Functions

Introduction

- **Function**
  - **A self-contained program segment that carries out some specific, well-defined task.**
- **Some properties:**
  - **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".**
  - **A function will carry out its intended action whenever it is *called* or *invoked*.**

- In general, a function will process information that is passed to it from the calling portion of the program, and returns a single value.
  - Information is passed to the function via special identifiers called arguments or parameters.
  - The value is returned by the “return” statement.
- Some function may not return anything.
  - Return data type specified as “void”.

```c
#include  <stdio.h>

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

```c
main()
{
    int  n;
    for  (n=1; n<=10; n++)
          printf (“%d! = %d \n”,
             n, factorial (n) );
}
```

Functions: Why?

- **Functions**
  - Modularize a program
  - All variables declared inside functions are local variables
    - Known only in function defined
  - Parameters
    - Communicate information between functions
    - They also become local variables.
- **Benefits**
  - Divide and conquer
    - Manageable program development
  - Software reusability
    - Use existing functions as building blocks for new programs
    - Abstraction - hide internal details (library functions)
  - Avoids code repetition

Defining a Function

- A function definition has two parts:
  - The first line.
  - The body of the function.

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

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

- **The argument data types can also be declared on the next line:**

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

- **The body of the function is actually a compound statement that defines the action to be taken by the function.**

```
int  gcd  (int A, int B)
{
    int  temp;
    while ((B % A) != 0)  {
      temp = B % A;
      B = A;
      A = temp;
    }
    return (A);
}
```

BODY

- **When a function is called from some other function, the corresponding arguments in the function call are called actual arguments or actual parameters.**
  - **The formal and actual arguments must match in their data types.**
- **Point to note:**
  - **The identifiers used as formal arguments are "local".**
    - **Not recognized outside the function.**
    - **Names of formal and actual arguments may differ.**

```
#include  <stdio.h>
/* Compute the GCD of four numbers */

main()
{
    int  n1, n2, n3, n4, result;
    scanf (“%d %d %d %d”, &n1, &n2, &n3, &n4);
    result  =  gcd ( gcd (n1, n2), gcd (n3, n4) );
    printf (“The GCD of %d, %d, %d and %d is %d \n”,
                 n1, n2, n3, n4, result);
}
```

Function Not Returning Any Value

- **Example: A function which only prints if a number if divisible by 7 or not.**

```
void  div7 (int n)
{
   if  ((n % 7) == 0)
        printf (“%d is divisible by 7”, n);
   else
        printf (“%d is not divisible by 7”, n);

   return;        <------------------------  OPTIONAL
}
```

- **Returning control**
  - **If nothing returned**
    - `return;`
    - **or, until reaches right brace**
  - **If something returned**
    - `return` ***expression***`;`

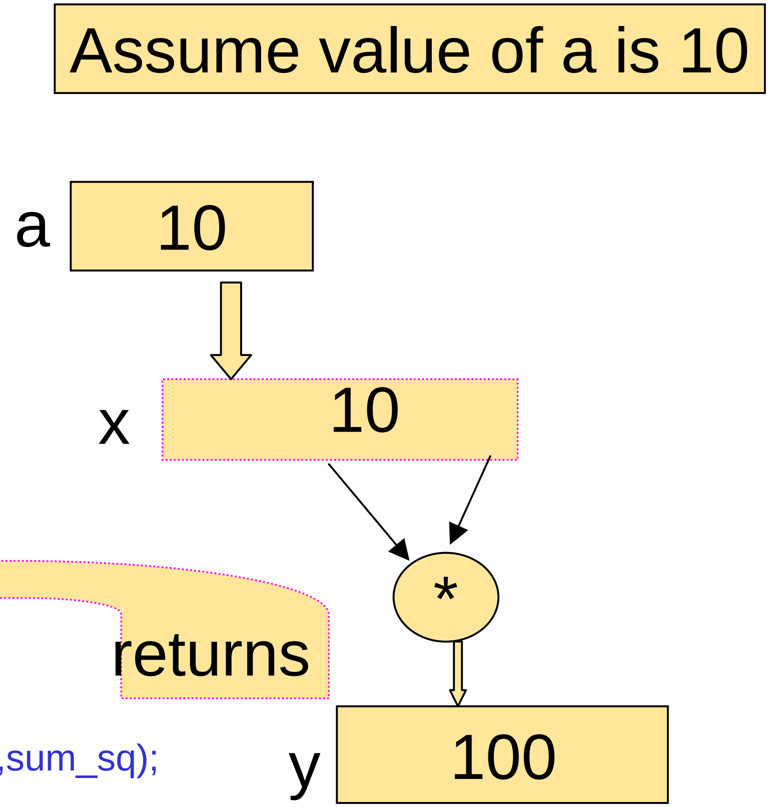
Function: An Example

```
#include <stdio.h>

int square(int x)
{
  int y;

  y=x*x;
  return(y);
}

 void main()
 {
   int a,b,sum_sq;

   printf("Give a and b \n");
   scanf("%d%d",&a,&b);

   sum_sq=square(a)+square(b);

   printf("Sum of squares= %d \n",sum_sq);
  }
```

- Function declaration
- *Name of function*
- Return data-type
- parameter
- Functions called
- Parameters Passed

Invoking a function call : An Example

```
#include <stdio.h>

int square(int x)
{
  int y;

  y=x*x;
  return(y);
}

 void main()
 {
   int a,b,sum_sq;

   printf(“Give a and b \n”);
   scanf(“%d%d”,&a,&b);

   sum_sq=square(a)+square(b);

   printf(“Sum of squares= %d \n”,sum_sq);
  }
```



Function Definitions

- **Function definition format (continued)**

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

  - **Declarations and statements: function body (block)**
    - **Variables can be declared inside blocks (can be nested)**
    - **Function can not be defined inside another function**
  - **Returning control**
    - **If nothing returned**
      - `return;`
      - **or, until reaches right brace**
    - **If something returned**
      - `return` ***expression***`;`

An example of a function

Return datatype

Function name

