C

C/C++ for Scientists and Engineers

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C OVERVIEW

Goals

- speed
- portability
- allow access to features of the architecture
- speed

C

- fast executables
- allows high-level structure without losing access to machine features
- many popular languages such as C++ , Java, Perl use C syntax/C as a basis
- generally a compiled language
- reasonably portable
- very available and popular

BASIC C PROGRAM STRUCTURE

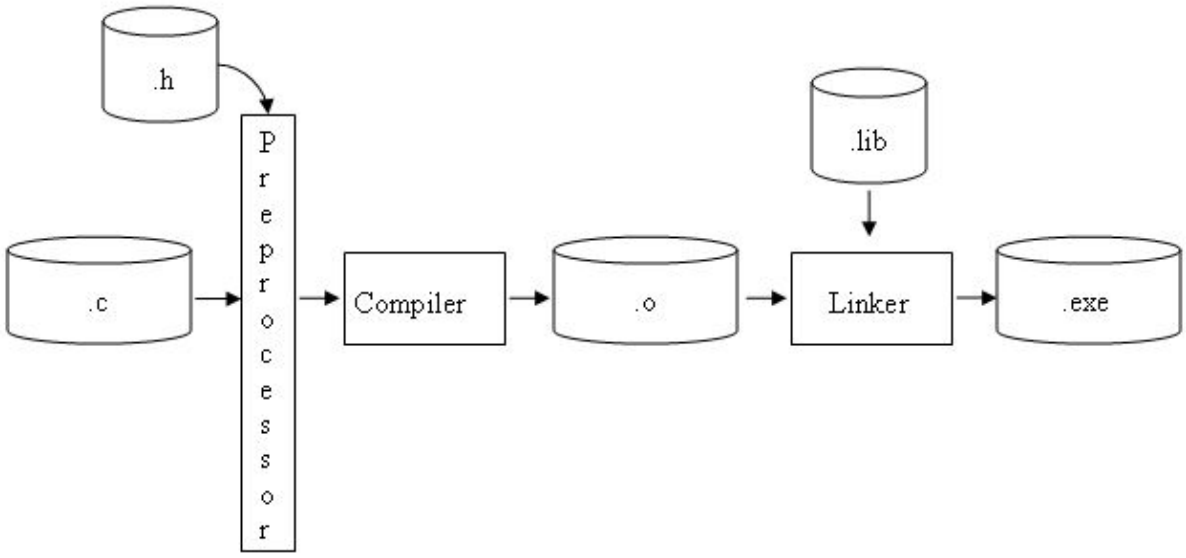
- The function main( ) is found in every C program and is where every C program begins execution.
- C uses braces { } to delimit the start/end of a function and to group sets of statements together into what C calls a block of code.
- Semicolons are used to terminate each C statement.
- Groups of instructions can be gathered together and named for ease of use and ease of programming. These “modules” are called functions in C.

Ex:

```
/*     FILE: first.c     */

#include <stdio.h>

int main( )
{
  printf("Hello world! \n");

  return 0;
}


/*    OUTPUT: first.c

          Hello world!

*/
```

COMPILING AND LINKING

- Producing an executable file from C source code involves a two step process, compiling and linking.
- The compiler translates the C code into machine code, the linker combines the new machine code with code for existing routines from available libraries and adds some startup code.
- The end result is a file full of machine instructions that are executable on the target machine.



Ex:

gcc first.c

- compile and link to a.exe

gcc -c first.c

- compile only, stop at object module

gcc -lm first.c

- link in math libraries

FUNDAMENTAL DATA TYPES

- there are three basic types of data, integer, floating-point, and character
- character data type is really a small integer
- signed and unsigned integer types available

Type	Size	Min	Max
char	1 byte	0 / -128	255 / 127
short	2 bytes	-32768	32767
int	2,4 bytes	-2147483648	2147483647
long	4 bytes	-2147483648	2147483647
long long	8 bytes	2^{63} ~ -9x10^{18}	2^{63}-1 ~ 9x10^{18}
float	4 bytes ~ 7 digits	$\pm$1.0x10^{-37}	$\pm$3.4x10^{+38}
double	8 bytes ~ 14 digits	$\pm$1.0x10^{-307}	$\pm$1.8x10^{+308}
long double	12 bytes ~ 20 digits	$\pm$1.0x10^{-4931}	$\pm$1.0x10^{+4932}

Ex:

```
/*     FILE: unsigned.c     */

/*
   Illustration of the unsigned keyword.  Allows
   recovering the use of the lead bit for magnitude.
*/
#include <stdio.h>

int main( )
{
  unsigned int x;

  x = 3333222111;

  printf("Unsigned x = %u\n", x);

  printf("Signed x = %d\n", x);

  return 0;
}


/*    OUTPUT: unsigned.c

          Unsigned x = 3333222111
          Signed x = -961745185

*/
```

COMMENTS

- Block-style comments /* … */ Everything between the opening /* and the first */ is a comment.
- Comment-to-end-of-line: // Everything from the // to the end of the line is a comment.
- Nesting of block-style comments doesn't work.
- Note: Some older compilers may not recognize the // comment indicator.

