Data Structures

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Introduction to Data Structures

Introduction

- Data structure is a storage that is used to store and organize data. It is a way of arranging data on a computer so that it can be accessed and updated efficiently.

- Depending on your requirement and project, it is important to choose the right data structure for your project. For example, if you want to store data sequentially in the memory, then you can go for the Array data structure.

Introduction

- Data structure is representation of the logical relationship existing between individual elements of data.
- In other words, a data structure is a way of organizing all data items that considers not only the elements stored but also their relationship to each other.
- Data structure affects the design of both structural & functional aspects of a program.

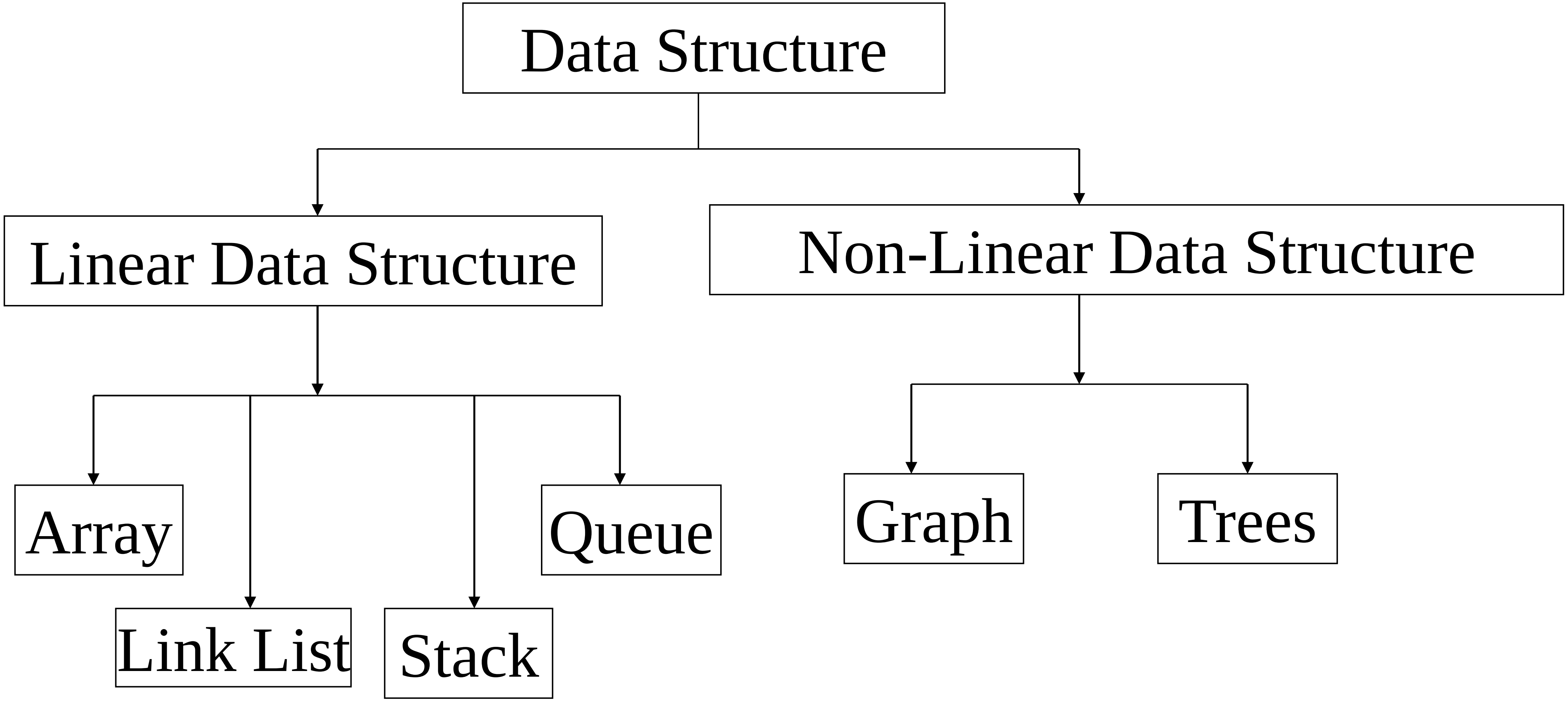
Program=algorithm + Data Structure

- You know that a algorithm is a step by step procedure to solve a particular function.

Introduction

- That means, algorithm is a set of instruction written to carry out certain tasks & the data structure is the way of organizing the data with their logical relationship retained.
- To develop a program of an algorithm, we should select an appropriate data structure for that algorithm.
- Therefore algorithm and its associated data structures from a program.

Classification of Data Structure



Data Structure

Linear Data Structure

Non-Linear Data Structure

Array

Link List

Stack

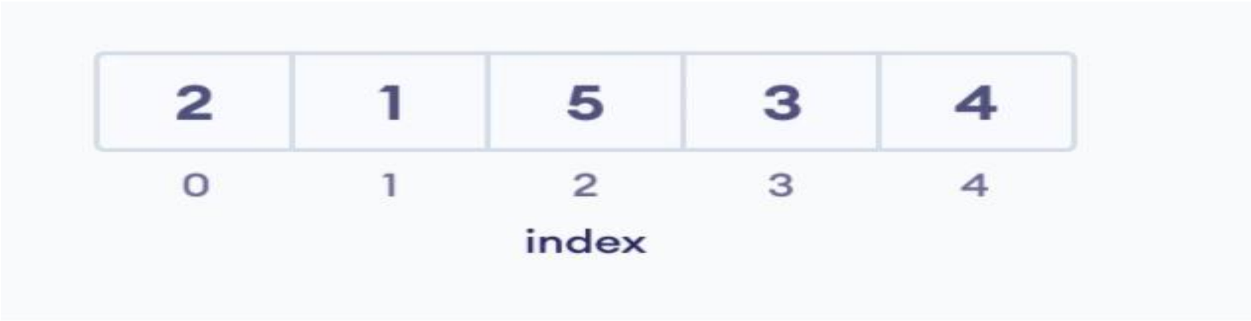
Queue

Graph

Trees

Array Data Structure :

- In an array, elements in memory are arranged in continuous memory. All the elements of an array are of the same type. And, the type of elements that can be stored in the form of arrays is determined by the programming language.

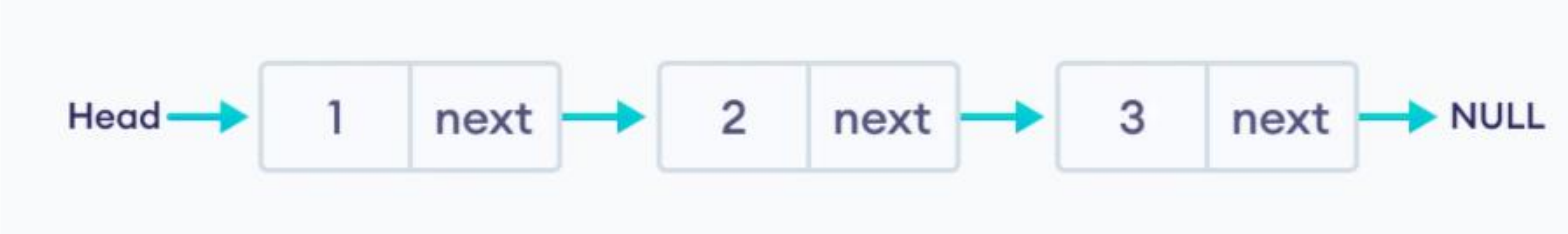


2	1	5	3	4
0	1	2	3	4

index

Linked Lists Data Structure:

- In linked list data structure, data elements are connected through a series of nodes. And, each node contains the data items and address to the next node.

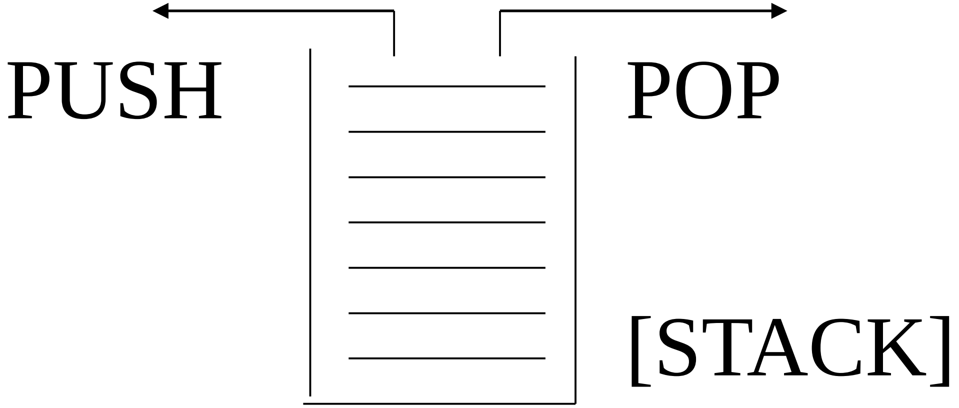


Stack Data Structure:

- A stack is also an ordered collection of elements like arrays, but it has a special feature that deletion and insertion of elements can be done only from one end called the top of the stack (TOP).
- Due to this property it is also called as last in first out type of data structure (LIFO).
- It could be through of just like a stack of plates placed on table in a party, a guest always takes off a fresh plate from the top and the new plates are placed on to the stack at the top.
- When an element is inserted into a stack or removed from the stack, its base remains fixed where the top of stack changes.

Stack Data Structure:

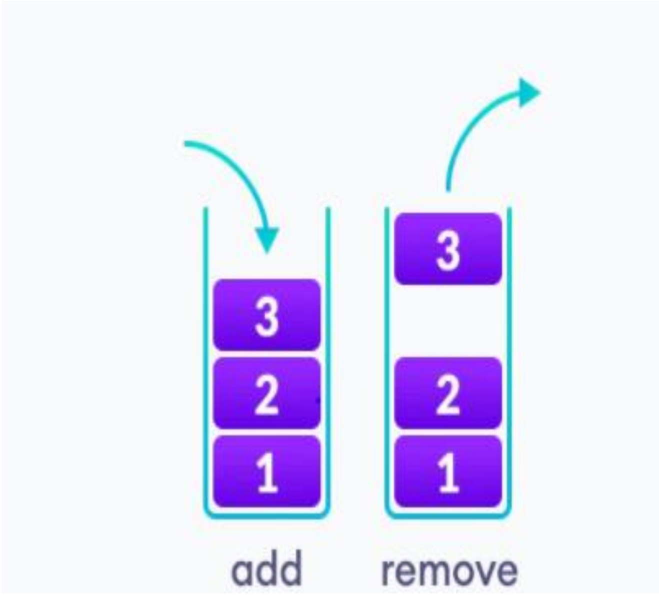
- Insertion of element into stack is called PUSH and deletion of element from stack is called POP.
- The below figure show how the operations take place on a stack:



PUSH

POP

[STACK]

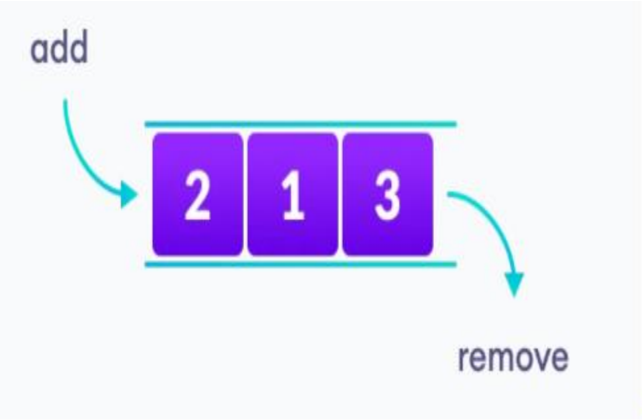


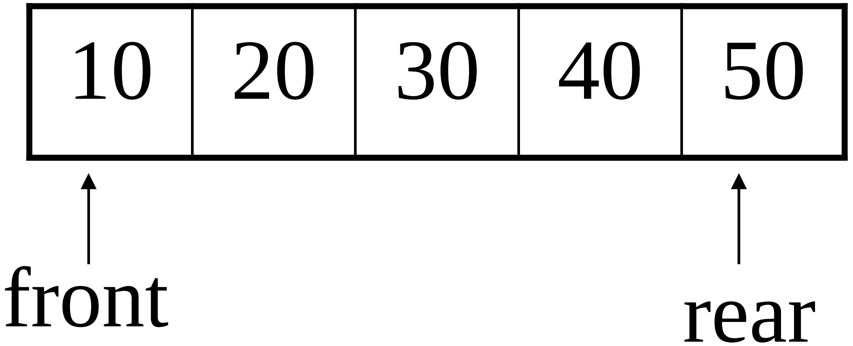
Queue Data Structure:

- Queue are first in first out type of data structure (i.e. FIFO)
- In a queue new elements are added to the queue from one end called REAR end and the element are always removed from other end called the FRONT end.
- The people standing in a railway reservation row are an example of queue.