```
int sum_of_digits(int n)
 {
   int sum=0;

      while (n != 0)  {
      sum = sum + (n % 10);
      n = n / 10;
      }
   return(sum);
 }
```

Parameter List

Local variable

Expression

Return statement

Variable Scope

- int A;
- void main()
    - { A = 1;
    - myProc();
    - printf ("A = %d\n", A);
    - }
    - void myProc()
    - { int A = 2;
    - while(A==2)
    - {
    - int A = 3;
    - printf ("A = %d\n", A);
    - break;
    - }
    - printf ("A = %d\n", A);
    - }
    - . . .

Printout:

A = 3

A = 2

A = 1

Function: Summary

```
#include <stdio.h>

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

Returned data-type

parameter

Function name

Local vars

Return statement

Self contained programme

```
main()
{
    int n;
    for (n=1; n<=10; n++)
     printf ("%d! = %d \n", n,
    factorial (n) );
}
```

main() is a function

Calling a function

Some Points

- A function cannot be defined 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.

Math Library Functions

- **Math library functions**
  - **perform common mathematical calculations**
  - `#include <math.h>`
  - `cc <prog.c> -lm`

- **Format for calling functions**

  `FunctionName (argument);`

    - **If multiple arguments, use comma-separated list**

  - `printf( "%.2f", sqrt( 900.0 ) );`
    - **Calls function** `sqrt`**, which returns the square root of its argument**
    - **All math functions return data type** `double`
  - **Arguments may be constants, variables, or expressions**

Math Library Functions

- **double acos(double x) -- Compute arc cosine of x.**
- **double asin(double x) -- Compute arc sine of x.**
- **double atan(double x) -- Compute arc tangent of x.**
- **double atan2(double y, double x) -- Compute arc tangent of y/x.**
- **double ceil(double x) -- Get smallest integral value that exceeds x.**

  double floor(double x) -- Get largest integral value less than x.
- **double cos(double x) -- Compute cosine of angle in radians.**
  double cosh(double x) -- Compute the hyperbolic cosine of x.

  double sin(double x) -- Compute sine of angle in radians.
  double sinh(double x) - Compute the hyperbolic sine of x.

  double tan(double x) -- Compute tangent of angle in radians.
  double tanh(double x) -- Compute the hyperbolic tangent of x.
- **double exp(double x -- Compute exponential of x**
  double fabs (double x) -- Compute absolute value of x.
  double log(double x) -- Compute log(x).
  double log10 (double x) -- Compute log to the base 10 of x.
  double pow (double x, double y) -- Compute x raised to the power y.
  double sqrt(double x) -- Compute the square root of x.

More about scanf and printf

Entering input data :: scanf function

- **General syntax:**

  scanf (control string, arg1, arg2, …, argn);

  – "control string refers to a string typically containing data types of the arguments to be read in;

  – the arguments arg1, arg2, … represent pointers to data items in memory.

  Example: scanf (%d %f %c", &a, &average, &type);

- **The control string consists of individual groups of characters, with one character group for each input data item.**

  – '%' sign, followed by a conversion character.

- Commonly used conversion characters:

c	single character
d	decimal integer
f	floating-point number
s	string terminated by null character
X	hexadecimal integer

- We can also specify the maximum field-width of a data item, by specifying a number indicating the field width before the conversion character.

  Example: `scanf ("%3d %5d", &a, &b);`

Writing output data :: printf function

- General syntax:

  printf (control string, arg1, arg2, …, argn);

  - "control string refers to a string containing formatting information and data types of the arguments to be output;
  - the arguments arg1, arg2, … represent the individual output data items.
- The conversion characters are the same as in scanf.

- **Examples:**

```
printf  ("The average of %d and %d is %f", a, b, avg);
printf  ("Hello \nGood \nMorning \n");
printf ("%3d %3d %5d", a, b, a*b+2);
printf ("%7.2f  %5.1f", x, y);
```

- **Many more options are available:**
  - Read from the book.
  - Practice them in the lab.
- **String I/O:**
  - Will be covered later in the class.

Function Prototypes

- **Usually, a function is defined before it is called.**
  - **main() is the last function in the program.**
  - **Easy for the compiler to identify function definitions in a single scan through the file.**
- **However, many programmers prefer a top-down approach, where the functions follow main().**
  - **Must be some way to tell the compiler.**
  - **Function prototypes are used for this purpose.**
    - **Only needed if function definition comes after use.**

Function Prototype (Contd.)

- Function prototypes are usually written at the beginning of a program, ahead of any functions (including main()).
- Examples:

```
int  gcd (int A, int B);
void div7 (int number);
```

;

- Note the semicolon at the end of the line.
- The argument names can be different; but it is a good practice to use the same names as in the function definition.

