

FUNCTIONS

CS10003: PROGRAMMING AND DATA STRUCTURES



Introduction

Function

- A program segment that carries out a specific, well-defined task.
- Examples
 - A function to find the gcd of two numbers
 - A function to find the largest of n numbers

A function will carry out its intended task whenever it is called

- Functions may call other functions (or itself)
- A function may be called multiple times (with different arguments)

Every C program consists of one or more functions.

- One of these functions must be called “main”.
- Execution of the program always begins by carrying out the instructions in “main”.

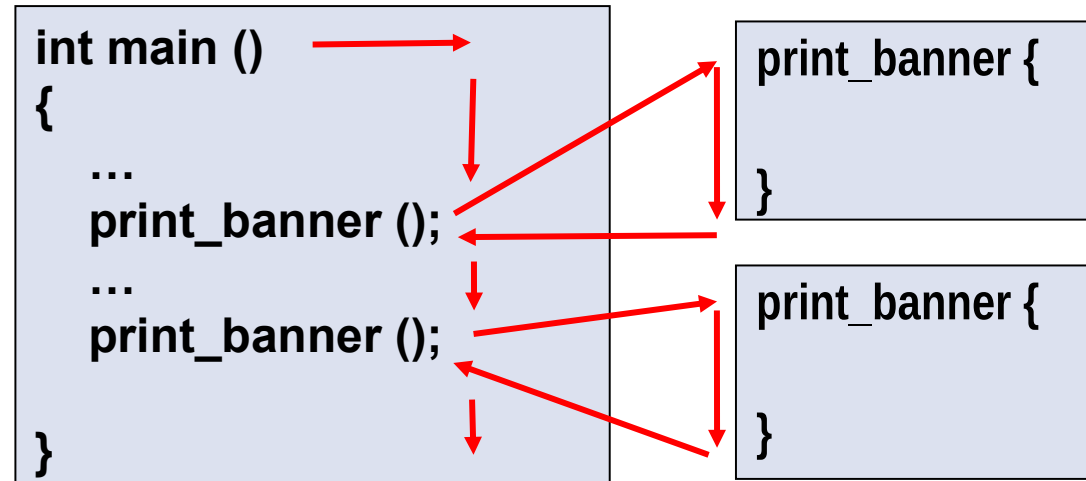
Function Control Flow

Code

```
void print_banner ( )  
{  
    printf("*****\n");  
}
```

```
int main ( )  
{  
    . . .  
    print_banner ( ) ;  
    . . .  
    print_banner ( ) ;  
}
```

Execution



If function A calls function B:

A : calling function / caller function

B : called function

Why Functions?

Functions allow one to develop a program in a modular fashion.

- Codes become readable
- Codes become manageable to debug and maintain

Write your own functions to avoid writing the same code segments multiple times

- If you check several integers for primality in various places of your code, just write a single primality-testing function, and call it on all occasions

Use existing functions as building blocks for new programs

- Use functions without rewriting them yourself every time it is needed
- These functions may be written by you or by others (like `sqrt()`, `printf()`)

Abstraction: Hide internal details (library functions)

Use of functions: *Area of a circle*

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

```
/* Function to compute the area of a circle */  
float  myfunc (float r)  
{  
    float  a;  
    a = 3.14159 * r * r;  
    return a;          /* return result */  
}
```

Function definition

Function argument

```
main()
```

```
{
```

```
    float  radius, area;
```

```
    scanf ("%f", &radius);
```

```
    area = myfunc (radius);
```

Function call

```
    printf ("\n Area is %f \n", area);
```

```
}
```

Use of functions: *Area of a circle*

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

```
/* Function to compute the area of a circle */  
float  myfunc (float r)  
{  
    float  a;  
    a = 3.14159 * r * r;  
    return a;      /* return  
}
```

Function definition

```
main()  
{  
    float  radius, area;  
  
    scanf ("%f", &radius);  
    area = myfunc (radius);  
    printf ("\n Area is %f \n", area);  
}
```

Function call

- A called function processes information that is passed to it from the calling function, and the called function may return a single value (result) to the calling function.
 - Information passed to the function via special identifiers called *arguments* or *parameters*.
 - The value is returned by the *return* statement.

Defining a Function

A function definition has two parts:

- The first line
- The body of the function

General syntax:

```
return-value-type function-name ( parameter-list )
{
    declarations and statements
}
```

The first line contains the return-value-type, the function name, and optionally a set of comma-separated arguments enclosed in ().

