

Week 5 - Lecture 1, 2

Functions

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Overview

- **Function**
- Function Call Stack
- Passing data by values and references



Prepacked Functions

- C standard libraries e.g. printf, scanf, pow

`#include <math.h>`

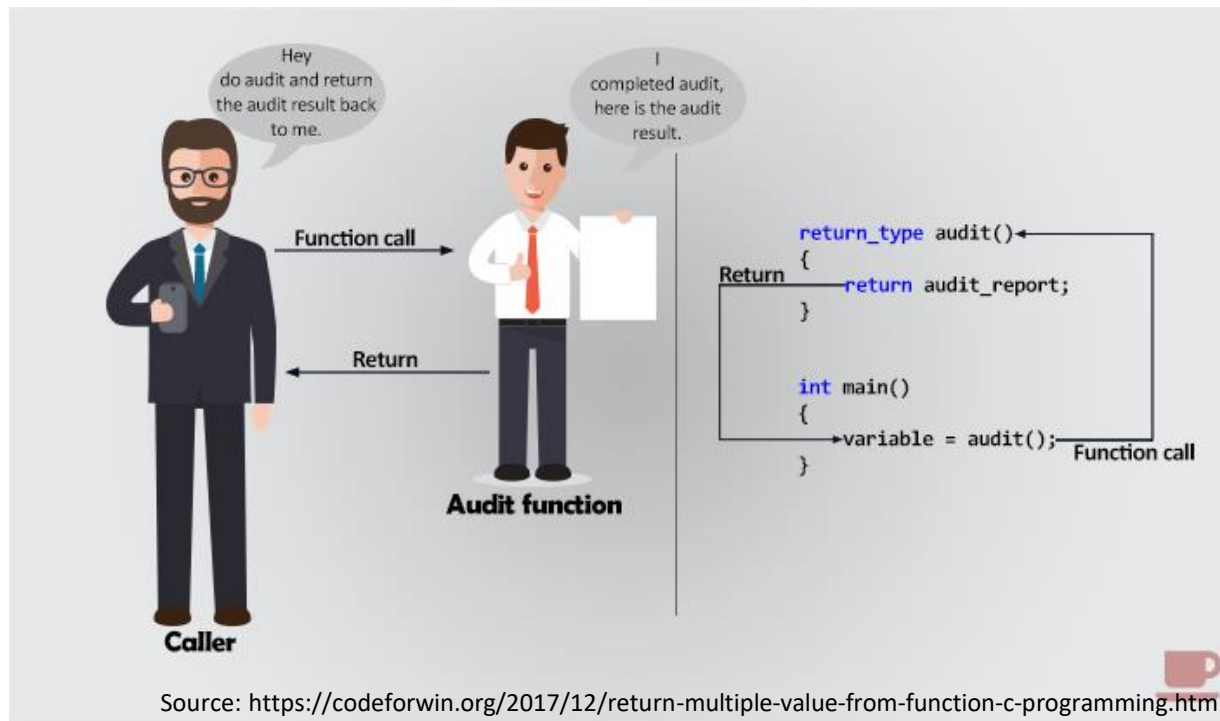
Function	Description	Example
<code>sqrt(x)</code>	square root of x	<code>sqrt(900.0)</code> is 30.0 <code>sqrt(9.0)</code> is 3.0
<code>cbrt(x)</code>	cube root of x (C99 and C11 only)	<code>cbrt(27.0)</code> is 3.0 <code>cbrt(-8.0)</code> is -2.0
<code>exp(x)</code>	exponential function e^x	<code>exp(1.0)</code> is 2.718282 <code>exp(2.0)</code> is 7.389056
<code>log(x)</code>	natural logarithm of x (base e)	<code>log(2.718282)</code> is 1.0 <code>log(7.389056)</code> is 2.0
<code>log10(x)</code>	logarithm of x (base 10)	<code>log10(1.0)</code> is 0.0 <code>log10(10.0)</code> is 1.0 <code>log10(100.0)</code> is 2.0
<code>fabs(x)</code>	absolute value of x as a floating-point number	<code>fabs(13.5)</code> is 13.5 <code>fabs(0.0)</code> is 0.0 <code>fabs(-13.5)</code> is 13.5
<code>ceil(x)</code>	rounds x to the smallest integer not less than x	<code>ceil(9.2)</code> is 10.0 <code>ceil(-9.8)</code> is -9.0
<code>floor(x)</code>	rounds x to the largest integer not greater than x	<code>floor(9.2)</code> is 9.0 <code>floor(-9.8)</code> is -10.0
<code>pow(x, y)</code>	x raised to power y (x^y)	<code>pow(2, 7)</code> is 128.0 <code>pow(9, .5)</code> is 3.0
<code>fmod(x, y)</code>	remainder of x/y as a floating-point number	<code>fmod(13.657, 2.333)</code> is 1.992
<code>sin(x)</code>	trigonometric sine of x (x in radians)	<code>sin(0.0)</code> is 0.0
<code>cos(x)</code>	trigonometric cosine of x (x in radians)	<code>cos(0.0)</code> is 1.0
<code>tan(x)</code>	trigonometric tangent of x (x in radians)	<code>tan(0.0)</code> is 0.0

Source: Deitel and Deitel (2016). C How to Program with an Introduction to C++ (8th Ed.). Pearson.



Function

- Same way you have been using printf or scanf.
- Hide (encapsulate) information from user.



Function (2)

- An independent block of code that performs a specific task when called, and it may **return a value** to the calling program.
 - e.g., `pow()`, `fmod()`.
- If you want, you can ignore return values from functions by just not using or storing them.
 - e.g., `printf()`, `scanf()`.



Function (3)

- Each function is essentially a small program, with its own **variables** and **statements**.
- Functions must be defined or declared before they are used.
- It has a name
- 0 or 1 return value
- A function body, includes the code
- 0 or more parameters i.e. argument.
 - E.g. `int main (void)`
 `int function(int x, char c)`



Function (4)


- Benefits:
 - The divide-and-conquer approach makes program development more manageable.
 - **software reusability**—using existing functions as *building blocks* to create new programs.
 - A third motivation is to avoid repeating code in a program.



