Character Strings Lesson Outline

`char` Arrays #1

In C, you can have an array of type `char`, just as you can have arrays of numeric types:

```
char my_name[12];
```

We can fill this `char` array with characters and be able to print them out.

`char` Arrays #2

```
my_name[ 0] = 'H';
my_name[ 1] = 'e';
my_name[ 2] = 'n';
my_name[ 3] = 'r';
my_name[ 4] = 'y';
my_name[ 5] = ' ';
my_name[ 6] = 'N';
my_name[ 7] = 'e';
my_name[ 8] = 'e';
my_name[ 9] = 'm';
my_name[10] = 'a';
my_name[11] = 'n';
```

Is this a good solution?

Character Array Example #1

```
#include <stdio.h>
int main ()
{ /* main */
    const int my_name_length = 12;
    char my_name[my_name_length];
    int  index;
    my_name[ 0] = 'H';
    my_name[ 1] = 'e';
    my_name[ 2] = 'n';
    my_name[ 3] = 'r';
    my_name[ 4] = 'y';
    my_name[ 5] = ' ';
    my_name[ 6] = 'N';
    my_name[ 7] = 'e';
    my_name[ 8] = 'e';
    my_name[ 9] = 'm';
    my_name[10] = 'a';
    my_name[11] = 'n';
    printf("My name is ");
    for (index = 0; index < my_name_length; index++) {
        printf("%c", my_name[index]);
    } /* for index */
    printf(".\n");
    return 0;
} /* main */
```

Character Array Example #2

```
% gcc -o chararray chararray.c
% chararray
My name is Henry Neeman.
```

This is an improvement, but it's still not an efficient way to assign a sequence of characters to a variable.

What we want is a kind of `char` variable that will be convenient to use for inputting, outputting and using sequences of characters.

Character Strings

A ***character string*** is a sequence of characters with the following properties:

- it is **stored** like a `char` array;
- it is **used** like a `char` scalar (kind of).

In C, we declare a character string like so:

```
char my_name[my_name_length+1];
```

Notice that a character string is declared **exactly** like a `char` array; in fact, a character string **is** a `char` array.

Character String Terminator

The only **difference** between a `char` **array** and a character **string** is that the **length** of the `char` **string** is **one greater** than the number of characters to be stored, and the last character in any C character string is the ***null character***, called `NUL`, which corresponds to integer value 0:

`'\0'`

A **null character** (integer 0) used to indicate the end of a string is known as a ***character string terminator***.

In general, a numeric value that is used to indicate that a particular state has been reached – for example, the end of a list – is called a ***sentinel*** value.

So, the character string terminator `NUL` is a sentinel that indicates the end of the string in question.

Jargon: Sentinel Value

A ***sentinel value*** is a numeric value – a number – that means something qualitative, even though it's in a variable whose value is intended to be a number.

For example, the individual characters in a character string are actually ASCII numeric values that encode the individual characters, as we saw in the ASCII table.

But the string terminator isn't a character as such; it's a value whose purpose is to indicate that the end of the string has been reached.

Another example is in weather data. For example, in a 3D array of of wind velocity (expressed in, e.g., km per hour), a value like -99999 might mean "no wind velocity measured in this location," for example if that location were inside the rocky interior of a mountain.

Character String Assignment Example #1

```
% cat charstrassnbad.c
#include <stdio.h>

int main ()
{ /* main */
    const int my_name_length       = 12;
    const int program_success_code =  0;
    char my_name[my_name_length + 1];

    my_name = "Henry Neeman"; /* <-- DOESN'T WORK! */
    printf("My name is %s.\n", my_name);
    return program_success_code;
} /* main */
% gcc -o charstrassnbad charstrassnbad.c
charstrassnbad.c: In function ‘main’:
charstrassnbad.c:8: incompatible types
  in assignment
```

The version above seems like it should work, but it doesn't!

Character String Assignment Example #2

```
% cat charstrassn.c
#include <stdio.h>
#include <string.h>

int main ()
{ /* main */
    const int my_name_length        = 12;
    const int program_success_code =  0;
    char my_name[my_name_length + 1];

    strcpy(my_name, "Henry Neeman"); /* <-- WORKS! */
    printf("My name is %s.\n", my_name);
    return program_success_code;
} /* main */
% gcc -o charstrassn charstrassn.c
% charstrassn
My name is Henry Neeman.
```

This version works!

#include <string.h>

When using string functions in C such as `strcpy`, you **MUST** add the following preprocessor directive to your C source file, just after the directive for `stdio.h`, like so:

```
#include <stdio.h>
#include <string.h>
```

Character String Declaration

In C, we declare a **character string** like so:

```
char my_name[my_name_length+1];
```

Notice that a character string is declared **exactly like** a `char` array; in fact, it **is** a `char` array.

The only difference in the declaration is that the length of the array of `char` elements that represents the string is **one greater** than the length of the string.

Character String Terminator

The last character in any C character string is the ***null character***, called `NUL`, which corresponds to integer value 0:

`'\0'`

Thus, the **null character** (integer 0) is often referred to as the ***character string terminator***.