- Each argument has an associated type declaration.
- The arguments are called *formal arguments* or *formal parameters*.

Example:

```
float myfunc (float r)
```

```
int gcd (int A, int B)
```

return value
type



```
#include <stdio.h>

/* Function to compute the area of a
circle */
float myfunc (float r)
{
    float a;
    a = 3.14159 * r * r;
    return a;
}

main()
{
    float radius, area;

    scanf ("%f", &radius);
    area = myfunc (radius);
    printf ("\n Area is %f \n", area);
}
```

Calling a function

- Called by specifying the function name and parameters in an instruction in the calling function.
- When a function is called from some other function, the corresponding arguments in the function call are called **actual arguments** or **actual parameters**.
 - The function call must include a matching actual parameter for each **formal parameter**.
 - Position of an actual parameters in the parameter list in the call must match the position of the corresponding formal parameter in the function definition.
 - The formal and actual arguments would match in their data types. Mismatches are auto-typecasted if possible.
 - The actual parameters can be expressions possibly involving other function calls (like $f(g(x)+y)$).

```
#include <stdio.h>

/* Function to compute the area of a
circle */
float myfunc (float r)
{
    float a;
    a = 3.14159 * r * r;
    return a;
}

main()
{
    float radius, area;

    scanf ("%f", &radius);
    area = myfunc (radius);
    printf ("\n Area is %f \n", area);
}
```


Function Prototypes: declaring a function

Usually, a function is defined before it is called.

- `main()` is usually the last function in the program written.
- Easy for the compiler to identify function definitions in a single scan through the file.

Some prefer to write the functions after `main()`. There may be functions that call each other.

- Must be some way to tell the compiler what is a function when compilation reaches a function call.
- Function prototypes are used for this purpose
 - **Only needed if function definition comes after a call to that function.**

- Function prototypes are usually written at the beginning of a program, ahead of any functions (including `main()`).
- Prototypes must specify the types. Parameter names are optional (ignored by the compiler).

- Examples:

```
int gcd (int , int );
```

```
void div7 (int number);
```

- Note the semicolon at the end of the line.
- The parameter name, if specified, can be anything; but it is a good practice to use the same names as in the function definition.

Example:

Function prototype / declaration

```
#include <stdio.h>
int sum( int, int );
int main( )
{
    int x, y;
    scanf("%d%d", &x, &y);
    printf("Sum = %d\n", sum(x, y));
}

int sum (int a, int b)
{
    return a + b;
}
```

This program needs a function prototype or function declaration since the function call comes before the function definition.

Function call

Function definition

Return value

- A function can return a single value

Using return statement

- Like all values in C, a function return value has a type
- The return value can be assigned to a variable in the calling function

```
int main( )
{
    int x, y, s;
    scanf("%d%d", &x, &y);
    s = sum(x, y);
}

int sum (int a, int b)
{
    return a + b;
}
```

- Sometimes a function is not meant for returning anything
- Such functions are of type void

Example: A function which prints if a number is divisible by 7 or not.

```
void div7 (int n)
{
    if ((n % 7) == 0)
        printf ("%d divisible by 7", n);
    else
        printf ("%d not divisible by 7", n);
    return;
}
```

- The return type is void
- The return statement for void functions is optional at the end

The return statement

In a value-returning function, **return** does two distinct things:

- Specify the value returned by the execution of the function.
- Terminate the execution of the called function and transfer control back to the caller function.

A function can only return **one value**.

- The value can be any expression matching the return type.
- It might contain more than one return statement.

In a void function:

- "return" is optional at the end of the function body.
- "return" may also be used to terminate execution of the function explicitly **before reaching the end**.
- No return value should appear following "return".

```
void compute_and_print_itax ()
{
    float income;
    scanf ("%f", &income);
    if (income < 50000)    {
        printf ("Income tax = Nil\n");
        return; /* Terminates function execution */
    }
    if (income < 60000)    {
        printf ("Income tax = %f\n", 0.1*(income-50000));
        return; /* Terminates function execution */
    }
    if (income < 150000)   {
        printf ("Income tax = %f\n", 0.2*(income-60000)+1000);
        return ; /* Terminates function execution */
    }
    printf ("Income tax = %f\n", 0.3*(income-150000)+19000);
}
```

