# CS 33

## Introduction to C
### Part 6

# Characters

- **ASCII**
  - **American Standard Code for Information Interchange**
  - **works for:**
    - **English**
    - **Swahili**
    - **not much else**
  - **doesn't work for:**
    - **French**
    - **Spanish**
    - **German**
    - **Korean**
    - **Arabic**
    - **Sanskrit**
    - **Chinese**
    - **pretty much everything else**

ASCII is appropriate for English. European colonial powers devised written forms of some languages, such as Swahili, using the English alphabet. What differentiates the English alphabet from those of other European languages is the absence of diacritical marks. ASCII has no support for characters with diacritical marks and works for English, Swahili, and very few other languages. (Swahili may be written either as a Latin script, which can be represented in ASCII, as well as an Arabic script, which doesn't have a standard ASCII representation. See https://www.omniglot.com/writing/swahili.htm.)

# Characters


- Unicode
  - support for the rest of world
  - defines a number of encodings
  - most common is UTF-8
    - » variable-length characters
    - » ASCII is a subset and represented in one byte
    - » larger character sets require an additional one to three bytes
  - not covered in CS 33

The Unicode standard first came out in 1991. It defines a number of character encodings. UTF-8, in which each character is represented with one to four bytes, is the most commonly used, particularly on web sites. Being variable in length, its decoding requires more computation than fixed-width character encodings. Unicode also defines some fixed-with encodings, but these require more space than variable-width encodings.

# ASCII Character Set

| | 00 | 10 | 20 | 30 | 40 | 50 | 60 | 70 | 80 | 90 | 100 | 110 | 120 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0: | \0 | \n | | ( | 2 | < | F | P | Z | d | n | x | |
| 1: | | \v | | ) | 3 | = | G | Q | [ | e | o | y | |
| 2: | | \f | sp | * | 4 | > | H | R | \ | f | p | z | |
| 3: | | \r | ! | + | 5 | ? | I | S | ] | g | q | { | |
| 4: | | | " | , | 6 | @ | J | T | ^ | h | r | \| | |
| 5: | | | # | - | 7 | A | K | U | _ | i | s | } | |
| 6: | | | $ | . | 8 | B | L | V | ` | j | t | ~ | |
| 7: | \a | | % | / | 9 | C | M | W | a | k | u | DEL | |
| 8: | \b | | & | 0 | : | D | N | X | b | l | v | | |
| 9: | \t | | ' | 1 | ; | E | O | Y | c | m | w | | |

ASCII uses only seven bits. Most European languages can be coded with eight bits (but not seven). Many Asian languages require far more than eight bits.

This table is a bit confusing: it's presented in column-major order, meaning that it's laid out in columns. Thus, the value of the character '0' is 48, the value of '1' is 49, the value of '2' is 50, the value of '3' is 51, etc. Note that there are no printable characters in the "20" column.

Some of the characters require some explanation. '\a' is the alarm or bell character: it rings a bell. '\b' is the backspace character. '\t' is the horizontal tab character (usually referred to just as "tab"). '\n' is the newline character. '\v' is the vertical tab character. '\f' is the form-feed character, and '\r' is the carriage-return character. Some of these characters are rarely, if ever, used.

## *char*s as Integers

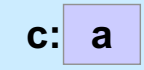
```
char tolower(char c) {
  if (c >= 'A' && c <= 'Z')
      return c + 'a' - 'A';
  else
      return c;
}
```

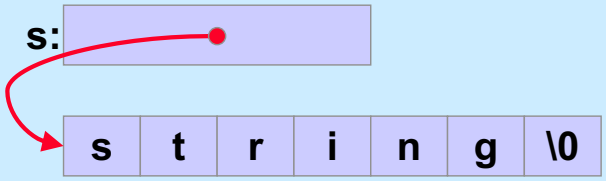
A variable of type **char** may be thought of as an 8-bit **int**.