In general, a numeric value that is used to indicate that a particular state has been reached – for example, the end of a list – is called a ***sentinel*** value.

So, the character string terminator `NUL` is a sentinel that indicates the end of the string in question.

How String Printing Really Works #1

```
% cat charstrassn.c
#include <stdio.h>
#include <string.h>
int main ()
{ /* main */
    const int my_name_length       = 12;
    const int program_success_code =  0;
    char my_name[my_name_length + 1];
    strcpy(my_name, "Henry Neeman");
    printf("My name is %s.\n", my_name);
    return program_success_code;
} /* main */
% gcc -o charstrassn charstrassn.c
% charstrassn
My name is Henry Neeman.
```

The program on the next page behaves **identically** to this program.

How String Printing Really Works #2

```
% cat printstring.c
#include <stdio.h>
#include <string.h>
int main ()
{ /* main */
    const int my_name_length       = 12;
    const int program_success_code =  0;
    char my_name[my_name_length + 1];
    int  index;
    strcpy(my_name, "Henry Neeman");
    printf("My name is ");
    index = 0;
    while (my_name[index] != '\0') {
        printf("%c", my_name[index]);
        index++;
    } /* while (my_name[index] != '\0') */
    printf(".\n");
    return program_success_code;
} /* main */
% gcc -o printstring printstring.c
% printstring
My name is Henry Neeman.
```

String Copy Function: `strcpy`

The C standard library function `strcpy` copies a character string into a `char` array.

```
strcpy(my_name, "Henry Neeman");
```

Notice that you **<u>CANNOT SIMPLY ASSIGN ONE STRING TO ANOTHER</u>:**

```
/* THIS WON'T WORK! */
 my_name = "Henry Neeman"; /* NO! */
```

strcpy Example

```
% cat charstrcpy.c
#include <stdio.h>
#include <string.h>

int main ()
{ /* main */
    const int my_name_length       = 12;
    const int program_success_code =  0;
    char my_name[my_name_length + 1];
    char my_name2[my_name_length + 1];

    strcpy(my_name, "Henry Neeman");
    printf("My name is %s.\n", my_name);
    strcpy(my_name2, my_name);
    printf("My name is %s.\n", my_name2);
    return program_success_code;
} /* main */
% gcc -o charstrcpy charstrcpy.c
% charstrcpy
My name is Henry Neeman.
My name is Henry Neeman.
```

String Placeholder

In a `printf` statement, the placeholder for a character string is:

`%s`

String Placeholder Example

```
% cat charstrcpy.c
#include <stdio.h>
#include <string.h>

int main ()
{ /* main */
    const int my_name_length       = 12;
    const int program_success_code =  0;
    char my_name[my_name_length + 1];
    char my_name2[my_name_length + 1];

    strcpy(my_name, "Henry Neeman");
    printf("My name is %s.\n", my_name);
    strcpy(my_name2, my_name);
    printf("My name is %s.\n", my_name2);
    return program_success_code;
} /* main */
% gcc -o charstrcpy charstrcpy.c
% charstrcpy
My name is Henry Neeman.
My name is Henry Neeman.
```

The `strlen` Function

The C Standard Library function `strlen` returns the length of the string that is passed to it, **EXCLUDING THE STRING TERMINATOR**:

```
my_name_length = strlen(my_name);
```

strlen Function Example

```
% cat charstrlen.c
#include <stdio.h>
#include <string.h>

int main ()
{ /* main */
    printf("strlen(%cHenry Neeman%c) = %d\n",
        '\042', '\042', strlen("Henry Neeman"));
    return 0;
} /* main */
% gcc -o charstrlen charstrlen.c
% charstrlen
strlen("Henry Neeman") = 12
```

Dynamic Allocation of Strings

You can dynamically allocate the space for a string, just as you can for any other array:

```
my_name =
    (char*)malloc(sizeof(char) *
                  (my_name_length + 1));
```

String Dynamic Allocation Example #1

```
% cat charstrdyn.c
#include <stdio.h>
#include <stdlib.h>
#include <string.h>

int main ()
{ /* main */
    const int program_success_code =  0;
    const int program_failure_code = -1;
    char* my_name = (char*)NULL;
    int   my_name_length;
```

String Dynamic Allocation Example #2

```
    my_name_length = strlen("Henry Neeman");
    my_name =
        (char*)malloc(sizeof(char) *
                      (my_name_length + 1));
    if (my_name == (char*)NULL) {
        printf("ERROR: can't allocate ");
        printf("char array my_name.\n");
        exit(program_failure_code);
    } /* if (my_name == (char*)NULL) */
    strcpy(my_name, "Henry Neeman");
    printf("My name is %s.\n", my_name);
    free(my_name);
    my_name = (char*)NULL;
    return program_success_code;
} /* main */
% gcc -o charstrdyn charstrdyn.c
% charstrdyn
My name is Henry Neeman.
```