Another Example: What is happening here?

```
int main()
{
    int numb, flag, j=3;
    scanf("%d",&numb);
    while (j <= numb) {
        flag = prime(j);
        if (flag == 0)
            printf( "%d is prime\n", j );
        j++;
    }
    return 0;
}
```

```
int prime (int x)
{
    int i, test;
    i=2, test =0;
    while ((i <= sqrt(x)) && (test ==0))
    {
        if (x%i==0) test = 1;
        i++;
    }
    return test;
}
```

Tracking the flow of control

```
int main()
{
    int numb, flag, j=3;
    scanf("%d",&numb);
    printf("numb = %d \n",numb);
    while (j <= numb)
    {
        printf("\nMain, j = %d\n",j);
        flag = prime(j);
        printf("Main, flag = %d\n",flag);

        if (flag == 0) printf("%d is prime\n",j);
        j++;
    }
    return 0;
}
```

```
int prime(int x)
{
    int i, test;
    i = 2; test = 0;
    printf("In function, x = %d \n",x);
    while ((i <= sqrt(x)) && (test == 0))
    {
        if (x%i == 0) test = 1;
        i++;
    }
    printf("Returning, test = %d \n",test);
    return test;
}
```

PROGRAM OUTPUT

5
numb = 5

Main, j = 3
In function, x = 3
Returning, test = 0
Main, flag = 0
3 is prime

Main, j = 4
In function, x = 4
Returning, test = 1
Main, flag = 1

Main, j = 5
In function, x = 5
Returning, test = 0
Main, flag = 0
5 is prime

Nested Functions

A function cannot be defined within another function. It can be called within another function.

- All function definitions must be disjoint.

Nested function calls are allowed.

- A calls B, B calls C, C calls D, etc.
- The function called last will be the first to return.

A function can also call itself, either directly or in a cycle.

- A calls B, B calls C, C calls back A.
- Called **recursive call** or **recursion**.

Example: main() calls ncr(), ncr() calls fact()

```
#include <stdio.h>

int ncr (int n, int r);
int fact (int n);

main()
{
    int i, m, n, sum=0;
    scanf ("%d %d", &m, &n);

    for (i=1; i<=m; i+=2)
        sum = sum + ncr(n, i) ;

    printf ("Result: %d \n", sum);
}
```

```
int ncr (int n, int r)
{
    return (fact(n) / fact(r) / fact(n-r));
}

int fact (int n)
{
    int i, temp=1;
    for (i=1; i<=n; i++)
        temp *= i;
    return (temp);
}
```


Local variables

A function can define its own local variables.

The local variables are known (can be accessed) only within the function in which they are declared.

- Local variables cease to exist when the function returns.
- Each execution of the function uses a new set of local variables.

Parameters are also local.

```
/* Find the area of a circle with  
diameter d */  
double circle_area (double d)  
{  
    double radius, area;  
    radius = d/2.0;  
    area = 3.14*radius*radius;  
    return (area);  
}
```

parameter

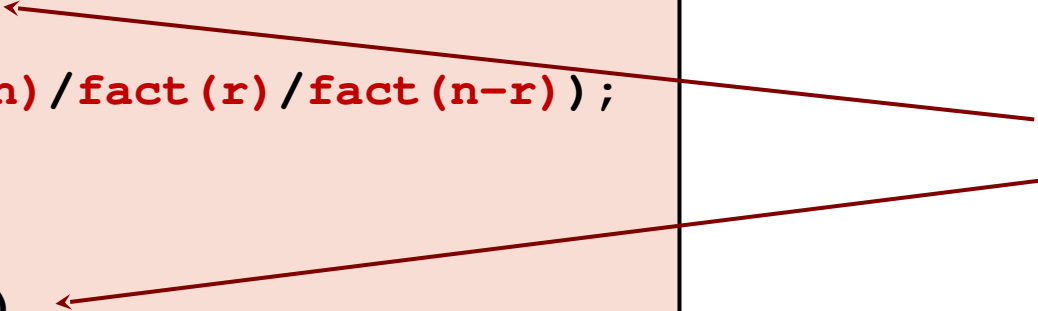
local variables

Revisiting nCr

```
int ncr (int n, int r)
{
    return (fact(n) / fact(r) / fact(n-r));
}

int fact (int n)
{
    int i, temp=1;
    for (i=1; i<=n; i++)
        temp *= i;
    return (temp);
}
```

The n in ncr() and
the n in fact() are
different



Scope of a variable

- Part of the program from which the value of the variable can be used (seen).
- Scope of a variable - Within the block in which the variable is defined.
 - Block = group of statements enclosed within { }
- Local variable – scope is usually the function in which it is defined.
 - So two local variables of two functions can have the same name, but they are different variables
- Global variables – declared outside all functions (even main).
 - Scope is entire program by default, but can be hidden in a block if local variable of same name defined
 - You are encouraged to avoid global variables

What happens here?

