CS2311 Computer Programming

LT8: Array of Characters (Strings)

Outline

- Characters (review)
  - Declaration and Initialization
  - ASCII
  - Input and Output: **`cin`** & **`cout`**
- Strings
  - Declaration and Initialization
  - Copy and compare
  - Input and output

Character Data Type

- Written between single quotes.
  - Examples :
    - `'A'`, `'b'`, `'*'`
- In C++ language, a **`char`** type is represented by an integer.
- Therefore, a character can also be treated as an integer.
- Examples

```
cout << 'a';          // a is printed
cout << (int)'a';     // 97 is printed
cout << (char)97;     // a is printed
```

ASCII Table

Dec	Hx	Oct	Char	Dec	Hx	Oct	Html	Chr	Dec	Hx	Oct	Html	Chr	Dec	Hx	Oct	Html	Chr
0	0	000	NUL (null)	32	20	040		Space	64	40	100	@	@	96	60	140	`	`
1	1	001	SOH (start of heading)	33	21	041	!	!	65	41	101	A	A	97	61	141	a	a
2	2	002	STX (start of text)	34	22	042	"	"	66	42	102	B	B	98	62	142	b	b
3	3	003	ETX (end of text)	35	23	043	#	#	67	43	103	C	C	99	63	143	c	c
4	4	004	EOT (end of transmission)	36	24	044	$	$	68	44	104	D	D	100	64	144	d	d
5	5	005	ENQ (enquiry)	37	25	045	%	%	69	45	105	E	E	101	65	145	e	e
6	6	006	ACK (acknowledge)	38	26	046	&	&	70	46	106	F	F	102	66	146	f	f
7	7	007	BEL (bell)	39	27	047	'	'	71	47	107	G	G	103	67	147	g	g
8	8	010	BS (backspace)	40	28	050	(	(	72	48	110	H	H	104	68	150	h	h
9	9	011	TAB (horizontal tab)	41	29	051	)	)	73	49	111	I	I	105	69	151	i	i
10	A	012	LF (NL line feed, new line)	42	2A	052	*	*	74	4A	112	J	J	106	6A	152	j	j
11	B	013	VT (vertical tab)	43	2B	053	+	+	75	4B	113	K	K	107	6B	153	k	k
12	C	014	FF (NP form feed, new page)	44	2C	054	,	,	76	4C	114	L	L	108	6C	154	l	l
13	D	015	CR (carriage return)	45	2D	055	-	-	77	4D	115	M	M	109	6D	155	m	m
14	E	016	SO (shift out)	46	2E	056	.	.	78	4E	116	N	N	110	6E	156	n	n
15	F	017	SI (shift in)	47	2F	057	/	/	79	4F	117	O	O	111	6F	157	o	o
16	10	020	DLE (data link escape)	48	30	060	0	0	80	50	120	P	P	112	70	160	p	p
17	11	021	DC1 (device control 1)	49	31	061	1	1	81	51	121	Q	Q	113	71	161	q	q
18	12	022	DC2 (device control 2)	50	32	062	2	2	82	52	122	R	R	114	72	162	r	r
19	13	023	DC3 (device control 3)	51	33	063	3	3	83	53	123	S	S	115	73	163	s	s
20	14	024	DC4 (device control 4)	52	34	064	4	4	84	54	124	T	T	116	74	164	t	t
21	15	025	NAK (negative acknowledge)	53	35	065	5	5	85	55	125	U	U	117	75	165	u	u
22	16	026	SYN (synchronous idle)	54	36	066	6	6	86	56	126	V	V	118	76	166	v	v
23	17	027	ETB (end of trans. block)	55	37	067	7	7	87	57	127	W	W	119	77	167	w	w
24	18	030	CAN (cancel)	56	38	070	8	8	88	58	130	X	X	120	78	170	x	x
25	19	031	EM (end of medium)	57	39	071	9	9	89	59	131	Y	Y	121	79	171	y	y
26	1A	032	SUB (substitute)	58	3A	072	:	:	90	5A	132	Z	Z	122	7A	172	z	z
27	1B	033	ESC (escape)	59	3B	073	;	;	91	5B	133	[	[	123	7B	173	{	{
28	1C	034	FS (file separator)	60	3C	074	<	<	92	5C	134	\	\	124	7C	174			|
29	1D	035	GS (group separator)	61	3D	075	=	=	93	5D	135	]	]	125	7D	175	}	}
30	1E	036	RS (record separator)	62	3E	076	>	>	94	5E	136	^	^	126	7E	176	~	~
31	1F	037	US (unit separator)	63	3F	077	?	?	95	5F	137	_	_	127	7F	177	&#127;	DEL

```
cout << (int)'7';
```

```
cout << (char)97;
```