Ex:

```
/*     FILE: example.c     */

#include <stdio.h>

/* C-style comments can span several lines
   ...where they are terminated by:
*/

int main( )
{
  printf("Here's a program\n");

  return 0;
}


/*    OUTPUT: example.c

          Here's a program

*/
```

IDENTIFIERS

- C identifiers must follow these rules:
  - C is case sensitive
  - may consist of letters, digits, and the underscore
  - first character must be a letter, (could be underscore but this is discouraged)
  - no length limit but only the first 31-63 may be significant

KEYWORDS

auto	extern	short	while
break	float	**signed**	*_Alignas*
case	for	sizeof	*_Alignof*
char	goto	static	*_Bool*
const	if	struct	*_Complex*
continue	*inline*	switch	*_Generic*
default	int	typedef	*_Imaginary*
do	long	union	*_Noreturn*
double	register	unsigned	*_Static_assert*
else	*restrict*	void	*#_Thread_local*
enum	return	**volatile**	

BASIC INPUT AND OUTPUT

- The basic I/O functions are printf( ) and scanf( ).
- printf( ) and scanf( ) are very generic. They always are processing text on one end. They get all their information about the data type they are to print or scan from the conversion specifiers.
- printf( ) always is producing text output from any number of internal data formats, i.e. int, float, char, double. The job of the conversion specifiers is to tell printf( ) how big a piece of data it's getting and how to interpret the internal representation.
- scanf( ) always receives a text representation of some data and must produce an internal representation. It is the conversion specifiers job to tell scanf( ) how to interpret the text and what internal representation to produce.
- printf( ) tips and warnings:
  - Make sure your conversion specifiers match your data values in number, type and order.
  - Use %f for both float and double.
  - Everything you put in the format string prints exactly as it appears, except conversion specifiers and escape sequences.
- scanf( ) tips and warnings:
  - Make sure your conversion specifiers match your data values in number, type and order.
  - As a general rule, scan only one value with each scanf( ) call, unless you really know what you are doing.
  - Use %f for float, %lf for double and %Lf for long double.
  - Don't forget the &, except with strings. {Someday you'll know why that is, and it will make sense.}
  - For %c every character you type is a candidate, even <return>. Placing a space in front of the %c in the format string will cause scanf( ) to skip whitespace characters.
  - scanf( ) is NOT without it's problems. However, it provides an easy way to get text input into a program and has some very handy conversion capabilities.

CONVERSION SPECIFIERS

printf( )

%d	signed decimal int
%hd	signed short decimal integer
%ld	signed long decimal integer
%lld	signed long long decimal integer
%u	unsigned decimal int
%lu	unsigned long decimal int
%llu	unsigned long long decimal int
%o	unsigned octal int
%x	unsigned hexadecimal int with lowercase
%X	unsigned hexadecimal int with uppercase
%f	float or double [-]dddd.dddd.
%e	float or double of the form [-]d.dddd e[+/-]ddd
%g	either e or f form, whichever is shorter
%E	same as e; with E for exponent
%G	same as g; with E for exponent if e format used
%Lf,	
%Le,	
%Lg	long double
%c	single character
%s	string
%p	pointer

scanf( )

%d	signed decimal int
%hd	signed short decimal integer
%ld	signed long decimal integer
%u	unsigned decimal int
%lu	unsigned long decimal int
%o	unsigned octal int
%x	unsigned hexadecimal int
%f	float
%lf	double **NOTE:** double & float are distinct for scanf !!!!
%LF	long double
%c	single character
%s	string

ESCAPE SEQUENCES

- Certain characters are difficult to place in C code so an escape code or escape sequence is used to encode these characters.
- These escape sequences all begin with a backslash '\' and cause the encoded character to be placed into the program.

Escape	value
\n	newline
\t	tab
\f	formfeed
\a	alarm
\b	backspace
\r	carriage return
\v	vertical tab

Ex:

```
/*     FILE: print.c     */

/*
   Illustration of printf( ) and conversion specifiers.
*/
#include <stdio.h>

int main( )
{
  int x = 12;
  float y = 3.75;

  printf("%d", x);

  printf("\nx = %d\n", x);

  printf("y = %f\n", y);

  return 0;
}


/*    OUTPUT: print.c

          12
          x = 12
          y = 3.750000

*/
```

Ex:

```
/*     FILE: scan.c     */

/*
   Illustration of scanf( ).
*/
#include <stdio.h>

int main( )
{
  int x;
  float y;

  printf("x = %d\n", x);

  printf("y = %f\n", y);

  printf("Enter an integer value for x: ");
  scanf("%d", &x);

  printf("Enter a floating-point value for y: ");
  scanf("%f", &y);

  printf("x = %d\n", x);

  printf("y = %f\n", y);

  return 0;
}


/*    OUTPUT: scan.c

          x = 4206596
          y = 0.000000
          Enter an integer value for x: 7
          Enter a floating-point value for y: 3.3
          x = 7
          y = 3.300000

*/
```

Ex:

```
/*     FILE: scan2.c     */

/*
   Illustration of scanf( ) with characters and characters
   are integers.
*/
#include <stdio.h>

int main( )
{
  char c;

  printf("Enter a character: ");
  scanf("%c", &c);

  printf("c = %c\n", c);

  printf("c = %d\n", c);

  return 0;
}


/*    OUTPUT: scan2.c

          Enter a character: A
          c = A
          c = 65

*/
```

Ex:

```
/*     FILE: scan3.c     */

/*
   Illustration of interpretation caused by conversion specifiers.
*/
#include <stdio.h>

int main( )
{
  char c;
  int x;

  printf("Enter a character: ");
  scanf("%c", &c);

  printf("c = %c\n", c);

  printf("c = %d\n", c);

  printf("Enter an integer: ");
  scanf("%d", &x);

  printf("x = %d\n", x);

  printf("x = %c\n", x);

  return 0;
}


/*    OUTPUT: scan3.c

          Enter a character: 6
          c = 6
          c = 54
          Enter an integer: 6
          x = 6
          x = _

*/
```

OPERATORS

Arithmetic operators:

* / %	multiplication/division/modulus
+ −	addition/subtraction
+ −	positive/negative sign (unary)
++ − −	increment/decrement (unary)

Logical operators:

&&	AND
||	OR
!	NOT (unary)

Relational operators:

< <= > >=	less than, less than or equal to, greater than, greater than or equal to
== !=	equal to and not equal to

Bit operators:

<< >>	left and right bit shift
&	bitwise AND
|	bitwise OR
^	bitwise exclusive or XOR
~	bitwise NOT (unary)