Function Prototype: Examples

```
#include  <stdio.h>

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

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

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

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

Prototype declaration

```
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);
}
```

Function definition

Header Files

- **Header files**
  - **contain function prototypes for library functions**
  - `<stdlib.h>`**,** `<math.h>`**, etc**
  - **Load with**

    `#include <filename>`
  - `#include <math.h>`

- **Custom header files**
  - **Create file with functions**
  - **Save as** `filename.h`
  - **Load in other files with** `#include "filename.h"`
  - **Reuse functions**

```c
/* Finding the maximum of three integers */
#include <stdio.h>

int maximum( int, int, int );   /* function prototype */

int main()
{
   int a, b, c;

   printf( "Enter three integers: " );
   scanf( "%d%d%d", &a, &b, &c );
   printf( "Maximum is: %d\n", maximum( a, b, c ) );

   return 0;
}

/* Function maximum definition */
int maximum( int x, int y, int z )
{
   int max = x;

   if ( y > max )
      max = y;

   if ( z > max )
      max = z;

   return max;
}
```

Prototype Declaration

Function Calling

Function Definition

Calling Functions: Call by Value and Call by Reference

- **Used when invoking functions**
- **Call by value**
  - **Copy of argument passed to function**
  - **Changes in function do not effect original**
  - **Use when function does not need to modify argument**
    - **Avoids accidental changes**
- **Call by reference**
  - **Passes original argument**
  - **Changes in function effect original**
  - **Only used with trusted functions**
- **For now, we focus on call by value**

An Example: Random Number Generation

- `rand` **function**
  - **Prototype defined in** `<stdlib.h>`
  - **Returns "random" number between** `0` **and** `RAND_MAX` **(at least 32767)**

    ```
    i = rand();
    ```
  - **Pseudorandom**
    - **Preset sequence of "random" numbers**
    - **Same sequence for every function call**
- **Scaling**
  - **To get a random number between** `1` **and** `n`

    ```
    1 + ( rand() % n )
    ```
    - `rand % n` **returns a number between** `0` **and** `n-1`
    - **Add** `1` **to make random number between** `1` **and** `n`

      ```
      1 + ( rand() % 6)   // number between 1 and 6
      ```

Random Number Generation: Contd.

- `srand` **function**
  - Prototype defined in <stdlib.h>
  - **Takes an integer seed - jumps to location in "random" sequence**

    ```
    srand( seed );
    ```

```c
/* A programming example
   Randomizing die-rolling program */
#include <stdlib.h>
#include <stdio.h>

int main()
{
   int i;
   unsigned seed;

   printf( "Enter seed: " );
   scanf( "%u", &seed );
   srand( seed );

   for ( i = 1; i <= 10; i++ ) {
      printf( "%10d ", 1 + ( rand() % 6 ) );

      if ( i % 5 == 0 )
         printf( "\n" );
   }

   return 0;
}
```

Algorithm

1. Initialize seed
2. Input value for seed

2.1 Use srand to change random sequence

2.2 Define Loop

3. Generate and output random numbers

Program Output

```
Enter seed: 67
         6         1         4         6         2
         1         6         1         6         4
```

```
Enter seed: 867
         2         4         6         1         6
         1         1         3         6         2
```

```
Enter seed: 67
         6         1         4         6         2
         1         6         1         6         4
```

#include: Revisited

- Preprocessor statement in the following form

  #include “filename”

- Filename could be specified with complete path.

  #include “/usr/home/rajan/myfile.h”

- The content of the corresponding file will be included in the present file before compilation and the compiler will compile thereafter considering the content as it is.

#include: Contd.

```c
#include <stdio.h>
int x;

main()
{
  printf("Give value of x \n)";
 scanf("%d",&x);
  printf("Square of x=%d \n",x*x);
}
```

prog.c

```c
#include <stdio.h>

int x;
```

myfile.h

#include <filename.h>

/usr/include/filename.h

It includes the file "filename.h" from a specific directory known as include directory.

#define: Macro definition

```c
#include <stdio.h>

#define PI 3.14

main()

{

  float r=4.0,area;

  area=PI*r*r;

}
```

```c
#include <stdio.h>

main()

{

  float r=4.0,area;

  area=3.14*r*r;

}
```

#define with argument

- **#define statement may be used with argument e.g.**

#define sqr(x) ((x)*(x))

```
#include <stdio.h>

main()
{
  int y=5;
  printf("value=%d \n", ((y)*(y))+3);
}
```

Which one is faster to execute?

sqr(x) written as macro definition?

sqr(x) written as an ordinary function?

#define with arguments: A Caution

- #define sqr(x) x*x
  - How macro substitution will be carried out?

    r = sqr(a) + sqr(30); ➔ r = a*a + 30*30;

    r = sqr(a+b); ➔ r = a+b*a+b;

    WRONG?

  - The macro definition should have been written as:

    #define sqr(x) (x)*(x)

    r = (a+b)*(a+b);

Recursion

- A process by which a function calls itself repeatedly.
  - Either directly.
    - X calls X.
  - Or cyclically in a chain.
    - X calls Y, and Y calls X.
- Used for repetitive computations in which each action is stated in terms of a previous result.
  - fact(n) = n * fact (n-1)

Contd.

- **For a problem to be written in recursive form, two conditions are to be satisfied:**
  - **It should be possible to express the problem in recursive form.**
  - **The problem statement must include a stopping condition**

```
fact(n)  =  1,                  if  n = 0
         =  n * fact(n-1),      if  n > 0
```

- **Examples:**
  - **Factorial:**

    fact(0) = 1

    fact(n) = n * fact(n-1), if n > 0
  - **GCD:**

    gcd (m, m) = m

    gcd (m, n) = gcd (m-n, n), if m > n

    gcd (m, n) = gcd (n, n-m), if m < n
  - **Fibonacci series (1,1,2,3,5,8,13,21,….)**

    fib (0) = 1

    fib (1) = 1

    fib (n) = fib (n-1) + fib (n-2), if n > 1

Example 1 :: Factorial

