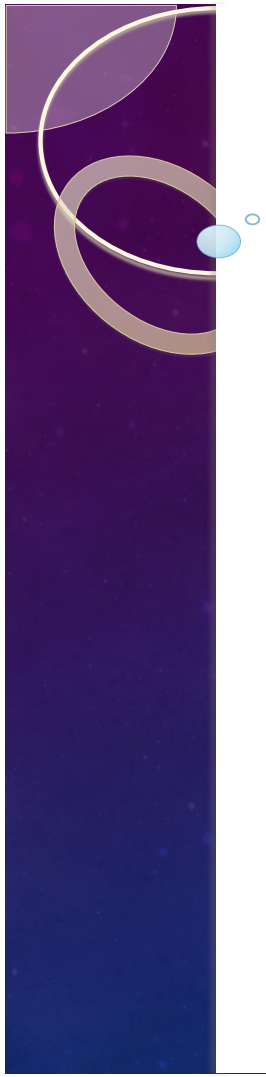
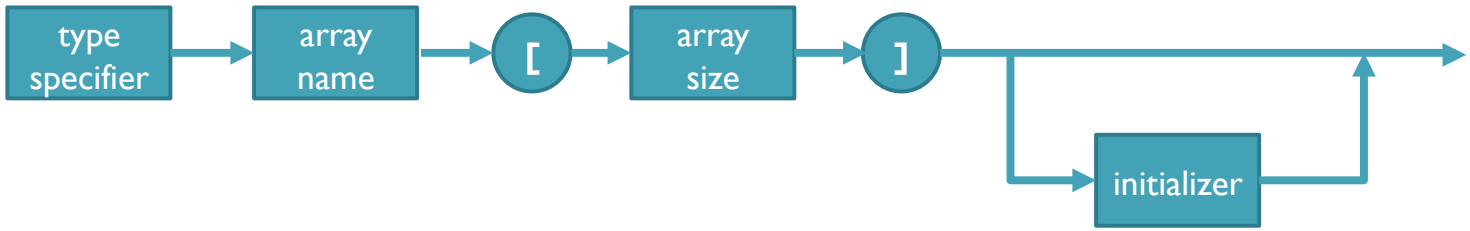


Pointers and arrays

outline

- Declaration
- How arrays stored in memory
- Initializing arrays
- Accessing array elements through pointers
- Examples
- Strings
- Multi-dimensional arrays

declaration




```
int dailyTemp[365];
dailyTemp[0] = 38;
dailyTemp[1] = 43;
…
```

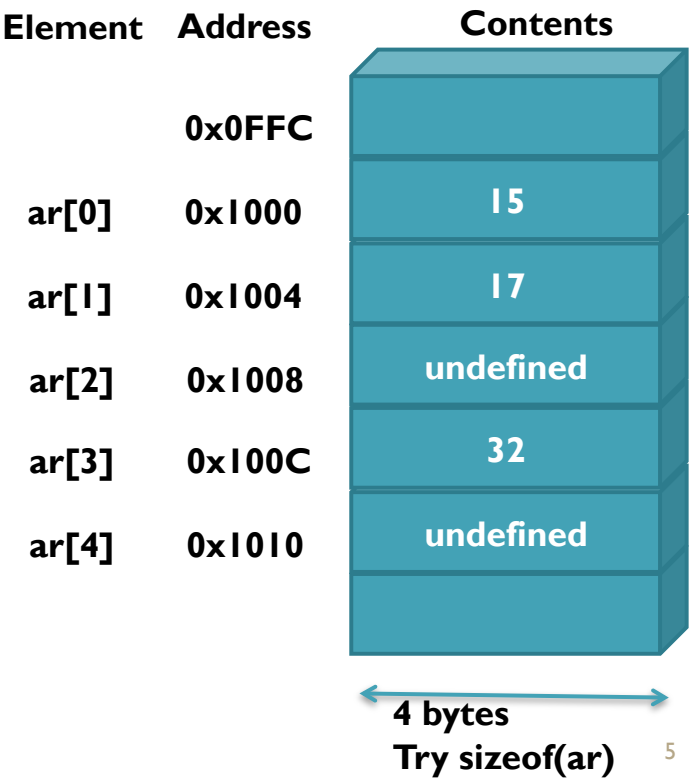
- **subscripts begin at 0, not 1 !**

```
#include <stdio.h>
#define DAYS_IN_YEAR 365
int main () {
    int j, sum = 0;
    int daily_temp[DAYS_IN_YEAR];

    /* Assign some values to the daily_temp array here. */

    for(j=0; j<DAYS_IN_YEAR; j++)
            sum += daily_temp[j];
    printf("The average temperature for this year is: %d. \n", sum/DAYS_IN_YEAR);
    return 0;
}
```

