Ch.9 Functions and Variables

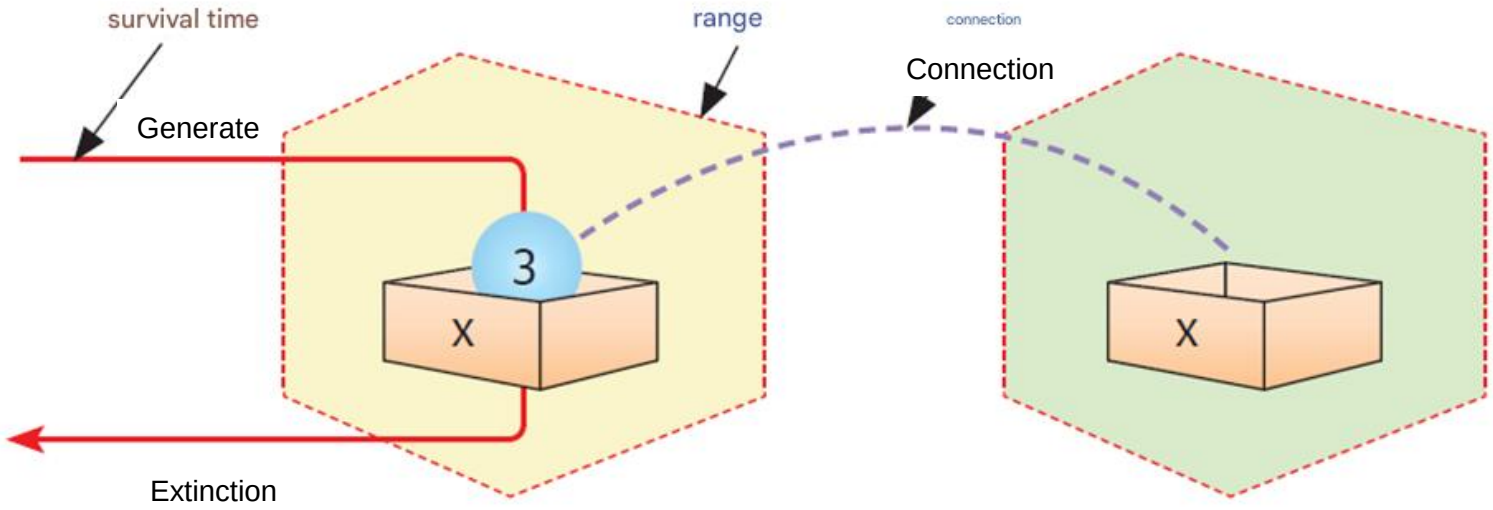
What you will learn in this chapter

- Understanding the concept of repetition
- Variable properties
- Global and local variables
- Automatic and static variables
- Recursive call

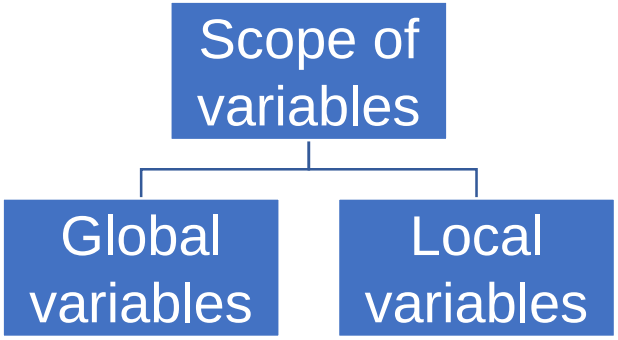
In this chapter, we will focus on the relationship between functions and variables. We will also look at recursive calls, where a function calls itself .

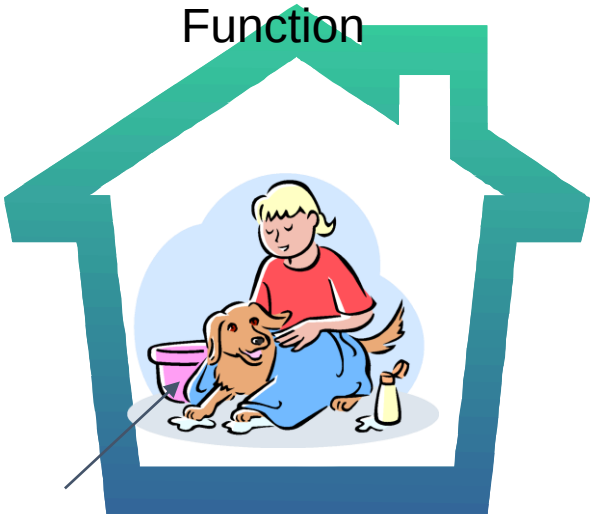
Variable properties

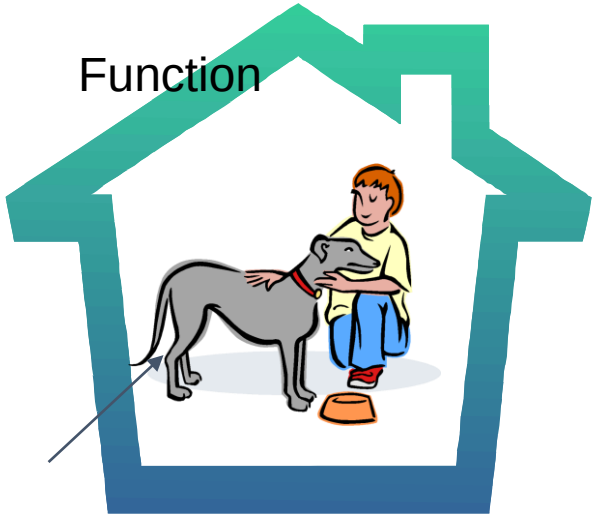
- **Variable properties :** name , type , size , value + range , life time , linkage
  - **Scope :** The region of a program where a variable is accessible — its *visibility*.
  - **Lifetime :** The duration for which a variable exists in memory.
  - **Linkage :** Indicates whether a variable is accessible from other files or translation units.



