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Character Strings

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Why Learning Character Strings

1. In addition to handling numerical data, programs are also required to deal with alphabetic data.
2. Strings are arrays of characters.
3. C libraries provide a number of functions for performing operations on strings.
4. In this lecture, string constants and string variables are first introduced. The different commonly used string functions from C libraries are then discussed.

Character Strings

- String Declaration, Initialization and Operations
- String Input and Output
- String Functions
- The ctype.h Character Functions
- String to Number Conversions
- Formatted String I/O
- Arrays of Character Strings

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Character Strings

1. Here, we start by discussing string declaration, initialization and operations.

Character Strings: String Constants

- A **string** is an array of characters terminated by a **NULL character** ('\0').



Null character

- String constant** is a set of characters in double quotes:
e.g. "C Programming" - is an array of characters and automatically terminated with the null character '\0'
- Using #define to define a string constant:
e.g. #define NTU "Nanyang Technological University"
- Used in function arguments, e.g. printf() and puts(): e.g. printf("Hello, how are you?");
- Character Constant 'X' vs String Constant "X": The character constant 'X' consists of a single character of type **char**, while the character string constant "X" consists of two characters, i.e. the character 'X' and the null character '\0', and is an array of type **char**.

String Constants

1. A character string is an array of characters terminated by a NULL character ('\0').
2. A string constant is a series of characters in double quotes, for example, "C Programming".
3. When the compiler encounters a string constant, it allocates space for each individual character of the string and adds a terminating null character at the end of the string. A pointer pointing to its first character is returned.
4. Therefore, a string constant is essentially a pointer to the first character of an array of characters.
5. We can use **#define** to define string constants. For example, #define NTU "Nanyang Technological University".
6. String constants can also be used as function arguments for **printf()** and **puts()** functions:

```
printf("Hello, how are you?\n");
puts("Hello, how are you?\n");
```

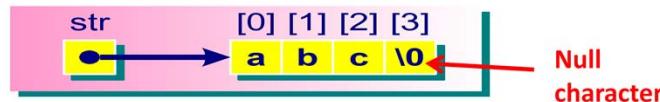
7. It is important to distinguish the difference between the character constant 'X' and a string constant "X". The character constant 'X' consists of a single character of data type **char**, while the character string constant "X" consists of two characters, i.e. the character 'X' and the null character '\0', and is an array

of type **char**.

String Variables: Declaration using Array Notation

- **String variables:** can be declared using array notation

```
char str[ ] = "some text";      // string
char str[10] = "yes";          // legal
char str[4] = "four";        // incorrect -> null character missing
char str[ ] = {'a','b','c','\0'}; // equivalent to: char str[ ] = "abc";
```



Note: '\0' differentiates a character string from an array of characters.

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String Variables: Declaration using Array Notation

1. A string is essentially an array of characters. Therefore, we can also define strings using the **array notation**.
2. To declare strings using array notation, we can use the following declarations:


```
char str[] = "some text";
char str[10] = "yes";
```
3. However, the declaration **char str[4] = "four";** is incorrect. The array **str** only allocates 4 elements to hold its data, which is not enough as it needs an additional element to hold the null character '\0' that is automatically added at the end of the sequence of characters.
4. We can also create strings using array initializer, for example, **char str[] = {'a','b','c','\0'};** An array of four elements of type **char** is created. However, it is tedious to initialize array by listing all the characters in braces. We can simply enclose the characters using double quotes as if they were a string constant. This is equivalent to **char str[] = "abc";**

String Variables: Declaration using Array Notation

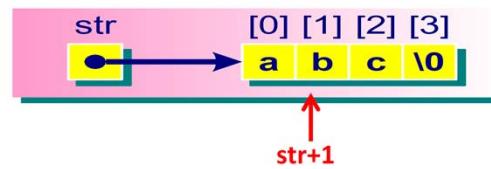
- Therefore, just like other kinds of arrays, the array name **str** gives the address of the 1st element of the array:

```
char str[ ] = "abc";
```

```
str == &str[0]
```

```
*str == 'a'
```

```
*(str+1) == str[1] == 'b'
```



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String Variables: Declaration using Array Notation

1. As a string constant returns a pointer to its first character, the array name **str** contains the address of the first element of the array as other kinds of arrays.
2. **str == &str[0]** - Therefore, the string **str** contains the address of the first element of the array of characters.
3. ***str == 'a'** - Also, we can use ***str** to retrieve the first element of the string.
4. ***(str+1) == str[1] == 'b'** - Similarly, we can use ***(str+1)** to retrieve the second element of the character string.

String Variables: Declaration using Pointer Notation

- **String variable** can also be declared using the [pointer notation](#).
- When declaring string variable using pointer notation, we assign a [string constant](#) to a [pointer](#) that points to data type char:

```
char *str = "C Programming";
```



Null character

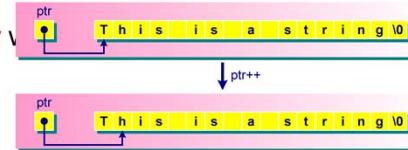
- When a [string constant](#) is assigned to a [pointer](#), C compiler will:
 1. allocate **memory space** to hold the string constant;
 2. store the **starting address** of the string in the pointer variable;
 3. terminate the string with [NULL](#) ('\0') character.

- Example:

```
char *ptr = "This is a string"; // declaration with initialization
```

- For the statement: **ptr++**:

- it means the pointer variable **ptr** will point to the next array location:



String Variables: Declaration using Pointer Notation

1. String variable can also be declared using the pointer notation.
2. Typically, we can declare a string variable by assigning the pointer of the string constant to a **pointer variable**: `char *str = "C Programming";`
3. When a **string constant** is assigned to a [pointer](#), C compiler will:
 - allocate **memory space** to hold the string constant;
 - store the **starting address** of the string in the pointer variable;
 - terminate the string with [NULL](#) ('\0') character.
4. Therefore, the string variable **str** will then contain the **address** of the first element of the string constant.
5. For example, we can assign a string constant to a pointer that points to type **char**: `char *ptr = "This is a string";`
6. When a string constant is assigned to a pointer, the C compiler will allocate memory space to hold the string constant "**This is a string**", store the starting address of the string (i.e. the address of the character 'T') in the pointer variable, and terminate the string with a null character.
7. However, **ptr** is a **pointer variable** that can be changed. For example, the statement `ptr++;` changes the **ptr** variable to point to the next character (i.e. 'h') in the string "**This is a string**".

String Variables: Array Declaration vs Pointer Declaration

- As can be seen earlier, there are two ways to declare a string:

`char str1[] = "How are you?"; // using array declaration`
and

`char *str2 = "How are you?"; // using pointer declaration`

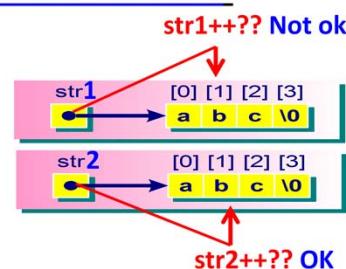
- Q: Can you tell the difference between the two declarations?