Queue Data Structure:

- Each new person comes and stands at the end of the row and person getting their reservation confirmed get out of the row from the front end.
- The below figure shows how the operations take place on a queue:





10 20 30 40 50

front

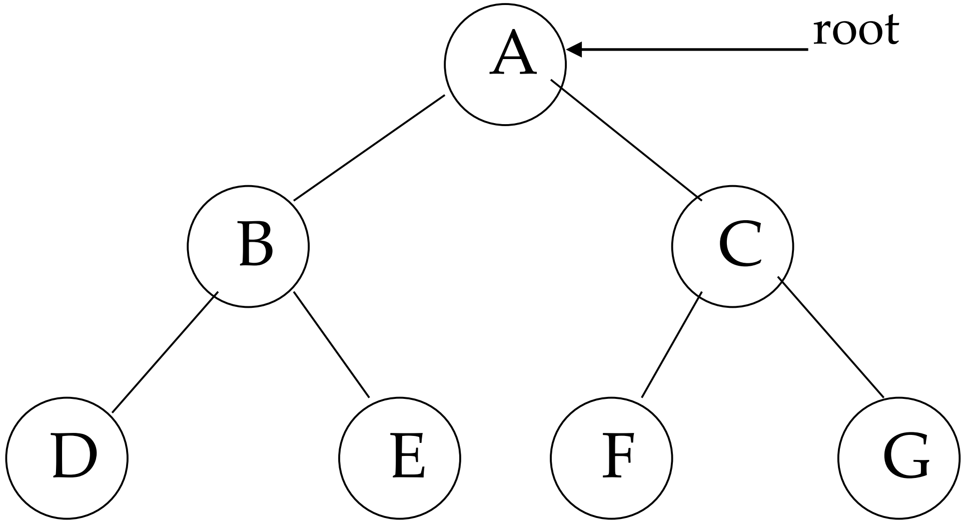
rear

Tree Data Structure:

- A tree can be defined as finite set of data items (nodes).
- Tree is non-linear type of data structure in which data items are arranged or stored in a sorted sequence.
- Tree represent the hierarchical relationship between various elements.
- There is a special data item at the top of hierarchy called the Root of the tree.
- The remaining data items are partitioned into number of mutually exclusive subset, each of which is itself, a tree which is called the sub tree.
- The tree always grows in length towards bottom in data structures, unlike natural trees which grows upwards.

Tree Data Structure:

- The tree structure organizes the data into branches, which related the information.

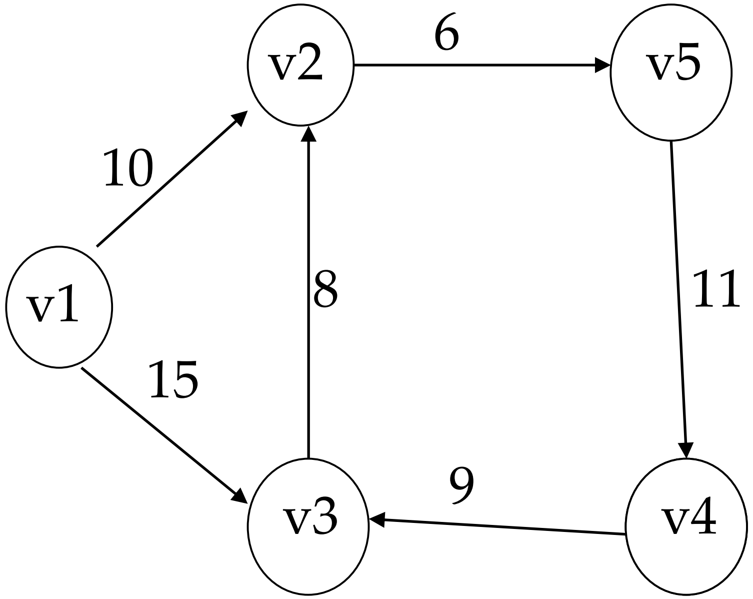


Graph Data Structure:

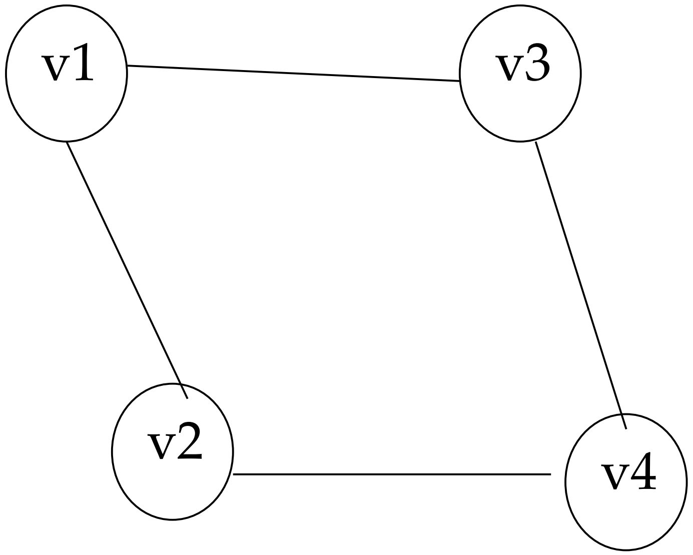
- Graph is a mathematical non-linear data structure capable of representing many kind of physical structures.
- It has found application in Geography, Chemistry and Engineering sciences.
- Definition: A graph G(V,E) is a set of vertices V and a set of edges E.
- An edge connects a pair of vertices and many have weight such as length, cost and another measuring instrument for according the graph.
- Vertices on the graph are shown as point or circles and edges are drawn as arcs or line segment.

Graph Data Structure:

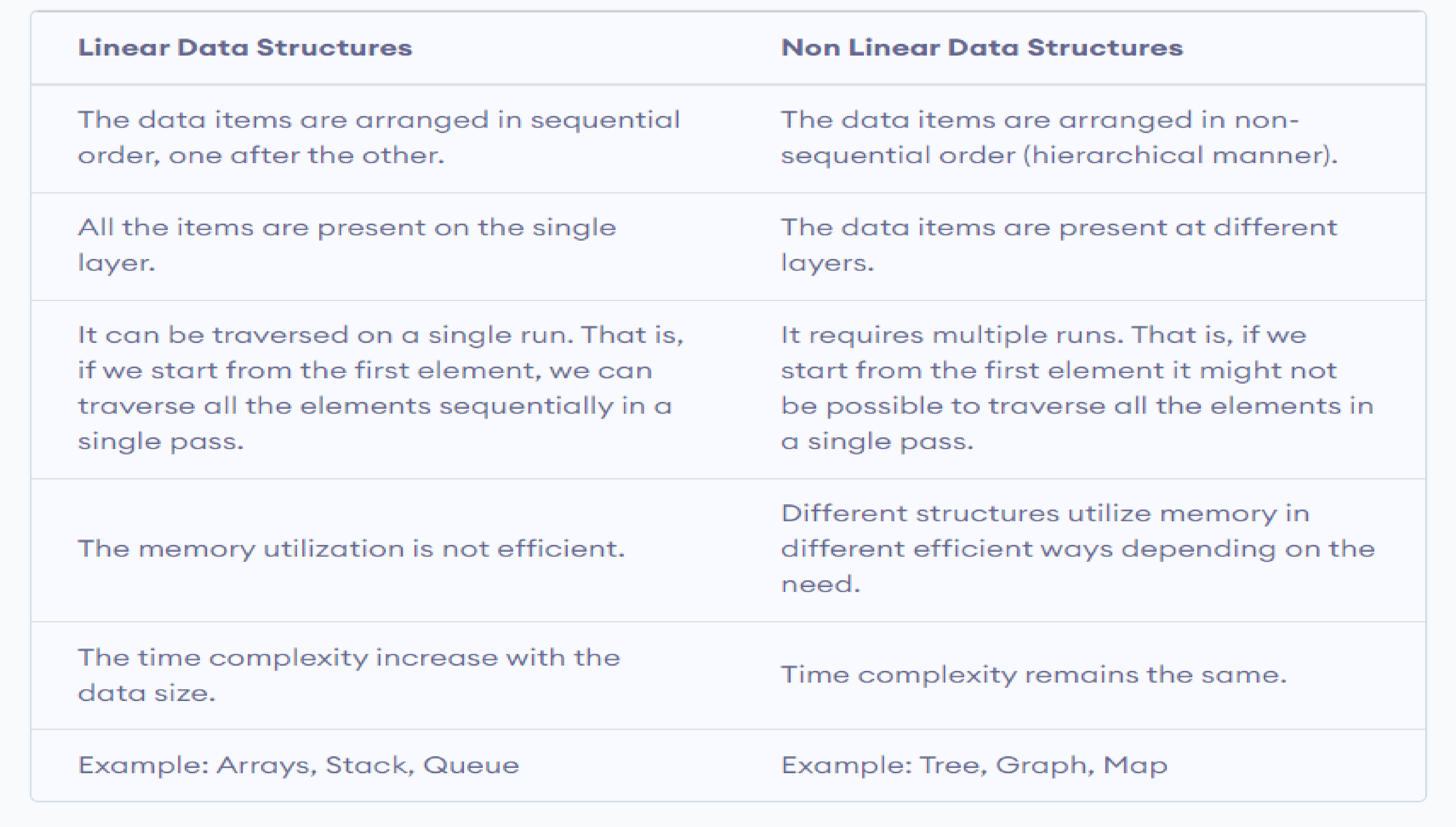
- Example of graph:



[a] Directed & Weighted Graph

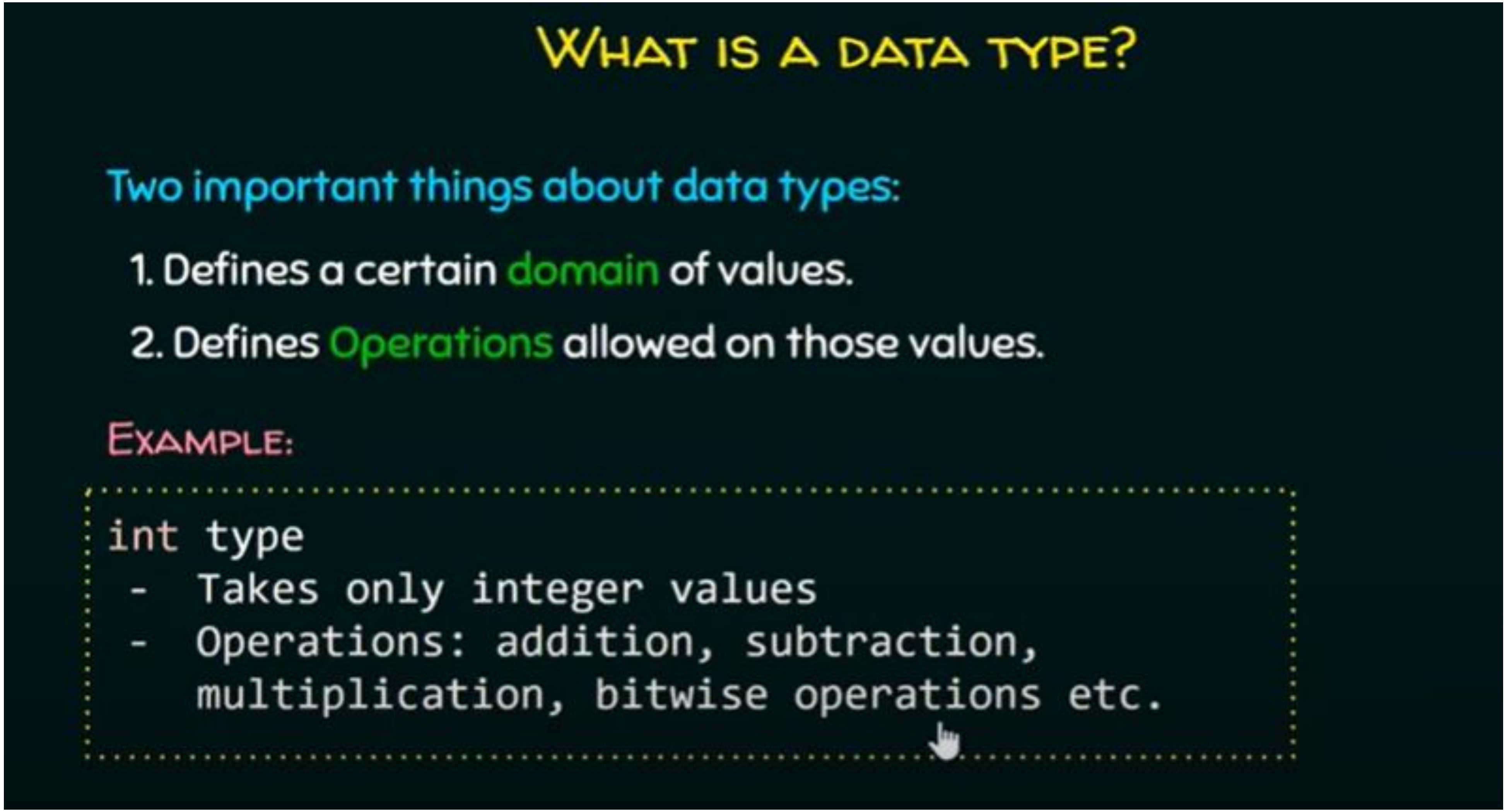


[b] Undirected Graph



Linear Data Structures	Non Linear Data Structures
The data items are arranged in sequential order, one after the other.	The data items are arranged in non-sequential order (hierarchical manner).
All the items are present on the single layer.	The data items are present at different layers.
It can be traversed on a single run. That is, if we start from the first element, we can traverse all the elements sequentially in a single pass.	It requires multiple runs. That is, if we start from the first element it might not be possible to traverse all the elements in a single pass.
The memory utilization is not efficient.	Different structures utilize memory in different efficient ways depending on the need.
The time complexity increase with the data size.	Time complexity remains the same.
Example: Arrays, Stack, Queue	Example: Tree, Graph, Map

What is Data Types:



WHAT IS A DATA TYPE?