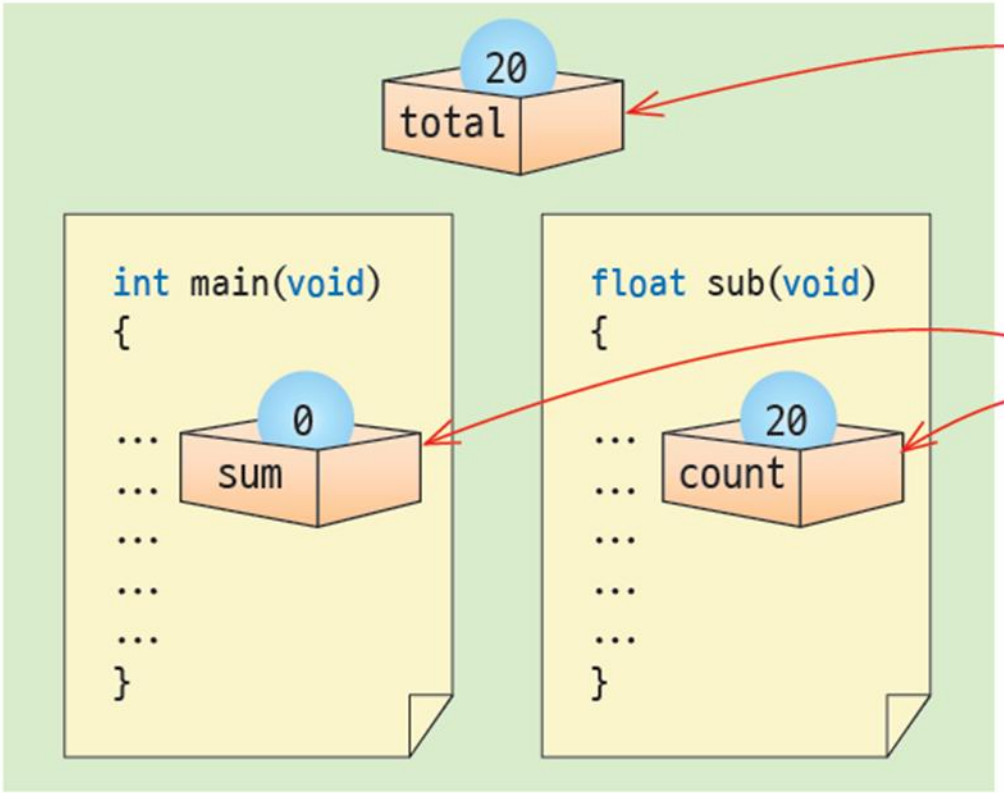
Scope of variables







Global Variables and local variables



Global variables:
defined outside of a function

Global variables:
defined inside of a function

Local variables

- **A local variable** is a variable declared within a block.

```
int sub(void)
{
        int x = 0;

        while(flag!= 0){
            int y;
            ...
        }

        y = 0; // Error!!
        ...
}
```

The scope in which local variable x can be used

The scope in which global variable x can be used

Error because y was used outside the block where it was declared

Local variables must not leave the block in which they are declared.

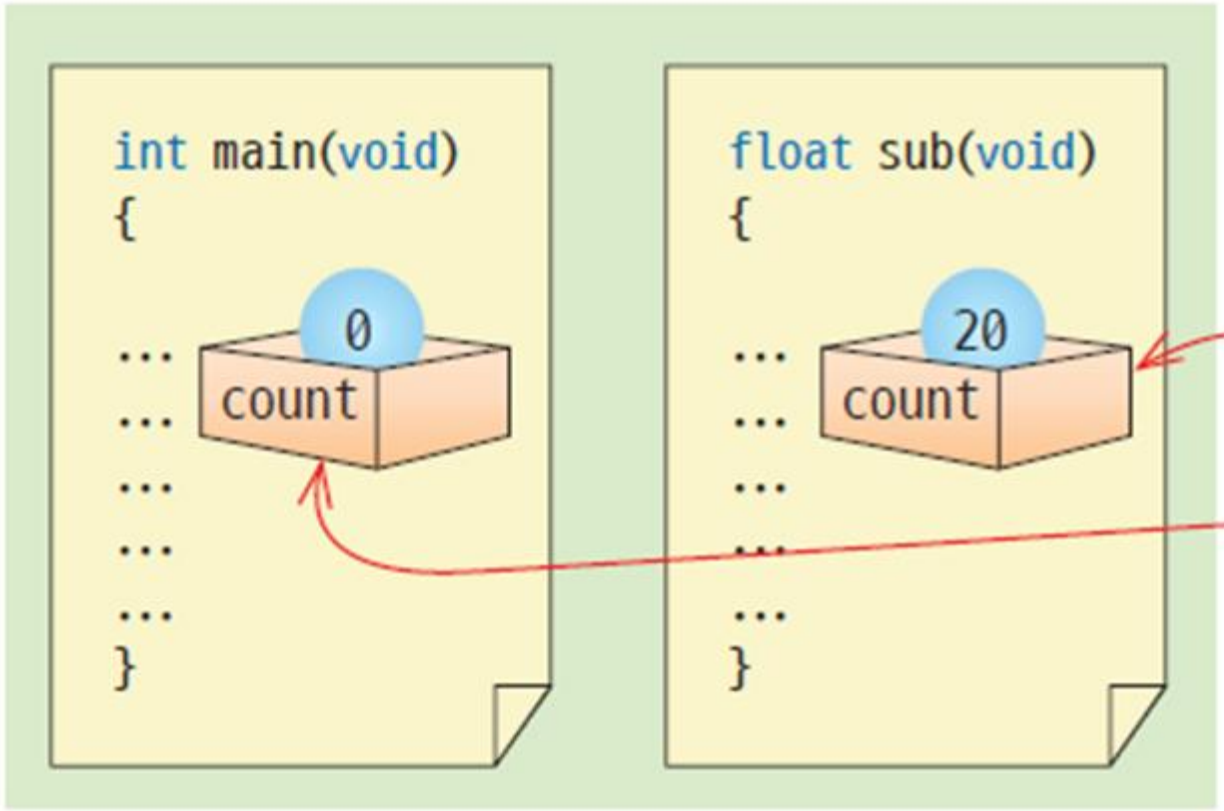
Local variable declaration location

- In C , it can be declared anywhere inside a block !!

```
while(1) {
        ...
        ...
        int sum = 0;
        ...
}
```