• **str1: address constant, str2: pointer variable.**

Therefore,

```
++str1;      // not allowed
++str2;      // allowed
str1 = str2; // not allowed
str2 = str1; // allowed
```

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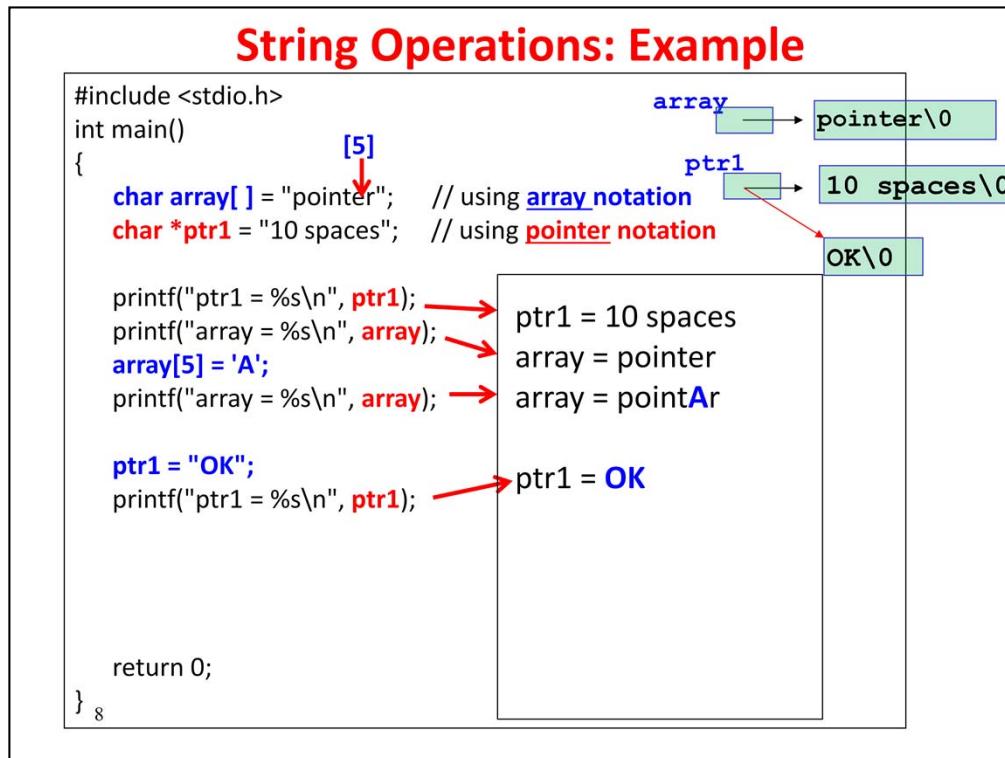


String Variables: Array Declaration vs Pointer Declaration

- It is important to distinguish the declaration of string variables that use array or pointer. For example, the following strings are defined as:

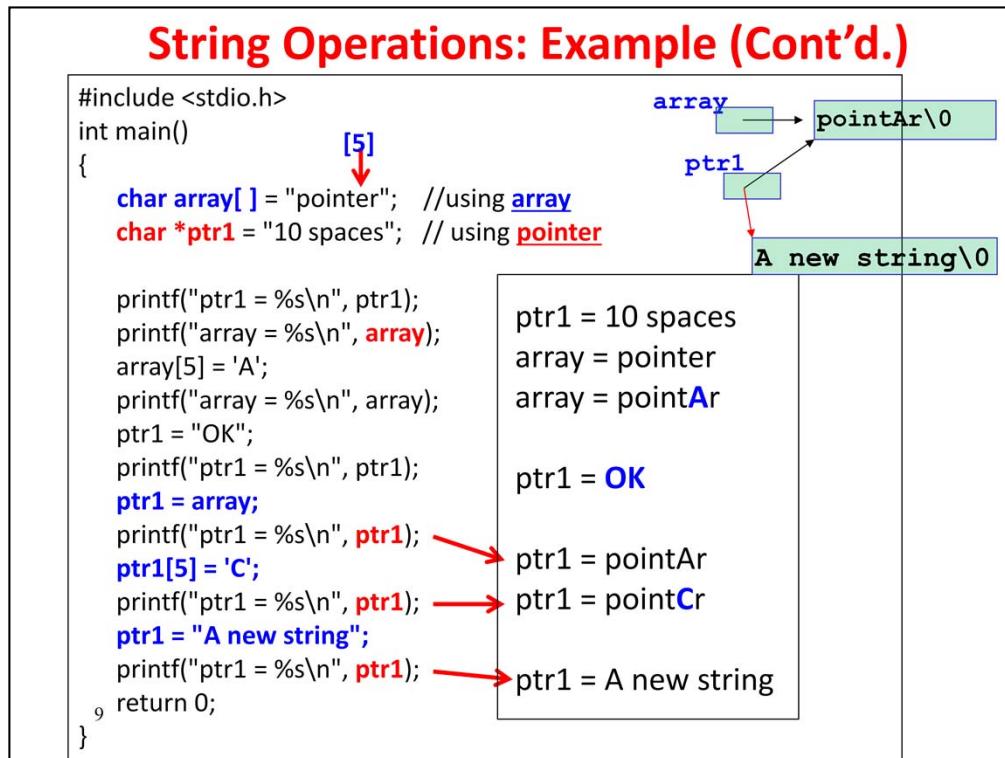

```
char str1[] = "How are you?"; /* using array declaration */
char *str2 = "How are you?"; /* using pointer declaration */
```
- The **str1** declaration creates an array of type **char**. The array has been allocated with memory to hold 13 elements including the null character. The C compiler also creates a pointer constant that is initialized to point to the first element of the array, **str1[0]**.
- In the **str2** declaration, the C compiler creates a pointer variable **str2** that points to the first character of the string. It contains the memory address of the first character of the string 'H'.
- Both **str1** and **str2** are pointers. However, the difference between the two declarations is that **str1** is a **pointer (or address) constant**, while **str2** is a **pointer variable**. Pointer constant means that the value cannot be changed, while pointer variable allows its value to be changed.
- Therefore, **str1** cannot change its value. It cannot perform any update operations. Therefore, the following statements: **str1++;** and **str1 = str2;** are invalid.
- However, it is valid for **str2** to perform any update operations. Therefore:

++str2; and **str2=str1;** are valid as **str2** is a pointer variable.



