# Dynamic memory allocation

# outline

- Memory allocation functions
- Array allocation
- Matrix allocation
- Examples

# Memory allocation functions (#include <stdlib.h>)

- ***malloc()***
  - Allocates a specified number of bytes in memory. Returns a pointer to the beginning of the allocated block.
- ***calloc()***
  - Similar to malloc(), but initializes the allocated bytes to zero. This function allows you to allocate memory for more than one object at a time.
- ***realloc()***
  - Changes the size of a previously allocated block.
- ***free()***
  - Frees up memory that was previously allocated with *malloc(), calloc(), or realloc()*.

# Memory allocation functions

- *void *malloc(size_t size);* // size: size of the memory block, in bytes
- *void *calloc(size_t nmemb, size_t size);* // the 1st arg: number of the objects to reserve the memory, the 2nd arg: size of each object.
- *void *realloc(void *ptr, size_t size);* //changes the size of the memory block pointed by ptr. The function may move the memory block to a new location (whose address is returned by the function).
- *void free(void *ptr);* // deallocate the memory block pointed by ptr

# Array allocation

```
#include <stdio.h>
#include <stdlib.h>
int main() {
  int n;
 int *list;
 printf("How many numbers are you going to enter ?");
 scanf("%d", &n);
 list = (int *) malloc( n * sizeof(int) );    // list = (int *) calloc( n, sizeof(int) );
 if(list==NULL)  {
    printf("Can not allocate memory for the array...\n");
    return -1;
  }
  return 0;
}
```

# Matrix allocation

```
int **mat;
int n,m;
printf("Please enter number of rows");        scanf("%d", &n);
printf("Please enter number of columns");     scanf("%d", &m);
mat = (int **) malloc( n * sizeof(int *) );
if(mat == NULL)  {
        printf("Can not allocate memory for the array...\n");
        return -1;
}
for(i = 0; i < n; i++)  {
        mat[i] = (int *)malloc(m * sizeof(int) );
}
```

# Example-1

- Write a simple program
  - ask number of elements in the array
  - allocate necessary space
  - ask for elements
  - sort the array

# Example-2

- Write a simple program
  - ask maximum possible size of a string
  - allocate necessary space for this string
  - ask maximum possible size of another string
  - allocate necessary space for the 2nd string
  - read the two strings, sequentially,
  - find the 2nd string within the 1st one,
  - return the starting position of str2 in str1; return -1 if not found.

# Functions

# Outline

- Passing arguments
  - pass by reference, pass by value
- Declarations and calls
  - definition, allusion, function call
- Examples
- Recursion
- The main function
- Function pointers

# Passing arguments

- Because C passes arguments by value, a function can assign values to the formal arguments without affecting the actual arguments

- If you **want** a function to change the value of an object, you must pass a pointer to the object and then make an assignment through the dereferenced pointer.
  - ***remember scanf function !!!***