# Character Strings

```
char c = 'a';
```




```
char *s = "string";
```



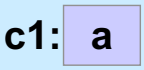

 

## Is there any difference between *c1* and *c2* in the following?

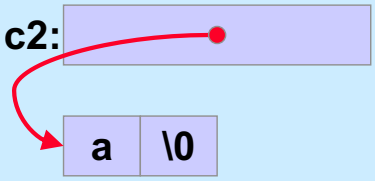
```
char c1 = 'a';
char *c2 = "a";
```

# Yes!!

```
char c1 = 'a';
```




```
char *c2 = "a";
```

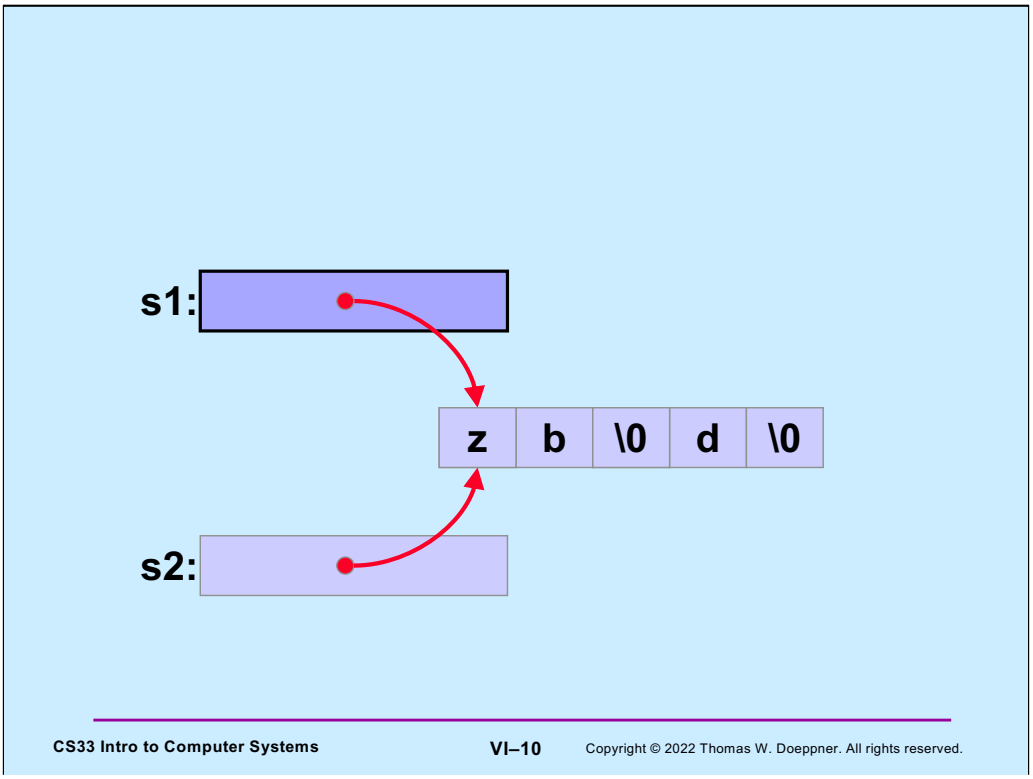


**What do *s1* and *s2* refer to after the following is executed?**

```
char s1[] = "abcd";
char *s2 = s1;
s1[0] = 'z';
s2[2] = '\0';
```

Note that the declaration of **s1** results in the allocation of 5 bytes of memory, into which is copied the string “abcd” (including the null at the end).




Note that if either **s1** or **s2** is printed (e.g., `printf("%s", s1)` ), all that will appear is "zb" — this is because the null character terminates the string. Recall that s1 is essentially a constant: its value cannot be changed (it points to the beginning of the array of characters), but what it points to may certainly be changed.

# Weird …

**Suppose we did it this way:**

```
char *s1 = "abcd";
char *s2 = s1;
s1[0] = 'z';
s1[2] = '\0';
```

```
% gcc -o char char.c
% ./char
Segmentation fault
```




String constants are stored in an area of memory that's read-only, ensuring that they really are constants; thus any attempt to modify them is doomed. In the example, **s1** is a pointer that points to such a read-only area of memory. This is unlike what was done two slides ago, in which the string in read-only memory was copied into read-write memory pointed to by **s1**.

# Copying Strings (1)

```
char s1[] = "abcd";
char s2[5];

s2 = s1;   // does this do anything useful?

// correct code for copying a string
for (i=0; s1[i] != '\0'; i++)
  s2[i] = s1[i];
s2[i] = '\0';

// would it work if s2 were declared:
char *s2;
// ?
```

The answer to the first question is no: the assignment is a syntax error, since the value of **s2** is the address of the array, which cannot be changed. What we really want to do is copy the array pointed to by **s1** into the array pointed to by **s2**.