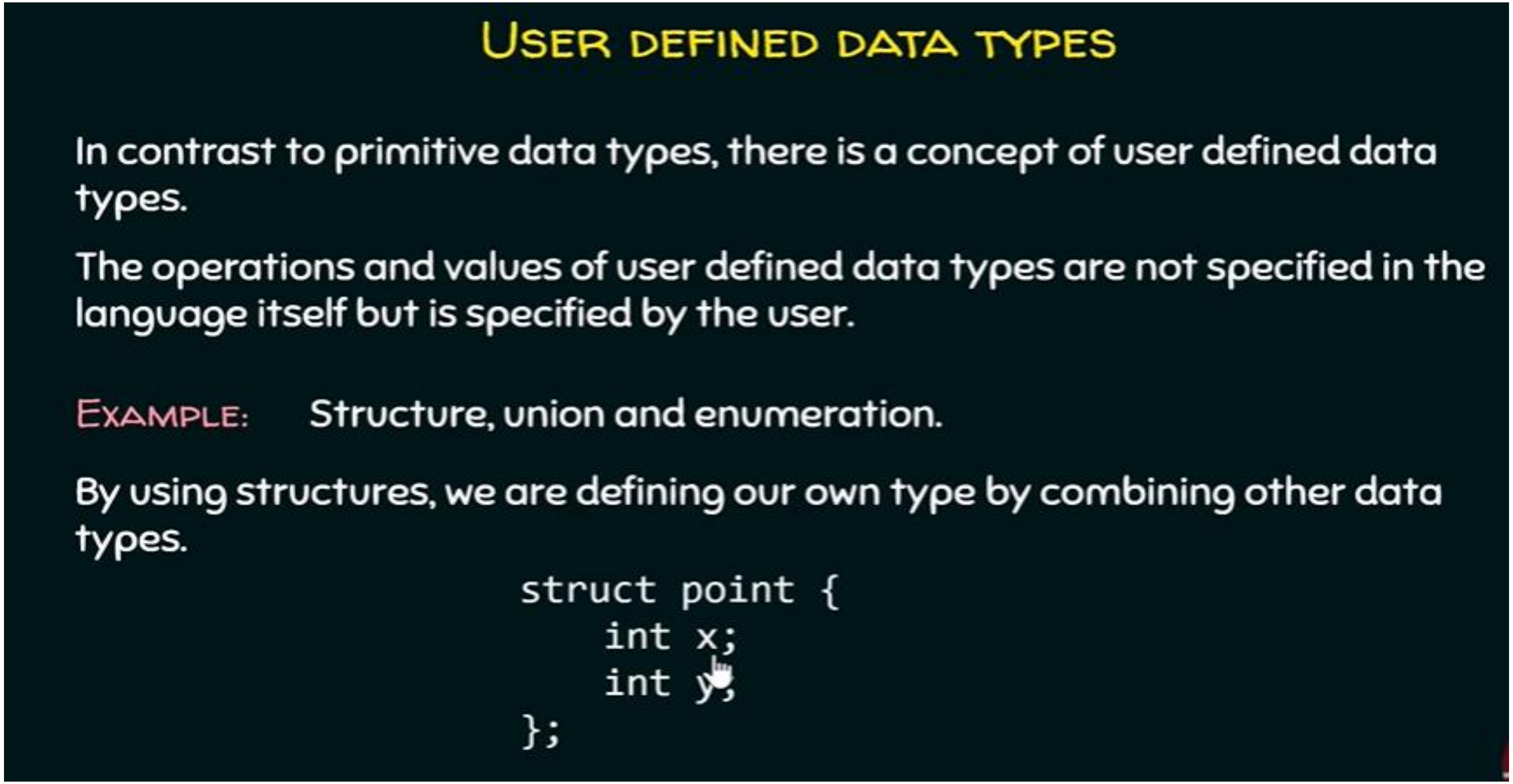
Two important things about data types:

1. Defines a certain domain of values.
2. Defines Operations allowed on those values.

EXAMPLE:

```
int type
 -  Takes only integer values
 -  Operations: addition, subtraction,
    multiplication, bitwise operations etc.
```

User Defined Data Types:



USER DEFINED DATA TYPES

In contrast to primitive data types, there is a concept of user defined data types.

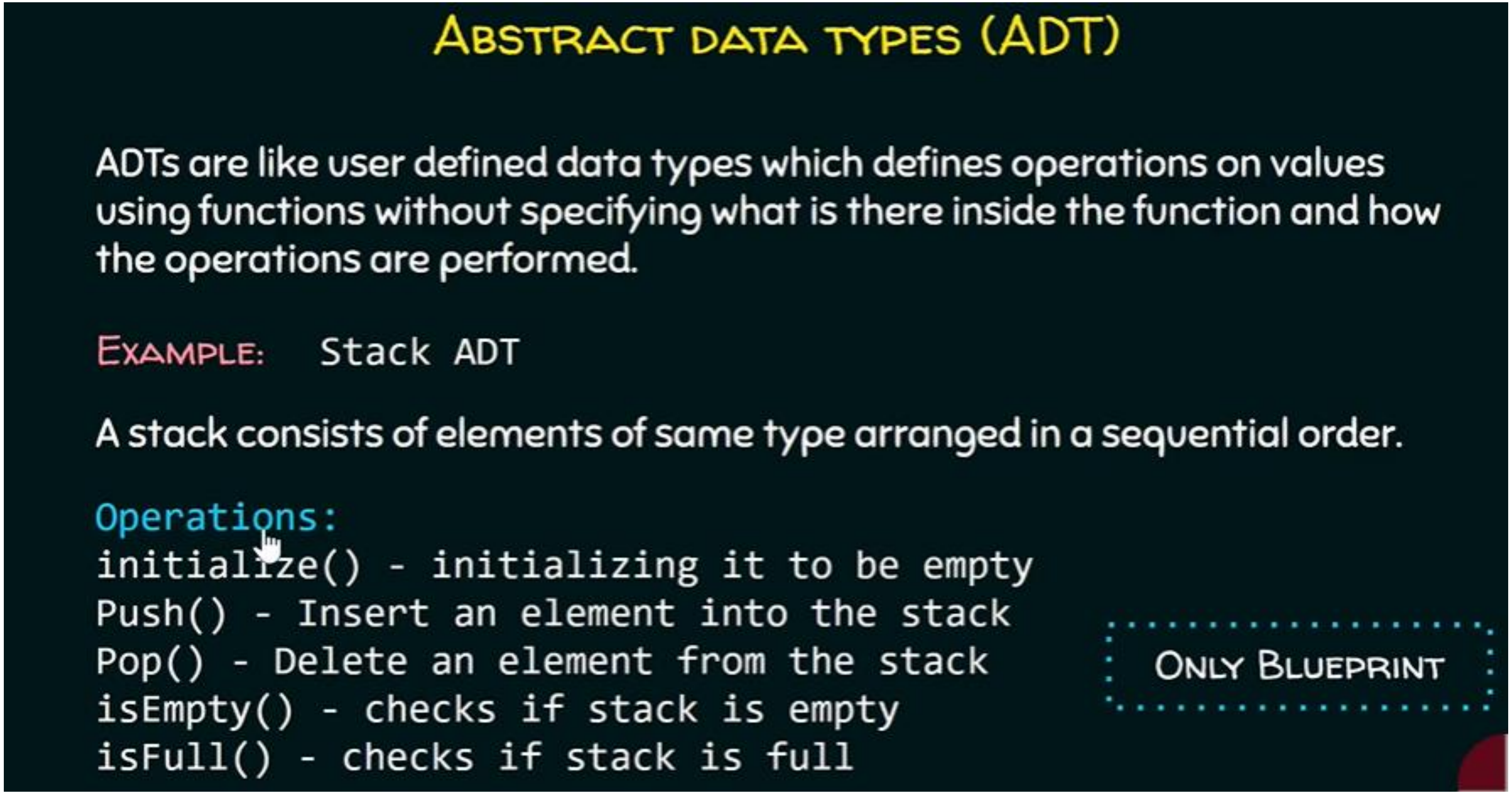
The operations and values of user defined data types are not specified in the language itself but is specified by the user.

EXAMPLE: Structure, union and enumeration.

By using structures, we are defining our own type by combining other data types.

```
struct point {
    int x;
    int y;
};
```

Abstract Data Types



ABSTRACT DATA TYPES (ADT)

ADTs are like user defined data types which defines operations on values using functions without specifying what is there inside the function and how the operations are performed.

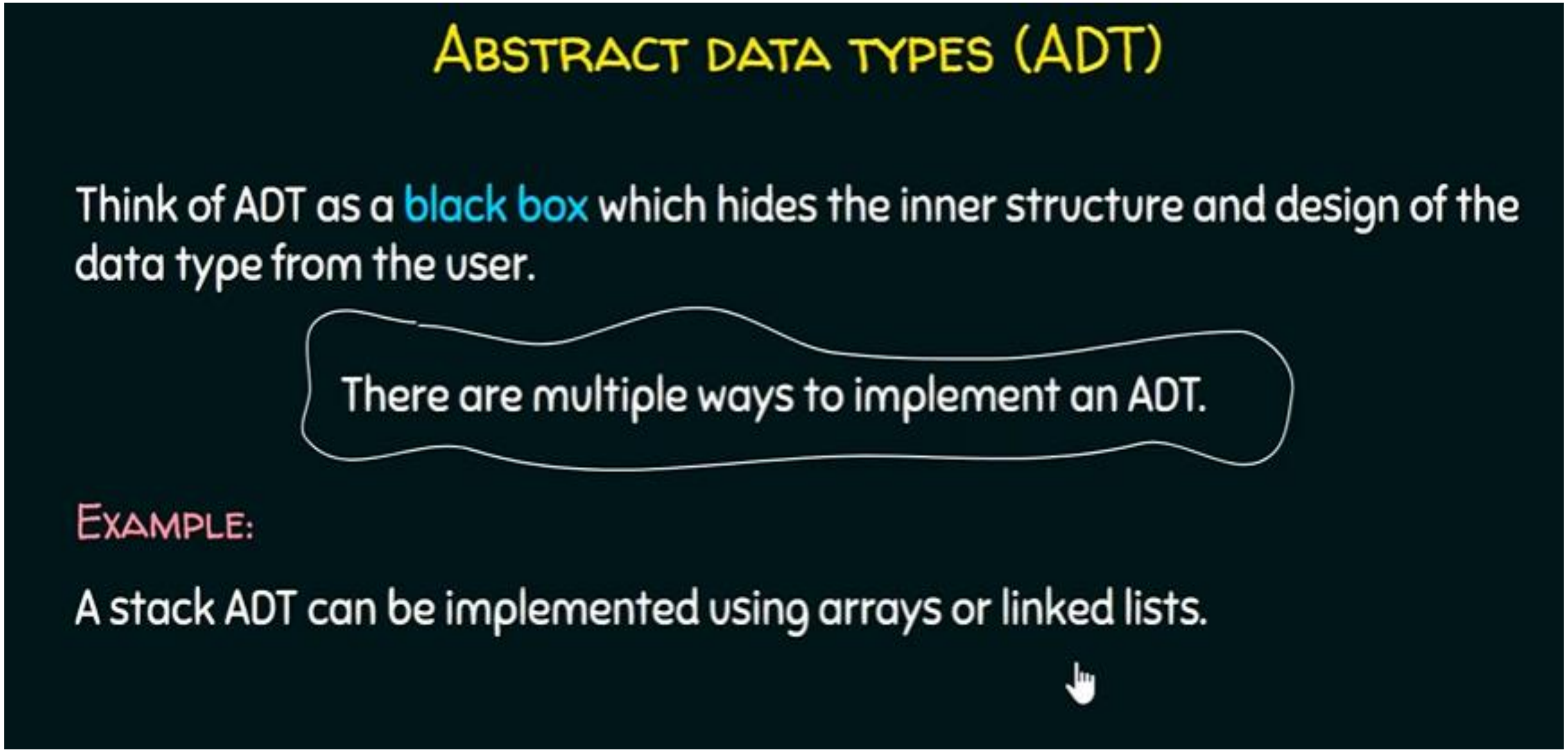
EXAMPLE: Stack ADT

A stack consists of elements of same type arranged in a sequential order.

```
Operations:
initialize() - initializing it to be empty
Push() - Insert an element into the stack
Pop() - Delete an element from the stack
isEmpty() - checks if stack is empty
isFull() - checks if stack is full
```

