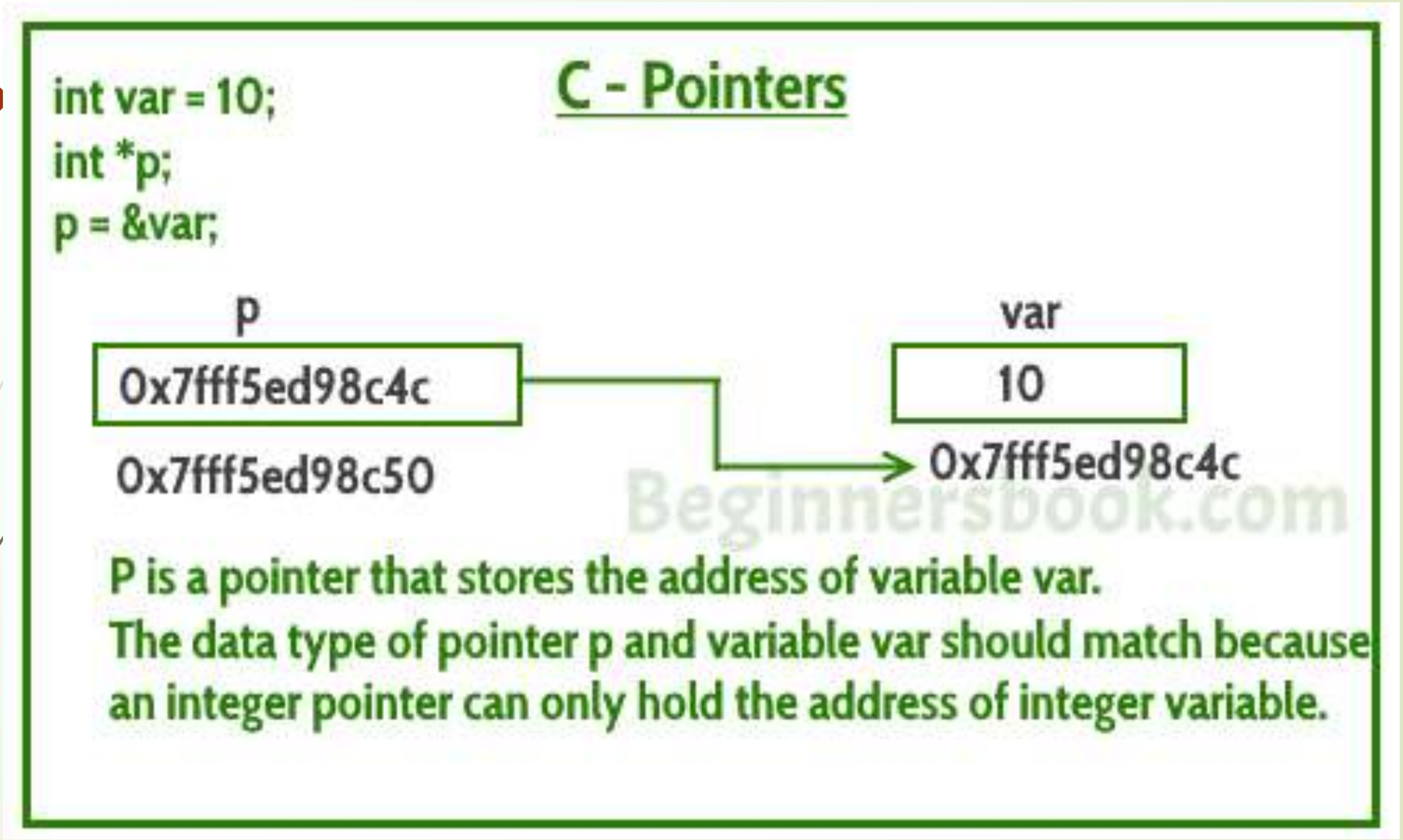
Pointers

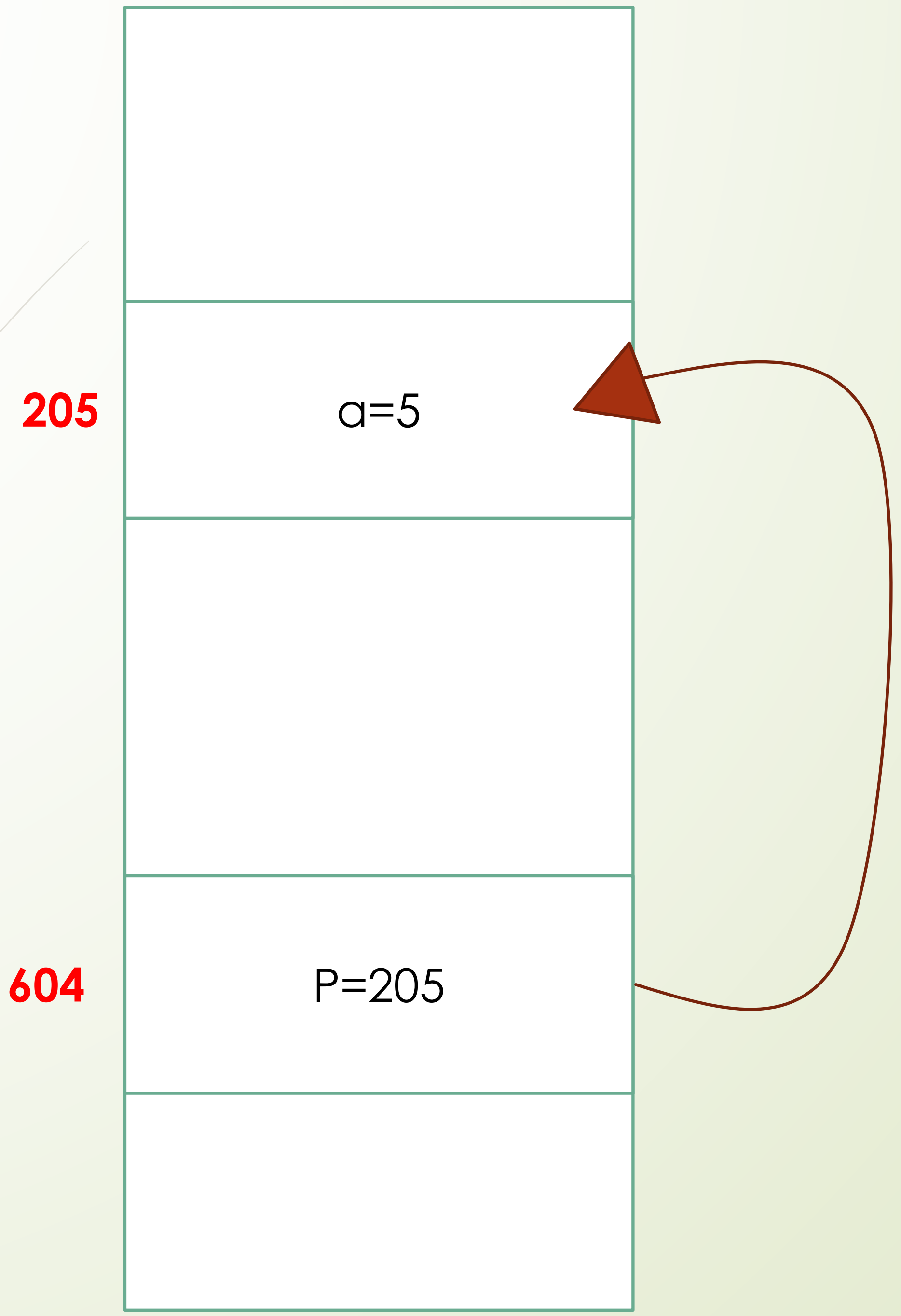
- Pointers are variables that store the address of other variables.
- The pointer variable might be belonging to any of the data type such as int, float, char, double, short etc.
- Normal variable stores the value whereas pointer variable stores the address of the variable.
- If you have a variable **var** in your program, **&var** will give you its address in the memory.
- Pointer Syntax : data_type *var_name; Example : int *p; char *p;
- Where, * is used to denote that “p” is pointer variable and not a normal variable.



C - Pointers

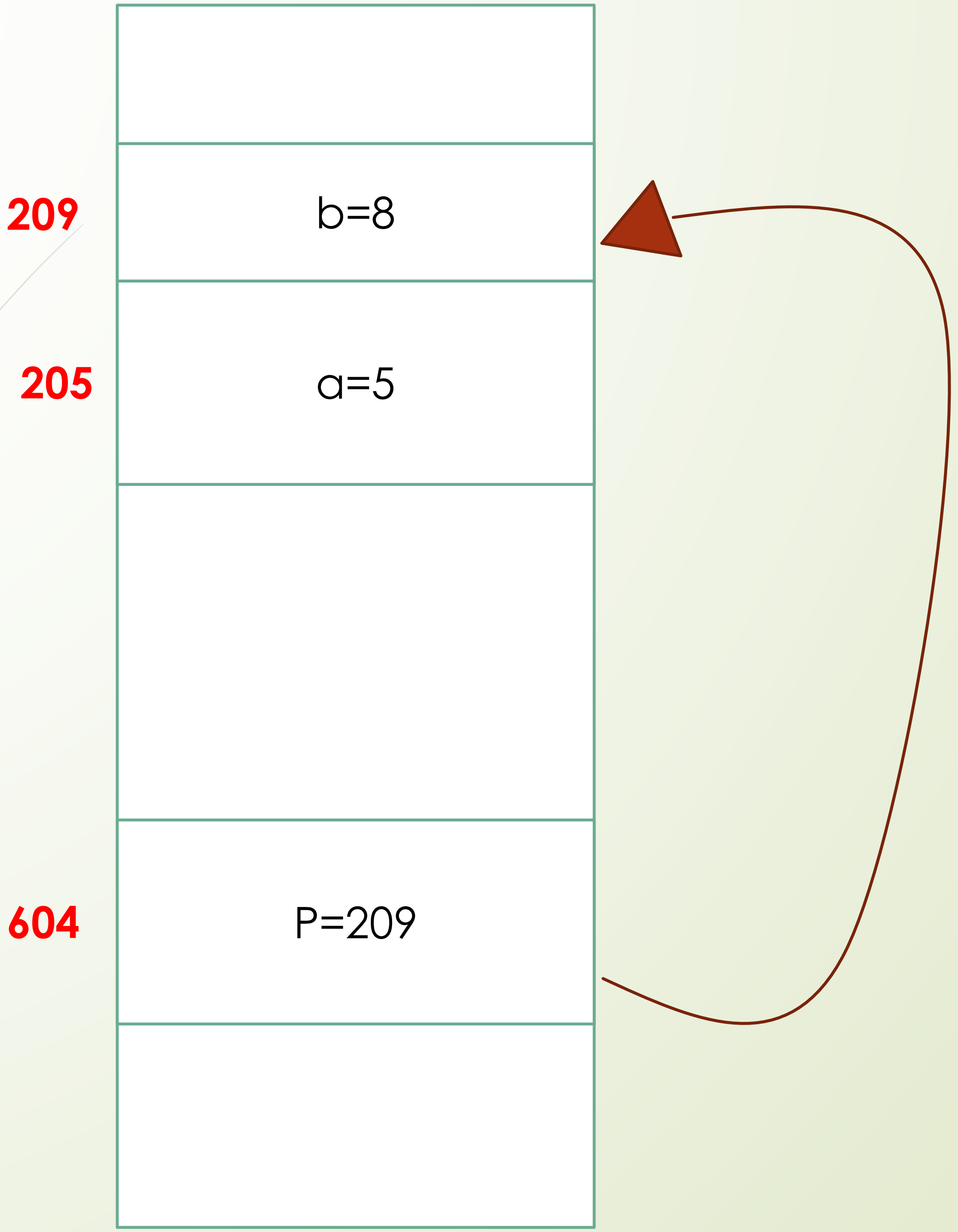
```
int var = 10;
int *p;
p = &var;
```

P is a pointer that stores the address of variable var.
The data type of pointer p and variable var should match because an integer pointer can only hold the address of integer variable.