Assignment operators:

= += −= *= /= %= &= ^= |= <<= >>=

Address/Pointer operators:

&	address of (unary)
*	dereference (unary)

Structure operators:

.	structure member acccess
−>	member access thru a structure pointer

Other operators:

( )	function call
[ ]	array access
(*type*)	type cast (unary)
sizeof	data object size in bytes (unary)
?:	conditional operator
,	comma operator

OPERATOR PRECEDENCE

- The C compiler determines the order of operations in a C statement by operator precedence.
- Operator Precedence is the ranking of operators in C. The higher the rank the sooner the operator is evaluated.
- Parentheses can be used to override operator precedence.
- There are many kinds of operators but all operators are ranked via operator precedence.
- In the case of operators with the same rank, associativity is used and the operators are evaluated left-to-right or right-to-left.
- Operator precedence and associativity are detailed in the Operator Precedence Chart in the appendix, on the following page, and on pg. 53 in the K&R book

OPERATOR PRECEDENCE CHART

Operators	Associativity
( ) [ ] –> .	left to right *{( ) function call}*
! ~ ++ – – + – * & (*type*) sizeof	right to left *{All Unary}*
* / %	left to right
+ –	left to right
<< >>	left to right
< <= > >=	left to right
= = !=	left to right
&	left to right
^	left to right
|	left to right
&&	left to right
||	left to right
?:	right to left
= += –= *= /= %= &= ^= |= <<= >>=	right to left
,	left to right

ARITHMETIC OPERATORS

- Arithmetic operators are the symbols used by C to indicate when an arithmetic operation is desired.
- Arithmetic operators follow the same precedence rules we learned as kids. Multiplication & division before addition and subtraction. In case of a tie evaluate left-to-right. { Look at a precedence chart and see if this is true. }
- The modulus operator, %, is an additional arithmetic operator. It produces the remainder of integer division and ranks at the same level as division in the precedence chart.
- The increment, ++, and decrement, --, operators are basically a shorthand notation for increasing or decreasing the value of a variable by one.

Ex:

```
/*     FILE: arith_1.c     */

/* Arithmetic operators */

#include <stdio.h>

int main( )
{
  int first, second, sum;

  first = 11;
  second = 12;

  sum = first + second;
  printf("sum = %d\n", sum);

  sum = first - second;
  printf("sum = %d\n", sum);

  sum = first * second;
  printf("sum = %d\n", sum);

  sum = first / second;
  printf("sum = %d\n", sum);

  return 0;
}


/*    OUTPUT: arith_1.c

          sum = 23
          sum = -1
          sum = 132
          sum = 0

*/
```

Ex:

```
/*     FILE: arith_2.c     */

/* Arithmetic operators with nicer output */

#include <stdio.h>

int main( )
{
  int first, second, sum;

  first = 11;
  second = 12;

  sum = first + second;
  printf("%d + %d = %d\n", first, second, sum);

  sum = first - second;
  printf("%d - %d = %d\n", first, second, sum);

  sum = first * second;
  printf("%d * %d = %d\n", first, second, sum);

  sum = first / second;
  printf("%d / %d = %d\n", first, second, sum);

  return 0;
}


/*    OUTPUT: arith_2.c

          11 + 12 = 23
          11 - 12 = -1
          11 * 12 = 132
          11 / 12 = 0

*/
```

Ex:

```
/*     FILE: arith_3.c     */

/* More arithmetic operators with nicer output */

#include <stdio.h>

int main( )
{
  int first, second, sum;

  first = 11;
  second = 12;

  sum = first + second;
  printf("%d + %d = %d\n", first, second, sum);

  sum = first - second;
  printf("%d - %d = %d\n", first, second, sum);

  sum = second - first;
  printf("%d - %d = %d\n", second, first, sum);

  sum = first * second;
  printf("%d * %d = %d\n", first, second, sum);

  sum = first / second;
  printf("%d / %d = %d\n", first, second, sum);

  return 0;
}


/*    OUTPUT: arith_3.c

          11 + 12 = 23
          11 - 12 = -1
          12 - 11 = 1
          11 * 12 = 132
          11 / 12 = 0

*/
```

Ex:

```
/*     FILE: arith_4.c     */

/* Arithmetic operators with floating-point data */

#include <stdio.h>

int main( )
{
  float first, second, sum;

  first = 11;
  second = 12;

  sum = first + second;
  printf("%f + %f = %f\n", first, second, sum);

  sum = first - second;
  printf("%f - %f = %f\n", first, second, sum);

  sum = second - first;
  printf("%f - %f = %f\n", second, first, sum);

  sum = first * second;
  printf("%f * %f = %f\n", first, second, sum);

  sum = first / second;
  printf("%f / %f = %f\n", first, second, sum);

  return 0;
}


/*    OUTPUT: arith_4.c

          11.000000 + 12.000000 = 23.000000
          11.000000 - 12.000000 = -1.000000
          12.000000 - 11.000000 = 1.000000
          11.000000 * 12.000000 = 132.000000
          11.000000 / 12.000000 = 0.916667

*/
```

Ex:

```
/*     FILE: arith_5.c     */

/* More arithmetic operators with floating-point data */

#include <stdio.h>

int main( )
{
  float first, second, sum;

  first = 1.35;
  second = 2.75;

  sum = first + second;
  printf("%f + %f = %f\n", first, second, sum);

  sum = first - second;
  printf("%f - %f = %f\n", first, second, sum);

  sum = second - first;
  printf("%f - %f = %f\n", second, first, sum);

  sum = first * second;
  printf("%f * %f = %f\n", first, second, sum);

  sum = first / second;
  printf("%f / %f = %f\n", first, second, sum);

  return 0;
}


/*    OUTPUT: arith_5.c

          1.350000 + 2.750000 = 4.100000
          1.350000 - 2.750000 = -1.400000
          2.750000 - 1.350000 = 1.400000
          1.350000 * 2.750000 = 3.712500
          1.350000 / 2.750000 = 0.490909

*/
```