ONLY BLUEPRINT

Abstract Data Types



Abstract data types (ADT)

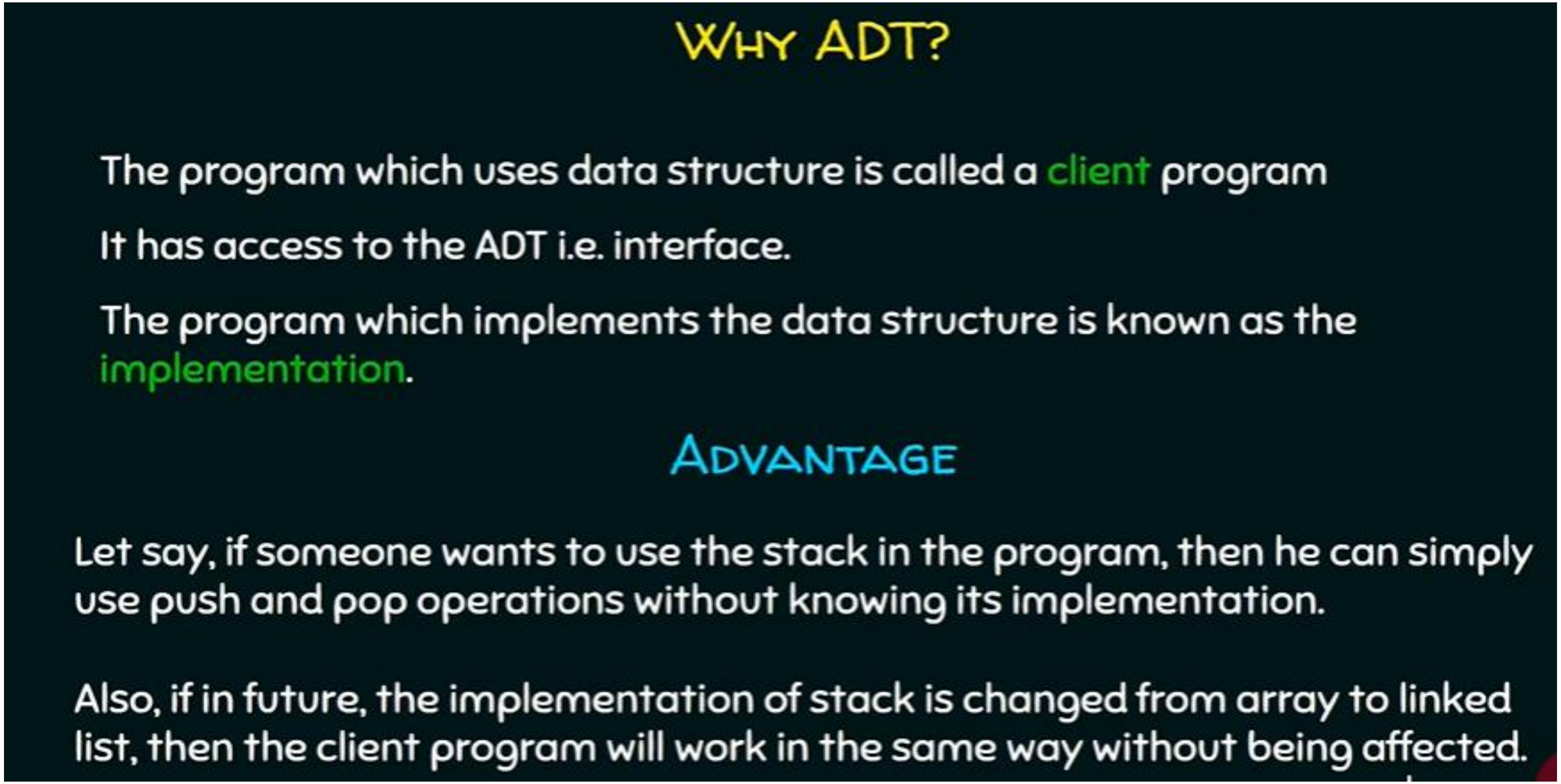
Think of ADT as a black box which hides the inner structure and design of the data type from the user.

There are multiple ways to implement an ADT.

Example:

A stack ADT can be implemented using arrays or linked lists.

Why ADT



Why ADT?

The program which uses data structure is called a client program

It has access to the ADT i.e. interface.

The program which implements the data structure is known as the implementation.

Advantage

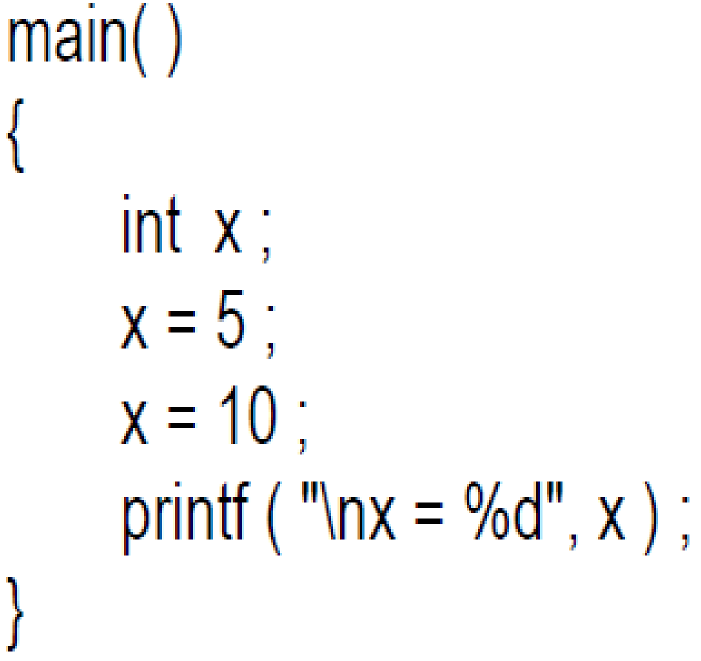
Let say, if someone wants to use the stack in the program, then he can simply use push and pop operations without knowing its implementation.

Also, if in future, the implementation of stack is changed from array to linked list, then the client program will work in the same way without being affected.

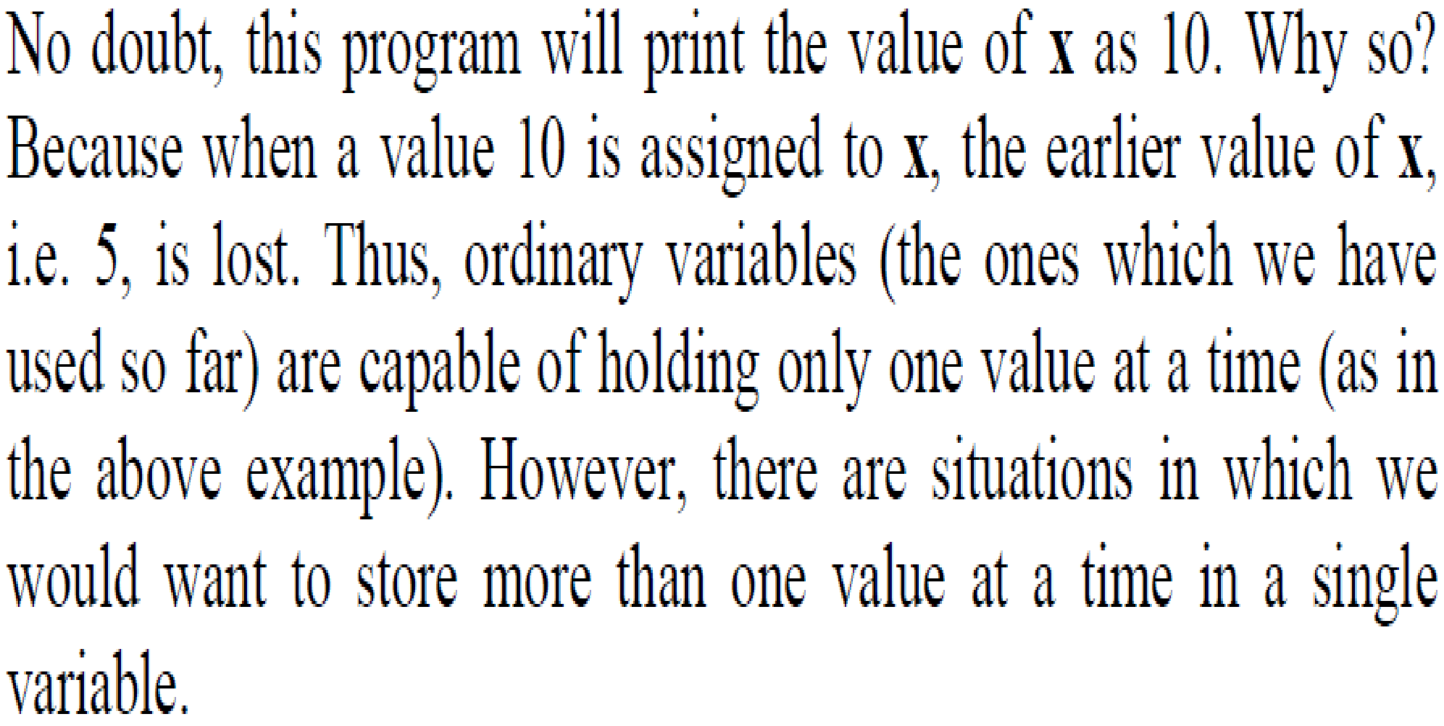
Arrays

Why we need Array?

- What will be output of the following program??



```
main( )
{
      int  x ;
      x = 5 ;
      x = 10 ;
      printf ( "\nx = %d", x ) ;
}
```



No doubt, this program will print the value of **x** as 10. Why so? Because when a value 10 is assigned to **x**, the earlier value of **x**, i.e. 5, is lost. Thus, ordinary variables (the ones which we have used so far) are capable of holding only one value at a time (as in the above example). However, there are situations in which we would want to store more than one value at a time in a single variable.

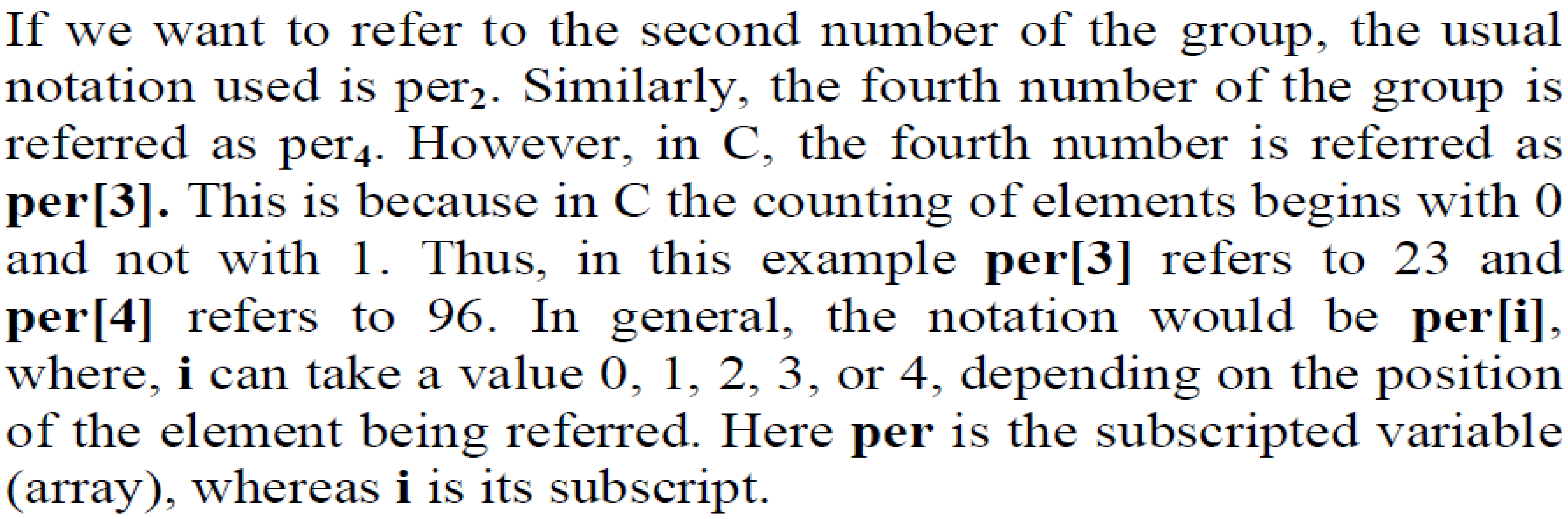
- For example, suppose we wish to arrange the percentage marks obtained by 100 students in ascending order. In such a case we have two options to store these marks in memory:
  - Construct 100 variables to store percentage marks obtained by 100 different students, i.e. each variable containing one student’s marks.
  - Construct one variable (called array or subscripted variable) capable of storing or holding all the hundred values.
- Which is the Best Option??
- Obviously, the second alternative is better. A simple reason for this is, it would be much easier to handle one variable than handling 100 different variables.

