Ch.10 Array

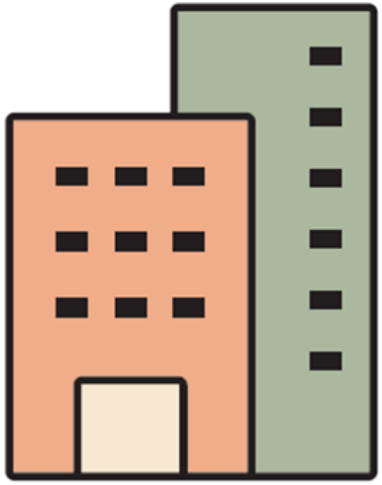
What you will learn in this chapter

- Understanding the concept of repetition
- The concept of arrays
- Declaration and initialization of arrays
- One-dimensional array
- Multidimensional array

Array

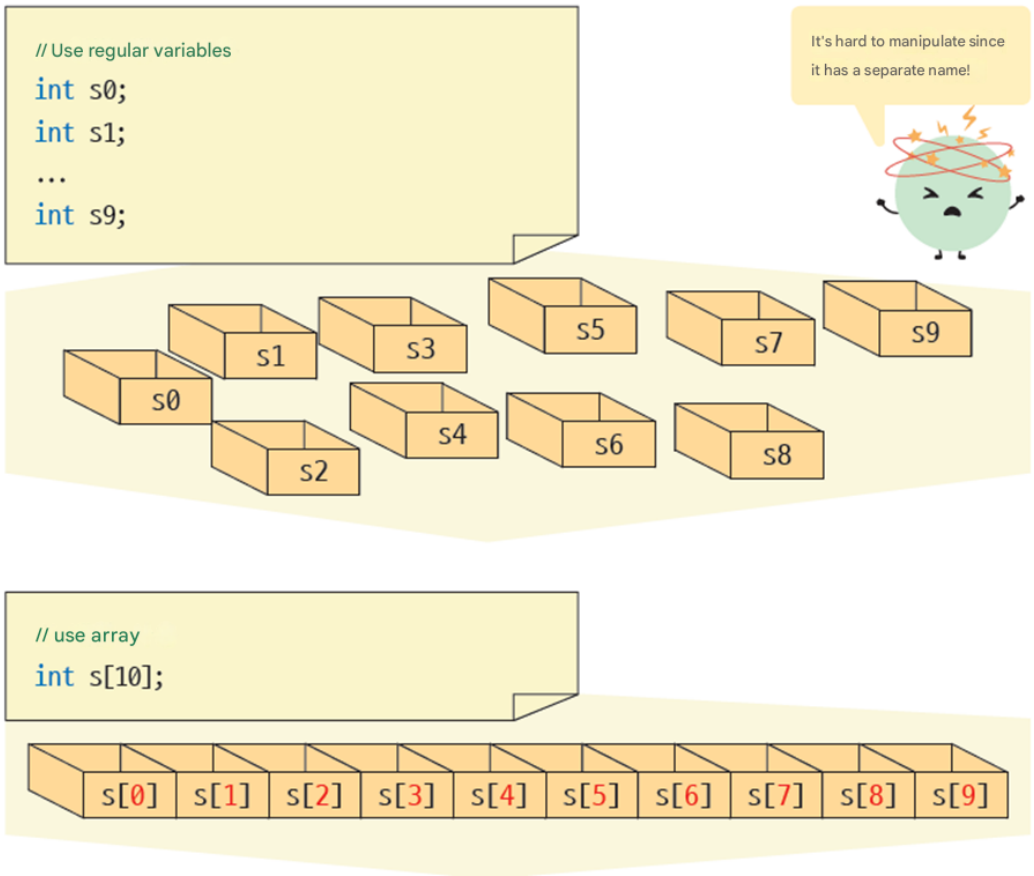
- Arrays allow you to create multiple variables at once .
- int s[10];

housing (variable)



Apartment (Arrangement)

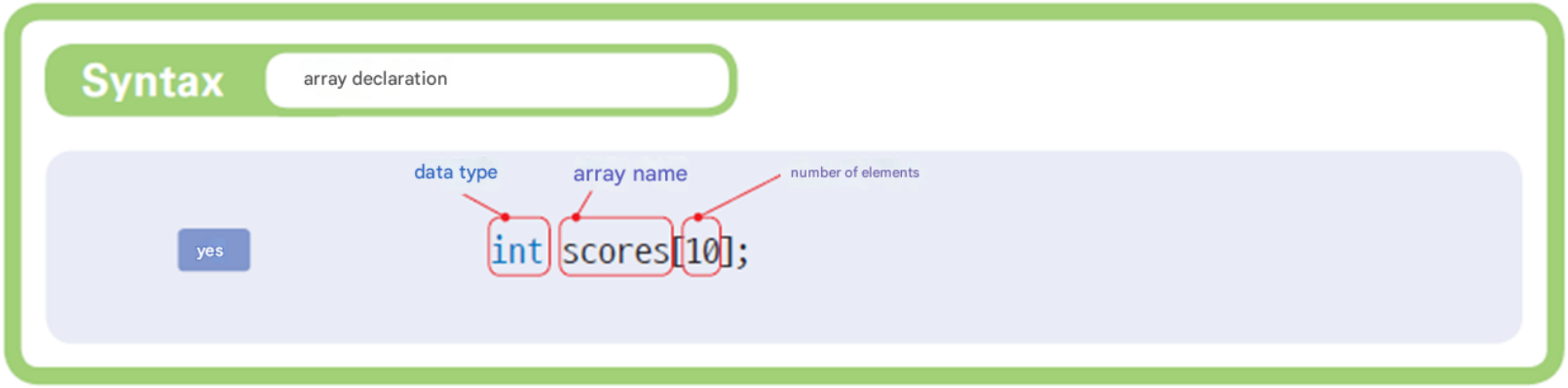
The need for arrays



Array of characteristic

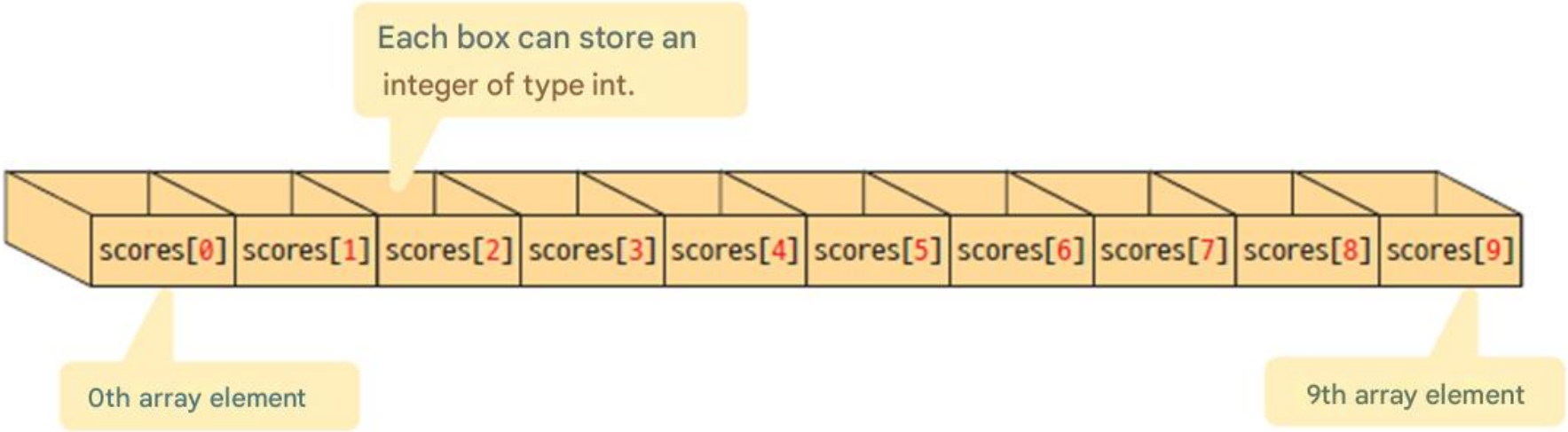
- Arrays are stored in a contiguous space in memory .
  For example, the array elements s[0] and s[1] above are physi cally adjacent to each other in memory.
- The biggest advantage of an array is that you can access and process related data sequentially . If the related data have different names, you would have to remember each name.
- However, if they share one name and only have different numbers, they are very easy to remember and convenient to use.

Array declaration



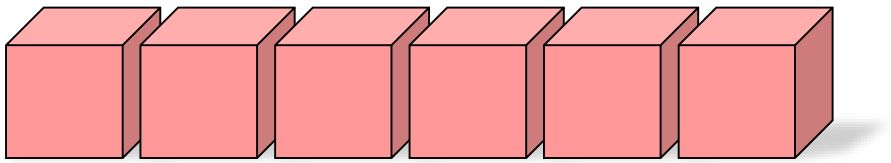
Array elements and indices

- *Index :* Number of array elements



Example of array declaration

```
// Array score with 60 int type values
int score[60];

float cost[12];
// Array cost with 12 float type values

char name[50];
// Array name with 50 char type values
```



caution

warning

You should always use constants when representing the size of an array. Using a variable as the size of an array will result in a compilation error.