Scope of
global A

```
#include <stdio.h>
int A;  /* This A is a global variable */
void main( )
{
    A = 1;
    myProc( );
    printf ( "A = %d\n", A );
}

void myProc( )
{
    A = 2;

    /* other statements */
    printf ( "A = %d\n", A );
}
```

A = 2

A = 2

Local Scope replaces Global Scope

Scope of
global A

Scope of
local A

```
#include <stdio.h>
int A;    /* This A is a global variable */
void main( )
{
    A = 1;
    myProc( );
    printf ( "A = %d\n", A ); —————> A=1
}

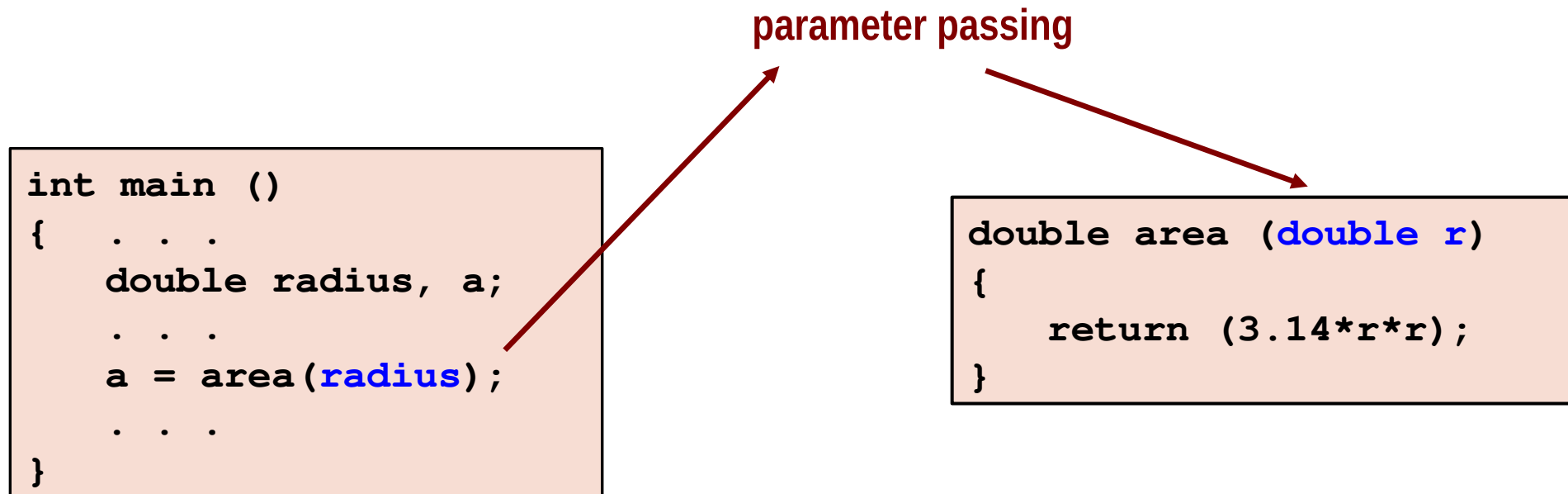
void myProc( )
{
    int A = 2;    /* This A is a local variable */

    /* other statements */
    /* within this function, A refers to the local A */

    printf ( "A = %d\n", A ); —————> A=2
}
```

Parameter Passing

When the function is called, the **value** of the actual parameter is **copied** to the formal parameter



Parameter Passing by Value in C

- Used when invoking functions

Call by value / parameter passing by value

- Called function gets a copy of the value of the actual argument passed to the function.
- **Execution of the function does not change the actual arguments.**
 - All changes to a parameter done inside the function are done on the copy.
 - The copy is removed when the control returns to the caller function.
 - The value of the actual parameter in the caller function is not affected.
- The arguments passed may very well be **expressions** (example: fact(n-r)).

Call by reference

- Passes the **address** of the original argument to a called function.
- Execution of the function may affect the original argument in the calling function.
- Not directly supported in C, but supported in some other languages like C++.
- In C, you can pass *copies* of addresses to get the desired effect.