Function (5)

- What does this program do?

```
2  #include <stdio.h>
3  #include <stdlib.h>
4
5  int max(int a, int b);
6
7  int main(int argc, char *argv[])
8  {
9      if(argc == 3)
10     {
11         printf("Max value between %s and %s is: ", argv[1], argv[2]);
12         printf("%d\n", max(atoi(argv[1]), atoi(argv[2])));
13     }
14
15     return 0;
16 }
17
18 int max(int a, int b)
19 {
20     if(a > b)
21     {
22         return a;
23     }
24     else
25     {
26         return b;
27     }
28 }
```




```

2  #include <stdio.h>
3  #include <stdlib.h>
4
5  int max(int a, int b);
6
7  int main(int argc, char *argv[])
8  {
9      if(argc == 3)
10     {
11         printf("Max value between %s and %s is: ", argv[1], argv[2]);
12         printf("%d\n", max(atoi(argv[1]), atoi(argv[2])));
13     }
14
15     return 0;
16 }
17
18 int max(int a, int b)
19 {
20     if(a > b)
21     {
22         return a;
23     }
24     else
25     {
26         return b;
27     }
28 }

```

C:\> maximum

Please enter two numbers

C:\> maximum 3 2

Maximum value between 3 and 2 is: 3



Function (6)

```
2  #include <stdio.h>
3  #include <stdlib.h>
4
5  int max(int a, int b);
6
7  int main(int argc, char *argv[])
8  {
9      if(argc == 3)
10     {
11         printf("Max value between %s and %s is: ", argv[1], argv[2]);
12         printf("%d\n", max(atoi(argv[1]), atoi(argv[2])));
13     }
14
15     return 0;
16 }
17
18 int max(int a, int b)
19 {
20     if(a > b)
21     {
22         return a;
23     }
24     else
25     {
26         return b;
27     }
28 }
```

Declaration

Arguments

Return statement

Definition



```

2  #include <stdio.h>
3  #include <stdlib.h>
4
5  int max(int a, int b);
6
7  int main(int argc, char *argv[])
8  {
9      if(argc == 3)
10     {
11         printf("Max value between %s and %s is: ", argv[1], argv[2]);
12         printf("%d\n", max(atoi(argv[1]), atoi(argv[2])));
13     }
14
15     return 0;
16 }
17
18 int max(int a, int b)
19 {
20     if(a > b)
21     {
22         return a;
23     }
24     else
25     {
26         return b;
27     }
28 }

```

Declaration

Arguments

Return statement

Definition

Function Declaration

Parameters are separated by commas.

Use “void” if no parameter or use an empty bracket.

- **return_type** function_name(parameter_list);

Return at most 1 value, if return type is missing, the function is presumed to return type int.

If returns nothing, use “void”.

e.g. **void** show(char ch);
double show(int a, float b);

- Declare in header files
 - If you use multiple ".c" source files, write a header file with declarations of functions to use in the other files.
- For library functions, use #include ...

e.g. printf(), scanf() use #include <stdio.h>



Function Definition

- **return_type** function_name(parameter_list)
{
 /* Function body */
}

No semi-colon at the end!

```
void test();  
int main(){  
    test();  
    return 0;  
}
```

The function's body is executed only if the function is called somewhere in the program.

```
void test(){  
    /* Function body. */  
    printf("In\n");  
}
```

The function terminates if either an exit statement (i.e., return) is called or its last statement is executed.



return Statement

- To terminate immediately the execution of a function and continues from the point where the function was called.

```
int main(void)
{
    while(1){
        printf("Enter number: ");
        scanf("%d", &num);
        if(num == 2)
            return 0; /* Program termination. */
        else
            printf("Num = %d\n", num);
    }
}
```

Don't do this!!

Indicates normal
program termination



return Statement (2)

- Make sure the type of the returned value matches the function's return type.

```
36 #include <stdio.h>
37
38 int avg(float a, float b);
39
40 int main(int argc, char *argv[])
41 {
42     printf("Outside function: %f\n\n", avg(4.9, 2.0));
43     printf("Outside function: %d\n", avg(4.9, 2.0));
44
45     return 0;
46 }
47
48 int avg(float a, float b)
49 {
50     printf("Inside function: %f\n", (a/b));
51     return (a/b);
52     // NOTE: the difference in output from both inside and outside of the function
53 }
```

The compiler will try to convert the returned value to the return type

Argument

- The argument can be any valid expression, such as constant, variable, math, or logical expression, even another function with a return value.

The number of the arguments and their types should match the number and the types of the corresponding parameters in the function definition - otherwise compile error.

```
void test(int a, int b);
```

```
int main(){  
    test(1, 2);  
    return 0;  
}
```

```
void test(int a, int b){  
    /* Function body. */  
    printf("In\n");  
}
```



Example 1

Output:

Hi
My name is John
How are you guys?

```
#include <stdio.h>
void introduction();
```

```
int main()
{
    /*calling function*/
    introduction();
    return 0;
}
```

```
void introduction()
{
    printf("Hi\n");
    printf("My name is John\n");
    printf("How are you guys?");
}
```

```
/* There is no return statement inside this function,
since its return type is void*/
```

```
}
```



Example 2

```
#include <stdio.h>
int addition (int x, int y);
```

```
int main()
{
    int var1, var2;
    printf("Enter number 1: ");
    scanf("%d",&var1);
    printf("Enter number 2: ");
    scanf("%d",&var2);

    int res = addition(var1, var2);
    printf ("Output: %d", res);

    return 0;
}
```

Enter number 1: 5
Enter number 2: 4
Output: 9

```
int addition(int num1, int num2)
{
    int sum;
    /* Arguments are used here*/
    sum = num1+num2;

    return sum;
}
```



Example 3

求前n个自然数的平方和

```
1 // Fig. 5.3: fig05_03.c
2 // Creating and using a programmer-defined function.
3 #include <stdio.h>
4
5 int square( int y ); // function prototype
6
7 // function main begins program execution
8 int main( void )
9 {
10     int x; // counter
11
12     // loop 10 times and calculate and output square of x each time
13     for ( x = 1; x <= 10; ++x ) {
14         printf( "%d ", square( x ) ); // function call
15     } // end for
16
17     puts( "" );
18 } // end main
19
20 // square function definition returns the square of its parameter
21 int square( int y ) // y is a copy of the argument to the function
22 {
23     return y * y; // returns the square of y as an int
24 } // end function square
```

1 4 9 16 25 36 49 64 81 100



Overview

- Function
- **Function Call Stack**
- Passing data by values and references



Function Call Stack

- The compiler allocates memory (i.e. stack) to store the function's parameters and the variables when the function is called.
- Once it's terminated, the memory is automatically deallocated.