Arrays - Introduction

- An array is a collection of similar type of elements that have a contiguous memory location.
- An array is a group of contiguous or related data items that share a common name.
- An array is a collective name given to a group of ‘similar quantities’. These similar quantities could be percentage marks of 100 students, or salaries of 300 employees, or ages of 50 employees.
- Used when programs have to handle large amount of data.
- Each value is stored at a specific position.
- Position is called a index or subscript. Base index = 0

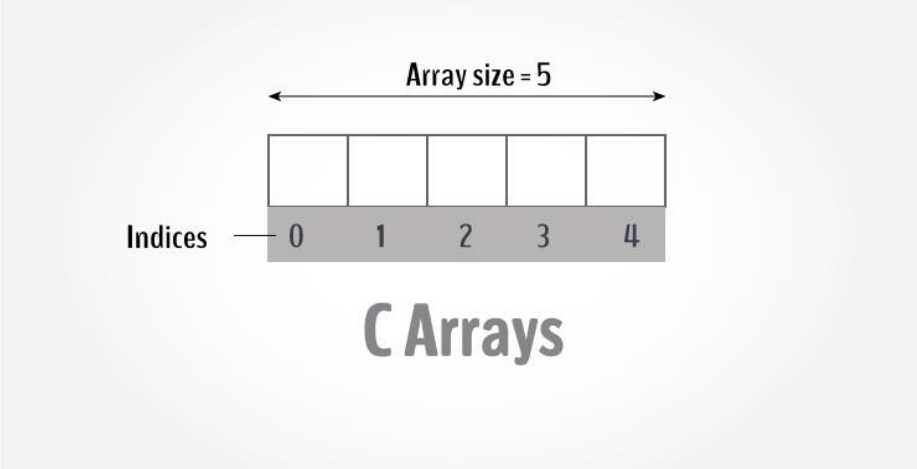
- For example, assume the following group of numbers, which represent percentage marks obtained by five students.

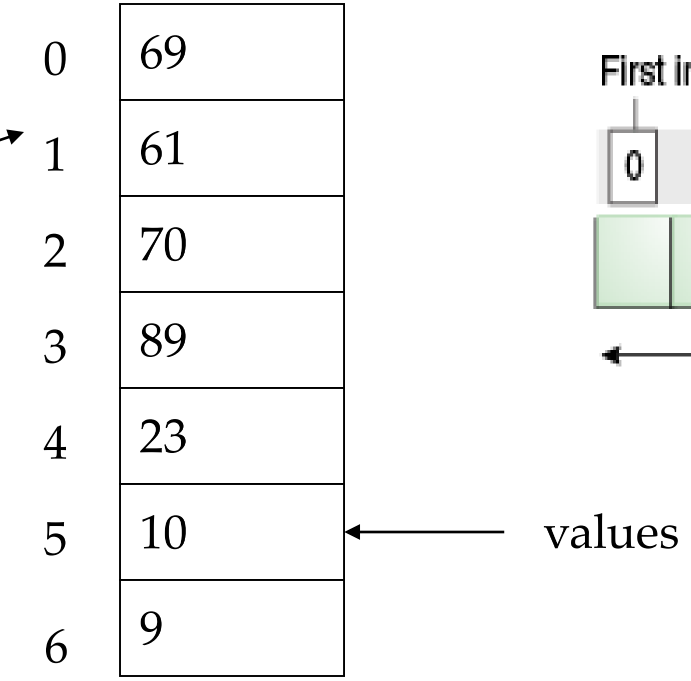
per = { 48, 88, 34, 23, 96 }



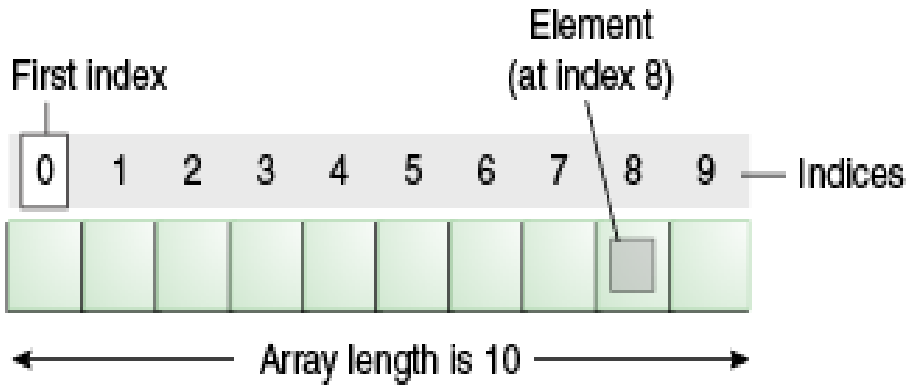
If we want to refer to the second number of the group, the usual notation used is per_2. Similarly, the fourth number of the group is referred as per_4. However, in C, the fourth number is referred as **per[3].** This is because in C the counting of elements begins with 0 and not with 1. Thus, in this example **per[3]** refers to 23 and **per[4]** refers to 96. In general, the notation would be **per[i]**, where, **i** can take a value 0, 1, 2, 3, or 4, depending on the position of the element being referred. Here **per** is the subscripted variable (array), whereas **i** is its subscript.

Arrays - Introduction





0	69
1	61
2	70
3	89
4	23
5	10
6	9



Note: Any given array must be of the same type. i.e. we cannot have an array of 10 numbers, of which 5 are **ints** and 5 are **floats**.

How to declare an Array?

- An array needs to be declared so that the compiler will know what kind of an array and how large an array we want.

- The syntax for array declaration is:

  dataType arrayName[arraySize];

- An array is a variable that can store multiple values. For example, if you want to store 100 integers, you can create an array for it.

  int data[100];

- we declared an array, mark, of floating-point type. And its size is 5.

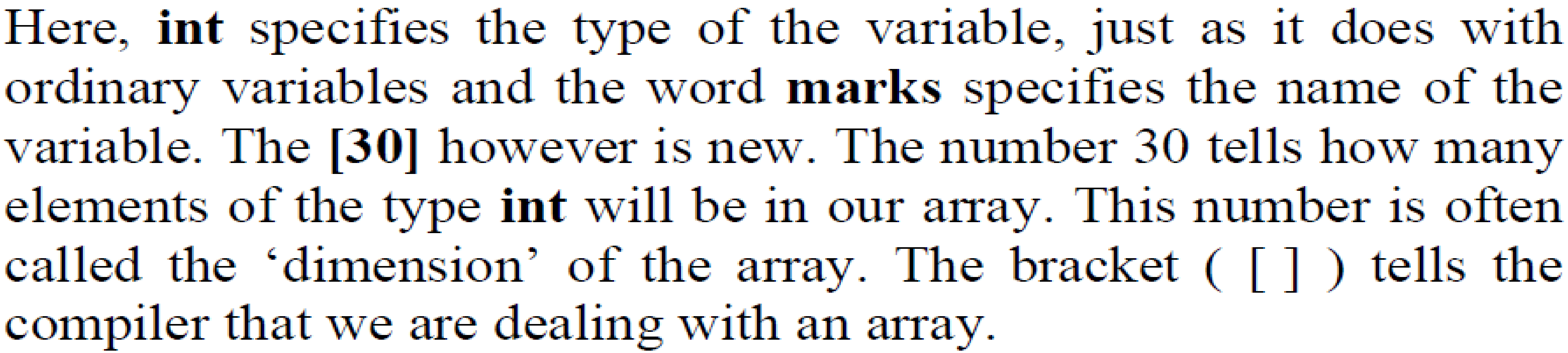
  float mark[5];

- **Note: the size and type of an array cannot be changed once it is declared.**

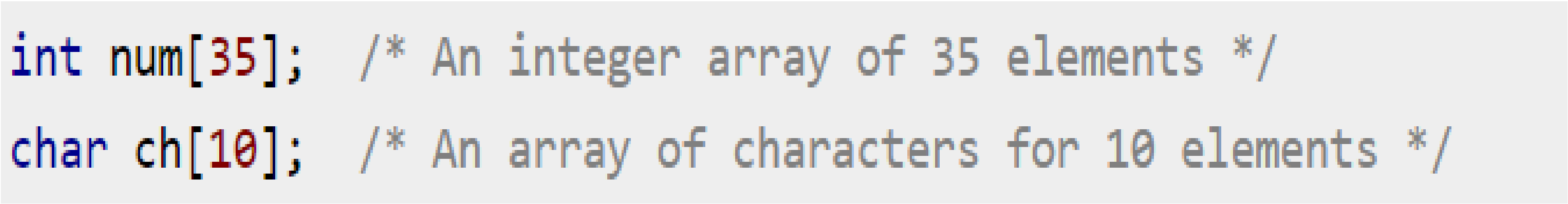
How to declare an Array?

- For Example

int marks[30] ;



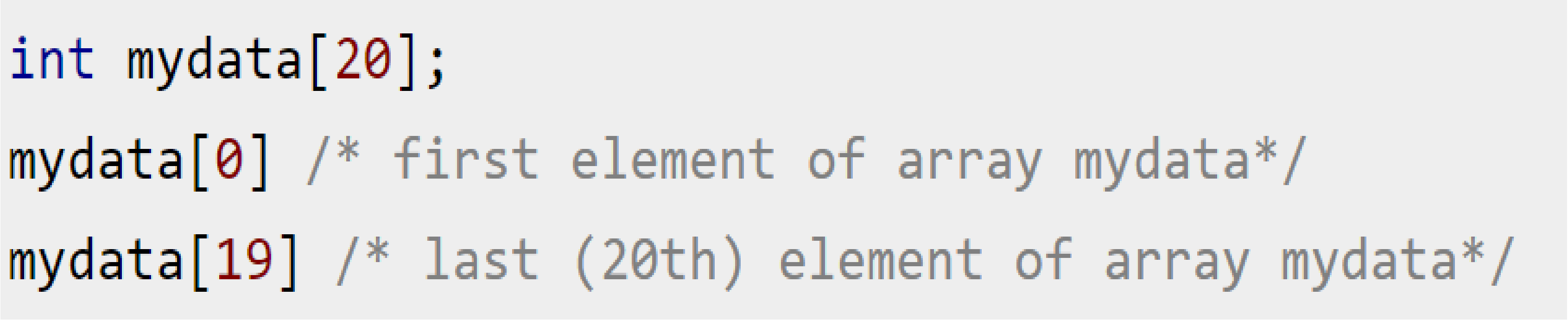
Here, **int** specifies the type of the variable, just as it does with ordinary variables and the word **marks** specifies the name of the variable. The **[30]** however is new. The number 30 tells how many elements of the type **int** will be in our array. This number is often called the 'dimension' of the array. The bracket ([ ]) tells the compiler that we are dealing with an array.



```
int num[35];  /* An integer array of 35 elements */
char ch[10];  /* An array of characters for 10 elements */
```

Accessing Array Elements:

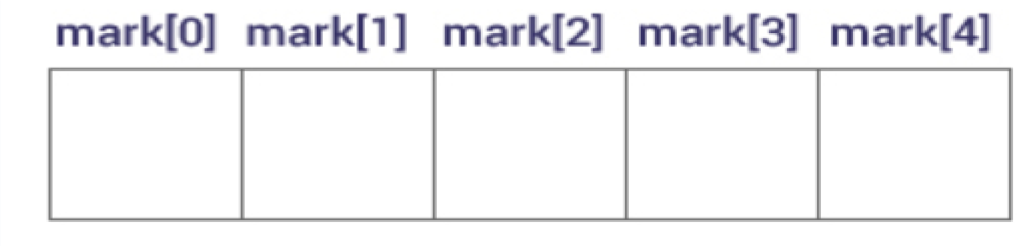
- An array subscript (or index) can be used to access any element stored in a array. Subscript starts with 0, which means **arr[0]** represents the first element in the array arr.
- In general **arr[n-1]** can be used to access **nth** element of an array. where n is any integer number.
- For example: We have declare integer array mydata with 20 elements in it as follow:



```
int mydata[20];
mydata[0] /* first element of array mydata*/
mydata[19] /* last (20th) element of array mydata*/
```

Accessing Array Elements:

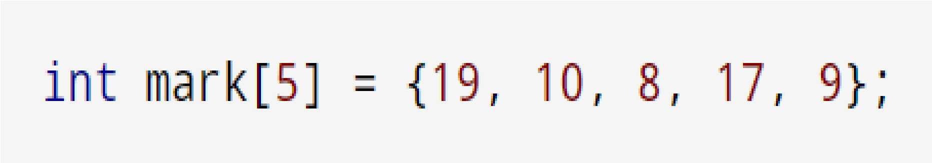
- Suppose you declared an array **mark**. The first element is **mark[0]**, the second element is **mark[1]** and so on.