Also, if the size of the array is negative, 0, or a real number, it is a compilation error.

```
int scores[];          // Error! Array size must be specified
int scores[size];      // The size of an array cannot be a variable!
int scores[-2];        // The size of the array cannot be negative
int scores[6.7];       // The size of the array must not be a real number
```

Using symbolic constants

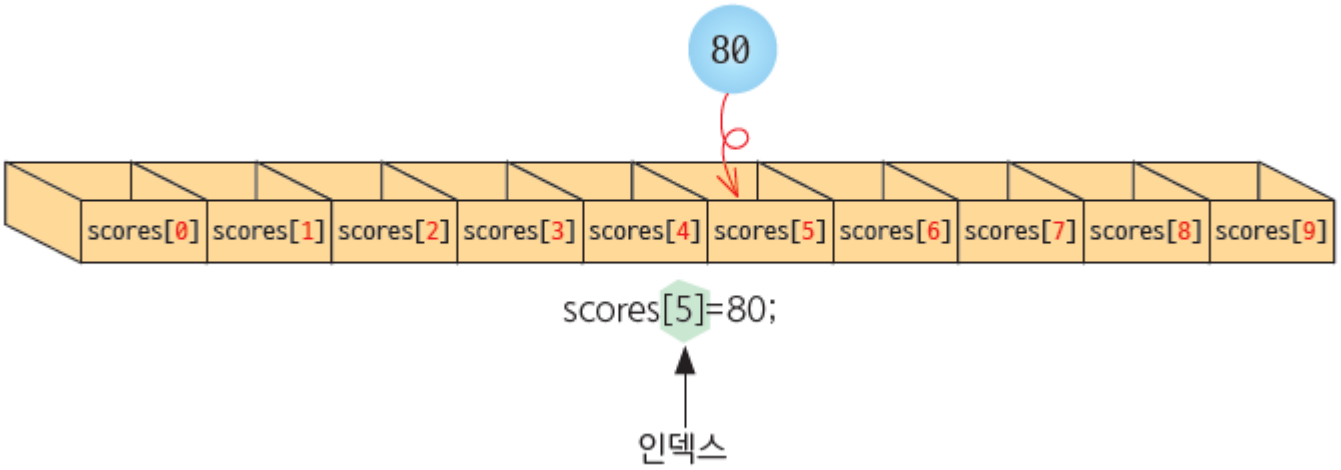
repair

Usually, when declaring an array, the size of the array is specified as a symbolic constant created with the #define directive. For example, as follows:

```
#define SIZE 10
int scores[SIZE];
```

If you specify the size of an array as a symbolic constant using #define, it becomes easy to change the size of the array. That is, you only need to change the definition of the symbolic constant without modifying other parts of the program.

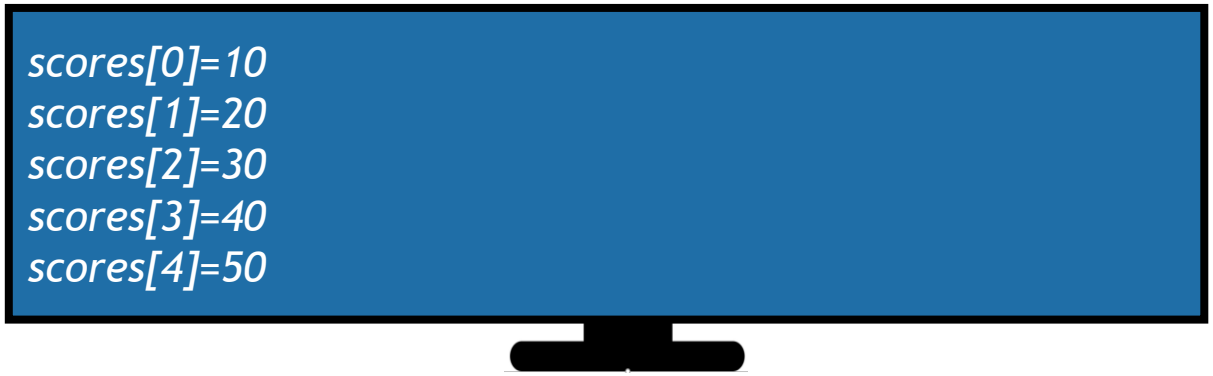
Accessing array elements

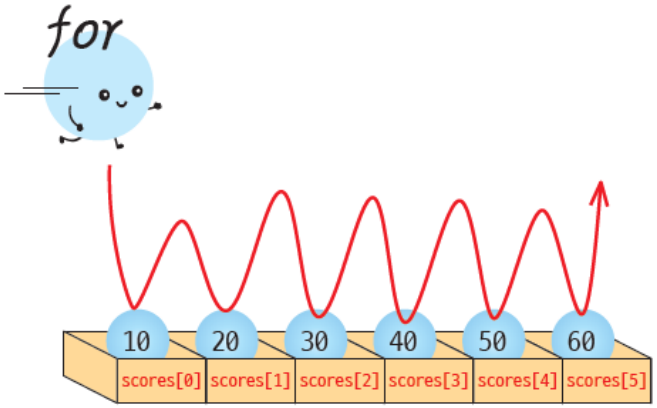



```
scores[5] = 80;
scores[1] = scores[0];
scores[ i ] = 100; // i is an integer variable
scores[i+2] = 100; // The formula becomes the index .
scores[index[3]] = 100; // index[] is an array of integers
```

Array Basics Example

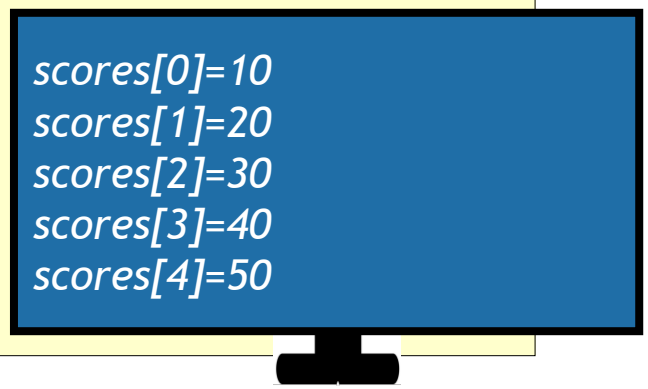
- Let's start with a basic example of declaring an array and assigning values to arra y elements . The for loop is useful when processing array elements one by one .





Array Basics Example

```
#include < stdio.h >

int main( void )
{
      int i ;
      int scores[5];

      scores[0] = 10;
      scores[1] = 20;
      scores[2] = 30;
      scores[3] = 40;
      scores[4] = 50;

      for ( i =0; i < 5; i ++)
            printf ( "scores[%d]=%d\n" , i , scores[ i ]);
      return 0;
}
```



Array and Loop

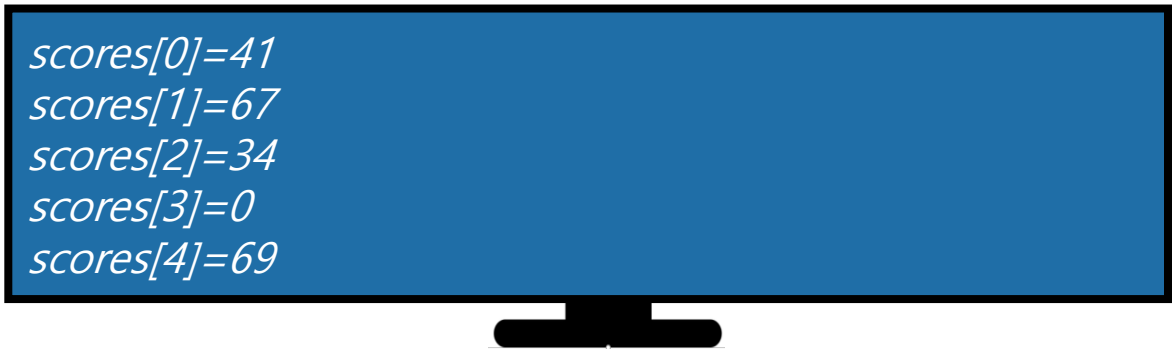
- The biggest advantage of arrays is that you can easily proces s the elements of the array using a loop.

```
scores[0] = 0;
scores[1] = 0;
scores[2] = 0;
scores[3] = 0;
scores[4] = 0;
```

```
#define SIZE 5
...
for ( i =0 ; i <SIZE ; i
++)
scores[ i ] = 0;
```

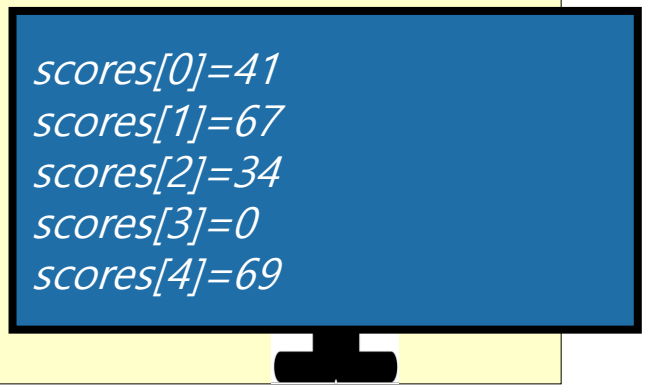
Fill array with random numbers

- This is an example of defining an array and using a repeating structure to initialize and print the values of the array elemen ts with random numbers .



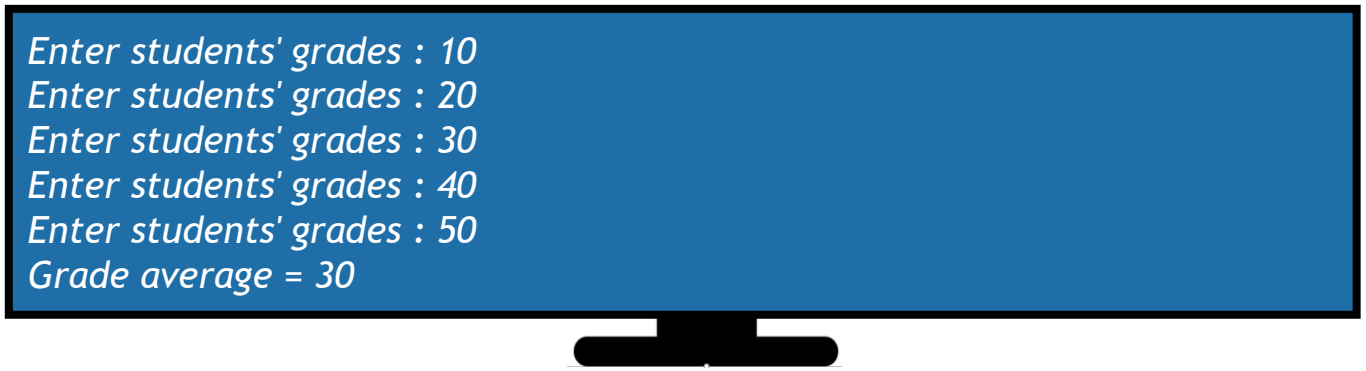
Fill array with random numbers

```
#include < stdio.h >
#include < stdlib.h >
#include < time.h >
#define SIZE 5

int main( void )
{
      int i ;
      int scores[SIZE];

      srand ((unsigned)time(NULL));
      for (i = 0; i < SIZE; i++)
            scores[ i ] = rand() % 100;

      for (i = 0; i < SIZE; i++)
            printf( "scores[%d]=%d\n" , i, scores[i]);
      return 0;
}
```



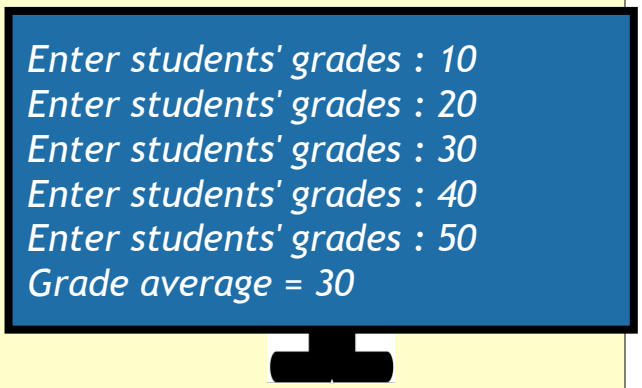
Example #3: Calculating the grade average

- five students using arrays . Imagine how difficult it would have been if we had used five variables instead of an array .