How arrays stored in memory

```
int ar[5]; /* declaration */
ar[0] = 15;
ar[1] = 17;
ar[3] = ar[0] + ar[1];
```

- **Note that ar[2] and ar[4] have undefined values!**
  - the contents of these memory locations are whatever left over from the previous program execution



Initializing arrays

- It is incorrect to enter more initialization values than the number of elements in the array
- If you enter fewer initialization values than elements, the remaining elements initialized to zero.
- **Note that 3.5 is converted to the integer value 3!**
- When you enter initial values, you may omit the array size
  - the compiler automatically figures out how many elements are in the array...

```
int a_ar[5];
int b_ar[5] = {1, 2, 3.5, 4, 5};
int c_ar[5] = {1, 2, 3};

char d_ar[] = {'a', 'b', 'c', 'd'};
```

Examples - Bubble sort

Example:

First Pass:

(**5 1** 4 2 8) –> (**1 5** 4 2 8), Here, algorithm compares the first two elements, and swaps since 5 > 1.

(1 **5 4** 2 8) –> (1 **4 5** 2 8), Swap since 5 > 4

(1 4 **5 2** 8) –> (1 4 **2 5** 8), Swap since 5 > 2

(1 4 2 **5 8**) –> (1 4 2 **5 8**), Now, since these elements are already in order (8 > 5), algorithm does not swap them.

Second Pass:

(**1 4** 2 5 8) –> (**1 4** 2 5 8)

(1 **4 2** 5 8) –> (1 **2 4** 5 8), Swap since 4 > 2

(1 2 **4 5** 8) –> (1 2 **4 5** 8)

(1 2 4 **5 8**) –> (1 2 4 **5 8**)

Now, the array is already sorted, but our algorithm does not know if it is completed. The algorithm needs one **whole** pass without **any** swap to know it is sorted.

Third Pass:

(**1 2** 4 5 8) –> (**1 2** 4 5 8)

(1 **2 4** 5 8) –> (1 **2 4** 5 8)

(1 2 **4 5** 8) –> (1 2 **4 5** 8)

(1 2 4 **5 8**) –> (1 2 4 **5 8**)

Examples - Bubble sort

```
#include <stdio.h>
// A function to implement bubble sort
void bubbleSort(int arr[], int n)
{
   int i, j, temp;
   for (i = 0; i < n-1; i++)

       // Last i elements are already in place
       for (j = 0; j < n-i-1; j++)
           if (arr[j] > arr[j+1]) {
              temp=arr[j];
              arr[j]=arr[j+1];
              arr[j+1]=temp;
           }
}
```

Examples - Selection sort

```
arr[] = 64 25 12 22 11

// Find the minimum element in arr[0...4]
// and place it at beginning
11 25 12 22 64

// Find the minimum element in arr[1...4]
// and place it at beginning of arr[1...4]
11 12 25 22 64

// Find the minimum element in arr[2...4]
// and place it at beginning of arr[2...4]
11 12 22 25 64

// Find the minimum element in arr[3...4]
// and place it at beginning of arr[3...4]
11 12 22 25 64
```

```
#include <stdio.h>
// A function to implement selection sort
void selectionSort(int arr[], int n)
{
    int i, j, min_idx, temp;
    // 1-by-1 move boundary of unsorted subarray
    for (i = 0; i < n-1; i++)
    {
        // Find the minimum element in unsorted array
        min_idx = i;
        for (j = i+1; j < n; j++)
          if (arr[j] < arr[min_idx])
            min_idx = j;

        // Swap the found min element with the 1st element
        temp=arr[min_idx];
        arr[min_idx]=arr[i];
         arr[i]=temp;
     }
}
```