```
long  int  fact (n)
int  n;
{
   if   (n = = 0)
      return (1);
   else
      return  (n * fact(n-1));
}
```

Mechanism of Execution

- **When a recursive program is executed, the recursive function calls are not executed immediately.**
  - **They are kept aside (on a stack) until the stopping condition is encountered.**
  - **The function calls are then executed in reverse order.**

Example :: Calculating fact(4)

– First, the function calls will be processed:

fact(4) = 4 * fact(3)

fact(3) = 3 * fact(2)

fact(2) = 2 * fact(1)

fact(1) = 1 * fact(0)

– The actual values return in the reverse order:

fact(0) = 1

fact(1) = 1 * 1 = 1

fact(2) = 2 * 1 = 2

fact(3) = 3 * 2 = 6

fact(4) = 4 * 6 = 24

Another Example :: Fibonacci number

- Fibonacci number f(n) can be defined as:

  $f(0) = 0$

  $f(1) = 1$

  $f(n) = f(n-1) + f(n-2), \quad \text{if } n > 1$

  – The successive Fibonacci numbers are:

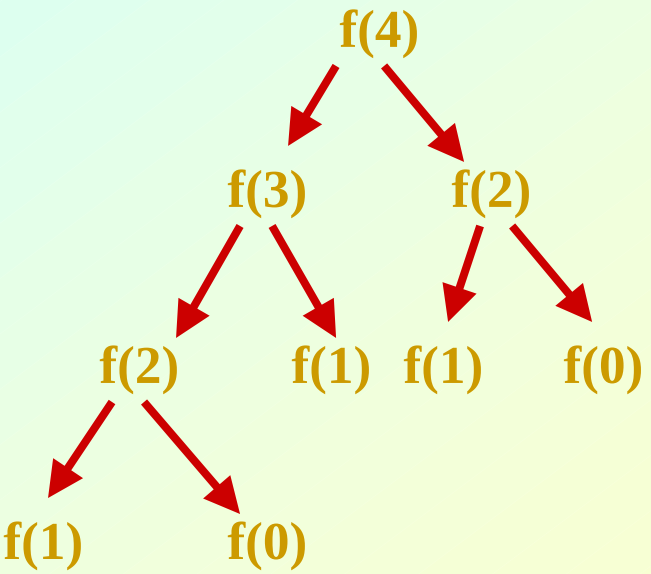
    0, 1, 1, 2, 3, 5, 8, 13, 21, …..

- Function definition:

```
int   f (int n)
{
    if  (n  < 2)   return (n);
    else  return (f(n-1) + f(n-2));
}
```

Tracing Execution

- **How many times the function is called when evaluating f(4) ?**



- **Inefficiency:**
  - Same thing is computed several times.

9 times

Example Codes: fibonacci()

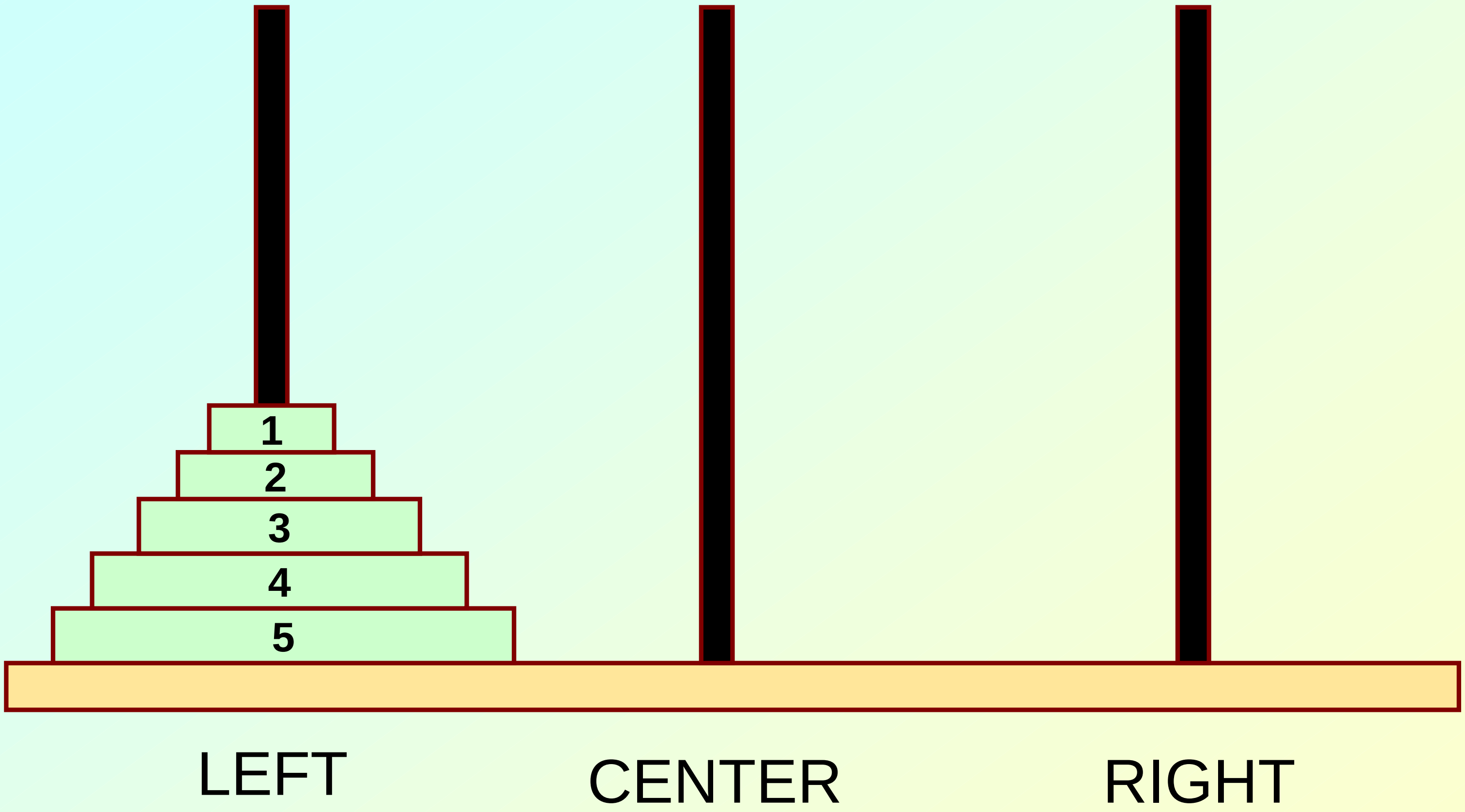
– Code for the `fibonacci` function