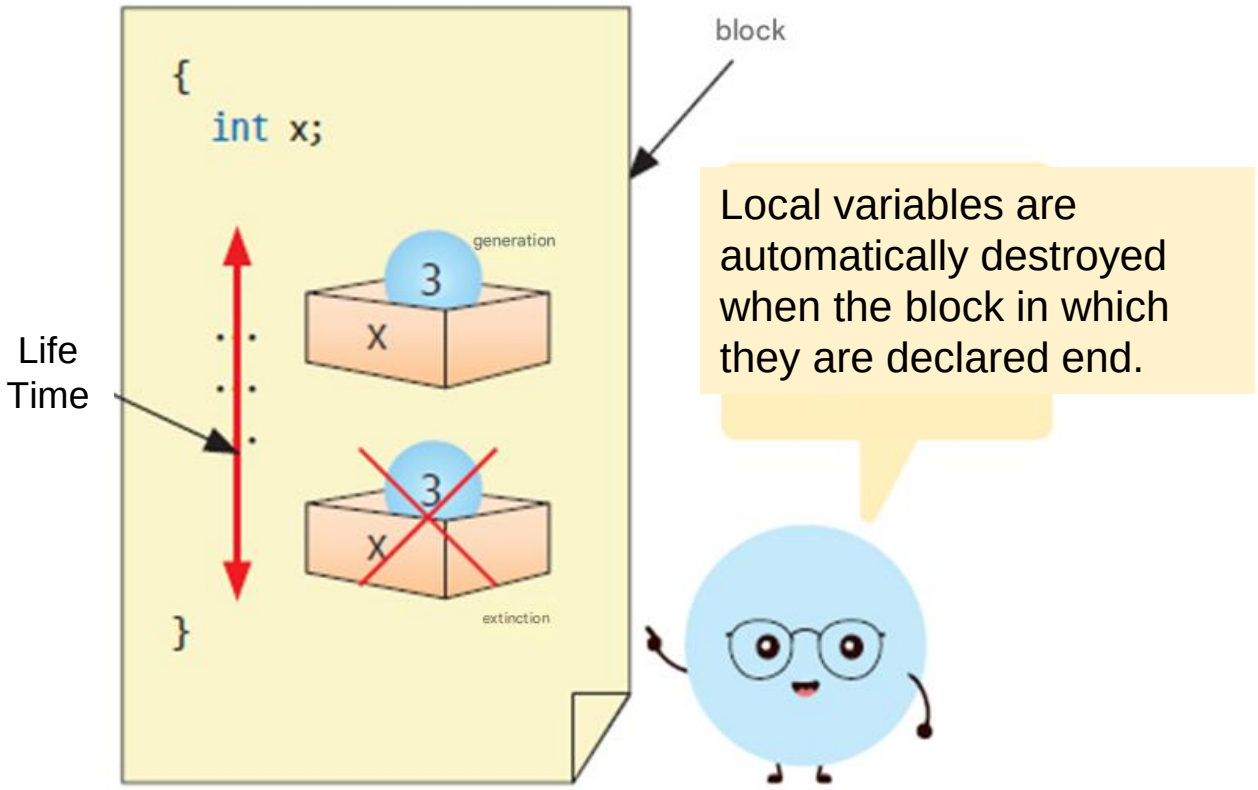
You can declare any number of local variables, even in the middle of a block

Local variables with the same name



The names can be the same
as long as the blocks are different.

Life time of local variables

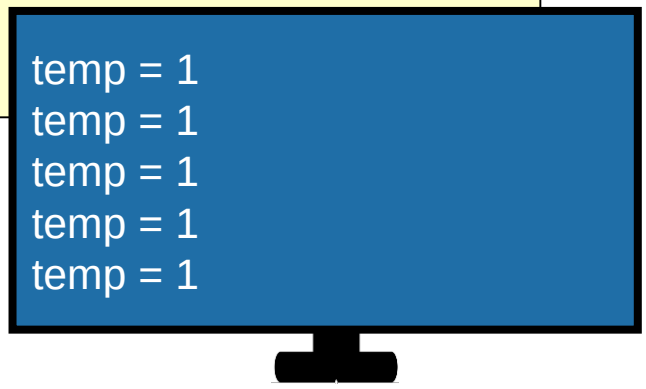


Local variable example

```
#include < stdio.h >

int main( void )
{
        int i ;

        for ( i = 0; i < 5; i ++)
        {
                int temp = 1;
                printf ( "temp = %d\n" , temp);
                temp++;
        }
       return 0;
}
```

Whenever each block is called, temp is created and initialized (Different address)

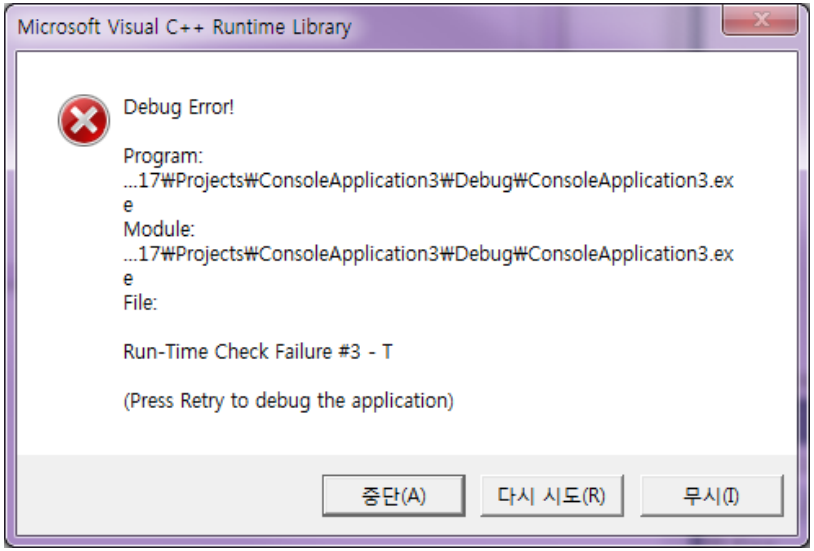
* The variable seems to have the same address each time because the compiler optimizes memory usage by reusing the same stack space for variables with the same scope



Initial value of local variable

```
#include < stdio.h >
int main( void )
{
        int temp;
         printf ( "temp = %d\n" , temp);
        return 0;
}
```

Since it is not initialized, it has a garbage value.



Function parameters

- Parameters defined in the header part of a function are also a type of local variable. That is, they have all the characteristics of local variables.
- What makes it different from local variables is that they are initialized with the argument values when the function is called.

```
int inc ( int counter )
{
    counter++;
    return counter;
}
```

Parameters are also a kind of local variable

Function parameters

```
#include < stdio.h >
int inc ( int counter);

int main( void )
{
        int i ;

        i = 10;
        printf ( " Before calling the function i =%d\n" , i );
        inc ( i );
        printf ( " After calling the function i =%d\n" , i );
        return 0;
}
void  inc ( int counter)
{
        counter++;
}
```