Accessing array elements through pointers

short ar[4];

short *p;

p = & ar[0]; // assigns the address of element 0 to p. (same with p=ar)

- p = ar; **is same as above assignment!**
- *(p+3) refers to the same memory content as ar[3]

float ar[5], *p;

---

p = ar ;	// legal
ar = p;	**// illegal**
&p = ar;	**// illegal**
ar++;	**// illegal**
ar[1] = *(p+3);	// legal
p++;	// legal

Pointer arithmetic

- C allows you to add and subtract integers to and from pointers:
  - p+3 // means: 3 objects after the object that *p* points to. This operation generates a new address value. But compiler does not simply add p with "3", it multiples the 3 with the size of the object that *p* points to
- Suppose p points to a float var, located at the address 1000. So, p+3 would be the address 1000+3object*4byte=1012.
- What would be p+3, if p pointed to a char?
- Subtraction: &a[3]-&a[0] is 3 but &a[0]-&a[3] is -3.
- Examples:
  - long *p1, *p2; int j; char *p3;
  - p2=p1+4; //legal
  - j=p2-p1; // legal, j will be 4
  - j=p1-p2; // legal, j will be -4
  - p1=p2-2; // legal, since both of them points the same data type
  - p3=p1-1; // ILLEGAL, they point different data types.
  - j=p1-p3; // ILLEGAL, they point different data types.

Null pointer

- A null pointer is guaranteed not to point a valid object.
- A null pointer is assigned to integer value 0:
  - char *p;
  - p = 0; // makes p a null pointer. There is no need to cast the int to the pointer type, since it is 0.
- Null pointer is useful in while statements:
  - while (p){
  - …
  - // iterate until p is a null pointer (0-valued pointer will cause to get a FALSE value and break the loop, otherwise it'll be TRUE and go on iteration
  - …
  - }
- The use of null pointers is mainly in applications using arrays of pointers.

Passing pointers as function arguments

```
void clear(int *p){
  *p=0; // store a 0 at address p.
}
main(){
  int s[3]={1,2,3};
  clear(&s[1]);
  return 0;
}

// s=> 1,0,3
```

```
void clear(long *p){
  *p=0; // store a 0 at address p.
}
main(){
  short s[3]={1,2,3};
  clear(&s[1]);
  return 0;
}

// s=> 1,0,0 => why?
```

Passing arrays as function arguments

```
main () {
  extern  float func();
  float x, farray[5];
  …
  x=func(farray); // same as func(&farray[0]);
  …
}
```

Send the array with its size information:

```
float func(float farray[], int farray_size) {
  …
}
```

Call the function from the main function:

```
func(farray, sizeof(farray)/sizeof(farray[0]) );
```

```
float func(float *ar){
  …
}
```

Or:

```
float func(float ar[]){
  …
}
```

Or:

```
float func(float ar[6]){
  …
}
```

Strings - declaring and initializing strings

- A string is an array of characters terminated by a null character.
  - **null character is a character with a numeric value of 0**
  - it is represented in C by the escape sequence '\0'
- A string constant is any series of characters enclosed in double quotes
  - it has datatype of array of char and each character in the string takes up one byte!
  - compiler automatically appends a *null character* to designate the end of the string.