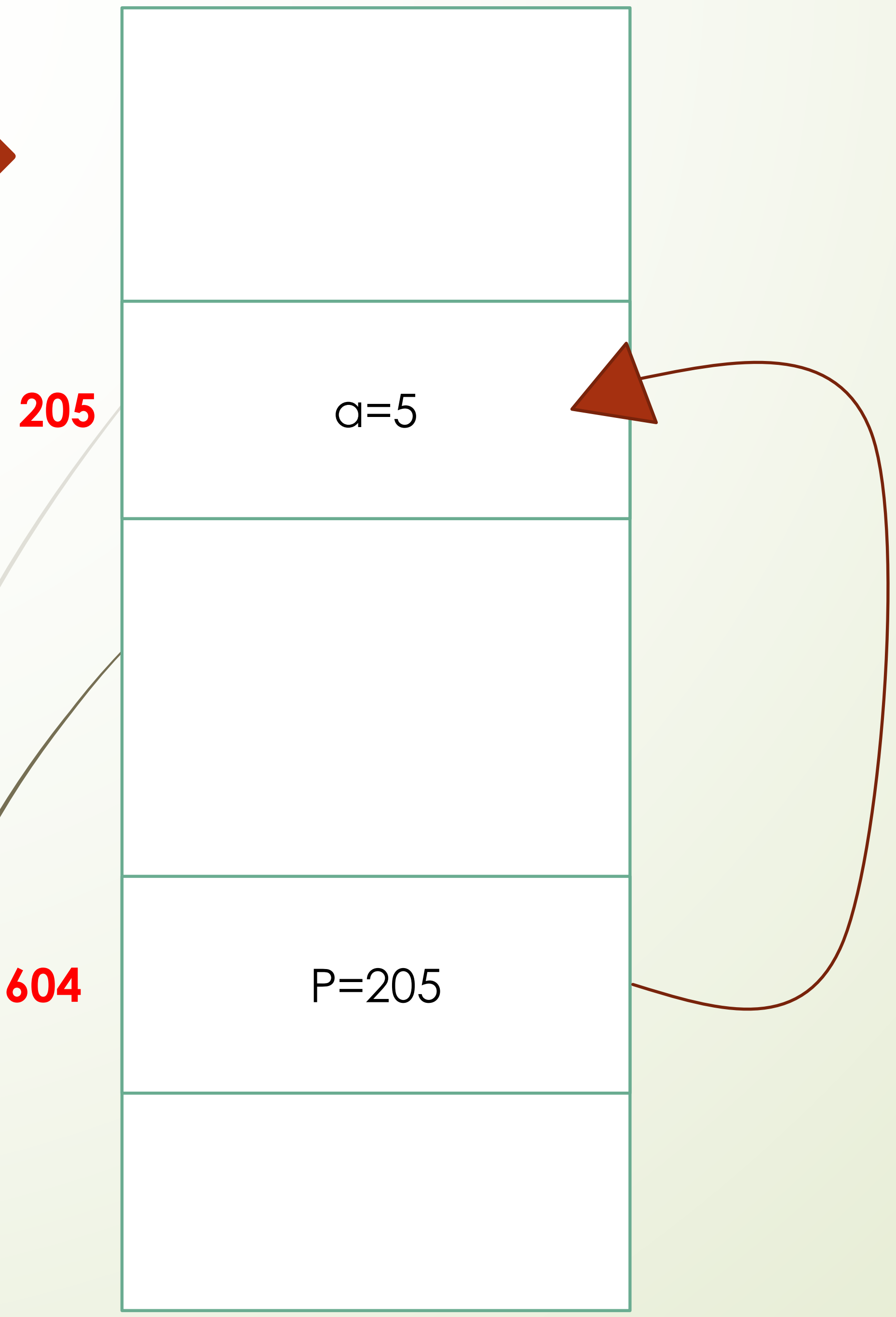


Int a;
Int *p;

P= &a;



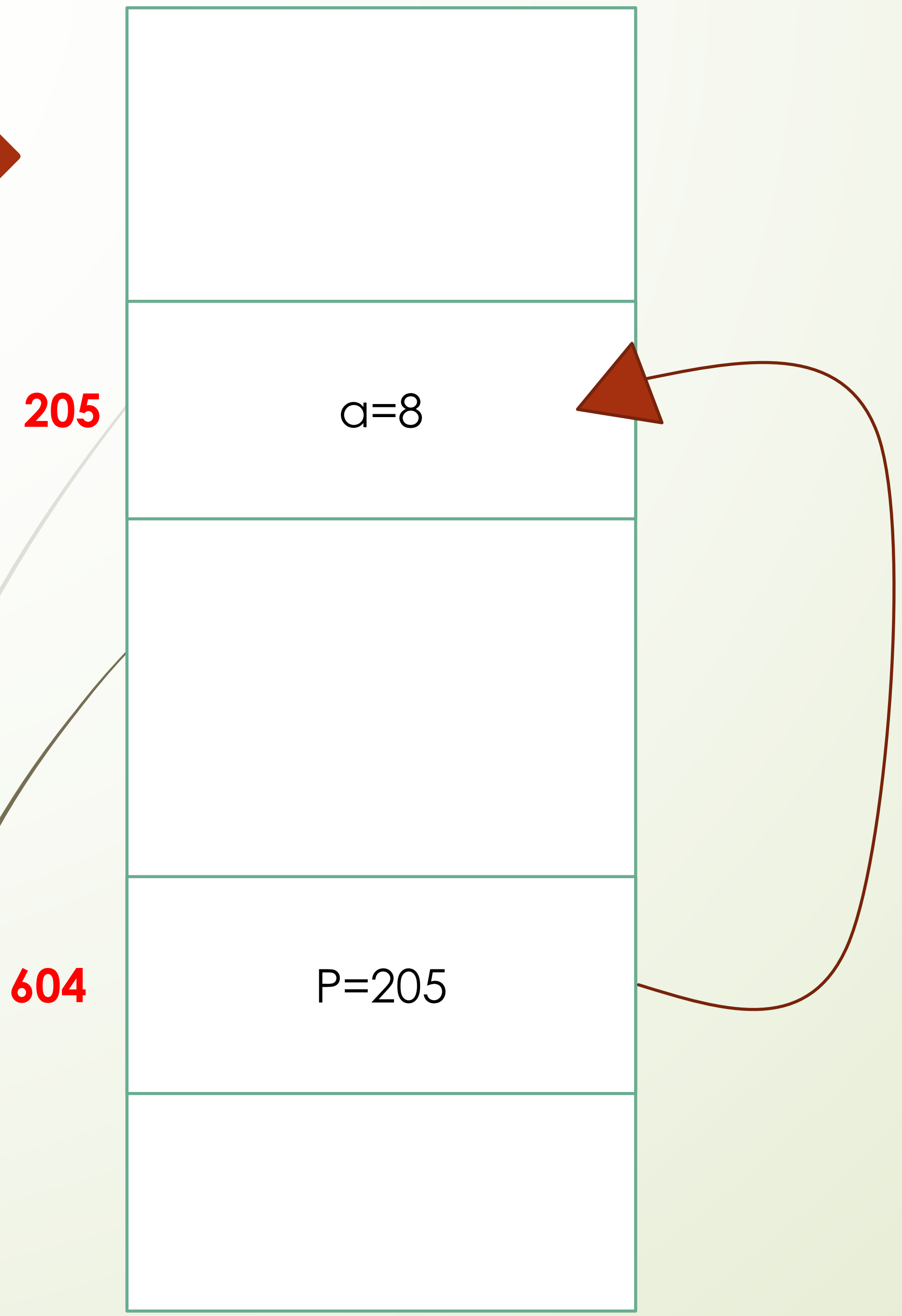
```
Int a;
Int *p;
Int b;
P=&b;
```



Assigning addresses to Pointers

- Int a=5;
- Int *p;
- we give the address to pointer as
  p=&a;
  Here, 5 is assigned to the a variable. And, the address of a is assigned to the p pointer.
- If we want to print p

```
cout<<p;  //205
cout<<&a;  //205
cout<<&p;  //604
cout<<*p;  //5     Derefrencing
```