Stack Overflows

results from too much data being pushed onto the stack. The memory/capacity of the stack is exceeded.



Function Call Stack (2)

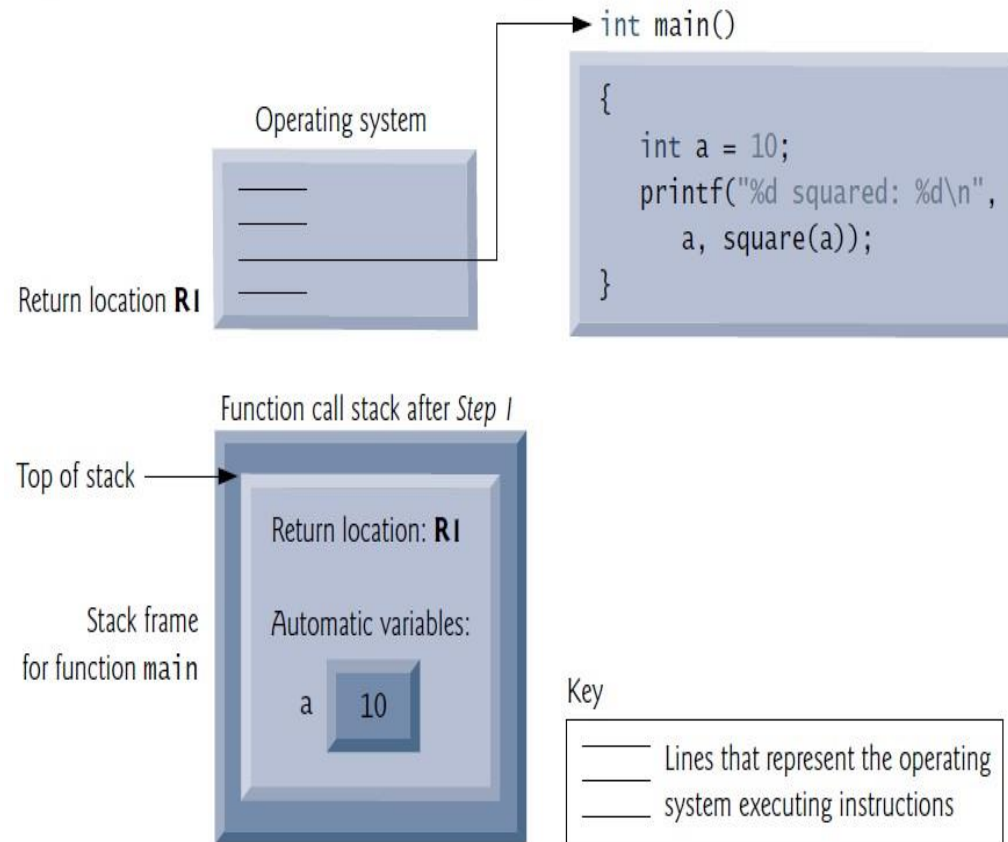
- Stacks are known as last-in, first-out (LIFO) data structures—the last item pushed (inserted) on the stack is the first item popped (removed) from the stack.
- The function call stack supports the creation, maintenance and destruction of each called function's automatic variables.



Function Call Stack (3)

```
1 // Fig. 5.6: fig05_06.c
2 // Demonstrating the function call stack
3 // and stack frames using a function square.
4 #include <stdio.h>
5
6 int square(int); // prototype for function square
7
8 int main()
9 {
10     int a = 10; // value to square (local automatic variable in main)
11
12     printf("%d squared: %d\n", a, square(a)); // display a squared
13 }
14
15 // returns the square of an integer
16 int square(int x) // x is a local variable
17 {
18     return x * x; // calculate square and return result
19 }
```

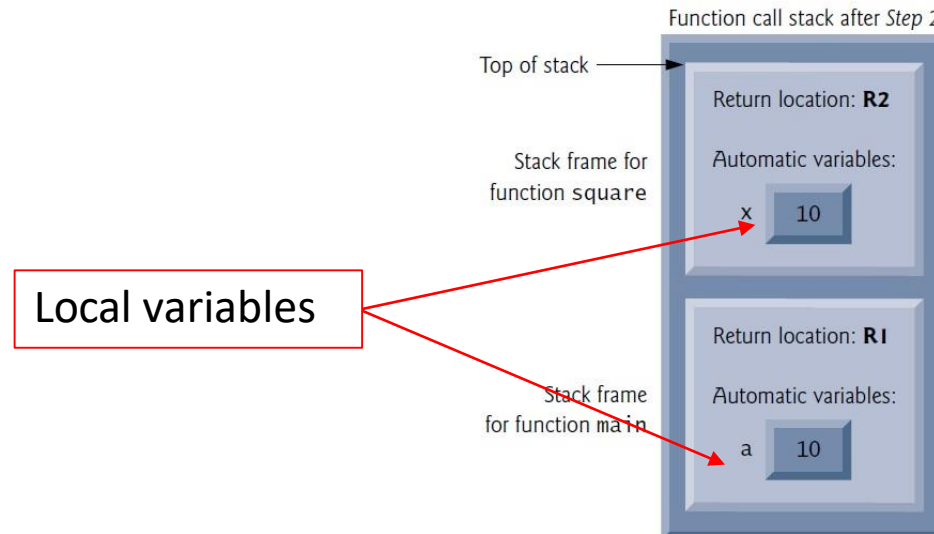
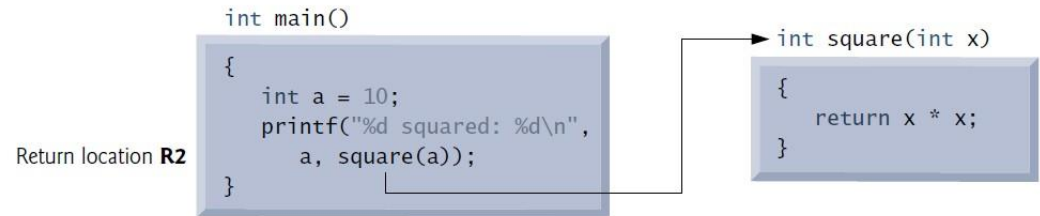
Step 1: Operating system invokes main to execute application