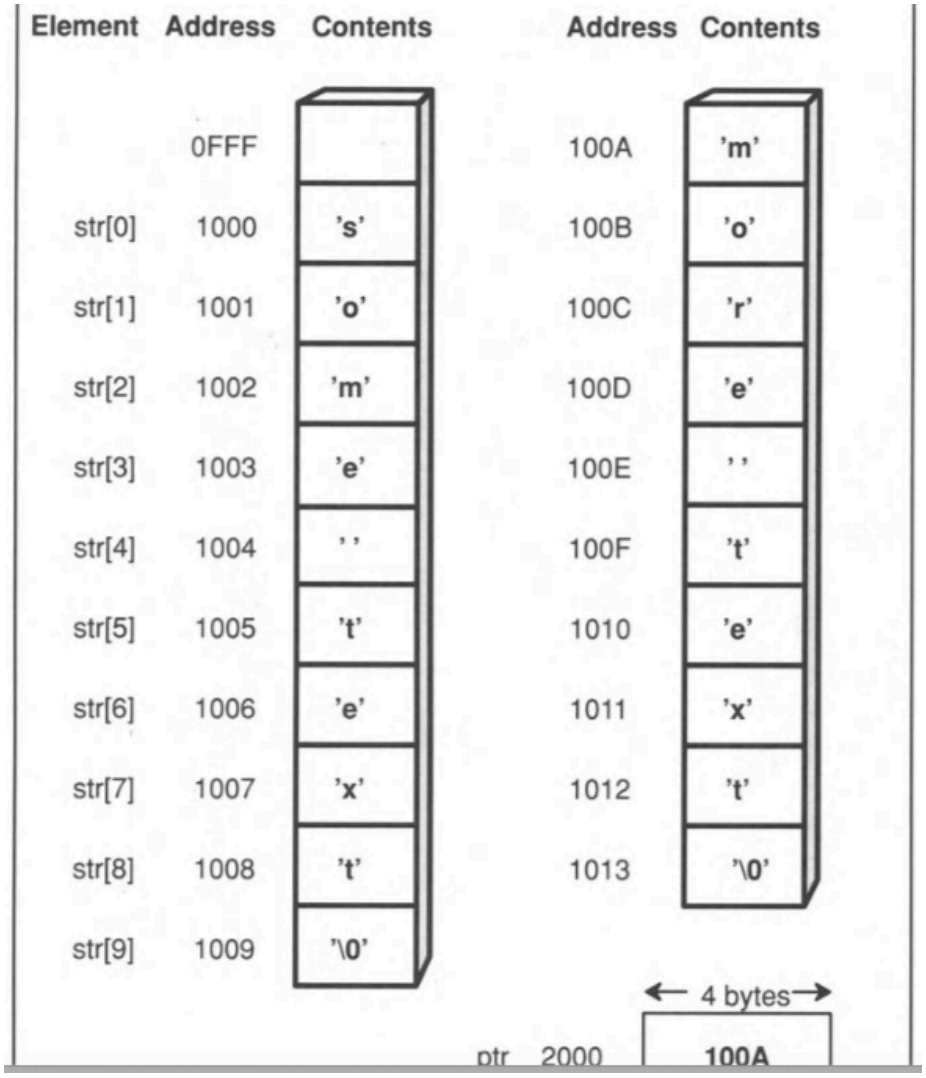
- static char str[] = "some text";
- static char str[10] = "yes";
- char str[3] = "four"; // **illegal**

// some compilers do not include the null character within the string size, some of them include it. Both are OK for the ANSI standard:

- **char str[4] = "four";**

- char *ptr = "more text" ;

- static char str[] = “some text”;
- char *ptr = "more text";



string assignments

```
main () {
    char array[10];
    char *ptr1="10 spaces";
    char *ptr2;
    array = "not OK";   /* can NOT assign to an address! "array" represents the address
    of the initial element of the array; it cannot be changed. Note, however, that the
    operand types agree */
    array[5] = 'A';          // OK
    ptr1[5] = 'B';           /* OK in old compilers BUT, ptr1 is a string literal and we can't
                        change its value, so, this will kill the program. you can't modify a string
                         literal.  See the code shown in the class for solution. */

    ptr1="OK";               // OK
    ptr1[5]='C';             // questionable due to the prior assignment
    *ptr2 = "not OK";   // type mismatch ERROR
    ptr2="OK";
}
```

strings vs. chars

```
char ch = 'a';    // one byte is
                  allocated for 'a'

*p = 'a';         // OK
p = 'a';          // Illegal, p is a
                  pointer, not a char
```

```
char *p = "a";        // two bytes
allocated for "a" (the 2nd one is '/0')

*p = "a";             // INCORRECT
p = "a";              // OK
*p = "string";        // INCORRECT
p = "string";         // OK
```

reading & writing strings

```c
#include <stdio.h>

#define MAX_CHAR 80

int main ( void )  {

        char str[MAX_CHAR];
        int i;

        printf("Enter a string :");
        scanf("%s", str);

        for(i=0;i<10;i++)  {
                printf("%s\n", str);
        }
        return 0;
}
```

You can read strings with *scanf()* function.