```
long fibonacci( long n )
{
  if (n == 0 || n == 1)  // base case
     return n;
  else
     return fibonacci( n - 1) +
        fibonacci( n – 2 );
}
```

Performance Tip

- Avoid Fibonacci-style recursive programs which result in an exponential "explosion" of calls.

Example: Towers of Hanoi Problem



- **The problem statement:**
  - **Initially all the disks are stacked on the LEFT pole.**
  - **Required to transfer all the disks to the RIGHT pole.**
    - **Only one disk can be moved at a time.**
    - **A larger disk cannot be placed on a smaller disk.**

- Recursive statement of the general problem of n disks.
  - Step 1:
    - Move the top (n-1) disks from LEFT to CENTER.
  - Step 2:
    - Move the largest disk from LEFT to RIGHT.
  - Step 3:
    - Move the (n-1) disks from CENTER to RIGHT.

```
#include  <stdio.h>

void  transfer (int n, char from, char to, char temp);

main()
{
     int  n;  /* Number of disks */
     scanf (“%d”, &n);
     transfer (n, ‘L’, ‘R’, ‘C’);
}

void  transfer (int n, char from, char to, char temp)
{
     if  (n > 0)  {
              transfer  (n-1, from, temp,to);
              printf (“Move disk %d from %c to %c \n”, n, from, to);
              transfer (n-1, temp, to, from);
     }
     return;
}
```

Telnet 144.16.192.60

```
3
Move disk 1 from L to R
Move disk 2 from L to C
Move disk 1 from R to C
Move disk 3 from L to R
Move disk 1 from C to L
Move disk 2 from C to R
Move disk 1 from L to R
[isg@facweb temp]$
```

Telnet 144.16.192.60

