

Variables, Strings, and Loops

CSE 220: Systems Programming

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Administrivia

Have you done your assigned reading?

Can you connect to Emon?

Did you compile and run Hello World?

Remember that many of you are new to the command prompt!
[Check the Piazza post on this.](#)

Read [everything](#) for all assignments and labs.

Check Piazza frequently.

Things you already know: expressions

An **expression** is a part of a program that has a **value**.

Expressions can be **simple** or **compound**

simple

4

4.5

x

'a'

"a"

true

compound

3 + 4

4.5 * 3.7

x++

'a' + 1

strlen("a")

y = 3

Expressions may have side effects (e.g. x++ and y = 3).

Things you already know: statements

A **statement** is a part of a program that:

- has a **side effect**
- does not have a value

Statements can be **simple** or **compound**.

simple

```
y = 3;  
puts("a");  
x++;
```

compound

```
if (x<y){...} else {...}  
while (x<y){...}  
for (int x=0; x<len; x++){...}
```

Things you already know: values

Every expression has a **value**.

Values can be **simple** or **compound**.

simple

3

'c'

compound

an array

a struct

Things you already know: types

Each value and variable is associated with a **type**.

The type determines:

- **size:** the number of bytes occupied by a value ¶
- **representation:** how a value is encoded as bits
- **operations:** which operators are valid with a value

minimal

```
// A minimal C program
// Execution of your code starts in the 'main'
  function
int main() {
    return 0;
}
```

puts

```
#include <stdio.h>

// Hello World
int main() {
    puts("Hello World"); // string literals are
                          // delimited by double quotes
    return 0;
}
```


delimiters

```
#include <stdio.h>

// Hello World
int main() {
    puts('Hello World'); // single quotes delimit
                          // single characters
    return 0;
}
```

putchar

```
#include <stdio.h>

int main() {
    putchar('H');
    putchar('i');
    putchar('\n');
    putchar(72);
    putchar(105);
    putchar(10);
    return 0;
}
```

printf

```
#include <stdio.h>

int main() {
    printf("Hello World\n");
    return 0;
}
```

printf specifiers

```
#include <stdio.h>
int main() {
    int i = 42;
    printf("The value of i: %d\n",i);
    printf("The value of i: %x\n",i);
    double d = 2.71828;
    printf("The value of d is %f\n",d);
    printf("The value of d is %d\n",d);
    char letter = 'X';
    printf("Hey, '%c' marks the spot.\n", letter);
    char name[] = "River";
    printf("%s said, \"No power in the 'verse can
        stop me\"\n",name);
    return 0;
}
```

command-line argument

```
#include <stdio.h>

int main(int argc, char * argv[]) {
    printf("Hello, %s!\n", argv[1]);
    return 0;
}
```

command-line arguments

```
#include <stdio.h>

int main(int argc, char * argv[]) {
    for (int i=0; i<argc; i++) {
        printf("argv[%d] is \"%s\"\n", i, argv[i]);
    }
    return 0;
}
```

cse-strlen1

```
#include <stdio.h>

int cse_strlen(char str[]) {
    int len = 0;
    for (int i=0; str[i] != '\0'; i++) {
        len = len + 1;
    }
    return len;
}
```

cse-strlen2

```
#include <stdio.h>

int cse_strlen(char str[]) {
    for (int i=0; str[i] != '\0'; i++)
        ;
    return i;
}
```


cse-strlen3

```
#include <stdio.h>

int cse_strlen(char str[]) {
    int i;
    for (i=0 ; str[i] != '\0' ; i++)
        ;
    return i;
}
```

Types

C is a **typed language**.

Every **variable** has a type, and is **declared**.

Every **value assigned to a variable** must match that type.

The compiler will automatically convert between some types.¹

Valid:

```
int x = 5;
float y = 2.0;
x = 37.0;
y = x;
```

Invalid:

```
int x = 0;
x = "Hello, world!";
```

¹Dennis M. Ritchie (DMR) said “C is strongly typed, but weakly enforced.”

Some Types

There are **many types**; for now, consider:

- **int**: Integers of a convenient size for the computer (32-bit for us)
- **char**: Characters (typically 8-bit integers)
- **double**: Double-precision floating-point numbers

There are also **array types**.

Array types are declared with square brackets: `[]`:

- **char** `a[]`: An array of **char** variables. Often used for **C strings**.
- **int** `scores[200]`: An array of **exactly 200 int** variables.

Declaring Variables

Variables are **declared** by **stating their type and name**.

```
int x;           /* x is an integer */
double d;       /* d is a floating-point double */
```

Various modifiers can be applied to variables.

In particular, **const** declares the variable to be a constant. A **const** variable can only be assigned a value in its declaration.

Scope, part 1

Variables in C have **scope**: the part of a program where the variable can be used.

Scope is determined by how and where the variable is declared.

The following are possible scopes in C:
global, **file-local**, and **local**.

A variable cannot be used **out of scope**.