String Operations: Example

1. The declaration `char array[] = "pointer";` declares a string variable **array** using array notation which is initialized with 7 characters plus the null character ('\0').
2. The declaration `char *ptr1 = "10 spaces";` declares a string variable **ptr1** using pointer notation which is initialized and pointed to the string "10 spaces".
3. When **ptr1** is printed, the string "10 spaces" will be displayed.
4. When **array** is printed, the string "pointer" will be displayed.
5. The statement `array[5] = 'A';` is valid and the string is updated accordingly.
6. When **array** is printed, the string "pointAr" will be displayed.
7. The statement `ptr1 = "OK";` will update **ptr1** to point to a new string "OK".
8. When **ptr1** is printed, the string "OK" will be displayed.



String Operations: Example

1. The statement **ptr1 = array;** changes the pointer variable **ptr1** to point to the same address contained in **array**.
2. However, if we have **array = ptr1;** which will be invalid because an error on type mismatch will occur. Also, we are not allowed to change the base address of **array**.
3. When **ptr1** is printed, the string "**pointAr**" will be displayed.
4. The statement **ptr1[5] = 'C';** is valid and the string is updated accordingly.
5. When **ptr1** is printed, the string "**pointCr**" will be displayed.
6. The statement **ptr1 = "A new string";** is valid which changes the pointer variable **ptr1** to point to the new string "**A new string**".

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- **String Input and Output**
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Character Strings

1. Here, we discuss Character String Input and Output.

String Input/Output

- There are 4 C library functions that can be used for string input/output:
 - **fgets()** (instead of **gets()**): function prototype **char *fgets(char *ptr, int n, FILE *stream);**
 - **puts()**: function prototype **int puts(const char *ptr);**
 - **scanf()**: function prototype **int scanf(control-string, argument-list);**
 - **printf()**: function prototype **int printf(control-string, argument-list);**
- The two most commonly used standard library functions for reading strings are **fgets()** and **scanf()**. For printing strings, the two standard library functions are **puts()** and **printf()**.
- We use **fgets()** because **gets()** is not safe as it does not check the array bound.

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String Input/Output

1. There are 4 C library functions that can be used for string input/output.
2. The two most commonly used standard library functions for reading strings are **fgets()** and **scanf()**. For printing strings, the two standard library functions are **puts()** and **printf()**.
3. We use **fgets()** because **gets()** is not safe as it does not check the array bound.
4. In **fgets()**, we use **stdin** as the argument for **stream** when reading from the keyboard.
5. Here, we will discuss the purposes of these functions.

The function prototypes of the 4 C library functions are given below:

- **fgets()**: function prototype **char *fgets(char *ptr, int n, FILE *stream);**
- **puts()**: function prototype **int puts(const char *ptr);**
- **scanf()**: function prototype **int scanf(control-string, argument-list);**
- **printf()**: function prototype **int printf(control-string, argument-list);**

String Input: fgets()

- **fgets()** returns **Null** if it fails, otherwise a pointer to the string is returned.
- Make sure **enough memory space** is allocated to hold the input string, **name**.

```
#include <stdio.h>
#include <string.h>
int main()
{
    char name[80], *p; // allocate memory
    /*read name*/
    printf("Hi, what is your name?\n");
    fgets(name, 80, stdin);
    if ( p=strchr(name, '\n') )
        *p = '\0'; // remove '\n' character in name
    /*display name*/
    printf("Nice name, %s.\n", name);
    return 0;
}
```

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name



Question: using pointer variable:
char *name;
Ok or not? Why?

name → ?? Not OK!

Output:

Hi, what is your name?
Hui Siu Cheung
Nice name, Hui Siu Cheung.

String Input: gets()

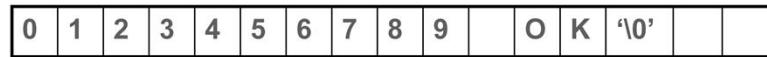
1. Before reading a string, it is important to allocate enough storage space to store the string. To create space for a string, we may include an explicit array size as shown in the following declaration: **char name[80];**
2. This declaration statement creates a character array **name** of 80 elements. Once the storage space has been acquired, we can read in the string through the C library functions.
3. The **fgets()** function gets a string from the standard input device. In **fgets(name, 80, stdin);** it reads characters until it reaches a newline character (**\n**). A newline character is generated when the **<Enter>** key is pressed. The **fgets()** function reads all the characters up to and including the newline character, and passes them to the calling function as a string.
4. In the program, it reads in a string and prints the string to the screen. It is important to ensure that the array size of **name** is big enough to hold the input string. Otherwise, the extra characters can overwrite the adjacent memory variables.
5. As **fgets()** reads the entire new line including the newline character, after **fgets()**, we execute the statement **if (p=strchr(name, '\n')) *p = '\0';** to remove the newline character from the character string for further processing.
6. Note that we cannot use pointer notation for creating the string as there will not have memory allocated for holding the input string data.

The **fgets()** function returns a null pointer if it fails, otherwise the same pointer **ptr** is returned. It is important to make sure that sufficient storage is allocated to hold the input string. The null pointer contains a null address that is the symbolic constant **NULL** defined in the header file *stdio.h*. This is different from the null character ('\0') in that the null character is a data object of type **char** with ASCII value 0, whereas the null pointer contains an address. In addition, the size of the null character is 1 byte, while the null pointer is 4 bytes long.

String Output: puts()

```
#include <stdio.h>
#include <string.h>
int main( )
{
    char str[80], *p;           // string with allocated memory
    printf("Enter a line of string: ");
    if (fgets(str, 80, stdin) == NULL) {
        printf("Error\n");
    }
    if ( p=strchr(str,'\\n') ) *p = '\\0';
    puts(str);
    return 0;
}
```

Input: 0123456789 OK



₁₃ *Output:* 0123456789 OK

String Output: puts()

1. The **puts()** function prints a string on the standard output device. A newline character is automatically added to the end of the string. Thus, the *newline* character is printed after the string. **EOF** is returned if **puts()** fails, otherwise the number of characters written will be returned.
2. In the program, it reads in a string using the **fgets()** function and prints the string on the screen using the **puts()** function.

The function prototype for the **puts()** function is

int puts(const char *ptr);

which prints a string on the standard output device.

String Input/Output: scanf() and printf()

- **scanf()**

- It reads the string up to the next **whitespace** character.
- **scanf()** **returns** the **number of items** read by **scanf()**, otherwise **EOF** if fails.
- Make sure that enough memory space is allocated for input string.

- **printf()**

- It **returns** the **number of characters** transmitted, otherwise a negative value will be returned if it fails.
- It differs from the **puts()** function in that no newline is added at the end of the string.
- The **printf()** function is less convenient to use than the **puts()** function. However, the **printf()** function provides the flexibility to the user to control the format of the data to be ¹⁴ printed.

String Input/Output: scanf() and printf()

1. The **scanf()** function can be used to read in a string. It will return **EOF** if it fails, otherwise the number of items read by **scanf()** will be returned. The **scanf()** function reads the string up to the next **whitespace** character.
2. It is important to ensure that **sufficient storage** is allocated to hold the string.
3. The **printf()** function prints formatted output on the standard output device. It returns a negative value if **printf()** fails, otherwise the number of characters printed will be returned.
4. It differs from the **puts()** function in that no newline is added at the end of the string.
5. The **printf()** function is less convenient to use than the **puts()** function. However, the **printf()** function provides the flexibility to the user to control the format of the data to be printed.