Ex:

```
/*     FILE: arith_6.c     */

/* Precedence of operators */

#include <stdio.h>

int main( )
{
  int first, second, sum;

  first = 10;
  second = 12;

  sum = first + second / 3;
  printf("%d + %d / 3 = %d\n", first, second, sum);

  return 0;
}


/*    OUTPUT: arith_6.c

          10 + 12 / 3 = 14

*/
```

Ex:

```
/*     FILE: arith_7.c     */

/* Parentheses override precedence of operators */

#include <stdio.h>

int main( )
{
  int first, second, sum;

  first = 10;
  second = 12;

  sum = (first + second) / 3;
  printf("(%d + %d) / 3 = %d\n", first, second, sum);

  return 0;
}


/*    OUTPUT: arith_7.c

          (10 + 12) / 3 = 7

*/
```

Ex:

```
/*     FILE: computation.c     */

/* Computes the cost per sq inch of pizza
   -- inspired by pizza.c example in C
      Primer Plus by Prata                */

#include <stdio.h>

int main( )
{
  int diameter, radius, area, price, pricePerInch;

  printf("What is the price of your pizza: ");
  scanf("%d", &price);

  printf("What is the diameter of your pizza: ");
  scanf("%d", &diameter);


  radius = diameter/2;
  area = 3.14159 * radius * radius;
  pricePerInch = price/area;

  printf("Pizza analysis:\n");
  printf("    diameter = %d\n", diameter);
  printf("      radius = %d\n", radius);
  printf("        area = %d\n", area);
  printf("       price = %d per sq. inch\n", pricePerInch);

  return 0;
}


/*    OUTPUT: computation.c

          What is the price of your pizza: 10.50
          What is the diameter of your pizza:
          Pizza analysis:
              diameter = 4206596
                radius = 2103298
                  area = -2147483648
                 price = 0 per sq. inch


          What is the price of your pizza: 10
          What is the diameter of your pizza: 14
          Pizza analysis:
              diameter = 14
                radius = 7
                  area = 153
                 price = 0 per sq. inch

*/
```

Ex:

```
/*     FILE: computation2.c     */

/* Computes the cost per sq inch of pizza

   Uses a float for price, to get dollars
   and cents.
                                          */

#include <stdio.h>

int main( )
{
  int diameter, radius, area, pricePerInch;
  float price;

  printf("What is the price of your pizza: ");
  scanf("%f", &price);

  printf("What is the diameter of your pizza: ");
  scanf("%d", &diameter);


  radius = diameter/2;
  area = 3.14159 * radius * radius;
  pricePerInch = price/area;

  printf("Pizza analysis:\n");
  printf("    diameter = %d\n", diameter);
  printf("      radius = %d\n", radius);
  printf("        area = %d\n", area);
  printf("       price = %d per sq. inch\n", pricePerInch);

  return 0;
}


/*    OUTPUT: computation2.c

          What is the price of your pizza: 10.50
          What is the diameter of your pizza: 14
          Pizza analysis:
              diameter = 14
                radius = 7
                  area = 153
                 price = 0 per sq. inch

*/
```

Ex:

```
/*     FILE: computation3.c     */

/* Computes the cost per sq inch of pizza

   More floating-point.
                                          */

#include <stdio.h>

int main( )
{
  int diameter;
  float price, radius, area, pricePerInch;

  printf("What is the price of your pizza: ");
  scanf("%f", &price);

  printf("What is the diameter of your pizza: ");
  scanf("%d", &diameter);


  radius = diameter/2;
  area = 3.14159 * radius * radius;
  pricePerInch = price/area;

  printf("Pizza analysis:\n");
  printf("    diameter = %d\n", diameter);
  printf("      radius = %f\n", radius);
  printf("        area = %f\n", area);
  printf("       price = %.2f per sq. inch\n", pricePerInch);

  return 0;
}


/*    OUTPUT: computation3.c

          What is the price of your pizza: 10.50
          What is the diameter of your pizza: 14
          Pizza analysis:
              diameter = 14
                radius = 7.000000
                  area = 153.937912
                 price = 0.07 per sq. inch


          What is the price of your pizza: 15.50
          What is the diameter of your pizza: 18
          Pizza analysis:
              diameter = 18
                radius = 9.000000
                  area = 254.468796
                 price = 0.06 per sq. inch


          What is the price of your pizza: 15.50
          What is the diameter of your pizza: 19
          Pizza analysis:
              diameter = 19
                radius = 9.000000
                  area = 254.468796
                 price = 0.06 per sq. inch

*/
```

Ex:

```
/*     FILE: computation4.c     */

/* Computes the cost per sq inch of pizza

   A type cast.
                                          */

#include <stdio.h>

#define PI 3.14159

int main( )
{
  int diameter;
  float price, radius, area, pricePerInch;

  printf("What is the price of your pizza: ");
  scanf("%f", &price);

  printf("What is the diameter of your pizza: ");
  scanf("%d", &diameter);


  radius = (float)diameter/2;
  area = PI * radius * radius;
  pricePerInch = price/area;

  printf("Pizza analysis:\n");
  printf("    diameter = %d\n", diameter);
  printf("      radius = %f\n", radius);
  printf("        area = %f\n", area);
  printf("       price = %.2f per sq. inch\n", pricePerInch);

  return 0;
}


/*    OUTPUT: computation4.c

          What is the price of your pizza: 15.50
          What is the diameter of your pizza: 18
          Pizza analysis:
              diameter = 18
                radius = 9.000000
                  area = 254.468796
                 price = 0.06 per sq. inch



          What is the price of your pizza: 15.50
          What is the diameter of your pizza: 19
          Pizza analysis:
              diameter = 19
                radius = 9.500000
                  area = 283.528503
                 price = 0.05 per sq. inch

*/
```

INCREMENT ++/DECREMENT -- OPERATORS

- C has two specialized operators for incrementing and decrementing the value of a variable.