Example #3: Calculating the grade average

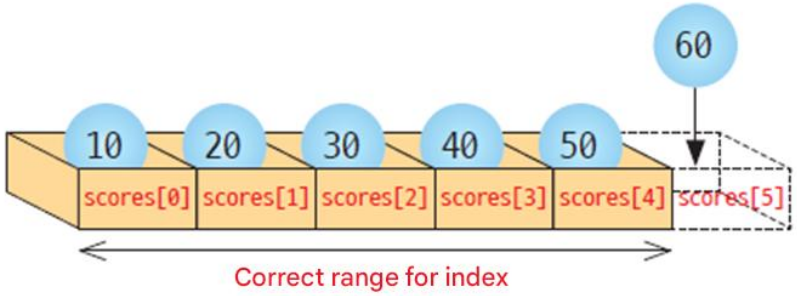
```c
#include < stdio.h >
#define STUDENTS 10

int main( void )
{
        int scores[ STUDENTS ];
        int sum = 0;
        int i , average;

        for (i = 0; i < STUDENTS ; i++)
        {
                printf ( " Enter students' grades : " );
                scanf ( "%d" , &scores[ i ]);
        }
        for (i = 0; i < STUDENTS ; i++)
                sum += scores[ i ];

        average = sum / STUDENTS ;
        printf ( " Grade average = %d\n" , average);

        return 0;
}
```



Bad index problem

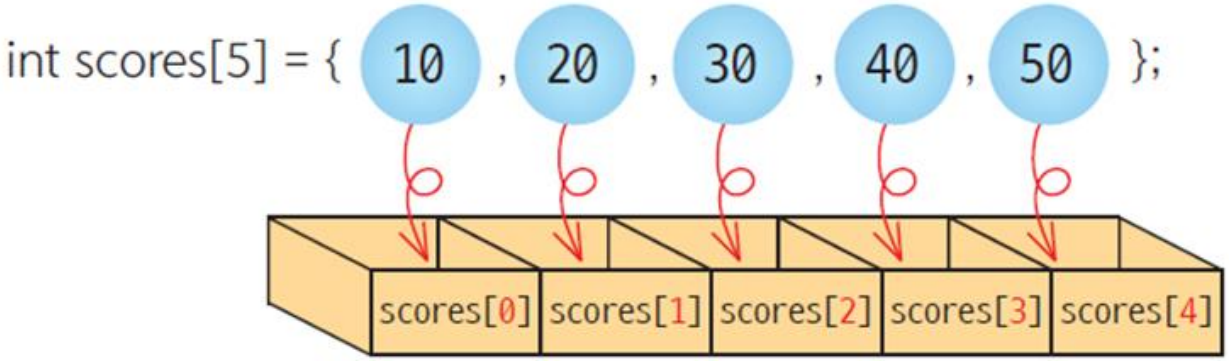
- If the index exceeds the size of the array, the program will cause a fatal error .
- C , it is the programmer's responsibility to ensure that the index is not out of range .

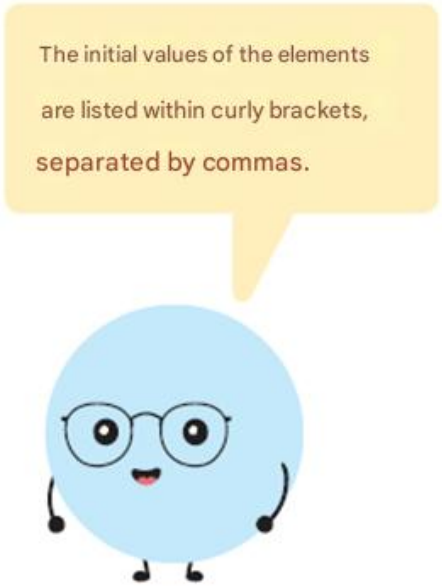
```
int scores[5];
...
scores[5] = 60; // Fatal error !
```



Initializing an array

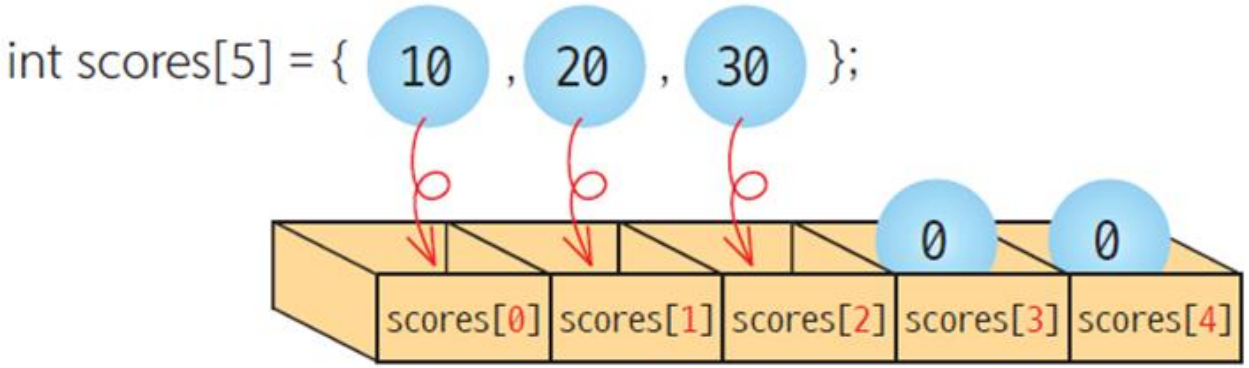
- To initialize an array, separate the initial values with commas, enclose them in curly brackets { } , and assign them when declaring the array .

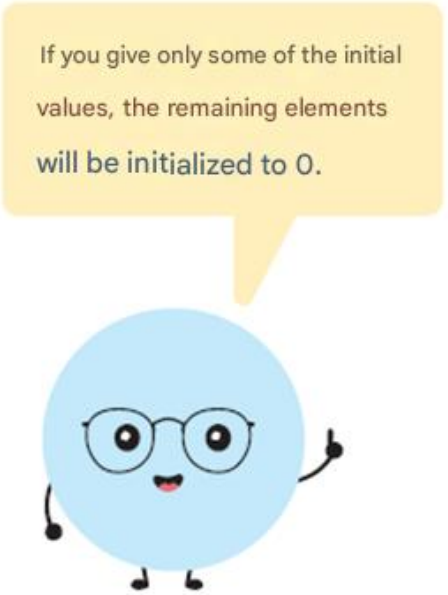




Initializing an array

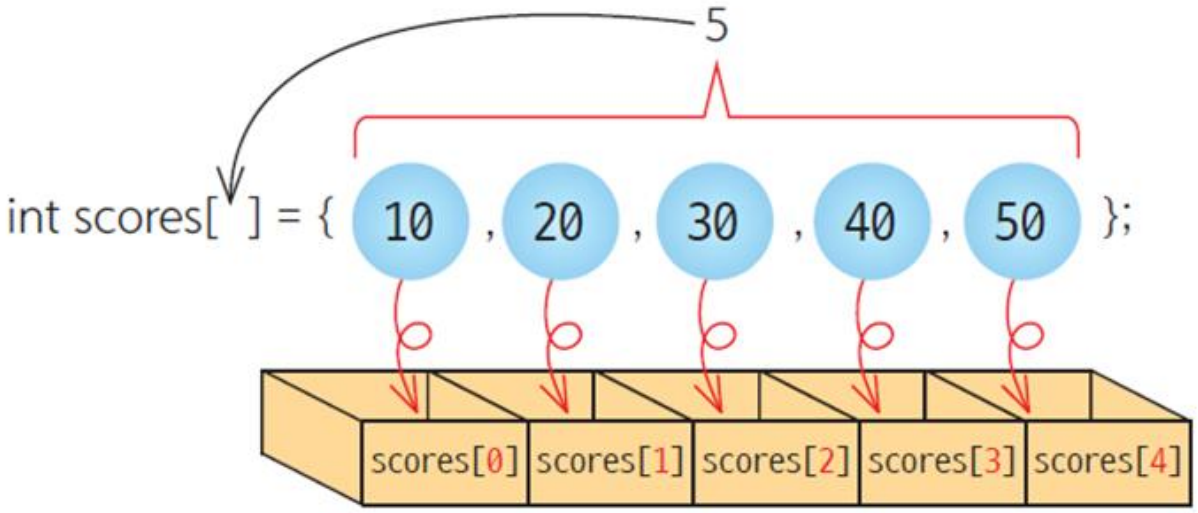
- If the number of initial values is less than the number of elements, only the elements in front are initialized .
  All remaining array elements are initialized to 0.

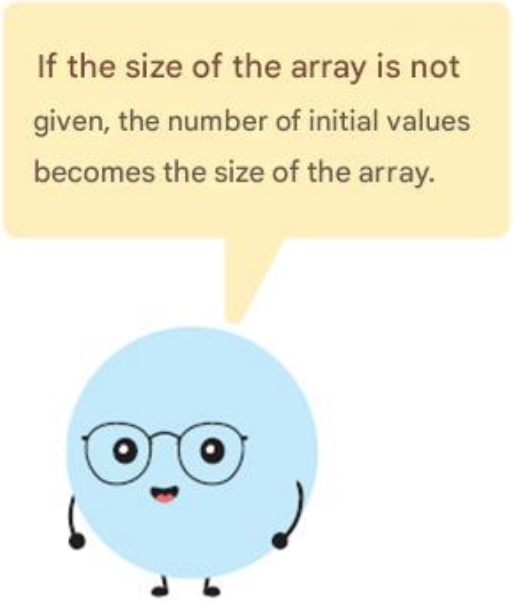




Initializing an array

- If you leave the array size empty, the compiler will automatic ally set the array size to the number of initial values .