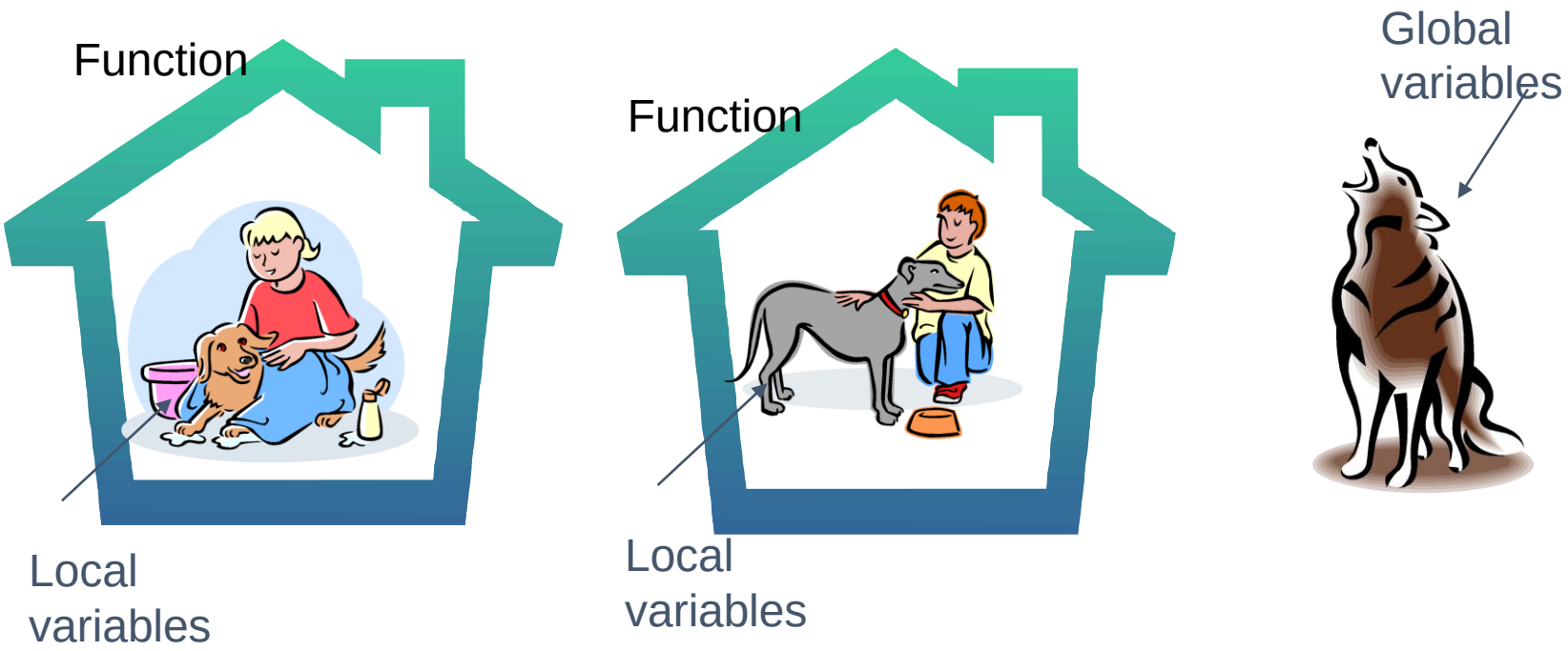
Call by value
(call by value)

Parameters are also
a type of local variable

Before calling a function i =10
After calling the function i =10

Global variables

- **A global variable** is a variable declared outside any function.
- The scope of a global variable is the entire source file.

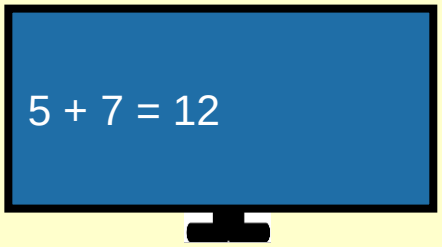


Initial values and life time of global variables

Scope of global variables

```
#include <stdio.h>
int A;
int B;
int add()
{
        return A + B;
}

int main( void )
{
        int answer;
        A = 5;
        B = 7;
        answer = add();
        printf (“ % d + % d = % d\n”, A, B, answer);
        return 0;
}
```

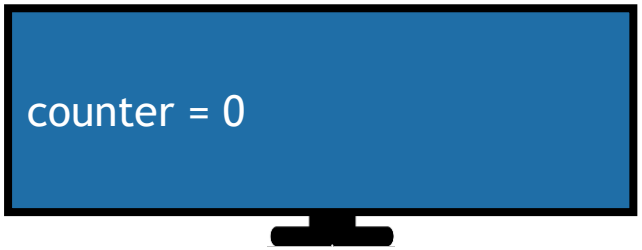
Global variables
The initial value is 0



Global Initial value of variable

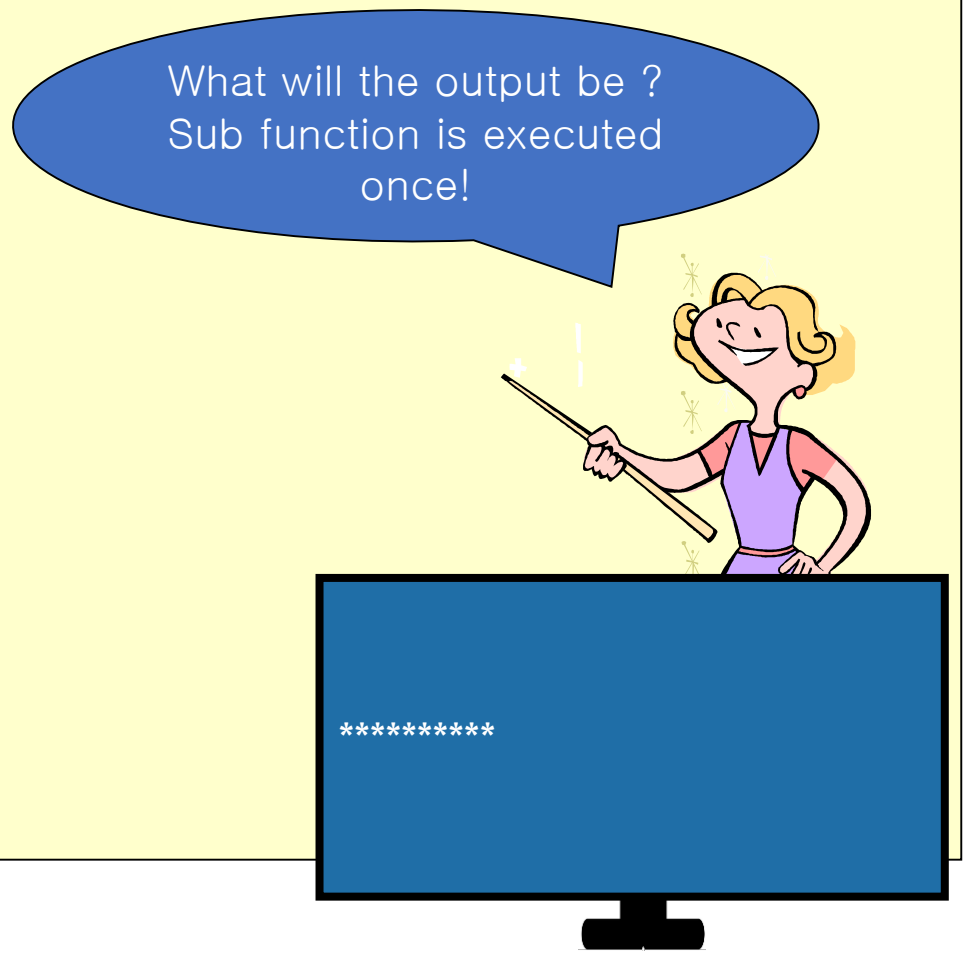
```
#include < stdio.h >

int counter;

int main( void )
{
        printf ( "counter = % d\n" , counter);
        return 0;
}
```

Global variables are initialized to 0 by the compiler when the program runs.