- Arrays have 0 as the first index, not 1. In this example, **mark[0]** is the first element.
- If the **size** of an array is **n**, to access the last element, the **n-1 index** is used. In this example, **mark[4].**

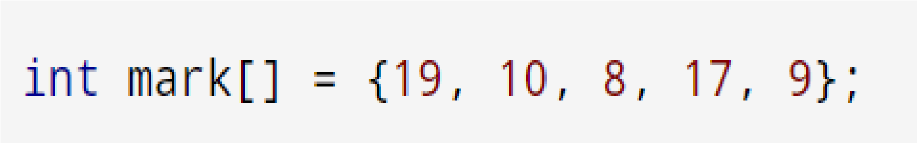
Initialization of an Array:

- We can initialize the array during declaration as follow:



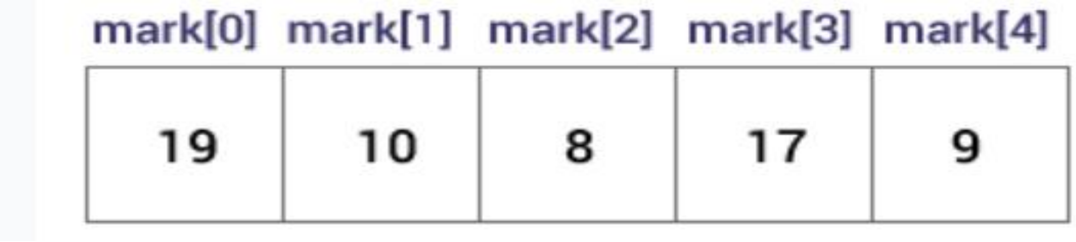
```
int mark[5] = {19, 10, 8, 17, 9};
```

- We can also initialize an array as follow:



```
int mark[] = {19, 10, 8, 17, 9};
```

- Here, the size of an array is not specified. However, the compiler knows its size is 5 as we are initializing it with 5 elements.



mark[0]	mark[1]	mark[2]	mark[3]	mark[4]
19	10	8	17	9

Initialization of one-d array…

Compile time initialization:

```
type array-name[size] = {list of values};
```

```
int number[3]={0,0,0};
```

- **Declare number as an array of size 3 and initialize each element to 0**

```
float total[5]={0.0,15.3,6.2};
```

- **Declare total as an array of size 5 and initialize first three elements to 0.0, 15.3 and 6.2 and remaining elements to 0.0**

```
int number[]={0,0,0};
```

- **Declare number as an array of size 3 and initialize each element to 0**

Initialization of one-d array…

```
char name[6]={‘h’,’e’,’l’,’l’,’o’,’\0’};
```

- **Declare name as a character array of size 6 and initialize it to “hello”.**
- **Same as,**

```
char name[6]=“hello”;
```

- **The following is illegal in C**

```
int x[2]={1,2,3,4};
```

More elements than array size !!!

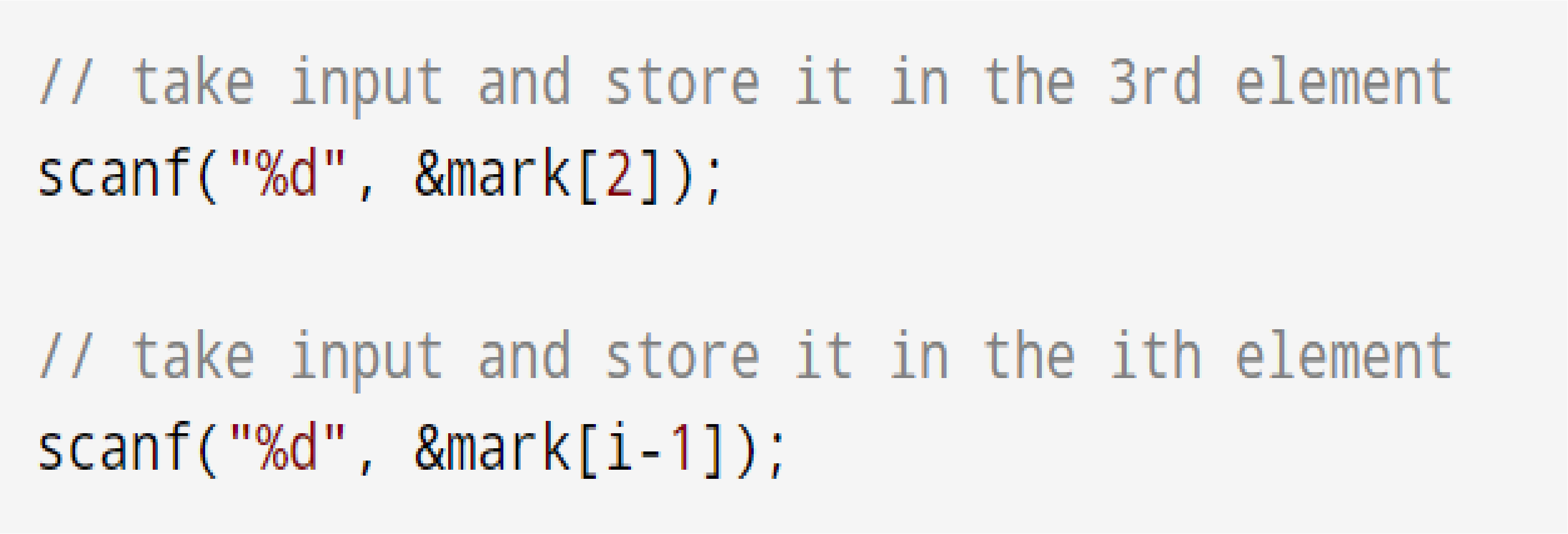
Initialization of one-d array…

- Run time initialization

```
int x[10];              // Declaration of array
for(i=0;i<10;i++)
{
    printf(“Enter a number\n”);
    scanf(“%d”,&x[i]);   // Initialization of array elements
}
```

Input Array Elements:

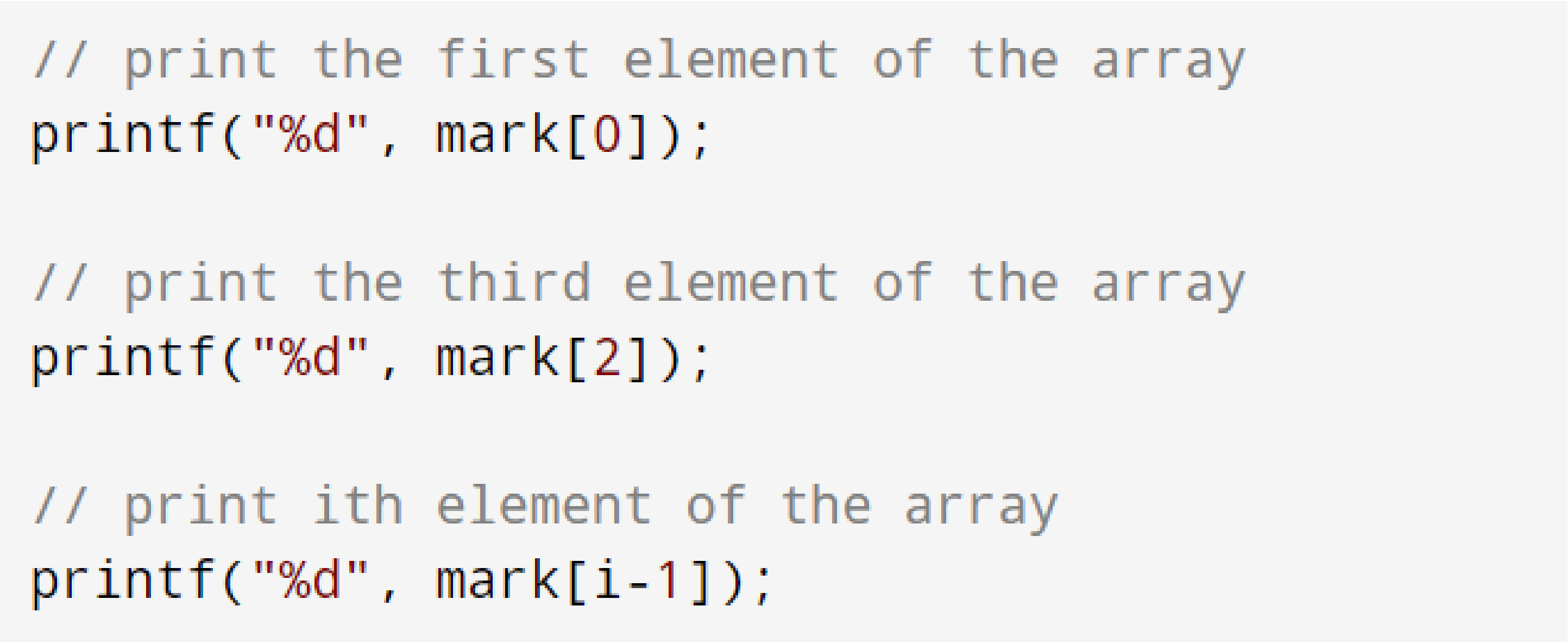
- We can take input from the user and store it in an array element as follow:



```
// take input and store it in the 3rd element
scanf("%d", &mark[2]);

// take input and store it in the ith element
scanf("%d", &mark[i-1]);
```

Output Array Elements:

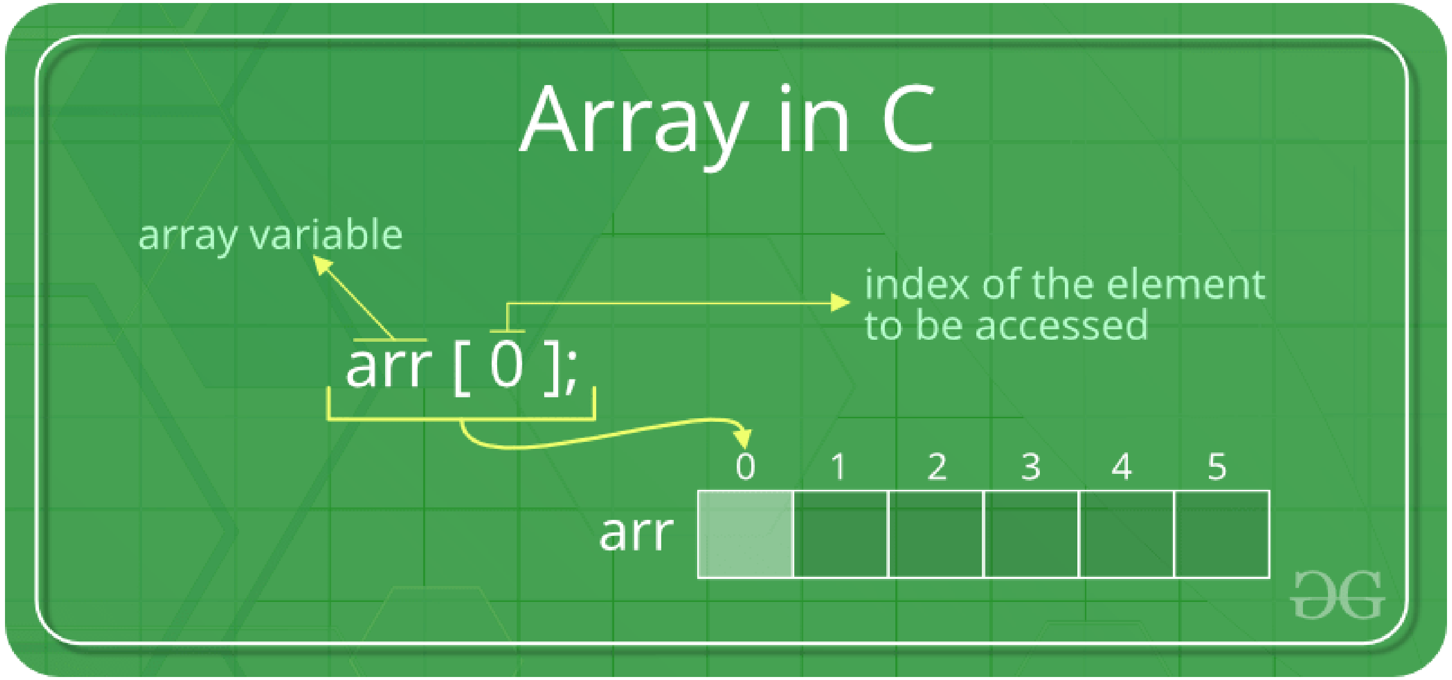
- We can print an individual element of an array as follow:



```c
// print the first element of the array
printf("%d", mark[0]);

// print the third element of the array
printf("%d", mark[2]);

// print ith element of the array
printf("%d", mark[i-1]);
```

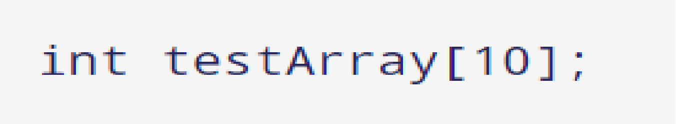
Accessing Array Elements:

- Array elements are accessed by using an integer index. Array index starts with 0 and goes till size of array minus 1.



Access elements out of its bound!