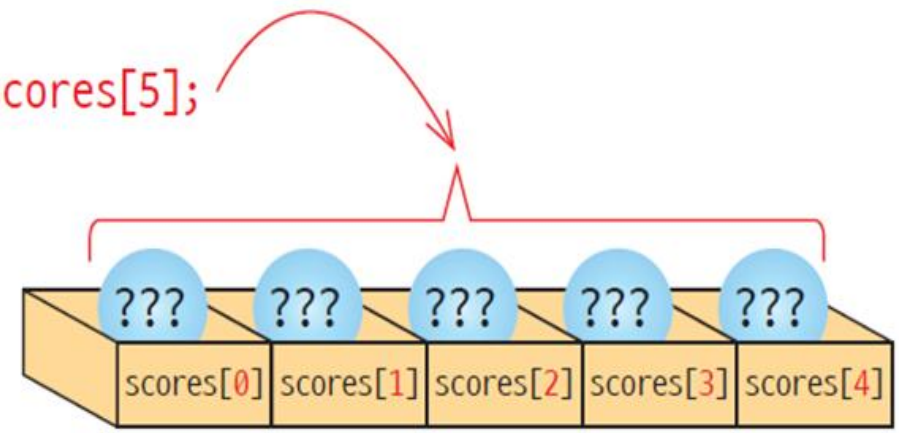




What if no initial value was given ?

- If the array is declared as a local variable and no initial value is given , it has no meaning, just like a normal local variable. The price of garbage is included .

```
int main(void)
{
  int scores[5];
  ...
}
```



warning

warning

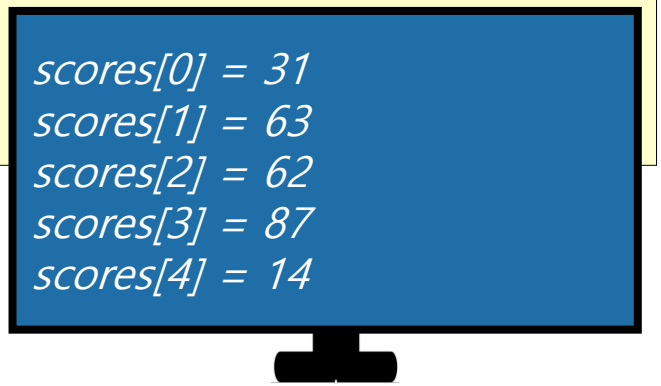
If you try to initialize all elements of an array to 10 as follows, it will be an error.

```
int scores[10] = { 10 };
```

At this time, only the first element becomes 10 and the remaining elements are all 0.

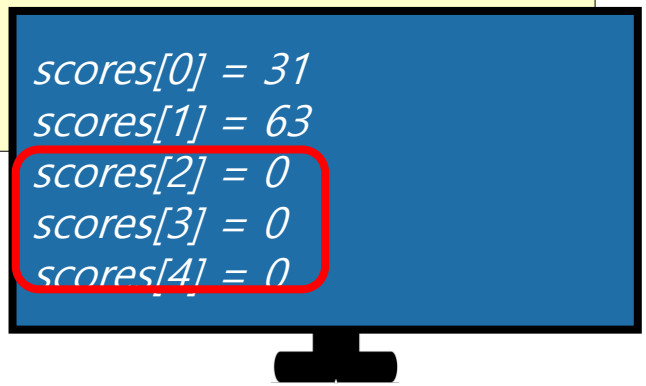
Array initialization example

```
#include < stdio.h >
#define SIZE 5

int main( void )
{
      int i ;
      int scores[SIZE] = { 31, 63, 62, 87, 14 };


      for (i = 0; i < SIZE; i++)
            printf( "scores[%d] = %d\n" , i, scores[i]);

      return 0;
}
```



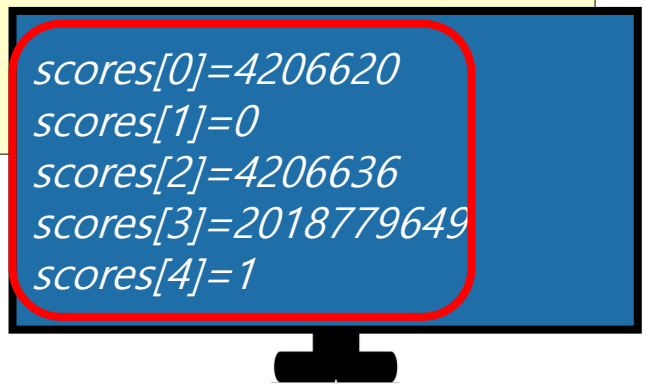
Array initialization example

```
#include < stdio.h >
#define SIZE 5

int main( void )
{
      int i ;
      int scores[SIZE] = { 31, 63 };


      for (i = 0; i < SIZE; i++)
            printf( "scores[%d] = %d\n" , i, scores[i]);

      return 0;
}
```



Array initialization example

```
#include < stdio.h >
#define SIZE 5

int main( void )
{
      int i ;
      int scores[SIZE] ;


      for (i = 0; i < SIZE; i++)
            printf( "scores[%d] = %d\n" , i, scores[i]);

      return 0;
}
```



reference

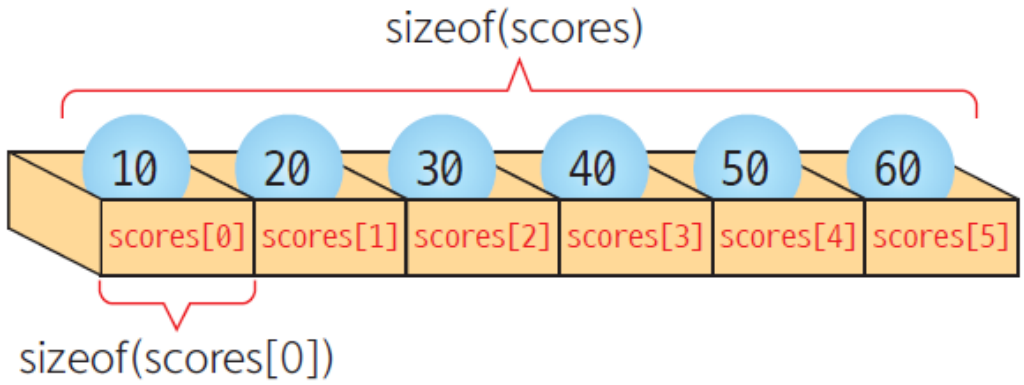
Note

You cannot assign values by enclosing them in curly brackets except when initializing an array. That is, if you use it like this, it will be an error: Assigning values to an array

To save, you must assign a value to each array element.

```
#define SIZE 3
int main(void)
{
        int scores[SIZE];
        scores = { 6, 7, 8 }; // Compile error!!
}
```

Counting the number of array elements




```
int scores[] = { 1, 2, 3, 4, 5, 6 };
int i , size;

size = sizeof (scores) / sizeof (scores[0]);

for ( i = 0; i < size ; i ++)
        printf ( "%d " , scores[ i ]);
```

Automatically calculate the number of array elements

Copying an array


```
int a[SIZE] ={1, 2, 3, 4, 5};
int b[SIZE];
a = b; // compile error !
```

Wrong way

```
int a[SIZE] ={1, 2, 3, 4, 5};
int b[SIZE];
int i ;

for ( i = 0; i < SIZE; i ++)
    a[ i ] = b[ i ];
```

Copy each element one by one

The right way

Comparing arrays

```
#include < stdio.h >
#define SIZE 5

int main( void )
{
        int i ;
        int a[SIZE] = { 1, 2, 3, 4, 5 };
        int b[SIZE] = { 1, 2, 3, 4, 5 };

        if ( a == b ) // ① Incorrect array comparison
                printf ( " Incorrect result .\n" );
        else
                printf ( " Incorrect result .\n" );
```

Comparing arrays

```
    for ( i = 0; i < SIZE ; i ++) // ② Correct array comparison
    {
          if ( a[ i ] != b[ i ] )
          {
                printf ( "a[] and b[] are not equal .\n" );
                return 0;
          }
    }
     printf ( "a[] and b[] are equal .\n" );
     return 0;
}
```

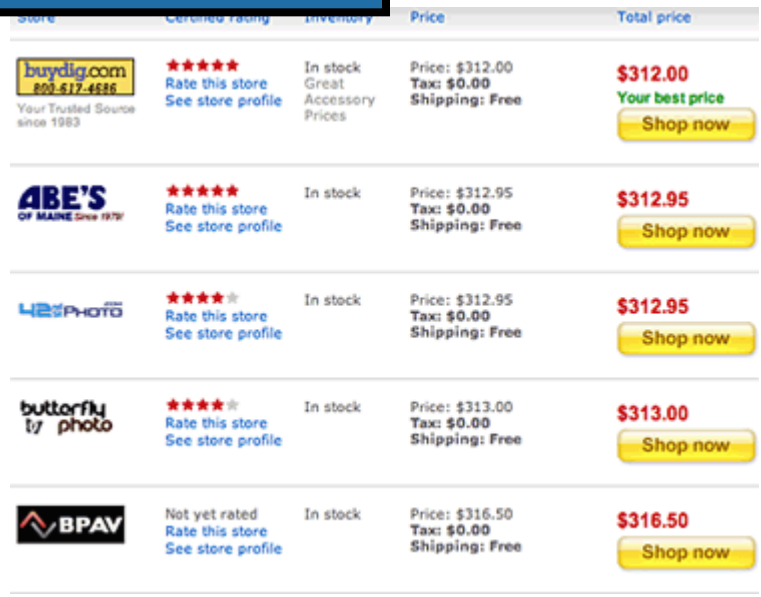
Compare elements **one by one**

Lab: Finding the minimum

- When we buy products on the Internet , we search for the ch eapest price through price comparison sites .
- similar to the problem of finding **the minimum value** among the integers in an array .