Use of global variables

```
#include < stdio.h >

int x;
void sub();

int main( void )
{
        for (x = 0; x < 10; x++)
                sub();
}

void sub()
{
        for (x = 0; x < 10; x++)
                printf ( "*" );
}
```



Use of global variables

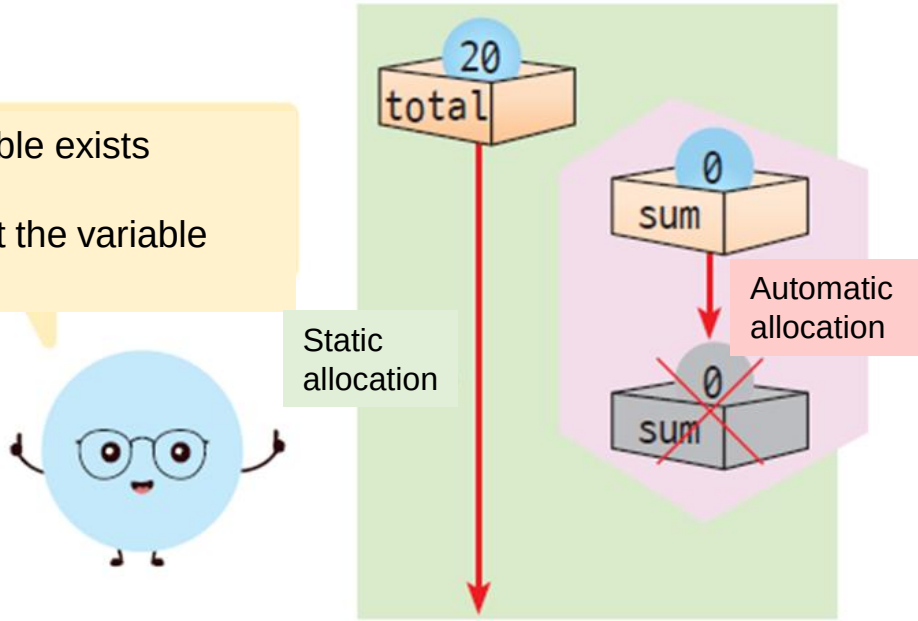
- Common data used in almost all functions is made into global variables.

- Data that is only used by some functions should be passed as function arguments rather than as global variables.

Lifetime of a variable

- Static allocation :
  - Keep it alive while the program runs
- Automatic allocation :
  - Created when entering a block
  - Destroys when exiting the block

Static allocation means that the variable exists throughout the execution time,
while automatic allocation means that the variable is destroyed when the block ends.



Lifetime of a variable

- Factors affecting variable lifetime:
  - Declaration location: Where the variable is declared
  - Storage type specifier
    - ✓ auto
    - ✓ register
    - ✓ static
    - ✓ extern

Concept only

static & extern

Keyword	Meaning	Effect
`static`	Local to the file (for global variables) or function (for local variables)	Limits visibility **inside the same file**; lifetime is the **entire program run**
`extern`	Declares a variable or function that is **defined elsewhere**	Tells the compiler "this variable is somewhere else" (another file)

- `static` = **"only usable inside this file"** (or **"remember between calls"** for local variables)
- `extern` = **"this is declared elsewhere, trust me"**

static & extern

1. `static`

Global scope (`file`):
If you declare a global variable or function `static`, it is **private to that `.c` file** — it cannot be seen or used by other files.

```
// file1.c
static int counter = 0; // Only visible in file1.c
```

Local scope (`function`):
If you declare a **local** variable `static`, it **keeps its value** between function calls.

```
void foo() {
    static int x = 0;
    x++;
    printf("%d\n", x);
}
```

Every time `foo()` runs, `x` remembers its previous value instead of resetting.

static & extern

2. `extern`

- Used to **declare** a global variable or function that is **defined in another file**.

```
// file1.c
int global_value = 42; // Define it


// file2.c
extern int global_value; // Just tell compiler it exists
void use_value() {
    printf("%d\n", global_value);
}
```

Without `extern`, the compiler would not know what `global_value` is in `file2.c`.

Visibility

- static
  - Inside a function : The variable **remembers its value** between function calls.

```
void counter() {
    static int count = 0;
    count++;
    printf("%d\n", count);
}
```

  - Outside a function: Limits **visibility to the same file** (not accessible from other files)

```
static int globalVar = 100;
```

- extern
  - Used to declare a **variable or function** that is **defined in another file**
  - Used for **cross-file access**

```
// file1.c
int x = 10;

// file2.c
extern int x;  // Use the variable from file1.c
```

Storage type specifier “auto”

- Specifies a storage type that is automatically created at the location where the variable is declared, and is automatically destroyed when the block is exited.
- Local variables become automatic variables even if auto is omitted.

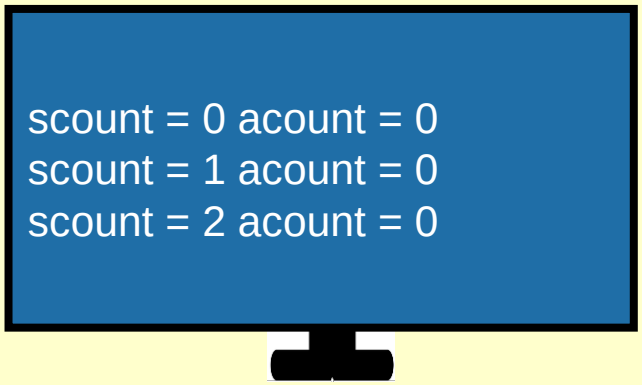
```
int main( void )
{
  auto int sum = 0;
  int i = 0;
…
…
}
```

All of them are automatic variables, created when the function starts and destroyed when it ends .

Storage type specifier “static”

```
#include < stdio.h >

void sub() {

        static int scount = 0;
        int acount = 0;
        printf ( " scount = %d\t" , scount );

        printf ( " acount = %d\n" , acount );
        scount ++;
        acount ++;

}

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

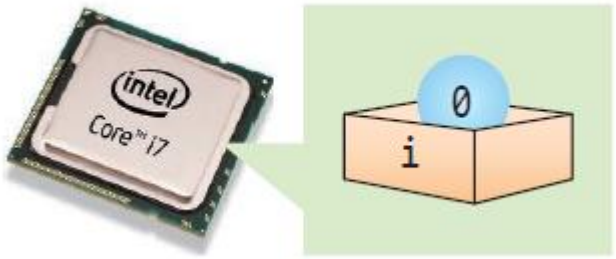
If you add
Local variables become static variables



Storage type specifier “register”

- Store variables in registers .