It would not work if **s2** were declared simply as a pointer. The original **s2**, declared as an array, has 5 bytes of memory associated with it, which is sufficient space to hold the string that's being copied. Thus, the original **s2** points to an area of memory suitable for holding a copy of the string. The second **s2**, being declared as simply a pointer and not given an initial value, points to an unknown location in memory. Copying the string into what **s2** points to will probably lead to disaster.

# Copying Strings (2)

```
char s1[] = "abcdefghijklmnopqrstuvwxyz";
char s2[5];

for (i=0; s1[i] != '\0'; i++)
  s2[i] = s1[i];
s2[i] = '\0';
```

Does this work?

```
for (i=0; (i<4) && (s1[i] != '\0'); i++)
  s2[i] = s1[i];
s2[i] = '\0';
```

Works!

The answer, of course, is that the first for loop doesn't work, since there's not enough room in the array referred to by **s2** to hold the contents of the array referred to by **s1**. Note that "&&" is the AND operator in C.

The correct way to copy a string is shown in the code beginning with the second for loop, which checks the length of the target: it copies no more than 4 bytes plus a null byte into **s2**, whose size is 5 bytes.

# String Length

```
char *s1;

s1 = produce_a_string();
// how long is the string?

sizeof(s1); // doesn't yield the length!!

for (i=0; s1[i] != '\0'; i++)
  ;
// number of characters in s1 is i
// (not including the terminating '\0')
```

**sizeof(s1)** yields the size of the variable **s1**, which, on a 64-bit architecture, is 8 bytes.

# Size

```
int main() {
   char s[] = "1234";
   printf("%d\n", sizeof(s));
   proc(s, 5);
   return 0;
}

void proc(char s1[], int len) {
   char s2[12];
   printf("%d\n", sizeof(s1));
   printf("%d\n", sizeof(s2));
}
```

```
$ gcc -o size size.c
$ ./size
5
8
12
$
```

**sizeof(s)** is 5 because 5 bytes of storage were allocated to hold its value (including the null).

**sizeof(s1)** is 8 because it's a pointer to a char, and pointers occupy 8 bytes.

**sizeof(s2)** is 12 because 12 bytes of storage were allocated for it.

# Quiz 1

```
void proc(char s[9]) {
   printf("%d\n", sizeof(s));
}
```

**What's printed?**

**a) 7**
**b) 8**
**c) 9**
**d) 10**

# Comparing Strings (1)

```
char *s1;
char *s2;

s1 = produce_a_string();
s2 = produce_another_string();
// how can we tell if the strings are the same?

if (s1 == s2) {
  // does this mean the strings are the same?
} else {
  // does this mean the strings are different?
}
```

Note that comparing **s1** and **s2** simply compares their numeric values as pointers, it doesn't take into account what they point to.

# Comparing Strings (2)

```
int strcmp(char *s1, char *s2) {
  int i;
  for (i=0;
       (s1[i] == s2[i]) && (s1[i] != 0) && (s2[i] != 0);
       i++)
    ; // an empty statement
  if (s1[i] == 0) {
    if (s2[i] == 0) return 0; // strings are identical
    else return -1; // s1 < s2
  } else if (s2[i] == 0) return 1; // s2 < s1
  if (s1[i] < s2[i]) return -1; // s1 < s2
  else return 1;  // s2 < s1;
}
```

The for loop finds the first position at which the two strings differ. The rest of the code then determines whether the two strings are identical (if so, they must be of the same length), and if not, it determines which is less than the other. The function returns -1 if **s1** is precedes **s2**, 0 if they are identical, and 1 if **s2** precedes **s1**.

# The String Library

```
#include <string.h>

char *strcpy(char *dest, char *src);
  // copy src to dest, returns ptr to dest
char *strncpy(char *dest, char *src, int n);
  // copy at most n bytes from src to dest
int strlen(char *s);
  // returns the length of s (not counting the null)
int strcmp(char *s1, char *s2);
  // returns -1, 0, or 1 depending on whether s1 is
  // less than, the same as, or greater than s2
int strncmp(char *s1, char *s2, int n);
  // do the same, but for at most n bytes
```

# The String Library (more)

```
size_t strspn(const char *s, const char *accept);
      // return length of initial portion of s
      // consisting entirely of bytes from accept

size_t strcspn(const char *s, const char *reject);
      // return length of initial portion of s
      // consisting entirely of bytes not from
      // reject
```

These will be useful in upcoming assignments.