- the data argument should be a pointer to an array of characters ***that is long enough to store*** the input string.
- after reading input characters scanf() automatically appends a null character to make it a proper string

You can write strings with *printf()* function.

- the data argument should be a pointer to a null terminated array of characters

string length function

- We test each element of array, one by one, until we reach the null character.
  - null char has a value of zero, making the while condition **false**
  - any other value of str[i] makes the while condition **true**
  - once the null character is reached, we exit the while loop and return *i*, which is the last subscript value

```
int strlen ( char *str)  {
        int i=0;

        while(str[i])  {
                i++;
        }

        return i;
}
```

string copy function

```
void strcpy ( char s1 [], char s2[] )
   {
   int i;
   for (i=0; s2[i]; ++i)
         s1[i] = s2[i];
   s1[++i] = '\0';
}
```

```
void strcpy ( char *s1, char *s2 ) {
   int i;
   for (i=0; *(s2+i); ++i)
         *(s1+i) = *(s2+i);
   s1[++i] = '\0';
}
```

```
void strcpy ( char *s1, char *s2 ) {
   while (*s1++ = *s2++;
}
```

strcpy()	Copies a string to an array.
strncpy()	Copies a portion of a string to an array.
strcat()	Appends one string to another.
strncat()	Copies a portion of one string to another.
strcmp()	Compares two strings.
strncmp()	Compares two strings up to a specified number of characters.
strchr()	Finds the first occurrence of a specified character in a string.
strcoll()	Compares two strings based on an implementation-defined collating sequence.
strcspn()	Computes the length of a string that does not contain specified characters.
strerror()	Maps an error number with a textual error message.
strlen()	Computes the length of a string.
strpbrk()	Finds the first occurrence of any specified characters in a string.
strrchr()	Finds the last occurrence of any specified characters in a string.
strspn()	Computes the length of a string that contains only specified characters.
strstr()	Finds the first occurrence of one string embedded in another.
strtok()	Breaks a string into a sequence of tokens.
strxfrm()	Transforms a string so that it is a suitable as an argument to *strcmp()*.

Table 6-1. String Functions in the Standard Library. See Appendix A for a more complete description of these routines.

other string functions

Pattern matching example

- Write a program that
  - gets two strings from the user
  - search the first string for an occurrence of the second string
  - if it is successful
    - return byte position of the occurrence
  - otherwise
    - return -1

- Return the position of str2 in str1; if not found then return -1.

```
#include <stdio.h>

/* Return the position of str2 in str1; -1 if not
 * found.
 */
int pat_match( str1, str2 )
char str1[], str2[];
{
  int j, k;

  for (j=0; j < strlen(str1); ++j)
  {
/*  test str1[j] with each character in str2[].  If
 *  equal, get next char in str1[].  Exit loop if we
 *  get to end of str1[], or if chars are equal.
 */
    for (k=0; (k < strlen(str2) && (str2[k] ==
         str1[k+j])); k++);

/*  Check to see if loop ended because we arrived at
 *  end of str2.  If so, strings must be equal.
 */
    if (k == strlen( str2 ))
      return j;
  }
  return -1;
}
```

multi-dimensional arrays

- In the following, ar is a 3-element array of 5-element arrays

  int ar[3][5];

- In the following, x is a 3-element array of 4-elemet arrays of 5-element arrays

  char x[3][4][5];

- the array reference

  ar[1][2]

- is interpreted as

  *(ar[1]+2)

- which is further expanded to

  ((ar+1)+2)

initialization of multi-dimensional arrays

```
int exap[5][3] = { {  1, 2, 3 },
                   { 4 },
                   { 5, 6, 7 } };
```