char Features

A	B	...	Z	...	a	b	...	z
65	66	...	90	..	97	98	...	122

'A' + 1 has the value of 'B',
'B' + 1 has the value of 'C', ...

test if character **c** is lower-case letter:

```
if ('a' <= c && c  <= 'z') ...
```

same as:

```
if (97 <=c && c <= 122) ...
```

If the variable **c** has the value of a lowercase letter, then the expression

```
c + ('A' - 'a') // same as c + (65 -97)
```

has the value of the corresponding uppercase letter

Example

```
#include <iostream>
using namespace std;

int main() {

   char c1 = 'D', c2 = 'e', c3, c4;
   c3 = c1 + 'a' - 'A';      // convert to lowercase
   c4 = c2 + 'A' - 'a';      // convert to uppercase
   cout << "c3=" << c3 << ", c4=" << c4 << endl; // c3=d, c4=E

   return 0;
}
```

Reading A Character

```
char c1,c2;
cin >> c1;
```

When **cin >> c1** is reached, the program will ask the user for input.

Suppose the character **'A'** is input, **c1** will evaluate to **65** (which is the ASCII code of **'A'**).

As a result, **65** will be assigned to the character **c1**. Therefore, **c1** holds the character **'A'**.

Some Facts About Keyboard Input

- Suppose >> is called to read a character.
- What if the user input more than 1 characters in a single line?
  - Answer:
    - The extra character will be stored in a buffer (certain memory location).
    - The character will be retrieved **later** when >> is called to read more characters.

Some Facts About Keyboard Input

```
char c1, c2, c3;
cin >> c1;    //enter the string "CS2311"
cin >> c2;    //get the character 'S' from buffer
cin >> c3;    //get the character '2' from buffer
```

	C1	C2	C3	Input Buffer
(user input "CS2311")				C S 2 3 1 1 ↵
cin >> c1;	'C'			S 2 3 1 1 ↵
cin >> c2;	'C'	'S'		2 3 1 1 ↵
cin >> c3;	'C'	'S'	'2'	3 1 1 ↵

Printing A Character

```
char c1 = 'A', c2 = 'B';
cout << c1;
cout.put(c1);
```

Example

- Write a program which *read*s a character from the user and output the character type.

- The program should distinguish between the following types of characters
  - An upper case character (`'A' – 'Z'`)
  - A lower case character (`'a' – 'z'`)
  - A digit (`'0' – '9'`)
  - Special character (e.g. `'#'`, `'$'`, etc.)

Code: Output Character Type

```
#include <iostream>
using namespace std;
int main() {
   char c;
   cin >> c;
   if (              )
      cout << "An upper case character";
   else if (              )
      cout << "A lower case character";
   else if (              )
      cout << "A digit";
   else
      cout << "Special character";
   cout << endl;
   return 0;
}
```

Code: Output Character Type

```
#include <iostream>
using namespace std;
int main() {
   char c;
   cin >> c;
   if (c >= 'A' && c <= 'Z')
      cout << "An upper case character";
   else if (c >= 'a' && c <= 'z')
      cout << "A lower case character";
   else if (c >= '0' && c <= '9')
      cout << "A digit";
   else
      cout << "Special character";
   cout << endl;
   return 0;
}
```

