CMSC 313
COMPUTER ORGANIZATION
&
ASSEMBLY LANGUAGE
PROGRAMMING

LECTURE 11, FALL 2012

TOPICS TODAY

- **Characters & Strings in C**
- **Structures in C**

CHARACTERS & STRINGS

char type

C supports the `char` data type for storing a single character.

`char` uses one byte of memory.

`char` constants are enclosed in single quotes

```
char myGrade = 'A';
char yourGrade = '?';
```

ASCII Character Chart

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

Source: www.LookupTables.com

Adapted from Dennis Frey CMSC 313 Spring 2011

Special Characters

Use \ for escape sequences.

For example

- **\n is the newline character**
- **\t is the tab character**
- **\" is the double quote (necessary since double quotes are used to enclose strings**
- **\' is the single quote (necessary since single quotes are used to enclose chars**
- **\\ is the backslash (necessary since \ now has special meaning**
- **\a is beep which is unprintable**

Special Char Example Code

What is the output from these statements?

```
printf("\t\tMove over\n\nWorld, here I come\n");
```

Move over

World, here I come

```
printf("I\'ve written \"Hello World\"\n\t many times\n\a");
```

I've written "Hello World"
many times <beep>

Character Library Functions

int isdigit (int c);

Determine if c is a decimal digit ('0' - '9')

int isxdigit(int c);

Determines if c is a hexadecimal digit ('0' - ' 9' , 'a' - f' , or 'A' - 'F')

int isalpha (int c);

Determines if c is an alphabetic character ('a' - 'z' or 'A- 'Z')

int isspace (int c);

Determines if c is a whitespace character (space, tab, etc)

int isprint (int c);

Determines if c is a printable character

int tolower (int c);

int toupper (int c);

Returns c changed to lower- or upper-case respectively, if possible

Character Library Functions

Include header file use character library functions:

```
#include <ctype.h>
```

Technically functions take an `int` parameter, not `char`.

Return type is also `int` . 0 = False, not 0 = True.

`man ctype.h` for more functions and complete documentation.

Character Input/Output

Use `%c` in `printf( )` and `fprintf( )` to output a single character.

```
char yourGrade = 'A';
printf( "Your grade is %c\n", yourGrade);
```

Input char(s) using `%c` with `scanf( )` or `fscanf( )`

```
char grade, scores[3];
```

%c inputs the next character, which may be whitespace

```
scanf("%c", &grade);
```

%nc inputs the next n characters, which may include whitespace.

```
scanf( "%3c", scores);      // note -- no & needed
```

Strings in C

- String = null terminated array of char.
- null = `'\0'`
- String constants in double quotes are null terminated.
- Strings do not "know" their own length.
- Initialization:

```
char name4[ 20 ] = {‘B’, ‘o’, ‘b’, ‘b’, ‘y’, ‘\0’ };
char name5[6] = “Bobby”;  // NOT assignment, needs 6 slots
char name6[ ] = “Bobby”;
```

String Output

```
char name[ ] = “Bobby Smith”;
printf( “My name is %s\n”, name);


// Right and left justify
printf (“My favorite books are %12s and %12s\n”, book1, book2);
printf (“My favorite books are %-12s and %-12s\n”, book1,
    book2);
```

Dangerous String Input

```
char name[22];
printf(“ Enter your name: “);
scanf( “%s”, name);
```

Why is this dangerous?

Long name will overwrite memory.

Safer String Input

```
char name[ 22 ];
printf( “Enter your name: “);

scanf(“%21s”, name);      // note 21, not 22, 1 byte for '\0'
```

C String Library

C provides a library of string functions.

To use the string functions, include `<string.h>`.

Some of the more common functions are listed here on the next slides.

To see all the string functions, type
`man string.h` at the unix prompt.

C String Library (2)

Must `#include <string.h>`

strlen(const char string[ ])

Returns length of string, not counting '\0'

strcpy(char s1[ ], const char s2[ ])

Copies s2 on top of s1. **Must have enough space in s1 !!!**

The order of the parameters mimics the assignment operator

strcmp (const char s1[ ] , const char s2[ ])

Returns < 0, 0, > 0 if s1 < s2, s1 == s2 or s1 > s2 lexigraphically

strcat(char s1[ ] , const char s2[ ])

Appends (concatenates) s2 to s1. **Must have enough space in s1 !!!**

C String Library (3)

Some safer functions from the C string library:

strncpy(char s1[ ], const char s2[ ], int n)

Copies at most n characters of s2 on top of s1.

Does not null terminate s1 if length of s2 >= n !!!