```
register int i;
for (i = 0;i < 100; i++)
    sum += i;
```



Variables are stored in registers inside the CPU

Modern C compilers (such as GCC, Clang, and MSVC)
already perform automatic optimization,
so using the register keyword makes little to no difference in performance

volatile

- The volatile specifier is used when the hardware changes the value of a variable from time to time.

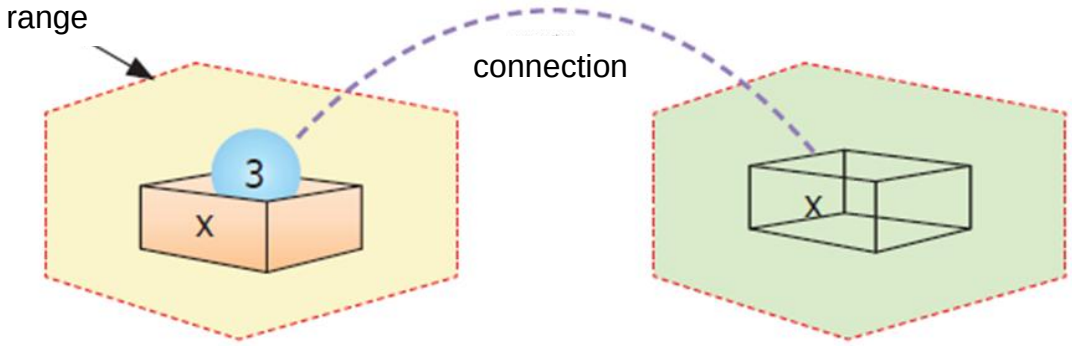
```
volatile int io_port ; // Variable connected to hardware

void wait( void ) {
        io_port = 0;
        while ( io_port != 255)
                ;
}
```

If you specify it as volatile,
Compiler will stop optimizing.

volatile is used when a variable's value may change unexpectedly
— typically due to hardware, interrupts, or concurrent access
— to prevent the compiler from optimizing it away.

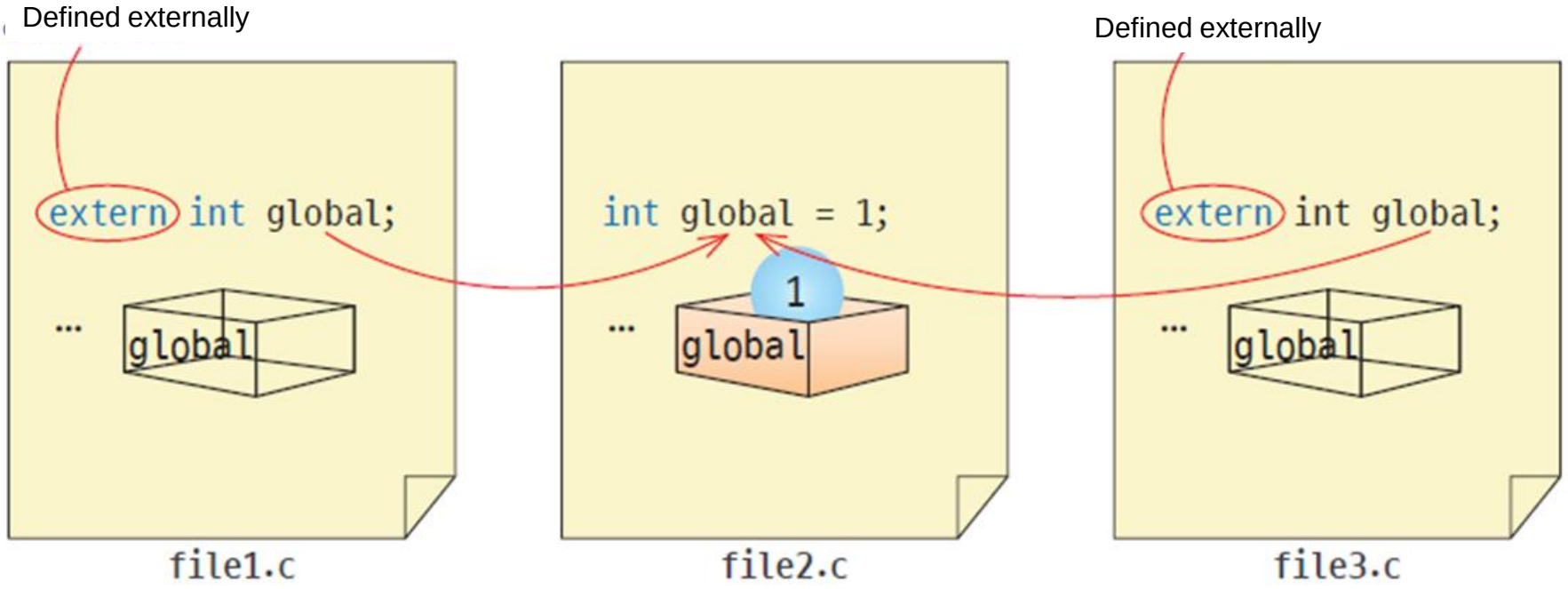
connection

- *Linkage :* Linking variables belonging to different scopes
  - External connection
  - Internal connection
  - No connection
- Only global variables can have associations .

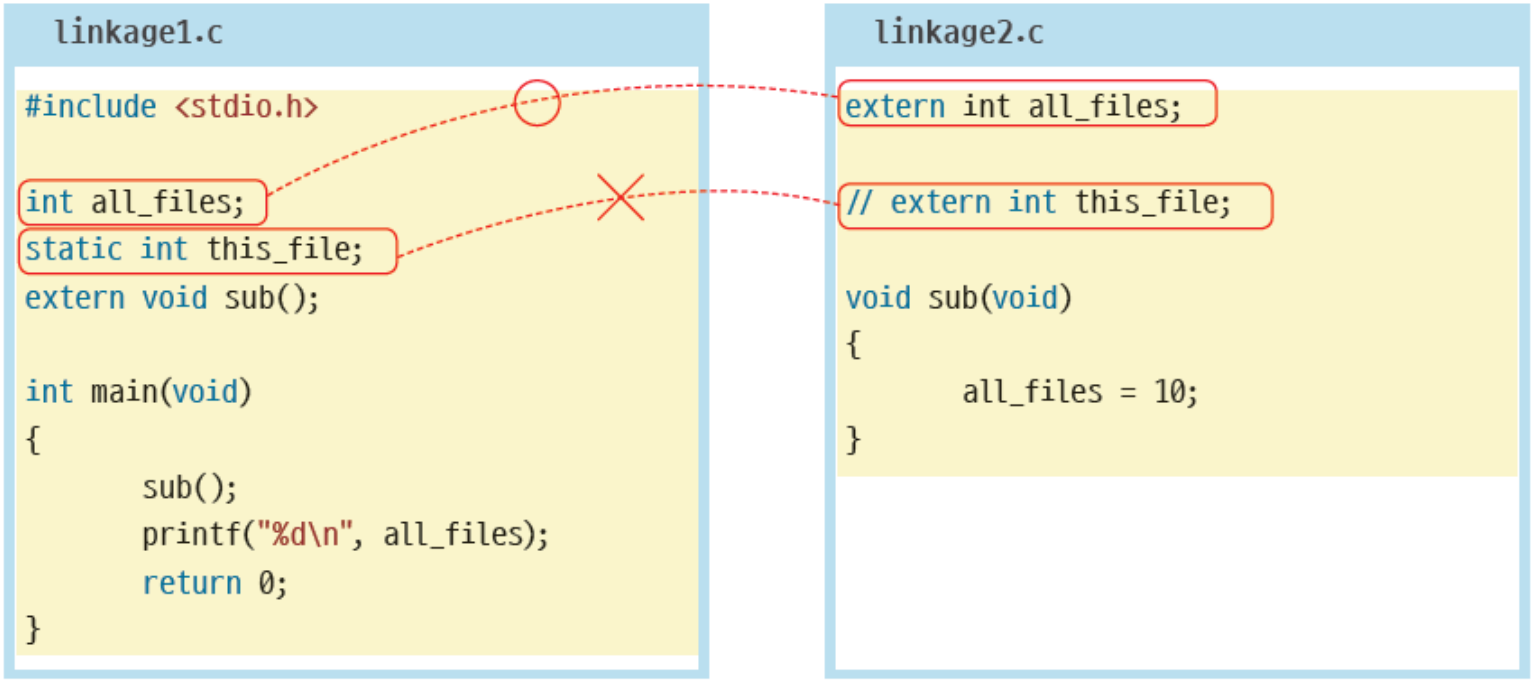


External connection

- Global variables using extern



Connection example



static in front of function

main.c