Strings

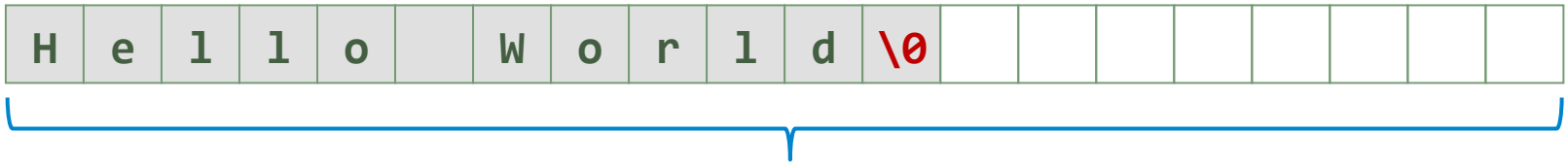
`cstring` vs `string` object

- In C++, there are two types of strings
- **`cstring`**: inherited from the C language
- **`string`**: class defined in **`<string>`** library

String : cstring

- A **cstring** is a **char** array, which is terminated by the end-of-string character or **null** character **'\0'**.
- A character array of size **n** may store a string with maximum length of **n-1**
- Consider the definition

```
char str[20] = "Hello World";
```



This character array may store a string with maximum length of **19**

Rule of Safety

- Declare a string with one more character than needed
- E.g.
  - `char studentID[9];  //51234567`
  - `char HKID[11];  //a123456(7)`

cstring: Declaration and Initialization

- String variable can be declared in two ways
- Without initialization
  - `char identifier[required size+1]`
  - E.g.

```
char name[12];       // name with 11 characters
char Address[50];    // address with 49 characters
```

- With initialization
  - `char identifier = string constant`
  - E.g.

```
char name[] = "John";           // name with 5 characters
char choice[] = "a,b,c,d,e";    // choice with 10 characters
```

- However, you cannot initialize a string after declaration

```
char name[10];
name = "john";
```

```
error C2440: '=' : cannot convert from 'const char [5]' to 'char [10]'
```

Example

```
#include<iostream>
using namespace std;
int main() {
   int mark;
   char grade;
   cin >> mark;
   if (mark > 80)
      grade ='A';     // error: grade = "A"
   else if (mark > 60)
      grade ='B';
   else if (mark > 50)
      grade ='C';
   else
      grade ='F';
   cout << grade << endl;
   return 0;
}
```

```
error C2440: cannot convert from 'const char [2]' to 'char'
```

cstring : Reading and Printing

```
#include<iostream>
using namespace std;
int main() {
   char word[20];

   cin >> word;     // read a string
   cout << word;    // print a string
   return 0;
}
```

The array word can **store 20 characters** but we can only have up to **19 characters** (the last character is reserved for null character).
No need to specify the brackets

Reading a Line of Characters

- **`cin >> str`** will *terminate* when *whitespace* characters (space, tab, linefeed, carriage-return, formfeed, vertical-tab and newline characters) is encountered

- Suppose "`hello world`" is input

```
char s[20];
cin >> s1; // read "hello"
cin >> s2; // read "world"
cin >> s1; // output "hello"
cin >> s2; // output "world"
```

- How to read a line of characters [before end-of-line is encountered]?

cin.get()

- **get()** : member function of **cin** to read in **one** character from input
- **>>**: skipping over whitespace (and eol) but **get()** won't
- Syntax:

```
char c;
cin.get(c);
```

cin.get()

```
#include <iostream>
using namespace std;

int main() {
    char c;
    do {
        cin.get(c);
        cout << c;
    } while (c != '\n');

    return 0;
}
```

cin.getline()

- Predefined member function of **cin** to read a **line** of text (including space)
- Two arguments:
  - **cstring** variable to receive the input
  - size of the **cstring**