  ++ - will increase a variables value by “one”

  -- - will decrease a variables value by “one”

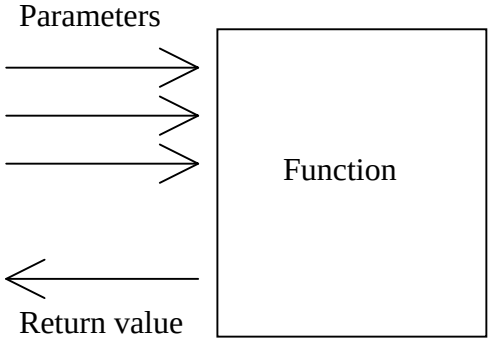
- Both operators can be written in both prefix and postfix notation. Each has implications as to when the actual increment or decrement takes place. Fortunately the implications are reasonable. Prefix notation causes the increment/decrement to occur “before” the value of the variable is supplied to an expression. Postfix notation causes the increment/decrement to occur “after” the value of the variable is supplied to an expression. In all cases the variables value is increased/decreased by “one”

Ex:

```
/*     FILE: incDec.c     */

/* Example of increment & decrement, postfix and prefix. */

#include <stdio.h>

int main( )
{
  int i =7;

  printf("i = %d\n", i++);
  printf("After postfix ++, i = %d\n", i);

  printf("i = %d\n", ++i);
  printf("After prefix ++, i = %d\n", i);

  printf("i = %d\n", i--);
  printf("After postfix --, i = %d\n", i);

  printf("i = %d\n", --i);
  printf("After prefix --, i = %d\n", i);

  return 0;
}

/*    OUTPUT: incDec.c

          i = 7
          After postfix ++, i = 8

          i = 9
          After prefix ++, i = 9

          i = 9
          After postfix --, i = 8

          i = 7
          After prefix --, i = 7

*/
```

FUNCTIONS

- C allows a block of code to be separated from the rest of the program and named.
- These named blocks of code, or modules, are called functions.
- Functions can be passed information thru a parameter list and can pass back a result thru a return value.
- Any number of parameters can be passed to a function but at most one return value can be produced.
- All the C data types are candidates for parameter types and return types.
- Ideally a function can be treated as a black-box. If you know what to pass it and what it will return you don't need to know how it works.
- C has a special keyword, *void,* that is used to explicitly state that there are no parameters or no return value.



Ex:

```
/*     FILE: aFunction.c     */

/* Computes the cost per sq inch of pizza

   A function example. No parameters, no
   return value.
                                          */

#include <stdio.h>
#define PI 3.14159

void instructions(void);   /* Function prototype */

int main( )
{
  int diameter;
  float price, radius, area, pricePerInch;

  instructions( );  /* Call the instructions( )
                               ... function        */

  printf("What is the price of your pizza: ");
  scanf("%f", &price);

  printf("What is the diameter of your pizza: ");
  scanf("%d", &diameter);


  radius = (float)diameter/2;
  area = PI * radius * radius;
  pricePerInch = price/area;

  printf("Pizza analysis:\n");
  printf("    diameter = %d\n", diameter);
  printf("      radius = %f\n", radius);
  printf("        area = %f\n", area);
  printf("       price = %.2f per sq. inch\n", pricePerInch);

  return 0;
}

void instructions(void)   /* Function definition */
{
  printf("This program will compute the price per \n");
  printf("square inch of a circular pizza.  \n\n");

  printf("It will prompt you for the price and the \n");
  printf("diameter of the pizza. Then it will display \n");
  printf("the results of its computations.\n\n");

  printf("Then compare several different price/size \n");
  printf("combinations to determine your best pizza \n");
  printf("value .\n\n");
}
```

cont…

```
/*    OUTPUT: aFunction.c

          This program will compute the price per
          square inch of a circular pizza.

          It will prompt you for the price and the
          diameter of the pizza. Then it will display
          the results of its computations.

          Then compare several different price/size
          combinations to determine your best pizza
          value .

          What is the price of your pizza: 10.50
          What is the diameter of your pizza: 14
          Pizza analysis:
              diameter = 14
                radius = 7.000000
                  area = 153.937912
                 price = 0.07 per sq. inch



          This program will compute the price per
          square inch of a circular pizza.

          It will prompt you for the price and the
          diameter of the pizza. Then it will display
          the results of its computations.

          Then compare several different price/size
          combinations to determine your best pizza
          value .

          What is the price of your pizza: 15.50
          What is the diameter of your pizza: 18
          Pizza analysis:
              diameter = 18
                radius = 9.000000
                  area = 254.468796
                 price = 0.06 per sq. inch

*/
```

Ex:

```
/*     FILE: aFunction2.c     */

/* Computes the cost per sq inch of pizza

   Functions with parameter(s) and return
   value.
                                          */

#include <stdio.h>
#define PI 3.14159

void instructions(void);
float circleArea(float radius);

int main( )
{
  int diameter;
  float price, radius, area, pricePerInch;

  instructions( );  /* Call the instructions( )
                               ... function        */

  printf("What is the price of your pizza: ");
  scanf("%f", &price);

  printf("What is the diameter of your pizza: ");
  scanf("%d", &diameter);


  radius = (float)diameter/2;

  area = circleArea(radius);  /* Call the circleArea( )
                               ... function        */

  pricePerInch = price/area;

  printf("Pizza analysis:\n");
  printf("    diameter = %d\n", diameter);
  printf("      radius = %f\n", radius);
  printf("        area = %f\n", area);
  printf("       price = %.2f per sq. inch\n", pricePerInch);

  return 0;
}

void instructions(void)
{
  printf("This program will compute the price per \n");
  printf("square inch of a circular pizza.  \n\n");

  printf("It will prompt you for the price and the \n");
  printf("diameter of the pizza. Then it will display \n");
  printf("the results of its computations.\n\n");

  printf("Then compare several different price/size \n");
  printf("combinations to determine your best pizza \n");
  printf("value .\n\n");
}

float circleArea(float radius)
{
  float area;

  area = PI * radius * radius;

  return area;
}
```