Passing a String as a Function Argument

Passing a string to a function as an argument is just like passing any other kind of array argument, whether statically allocated or dynamically allocated, except that you **DON'T** also need to pass a length argument (because its length is implied by its string terminator):

```
int main ()
{ /* main */
    char my_name[my_name_length + 1];
    char* my_name2 = (char*)NULL;
    ...
    print_a_string(my_name);
    ...
    print_a_string(my_name2);
    ...
} /* main */

void print_a_string (char* the_string)
```

String Function Argument Example #1

```
#include <stdio.h>
#include <stdlib.h>
#include <string.h>

int main ()
{ /* main */
    const int my_name_length       = 12;
    const int program_success_code =  0;
    const int program_failure_code = -1;
    char my_name[my_name_length + 1];
    char* my_name2 = (char*)NULL;
    void print_a_string(char* the_string);
```

String Function Argument Example #2

```
    strcpy(my_name, "Henry Neeman");
    printf("My name is %s.\n", my_name);
    print_a_string(my_name);
    my_name2 =
        (char*)malloc(sizeof(char) *
                      (strlen(my_name) + 1));
    if (my_name2 == (char*)NULL) {
        printf("ERROR: can’t allocate ");
        printf("char array my_name2.\n");
        exit(program_failure_code);
    } /* if (my_name2 == (char*)NULL) */
    strcpy(my_name2, my_name);
    printf("My name is still %s.\n", my_name);
    print_a_string(my_name2);
    free(my_name2);
    my_name2 = (char*)NULL;
    return program_success_code;
} /* main */
```

String Function Argument Example #3

```
void print_a_string (char* the_string)
{ /* print_a_string */
    const int program_failure_code = -1;

    printf("The string that was passed is:\n");
    if (the_string == (char*)NULL) {
        printf("ERROR: can't print a ");
        printf("non-existent string\n");
        printf(" in print_a_string.\n");
        exit(program_failure_code);
    } /* if (the_string == (char*)NULL) */
    printf("%s\n", the_string);
} /* print_a_string */
% gcc -o charstrpass charstrpass.c
% charstrpass
My name is Henry Neeman.
The string that was passed is:
Henry Neeman
My name is still Henry Neeman.
The string that was passed is:
Henry Neeman
```

String Comparisons

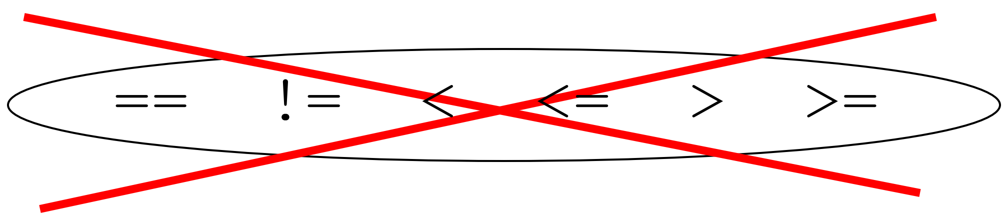
Just as numeric values can be compared, so can string values.

However, strings aren’t scalars.

In C, two strings are defined to be equal if they have the exact same contents.

In C, strings are compared using the `strcmp` function from the C Standard Library.

<u>**The relational operators CANNOT CANNOT CANNOT be used to compare strings!**</u>



String Comparison is Case Sensitive

String comparison is **case sensitive**.

Thus, if two strings are identical, except that, in a single character, they differ by case – for example, an `"H"` for one string corresponds to an `"h"` for the other – then they **WON'T** be equal.

For example:

`"Henry"` is not equal to `"henry"`

String Comparison Example #1

```
#include <stdio.h>
#include <string.h>

int main ()
{ /* main */
    const int my_name_length       = 12;
    const int program_success_code =  0;
    char my_name[my_name_length + 1];
    char my_name2[my_name_length + 1];
    char my_first_name[my_name_length + 1];
    char my_first_name_lower[my_name_length + 1];
    char my_last_name[my_name_length + 1];
```

String Comparison Example #2

```
    strcpy(my_name, "Henry Neeman");
    strcpy(my_name2, my_name);
    strcpy(my_first_name, "Henry");
    strcpy(my_first_name_lower, "henry");
    strcpy(my_last_name, "Neeman");
    printf("strcmp(%s,%s) = %2d\n",
        my_name, my_name2,
        strcmp(my_name, my_name2));
    printf("strcmp(%s,%s) = %2d\n",
        my_first_name, my_first_name_lower,
        strcmp(my_first_name, my_first_name_lower));
    printf("strcmp(%s,%s) = %2d\n",
        my_last_name, my_first_name,
        strcmp(my_last_name, my_first_name));
    return program_success_code;
} /* main */
```

String Comparison Example #3

```
% gcc -o charstrcmp charstrcmp.c
% charstrcmp
strcmp(Henry Neeman,Henry Neeman) = 0
strcmp(Henry,henry) = -1
strcmp(Neeman,Henry) = 1
```

Notice that the return value for `strcmp` can be interpreted as:

- **zero**: the strings are equal
- **negative**: the first string is less
- **positive**: the first string is greater