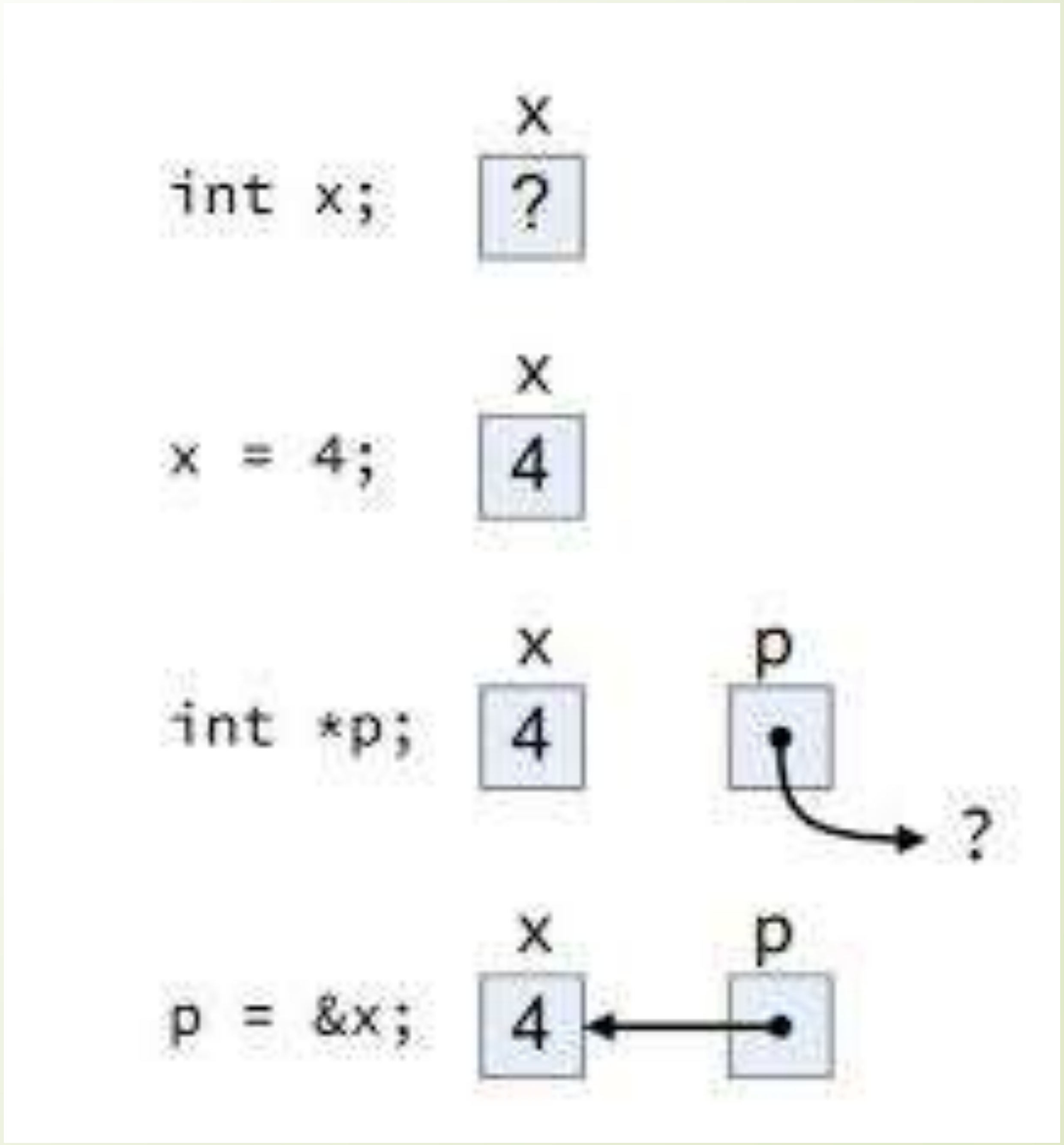
Assigning addresses to Pointers

- Int a=5;
- Int *p;
- we give the address to pointer as
  p=&a;
  Here, 5 is assigned to the a variable. And, the address of a is assigned to the p pointer.
- If we want to print p

```
cout<<p;  //205
cout<<&a;  //205
cout<<&p;  //604
cout<<*p;  //5     Derefrencing
*p=8
        cout<<*p;  //8
```

Some Important points

- Always C pointer is initialized to null, i.e. int *p = null.
- The value of null pointer is 0.
- & symbol is used to get the address of the variable.
- * symbol is used to get the value of the variable that the pointer is pointing to.
- If a pointer in C is assigned to NULL, it means it is pointing to nothing.
- Pointer addition, multiplication, division are not allowed. You have to deference it first then you can Add, divide and multiply etc.
  - *int   *ip;   /* pointer to an integer */*
  - *double *dp;   /* pointer to a double */*
  - *float *fp;   /* pointer to a float */*
  - *char   *ch   /* pointer to a character */*
- The actual data type of the value of all pointers, whether integer, float, character, or otherwise, is the same, a long hexadecimal number that represents a memory address. The only difference between pointers of different data types is the data type of the variable or constant that the pointer points to.


int x;
x
?
x = 4;
x
4
int *p;
x
4
p
?
p = &x;
x
4
p

Representation of integer

Suppose we take an integer
int a=1025;
1025 is representing as 32 bits because integer is of 4 bytes and every bytes contains 8 bits. So 1025 is representing the following way.

00000000	**00000000**	**00000100**	**00000001**
204	203	202	201

Void pointer

Void *p0;

P0=p1;

We can’t dereference it like we do in printing , and we can’t do this p0+1
We will discuss about this later.

Common mistakes

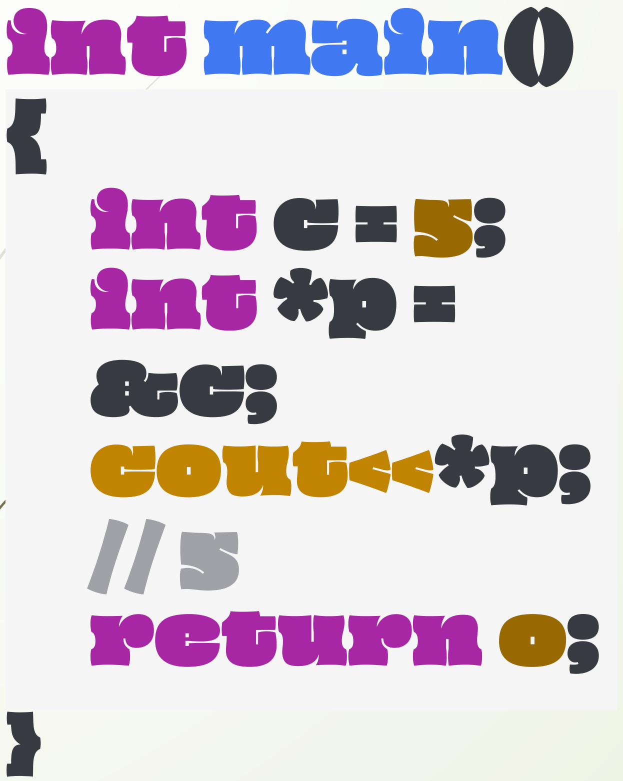
- int c, *pc;
- Pc=&c;
- // pc is address but c is not
- pc = c; // Error

- // &c is address but *pc is not
- *pc = &c; // Error
-

- // both &c and pc are addresses
- pc = &c;

- // both c and *pc values
- *pc = c;

Do not confuse on it



```
int main()
{
    int c = 5;
    int *p =
    &c;
    cout<<*p;
    //5
    return 0;
}
```

Why didn't we get an error when using
int *p = &c;?

It's because

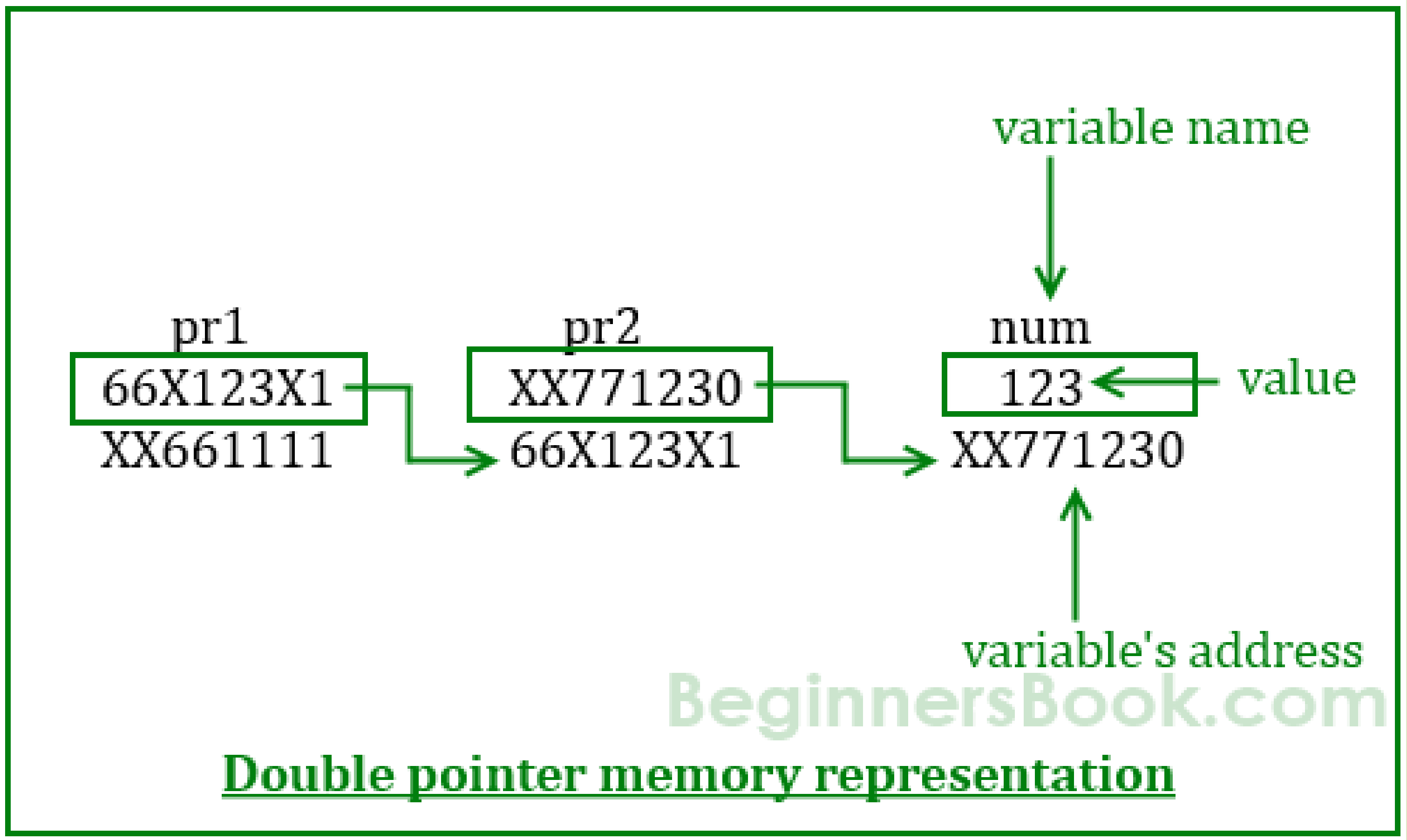
int *p = &c;
is equivalent to

int *p:
p = &c;

Find Sum
Find MAx

Pointers to Pointers

- When a pointer holds the address of another pointer then such type of pointer is known as **pointer-to-pointer** or **double pointer**.
- int **pr1;
  pr1=&pr2;

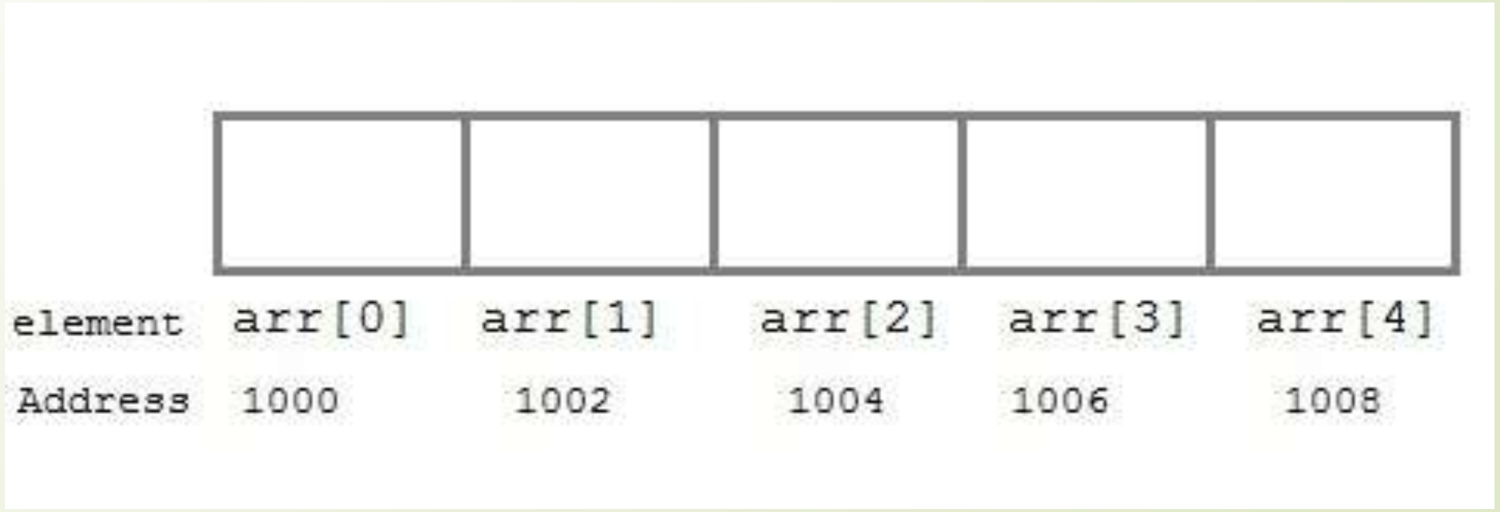


Double pointer memory representation

Pointers and arrays

- Suppose we declare an array arr,

- int arr[5] = { 1, 2, 3, 4, 5 };
- Assuming that the base address (i.e address of the first element of the array) of arr is 1000 and each integer requires two bytes, the five elements will be stored as follows:



- Here variable arr will give the base address, which is a constant pointer pointing to the first element of the array, arr[0]. Hence arr contains the address of arr[0] i.e 1000. In short, arr has two purpose - it is the name of the array and it acts as a pointer pointing towards the first element in the array.
- arr is equal to &arr[0] by default
- We can also declare a pointer of type int to point to the array arr.

```
int *p;
p = arr;
// or,
p = &arr[0];    //both the statements are equivalent.
```

Similarly if you print *(arr+1) it is same as arr[1]

Now we can access every element of the array arr using p++ to move from one element to another.

```
int main()
{
    int i;
    int a[5] = {1, 2, 3, 4, 5};
    int *p = a;     // same as int*p = &a[0]
    for (i = 0; i < 5; i++)
    {
        cout<<*p;
        p++;
    }

    return 0;
}
```

In the above program, the pointer *p will print all the values stored in the array one by one. We can also use the Base address (a in above case) to act as a pointer and print all the values.

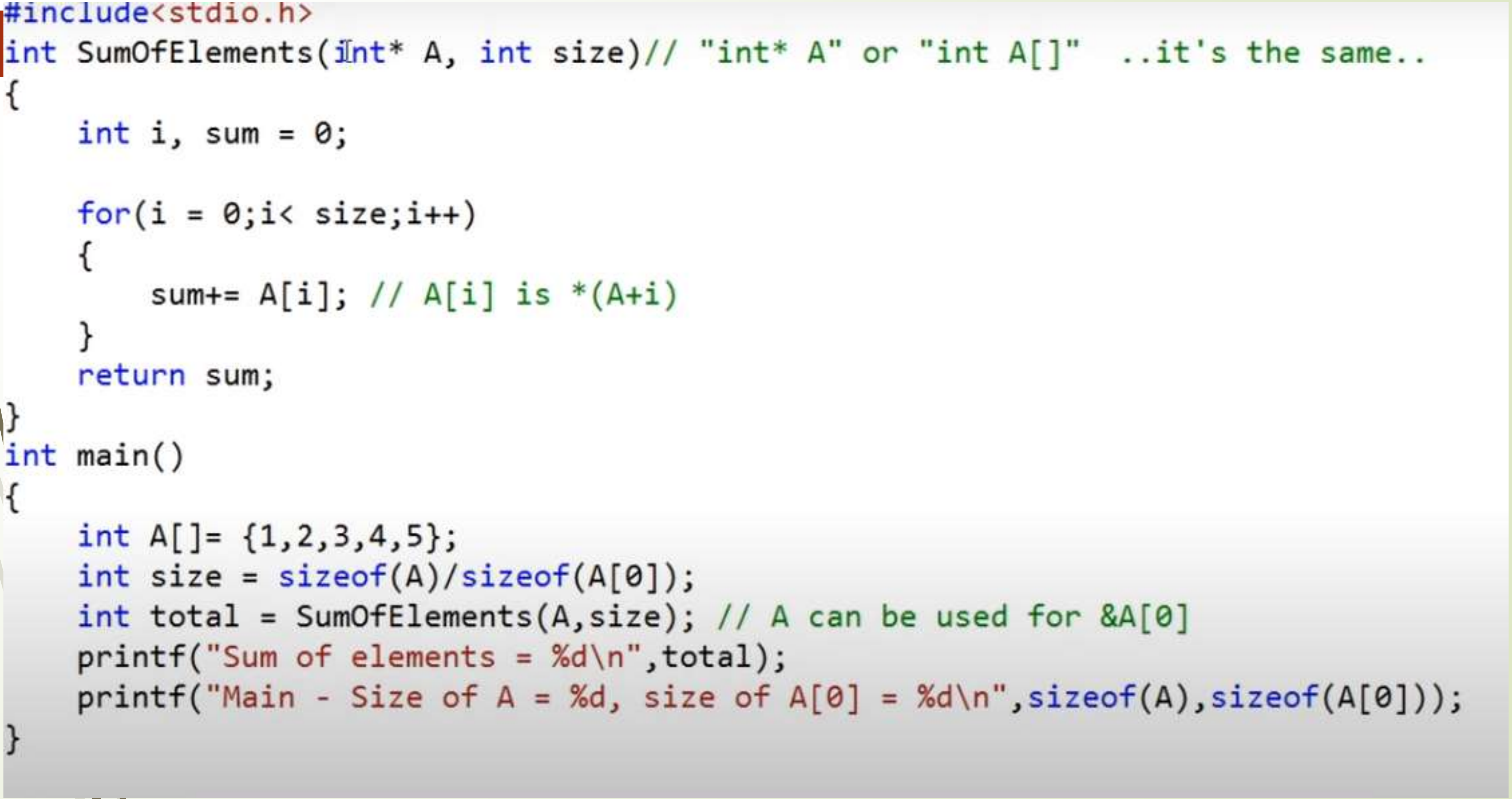
Array to Function as parameters

- Arrays always passed as referenced parameter.
- It never get copied completely.
- We cant increment and decrement like pointer

Why we use Pointers

- **Pointers** are used to store and manage the addresses of dynamically allocated blocks of memory. Such blocks are used to store data objects or arrays of objects.
- Most structured and object-oriented languages provide an area of memory, called the heap or free store, from which objects are dynamically allocated.
- you can even use **++** and **--** with a pointer, but not with an array name because this is a constant pointer and cannot be changed. So to summarise: An array's name is a ***constant pointer*** to the first element in the array that is **a==&a[0]** and ***a==a[0]**.

Array to Function as parameters



```c
#include<stdio.h>
int SumOfElements(int* A, int size)// "int* A" or "int A[]"  ..it's the same..
{
    int i, sum = 0;

    for(i = 0;i< size;i++)
    {
        sum+= A[i]; // A[i] is *(A+i)
    }
    return sum;
}
int main()
{
    int A[]= {1,2,3,4,5};
    int size = sizeof(A)/sizeof(A[0]);
    int total = SumOfElements(A,size); // A can be used for &A[0]
    printf("Sum of elements = %d\n",total);
    printf("Main - Size of A = %d, size of A[0] = %d\n",sizeof(A),sizeof(A[0]));
}
```

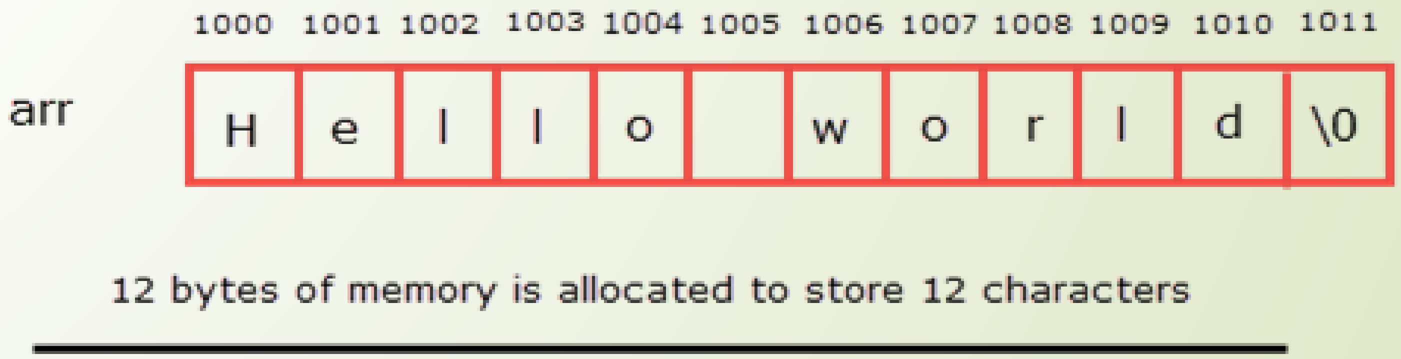
```
int* fun()
{
    int A = 10;
    return (&A);
}

// Driver Code
int main()
{
    // Declare a pointer
    int* p;

    // Function call
    p = fun();

    cout<<p;
    cout<<*p;
    return 0;
}
```

ERRor

```
  int* fun()
{
    // Declare a static integer
    static int A = 10;
    return (&A);
}

// Driver Code
int main()
{
    // Declare a pointer
    int* p;

    // Function call
    p = fun();

    // Print Address
    cout<<p;

    // Print value at the above address
    cout<<*p;
    return 0;
}
```

Character Arrays and pointers

- Character arrays should be large enough to store a string.