The function prototype for the **scanf()** function is

scanf(control-string, argument-list);

The **scanf()** function with the **%s** format specification can be used to read in a string. An example of the **scanf()** function to read in a string is given as follows:
scanf("%s", str); Unlike other data input, there is no need to have the address-of (&) operator to be placed before the name of the array. This is due to the fact that

the array name is the address of the first element of the array.

It is important to ensure that **sufficient storage** is allocated to hold the string. If more characters are read in than the storage space allocated to hold the string, the additional characters will be overwritten to the adjacent memory locations. For example, consider the following declaration statements:

```
char *str = "string space";
scanf("%s", str);
```

A string pointer constant is created, and 13 bytes of storage are created to hold the string constant. If the string read in by the **scanf()** function is longer than 13 bytes, it will be overwritten to the adjacent memory locations.

There are two ways to read input string in **scanf()**. We may use either a **%s** or **%ns** conversion specifier, where **n** is the field width specification. In both cases, reading starts at the first non-whitespace character. When **%ns** is used, **scanf()** reads up to **n** input characters or when the first whitespace character (i.e. blank, tab or newline) is encountered. For example, **%6s** will stop after the first six characters are read. When **%s** is specified, the **scanf()** function reads the string up to the next whitespace character.

The function prototype for the **printf()** function is

```
printf(control-string, argument-list);
```

scanf() and printf(): Example

```
#include <stdio.h>
int main( )
{
    char name1[20], name2[20], name3[20];
    int count;
    printf("Please enter your strings.\n");
    count = scanf("%s %s %s", name1, name2, name3);
    printf("I read the %d strings: %s %s %s\n", count, name1,
           name2, name3);
    return 0;
}
```

Output

Please enter your strings.

Hui Siu Cheung
I read the 3 strings: Hui Siu Cheung

Separated by space

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scanf() and printf(): Example

1. In the program, the **scanf()** function is used to read a string from the input. If the input "Hui Siu Cheung" is entered, then **name1** = "Hui", **name2** = "Siu" and **name3** = "Cheung". The **scanf()** function returns the **count** on the number of input strings.
2. Note that the **fgets()** function differs from the **scanf()** function in that **fgets()** reads an entire line up to the first newline character, and it also stores any characters, including whitespace and the first newline character.
3. The **scanf()** function is less convenient to use than the **fgets()** function for reading string input. The **fgets()** function is also faster than the **scanf()** function.

String Processing – Using Indexes

```
#include <stdio.h>
int length1(char []);
int main()
{
    char *greeting = "hello", word[] = "abc";
    printf("The length is %d\n",
           length1(greeting),
    return 0;
}
```

Output
The length is 5

The diagram illustrates the memory layout for the variables defined in the code. The variable `greeting` is a pointer to the string "Hello". The variable `word` is an array containing the characters 'a', 'b', and 'c', followed by a null terminator '\0'. The variable `string` is also a pointer to the string "Hello". Arrows indicate the pointers pointing to their respective memory locations.

using index notation

```
int length1(char string[]) // int length1(char *string)
{
    int count = 0;
    while (string[count] != '\0')
        count++;
    return(count);
}
```

String Processing: Using Indexes

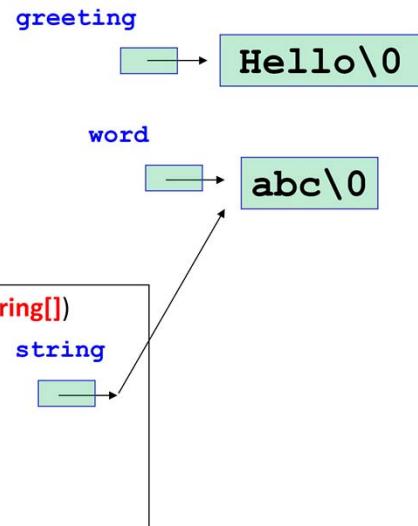
1. In this program, the function `length1()` uses the array notation to compute the length of a string.
2. In the `main()` function, the declaration `char *greeting = "hello";` creates a pointer variable called `greeting` that points to the first character of the string "hello".
3. The function `length1()` uses the statement `while (string[count] != '\0')` to check for the null character ('\0') in the `while` loop while measuring the length of the string.

String Processing – Using Pointers

```
#include <stdio.h>
int length2(char *);
int main()
{
    char *greeting = "hello", word[] = "abc";
    printf("The length is %d\n",
           length2(word));
    return 0;
}
```

Output

The length is 3



using pointer notation

```
int length2(char *string) // int length2(char string[])
{
    int count = 0;
    while (*(string+count) != '\0')
        count++;
    return(count);
}
```

String Processing: Using Pointers

1. In this program, the function **length2()** uses the pointer notation to compute the length of a string.
2. The declaration **char word[] = "abc";** creates an array of type **char** called **word[]**. This array contains four elements including the null character.
3. The function **length2()** uses the statement **while (*(string + count) != '\0')** to check for terminating null character. The expression **(*(string + count))** first gets the character stored at the address location contained in **(string + count)**, and then tests whether it is a null character. For any characters other than the null character, the condition will be true, and the statements in the body of the **while** loop will be executed to measure the length of the string.

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Character Strings

1. Here, we discuss some commonly used string functions.

String Functions

Must include the following header file: **#include <string.h>**

Some standard string functions are:

strcat()	appends one string to another
strncat()	appends a portion of a string to another string
strchr()	finds the first occurrence of a specified character in a string
strrchr()	finds the last occurrence of a specified characters in a string
strcmp()	compares two strings
strncmp()	compares two strings up to a specified number of characters
strcpy()	copies a string to an array
strncpy()	copies a portion of a string to an array
strcspn()	computes the length of a string that does not contain specified characters
strstr()	searches for a substring
strlen()	computes the length of a string
strpbrk()	finds the first occurrence of any specified characters in a string
¹⁹ strtok()	breaks a string into a sequence of tokens

String Functions

1. The standard C library provides many functions that perform string operations. To use any of these functions, we must include the header file `string.h` in the program: **#include <string.h>**
2. String functions are very useful for writing programs that involve the manipulation of strings. Some examples of string functions include finding the length of strings, combining two strings, comparing two strings, and searching a string for a specific character. Programmers are encouraged to use these functions instead of developing their own functions. The table lists some of the more commonly used string functions provided in *string.h*.
3. Here, we describe some of the most useful C string handling functions. These include **strlen()**, **strcat()**, **strcpy()**, and **strcmp()**.
 - The **strlen()** function computes the length of a string.
 - The **strcat()** function appends one string to another.
 - The **strcpy()** function copies a string to an array.
 - The **strcmp()** function compares two strings.