- Suppose you declared an array of 10 elements. Let's say,

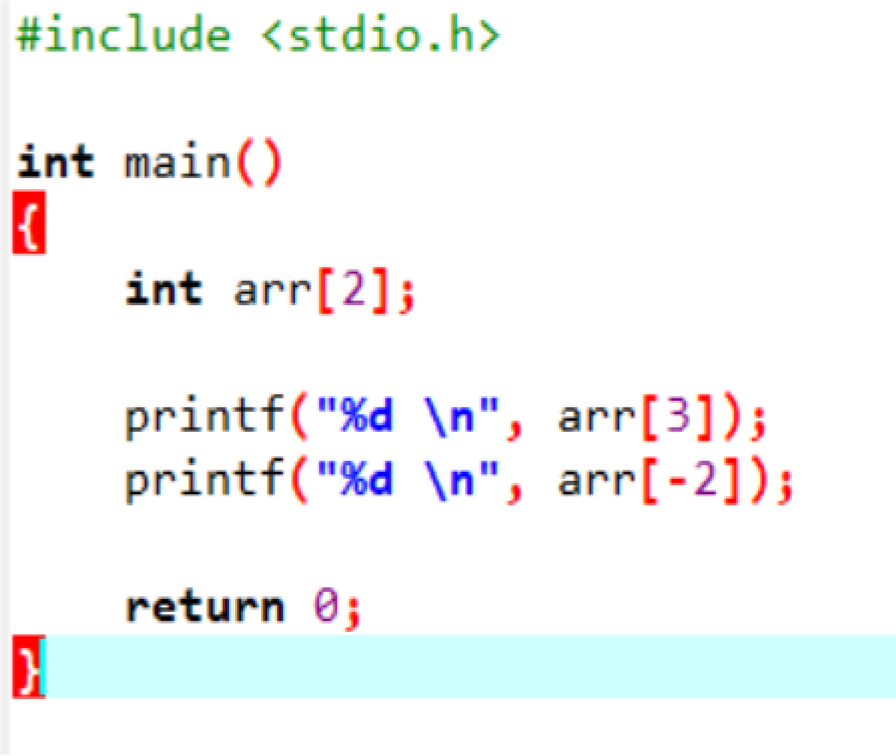


```
int testArray[10];
```

- We can access the array elements from **testArray[0]** to **testArray[9].**
- Now let's say if you try to access **testArray[12].**
- **The element is not available. This may cause unexpected output (undefined behavior). Sometimes you might get an error and some other time your program may run correctly.**
- Hence, we should never access elements of an array outside of its bound.

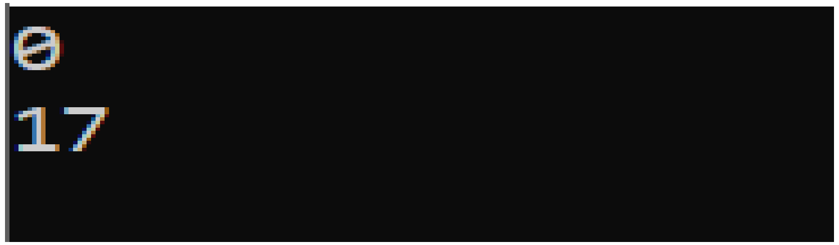
Access elements out of its bound!

What will be the output of the following Program??



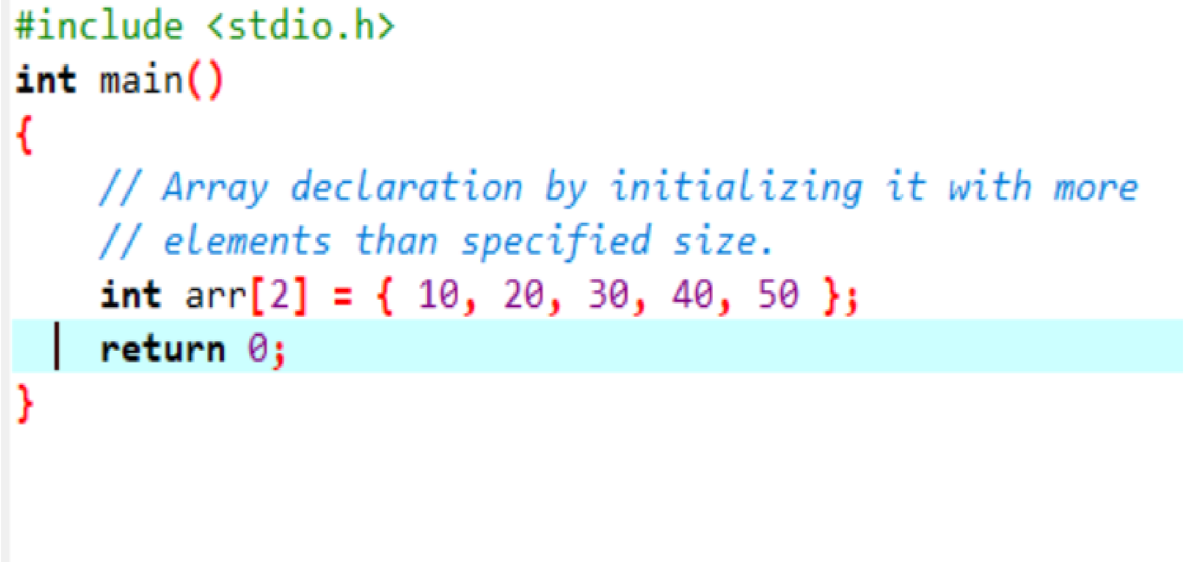
```
#include <stdio.h>

int main()
{
    int arr[2];

    printf("%d \n", arr[3]);
    printf("%d \n", arr[-2]);

    return 0;
}
```

In this program, we are trying to access the out of bound values of an array as we have define array size is 2 and trying to access values at index 3 and -2 respectively. So, compiler will print some unexpected value as output as shown in output window.



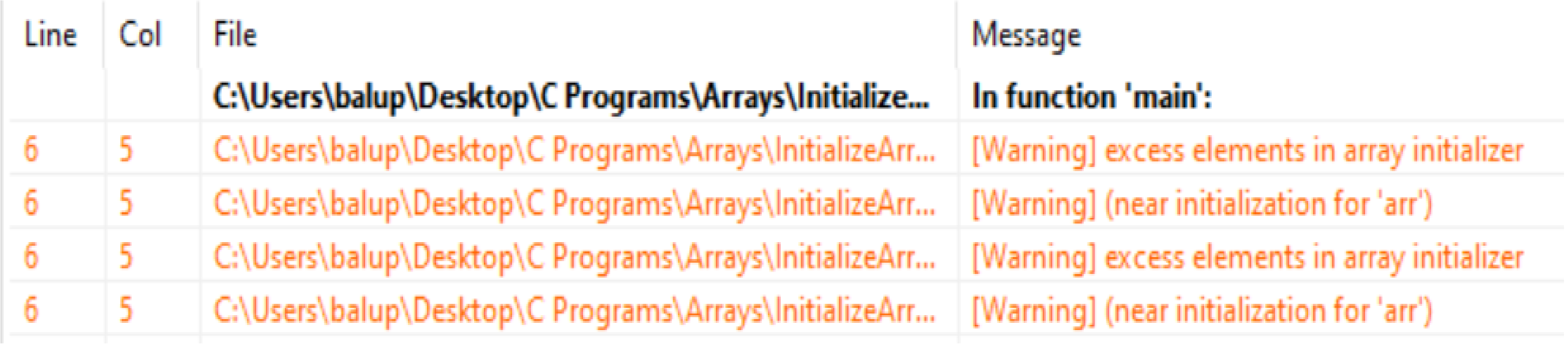
```
0
17
```

Access elements out of its bound!



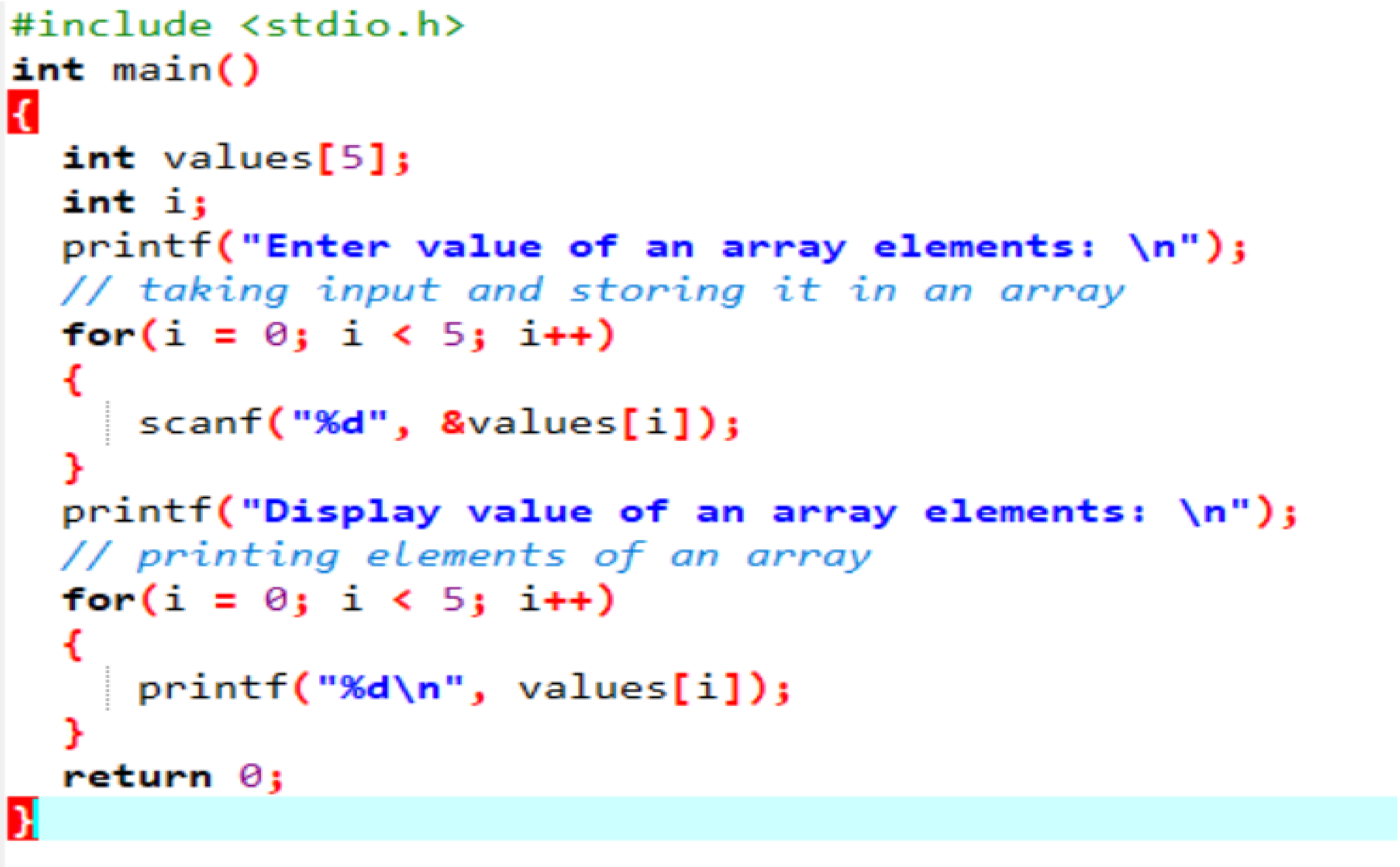
```c
#include <stdio.h>
int main()
{
    // Array declaration by initializing it with more
    // elements than specified size.
    int arr[2] = { 10, 20, 30, 40, 50 };
    return 0;
}
```

In C, it is not compiler error to initialize an array with more elements than the specified size. For example, the below program compiles fine and shows just Warning.