Parameter passing and return: 1

```
int main()
{
    int a=10, b;
    printf ("Initially a = %d\n", a);
    b = change (a);
    printf ("a = %d, b = %d\n", a, b);
    return 0;
}

int change (int x)
{
    printf ("Before x = %d\n", x);
    x = x / 2;
    printf ("After x = %d\n", x);
    return (x);
}
```

Output

```
Initially a = 10
Before x = 10
After x = 5
a = 10, b = 5
```


Parameter passing and return: 2

```
int main()
{
    int x=10, b;
    printf ("M: Initially x = %d\n", x);
    b = change (x);
    printf ("M: x = %d, b = %d\n", x, b);
    return 0;
}

int change (int x)
{
    printf ("F: Before x = %d\n", x);
    x = x / 2;
    printf ("F: After x = %d\n", x);
    return (x);
}
```

Output

M: Initially x = 10

F: Before x = 10

F: After x = 5

M: x = 10, b = 5

Parameter passing and return: 3

```
int main()
{
    int x=10, y=5;
    printf ("M1: x = %d, y = %d\n", x, y);
    interchange (x, y);
    printf ("M2: x = %d, y = %d\n", x, y);
    return 0;
}

void interchange (int x, int y)
{
    int temp;
    printf ("F1: x = %d, y = %d\n", x, y);
    temp= x; x = y; y = temp;
    printf ("F2: x = %d, y = %d\n", x, y);
}
```

Output

M1: x = 10, y = 5

F1: x = 10, y = 5

F2: x = 5, y = 10

M2: x = 10, y = 5

How do we write an interchange function?
(will see later)

Header files and preprocessor



Header Files

Header files:

- Contain function declarations / prototypes for library functions.
- `<stdlib.h>` , `<math.h>` , etc.
- Load with: `#include <filename>`
- Example: `#include <math.h>`
- The function definitions of library functions are in the actual libraries (e.g., math library).

We can also create custom header files:

- Create file(s) with function prototypes / declarations.
- Save as `filename.h` (say).
- Load in other files with `#include "filename.h"`

C preprocessor

- Statements starting with `#` are handled by the C preprocessor
- May be done by the compiler or by a separate program
- Preprocessing is done before the actual compilation process begins
- The C preprocessor is basically a text substitution tool
- For instance, `#include` command is replaced by the contents of the specified header file
- Such commands are called **preprocessor directives**
- We will study another preprocessor directive: `#define`
- There are more such directives – see book

#define: Macro definition

Preprocessor directive in the following form:

#define string1 string2

- Replaces string1 by string2 wherever it occurs before compilation. For example,

#define PI 3.1415926

```
#define PI 3.1415926
main()
{
    float r = 4.0, area;
    area = PI * r * r;
}
```

macro pre-processing

```
main()
{
    float r = 4.0, area;
    area = 3.1415926 * r * r;
}
```

#define with arguments

#define statement may be used with arguments.

- Example: `#define sqr(x) x*x`
- How will macro substitution be carried out?
`r = sqr(a) + sqr(30);` \rightarrow `r = a*a + 30*30;`
`r = sqr(a+b);` \rightarrow `r = a+b*a+b;`

- The macro should better be written as:

```
#define  sqr(x)  (x) * (x)
r = sqr(a+b);    $\rightarrow$       r = (a+b) * (a+b);
```

WRONG?



- Is this still correct?

```
r = c / sqr(a+b);    $\rightarrow$       r = c / (a+b) * (a+b);
```

Macros are not functions. They are literally substituted without evaluation.

Practice Problems

No separate problems needed.

- Look at everything that you did so far, such as finding sum, finding average, counting something, checking if something is true or false (“Is there an element in array A such that...”) etc. in which the final answer is one thing only (like sum, count, 0 or 1,...).
- Then for each of them, rather than doing it inside main (as you have done so far), write it as a function with appropriate parameters, and call from main() to find and print.
- Normally, read and print everything from main(). Do not read or print anything inside the function. This will give you better practice.
- However, you can write simple functions for printing an array.

Passing Arrays to a Function



How to pass arrays to a function?

An array name can be used as an argument to a function.

- Permits the entire array (not exactly) to be passed to the function.
- The way it is passed differs from that for ordinary variables.