Functions in string.h

String functions	Description
strcat ( )	**Concatenates str2 at the end of str1**
strncat ( )	**Appends a portion of string to another**
strcpy ( )	**Copies str2 into str1**
strncpy ( )	**Copies given number of characters of one string to another**
strlen ( )	**Gives the length of str1**
strcmp ( )	**Returns 0 if str1 is same as str2. Returns <0 if strl < str2. Returns >0 if str1 > str2**
strcmpi ( )	Same as strcmp() function. But, this function negotiates case. "A" and "a" are treated as same.
strchr ( )	Returns pointer to first occurrence of char in str1
strrchr ( )	last occurrence of given character in a string is found

strstr ( )	Returns pointer to first occurrence of str2 in str1
strrstr ( )	Returns pointer to last occurrence of str2 in str1
strdup ( )	Duplicates the string
strlwr ( )	**Converts string to lowercase**
strupr ( )	**Converts string to uppercase**
strrev ( )	**Reverses the given string**
strset ( )	Sets all character in a string to given character
strnset ( )	It sets the portion of characters in a string to given character
strtok ( )	Tokenizing given string using delimiter

https://www.tutorialspoint.com/c_standard_library/string_h.htm

Character Arrays and pointers

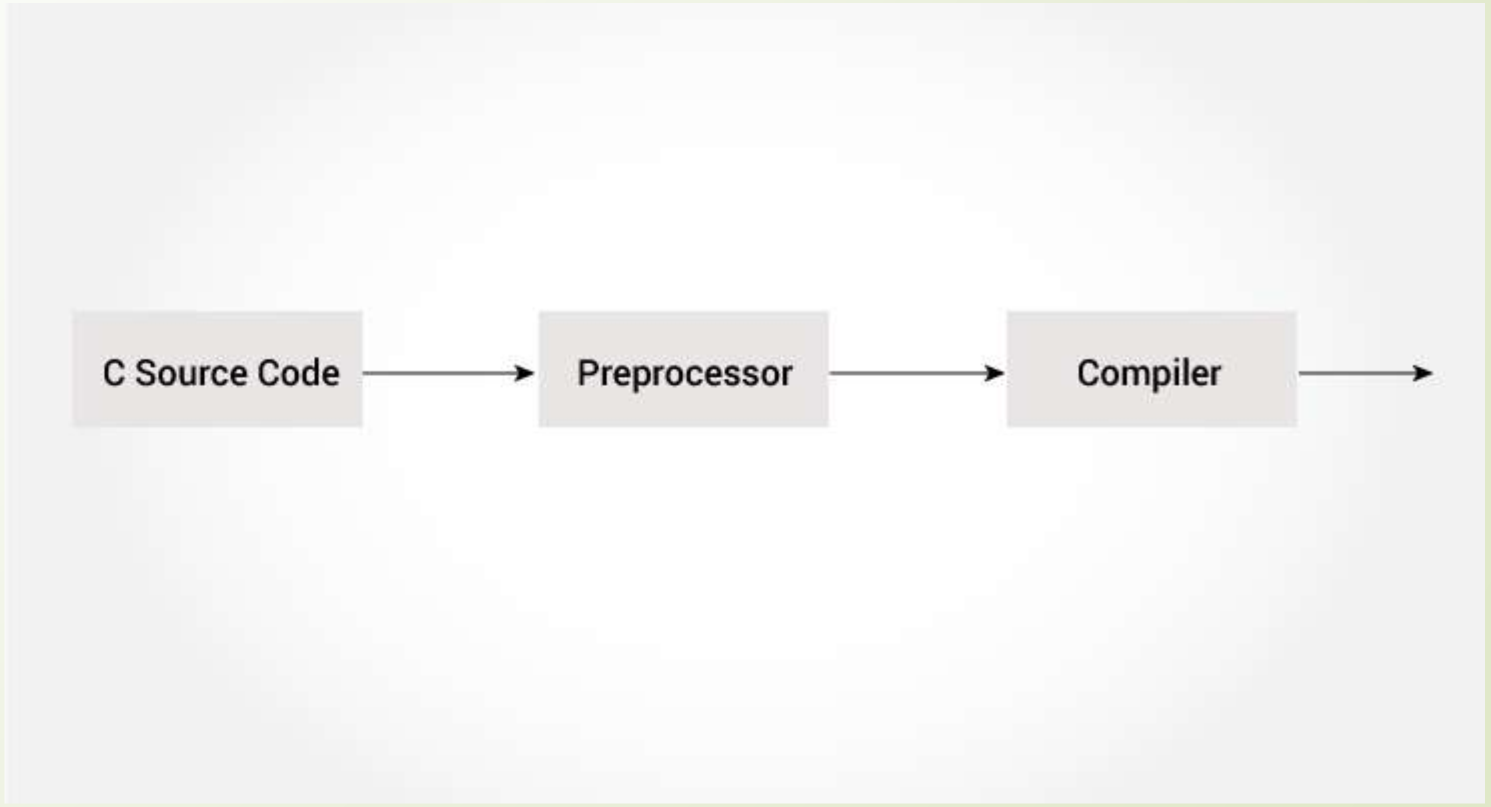
- Like we can handle pointers with array, similarly we can use character type pointers for character arrays.

```
char arr[] = "Hello"; // array version
char *ptr ;// pointer version
ptr=arr ;
```

- We can also print the array as ptr[2]; l
- Ptr[0] = A; //Aello
- *ptr=A;
- Ptr++…

Macros

- With **macro**(#define): **macro** will be replaced with its **value** in source code compile time only, so compiler does not need to look into memory even single time, **it** compiles code directly with **constant value**. So **it** is better to **use macro** than **constant** variable



Dynamic Memory

- Sometimes the size of the array you declared may be insufficient. To solve this issue, you can allocate memory manually during run-time. This is known as dynamic memory allocation in C programming.

Heap

- Many times, you are not aware in advance how much memory you will need to store particular information in a defined variable and the size of required memory can be determined at run time.
- You can allocate memory at run time within the heap for the variable of a given type using a special operator in C++ which returns the address of the space allocated. This operator is called **new** operator.
- If you are not in need of dynamically allocated memory anymore, you can use **delete** operator, which de-allocates memory that was previously allocated by new operator.

Heap

```
double* pvalue  = NULL; // Pointer initialized with null
pvalue  = new double;
    double* pvalue  = NULL;
    if( !(pvalue  = new double )) {
       cout << "Error: out of memory." <<endl;
       exit(1);
    }
```

Heap deletion

At any point, when you feel a variable that has been dynamically allocated is not anymore required, you can free up the memory that it occupies in the free store with the ‘delete’ operator as follows −

```
delete pvalue;
```

Dynamic Memory Allocation for Arrays

```
char* pvalue  = NULL;         // Pointer initialized with null
pvalue  = new char[20];
delete [] pvalue;


double** pvalue  = NULL;      // Pointer initialized with null
pvalue  = new double [3][4];
delete [] pvalue;
```

Dynamic Memory Allocation for Arrays

UNION and INTERSECTION

MEMORY LEAK & DANGLING POINTERS

A **dangling pointer** points to memory that has already been freed. The storage is no longer allocated. Trying to access it might cause a Segmentation fault.

```
int *c = new int();

Delete c;

*c = 3; //writing to freed location!
```

A **memory leak** is memory which hasn't been freed, there is no way to access (or free it) now, as there are no ways to get to it anymore. (E.g. a pointer which **was** the only reference to a memory location **dynamically allocated** (and not freed) which points somewhere else now.)

```
void func(){

    char *ch = new int(10);

}

//ch not valid outside, no way to access malloc-ed memory
```

Character Arrays

```
#include <iostream>
const max_len = 256;
int main()
{
        using namespace std;

        cout << "Please enter string: ";

        char* str = new char[max_len + 1];
        for (int i = 0; i < max_len; i++)
        {
cin >> str[i];
          if (str[i] == '\n')
          {
                str[i] = '\0';
                break;
          }
}
cout << "Entered string is:" << str << endl;
delete [] str;

return 0;
```

Unusual behaviour with character pointers

```
using namespace std;

// Driver Code
int main()
{
    // Integer array
    int a[] = { 1, 2, 3 };

    // Character array
    char ch[] = "abc";

    // Print the value of a and b
    cout << a << endl;

    cout << ch << endl;
    return 0;
}
```

Output:

```
0x7ffc623e56c0
abc
```

Unusual behaviour with character pointers

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

// Driver Code
int main()
{
    // Character array b
    char b[] = "abc";

    // Pointer to character array
    char* c = &b[0];

    // Print the value of c
    cout << c << endl;
}
```

Output:

```
abc
```

Explanation:
In this example as well, the character type pointer c is storing the base address of the char array b[] and hence when used with cout, it starts printing each and every character from that base address till it encounters a NULL character.

Dynamic character array

```
#include <iostream>
#include <cstring>
using namespace std;
int main()
{
    char *s1=new char[50];
    char *s2=new char[50];

    cout << "Enter string s1: ";
    cin.getline(s1, 50);

    cout << "Enter string s2: ";
    cin.getline(s2, 50);

    strcat(s1, s2);

    cout << "s1 = " << s1 << endl;
    cout << "s2 = " << s2;

}
```

Void Pointer

A void pointer is a pointer that has no associated data type with it. A void pointer can hold address of any type and can be typecasted to any type.

```
int a = 10;
char b = 'x';

void *p = &a;  // void pointer holds address of
int 'a'
p = &b; // void pointer holds address of char 'b'
```

Facts about Void Pointer

void pointers cannot be dereferenced. For example the following program doesn’t compile.

```
#include<iostream>
using namespace std;
int main()
{
    int a = 10;
    void *ptr = &a;
    cout<< *ptr;
    return 0;
}
```

The following program compiles and runs fine.