The order of the parameters mimics the assignment operator

strncmp (const char s1[ ] , const char s2[ ], int n)

Compares up to n characters of s1 with s2

Returns < 0, 0, > 0 if s1 < s2, s1 == s2 or s1 > s2 lexigraphically

strncat(char s1[ ], const char s2[ ] , int n)

Appends at most n characters of s2 to s1.

String Code

```
char first[10] = “bobby”;
char last[15] = “smith”;
char name[30];
char you[ ] = “bobo”;

strcpy( name, first );
strcat( name, last );
printf( “%d, %s\n”, strlen(name), name );

strncpy( name, last, 2 );
printf( “%d, %s\n”, strlen(name), name );

int result = strcmp( you, first );
result = strncmp( you, first, 3 );

strcat( first, last );
```

Simple Encryption

```
char c, msg[] = "this is a secret message";
int i = 0;
char code[26] =  /* Initialize our encryption code */
 {'t','f','h','x','q','j','e','m','u','p','i','d','c',
'k','v','b','a','o','l','r','z','w','g','n','s','y'} ;

printf ("Original phrase: %s\n", msg);

/* Encrypt */
while( msg[i] != '\0' ){
    if( isalpha( msg[ i ] ) ) {
        c = tolower( msg[ i ] ) ;
        msg[ i ] = code[ c - 'a' ] ;
    }
    ++i;
}
printf("Encrypted: %s\n", msg ) ;
```

Arrays of Strings

An initialized array of string constants

```
char months[][4] = {"Jan", "Feb", "Mar", "Apr",
                    "May", "Jun", "Jul", "Aug",
                    "Sep", "Oct", "Nov", "Dec" } ;
int m;
for ( m = 0; m < 12; m++ )
   printf( "%s\n", months[ m ] );
```

Alternative: use typedef

```
typedef char Acronym[4] ;
Acronym months[] = {"Jan", "Feb", "Mar", "Apr",
                    "May", "Jun", "Jul", "Aug",
                    "Sep", "Oct", "Nov", "Dec" } ;
```

sprintf( )

sprintf( ) works just like printf( ) or fprintf( ), but puts its "output" into the specified character array.

The character array must be big enough.

```
char message[ 100 ];
int myAge = 4;

sprintf( message, "I am %d years old\n", age);
printf( "%s\n", message);
```

STRUCT

Java vs C

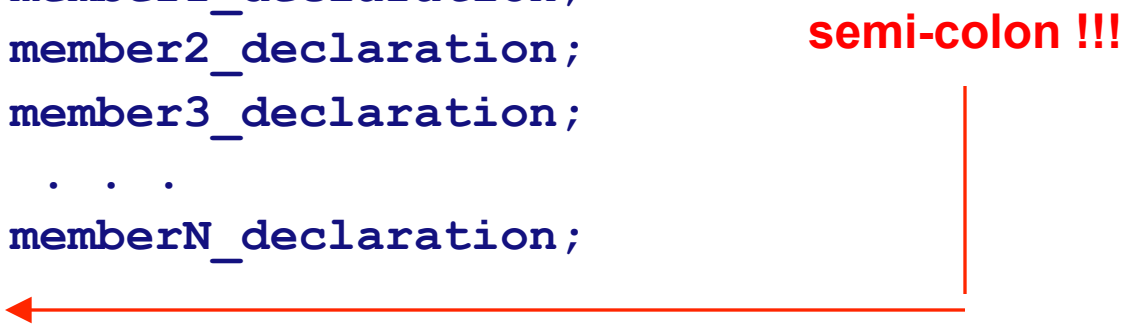
- Suppose you were assigned a write an application about points and straight lines in a coordinate plane.
- In Java, you'd correctly design a Point class and a Line class using composition.
- What about in C?

No Classes in C

- Because C is not an OOP language, ~~there is no way to combine data and code into a single entity.~~
- Related data and functions are form an "Abstract Data Type." Accessibility is enforced by a programmer's good judgment and not by the compiler.
- C does allow us to combine related data into a structure using the keyword `struct`.
- All data in a `struct` variable can be accessed by any code.
- Think of a `struct` as an OOP class in which all data members are public, and which has no methods.

Struct definition

```
struct tag
{
    member1_declaration;
    member2_declaration;
    member3_declaration;
      . . .
    memberN_declaration;
 };
```



`struct` is the keyword

`tag` names this kind of `struct`,

`member_declarations` are variable declarations which define the data members.