cont…

```
/*    OUTPUT: aFunction2.c

          This program will compute the price per
          square inch of a circular pizza.

          It will prompt you for the price and the
          diameter of the pizza. Then it will display
          the results of its computations.

          Then compare several different price/size
          combinations to determine your best pizza
          value .

          What is the price of your pizza: 10.50
          What is the diameter of your pizza: 14
          Pizza analysis:
              diameter = 14
                radius = 7.000000
                  area = 153.937912
                 price = 0.07 per sq. inch



          This program will compute the price per
          square inch of a circular pizza.

          It will prompt you for the price and the
          diameter of the pizza. Then it will display
          the results of its computations.

          Then compare several different price/size
          combinations to determine your best pizza
          value .

          What is the price of your pizza: 15.50
          What is the diameter of your pizza: 18
          Pizza analysis:
              diameter = 18
                radius = 9.000000
                  area = 254.468796
                 price = 0.06 per sq. inch

*/
```

Ex:

```
/*     FILE: aFunction3.c     */

/* Computes the cost per sq inch of pizza

   Functions with parameter(s) and return
   value.
                                          */

#include <stdio.h>
#define PI 3.14159

void instructions(void);
float circleArea(float radius);
float computePPI(float price, float area);

int main( )
{
  int diameter;
  float price, radius, area, pricePerInch;

  instructions( );

  printf("What is the price of your pizza: ");
  scanf("%f", &price);

  printf("What is the diameter of your pizza: ");
  scanf("%d", &diameter);


  radius = (float)diameter/2;

  area = circleArea(radius);

  pricePerInch = computePPI(price, area);

  printf("Pizza analysis:\n");
  printf("    diameter = %d\n", diameter);
  printf("      radius = %f\n", radius);
  printf("        area = %f\n", area);
  printf("       price = %.2f per sq. inch\n", pricePerInch);

  return 0;
}

void instructions(void)
{
  printf("This program will compute the price per \n");
  printf("square inch of a circular pizza.  \n\n");

  printf("It will prompt you for the price and the \n");
  printf("diameter of the pizza. Then it will display \n");
  printf("the results of its computations.\n\n");

  printf("Then compare several different price/size \n");
  printf("combinations to determine your best pizza \n");
  printf("value .\n\n");
}

float circleArea(float radius)
{
  return PI * radius * radius;
}

float computePPI(float price, float area)
{
  return price/area;
}
```

cont…

```
/*    OUTPUT: aFunction3.c

          This program will compute the price per
          square inch of a circular pizza.

          It will prompt you for the price and the
          diameter of the pizza. Then it will display
          the results of its computations.

          Then compare several different price/size
          combinations to determine your best pizza
          value .

          What is the price of your pizza: 10.50
          What is the diameter of your pizza: 14
          Pizza analysis:
              diameter = 14
                radius = 7.000000
                  area = 153.937912
                 price = 0.07 per sq. inch



          This program will compute the price per
          square inch of a circular pizza.

          It will prompt you for the price and the
          diameter of the pizza. Then it will display
          the results of its computations.

          Then compare several different price/size
          combinations to determine your best pizza
          value .

          What is the price of your pizza: 15.50
          What is the diameter of your pizza: 18
          Pizza analysis:
              diameter = 18
                radius = 9.000000
                  area = 254.468796
                 price = 0.06 per sq. inch

*/
```

Ex:

```
/*     FILE: aFunction4.c     */

/* Computes the cost per sq inch of pizza

   Embedded function calls. (This is NOT
   necessarily the right way to do this.)

   main( ) has fewer variables, no need to
   store what you don't need.

   Functions have fewer variables.
                                          */

#include <stdio.h>
#define PI 3.14159

void instructions(void);
float circleArea(float radius);
float computePPI(float price, float area);

int main( )
{
  int diameter;
  float price;

  instructions( );

  printf("What is the price of your pizza: ");
  scanf("%f", &price);

  printf("What is the diameter of your pizza: ");
  scanf("%d", &diameter);


  printf("Pizza analysis:\n");
  printf("       price = %.2f per sq. inch\n",
           computePPI(price, circleArea((float)diameter/2)));

  return 0;
}

void instructions(void)
{
  printf("This program will compute the price per \n");
  printf("square inch of a circular pizza.  \n\n");

  printf("It will prompt you for the price and the \n");
  printf("diameter of the pizza. Then it will display \n");
  printf("the results of its computations.\n\n");

  printf("Then compare several different price/size \n");
  printf("combinations to determine your best pizza \n");
  printf("value .\n\n");
}

float circleArea(float radius)
{
  return PI * radius * radius;
}

float computePPI(float price, float area)
{
  return price/area;
}
```

cont…

```
/*    OUTPUT: aFunction4.c

          This program will compute the price per
          square inch of a circular pizza.

          It will prompt you for the price and the
          diameter of the pizza. Then it will display
          the results of its computations.

          Then compare several different price/size
          combinations to determine your best pizza
          value .

          What is the price of your pizza: 10.50
          What is the diameter of your pizza: 14
          Pizza analysis:
                 price = 0.07 per sq. inch



          This program will compute the price per
          square inch of a circular pizza.

          It will prompt you for the price and the
          diameter of the pizza. Then it will display
          the results of its computations.

          Then compare several different price/size
          combinations to determine your best pizza
          value .

          What is the price of your pizza: 15.50
          What is the diameter of your pizza: 18
          Pizza analysis:
                 price = 0.06 per sq. inch

*/
```

LOGICAL, TRUE/FALSE VALUES

- The C definition of true and false is that 0 is false and any non-zero value is true.
- This definition allows some unusual expressions to be used as test conditions.