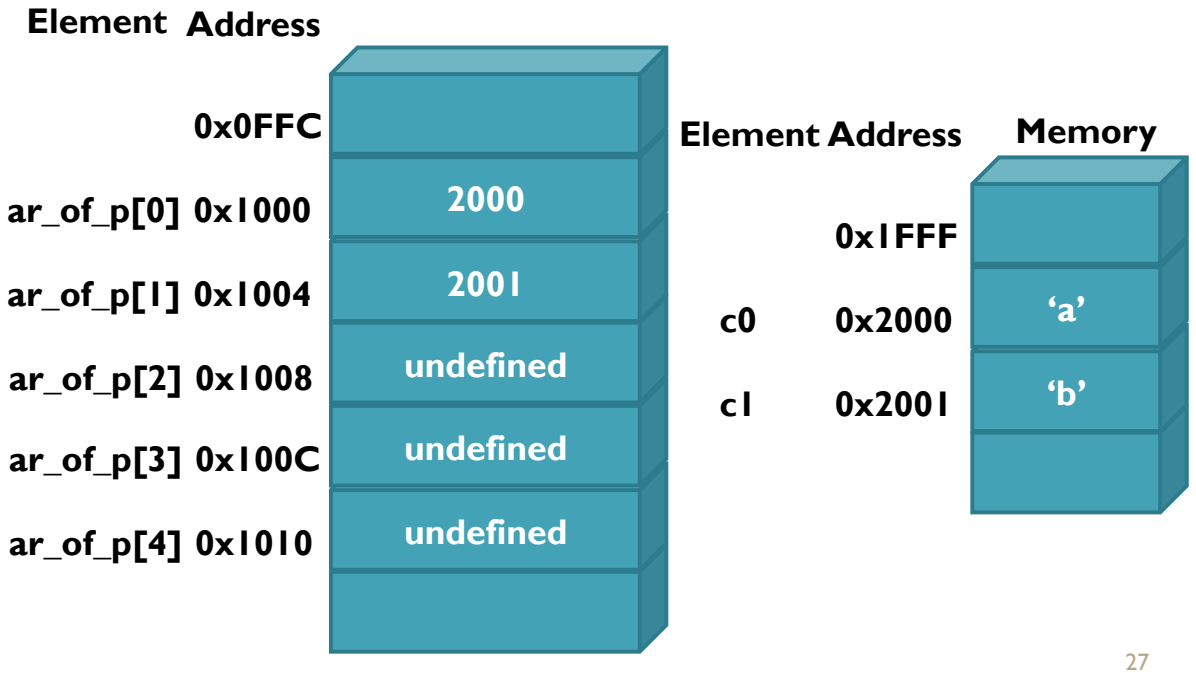
1	2	3
4	0	0
5	6	7
0	0	0
0	0	0

```
int exap[5][3] = {  1, 2, 3,
                    4,
                    5, 6, 7 };
```

1	2	3
4	5	6
7	0	0
0	0	0
0	0	0

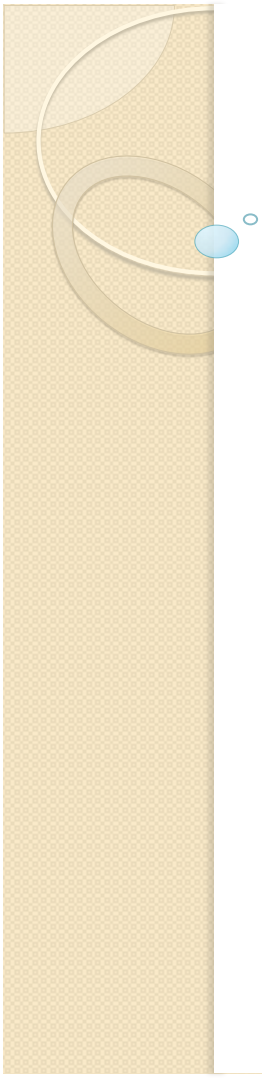
array of pointers

```
char *ar_of_p[5];
char c0 = 'a';
char c1 = 'b';

ar_of_p[0] = &c0;
ar_of_p[1] = &c1;
```



pointers to pointers

int r = 5;	declares ***r*** to be an int
int *q = &r;	declares ***q*** to be a pointer to an int
int **p = &q;	declares ***p*** to be a pointer to a pointer to an int
r = 10;	Direct assignment
*q = 10;	Assignment with one indirection
**p = 10;	Assignment with two indirections



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.