```c
#include <stdio.h>


//extern void f1();
extern void f2();

int main(void)
{
        f2();
        return 0;
}
```

sub.c

```c
#include <stdio.h>

static void f1()
{
        printf("f1()가 호출되었습니다.\n");
}

void f2()
{
        printf("f2()가 호출되었습니다.\n");
}
```

Private function

Referencing global variables using extern in a block

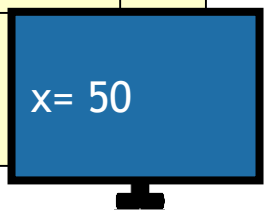
- extern is also used to access global variables from a block .

```
#include < stdio.h >
int x = 50;

int main( void )
{
        int x = 100;
        {
                extern int x;
                printf( "x= %d\n" , x);
        }
        return 0;
}
```

Global variable: scope (entire this file)

Local variable: scope (in main function)
Local variable → hides the global x (Shadowing)

Refer to global variable : scope (entire this file)
you can re-access the global variable using the extern keyword



When you declare a **local variable** with the same name as a **global variable**, the local one takes **precedence** inside its scope, and the global variable becomes **inaccessible (hidden)** within that block.

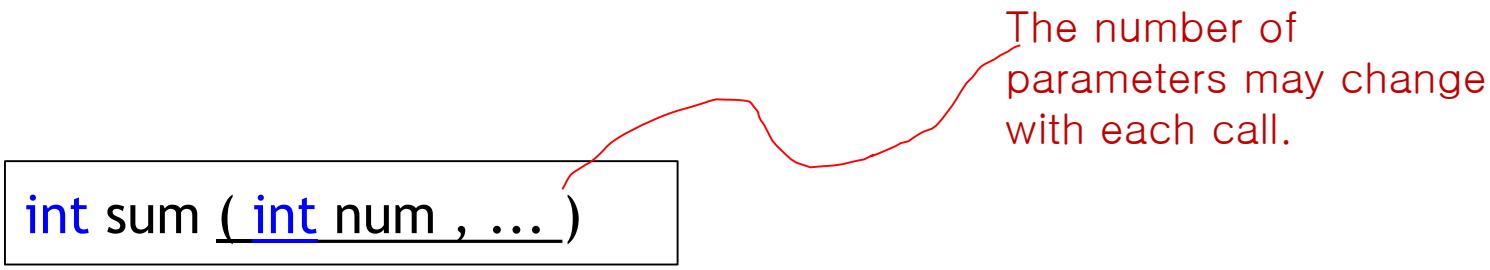
What storage type do you use ?

- In general, it is recommended to use *the auto-save type.*
- If the value of a variable needs to remain the same even after the function call ends, use *local static*
- If it is a variable that needs to be shared among many function, *it is an external reference variable.*

storage type	keyword	position to be defined	range	survival time
automatic	auto	Inside the function	region	temporary
register	register	Inside the function	region	temporary
static area	staic	Inside the function	region	everlasting
Global	doesn't exist	outside the function	all source files	everlasting
static global	static	outside the function	one source file	everlasting
external reference	extern	outside the function	all source files	everlasting

Variable parameters

- A feature where the number of parameters can vary.



Variable parameters

```
#include < stdio.h >
#include < stdarg.h >
int sum( int , ... );
int main( void )
{
        int answer = sum( 4, 4, 3, 2, 1 );
        printf ( " The sum is %d .\n" , answer );
        return ( 0 );
}
int sum( int num , ... )
{       int answer = 0;
        va_list argptr ;
        va_start ( argptr , num );
        for ( ; num > 0; num -- ) {
            int temp = va_arg ( argptr , int );
            printf("va_arg num=%d (%d)\n", num, temp);
            answer += temp;
        }
        va_end ( argptr );
        return ( answer );
}
```

The sum is 10 .

Number of parameters

Main function with variable arguments


```c
#include <stdio.h>

int main(int argc, char *argv[]) {
    printf("Number of arguments: %d\n", argc);

    for (int i = 0; i < argc; i++) {
        printf("Argument %d: %s\n", i, argv[i]);
    }