Execution results

```
----------------------------------------
1 2 3 4 5 6 7 8 9 10
----------------------------------------
28 81 60 83 67 10 66 97 37 94

The minimum value is 10 .
```



Algorithm

1. *Initialize the elements of array prices[] to random numbers .*
2. *assume that the first element is the minimum value minium .*
3. *for(i =1; i < size of array ; i ++)*
4. *if (prices[i] < minimum)*
5. *minimum = prices[i]*
6. *When the iteration ends, the minimum value is stored in minimum .*

Lab: Finding the minimum

```
#include < stdio.h >
#include < stdlib.h >
#include < time.h >
#define SIZE 10
int main( void )
{
    int prices[SIZE] = { 0 };
    int i , minimum;
    printf ( "-------------------------------------\n" );
    printf ( "1 2 3 4 5 6 7 8 9 10\n" );
    printf ( "-------------------------------------\n" );
    srand ( ( unsigned )time( NULL ) );
    for ( i = 0; i < SIZE; i ++){
            prices[ i ] = (rand()%100)+1;
              printf ( "%-3d " ,prices[ i ]);
    }
    printf ( "\n\n" );
```

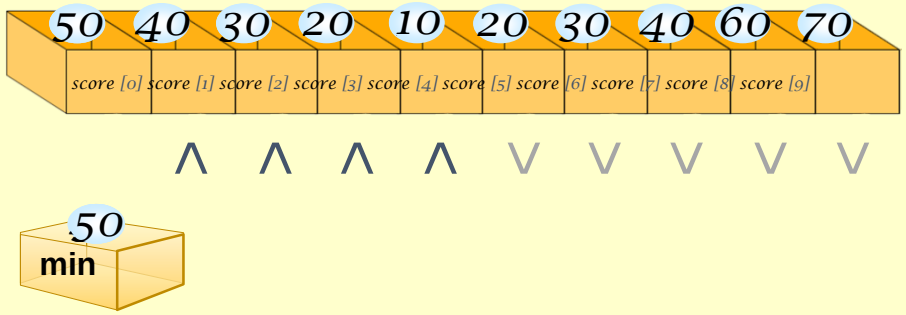
Output the price of the item

Lab: Finding the minimum

Assume the first array element is the minimum

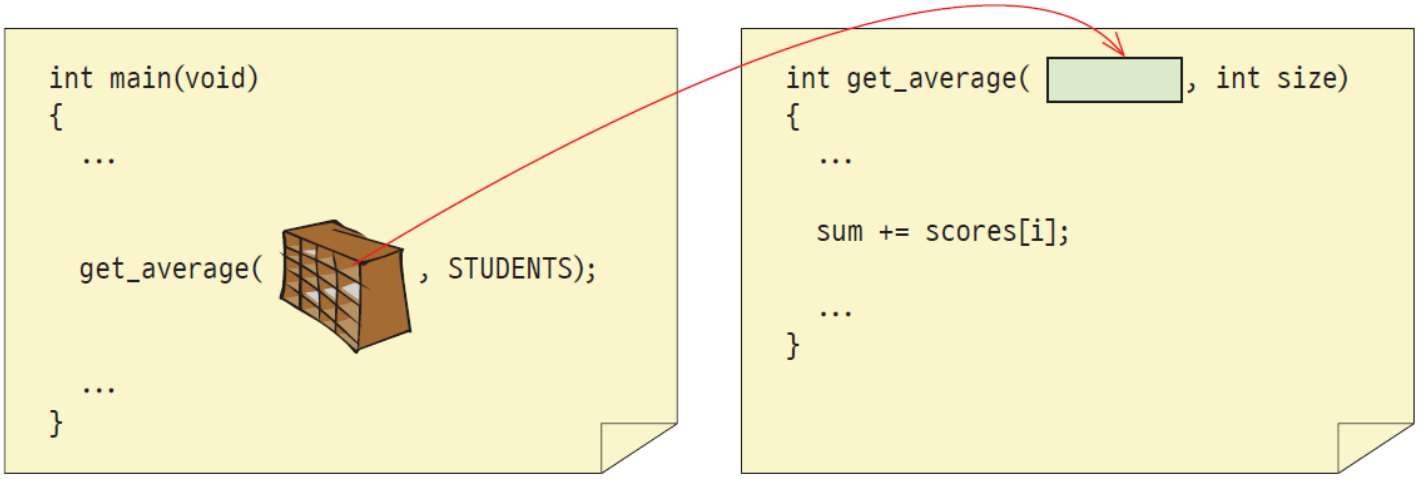
```
    minimum = prices[0];
    for ( i = 1; i < SIZE; i ++)
    {
        if ( prices[ i ] < minimum )
            minimum = prices[ i ];
    }
    printf ( " The minimum value is %d .\n" , minimum);
    return 0;
}
```

If an array element is smaller than the current minimum , the array element is copied to the minimum .



Arrays and functions

- In the case of arrays, the original is passed, not a copy .



Arrays and functions

```
#include < stdio.h >
#define STUDENTS 5
int get_average ( int scores[], int n);     // ①

int main( void )
{
        int scores[STUDENTS] = { 1, 2, 3, 4, 5 };
        int avg ;

        avg = get_average (scores, STUDENTS);
        printf ( " The average is %d .\n" , avg );
        return 0;
}

int get_average ( int scores[], int n) // ②
{
        int i ;
        int sum = 0;

        for ( i = 0; i < n; i ++)
                sum += scores[ i ];
        return sum / n;
}
```

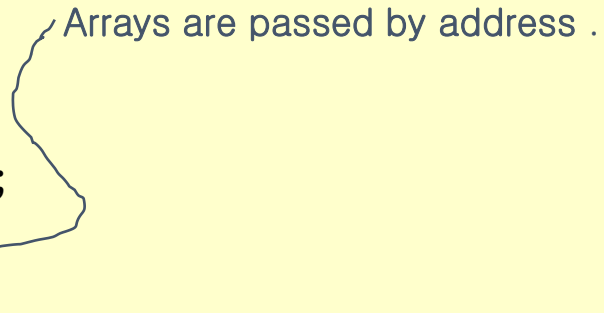
If the argument is an array ,
The address of the array is passed .

The original of the array
is passed to score[]

The average is 3 .

When array is an argument of a function

```
#include < stdio.h >
#define SIZE 7

void modify_array ( int a[], int size);
void print_array ( int a[], int size);

int main( void )
{
        int list[SIZE] = { 1, 2, 3, 4, 5, 6, 7 } ;

        print_array ( list , SIZE);
        modify_array ( list , SIZE);
        print_array ( list , SIZE);

        return 0;
}
```



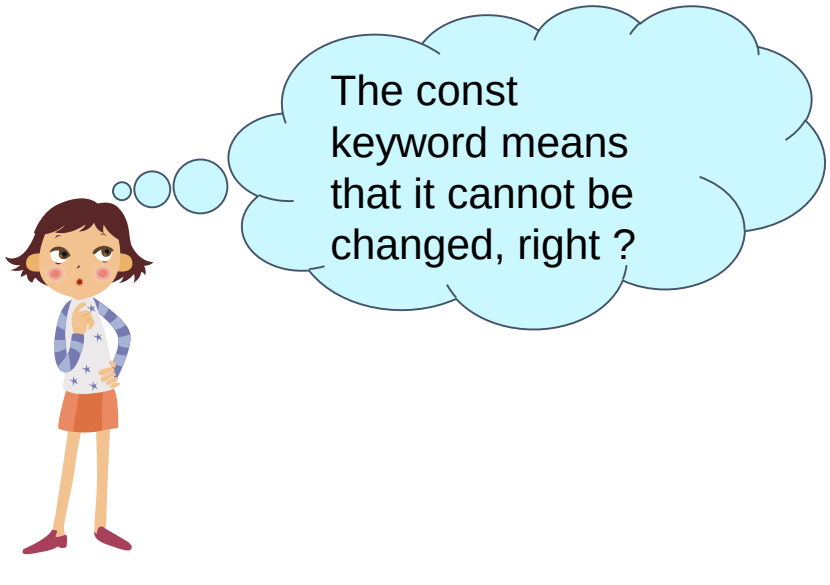
When array is an argument of a function

```
void modify_array ( int a[], int size)
{
        int i ;

        for ( i = 0; i < size; i ++)
              ++a[ i ];
}

void print_array ( int a[], int size)
{
        int i ;

        for ( i = 0; i < size; i ++)
               printf ( "%3d " , a[ i ]);
        printf ( "\n" );
}
```

How to prevent changes to the original array

```
void print_array ( const int a[], int size)
{
   ...
a[0] = 100; // Compile error !
}
```

a[] cannot be changed inside the function



What is sorting?

- Sorting is arranging items in ascending or descending order of size.
- Sorting is one of the most basic and important algorithms in c omputer engineering.

What is sorting ?

- Sorting is essential for data exploration .

  (Example) What if the words are not sorted in the dictiona ry ?

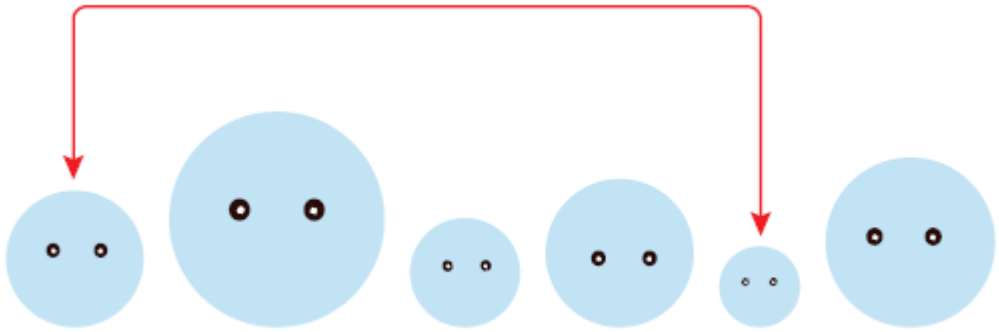
Selection sort

- Selection sort : Select the minimum value from the unsorted numbers and exchange it with the first element of the array.

left arrangement	right arrangement	explanation
( )	(5,3,8,1,2,7)	initial state
(1)	(5,3,8,2,7)	1Choose
(1,2)	(5,3,8,7)	2Choose
(1,2,3)	(5,8,7)	3Choose
(1,2,3,5)	(8,7)	5Choose
(1,2,3,5,7)	(8)	7Choose
(1,2,3,5,7,8)	()	8Choose