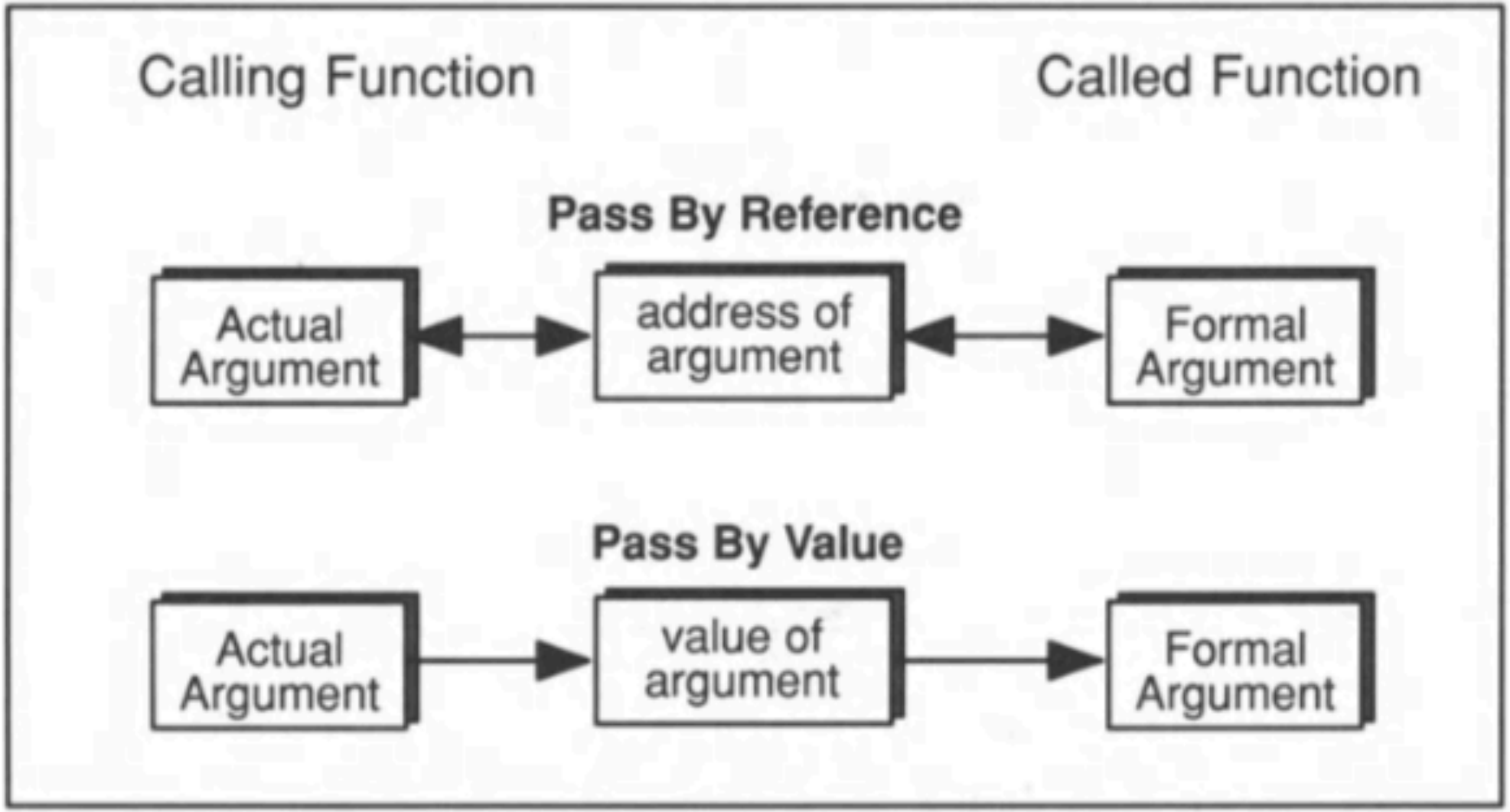



*Figure 9-1. Pass By Reference vs. Pass By Value. In Pass By Reference, the actual and formal arguments refer to the same memory area; in Pass By Value, the formal argument is a copy of the actual argument.*

# Declarations and calls

- Definition
  - Actually defines what the function does, as well as number and type of arguments
- Function Allusion
  - Declares a function that is defined somewhere else
  - Also specifies what kind of value the function returns.
- Function Call
  - Invokes a function, causing program execution to jump to the next invoked function. When the function returns, execution resumes at the point just after the call

# Function definition

- A very simple example
  - no arguments
  - no return

```
void simpleFunction1 ( void ) {

        printf("\nThis is
simpleFunction1\n");
}
```

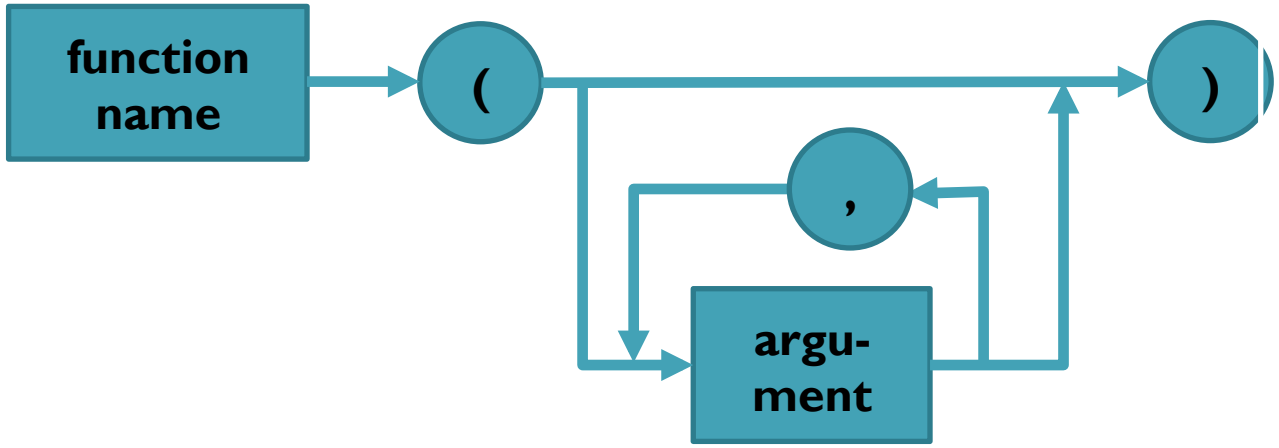
- A relatively complex example
  - a function to calculate factorial n

```
int factorial( int n) {
        int i,f=1;
        for(i=2;i<=n;i++)
                f = f * i;
        return f;
}
```