# Quiz 2

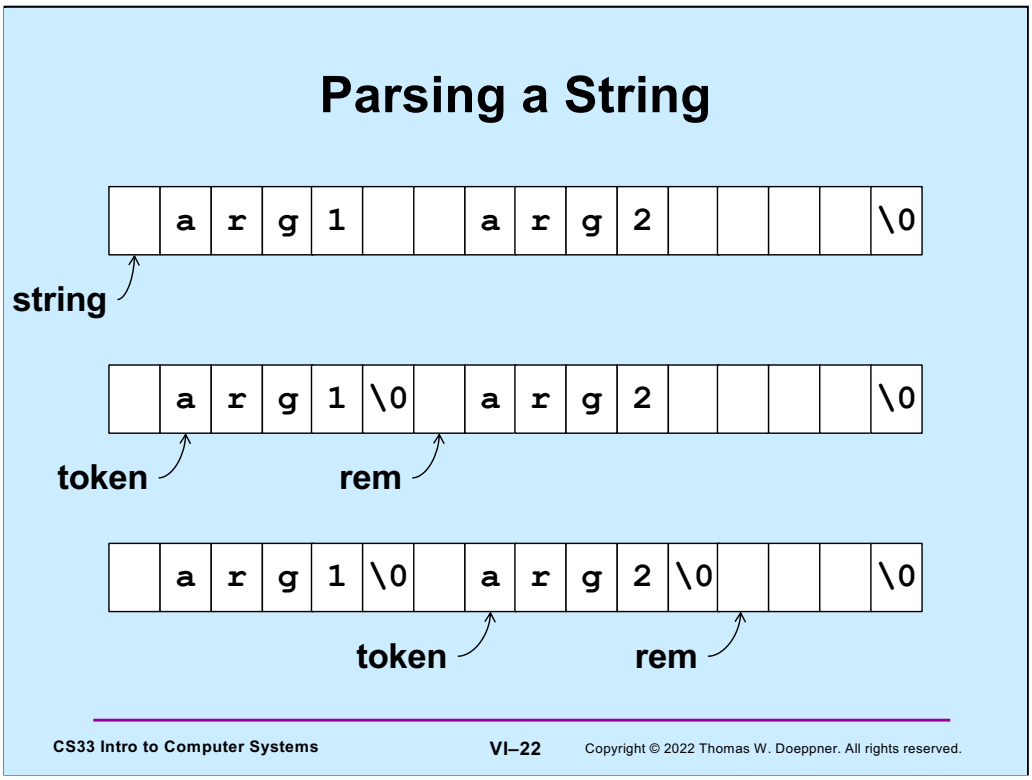
```
#include <stdio.h>
#include <string.h>

int main() {
  char s1[] = "Hello World!\n";
  char *s2;
  strcpy(s2, s1);
  printf("%s", s2);
  return 0;
}
```

**This code:**

a) has syntax problems
b) might seg fault
c) is a great example of well written C code




Suppose we have a string of characters (perhaps typed into the command line of a shell). We'd like to parse this string to pull out individual words or "tokens" (to be used as arguments to a command); these tokens are separated by one or more characters of white space. Starting with a pointer to this string, we call a function that null-terminates the first token and returns a pointer to that word (**token**) and sets **rem** to point to the remainder of the string. We call it again to get the second token, etc.

# Designing the Parse Function

- It modifies the string being parsed
  - puts nulls at the end of each token
- Each call returns a pointer to the next token
  - how does it know where it left off the last time?
    - » how is *rem* dealt with?

The parse function must keep track of where it left off after each call to it. One way of doing this is via the use of a static local variable.

# Design of *strtok*

- **char** *strtok(**char** *string,
  **const char** *sep)
  - **if *string* is non-NULL, *strtok* returns a pointer to the first token in *string* (and keeps track of where the next token would be)**
  - **if *string* is NULL, *strtok* returns a pointer to the token just after the one returned in the previous call, or NULL if there are no more tokens**
  - **tokens are separated by any non-empty combination of characters in *sep***

**strtok** is a standard function in the C strings library. Note that, since the second argument is declared to be a pointer to a constant, there's a promise that **strtok** will not modify what its second argument points to.