    return 0;
}
```

```
gcc args.c -o args
./args hello world 123
```

What is recursion ?

Important

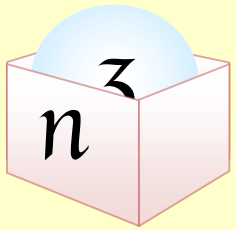
- A function can also call itself. This is called recursion.

$$n! = \begin{cases} 1 & n = 0 \\ n^*(n-1)! & n \geq 1 \end{cases}$$

Calculating factorial

- Factorial Programming : Calculate the factorial of (n-1)!
  by calling the function you are currently writing again (recursive call)

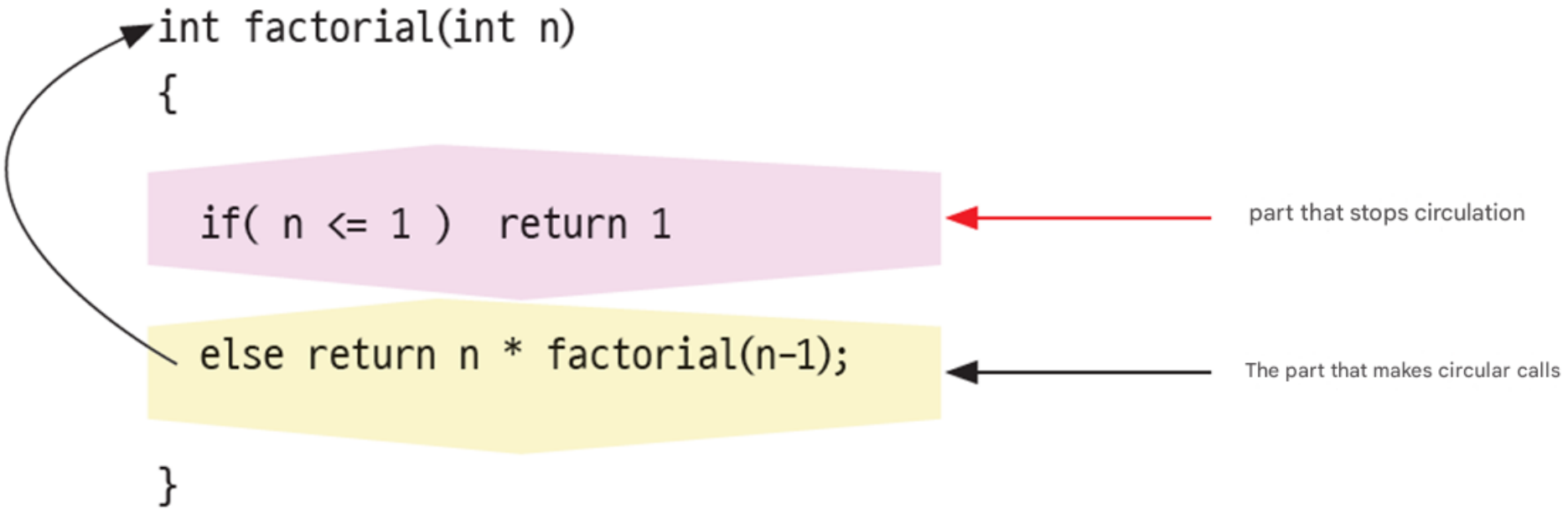
```
int factorial( int n)
{
    if ( n <= 1 ) return (1);
    else return (n * factorial(n-1) );
}
```



Structure of a factorial function

- The recursive algorithm consists of a part that recursively calls itself and a part that stops the recursive call.

  n! = n × (n-1) × (n-2) × ... × 1



Calculating factorial

- Factorial calling order

factorial(3)

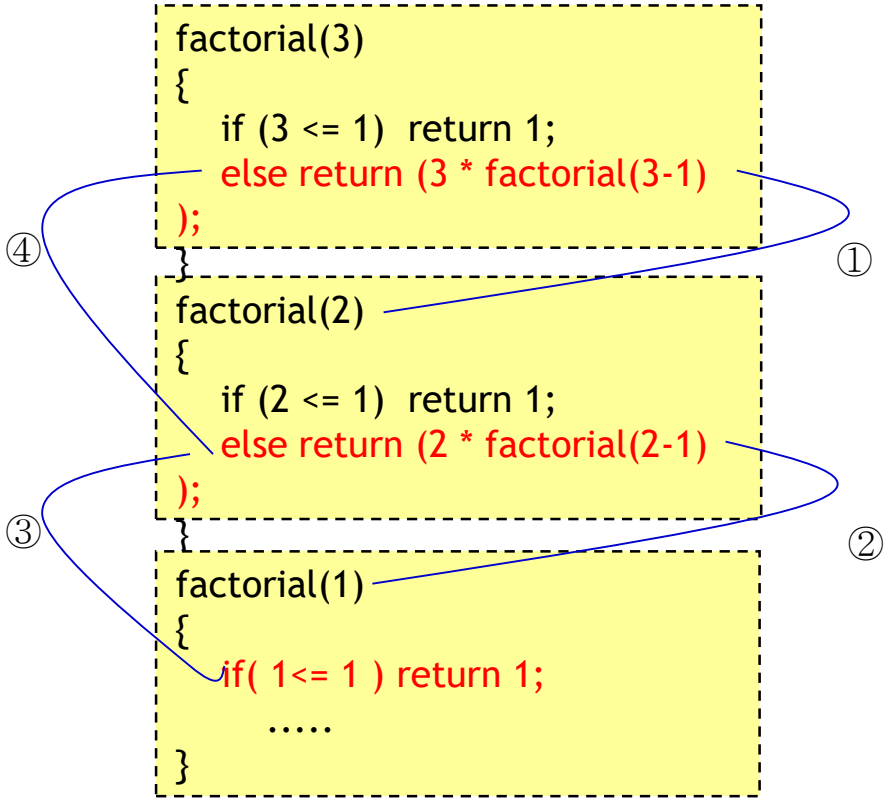
= 3 * factorial(2)

= 3 * 2 * factorial(1)

= 3 * 2 * 1

= 3 * 2

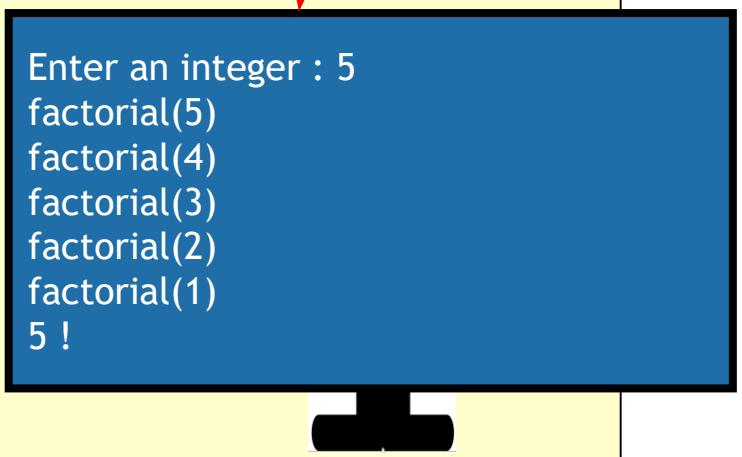
= 6



Factorial calculation

Practice
Ch9-2.c

```
// Calculate the
#include < stdio.h >

long factorial( int n )
{
        printf( "factorial(%d)\n" , n );

        if ( n <= 1)
              return 1;
        else
             return n * factorial( n - 1);
}

int main( void )
{
        int x = 0;
        long f;

        printf ( " Enter an integer :" );
        scanf (“%d”, &x);
        printf (“%d! is %ld . \n”, x, factorial(x));
        return 0;
}
```



Q & A