The **strlen()** Function

- The function prototype of **strlen** is
`size_t strlen(const char *s);`
strlen computes and **returns the length of the string** pointed to by **s**, i.e. the number of characters that precede the terminating null character.
- Example:

```
#include <stdio.h>
#include <string.h>
int main()
{
    char line[81] = "This is a string";
    printf("The length of the string is %d.\n", strlen(line));
    return 0;
}
```

Output

The length of the string is 16.

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The **strlen()** Function

1. The function prototype of **strlen()** is given here:
`unsigned strlen(const char *str);`
2. **strlen()** computes the length of the string pointed to by **str**. It returns the number of characters that precede the terminating null character. The null character is excluded in the calculation.
3. In the program, it uses the **strlen()** function to obtain the length of the string variable **line**. The program creates a character array called **line[]** to store the string. The character array **line[]** is initialized to the character string constant "**This is a string**". The length of this string is then calculated using the **strlen()** function, and printed on the display.

Note that the **sizeof** operator can also be used to determine the number of characters in a string. However, this function includes the terminating null character in its calculation.

The strcat() Function

- The function prototype of **strcat** is

```
char *strcat(char *s1, const char *s2);
```

strcat **appends** a copy of the string pointed to by s2 to the end of the string pointed to by s1.

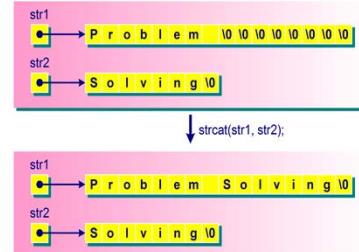
The initial character of s2 overwrites the null character at the end of s1. strcat **returns** the value of **s1** (i.e. string).

- Example**

```
#include <stdio.h>
#include <string.h>
int main() {
    char str1[40] = "Problem ";
    char *str2 = "Solving";
    printf("The first string: %s\n", str1);
    printf("The second string: %s\n", str2);
    strcat(str1, str2);
    printf("The combined string: %s\n", str1);
    return 0;
}
```

Output

The first string: Problem
 The second string : Solving
 The combined string: Problem Solving



The strcat() Function

- The **strcat()** function concatenates two strings to form a new string. The function prototype of **strcat()** is given here:


```
char *strcat(char *str1, const char *str2);
```
- strcat()** appends a copy of the string pointed to by **str2** to the end of the string pointed to by **str1**. The initial character of **str2** overwrites the null character at the end of **str1**. **strcat()** returns the address value of **str1**. **str2** is unchanged.
- In the program, it uses the **strcat()** function to concatenate two strings. The two strings are declared and initialized:


```
char str1[40] = "Problem ";
char *str2 = "Solving";
```
- After the function **strcat(str1, str2);** is executed, **str2** is unchanged and **str1** has been changed to store "**Problem Solving**".
- It is important to note that the storage allocated to **str1** should be big enough to hold the concatenated string as **strcat()** will not check the storage requirement before performing the concatenation operation.

The strcpy() Function

- The function prototype of **strcpy** is
`char *strcpy(char *s1, const char *s2);`

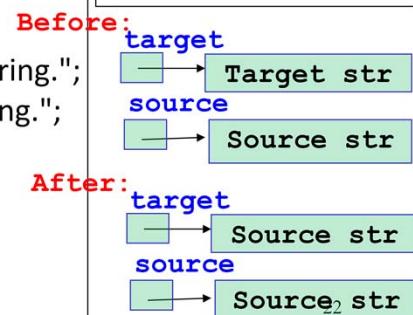
strcpy copies the string pointed to by s2 into the array pointed to by s1.

It **returns** the value of **s1** (i.e. string).

- Example

```
#include <stdio.h>
#include <string.h>
int main(){
    char target[40] = "This is the target string.";
    char *source = "This is the source string.";
    puts(target); puts(source);
    strcpy(target, source);
    puts(target); puts(source);
    return 0;
}
```

Output
 This is the target string.
 This is the source string.
This is the source string.
 This is the source string.



The strcpy() Function

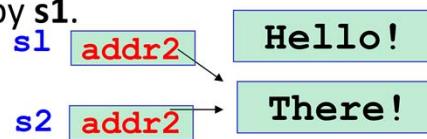
- The **strcpy()** function copies one string to another. The function prototype of **strcpy()** is given here:
`char *strcpy(char *str1, const char *str2);`
- The function copies all the characters in the string pointed to by **str2** into the array pointed to by **str1**. The copy operation includes the null character in **str2**. **str1** acts as the target string while **str2** is the source string. The order of the strings is similar to the assignment statement where the target string is on the left-hand side. The **strcpy()** function returns the value of **str1**.
- In the program, it uses the **strcpy()** function to copy a string to another string. It is important to note that the target array must have enough space to hold the updated string contents.
- The array declaration **char target[40];** is used instead of pointer declaration **char *target;** It is because the latter declaration does not have space allocated to hold the string.

The strcpy() Function (Cont'd.)

- If we have two strings **s1** and **s2**, can we use the following assignment to copy **s2** to **s1**?



- The answer is NO, as the assignment operation will only assign pointer **s2** to pointer **s1**, not updating the contents pointed to by **s1**.



should use: **strcpy(s1, s2);**

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The strcpy() Function

- Note that when you want to copy a string **s2** to another string **s1**, you cannot use the following statement: **s1 = s2;**
- The assignment statement will only assign pointer **s2** to pointer **s1**, it does not update the contents pointed to by **s1**. Therefore, you need to use the **strcpy()** function when you want to copy the content of a string to another string.

The strcmp() Function

- The function prototype of **strcmp** is
`int strcmp(const char *s1, const char *s2);`
strcmp compares the string pointed to by s1 to the string pointed to by s2.
- It **returns** an integer >, =, or < zero, accordingly if the string pointed to by s1 is >, =, or < the string pointed to by s2:
 - **0**: if the two strings are equal
 - **> 0 (i.e. the difference or 1 depending on system)**: if the first string follows the second string alphabetically, i.e. first string is larger (based on ASCII values)
 - **< 0 (i.e. the difference or -1)**: if the first string comes first alphabetically, i.e. the first string is smaller (based on ASCII values)

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The strcmp() Function

1. The **strcmp()** function compares the contents of two strings. The prototype of **strcmp()** is given here:
`int strcmp(const char *str1, const char *str2);`
2. It compares the string pointed to by **str1** to the string pointed to by **str2**. It takes the two strings and performs a letter-by-letter, alphabetic order comparison.
3. The comparison is based on ASCII codes for the characters. It returns an integer greater than, equal to or less than zero, according to whether the string pointed to by **str1** is greater than, equal to or less than the string pointed to by **str2** respectively.