```
4
Move disk 1 from L to C
Move disk 2 from L to R
Move disk 1 from C to R
Move disk 3 from L to C
Move disk 1 from R to L
Move disk 2 from R to C
Move disk 1 from L to C
Move disk 4 from L to R
Move disk 1 from C to R
Move disk 2 from C to L
Move disk 1 from R to L
Move disk 3 from C to R
Move disk 1 from L to C
Move disk 2 from L to R
Move disk 1 from C to R
[isg@facweb temp]$ _
```

Recursion vs. Iteration

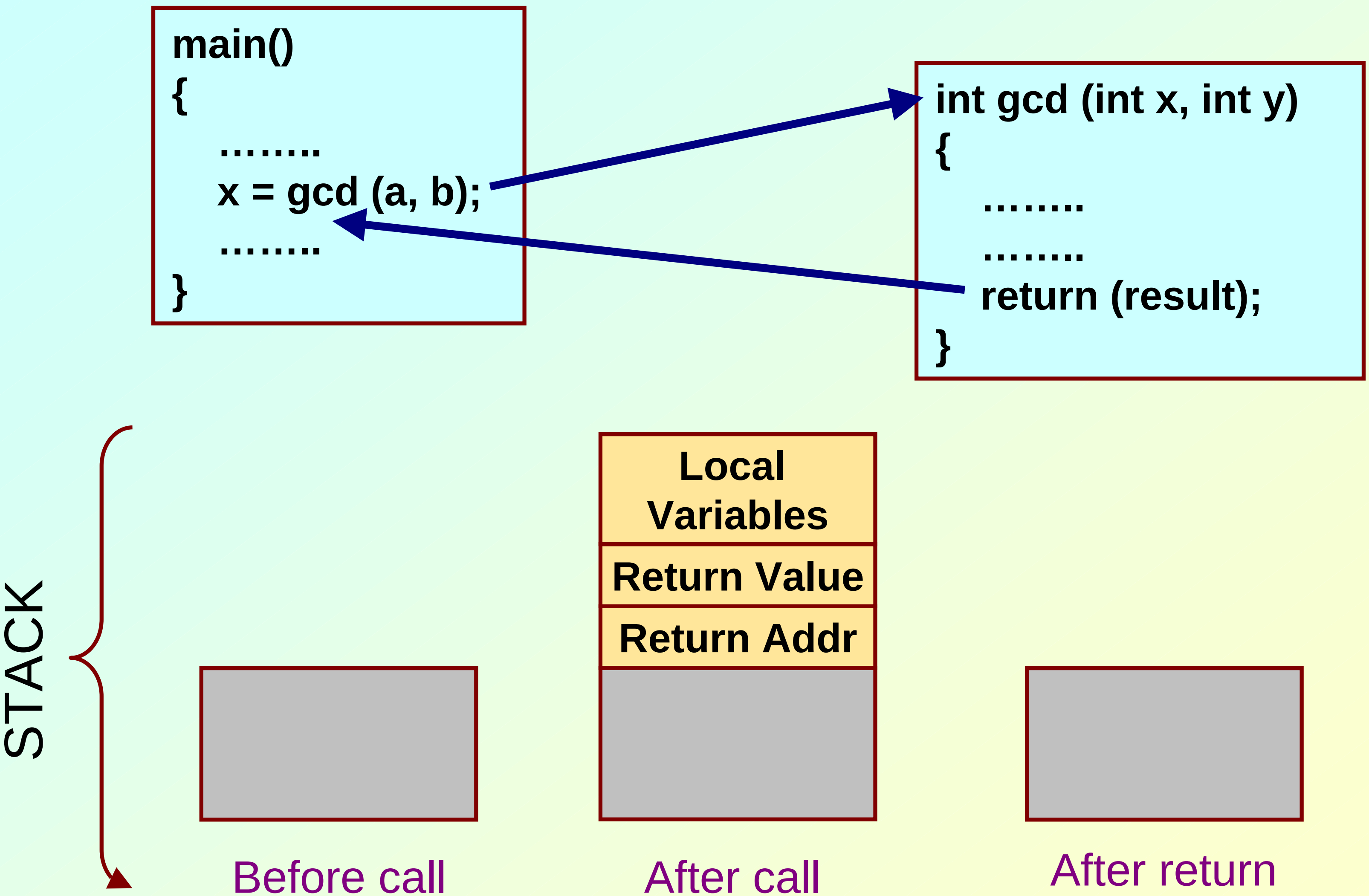
- Repetition
  - Iteration: explicit loop
  - Recursion: repeated function calls
- Termination
  - Iteration: loop condition fails
  - Recursion: base case recognized
- Both can have infinite loops
- Balance
  - Choice between performance (iteration) and good software engineering (recursion)

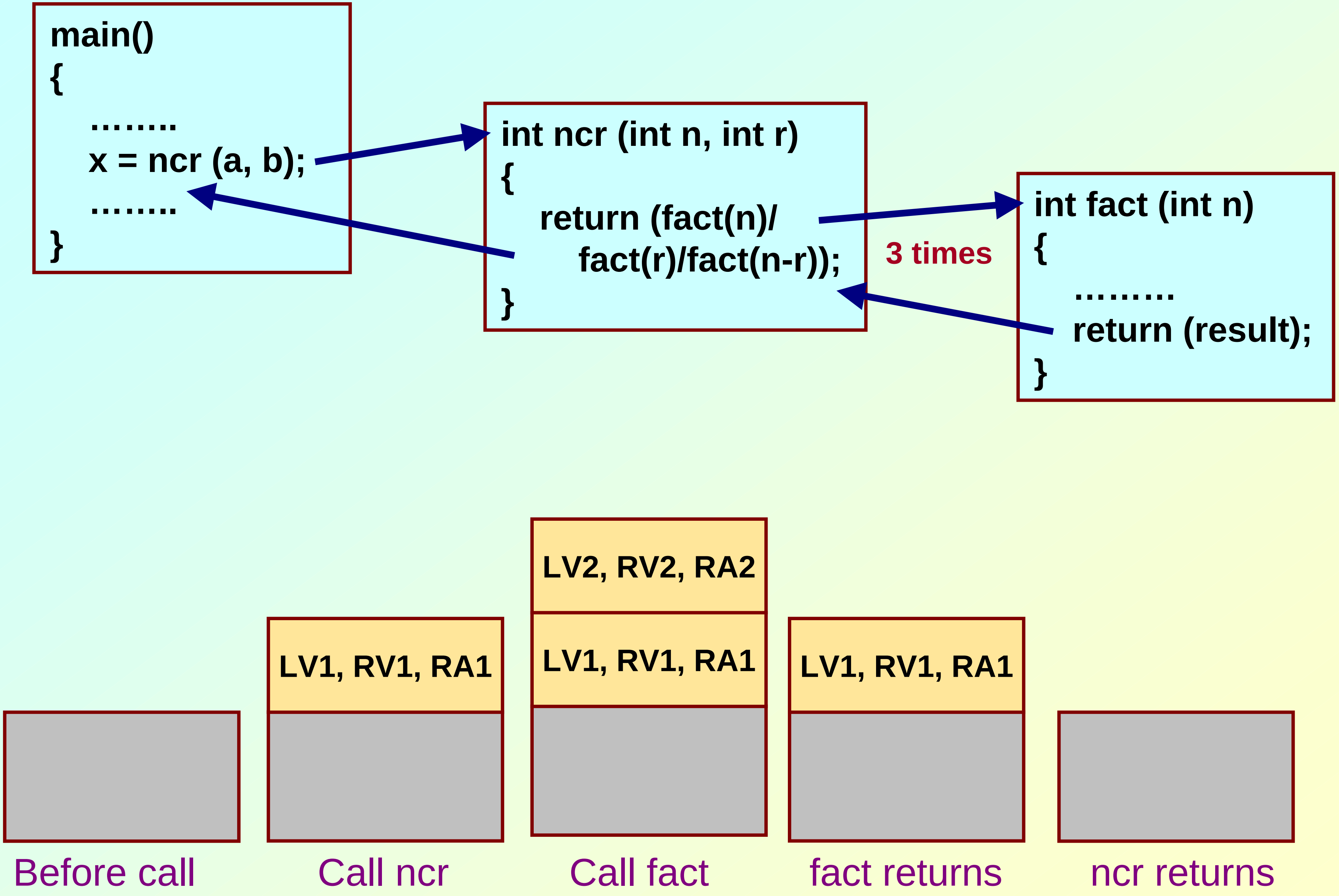
Performance Tip

- **Avoid using recursion in performance situations. Recursive calls take time and consume additional memory.**

How are function calls implemented?

- In general, during program execution
  - The system maintains a stack in memory.
    - Stack is a last-in first-out structure.
    - Two operations on stack, push and pop.
  - Whenever there is a function call, the activation record gets pushed into the stack.
    - Activation record consists of the return address in the calling program, the return value from the function, and the local variables inside the function.