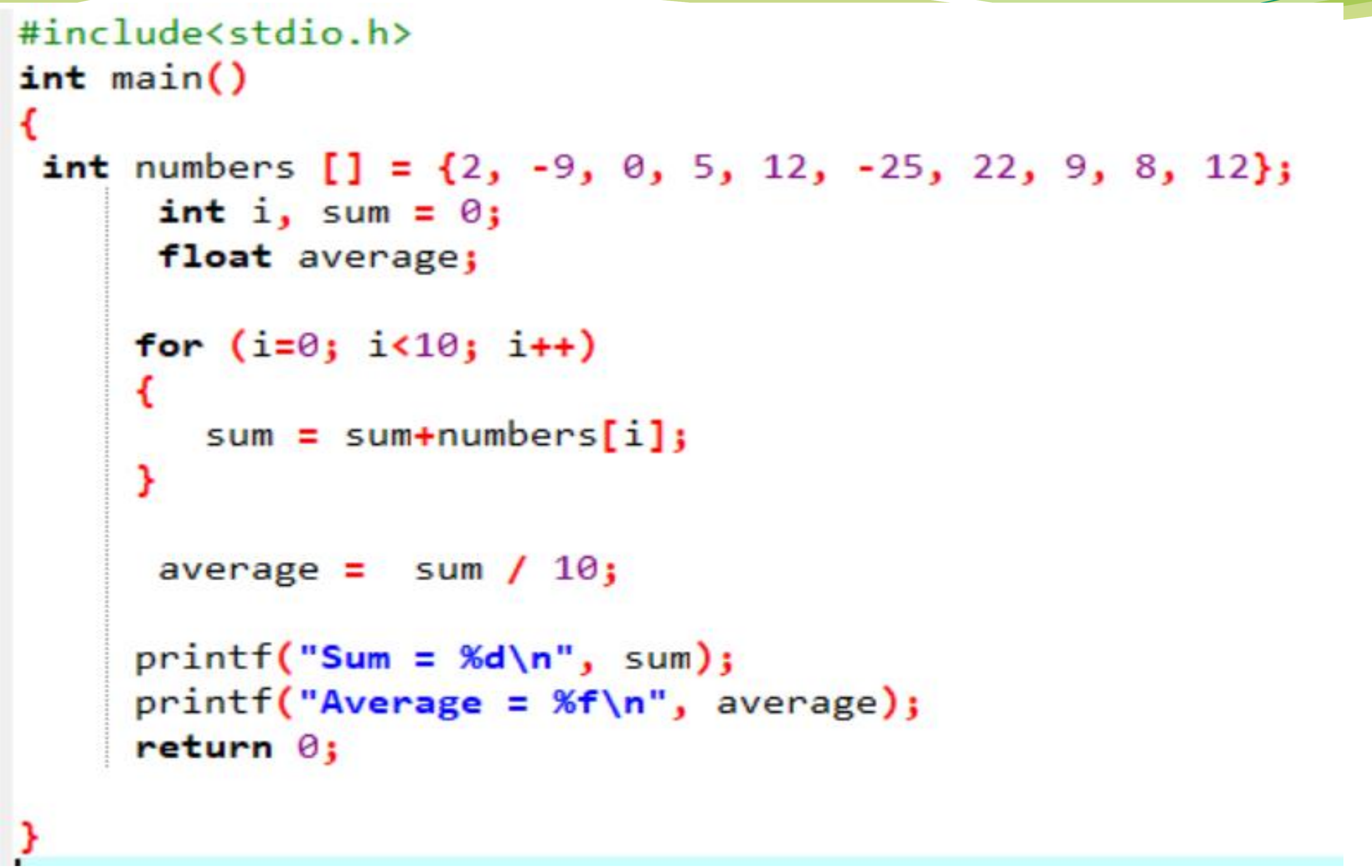
Line	Col	File	Message
		C:\Users\balup\Desktop\C Programs\Arrays\Initialize...	**In function 'main':**
6	5	C:\Users\balup\Desktop\C Programs\Arrays\InitializeArr...	[Warning] excess elements in array initializer
6	5	C:\Users\balup\Desktop\C Programs\Arrays\InitializeArr...	[Warning] (near initialization for 'arr')
6	5	C:\Users\balup\Desktop\C Programs\Arrays\InitializeArr...	[Warning] excess elements in array initializer
6	5	C:\Users\balup\Desktop\C Programs\Arrays\InitializeArr...	[Warning] (near initialization for 'arr')

- **Write a Program to take 5 values from the user and store them in an array and Print the elements stored in the array.**

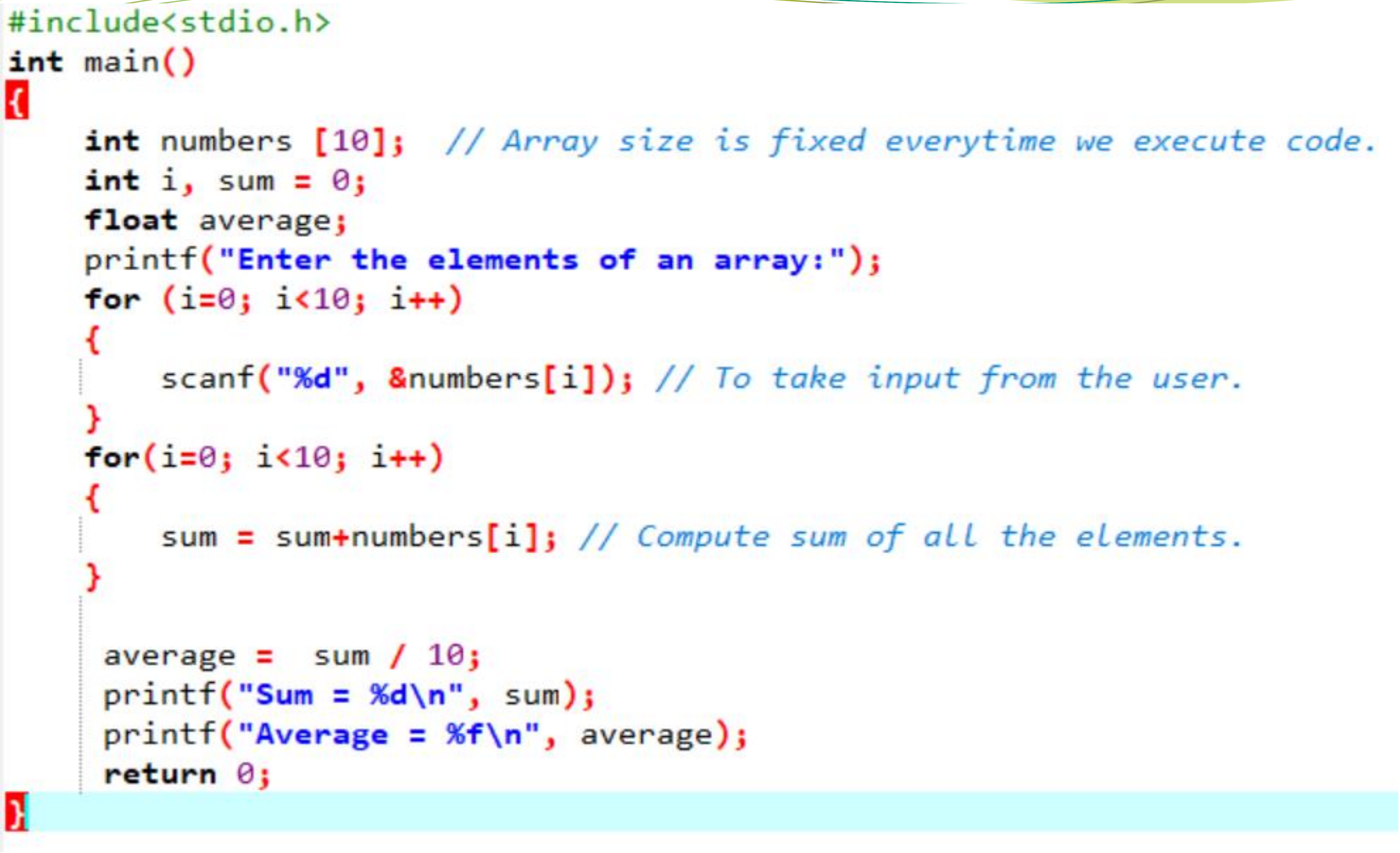


```c
#include <stdio.h>
int main()
{
   int values[5];
   int i;
   printf("Enter value of an array elements: \n");
   // taking input and storing it in an array
   for(i = 0; i < 5; i++)
   {
      scanf("%d", &values[i]);
   }
   printf("Display value of an array elements: \n");
   // printing elements of an array
   for(i = 0; i < 5; i++)
   {
      printf("%d\n", values[i]);
   }
   return 0;
}
```

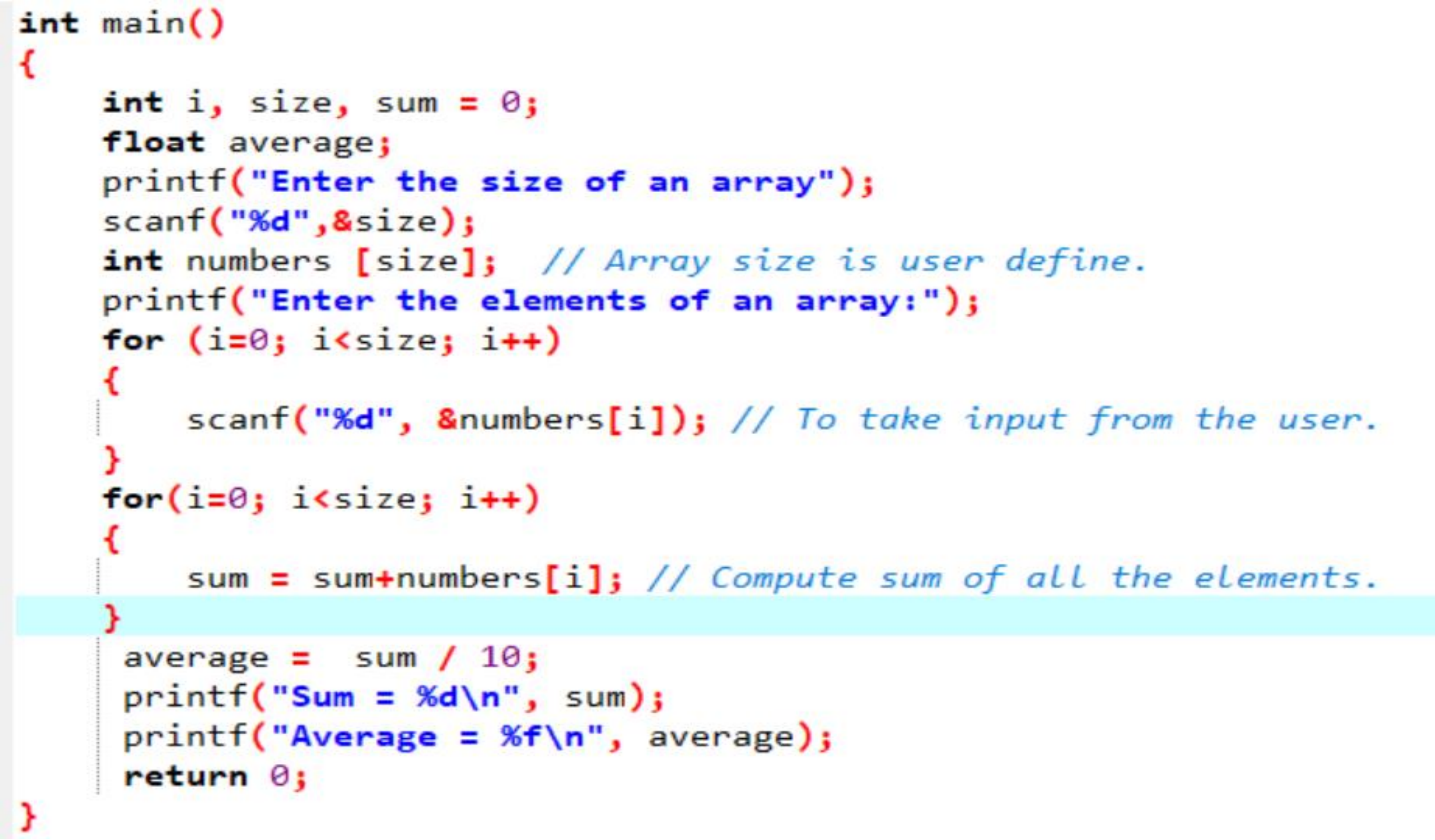
- **Write a program to print sum and average of 10 values stored in an arrays of type integer.**



```
#include<stdio.h>
int main()
{
 int numbers [] = {2, -9, 0, 5, 12, -25, 22, 9, 8, 12};
      int i, sum = 0;
      float average;

     for (i=0; i<10; i++)
     {
        sum = sum+numbers[i];
     }

      average =  sum / 10;

     printf("Sum = %d\n", sum);
     printf("Average = %f\n", average);
     return 0;

}
```



```
#include<stdio.h>
int main()
{
    int numbers [10];  // Array size is fixed everytime we execute code.
    int i, sum = 0;
    float average;
    printf("Enter the elements of an array:");
    for (i=0; i<10; i++)
    {
        scanf("%d", &numbers[i]); // To take input from the user.
    }
    for(i=0; i<10; i++)
    {
        sum = sum+numbers[i]; // Compute sum of all the elements.
    }

     average =  sum / 10;
     printf("Sum = %d\n", sum);
     printf("Average = %f\n", average);
     return 0;
}
```



```c
int main()
{
    int i, size, sum = 0;
    float average;
    printf("Enter the size of an array");
    scanf("%d",&size);
    int numbers [size];  // Array size is user define.
    printf("Enter the elements of an array:");
    for (i=0; i<size; i++)
    {
        scanf("%d", &numbers[i]); // To take input from the user.
    }
    for(i=0; i<size; i++)
    {
        sum = sum+numbers[i]; // Compute sum of all the elements.
    }
     average =  sum / 10;
     printf("Sum = %d\n", sum);
     printf("Average = %f\n", average);
     return 0;
}
```

Summary:

- An array is a collection of similar elements.
- The first index in the array is numbered 0, so the last element is 1 less than the size of the array.
- An array is also known as a subscripted variable.
- Before using an array its type and dimension must be declared.
- However big an array its elements are always stored in contiguous memory locations.