The **strcmp()** Function: String Comparison based on ASCII Values

	0	1	2	3	4	5	6	7	8	9
0	NUL							BEL	BS	TAB
1	LF		FF	CR						
2								ESC		
3			SP	!	"	#	\$	%	&	'
4	()	*	+	,	-	.	/	0	1
5	2	3	4	5	6	7	8	9	:	;
6	<	=	>	?	@	A	B	C	D	E
7	F	G	H	I	J	K	L	M	N	O
8	P	Q	R	S	T	U	V	W	X	Y
9	Z	[\]	^	_	'	a	b	c
10	d	e	f	g	h	i	j	k	l	m
11	n	o	p	q	r	s	t	u	v	w
12	x	y	z	{		}	~	DEL		

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The **strcmp()** Function: String Comparison

1. The comparison between characters in the two strings is based on ASCII values.
2. It is interesting to note that in ASCII codes, uppercase characters come before lowercase characters, and digits come before the letters. For example, 'a' has the ASCII code value of 97, while 'A' has 65.
3. If the initial characters are the same, then the **strcmp()** function moves along the string until it finds the first pair of different characters, and returns the comparison result.
4. For example, when comparing "abcde" with "abcd", the first four characters are the same in the two strings. But when it comes to the character 'e' in the first string, it will be comparing with the terminating null character with ASCII code value of 0 in the second string. The function then returns a positive value.
5. This way of ordering strings is called *lexicographic order*.

The strcmp() Function:

Example 1

```
#include <stdio.h>
#include <string.h>
int main()
{
    char str1[81], str2[81], *p;
    int result;
    printf("String Comparison:\n");
    printf("Enter the first string: ");
    fgets(str1, 81, stdin);
    if ( p=strchr(str1,'\'\n') ) *p = '\0';
    printf("Enter the second string: ");
    fgets(str2, 81, stdin);
    if ( p=strchr(str2,'\'\n') ) *p = '\0';
    result = strcmp(str1, str2);
    printf("The result of the comparison is
        %d\n\n", result);
    return 0;
}
```

Compare char by char using ASCII value in the strings:

Output

String Comparison:
Enter the first string: A
Enter the second string: B
The result of the comparison is **-1**

Enter the first string: ABCd
Enter the second string: ABCD
The result of the comparison is **1**

Enter the first string: A0
Enter the second string: A1
The result of the comparison is **-1**

Here, only 1, 0 or -1 is returned, it could also be the difference in ASCII values depending on the system.
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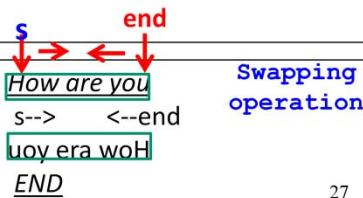
The strcmp() Function: Example 1

1. In the program, it uses the **strcmp()** function to compare two strings.
2. Generally, we are not interested in the actual values returned by **strcmp()**. The actual values to be returned depend on individual system implementation.
3. When comparing "A" to "C", some systems return -1, others return -2, i.e. the difference in ASCII code values.
4. However, in many applications, we are only interested to find out whether the two strings are equal or not.

The strcmp() Function: Example 2

```
/* Read a few lines from standard input &
write each line to standard output with
the characters reversed. The input
terminates with the line "END"*/
#include <stdio.h>
#include <string.h>
void reverse(char *);
int main()
{
    char line[132], *p;
    fgets(line, 132, stdin);
    if ( p=strchr(line, '\n') ) *p = '\0';
    while (strcmp(line, "END") !=0) {
        reverse(line);
        printf("%s\n", line);
        fgets(line, 132, stdin);
        if ( p=strchr(line, '\n') ) *p = '\0';
    }
}
```

```
void reverse(char *s)
{
    char c, *end;
    end = s + strlen(s) - 1;
    while (s < end) {
        /* 2 ends approaching centre */
        /* swapping operation */
        c = *s;
        *s++ = *end; /* postfix op */
        // i.e. *s = *end; s++;
        *end-- = c;
        // i.e. *end = c; end--;
    }
}
```



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The strcmp() Function: Example 2

1. In the program, it uses the **strcmp()** function to check whether to exit the loop after reading in an input string. The loop will end if the input string is "**END**".
2. In the **main()** function of the program, it reads in a string from the standard input, calls the function **reverse()** to reverse the characters in the string, and writes the reversed string to the standard output. The loop will continue until the user enters the string "**END**".
3. In the **reverse()** function, it accepts an input string as its parameter. The function then determines the position of the **end** pointer with the following statement: **end = s + strlen(s) - 1;**
4. The function then uses a **while** loop to process each character in the string. In the loop, it swaps the characters from both ends of the string, and then moves the string pointer **s** and the end string pointer **end** towards the center of the string with **s++** and **end--**. The swapping operation repeats until the condition **s < end** is false.
5. After the operation, the input string will be reversed. For example, if the input string **s** = "How are you", then the reversed string will be "uoy era who".
6. Note that the **reverse()** function illustrates a typical example on string processing.

The strcmp() Function (Cont'd.)

Question: In the program, could we just use the operator '=='?

For example:

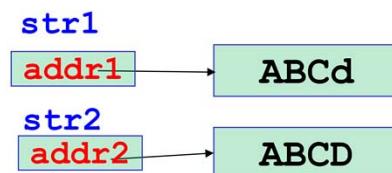
```
if (str1 == str2)
```

.....

instead of

```
if (strcmp(str1,str2) == 0) ...
```

Here, it compares the **addresses** stored in str1 (**addr1**) and str2 (**addr2**) only, not comparing the contents.



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The strcmp() Function (Cont'd.)

1. In this program, if we use the == operator such as **if (str1 == str2)** to compare the two strings instead of using the **strcmp()** function, will this be ok?
2. The answer to this question is “not ok”. It is because the contents of the two strings are addresses. Comparing the two strings in this way only compares the addresses contained in the two string variables. It does not compare the character contents stored in the strings.
3. Therefore, we need to use the **strcmp()** function to compare the two strings.

Character Strings

- String Declaration, Initialization and Operations
- String Input and Output
- String Functions
- **The ctype.h Character Functions**
- String to Number Conversions
- Formatted String I/O
- Arrays of Character Strings

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Character Strings

1. Here, we discuss the **ctype.h** character functions.

Name	True If Argument is
isalnum	Alphanumeric (alphabetic or numeric)
isalpha	Alphabetic
iscntrl	A control character, e.g. Control-B
isdigit	A digit
isgraph	Any printing character other than a space
islower	A lowercase character
isprint	A printing character
ispunct	A punctuation character (any printing character other than a space or an alphanumeric character)
isspace	A whitespace character: space, newline, formfeed, carriage return, etc.
isupper	An uppercase character
Isxdigit	A hexadecimal-digit character

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ctype.h Functions

- Return **true** (**non-zero**) if the character belongs to a particular class;
- Return **false** (**zero**) otherwise.
- Must include the following header file: **#include <ctype.h>**