  - At the end of function call, the corresponding activation record gets popped out of the stack.

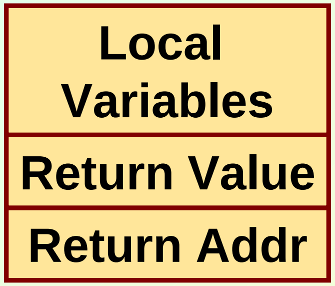

main()
{
....
x = gcd (a, b);
....
}
int gcd (int x, int y)
{
....
....
return (result);
}
STACK
Local Variables
Return Value
Return Addr
Before call
After call
After return


main()
{
....
x = ncr (a, b);
....
}
int ncr (int n, int r)
{
return (fact(n)/
fact(r)/fact(n-r));
}
3 times
int fact (int n)
{
....
return (result);
}
LV2, RV2, RA2
LV1, RV1, RA1
LV1, RV1, RA1
LV1, RV1, RA1
Before call
Call ncr
Call fact
fact returns
ncr returns

What happens for recursive calls?

- What we have seen ….
  - Activation record gets pushed into the stack when a function call is made.
  - Activation record is popped off the stack when the function returns.
- In recursion, a function calls itself.
  - Several function calls going on, with none of the function calls returning back.
    - Activation records are pushed onto the stack continuously.
    - Large stack space required.
    - Activation records keep popping off, when the termination condition of recursion is reached.

- We shall illustrate the process by an example of computing factorial.
  - Activation record looks like:

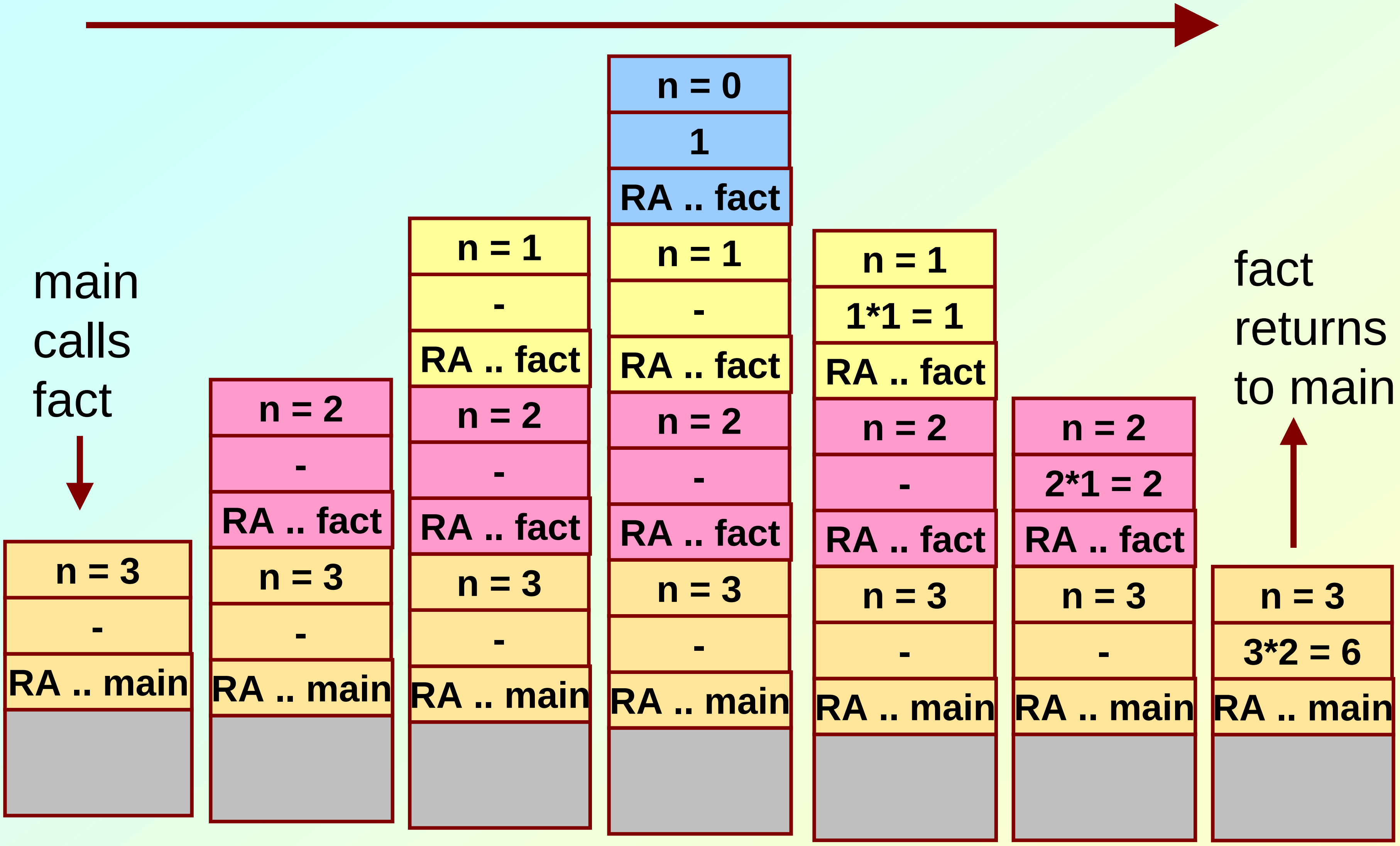


Example:: main() calls fact(3)