```
#include<iostream>
using namespace std;
int main()
{
    int a = 10;
    void *ptr = &a;
    cout<< *(int *)ptr;
    return 0;
}
```

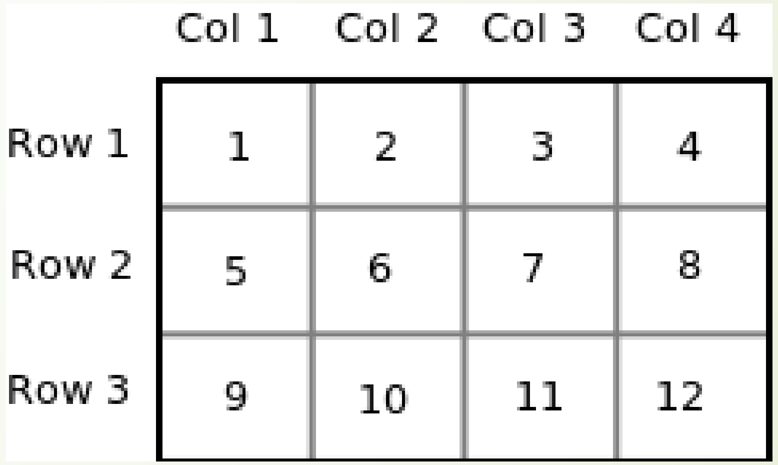
Pointers to 2D array

- In a two dimensional array, we can access each element by using two subscripts, where first subscript represents the row number and second subscript represents the column number.

- The elements of 2-D array can be accessed with the help of pointer notation also. Suppose arr is a 2-D array, we can access any element *arr[i][j]* of the array using the pointer expression ***(*(arr + i) + j)**. Now we'll see how this expression can be derived.

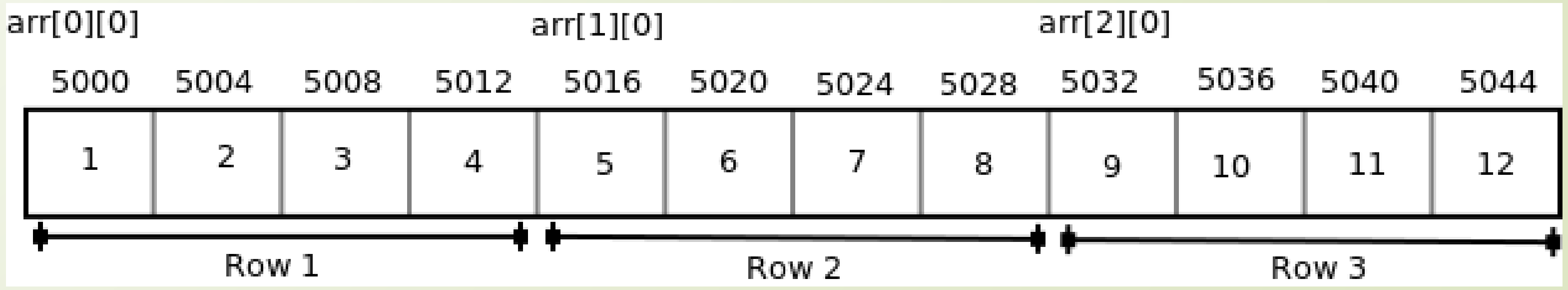
Pointers to 2D array

- int arr[3][4] = { {1, 2, 3, 4}, {5, 6, 7, 8}, {9, 10, 11, 12} };

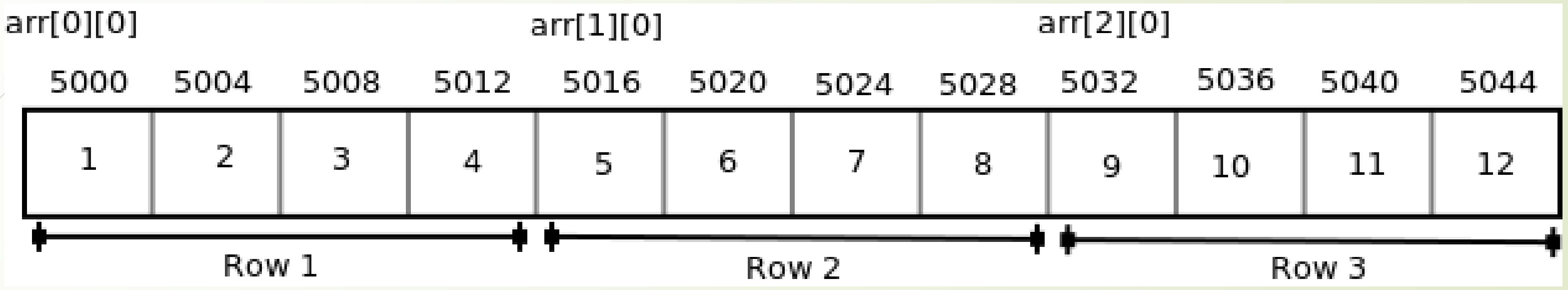


	Col 1	Col 2	Col 3	Col 4
Row 1	1	2	3	4
Row 2	5	6	7	8
Row 3	9	10	11	12

Since memory in a computer is organized linearly it is not possible to store the 2-D array in rows and columns. The concept of rows and columns is only theoretical, actually, a 2-D array is stored in row-major order i.e rows are placed next to each other. The following figure shows how the above 2-D array will be stored in memory.



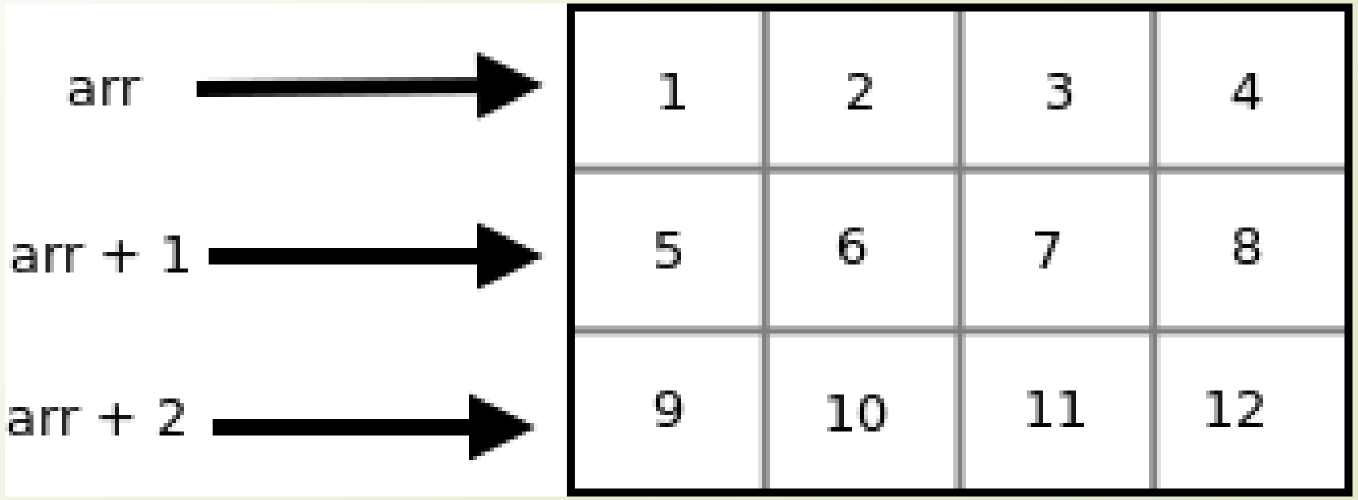
Pointers to 2D array

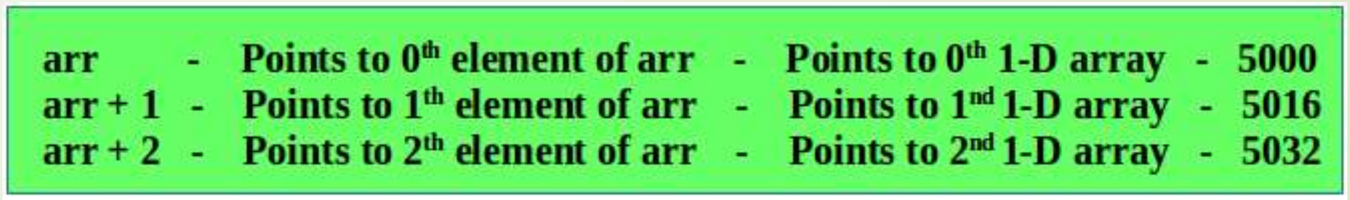


Each row can be considered as a 1-D array, so a two-dimensional array can be considered as a collection of one-dimensional arrays that are placed one after another.
So here *arr* is an array of 3 elements where each element is a 1-D array of 4 integers.

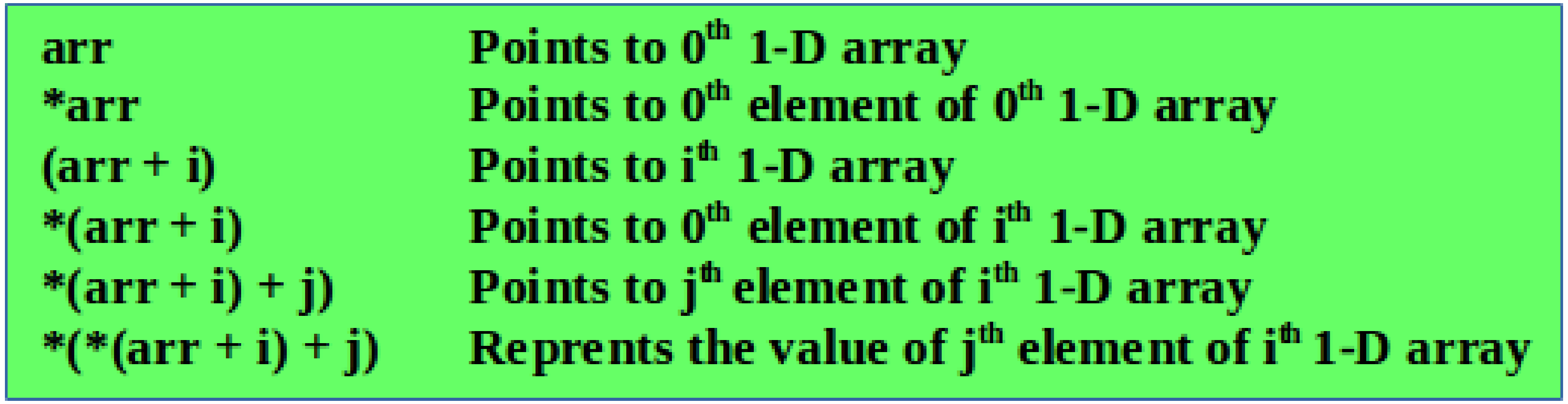
Pointers to 2D array

Since *arr* is a 'pointer to an array of 4 integers', according to pointer arithmetic the expression arr + 1 will represent the address 5016 and expression arr + 2 will represent address 5032.
So we can say that *arr* points to the 0th 1-D array, *arr + 1* points to the 1st 1-D array and *arr* + 2 points to the 2nd 1-D array.





arr	-	Points to 0th element of arr	-	Points to 0th 1-D array	-	5000
arr + 1	-	Points to 1th element of arr	-	Points to 1nd 1-D array	-	5016
arr + 2	-	Points to 2th element of arr	-	Points to 2nd 1-D array	-	5032



arr	Points to 0th 1-D array
*arr	Points to 0th element of 0th 1-D array
(arr + i)	Points to ith 1-D array
*(arr + i)	Points to 0th element of ith 1-D array
*(arr + i) + j)	Points to jth element of ith 1-D array
((arr + i) + j)	Reprents the value of jth element of ith 1-D array

- To access an individual element of our 2-D array, we should be able to access any jth element of ith 1-D array.

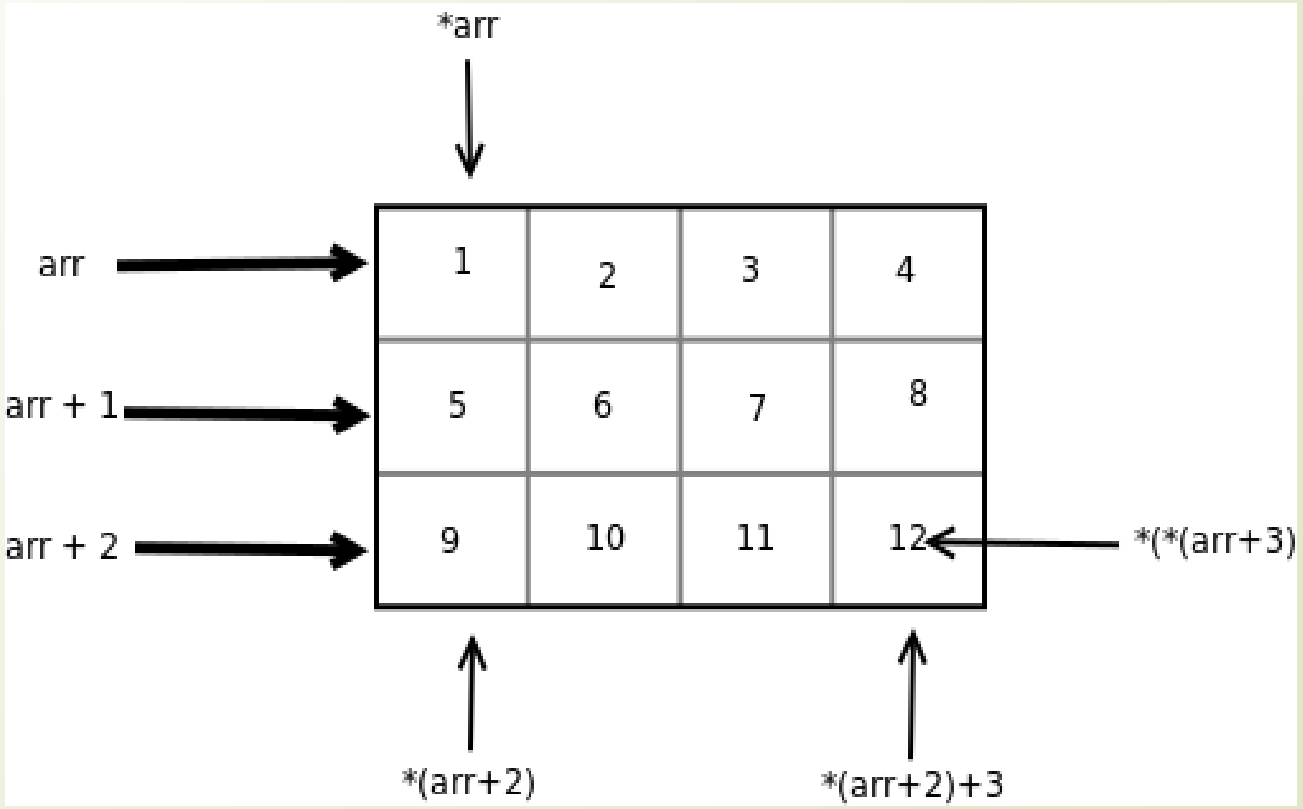
- Since the base type of *(arr + i) is int and it contains the address of 0th element of ith 1-D array, we can get the addresses of subsequent elements in the ith 1-D array by adding integer values to *(arr + i).

- For example *(arr + i) + 1 will represent the address of 1st element of 1st element of ith 1-D array and *(arr+i)+2 will represent the address of 2nd element of ith 1-D array.

- Similarly *(arr + i) + j will represent the address of jth element of ith 1-D array. On dereferencing this expression we can get the jth element of the ith 1-D array.

- For example *(arr + i) + 1 will represent the address of 1st element of 1st element of ith 1-D array and *(arr+i)+2 will represent the address of 2nd element of ith 1-D array.

- Similarly *(arr + i) + j will represent the address of jth element of ith 1-D array. On dereferencing this expression we can get the jth element of the ith 1-D array.