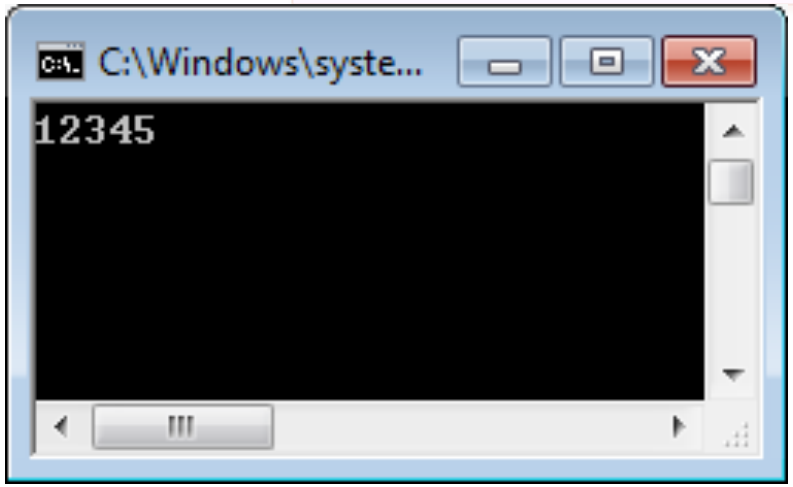
```
#include <iostream>
using namespace std;
int main() {
   char s[20];
   while (1) {
     cin.getline(s,20);
     cout << "\"" << s << "\"" << endl;
   }
   return 0;
}
```

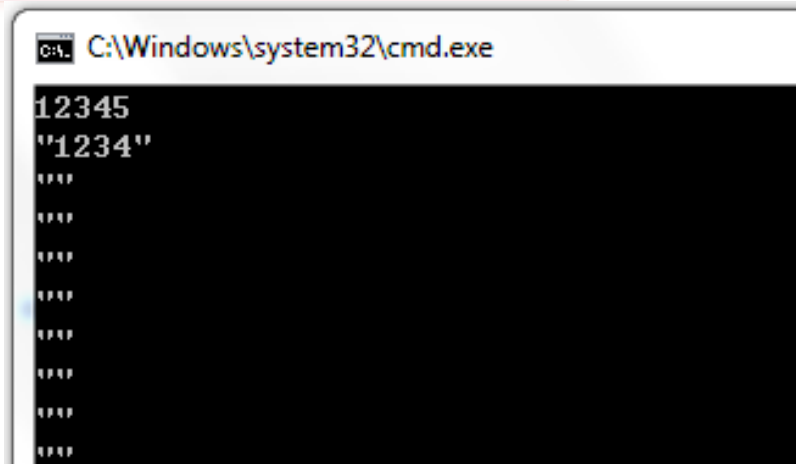
`cin.getline()`

- What if
  - Input is *longer than* the string variable?
  - End of the *source characters* is reached?
  - Error occurred?
    - **Internal** state **flags** (**`eofbit`**, **`failbit`**, **`badbit`**) of **`cin`** object will be set
    - To reset those flags, call method **`clear()`** of **`cin`**.
      - E.g. **`cin.clear();`**

Example

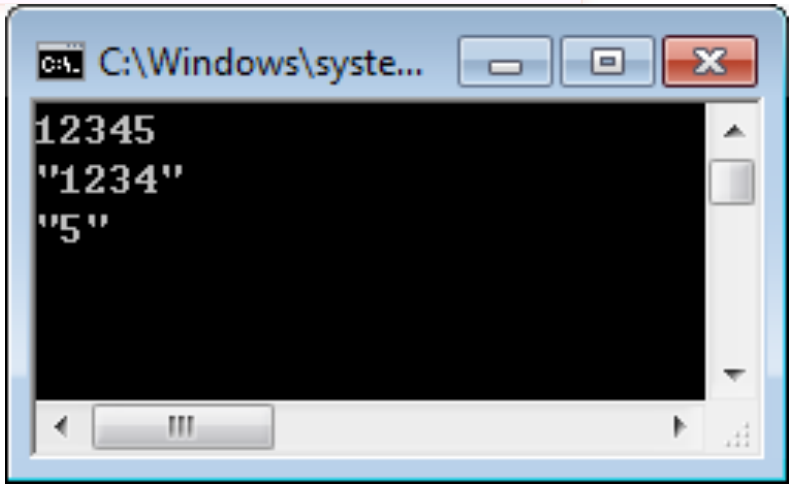
```
#include <iostream>
using namespace std;
int main() {
   char s[5];
   while (1) {
      cin.getline(s,5);
      cout << "\"" << s << "\"" << endl;
   }
   return 0;
}
```





