single dimensional array (*stored contiguously* in memory space)
- To define a two-dimensional array, we specify the size of each dimension as follows

```
int major[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]

Row-major vs Column-major





Multi-dimensional Array

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

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

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

BMI Program

```
int main() {
    const int N=10;
    double data[N][2]; // N records, each holds weight and height
    int i, position;
    for (i=0; i<N; i++) {
        cout << "Weigth(kg) Height(m):";
        cin >> data[i][0];
        cin >> data[i][1];
    }
    for (i=0; i<count; i++) {
        cout << "BMI for " << i+1 << "is :";
        cout << data[i][0] / (data[i][1]*data[i][1]) << endl;
    }
    return 0;
}
```

Summary

- Array is a sequence of variables of the ***same*** data type
- Array elements are indexed and can be accessed by the use of subscripts,
  - e.g. **array_name[1]**, **array_name[4]**
- Array elements are ***stored contiguously*** in memory space
- Array Declaration, Initialization, Searching and Sorting
- Array can be multi-dimensional, i.e. 2D