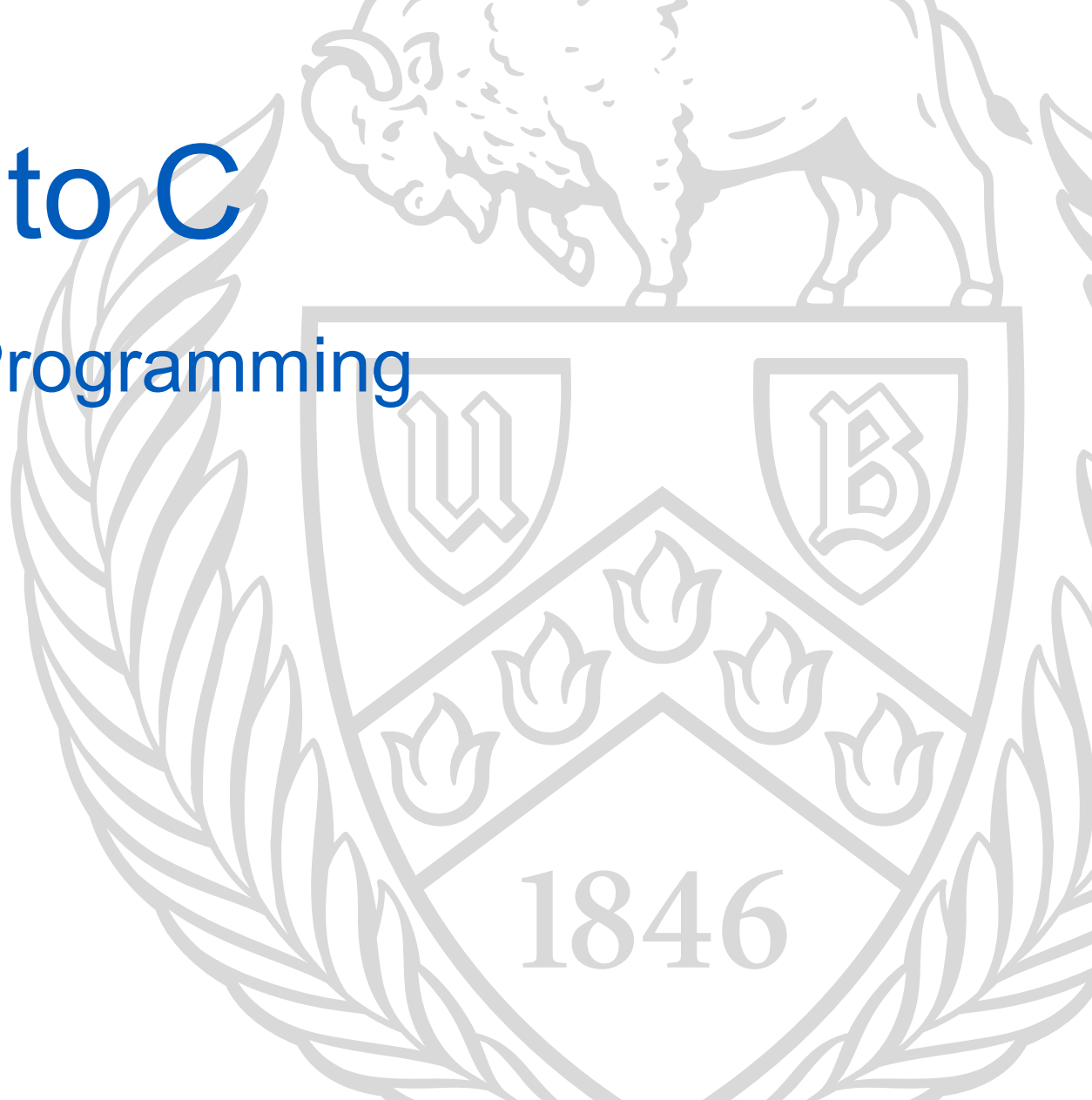


Introduction to C

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** ¶
- 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.^{dubious}

This means that **illegal accesses aren't caught**.¹

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

¹If you're lucky, you might get a warning about uninitialized access.

Array Indexing

C array indices **start at 0**.

An array of **size 10** contains elements **0 through 9**.

Arrays can be **dereferenced with []**:

```
int array[10];
```

```
int i = 7;
```

```
array[4] = 0;
```

```
array[i] = 0;
```

```
array[i + 1] = 0;
```

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

ASCII¹ 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.

¹American 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

Bibliography

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.

Optional Readings

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