Example

```
#include <iostream>
using namespace std;
int main() {
   char s[5];
   while (1) {
      cin.getline(s,5);
      cin.clear();
      cout << "\"" << s << "\"" << endl;
   }
   return 0;
}
```



The Null Character `'\0'`

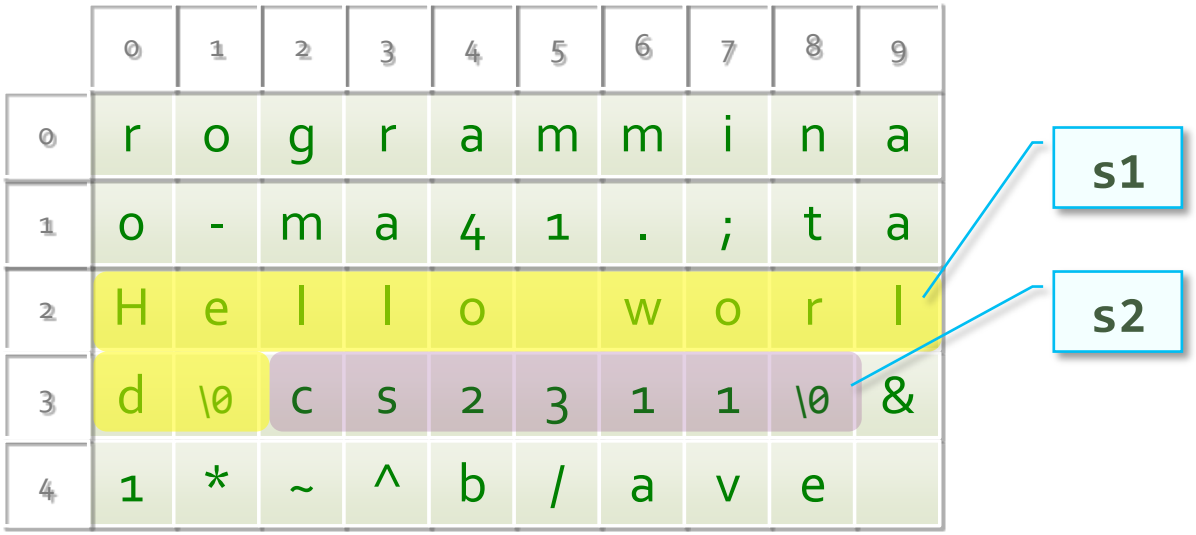
- The null character, `'\0'`, is used to mark the end of a `cstring`
- `'\0'` is a single character (although written in two symbols)
- It is used to distinguish a `cstring` *variable* from an ordinary array of characters (`cstring` variable must contain the `null` character

Why need '\0'?

- **cstring** is stored in main memory continuously
- Only the starting address of the **cstring** is stored in **cstring** variable

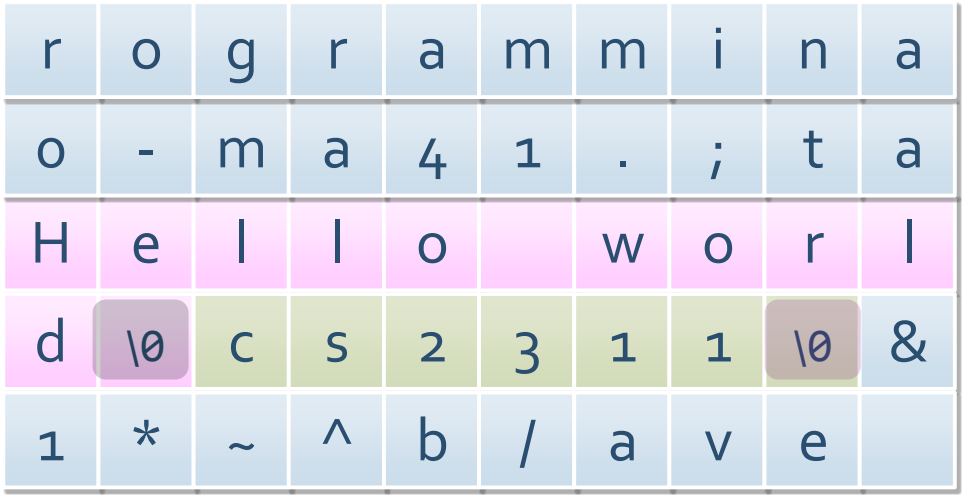
```
char s1[] = "Hello world";      // s1=20
char s2[] = "cs2311";           // s2=32
```