# Function allusion

- void simpleFunction1( void );  // prototype of the function
- simpleFunction1();  // alternative to the above allusion
- extern float simpleFunction2();  // no input argument, returns float
- int factorial( int );  // takes integer, returns integer
- void sortArray(int *, int);  // takes 1 int-pointer, 1 int, returns nothing
- float *mergeSort(float *, int, float *, int, int *);

# Function call




```
printf("Hello World\n");
printf("Result is %d\n", factorial(10));
scanf("%s", str);
x = factorial(n) / factorial(m);
printf("%d : %d  : %s : %d\n", i, j, line, rc);
matT = transpose(mat, rows, cols);
```

- Number of the arguments in the function-definition and function-call should be consistent.
- When we call a function, argument types should be consistent and in the same order as they defined.

# Order of functions

- In order to use a function you must define it beforehand.
  - In order to use your own function in the ***main() function***, you should define it ***before the main()*** in the same file

- It is also possible to use function allusion (function prototype)
  - You can write the prototype of your function before the ***main() function*** and use it anywhere (main() or any other function of yours)

# Function arguments

# Passing arrays as function parameter

- Several ways to do it…
- Do NOT forget
  - no boundary checking !
  - remember your motivation to create a function
- Using actual array size
  - void myFunction( int ar[5] )
- Using array and a size parameter
  - void myFunction( int ar[], int size )
- Using a pointer and an integer
  - void myFunction( int *ar, int size )

# How to return an array from a function

- We don't return an array from functions, rather we return a pointer holding the base address of the array to be returned.

- We must, make sure that the array exists after the function ends!
  - you can **NOT** return local arrays!

- **SOLUTION** : dynamic memory allocation + pointers

# EXAMPLE -1

- Create a sort function for one dimensional arrays
- Use any type of sorting algorithm

# EXAMPLE -2

- Write a function that compresses a sparse matrix
- The function should take a matrix as a parameter
- The function should return a new matrix 3 x n or n x 3

# RECURSION

- A recursive function is one that calls itself.
  - An example is given on the right side
- It is important to notice that this function will call itself forever.
  - Actually not forever, but till the computer runs out of stack memory
  - It means a runtime error
- Thus, remember to include a stop point in your recursive functions.

```
void recurse ()  {
        static count = 1;
        printf("%d\n", count);
        count++;
        recurse();
}
main()  {
        recurse();
}
```

# Recursion

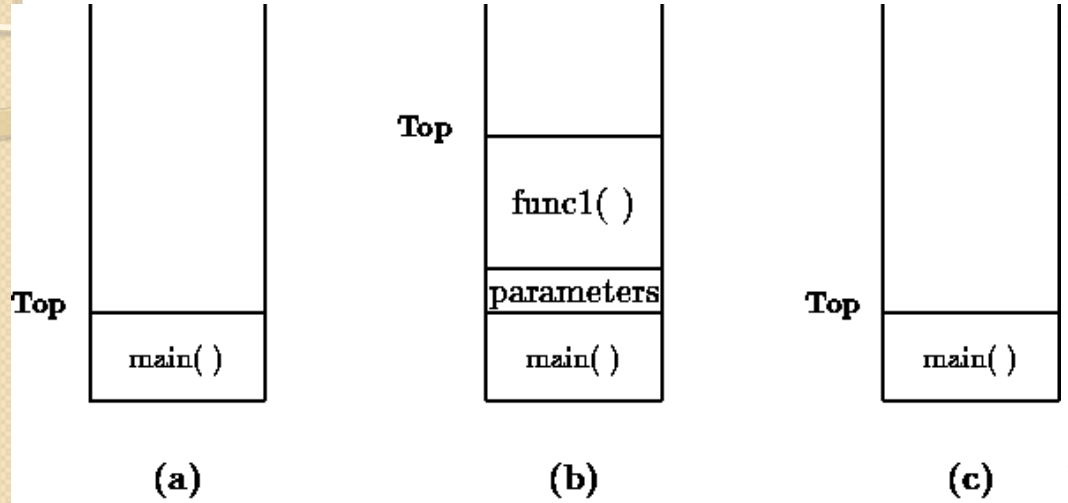



Figure 14.13: Organization of the Stack

- When a program begins executing in the function main(), space is allocated on the stack for all variables declared within main(), **Figure 14.13(a)**
- If main() calls a function, func1(), additional storage is allocated for the variables in func1() at the top of the stack **Figure 14.13(b)**
  - Notice that the parameters passed by main() to func1() are also stored on the stack.
- When func1() returns, storage for its local variables is deallocated, and the top of the stack returns to the 1st position **Figure 14.13(c)**
- As can be seen, the memory allocated in the stack area is used and reused during program execution.
  - *It should be clear that memory allocated in this area will contain garbage values left over from previous usage.*