# Using *strtok*

```
int main() {
  char line[] = "  arg0   arg1 arg2   arg3   ";
  char *str = line;
  char *token;
  while ((token = strtok(str, " \t\n")) != NULL) {
    printf("%s\n", token);
    str = NULL;
  }
  return 0;
}
```

**Output:**

```
arg0
arg1
arg2
arg3
```

## *strtok* Code part 1

```
char *strtok(char *string, const char *sep) {
  static char *rem = NULL;
  if (string == NULL) {
    if (rem == NULL) return NULL;
    string = rem;
  }
  int len = strlen(string);
  int slen = strspn(string, sep);
      // initial separators
  if (slen == len) {
    // string is all separators
    rem = NULL;
    return NULL;
  }
```

Note the static declaration of **rem** – this allows **strtok** to keep track of the remaining portion of the string.

# *strtok* Code part 2

```
  string = &string[slen]; // skip over separators
  len -= slen;
  int tlen = strcspn(string, sep); // length of first token
  if (tlen < len) {
    // token ends before end of string: terminate it with 0
    string[tlen] = '\0';
    rem = &string[tlen+1];
  } else {
    // there's nothing after this token
    rem = NULL;
  }
  return string;
}
```

## Numeric Conversions

```
short a;
int b;
float c;

b = a;    /* always works */
a = b;    /* sometimes works */
c = b;    /* sort of works */
b = c;    /* sometimes works */
```

Assigning a short to an int will always work, since all possible values of a short can be represented by an int. The reverse doesn't always work, since there are many more values an int can take on than can be represented by a short.

A float can represent an int in the sense that the smallest and largest ints fall well within the range of the smallest (most negative) and largest floats. However, floats have fewer significant digits than do ints and thus, when converting from an int to a float, there may well be a loss of precision.

When converting from a float to an int there will not be any loss of precision, but large floats and small (most negative) floats cannot be represented by ints.

# Implicit Conversions (1)

```
float x, y=2.0;
int i=1, j=2;

x = i/j + y;
  /* what's the value of x? */
```

**x**'s value will be 2, since the result of the (integer) division of **i** by **j** will be 0.

# Implicit Conversions (2)

```
float x, y=2.0;
int i=1, j=2;
float a, b;

a = i;
b = j;
x = a/b + y;
  /* now what's the value of x? */
```

Here the values of **i** and **j** are converted to float before being assigned to **a** and **b**, thus the value assigned to **x** is 2.5.

# Explicit Conversions: Casts

```
float x, y=2.0;
int i=1, j=2;

x = (float)i/(float)j + y;
  /* and now what's the value of x? */
```

Here we do the int-to-float conversion explicitly; **x**'s value will be 2.5.

# Purposes of Casts

- **Coercion**

```
int i, j;
float a;
a = (float)i/(float)j;
```

modify the value appropriately

- **Intimidation**

```
float x, y;
    // sizeof(float) == 4
swap((int *)&x, (int *)&y);
```

it's ok as is (trust me!)

"Coercion" is a commonly accepted term for one use of casts. "Intimidation" is not. The concept is more commonly known as a "sidecast". Coercion means to convert something of one datatype to another. Intimidation (or sidecasting) means to treat an instance one datatype as being another datatype without doing any conversion of the actual data. Intimidation works only for pointer datatypes.

# Quiz 3

- **Will this work?**

```
double x, y; //sizeof(double) == 8

...
swap((int *)&x, (int *)&y);
```

a) **yes**
b) **no**

## Caveat Emptor

- **Casts tell the C compiler: "Shut up, I know what I'm doing!"**
- **Sometimes true**

```
float x, y;
swap((int *)&x, (int *)&y);
```

- **Sometimes false**

```
double x, y;
swap((int *)&x, (int *)&y);
```

The call to **swap** makes sense as long as what **x** and **y** point to are the same size as **int**'s.

The moral is to be careful with casting, particularly intimidation casts, since they effectively turn off type checking.