The ctype.h Functions

1. C also contains the character processing library, whose functions are declared in the *ctype.h* header file. These functions are used to test the nature of a character. It returns *true* if the condition being tested is satisfied, or *false* otherwise.
2. To use these functions, we must include the *ctype.h* header file in the programs. Some of the most commonly used functions are given in the table.
3. The character testing functions are very useful. For example, when an input might contain any sequence of input characters, we can use the function such as **islower()**, **isupper()**, **isdigit()**, **isalpha()**, **isalnum()** or **isspace()** to test each input character and then process the character accordingly.

ctype: Character Conversion Functions

- **toupper()** - maps lowercase character to uppercase;
- **tolower()** - maps uppercase character to lowercase;

```
#include <stdio.h>
#include <string.h>
#include <ctype.h>
void modify(char* str);
int main() {
    char str[80], *p; // allocate memory
    printf("Enter a string of text: \n");
    fgets(str,80,stdin);
    if ( p=strchr(str,'\'\n') ) *p = '\0';
    modify(str); puts(str);
    return 0;
}
void modify(char* str) {
    while (*str != '\0') {
        if (isupper(*str))
            *str = tolower(*str);
        else if (islower(*str))
            *str = toupper(*str);
        str++;
    }
}
```

Output

This is a test



t H...

tHIS IS A TEST

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ctype.h: Character Conversion Functions

1. In addition to the functions that test characters in *ctype.h*, there are several character conversion functions for converting characters. The two most commonly used functions are **toupper()** and **tolower()**.
2. The function **toupper()** converts lowercase characters to uppercase, while the function **tolower()** converts uppercase characters to lowercase. These two functions are commonly used to test character input, and convert all of them into either lowercase or uppercase, so that the program is not sensitive to the case of the letters the user enters.
3. In the program, the function **modify()** aims to convert lower case letters to upper case letters and vice versa from an input string. It uses the functions **isupper()**, **islower()**, **tolower()** and **toupper()** for implementing character conversion. In the **while** loop, if a character in the input string is tested to be in uppercase, it will be converted into lowercase using the function **tolower()**. Similarly, if a character in the input string is tested to be in lowercase, it will be converted to uppercase using the function **toupper()**.

Character Strings

- String Declaration, Initialization and Operations
- String Input and Output
- String Functions
- The ctype.h Character Functions
- **String to Number Conversions**
- Formatted String I/O
- Arrays of Character Strings

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Character Strings

1. Here, we discuss the string to number conversion functions.

String to Number Conversions

- Must include the following header file:

`#include <stdlib.h>`

atof()

- Prototype: `double atof (const char *ptr);`
- Functionality: converts the **string** pointed to by the pointer **ptr** into a **double** precision floating number.
- Return value: converted value.

atoi()

- Prototype: `int atoi (const char *ptr);`
- Functionality: converts the **string** pointed to by the pointer **ptr** into an **integer**.
- Return value: converted value.

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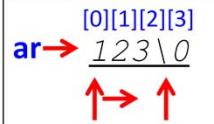
String to Number Conversions

1. There are two ways to store a number. It can be stored as strings or in numeric form. Sometimes, it is convenient to read in the numerical data as a string and convert it into the numeric form. To do this, C provides the functions: **atoi()** and **atof()**.
2. To use these functions, we must include the *stdlib.h* file in the program:
`#include <stdlib.h>`
3. The **atoi()** function converts a character string into an integer and returns the integer value. The function prototype is `int atoi(const char *ptr);`
4. The **atoi()** function processes the digits in the string and stops when the first non-digit character is encountered. Leading blanks are ignored and leading algebraic sign (+/-) can be recognized.
5. The **atof()** function converts a string into a double precision floating point value.

String to Number Conversions: Example

```
#include <stdio.h>
#include <stdlib.h>
#include <ctype.h>
int main()
{
    char ar[80];
    int i, num;

    scanf("%s", ar);           // read input string
    i=0;
    while (isdigit(ar[i]))    // check digit in string
        i++;                  // until not a digit
    if (ar[i] != '\0')         // if not a null character
        printf("The input is not a number\n");
    /* for example, "1a2" */
    else {
        num = atoi(ar);
        printf("Input is %d\n", num);
    }
}
```



atof() and **atoi()** are useful when the program reads in a string and then converts the string into the corresponding number representation for further processing.

Why? Sometimes it is more convenient to read in a string instead of reading in a number directly.

Output

123
Input is 123

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String to Number Conversions: Example

1. **atof()** and **atoi()** are useful when the program reads in a string and then converts the string into the corresponding number representation for further processing, as sometimes it is more convenient to read in a string instead of reading in a number directly.
2. In the program, it uses the **atoi()** function for string to integer number conversion. The program reads in an input string and store it in the string variable **ar**.
3. The while loop: **while (isdigit(ar[i])** will be executed and stopped when a non-digit character is processed from the input string.
4. After that the statement: **if (ar[i] != '\0')** is used to check whether the next character is a null character. If yes, it means that the string contains only digit characters. If not, the string does not contain a valid integer number and an error message is printed to the screen.
5. If the string contains valid digit characters, the function **atoi()** is called to convert the number string to the corresponding number and stores it into the variable **num**.
6. And finally, the converted number is printed on the screen.

Character Strings

- String Declaration, Initialization and Operations
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- **Formatted String I/O**
- Arrays of Character Strings

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Character Strings

1. Here, we discuss the formatted string I/O functions.

Formatted String I/O

sscanf()

- The function `sscanf()` is similar to `scanf()`. The only difference is that `sscanf()` takes input characters from a **string** instead of from the keyboard.
- `sscanf()` can be used **to transform numbers represented in characters/strings**, i.e. "123", into numbers, i.e. 123, 123.0, of data types `int`, `float`, `double`, ..., etc.
- Function prototype:

`sscanf(string_ptr, control-string, argument-list);`

sprintf()

- The function `sprintf()` is similar to `printf()`. The only difference is that `sprintf()` prints output to a **string**.
- `sprintf()` can be used to **transform numbers into strings**.
- Function prototype:

`sprintf(string_ptr, control-string, argument-list);`

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Formatted String I/O

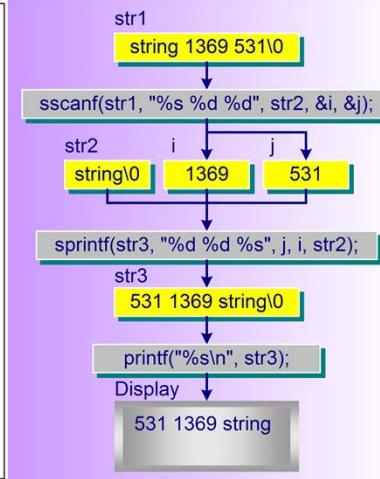
1. The C Standard I/O library provides two functions for performing formatted input and output to strings. These functions are **sscanf()** and **sprintf()**.
2. The function **sscanf()** is similar to **scanf()**. The only difference is that **sscanf()** takes input characters from a string instead of from the standard input, i.e. the keyboard. It reads characters from a string and converts them into data of different types, and stores them into variables. The **sscanf()** function can be used to transform numbers represented in characters or strings (e.g. "123") into numeric numbers (e.g. 123, 123.0) of data types **int**, **float**, **double**, etc.
3. The syntax for the function **sscanf()** is **sscanf(string_ptr, control-string, argument-list)**; where **string_ptr** is a pointer to a string containing the characters to be processed. The other arguments of **sscanf()** are the same as those in **scanf()**.
4. The function **sprintf()** is similar to **printf()**. The only difference is that **sprintf()** prints output to a string. It formats the input data and stores them in a string. It appends a null character at the end of the string. The **sprintf()** function can be used to combine several elements into a single string. It can also be used to transform numbers into strings.
5. The syntax for the function **sprintf()** is **sprintf(string_ptr, control-string, argument-list)**; where **string_ptr** is a pointer to a string. The other arguments are the same as those in **printf()**.