- '\0' indicates the end of **cstring**



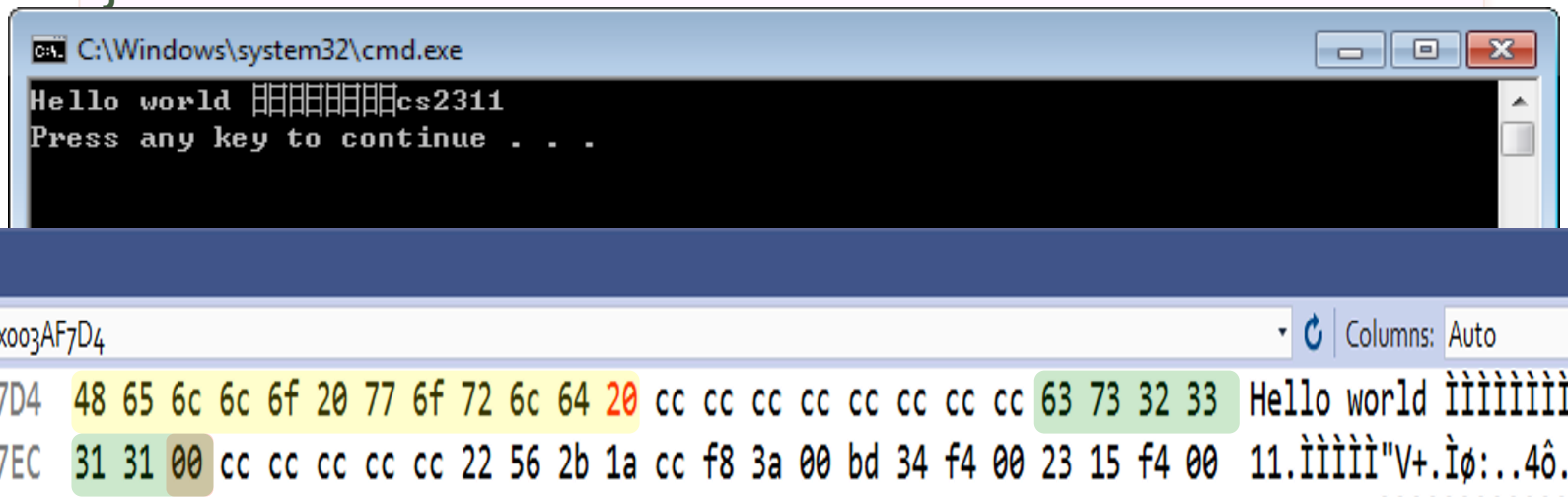
Why need `'\0'`?

- When a `cstring` variable is passed to an output function, i.e. `cout`, the function will print all the memory content until `'\0'` is encountered



Why need '\0'?

```
#include <iostream>
using namespace std;
int main() {
   char s1[] = "cs2311";
   char s2[] = "Hello world";
   s2[11] = ' '; // change '\0' to a space character
   cout << s2 << endl;
   return 0;
}
```



Passing strings to functions

- Example:
  - Write a function to count the number of *occurrences* of a character in a string
- Functions
  - **`count`**: given a character and a string as input, return the number of occurrences of the character in the string
  - **`main`** function: call **`count`** function