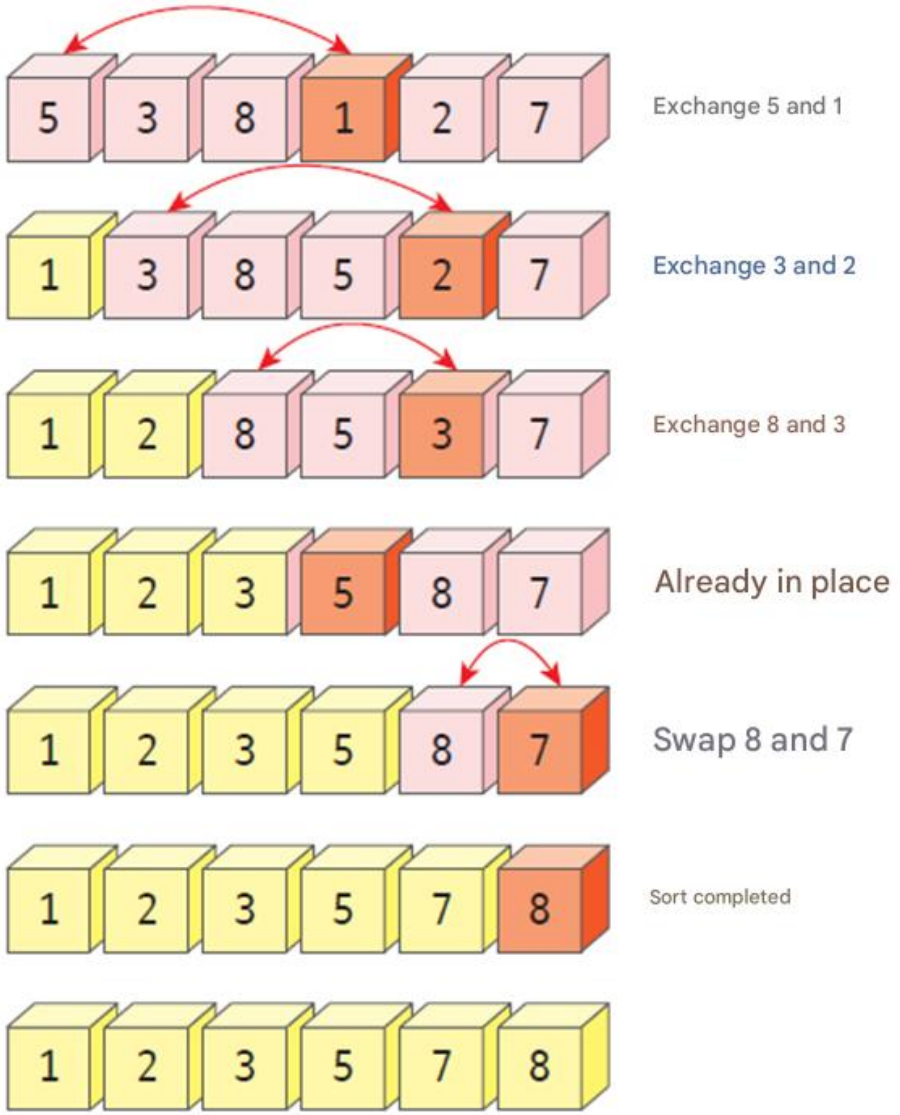
Array If you only want to use one ?

- to handle the value in the first place, and we can do this by t aking advantage of the fact that the place where the minimu m val



Selection sort

- Selection sort : Select the minimum value from the unsorted numbers and exchange it with the first element of the array.



Selection Sort

```
#include < stdio.h >
#define SIZE 10

int main( void )
{
   int list[SIZE] = { 3, 2, 9, 7, 1, 4, 8, 0, 6, 5 };
   int i , j, temp, least;

  for ( i = 0; i < SIZE-1; i ++)
  {
       least = i ;
      for (j = i + 1; j < SIZE; j++)
           if (list[j] < list[least])
               least = j;

      temp = list[ i ];
      list[ i ] = list[least];
      list[least] = temp;
  }
```

an inner for loop, it finds the minimum value from the (i+1) th element to the last element of the array. If a smaller integer is found by comparing it to the current minimum value, the index containing that integer is stored in least.

Swap list[i] and list[least]

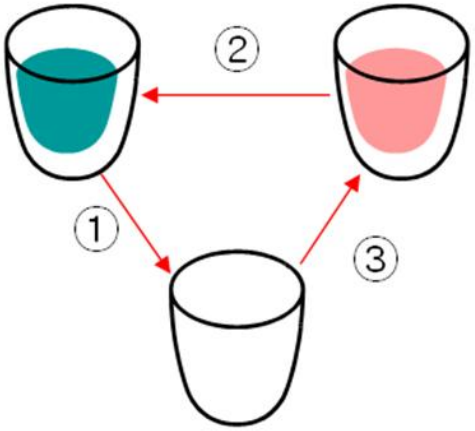
Selection Sort

```
  for ( i = 0; i < SIZE; i ++)
       printf ( "%d " , list[ i ]);

  printf ( "\n" );
  return 0;
}
```

When exchanging the values of variables

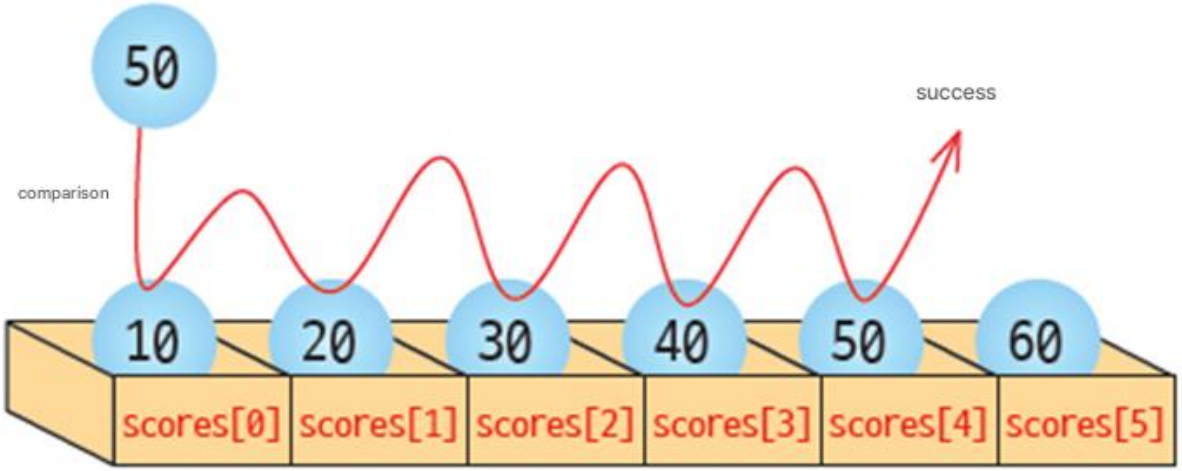
- Do not do the following:
  - list[i] = list[least]; // The existing value of list[i] is destroyed !
  - list[least] = list[i];

- The right way
  - temp = list[i];
  - list[i] = list[least];
  - list[least] = temp;



Sequential search

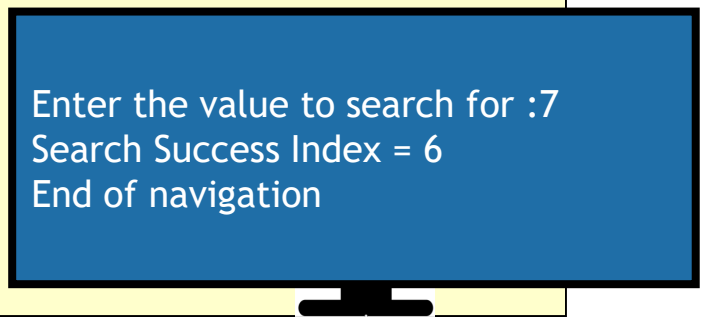
- Sequential The search is Array of The elements In order singly Take it out With the navigation keys By comparison desirous The value Go to method



Sequential search

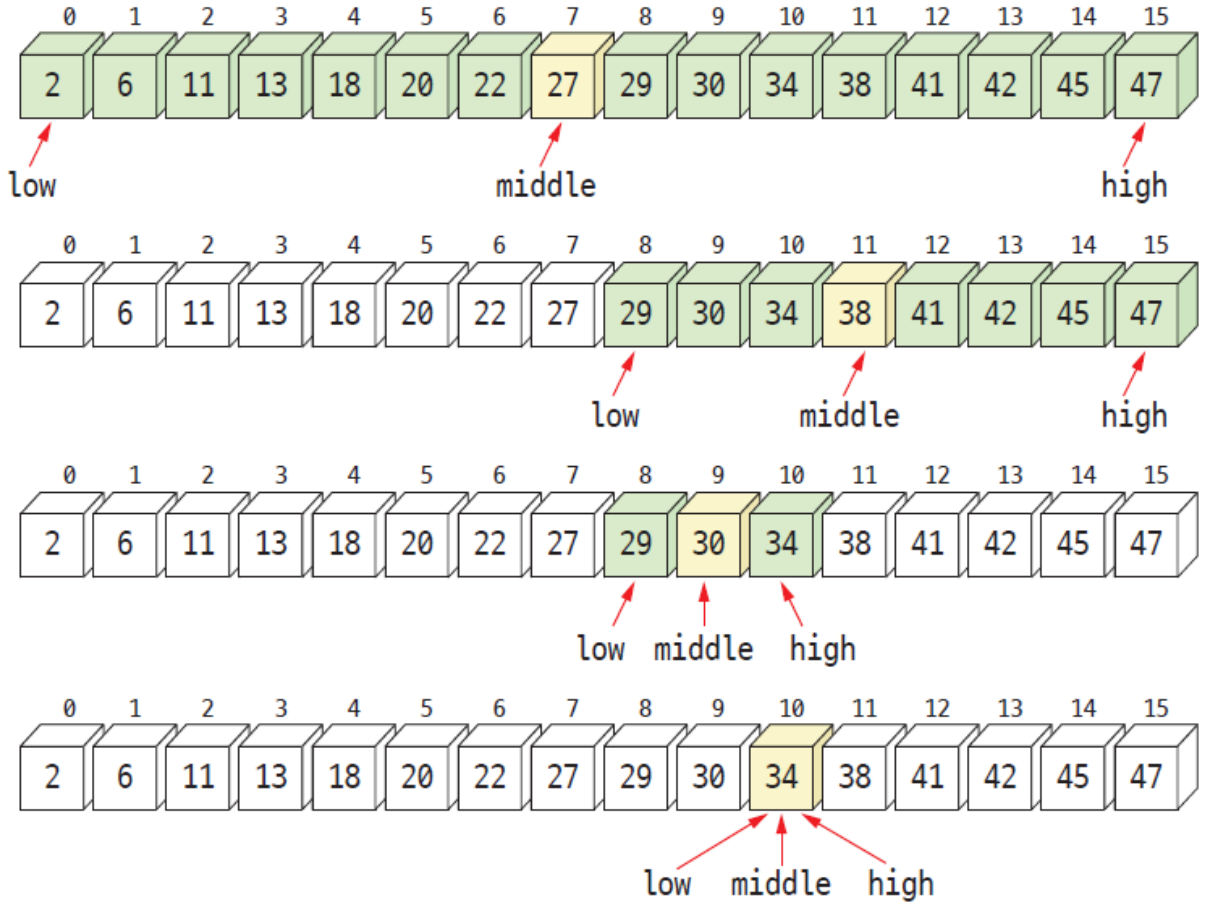
```
#include < stdio.h >
#define SIZE 10

int main( void )
{
   int key, i ;
   int list[SIZE] = { 1, 2, 3, 4, 5, 6, 7, 8, 9 };

   printf ( " Enter the value to search for :");
   scanf ( "%d" , &key);

  for ( i = 0; i < SIZE; i ++)
        if (list[ i ] == key)
              printf ( " Search success index = %d\n", i );

  printf ( " Search ended \n");
  return 0;
}
```

Using a for loop , the operation of comparing list[i] and key is repeated as many times as the size of the array. If list[i] and key are the same, the search is successful and the index of the array where the key value was found is printed .