Formatted String I/O - Example

```
#include <stdio.h>
#define MAX_CHAR 80

int main()
{
    char str1[MAX_CHAR] = "string 1369 531";
    char str2[MAX_CHAR], str3[MAX_CHAR];
    int i, j;

    sscanf(str1, "%s %d %d", str2, &i, &j);
    sprintf(str3, "%d %d %s", j, i, str2);
    printf("%s\n", str3);
}
```



Output

531 1369 string

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Formatted String I/O – Example

1. The example illustrates the use of the **sscanf()** and **sprintf()** functions.
2. The **sscanf()** function is useful to convert numbers in a string to its corresponding numeric value.
3. The **sprintf()** function is useful to combine different data items into a string.
4. In the example, the function **sscanf()** reads from the string **str1** and stores the elements of the string into another string **str2**, and two integers, **i** and **j**. The function **sprintf()** then combines the three elements in a different order and stores them in a new string **str3**.

Character Strings

- String Declaration, Initialization and Operations
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- **Arrays of Character Strings**

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Character Strings

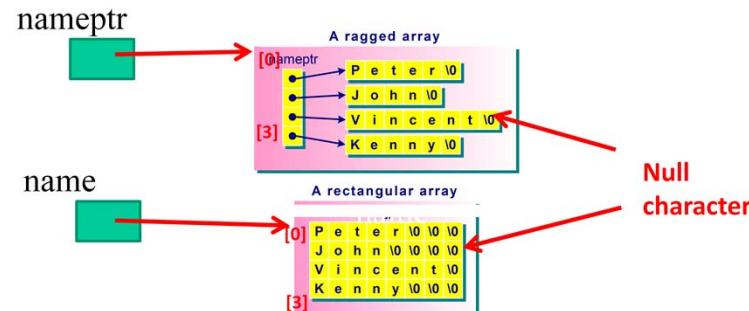
1. Here, we discuss array of character strings.

Array of Character Strings

- **Arrays of Character Strings [declared as array of pointer variables]**

```
char *nameptr[4] = {"Peter", "John", "Vincent", "Kenny"};
```

nameptr is a **ragged array**, an *array of pointers* (save storage)



- **Arrays of Character Strings [declared using 2-D arrays]**

```
char name[4][8] = {"Peter", "John", "Vincent", "Kenny"};
```

name is a **rectangular array**.

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Array of Character Strings

1. It is possible to define an array of character strings.
2. For example, we can declare: **char *namePtr[4] = {"Peter", "John", "Vincent", "Kenny"};** where **namePtr** is a one-dimensional array of four pointers to type **char**. This is also called a **ragged array**.
3. Each pointer points to the first character of the corresponding string. That is, the first pointer **namePtr[0]** points to the first character of the first string, the second pointer **namePtr[1]** points to the first character of the second string, and so on. **namePtr** is an array of pointers.
4. Another way to store an array of strings is to use a two-dimensional array. For example, we can declare **name** as **char name[4][8] = {"Peter", "John", "Vincent", "Kenny"};** This is called a **rectangular array**. All the rows are of the same length. The two-dimensional array **name** needs to be defined with enough storage space to hold the longest string. Thus, some space will be wasted as not all the other strings will have the same length as the longest string.
5. However, the ragged array declaration **namePtr** can help save storage space when compared with the rectangular array declaration.

Array of Character Strings: Example

```
#include <stdio.h>
int main()
{
    char *nameptr[4] = {"Peter", "John", "Vincent", "Kenny"};
    char name[4][10] = {"Mary", "Victoria", "Susan", "May"};
    int i, j;

    Using for loop

    printf("Ragged Array: \n");
    for (i=0; i<4; i++)
        printf("nameptr[%d] = %s\n", i,
               nameptr[i]);

    printf("Rectangular Array: \n");
    for (j=0; j<4; j++)
        printf("name[%d] = %s\n", j,
               name[j]);
    return 0;
}
```

Output

Ragged Array:

nameptr[0] = Peter
 nameptr[1] = John
 nameptr[2] = Vincent
 nameptr[3] = Kenny
Rectangular Array:
 name[0] = Mary
 name[1] = Victoria
 name[2] = Susan
 name[3] = Mary

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Array of Character Strings: Example

1. In the program, we can process array of strings declared using ragged array or rectangular array.
2. After we declare an array of strings **char *namePtr[4] = {"Peter", "John", "Vincent", "Kenny"};** we can then use an index (or subscript) to access each element of the array for the character strings as follows:

```
for (i=0; i<4; i++)
    printf("namePtr[%d] = %s\n", i, namePtr[i]);
```

3. Similarly, we can access each element of the rectangular array declaration **name** as follows:

```
for (j=0; j<4; j++)
    printf("name[%d] = %s\n", j, name[j]);
```

4. Note that if we want to print a character from the string, we can use the indirection operator (i.e. '*'). For example, the following statement prints the character 't' from the string "**Peter**".

```
printf("%c", *(namePtr[0] + 2));
```

Array of Character Strings: Example

```
#include <stdio.h>
int main()
{
    char name[4][10];           // if you read the data from user,
    int i,j;                   // use array declaration to store the data;
                                // not pointer declaration

    printf("Enter 4 names: ");
    for (i=0; i<4; i++)
        scanf("%s", name[i]);

    printf("Rectangular Array: \n");
    for (j=0; j<4; j++)
        printf("name[%d] = %s\n", j, name[j]);
    return 0;
}
```

Enter 4 names: *Peter John Vincent Kenny*
 Rectangular Array:
 name[0] = Peter
 name[1] = John
 name[2] = Vincent
 name[3] = Kenny

Array of Character Strings: Example

1. Note that if we read input string data from the user, we will need to use the array declaration in order to store the input string data. This will enable the allocation of memory to store the input string data.
2. If we use the pointer declaration, no memory will be allocated to store the input string data. The program will be incorrect.

Thank you !!!



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