Function : count

The size 100 is optional

```
int count(char s[100], char c) {
   int occurrence = 0;
   for (int i=0; s[i] != '\0'; i++) {
      if (s[i] == c)
         occurrence++;
   }
   return occurrence;
}
```

```
int count(char s[100], char c) {
    int occurrence = 0;
    int i = 0;
    while (s[i] != '\0') {
        if (s[i] == c)
            occurrence++;
        i++;
    }
    return occurrence;
}
```

The `main` function

```
int main() {

   char str[50] = "CityU is a very good university";
   int cnt = count(str, 'a');
   cout << "count = " << cnt << endl);

   return 0;
}
```

```
int count(char s[100], char c) {
   …
   return occurrence;
}
```

Common `cstring` functions in `<cstring>`

Function	Description	Remarks
`strcpy(dest,src)`	Copy the content of string **`src`** to the string **`dest`**	No error check on the size of **`dest`** is enough for holding **`src`**
`strcat(dest,src)`	Append the content of string **`src`** onto the end of string **`dest`**	No error check on the size of **`dest`** is enough for holding **`src`**
`strcmp(s1,s2)`	Lexicographically compare two strings, **`s1`** and **`s2`**, character by character.	`=0`: **`s1`** and **`s2`** is identical `>0`: **`s1`** is greater than **`s2`** `<0`: **`s1`** is less than **`s2`**
`strlen(str)`	Returns the number of characters (exclude the **`null`** character) contain in **`str`**	

Note: you may need to use **`strcpy_s`** and **`strcat_s`** instead of **`strcpy`** and **`strcat`** if you are using the latest visual studio.

Additional notes

- `strcpy` copies the entire string, including the **null** character.
- These string functions are considered unsafe, as they don't check if enough memory has been allocated for the destination string.
- In **VS**, the compiler refuses to run them by default. You need to add a pre-processor directive `_CRT_SECURE_NO_WARNINGS`.

strcpy(dest, src), strcat(dest, src)

```
#define _CRT_SECURE_NO_WARNINGS
#include<iostream>
using namespace std;

int main() {

   char src[] = "This is CS2311";
   char dest[40];

   strcpy_s(dest, src);
   cout << dest << endl;

   strcat_s(dest, " Lecture08.");
   cout << dest << endl;

   return 0;
}
```

cstring: copy

- Suppose there are two strings, **str1** and **str2**
- **str1** is initialized to "Hello world"
- Copy **str1** to **str2**
  - We should **NOT** use the following expression to copy array elements

```
str2 = str1;
```

✗

  - Similarly, we should **NOT** use the following expression to compare strings

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

✗

Idea

- Use a loop to read characters one by one from **`str1`** until a **null character** (**`'\0'`**) is read
  - Copy the character to the corresponding position of **`str2`**
- Put a **`null`** character at the end of **`str2`**

Try to implement: Copy

```
#include<iostream>
using namespace std;

int main() {

   char str1[20] = "Hello world";
   char str2[16];
   int i;
   // beware of the boundary condition!
   for (i = 0; i < 15 && str1[i] != '\0'; i++) {
      str2[i] = str1[i];
   }
   str2[i] = '\0';
   return 0;
}
```

```
int i = 0;
// beware of the boundary condition!
while (i < 15 && str1[i] != '\0') {
   str2[i++] = str1[i];
}
```

Try to implement: Append Content

```
#include<iostream>
using namespace std;

int main() {

   char s1[20] = "Welcome to ";
   char s2[20] = "CS2311";
   int s1_len = strlen(s1);
   int s2_len = strlen(s2);

   char s[50];    // result
   for (int  i = 0; i < s1_len; i++)
     s[i] = s1[i];

   for (int  i = s1_len; i < s1_len + s2_len; i++)
     s[i] = s2[i - s1_len];

   s[s1_len + s2_len] = '\0';

   cout << s << endl;
   return 0;
}
```

<cstring> strlen()