Binary search

- Binary search : Repeated comparison with the element located at the center of a sorted array.



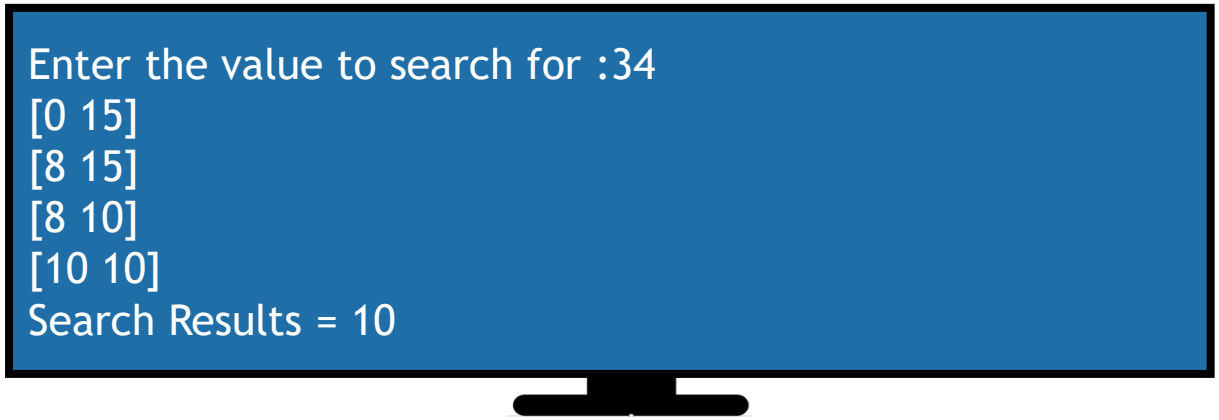
Binary search

```
#include < stdio.h >
#define SIZE 16
int binary_search ( int list[], int n, int key);

int main( void )
{
        int key;
        int grade [SIZE] = { 2,6,11,13,18,20,22,27,29,30,34,38,41,42,45,47 };
        printf ( " Enter the value to search for :" );
        scanf ( "%d" , &key);
        printf ( " Search result = %d\n" , binary_search (grade, SIZE, key));

        return 0;
}
```

Binary search

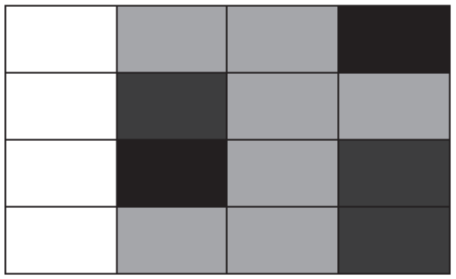
```
int binary_search ( int list[], int n, int key)
{
    int low, high, middle;
    low = 0;
    high = n-1;
    while ( low <= high ){ // If there are still numbers left
        printf ( "[%d %d]\n" , low, high); // Print the lower and upper limits .
        middle = (low + high)/2; // Calculate the middle position .
            if ( key == list[middle] ) // If matched, search succeeds
                return middle;
            else if ( key > list[middle] ) // If it is greater than the middle element
                low = middle + 1; // set
             else
                high = middle - 1; // set high to a new value
            }
            return -1;
}
```

Execution results



2-dimensional array

- The data itself is often two-dimensional . For example, digital images or board games are fundamentally two-dimensional.

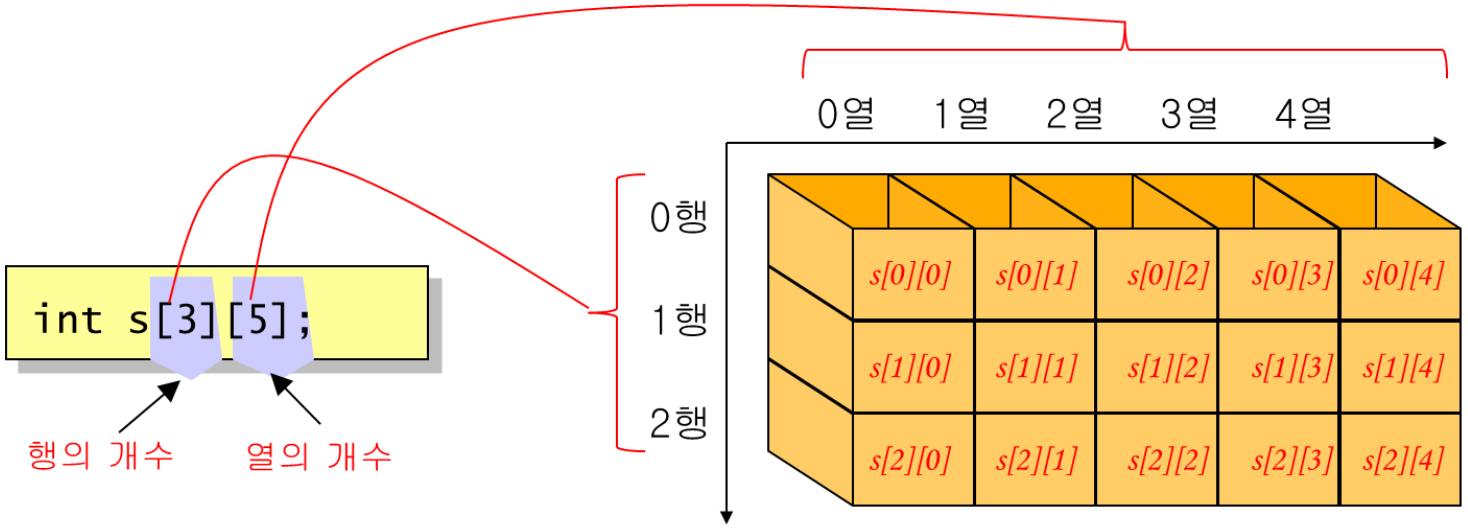


255	120	120	0
255	80	120	120
255	0	120	80
255	120	120	80

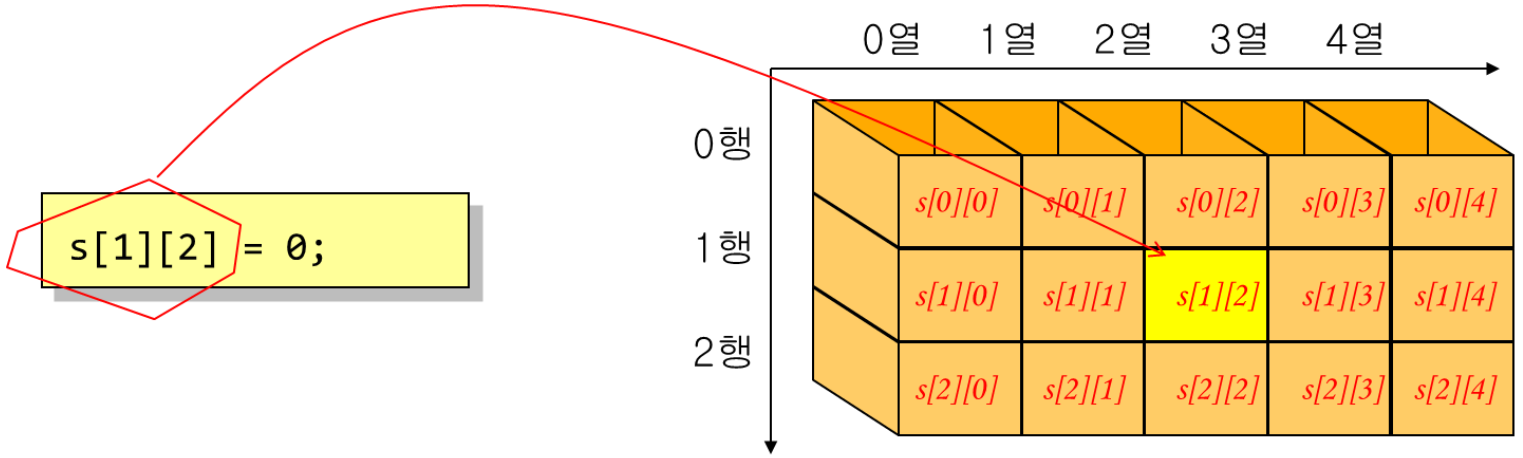
student number	Midterm Exam (30%)	Final exam (40%)	Final assignment (20%)	Quiz Score (10%)	Number of absences (point deduction)
1	87	98	80	76	3
2	99	89	90	90	0
3	65	68	50	49	0

2-dimensional array

```
int s[10]; // one- dimensional array
int s[3][10]; // 2- dimensional array
int s[5][3][10]; // 3- dimensional array
```



Index in a 2-dimensional array

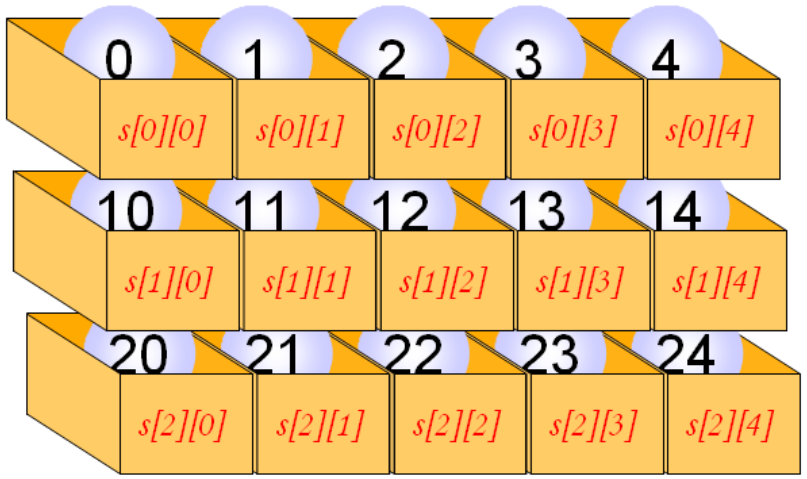


Utilizing 2-dimensional arrays

```
#include < stdio.h >
#include < stdlib.h >
#include < time.h >
#define ROWS 3
#define COLS 5

int main( void )
{
        int s[ ROWS ][ COLS ]; // Declare a two-dimensional array
        int i , j; // 2 index variables
         srand (( unsigned )time(NULL)); // Initialize

        for (i = 0; i < ROWS ; i++)
                for (j = 0; j < COLS ; j++ )
                        s[i][j] = rand() % 100;

        for (i = 0; i < ROWS ; i++) {
                for (j = 0; j < COLS ; j++ )
                        printf( " % 02d " , s[i][j]);
                printf ( "\n" );
        }
        return 0;
}
```