Function Call Stack (4)

```
1 // Fig. 5.6: fig05_06.c
2 // Demonstrating the function call stack
3 // and stack frames using a function square.
4 #include <stdio.h>
5
6 int square(int); // prototype for function square
7
8 int main()
9 {
10     int a = 10; // value to square (local automatic variable in main)
11
12     printf("%d squared: %d\n", a, square(a)); // display a squared
13 }
14
15 // returns the square of an integer
16 int square(int x) // x is a local variable
17 {
18     return x * x; // calculate square and return result
19 }
```

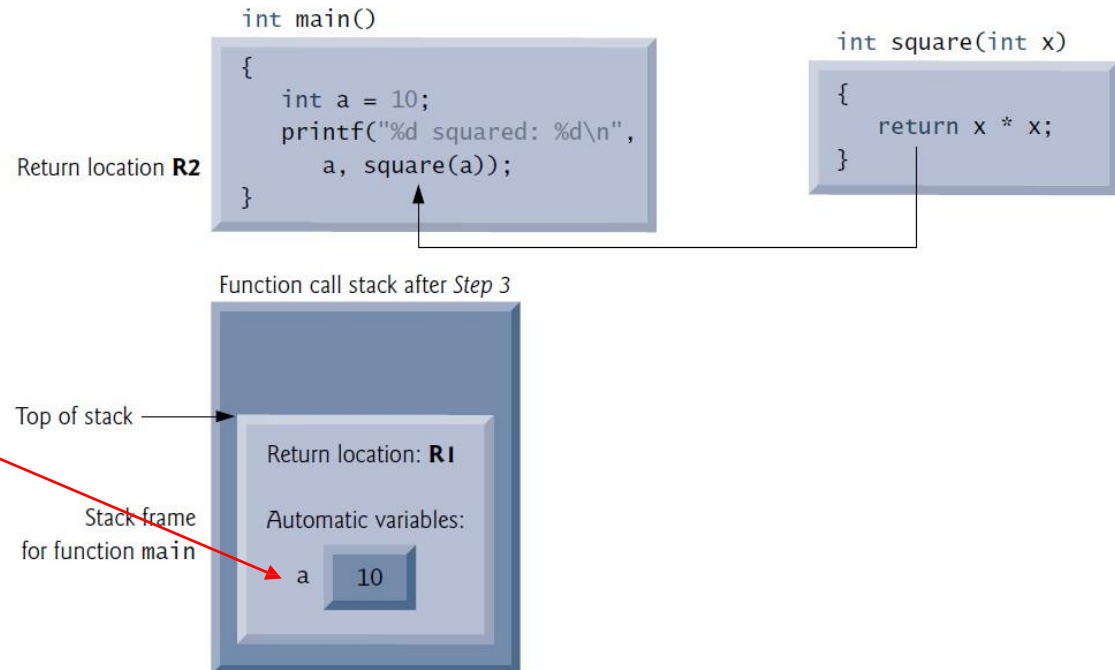
Step 2: main invokes function square to perform calculation



Function Call Stack (5)

```
1 // Fig. 5.6: fig05_06.c
2 // Demonstrating the function call stack
3 // and stack frames using a function square.
4 #include <stdio.h>
5
6 int square(int); // prototype for function square
7
8 int main()
9 {
10     int a = 10; // value to square (local automatic variable in main)
11
12     printf("%d squared: %d\n", a, square(a)); // display a squared
13 }
14
15 // returns the square of an integer
16 int square(int x) // x is a local variable
17 {
18     return x * x; // calculate square and return result
19 }
```

Step 3: square returns its result to main

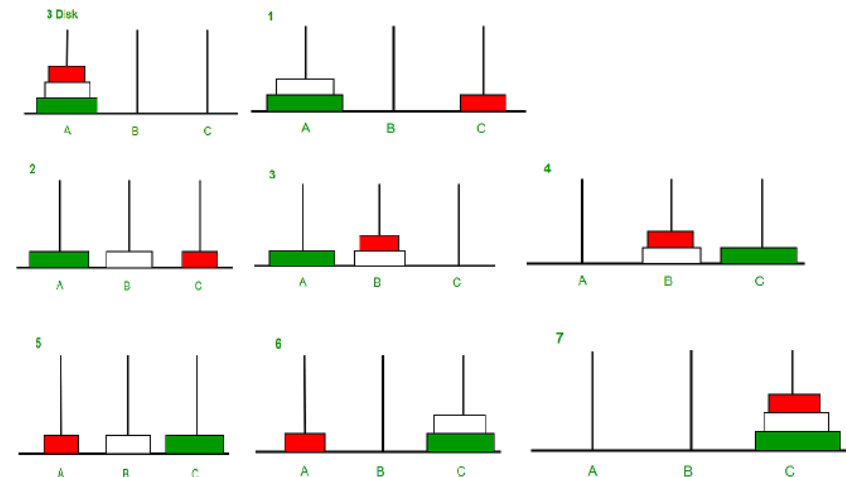


Stack Overflow

- Recursive function is a function which call itself.
- E.g. factorial, tower of hanoi