## Nothing, and More …

- ***void*** **means, literally, nothing:**

```
void NotMuch(void) {
   printf("I return nothing\n");
}
```

- **What does *void* * mean?**
  - **it's a pointer to anything you feel like**
    - » **a generic pointer**

The **void *** type is an exception to the rule that the type of the target of a pointer must be known.

# Rules

- **Use with other pointers**

```
int *x;
void *y;
x = y; /* legal */
y = x; /* legal */
```

- **Dereferencing**

```
void *z;
func(*z); /* illegal!*/
func(*(int *)z); /* legal */
```

Dereferencing a pointer must result in a value with a useful type. “void” is not a useful type.

# Swap, Revisited

```
void swap(int *i, int *j) {
  int tmp;
  tmp = *j; *j = *i; *i = tmp;
}
/* can we make this generic? */
```

Can we write a version of **swap** that handles a variety of data types?

# An Application: Generic Swap

```
void gswap (void *p1, void *p2,
     int size) {
  int i;
  for (i=0; i < size; i++) {
     char tmp;
     tmp = ((char *)p1)[i];
     ((char *)p1)[i] = ((char *)p2)[i];
     ((char *)p2)[i] = tmp;
  }
}
```

Note that there is a function in the C library that one may use to copy arbitrary amounts of data — it's called **memmove**. To see its documentation, use the Linux command "man memmove".

# Using Generic Swap

```
short a=1, b=2;
gswap(&a, &b, sizeof(short));

int x=6, y=7;
gswap(&x, &y, sizeof(int));

int A[] = {1, 2, 3}, B[] = {7, 8, 9};
gswap(A, B, sizeof(A));
```

# Fun with Functions (1)

```
void ArrayDouble(int A[], int len) {
  int i;
  for (i=0; i<len; i++)
      A[i] = 2*A[i];
}
```

# Fun with Functions (2)

```
void ArrayBop(int A[],
     int len,
     int (*func)(int)) {
  int i;
  for (i=0; i<len; i++)
     A[i] = (*func)(A[i]);
}
```

Here **func** is declared to be a pointer to a function that takes an **int** as an argument and returns an **int**.

What's the difference between a pointer to a function and a function? A pointer to a function is, of course, the address of the function. The function itself is the code comprising the function. Thus, strictly speaking, if **func** is the name assigned to a function, **func** really represents the address of the function. You might think that we should invoke the function by saying "***func**", but it's understood that this is what we mean when we say "**func**". Thus, when one calls **ArrayBop**, one supplies the name of the desired function as the third argument, without prepending "&".

# Fun with Functions (3)

```
int triple(int arg) {
  return 3*arg;
}

int main() {
  int A[20];
  … /* initialize A */
  ArrayBop(A, 20, triple);
  return 0;
}
```

Here we define another function that takes a single **int** and returns an **int**, and pass it to **ArrayBop**.

# Laziness …

- Why type the declaration

```
void *(*f)(void *, void *);
```

- You could, instead, type

```
MyType f;
```

- (If, of course, you can somehow define *MyType* to mean the right thing)

# typedef

- Allows one to create new names for existing types

```
typedef int *IntP_t;
```

```
IntP_t x;
```

  - means the same as

```
int *x;
```

# More typedefs

```
typedef struct complex {
  float real;
  float imag;
} complex_t;

complex_t i, *ip;
```

A standard convention for C is that names of datatypes end with "_t". Note that it's not necessary to give the struct a name in this example (we could have omitted the "complex" following "struct"). It's also not necessary for the name of the type to be different from the name of the struct. Though it's a bit confusing, we could have coded the above as:

```
typedef struct complex {
            float real;
            float imag;
} complex;


complex i, *ip;
```

After doing this, "struct complex" and "complex" would mean exactly the same thing.

# And …

```
typedef void *(MyFunc_t)(void *, void *);

MyFunc_t f;

// you must do its definition the long way

void *f(void *a1, void *a2) {
  …
}
```

**MyFunc_t** is the type of a function that takes two **void *** arguments and returns a **void *.** Note that **f**, declared as a **MyFunc_t**, is function, not a pointer to a function.

# Quiz 4

- **What's A?**

```
typedef double X_t[N];
X_t A[M];
```

a) an array of M doubles
b) an MxN array of doubles
c) an NxM array of doubles
d) a syntax error