```
main()
{
   int  n;
   n = 4;
   printf (“%d \n”, fact(n) );
}
```

```
int  fact (int n)
{
    if   (n = = 0)
        return (1);
    else
        return  (n * fact(n-1));
}
```

TRACE OF THE STACK DURING EXECUTION



Do Yourself

- Trace the activation records for the following version of Fibonacci sequence.

```
#include <stdio.h>
int   f (int n)
{
     int a, b;
     if  (n  < 2)   return (n);
     else  {
       a = f(n-1);
       b = f(n-2);
       return (a+b);  }
}

main() {
   printf(“Fib(4) is: %d \n”, f(4));
}
```

X → (points to `b = f(n-2);`)

Y → (points to `return (a+b);`)

main → (points to `%d` in the `printf` line)

Local Variables (n, a, b)
Return Value
Return Addr (either main, or X, or Y)

Storage Class of Variables

What is Storage Class?

- It refers to the permanence of a variable, and its *scope* within a program.
- Four storage class specifications in C:
  - Automatic: `auto`
  - External: `extern`
  - Static: `static`
  - Register: `register`

Automatic Variables

- These are always declared within a function and are local to the function in which they are declared.
  - Scope is confined to that function.
- This is the default storage class specification.
  - All variables are considered as `auto` unless explicitly specified otherwise.
  - The keyword `auto` is optional.
  - An automatic variable does not retain its value once control is transferred out of its defining function.

```c
#include <stdio.h>

int factorial(int m)
{
   auto int i;
   auto int temp=1;
   for (i=1; i<=m; i++)
       temp = temp * i;
   return (temp);
}
```

```c
main()
{
   auto int  n;
   for (n=1; n<=10; n++)
     printf ("%d! = %d \n",
          n, factorial (n));
}
```

Static Variables

- Static variables are defined within individual functions and have the same scope as automatic variables.
- Unlike automatic variables, static variables retain their values throughout the life of the program.
  - If a function is exited and re-entered at a later time, the static variables defined within that function will retain their previous values.
  - Initial values can be included in the static variable declaration.
    - Will be initialized only once.
- An example of using static variable:
  - Count number of times a function is called.

EXAMPLE 1

```
#include <stdio.h>

int factorial (int n)
{
   static int count=0;
   count++;
   printf (“n=%d, count=%d \n”, n, count);
   if (n == 0) return 1;
   else return (n * factorial(n-1));
}
```

```
main()
{
    int i=6;
    printf (“Value is: %d \n”, factorial(i));
}
```

- **Program output:**

```
n=6, count=1
n=5, count=2
n=4, count=3
n=3, count=4
n=2, count=5
n=1, count=6
n=0, count=7
Value is: 720
```

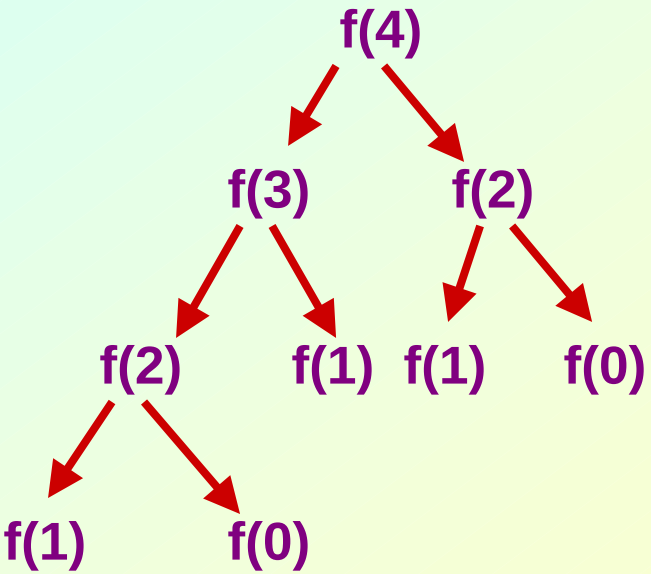
EXAMPLE 2

```
#include <stdio.h>

int fib (int n)
{
   static int count=0;
   count++;
   printf ("n=%d, count=%d \n", n, count);
   if (n < 2) return n;
   else return (fib(n-1) + fib(n-2));
}
```

```
main()
{
    int i=4;
    printf ("Value is: %d \n", fib(i));
}
```

- **Program output:**

```
n=4, count=1
n=3, count=2
n=2, count=3
n=1, count=4
n=0, count=5
n=1, count=6
n=2, count=7
n=1, count=8
n=0, count=9
Value is: 3
```



[0,1,1,2,3,5,8,….]

Register Variables

- These variables are stored in high-speed registers within the CPU.
  - Commonly used variables may be declared as register variables.
  - Results in increase in execution speed.
  - The allocation is done by the compiler.

External Variables

- They are not confined to single functions.
- Their scope extends from the point of definition through the remainder of the program.
  - They may span more than one functions.
  - Also called global variables.
- Alternate way of declaring global variables.
  - Declare them outside the function, at the beginning.

```c
#include <stdio.h>

int count=0;    /** GLOBAL VARIABLE **/
int factorial (int n)
{
   count++;
   printf ("n=%d, count=%d \n", n, count);
   if (n == 0) return 1;
   else return (n * factorial(n-1));
}
```

```c
main()  {
     int i=6;
     printf ("Value is: %d \n", factorial(i));
     printf ("Count is: %d \n", count);
}
```

- **Program output:**

```
n=6, count=1
n=5, count=2
n=4, count=3
n=3, count=4
n=2, count=5
n=1, count=6
n=0, count=7
Value is: 720
Count is: 7
```