$$\text{Factorial}(5) = 5 \times 4 \times 3 \times 2 \times 1$$

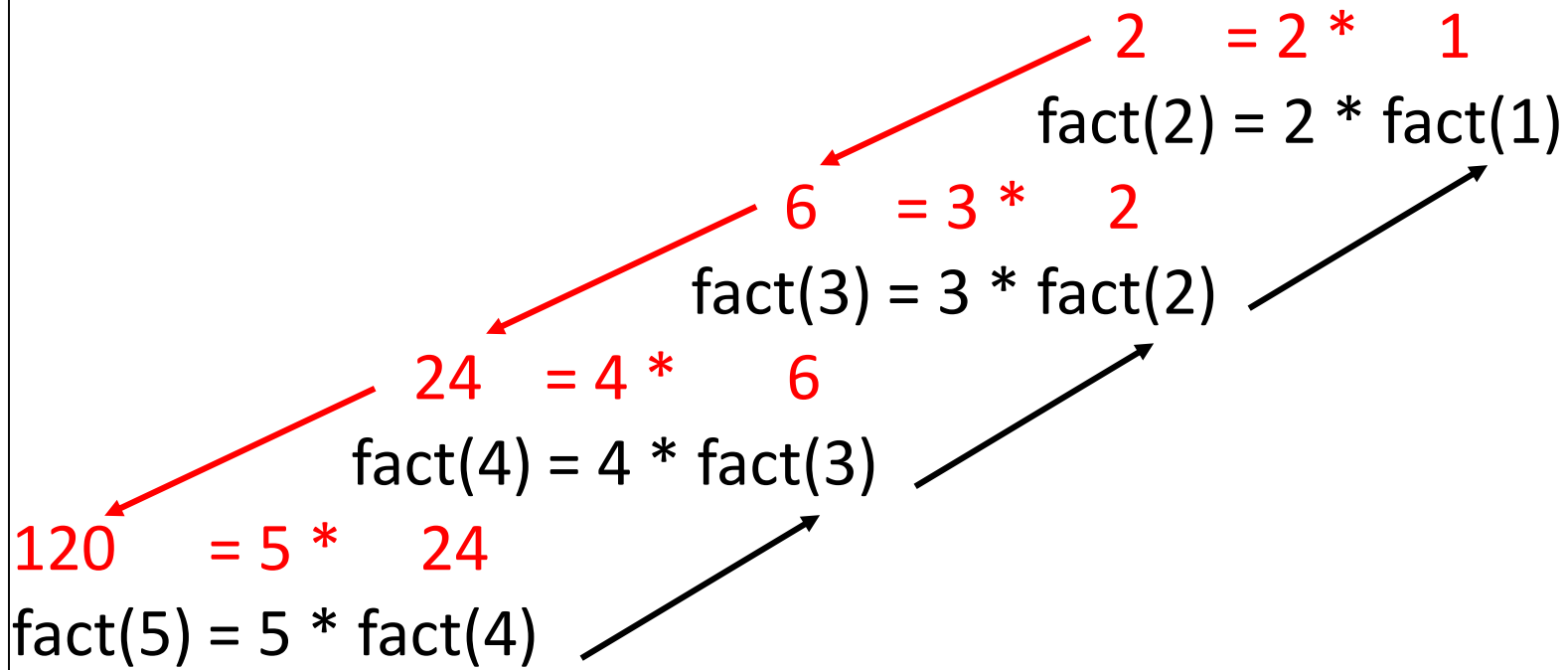
```
int fact(int n)
{
    if (n <= 1) // base case
        return 1;
    else
        return n*fact(n-1);
}
```



Source: <https://www.geeksforgeeks.org/c-program-for-tower-of-hanoi/>

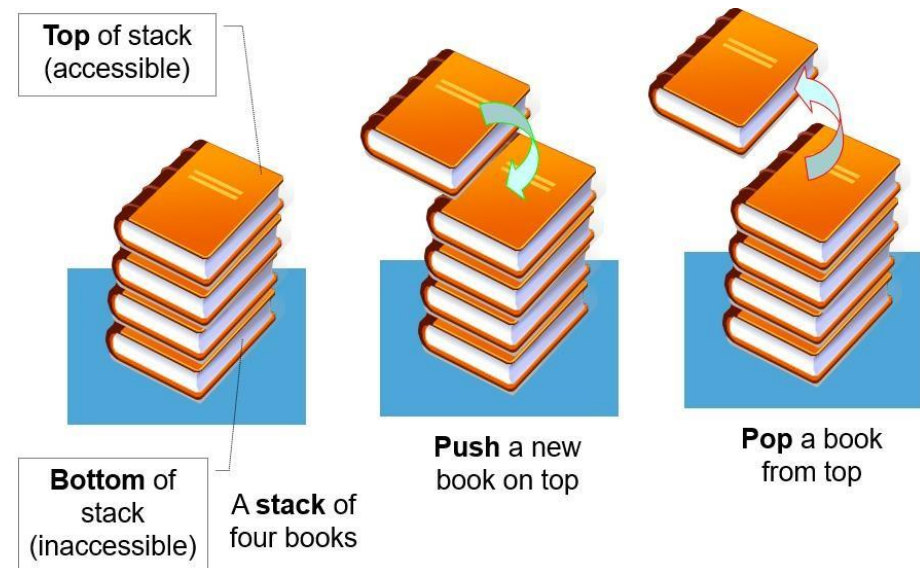


```
int fact(int n)
{
    if (n <= 1) // base case
        return 1;
    else
        return n*fact(n-1);
}
```



Stack Overflow (2)