```
int main()
{
  int arr[3][4] = {
                    { 10, 11, 12, 13 },
                    { 20, 21, 22, 23 },
                    { 30, 31, 32, 33 }
                  };
  int i, j;
  for (i = 0; i < 3; i++)
  {
   cout<<  i, arr[i], *(arr + i);

    for (j = 0; j < 4; j++)
      cout<<arr[i][j]<< *(*(arr + i) + j);
    cout<<\n";
  }

  return 0;
```

```
Address of 0th array = 0x7ffe50edd580
0x7ffe50edd580
10 10 11 11 12 12 13 13
Address of 1th array = 0x7ffe50edd590
0x7ffe50edd590
20 20 21 21 22 22 23 23
Address of 2th array = 0x7ffe50edd5a0
0x7ffe50edd5a0
30 30 31 31 32 32 33 33
```

```
using namespace std;

// Driver Code
int main()
{
    // Dimensions of the array
    int m = 3, n = 4, c = 0;

    // Declare memory block of size M
    int** a = new int*[m];

    for (int i = 0; i < m; i++) {

        // Declare a memory block
        // of size n
        a[i] = new int[n];
    }

    // Traverse the 2D array
    for (int i = 0; i < m; i++) {
        for (int j = 0; j < n; j++) {

            // Assign values to the
            // memory blocks created
            a[i][j] = ++c;
        }
    }

    // Traverse the 2D array
    for (int i = 0; i < m; i++) {
        for (int j = 0; j < n; j++) {

            // Print the values of
            // memory blocks created
            cout << a[i][j] << " ";
        }
        cout << endl;
    }

    //Delete the array created
    for(int i=0;i<m;i++)    //To delete the inner arrays
    delete [] a[i];
    delete [] a;            //To delete the outer array
                    //which contained the pointers
                    //of all the inner arrays

    return 0;
}
```

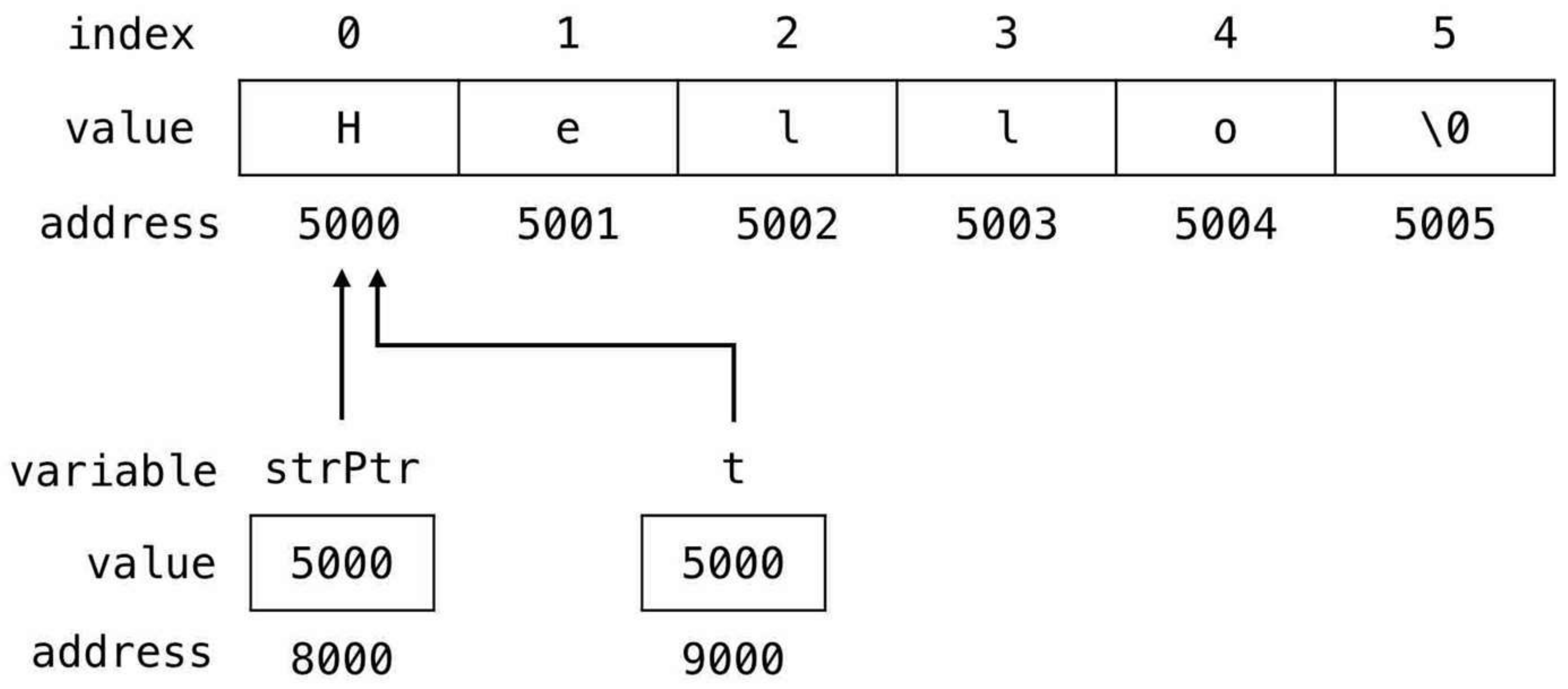
Accessing ctype string via pointer

```
int main() {

  // string variable
  char str[6] = "Hello";

  // pointer variable
  char *ptr = str;

  // print the string
  while(*ptr != '\0') {
    cout<< *ptr;

    // move the ptr pointer to the next memory 
location
    ptr++;

  }
```

Using pointer to store string

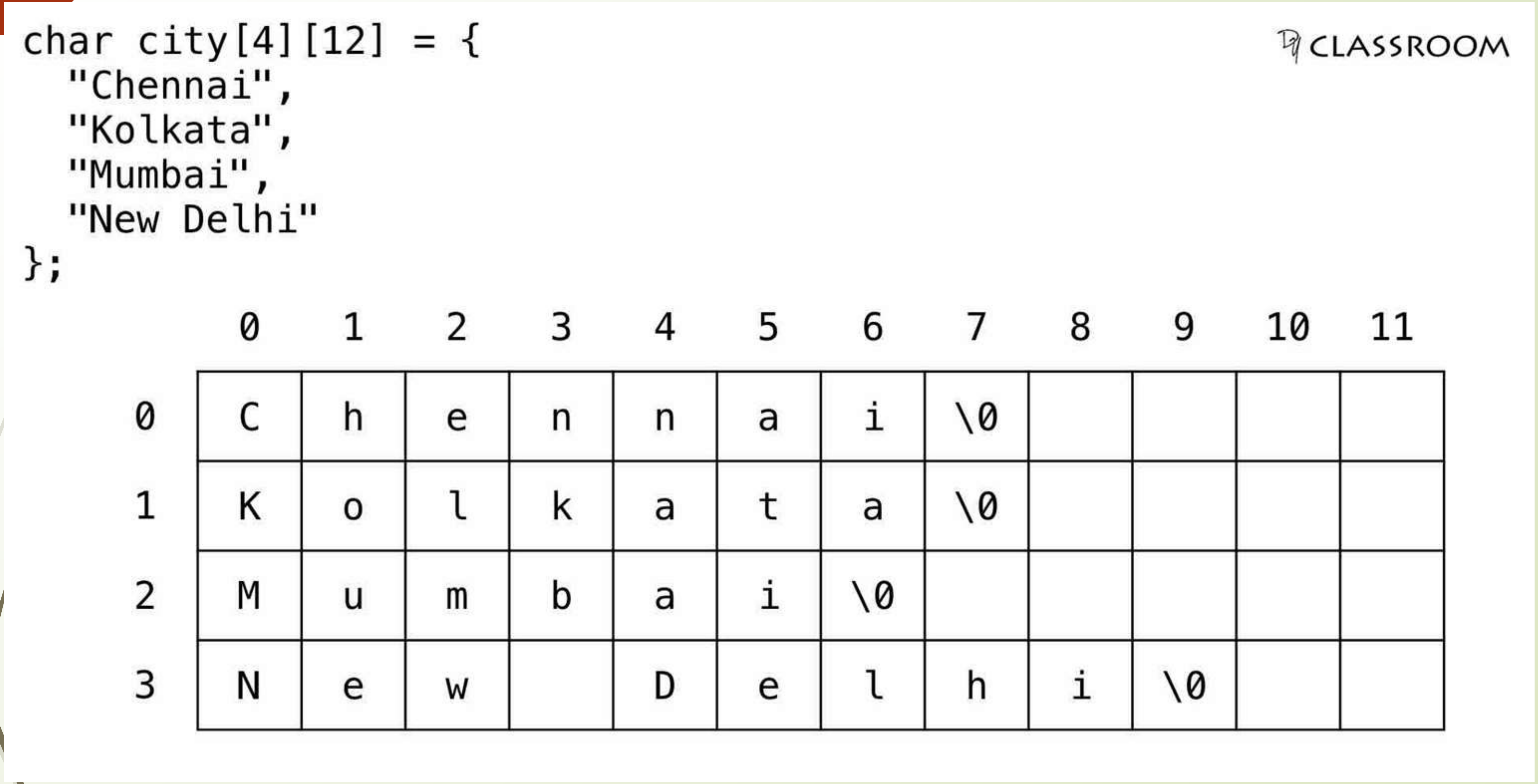
```
int main() {