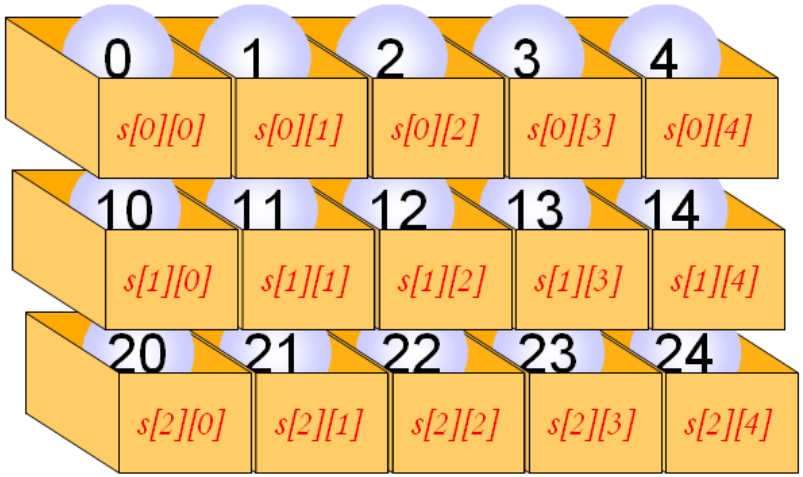
Initializing a 2-dimensional array

```
int s[3][5] = {
{ 0, 1, 2, 3, 4 }, // Initial values of elements in the first row
  { 10, 11, 12, 13, 14 }, // Initial values of elements in the second row
  { 20, 21, 22, 23, 24 } // Initial values of elements in the third row
};
```



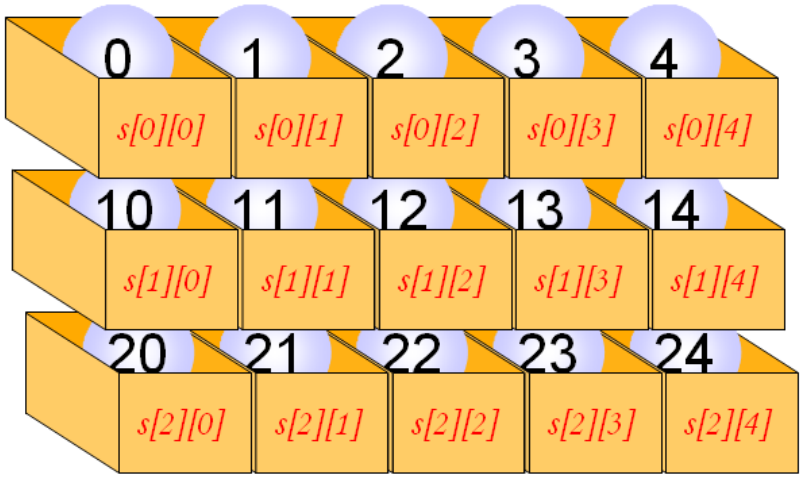
Initializing a 2-dimensional array

```
int s[ ][5] = {
{ 0, 1, 2, 3, 4 }, // Initial values of elements in the first row
  { 10, 11, 12, 13, 14 }, // Initial values of elements in the second row
  { 20, 21, 22, 23, 24 }, // Initial values of elements in the third row
};
```



Initializing a 2-dimensional array

```
int s[ ][5] = {
0, 1, 2, 3, 4, 10, 11, 12, 13, 14, 20, 21, 22, 23, 24
};
```



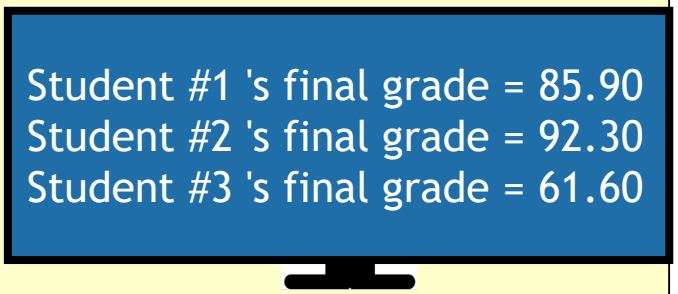
Example

- the students' grade sheets in a two- dimensional array and c alculate the final grade for each student .

student number	Midterm Exam (30%)	Final exam (40%)	Final assignment (20%)	Quiz Score (10%)	Number of absences (point deduction)
1	87	98	80	76	3
2	99	89	90	90	0
3	65	68	50	49	0

Initializing a 2-dimensional array

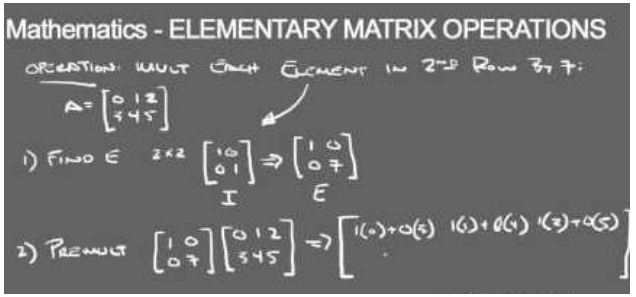
```
#include < stdio.h >
#define ROWS 3
#define COLS 5


int main( void )
{
        int a[ ROWS ][ COLS ] = { { 87, 98, 80, 76, 3 },
        { 99, 89, 90, 90, 0 },
        { 65, 68, 50, 49, 0 }
        };

        int i ;

        for (i = 0; i < ROWS ; i++) {
                double final_scores = a[ i ][0] * 0.3 + a[ i ][1] * 0.4 +
                                a[ i ][2] * 0.2 + a[ i ][3] * 0.1 - a[ i ][4];
                printf ( " Student #%i 's final grade =%10.2f \n" , i + 1, final_scores );
        }
        return 0;
}
```



Matrix

- The matrix is Used to solve many problems in natural science

$$A = \begin{bmatrix} 2 & 3 & 0 \\ 8 & 9 & 1 \\ 7 & 0 & 5 \end{bmatrix} \quad B = \begin{bmatrix} 0 & 0 & 0 & 7 & 0 & 0 \\ 9 & 0 & 0 & 0 & 0 & 8 \\ 0 & 0 & 0 & 0 & 0 & 0 \\ 6 & 5 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 1 \\ 0 & 0 & 2 & 0 & 0 & 0 \end{bmatrix}$$



Representation of matrices using multidimensional arrays

```
#include < stdio.h >
#define ROWS 3
#define COLS 3

int main( void )
{
        int A[ROWS][COLS] = { { 2,3,0 },
                              { 8,9,1 },
                              { 7,0,5 } };
        int B[ROWS][COLS] = { { 1,0,0 },
                              { 1,0,0 },
                              { 1,0,0 } };
        int C[ROWS][COLS];
```

Representation of matrices using multidimensional arrays

```
        int r, c;


        // Add two matrices .
        for (r = 0;r < ROWS; r++)
                for (c = 0;c < COLS; c++ )
                        C[r][c] = A[r][c] + B[r][c];


        // Print the matrix .
        for (r = 0;r < ROWS; r++)
        {
                for (c = 0;c < COLS; c++ )
                        printf ( "%d " , C[r][c]);
                printf ( "\n" );
        }
        return 0;
}
```

Using nested for loops, add each element of matrix A to each element of matrix B and assign it to matrix C.

```
3 3 0
9 9 1
8 0 5
```

Passing a 2-dimensional array to a function

```
#define _CRT_SECURE_NO_WARNINGS
#include < stdio.h >

#define  YEARS 3
#define  PRODUCTS 5

int sum( int scores [ YEARS ][ PRODUCTS ]);

int main( void )
{
        int sales[ YEARS ][ PRODUCTS ] = { {1, 2, 3}, {4, 5, 6}, {7, 8, 9} };
        int total_sale ;

        total_sale = sum(sales);
        printf ( " Total sales is %d .\n" , total_sale );


        return 0;
}
```

Passing a 2-dimensional array to a function

```
int sum( int scores [ YEARS ][ PRODUCTS ])
{
        int y, p;
        int total = 0;

        for (y = 0; y < YEARS ; y++)
                for (p = 0; p < PRODUCTS ; p++)
                        total += scores [y][p];

        return total;
}
```

reference

Note

In C, you can generally have n-dimensional arrays, such as two-dimensional arrays and three-dimensional arrays. In fact, there is no limit to the number of dimensions you can have in C.

```
int s[3][3][5]; //        3-dimensional array
```

However, you need to be careful because the amount of memory required increases drastically when it becomes multidimensional. It is usually better to avoid multidimensional arrays with three or more dimensions except in special cases. For example, a one-dimensional array that can store 100 integers only needs to be 400 bytes since one integer is 4 bytes, but a two-dimensional array of the size of 100 x 100 requires 40,000 bytes, and a three-dimensional array of the size of 100 x 100 x 100 requires 4,000,000 bytes. Therefore, you need to be careful not to increase the dimensions more than necessary.

Lab: **Image Processing**

- A digital image can be thought of as a 2-dimensional array

```
int image[8][16] = {
    { 1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1 },
    { 1,1,1,1,0,1,1,1,1,1,1,1,1,1,1,1 },
    { 1,1,1,0,0,1,1,1,1,1,1,1,1,1,1,1 },
    { 1,1,1,0,0,0,1,1,0,0,1,1,1,1,1,1 },
    { 1,1,0,0,0,0,0,0,0,0,1,1,1,1,1,1 },
    { 1,0,0,0,0,0,0,0,0,0,0,0,1,1,1,1 },
    { 1,0,0,0,0,0,0,0,0,0,0,0,0,1,1,1 },
    { 1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1 } };
```

Q & A