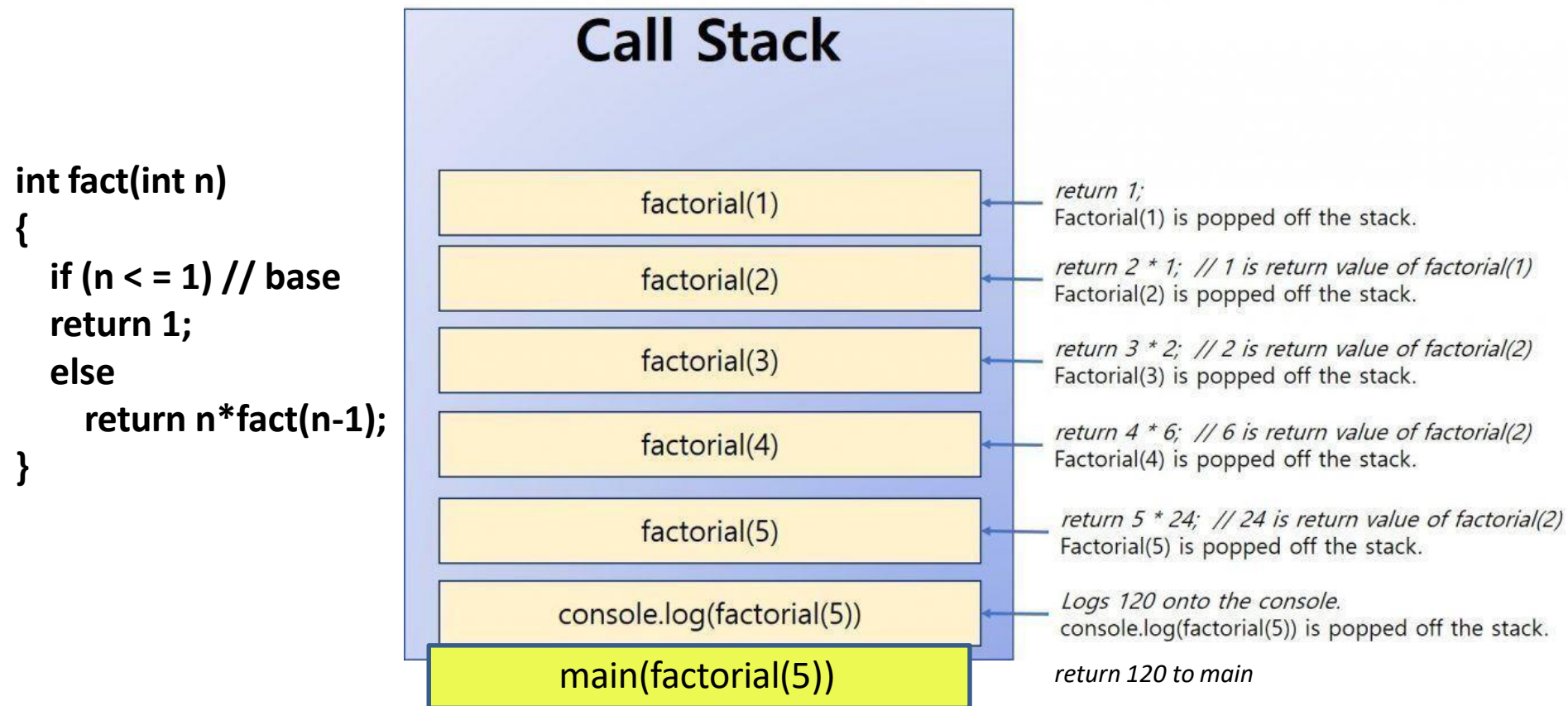
- Finite amount of memory in a computer
- Only a certain amount of memory can be used to store stack frames.
- If more function calls occur than the amount of memory for stack -> fatal error.



Source: <https://visualgo.net/en/list?slide=4>.



Stack Overflow (3)



Source: <https://www.thecodingdelight.com/understanding-recursion-javascript/>



Overview

- Function
- Function Call Stack
- **Passing data by values and references**

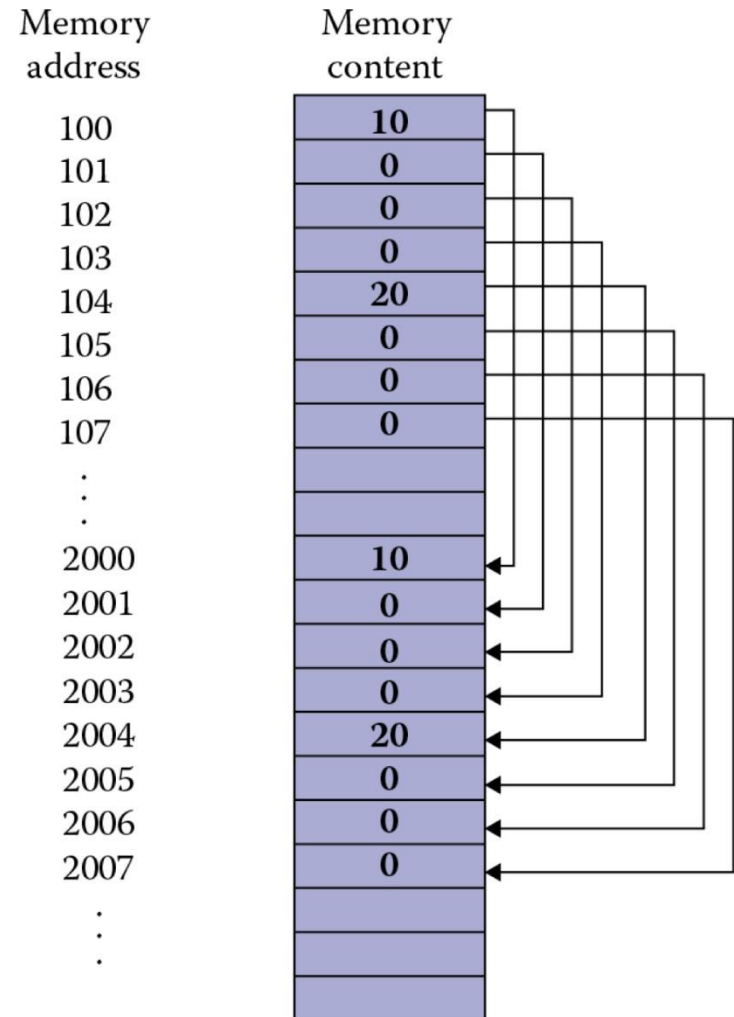


Passing Values: by Value (or Copy)

```
void test(int a, int b);

int main(){
    test(10, 20);
    return 0;
}

void test(int a, int b){
    /* Function body. */
}
```



Pass By Value

- Each parameter copies the value given to the function when it is called.
- Changes to the copy do not affect an original variable's value in the caller.
- Pass-by-value should be used whenever the called function does not need to modify the value of the caller's original variable.