   // pointer variable to store string
  char *strPtr = "Hello";

  // temporary pointer variable
  char *t = strPtr;

  // print the string
  while(*t != '\0') {
    cout<< *t;

    // move the t pointer to the next memory location
    t++;
  }
}
```

```
char *strPtr = “Hello”;
```



Array of strings

```
int main() {


  char city[4][12] = {
   "Chennai",
   "Kolkata",
   "Mumbai",
   "New Delhi"
};


}
```

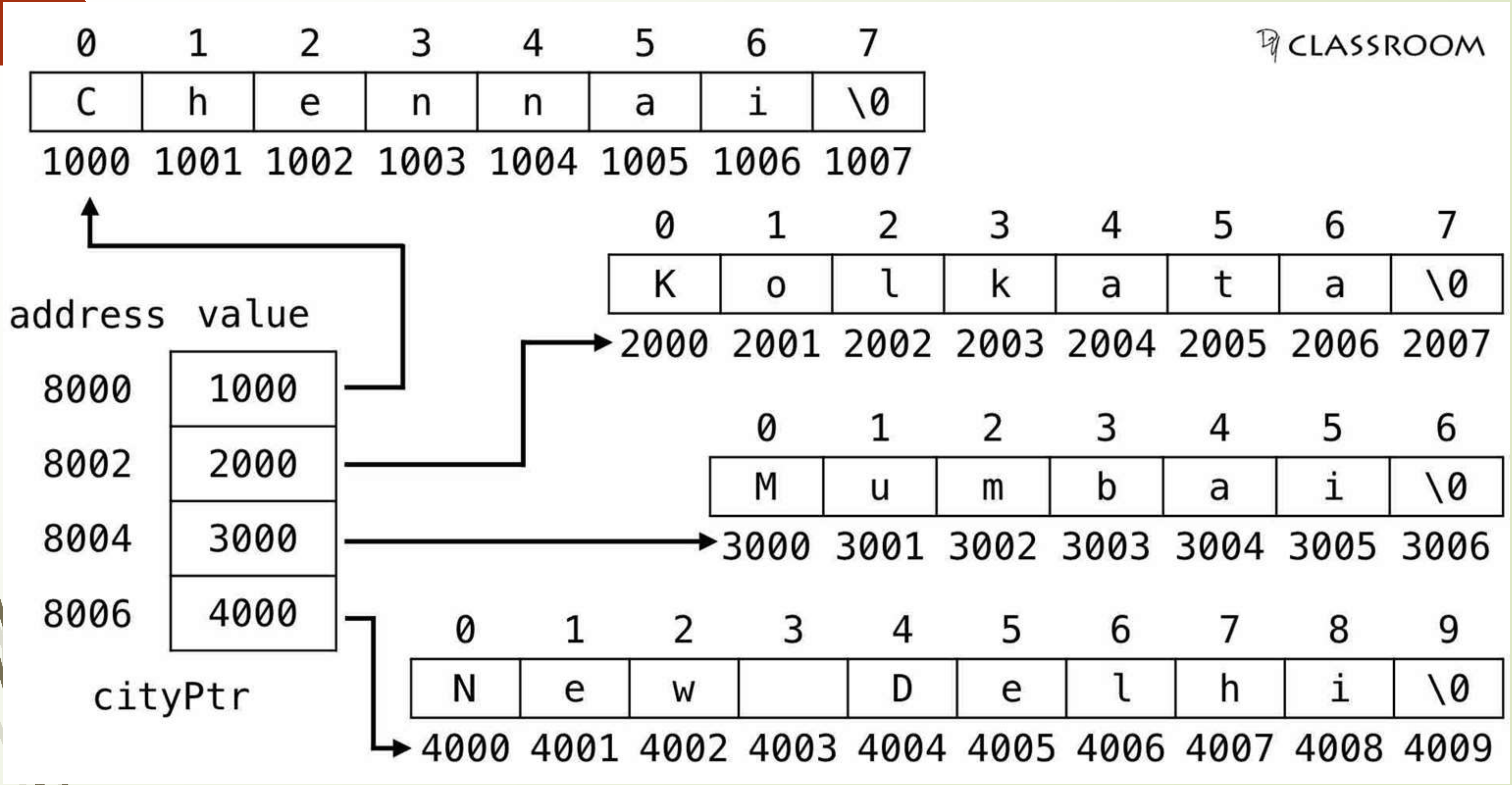


```c
char city[4][12] = {
  "Chennai",
  "Kolkata",
  "Mumbai",
  "New Delhi"
};
```

	0	1	2	3	4	5	6	7	8	9	10	11
0	C	h	e	n	n	a	i	\0				
1	K	o	l	k	a	t	a	\0				
2	M	u	m	b	a	i	\0					
3	N	e	w		D	e	l	h	i	\0		

character array

```
int main() {

char *cityPtr[4] = {
   "Chennai",
   "Kolkata",
   "Mumbai",
   "New Delhi"
};

}
```


CLASSROOM
0 1 2 3 4 5 6 7
C h e n n a i \0
1000 1001 1002 1003 1004 1005 1006 1007
0 1 2 3 4 5 6 7
K o l k a t a \0
2000 2001 2002 2003 2004 2005 2006 2007
address value
8000 1000
8002 2000
8004 3000
8006 4000
0 1 2 3 4 5 6
M u m b a i \0
3000 3001 3002 3003 3004 3005 3006
0 1 2 3 4 5 6 7 8 9
N e w D e l h i \0
4000 4001 4002 4003 4004 4005 4006 4007 4008 4009
cityPtr

string array

```
int main()
{
const int MAX = 80; //max characters in string
char str[MAX]; //string variable str
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cout << “Enter a string: “;
cin >> str; //put string in str
//display string from str
cout << “You entered: “ << str << endl;
return 0;
}
```
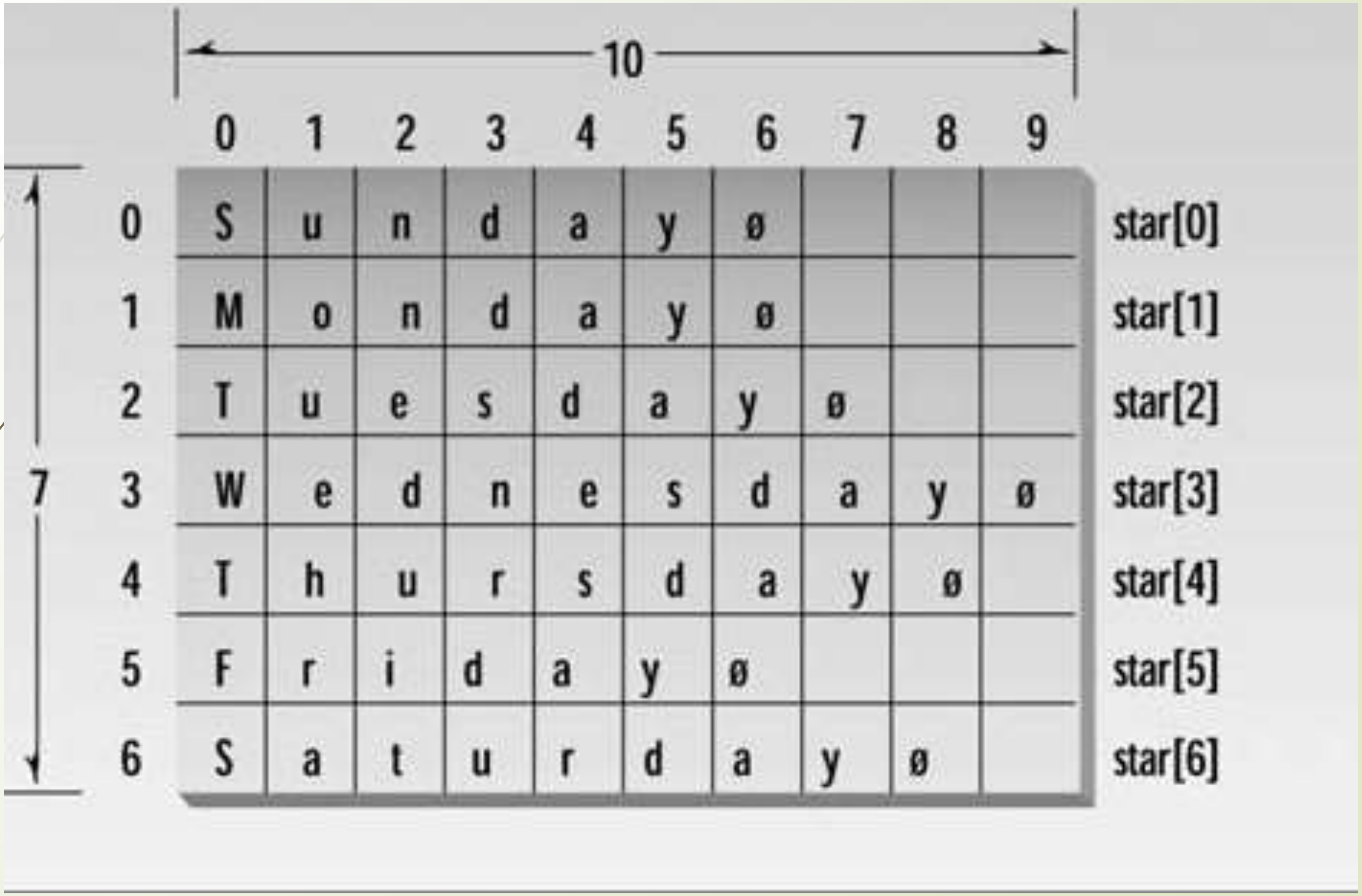

The definition of the string variable str looks like (and is) the definition of an array of type char:
char str[MAX];

Arrays of Strings

```
#include <iostream>
using namespace std;
int main()
{
    const int DAYS = 7; //number of strings in array
    const int MAX = 10; //maximum size of each string
    //array of strings
    char star[DAYS][MAX] = { “Sunday”, “Monday”, “Tuesday”,
        “Wednesday”, “Thursday”,
        “Friday”, “Saturday” };
    for(int j=0; j<DAYS; j++) //display every string
        cout << star[j] << endl;
    return 0;
}
```

Arrays of Strings



	0	1	2	3	4	5	6	7	8	9	
0	S	u	n	d	a	y	ø				star[0]
1	M	o	n	d	a	y	ø				star[1]
2	T	u	e	s	d	a	y	ø			star[2]
3	W	e	d	n	e	s	d	a	y	ø	star[3]
4	T	h	u	r	s	d	a	y	ø		star[4]
5	F	r	i	d	a	y	ø				star[5]
6	S	a	t	u	r	d	a	y	ø		star[6]