# Recursion

- A few examples to solve with recursion
  - Factorial – n!
  - Fibonacci numbers – $F_{n+1} = F_n + F_{n-1}$
  - Binary search
  - Depth-first search

```
int fact( int n )  {
        if( n <= 1 )
                return 1;
        else
                return n*fact(n-1);
}
main()  {
        printf("5! is %d\n", fact(5));
}
```

# Recursion

- A few examples to solve with recursion
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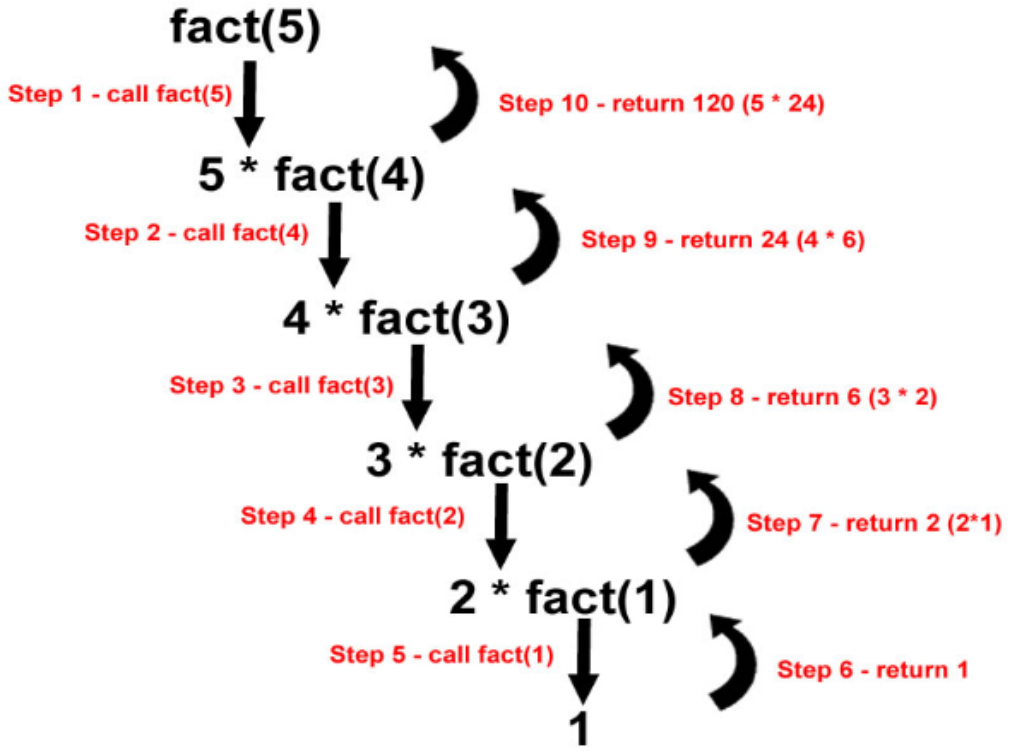
  - Binary search
  - Depth-first search



# ***MAIN()*** FUNCTION

- All C programs must contain a function called ***main()***, which is always the first function executed in a C program.
- When ***main()*** returns, the program is done.
- The compiler treats the main() function like any other function, except that at runtime the host environment is responsible for providing two arguments
  - **argc** – number of arguments that are presented at the command line
  - **argv** – an array of pointers to the command line arguments

```
main(int argc, char *argv[])  {

        while(--argc > 0 )
                printf("%s\n", *++argv);
        exit(0);
}
```

# ***MAIN()*** FUNCTION

- A better way to handle command line arguments
  - getopt
- The getopt() function parses the command-line arguments. Its arguments *argc* and *argv* are the argument count and array as passed to the main() function on program invocation.
- The variable *optind* is the index of the next element to be processed in *argv*. The system initializes this value to 1.
- If there are no more option characters, getopt() returns -1.

```
#include <unistd.h>
int getopt(int argc, char * const argv[], const
char *optstring);
extern char *optarg;
extern int optind, opterr, optopt;
```

```
while ((c = getopt (argc, argv, "abc:")) != -1)
  switch (c)
    {
    case 'a':
      aflag = 1;
      break;
....
    default:
      abort ();
    }
```

**http://www.gnu.org/software/libc/manual/html_node/Example-of-Getopt.html#Example-of-Getopt**