Pass By Value (2)

```
#include <stdio.h>
void swap(int , int); //prototype of the function
int main()
{
    int a = 10;
    int b = 20;
    printf("Before swapping the values in main a = %d, b = %d\n",a,b);
    swap(a,b);
    printf("After swapping values in main a = %d, b = %d\n",a,b);
}
void swap (int a, int b)
{
    int temp;
    temp = a;
    a=b;
    b=temp;
    printf("After swapping values in function a = %d, b = %d\n",a,b);
}
```

Output:

```
Before swapping the values in main a = 10, b = 20
After swapping values in function a = 20, b = 10
After swapping values in main a = 10, b = 20
```

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

```
void swap(int , int);
```

```
int main()  
{  
    int a = 10;  
    int b = 20;  
    printf("Before swapping the values in main a = %d, b = %d\n", a, b);  
    swap(a, b);  
    printf("After swapping values in main a = %d, b = %d\n", a, b);  
}
```

a	b
10	20
1000	2000

Output:

Before swapping the values in main a = 10, b = 20
After swapping values in function a = 20, b = 10
After swapping values in main a = 10, b = 20

```
void swap (int a, int b)
```

```
{  
    int temp;  
    temp = a;  
    a=b;  
    b=temp;  
    printf("After swapping values in function a = %d, b = %d\n", a, b);  
}
```

a	b
20	10
3000	4000

Pass By Reference

- Pass-by-reference should be used only with trusted called functions that need to modify the original variable, or when a huge data-structure needs to be passed around.
- The **memory address is passed by copy** into a variable.
- This allows a function to simulate return multiple values!!

Pass By Reference (2)

```
#include <stdio.h>
void swap(int *, int *); //prototype of the function
int main()
{
    int a = 10;
    int b = 20;
    printf("Before swapping the values in main a = %d, b = %d\n",a,b);
    swap(&a,&b);
    printf("After swapping values in main a = %d, b = %d\n",a,b);
}
void swap (int *a, int *b)
{
    int temp;
    temp = *a;
    *a=*b;
    *b=temp;
    printf("After swapping values in function a = %d, b = %d\n",*a,*b);
}
```

Output:

```
Before swapping the values in main a = 10, b = 20
After swapping values in function a = 20, b = 10
After swapping values in main a = 20, b = 10
```

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

```
void swap(int *, int *);
```

```
int main()
```

```
{
```

```
    int a = 10;
```

```
    int b = 20;
```

```
    printf("Before swapping the values in main a = %d, b = %d\n", a, b);
```

```
    swap(&a, &b);
```

```
    printf("After swapping values in main a = %d, b = %d\n", a, b);
```

```
}
```

```
void swap (int *a, int *b)
```

```
{
```

```
    int temp;
```

```
    temp = *a;
```

```
    *a=*b;
```

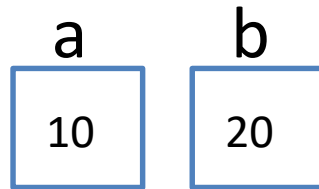
```
    *b=temp;
```

```
    printf("After swapping values in function a = %d, b = %d\n", *a, *b);
```

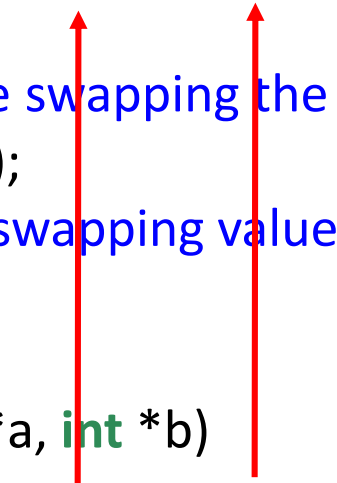
```
}
```

Output:

Before swapping the values in main a = 10, b = 20



1000 2000



3000 4000

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

```
void swap(int *, int *);
```

```
int main()
```

```
{
```

```
    int a = 10;
```

```
    int b = 20;
```

```
    printf("Before swapping the values in main a = %d, b = %d\n", a, b);
```

```
    swap(&a, &b);
```

```
    printf("After swapping values in main a = %d, b = %d\n", a, b);
```

```
}
```

```
void swap (int *a, int *b)
```

```
{
```

```
    int temp;
```

```
    temp = *a;
```

```
    *a=*b;
```

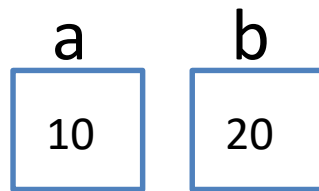
```
    *b=temp;
```

```
    printf("After swapping values in function a = %d, b = %d\n", *a, *b);
```

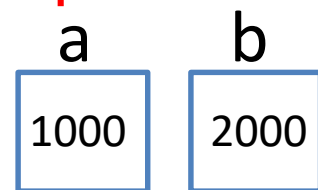
```
}
```

Output:

Before swapping the values in main a = 10, b = 20

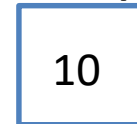


1000 2000



3000 4000

temp



5000

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

```
void swap(int *, int *);
```

```
int main()
```

```
{
```

```
    int a = 10;
```

```
    int b = 20;
```

```
    printf("Before swapping the values in main a = %d, b = %d\n", a, b);
```

```
    swap(&a, &b);
```

```
    printf("After swapping values in main a = %d, b = %d\n", a, b);
```

```
}
```

```
void swap (int *a, int *b)
```

```
{
```

```
    int temp;
```

```
    temp = *a;
```

```
    *a=*b;
```