RELATIONAL OPERATORS

- Relational operators are used quite often to produce the logical value for a conditional statement.

operator	function
= =	equality
<	less than
>	greater than
<=	less than or equal
>=	greater than or equal
!=	not equal

LOGICAL OPERATORS

- Logical operators work on logical values, i.e. true and false.

operator	function
&&	AND
||	OR
!	NOT

LOOPING

- C has three looping constructs, for, while, and do while.
- The while loop is a fundamental pre-test condition loop that repeats as long as the test condition is true.
- The for loop is just a specialized while loop that allows initialization and post-iteration processing to be specified adjacent to the test condition. It is the most commonly used loop in C.
- The do while is just a while loop with the test condition moved to the bottom of the loop. It is a post-test condition loop so the test is executed after each iteration of the loop. (The positioning of the test makes the timing clear.) The main feature of the do while is that it will always execute the body of the loop at least once.

Ex:

```
/*     FILE: for_1.c     */

/* for loop example. */

#include <stdio.h>

int main( )
{
  int i;

  for(i = 0; i < 10; i++)
  {
     printf("i = %d\n", i);
  }

  return 0;
}


/*    OUTPUT: for_1.c

          i = 0
          i = 1
          i = 2
          i = 3
          i = 4
          i = 5
          i = 6
          i = 7
          i = 8
          i = 9

*/
```

Ex:

```
/*     FILE: for_2.c     */
/* for loop example with adjustment for counting from 0. */

#include <stdio.h>

int main( )
{
  int i;

  for(i = 0; i < 10; i++)
  {
     printf("i = %d\n", i + 1);
  }

  return 0;
}

/*    OUTPUT: for_2.c

          i = 1
          i = 2
          i = 3
          i = 4
          i = 5
          i = 6
          i = 7
          i = 8
          i = 9
          i = 10
*/
```

Ex:

```
/*     FILE: while_1.c     */
/* while loop example. */

#include <stdio.h>

int main( )
{
  int i;

  i = 0;
  while (i < 10)
  {
     printf("i = %d\n", i + 1);
     i++;
  }

  return 0;
}

/*    OUTPUT: while_1.c

          i = 1
          i = 2
          i = 3
          i = 4
          i = 5
          i = 6
          i = 7
          i = 8
          i = 9
          i = 10

*/
```

Ex:

```
/*     FILE: loopChar.c     */

/* Reading characters in a loop.

   Note the space in front of the %c.
   It causes scanf( ) to skip leading
   whitespace characters.

   Ctrl/z produces an EOF from the
   keyboard on a PC.

*/

#include <stdio.h>

int main( )
{
  int ch;

  while(scanf(" %c", &ch) != EOF)
  {
     printf("character = %c\n", ch);
  }

  return 0;
}


/*    OUTPUT: loopChar.c

          character = a
          character = b
          character = c
          character = d
          character = F

       INPUT:

          a
          b

          c  d



          F

*/
```

Ex:

```
/*     FILE: loopChar2.c     */

/* Reading characters in a loop with
   getchar( ).

*/

#include <stdio.h>

int main( )
{
  int ch;

  while((ch = getchar( )) != EOF)
  {
     printf("character = %c\n", ch);
  }

  return 0;
}


/*    OUTPUT: loopChar2.c

          character = a
          character =

          character = b
          character =

          character =

          character = c
          character =
          character =
          character = d
          character =

          character =

          character =

          character =

          character = F
          character =


       INPUT:

          a
          b

          c  d



          F

*/
```

Ex:

```
/*     FILE: loopChar3.c     */

/* Reading characters in a loop with
   getchar( ).

*/

#include <stdio.h>

int main( )
{
  int ch;

  while((ch = getchar( )) != EOF)
  {
     if (ch != '\n' && ch != '\t' && ch != ' ')
       printf("character = %c\n", ch);
  }

  return 0;
}


/*    OUTPUT: loopChar3.c

          character = a
          character = b
          character = c
          character = d
          character = F

       INPUT:

          a
          b

          c  d



          F

*/
```

Ex:

```
/*     FILE: loopChar4.c     */

/*
   Reading characters in a loop with
   getchar( ).

   Using the isspace( ) function to skip
   whitespace.
*/

#include <stdio.h>
#include <ctype.h>

int main( )
{
  int ch;

  while((ch = getchar( )) != EOF)
  {
     if (!isspace(ch))
       printf("character = %c\n", ch);
  }

  return 0;
}


/*    OUTPUT: loopChar4.c

          character = a
          character = b
          character = c
          character = d
          character = F

       INPUT:

          a
          b

          c  d



          F

*/
```

MATH LIBRARIES

- C has a library of pre-defined mathematical functions.