C `struct` Example

- Defining a `struct` to represent a point in a coordinate plane

```
struct point
{
    int x; /* x-coordinate */
    int y; /* y-coordinate */
};
```

point is the struct tag

- Given the declarations

```
struct point p1;
struct point p2;
```

- we can access the members of these `struct` variables:
  - the x-coordinate of p1 is `p1.x`
  - the y-coordinate of p1 is `p1.y`
  - the x-coordinate of p2 is `p2.x`
  - the y-coordinate of p2 is `p2.y`

Using struct members

```
int main ( )
{
   struct point lefEendPt, rightEndPt, newEndPt;

   printf("Left end point cooridinates ");
   scanf( "%d %d", &lefEendPt.x, &leftEndPt.y);

   printf("Right end point's x-coordinate: ");
   scanf( "%d %d", &rightEendPt.x, &rightEndPt.y);

   // add the endpoints
   newEndPt.x = leftEndPt.x + rightEndPt.x;
   newEndPt.y = leftEndPt.y + rightEndPt.y;

   // print new end point
   printf("New endpoint (%2d, %2d)", newEndPt.x, newEndPt.);

   return 0;
}
```

Initializing a `struct`

```
struct point middle = { 6, -3 };
```

is equivalent to

```
struct point middle ;
middle.x = 6 ;
middle.y = -3 ;
```

`struct` Variants

```
struct point {
  int x, y;
} endpoint, upperLeft ;
```

defines the structure named `point`

AND

the variables `endpoint` and `upperLeft` to be of this type.

`struct` + typedef

```
typedef struct point {
    int x, y;
} POINT;
```

`POINT` is now a TYPE.

```
POINT endpoint ;
```

is equivalent to

```
struct point endpoint;
```

`struct` assignment

```
struct point p1;
struct point p2;

p1.x = 42;
p1.y = 59;

p2 = p1;  /* structure assignment copies members */
```

`struct` within a `struct`

```
typedef struct line
{
  POINT leftEndPoint;
  POINT rightEndPoint;
} LINE;

LINE line1, line2;

line1.leftEndPoint.x = 3 ;
line1.leftEndPoint.y = 4 ;
```

Arrays of `struct`

```
LINE lines[5];   // or struct line lines[5];

printf("%d\n", lines[2].leftEndPoint.x);
```

Arrays within a `struct`

- Structs may contain arrays as well as primitive types

```
struct month
{
  int nrDays;
  char name[ 3 + 1 ];
};

struct month january = { 31, "JAN"};
```

A bit more complex

```
struct month allMonths[ 12 ] = {
  {31, "JAN"}, {28, "FEB"}, {31, "MAR"},
  {30, "APR"}, {31, "MAY"}, {30, "JUN"},
  {31, "JUL"}, {31, "AUG"}, {30, "SEP"},
  {31, "OCT"}, {30, "NOV"}, {31, "DEC"}
};

// write the code to print the data for September
printf( "%s has %d days\n",
  allMonths[8].name, allMonths[8].nrDays);

// what is the value of allMonths[3].name[1]
```

Size of a struct

As with primitive types, we can use sizeof( ) to determine the number of bytes in a struct

```
int pointSize = sizeof( POINT );
int lineSize = sizeof (struct line);
```

As we'll see later, the answers may surprise you!

Unions

- A `union` is a variable type that may hold different type of members of different sizes, BUT only one type at a time. `All members of the union share the same memory`. The compiler assigns enough memory for the largest of the member types.

- The syntax for defining a `union` and using its members is the same as the syntax for a `struct`.

Formal Union Definition

```
union tag
{
    member1_declaration;
    member2_declaration;
    member3_declaration;
      . . .
    memberN_declaration;
 };
```

An application of Unions

```
struct square { int length; };
struct circle { int radius; };
struct rectangle { int width; int height; };
enum shapeType {SQUARE, CIRCLE, RECTANGLE };

union shapes
{
   struct square aSquare;
   struct circle aCircle;
   struct rectangle aRectangle;
};

struct shape
{
   enum shapeType type;
   union shapes theShape;
};
```

An application of Unions (2)

```
double area( struct shape s)
{
   switch( s.type ) {
       case SQUARE:
             return s.theShape.aSquare.length
                   * s.theShape.aSquare.length;
       case CIRCLE:
             return 3.14 * s.theShape.aCircle.radius
                   * s.theShape.aCircle.radius;
       case RECTANGLE :
             return s.theShape.aRectangle.height
                   * s.theShape.aRectangle.width;
   }
}
```

Union vs. Struct

- **Similarities**
  - **Definition syntax virtually identical**
  - **Member access syntax identical**

- **Differences**
  - **Members of a `struct` each have their own address in memory.**
  - **The size of a `struct` is >= the sum of the sizes of the members.**
  - **Members of a union share the same memory.**
  - **The size of a union is the size of the largest member.**

NEXT TIME

- Parameter passing
- Separate Compilation
- Scope & Lifetime