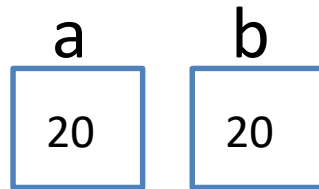
```
    *b=temp;
```

```
    printf("After swapping values in function a = %d, b = %d\n", *a, *b);
```

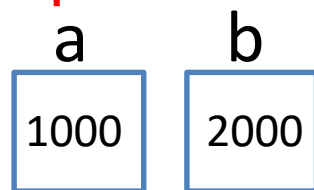
```
}
```

Output:

Before swapping the values in main a = 10, b = 20

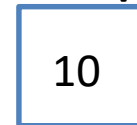


1000 2000



3000 4000

temp



5000

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

```
void swap(int *, int *);
```

```
int main()
```

```
{
```

```
    int a = 10;
```

```
    int b = 20;
```

```
    printf("Before swapping the values in main a = %d, b = %d\n", a, b);
```

```
    swap(&a, &b);
```

```
    printf("After swapping values in main a = %d, b = %d\n", a, b);
```

```
}
```

```
void swap (int *a, int *b)
```

```
{
```

```
    int temp;
```

```
    temp = *a;
```

```
    *a=*b;
```

```
    *b=temp;
```

```
    printf("After swapping values in function a = %d, b = %d\n", *a, *b);
```

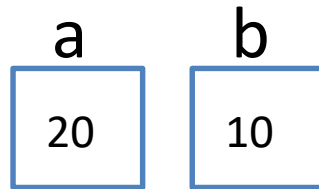
```
}
```

Output:

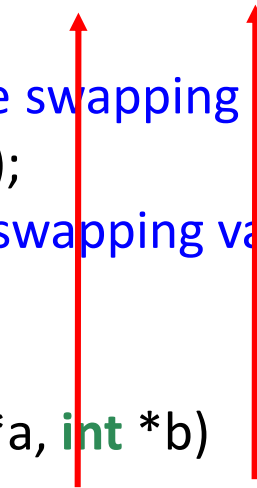
Before swapping the values in main a = 10, b = 20

After swapping values in function a = 20, b = 10

After swapping values in main a = 20, b = 10



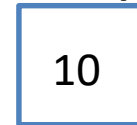
1000 2000



1000 2000

3000 4000

temp



5000

Passing Values: by Reference

```
void test(int a, int b);
```

```
int main(){  
    test(10, 20);  
    return 0;  
}
```

```
void test(int a, int b){  
    /* Function body. */  
}
```

```
void test(int *a, int b);
```

```
int main(){  
    int *ptr, i = 10;  
    ptr = &i;  
    test(ptr, 20);  
    return 0;  
}
```

```
void test(int *a, int b){  
    /* Function body. */  
}
```

Or test(&i, 20);

Since a function can't return more than one value, passing arguments by reference is the most flexible way to change the values of the arguments.



Pass By Value vs. Pass By Reference

```
133 #include <stdio.h>
134
135 int add(int a);
136
137 int main(void)
138 {
139     int b = 2;
140     printf("b = %d, return value from add() is %d\n", b, add(b));
141
142     return 0;
143 }
144
145 int add(int a)
146 {
147     return (++a);
148 }
```

```
152 #include <stdio.h>
153
154 int add(int *a);
155
156 int main(void)
157 {
158     int b = 2;
159     printf("b = %d, return value from add() is %d\n", b, add(&b));
160
161     return 0;
162 }
163
164 int add(int *a)
165 {
166     return (++(*a));
167 }
```



Pass By Value vs. Pass By Reference (2)

```
71 #include <stdio.h>
72 #include <stdlib.h>
73
74 int max(int a, int b);
75
76 int main(int argc, char *argv[])
77 {
78     int x = 3;
79     int y = 4;
80     int m = max(x, y);
81     printf("Between %d and %d, max is %d\n", x, y, m);
82
83     return 0;
84 }
85
86 int max(int a, int b)
87 {
88     if(a > b)
89     {
90         printf("a is %d, and b is %d\n", a, b);
91         a = 1;
92         b = 2;
93         printf("a is %d, and b is %d\n", a, b);
94         return a;
95     }
96     else
97     {
98         printf("a is %d, and b is %d\n", a, b);
99         a = 5;
100        b = 6;
101        printf("a is %d, and b is %d\n", a, b);
102        return b;
103    }
104 }
```

```
107 #include <stdio.h>
108 #include <stdlib.h>
109
110 int max(int *a, int *b);
111
112 int main(int argc, char *argv[])
113 {
114     int x = 3;
115     int y = 4;
116     int m = max(&x, &y);
117     printf("Between %d and %d, max is %d\n", x, y, m);
118
119     return 0;
120 }
121
122 int max(int *a, int *b)
123 {
124     if(*a > *b)
125     {
126         printf("a is %d, and b is %d\n", *a, *b);
127         *a = 1;
128         *b = 2;
129         printf("a is %d, and b is %d\n", *a, *b);
130         return *a;
131     }
132     else
133     {
134         printf("a is %d, and b is %d\n", *a, *b);
135         *a = 5;
136         *b = 6;
137         printf("a is %d, and b is %d\n", *a, *b);
138         return *b;
139     }
140 }
```



Pass By Value vs. Pass By Reference (3)

```
#include<stdio.h>
void change(int num) {
    printf("Before adding value inside function num=%d \n",num);
    num=num+100;
    printf("After adding value inside function num=%d \n", num);
}
int main() {
    int x=100;
    printf("Before function call x=%d \n", x);
    change(x);
    printf("After function call x=%d \n", x);
    return 0;
}
```

```
#include<stdio.h>
void change(int *num) {
    printf("Before adding value inside function num=%d \n",*num);
    (*num) += 100;
    printf("After adding value inside function num=%d \n", *num);
}
int main() {
    int x=100;
    printf("Before function call x=%d \n", x);
    change(&x);
    printf("After function call x=%d \n", x);
    return 0;
}
```



Summary

- Function
- Function Call Stack
- Passing data by values and references