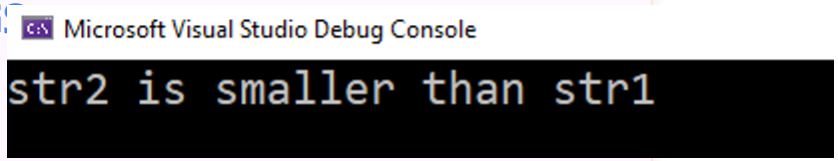
```
#include<iostream>
using namespace std;

int main() {

   char str[50];
   long len;
   strcpy_s(str, "This is CS2311");

   len = strlen(str);
   cout << "The length of str is " << len << endl;

   return 0;
}
```

Try to implement: strlen(str)

```
#include<iostream>
using namespace std;
int strlength(char s[]) {
   int length = 0;
   while (s[length] != '\0')
      length++;
   return length;
}
int main() {

   char s[20] = "Hello world";
   cout << "The length of " << s << " is " << strlength(s) << endl;

   return 0;
}
```

strcmp(s1,s2)

```
#define _CRT_SECURE_NO_WARNING
#include<iostream>
using namespace std;
int main() {
   char str1[15];
   char str2[15];
   strcpy_s(str1, "abcdef");
   strcpy_s(str2, "ABCDEF");
   int ret = strcmp(str1, str2);
   if (ret < 0)
     cout << "str1 is smaller than str2" << endl;
   else if (ret > 0)
     cout << "str2 is smaller than str1" << endl;
   else
     cout << "str1 is equal with str2" << endl;

   return 0;
}
```



Try to implement: Compare two strings with the *same length*

```
#include<iostream>
using namespace std;

int main() {

   char s1[15] = "abcdef";
   char s2[15] = "abcdEF";
   int len = strlen(s1);
   for (int i = 0; i < len; i++)
     if (s1[i] < s2[i])
         cout << "str1 is smaller than str2" << endl;
     else if (s1[i] > s2[i])
         cout << "str2 is smaller than str1" << endl;
     else
         cout << "str1 is equal to str2" << endl;
   return 0;
}
```

Example

- Write a program to print a word backward.
- Example:
  - Input:

    hello
  - Output:

    olleh

```
#include <iostream>
using namespace std;

int main() {
   char   ____;   // define an array input with size 50
   int n;         // length of str

   cin >>____;
   n = ______;    // compute string length
   for (int i =____; i >= 0 ; i--)
      cout <<____ ;
   return 0;
}
```

The program

```
#include <iostream>
using namespace std;
int main() {
   char input[50];      // define an array input with size 50
   int n;               // length of string

   cin >> input;
   n = strlen(input); // compute string length
   for (int i = n-1; i >= 0 ; i--)
      cout << input[i];

   return 0;
}
```

Exercise

- Write a program to let the user to input a line of string from the user
- The program should reverse the case of the input characters and print the result
  - lowercase characters are changed to uppercase
  - uppercase characters are changed to lowercase
- Example input/output:

```
Hello World
hELLO wORLD
```

Program

```
#include <iostream>
using namespace std;
int main() {
   char s[50];
   cin.getline(s,50);
   for (int i=0; s[i] != '\0'; i++){
      if (                    ) // uppercase letter
         cout <<              ; // to lowercase
      else if (s[i] >= 'a' && s[i] <= 'z') // lowercase letter
         cout <<              ; // convert to uppercase
      else                     // other characters
         cout <<              ;
   }
   return 0;
}
```

Answer

```
#include<iostream>
using namespace std;

int main() {

   char s[50];
   cin.getline(s,50);
   cout << s << endl;
   for (int i = 0; s[i] != '\0'; i++) {
      if (s[i] >= 'A' && s[i] <= 'Z')          // uppercase letter
         cout << char(s[i] + 'a' - 'A');       // to lowercase
      else if (s[i] >= 'a' && s[i] <= 'z')     // lowercase letter
         cout << char(s[i] + 'A' - 'a');       // convert to uppercase
      else                                     // other characters
         cout << char(s[i]);
   }
   return 0;
}
```

Summary

- Character is an integer
- **`cin.get(…)`**, **`cin.getline (…)`**, **`cin.clear(…)`**
- **`String`** is an array of character terminated by **`'\0'`**
- Access string content is similar to access individual element of an array
- **`String`** copy, comparison, concatenation can be done by functions provided in **`<cstring>`**