Scope, part 2

Variables declared **outside of any block** ({}):

- are normally **global**: they can be accessed by **any code** ¶ must be declared **extern** in other files
- are **file-local** with the modifier **static**: they can be accessed by any code **in this file**

Variables declared **in a block**:

- Come into scope **where declared** ¶
- are valid until the scope's } or end-of-file

Lifetime

Variables in C have **lifetime**: the period of time during the execution of a program that the variable exists in memory.

For many **variables**, their lifetime is **as long as their scope exists**.

So far:

- **Global** variables have a lifetime of “forever”
- **Local** variables have a lifetime of “while in scope”

Arrays

C arrays are **a series of contiguous memory locations**.
(This will become important later.)

Arrays are declared with `[]`. The size is between `[]`.

Every array has a fixed size, however array declarations can have three “sizes”, depending on what’s in the `[]`:

- **Unknown size**: Nothing is specified
- **Constant size**: A constant expression is specified
- **Variable size**: A run-time computed expression is specified

Array Sizes

Array sizes specify **how many elements are in the array.**

```
int x[32];  
int matrix[32][16];
```

C **does not remember** the array's size.¹

This means that **illegal accesses aren't caught.**²

```
int x[4];  
x[10234] = 0;           /* Whoops. */
```

²If you're lucky, you might get a warning about uninitialized access.

Static Initializers

An array can be initialized **all at once** at declaration.

```
int array[10] = { 0, 3, 5, 0, 0,  
                1, 0, 0, 2, 0 };
```

This is called a **static initializer**.

Static initializers **can be used only at declaration**.

```
int array[3];
```

```
array = { 1, 3, 5 };    /* syntax error */
```

C Strings

C strings are just arrays.

Strings, as they are arrays, **are not associated with a length**.
(You have to **count the characters** to know how long they are.)[¶]

A C string consists of:

- the characters in the string, followed by
- a **zero byte** (the ASCII NUL character) (**NUL terminator**).

The zero byte is **idiomatically** written `'\0'`.

ASCII

ASCII³ is a mapping of numbers to characters.

C strings can be in many encodings, but C code is in ASCII.[¶]

ASCII contains Latin characters, numbers, and punctuation.

The Unix manual page at `man 7 ascii` describes the mapping.

³American Standard Code for Information Interchange

Quoted Strings

Quoted strings automatically build such arrays.

```
char str[] = "Hello";  
char str[] = { 'H', 'e', 'l', 'l', 'o', '\0' };
```

A quoted string may be assigned to an **array only at declaration**.

After declaration, quoted strings must be **copied into** arrays:

```
char str[32];  
  
strncpy(str, 32, "Hello"); /* See man 3 strncpy */
```

String Functions

There are **many string functions** in the C library.

Most of them are defined in `<string.h>`.

Some useful examples:

- `strlen()`: Compute the length of a string by counting bytes
- `strncpy()`: Copy a string until its NUL character
- `strncat()`: Concatenate one string to another
- `strstr()`: Search for one string inside another

Strings as Pointers

The idiomatic string type is `char *`.

Arrays and pointers are `closely related`, we'll discuss this later.

```
char *str = "Hello, CSE 220";
```

```
char array[] = "Another string";
```

```
char *otherstr = array;
```

Character Constants

An ASCII character can be interpreted as an integer with `' '`.

```
char c = 'A';           /* 65 */
int i = 'B';           /* 66 */
```

Each byte of a string can be assigned in this fashion.

```
char str[] = "emacs";
/* Give it the respect it deserves */
str[0] = 'E';
```


The for Loop

The C for loop is its **most versatile** loop.

It allows looping over **almost anything**.

```
for (initialization; condition; increment) {  
    body;  
}
```

It translates to a more traditional while loop (with caveats):

```
initialization;  
while (condition) {  
    body;  
    increment;  
}
```

Looping over Arrays

A common use of the `for` loop is looping over arrays:

```
int array[ARRAYSZ];

for (int i = 0; i < ARRAYSZ; i++) {
    /* Use array[i] */
}
```

Remember that you must somehow know the size of the array.

Looping over Strings

It is **idiomatic** to loop over strings:

```
for (int i = 0; str[i] != '\0'; i++) {  
    /* use str[i] */  
}
```

Note that the string length is **never directly computed!**

Strings, Arrays, and Loop Example

We will develop `strlen()` together.

Summary

- C is a **typed language**
- **Every variable** has a type
- Variable values must **match** the type
- Variables have **scope**, and cannot be used outside that scope
- Arrays are **contiguous memory locations**
- Array syntax uses `[]`
- C strings are arrays of characters
- Every C string is **terminated with a zero byte**
- For loop syntax
- For loops are very flexible

Next Time ...

- Boolean values
- Conditional statements
- Control flow

References I

Required Readings

- [1] Brian W. Kernighan and Dennis M. Ritchie. *The C Programming Language*. Second Edition. Chapter 1: 1.9, 1.10; Chapter 2: Intro, 2.1–2.4. Prentice Hall, 1988.

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