Rules:

- **Function definition:** corresponding formal argument is declared by writing the array name followed by a pair of empty brackets.

```
f ( int A[] )  
{  
    ...  
}
```

- **Function call:** the array name must appear by itself as argument, without brackets or subscripts.

```
f (A) , f (B)
```

We can also write

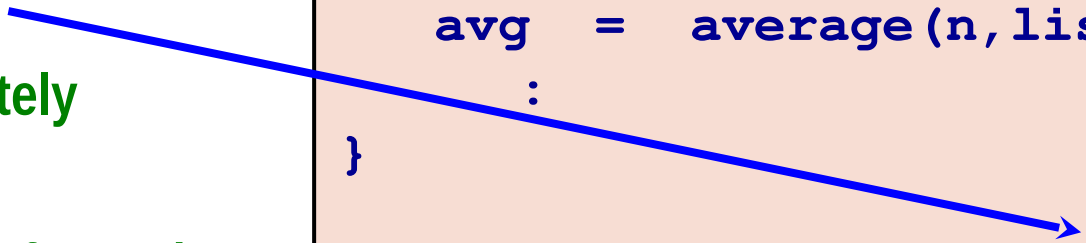
float x[100]

The compiler completely ignores the size 100.

You can pass arrays of any size to the function. There is no obligation that only an array of size 100 has to be passed.

```
main()
{
    int    n;
    float  list[100], avg;
        :
    avg   =  average(n, list);
        :
}

float average(int a, float x[])
{
    :
    sum = sum + x[i];
}
```



Example: Minimum of a set of numbers

```
#include <stdio.h>
int minimum (int x[], int y);

main()
{
    int a[100], i, n;

    scanf ("%d", &n);
    for (i=0; i<n; i++)
        scanf ("%d", &a[i]);

    printf ("\n Minimum is %d",

                minimum(a,n) );
}
```

```
int minimum(int x[], int size)
{
    int i, min = 99999;

    for (i=0; i<size; i++)
        if (min > x[i])
            min = x[i];
    return (min);
}
```

Note: When a function takes an array as argument, it does not care about how big the array is declared to be. Moreover, the user is not forced to use the entire allocated array. The programmer must specify to the function “I am using *only these many elements of the array*.”

The Actual Mechanism

When an array is passed to a function, the values of the array elements are *not passed* to the function.

- The array name is interpreted as the **address** of the first array element.
- The formal argument therefore becomes a **pointer** to the first array element.
- When an array element is accessed inside the function, the address is calculated using the formula stated before.
- **Changes made to the array elements inside the called function are also reflected in the calling function.**

Parameters are passed in C using *call-by-value*.

Passing the starting address when an array is sent as argument simulates *call-by-reference*.

Basically what it means:

- If a function changes the elements of an array that is passed as argument, these changes will be made to the **original** array that is passed to the function.
- This does **not** apply when an individual element of an array is passed as argument.

```
void f ( int A[], int B )
{
    A[2] = 10;
    B = 10;
}
int main ()
{
    int A[] = {1,2,3,4,5}, B[] = {1,2,3,4,5};
    f(A,B[2]);
    printf("A[2] = %d, B[2] = %d\n", A[2], B[2]);
}
```

A[2] = 10, B[2] = 3

Example: Square each element of array

```
#include <stdio.h>
void square (int a[], int b);

main()
{
    int a[100], i, n;

    scanf ("%d", &n);
    for (i=0; i<n; i++)
        scanf ("%d", &a[i]);

    square (a, n);

    printf ("\nNew array is: ");
    for (i=0; i<n; i++)
        printf (" %d", a[i]);
    printf ("\n");
}
```

```
void square (int x[], int size)
{
    int i;

    for (i=0; i<size; i++)
        x[i] = x[i]*x[i];

    return;
}
```

Address of parameter x (an array) is passed, but parameter size is passed normally by value.

Practice Problems

1. Read in an integer n ($n < 25$). Read n integers in an array A . Then do the following (write separate programs for each, only the reading part is common).
 - a) Find the sum of the absolute values of the integers.
 - b) Copy the positive and negative integers in the array into two additional arrays B and C respectively. Print A , B , and C .
 - c) Exchange the values of every pair of values from the start (so exchange $A[0]$ and $A[1]$, $A[2]$ and $A[3]$ and so on). If the number of elements is odd, the last value should stay the same.

2. Read in two integers n and m ($n, m < 50$). Read n integers in an array A . Read m integers in an array B . Then do the following (write separate programs for each part, only the reading part is common).
 - a) Find if there are any two elements x, y in A and an element z in B , such that $x + y = z$
 - b) Copy in another array C all elements that are in both A and B (intersection)
 - c) Copy in another array C all elements that are in either A and B (union)
 - d) Copy in another array C all elements that are in A but not in B (difference)