Ex:

```
/*     FILE: math1.c     */

/* Program to compute the sine function for
   various values.                          */

#include <stdio.h>
#include <math.h>

int main( )
{
  double start, end, current, step, value;

  /* Set initial values */
  start = 0.0;
  end = 2 * M_PI;
  step = 0.01;

  /* Loop to compute and display values */
  for(current = start; current <= end; current += step){
    value = sin(current);
    printf("%f\n", value);
  }

  return 0;
}


/*    OUTPUT: math1.c

          0.000000
          0.010000
          0.019999
          0.029996
          0.039989
          0.049979
          0.059964
          0.069943
          0.079915
          0.089879
          0.099833
      .
      .
      .
          0.021591
          0.011592
          0.001593
          -0.008407
          -0.018406
          -0.028404
          -0.038398
          -0.048388
      .
      .
      .
          -0.023183
          -0.013185
          -0.003185

*/
```

Ex:

```
/*     FILE: math2.c     */

/* Program to compute the sine function for
   various values.

   Reads inputs.                              */

#include <stdio.h>
#include <math.h>

int main( )
{
  double start, end, current, step, value;

  /* Read initial values */
  scanf("%lf", &start);
  scanf("%lf", &end);
  scanf("%lf", &step);

  /* Loop to compute and display values */
  for(current = start; current <= end; current += step){
    value = sin(current);
    printf("%f\n", value);
  }

  return 0;
}


/*    OUTPUT: math2.c

          0.000000
          0.010000
          0.019999
     .
     .
     .
          0.021591
          0.011592
          0.001593
          -0.008407
          -0.018406
          -0.028404
     .
     .
     .
          -0.023183
          -0.013185
          -0.003185
          0.006815
          0.016814
          0.026811
     .
     .
     .
          0.024775
          0.014777
          0.004778

      INPUT:

          0.0
          9.4247779
          0.01

*/
```

Ex:

```
/*     FILE: math3.c     */

/* Program to compute various values using
   the power function.    pow( )             */

#include <stdio.h>
#include <math.h>

int main( )
{
  double start, end, current, step, value;

  /* Read initial values */
  scanf("%lf", &start);
  scanf("%lf", &end);
  scanf("%lf", &step);

  /* Loop to compute and display values */
  for(current = start; current <= end; current += step){
    value = pow(current,2.0);
    printf("%f\n", value);
  }

  return 0;
}


/*    OUTPUT: math3.c

          0.000000
          0.000100
          0.000400
     .
     .
     .
          88.172100
          88.360000
          88.548100
          88.736400

       INPUT:

          0.0
          9.4247779
          0.01

*/
```

CONDITIONAL STATEMENTS

- C has two conditional statements and a conditional operator.
- The basic conditional statement in C is the if. An if is associated with a true/false condition. Code is conditionally executed depending on whether the associated test evaluates to true or false.
- The switch statement allows a labeled set of alternatives or cases to be selected from based on an integer value.
- The conditional operator ?: allows a conditional expression to be embedded in a larger statement.

Ex:

```
/*     FILE: if.c     */

/* if examples. */

#include <stdio.h>

int main( )
{
  int i;

  i = 5;
  if(i > 0)
    printf("%d > 0\n", i);

  i = -2;
  if(i > 0)
    printf("%d > 0\n", i);
  else
    printf("%d <= 0\n", i);

  i = -2;
  if(i > 0)
    printf("%d > 0\n", i);
  else
    if(i == 0)              /* Test for equality is == */
      printf("%d == 0\n", i);
    else
      printf("%d < 0\n", i);

  return 0;
}


/*    OUTPUT: if.c

          5 > 0
          -2 <= 0
          -2 < 0

*/
```

Ex:

```
/*     FILE: switch.c     */

/* switch example. */

#include <stdio.h>

int main( )
{
  int ch;

  /* Display menu of choices */
  printf("\tA- append data\n");
  printf("\tD- delete data\n");
  printf("\tR- replace data\n");

  printf("\n\tQ- to quit\n");
  printf("\n\n\tChoice: ");

  ch =getchar( );

  /* Loop to quit on upper or lower case Q */
  while(ch != 'q' && ch != 'Q'){
    switch(ch){
      case 'a':
      case 'A':
         printf("Case 'Append' selected.\n", ch);
         break;
      case 'd':
      case 'D':
         printf("Case 'Delete' selected.\n", ch);
         break;
      case 'r':
      case 'R':
         printf("Case 'Replace' selected.\n", ch);
         break;
      default:
         printf("Invalid choice- '%c'.\n", ch);
         break;
    }

    getchar( );         /* strip trailing newline */

    /* Display menu of choices */
    printf("\n\n");
    printf("\tA- append data\n");
    printf("\tD- delete data\n");
    printf("\tR- replace data\n");

    printf("\n\tQ- to quit\n");
    printf("\n\n\tChoice: ");

    ch =getchar( );
  }

  return 0;
}
```

cont…

```
/*    OUTPUT: switch.c

                A- append data
                D- delete data
                R- replace data

                Q- to quit


                Choice: r
            Case 'Replace' selected.


                A- append data
                D- delete data
                R- replace data

                Q- to quit


                Choice: R
            Case 'Replace' selected.


                A- append data
                D- delete data
                R- replace data

                Q- to quit


                Choice: d
            Case 'Delete' selected.


                A- append data
                D- delete data
                R- replace data

                Q- to quit


                Choice: t
            Invalid choice- 't'.


                A- append data
                D- delete data
                R- replace data

                Q- to quit


                Choice: w
            Invalid choice- 'w'.


                A- append data
                D- delete data
                R- replace data

                Q- to quit


                Choice: q

*/
```

Ex:

```
/*     FILE: switch2.c     */

/* A function that displays info. */

#include <stdio.h>

void print_menu(void);

int main( )
{
  int ch;

  /* Display menu of choices */
  print_menu( );
  ch =getchar( );

  /* Loop to quit on upper or lower case Q */
  while(ch != 'q' && ch != 'Q'){
    switch(ch){
      case 'a':
      case 'A':
         printf("Case 'Append' selected.\n", ch);
         break;
      case 'd':
      case 'D':
         printf("Case 'Delete' selected.\n", ch);
         break;
      case 'r':
      case 'R':
         printf("Case 'Replace' selected.\n", ch);
         break;
      default:
         printf("Invalid choice- '%c'.\n", ch);
         break;
    }

    getchar( );         /* strip trailing newline */

    /* Display menu of choices */
    printf("\n\n");
    print_menu( );

    ch =getchar( );
  }

  return 0;
}

void print_menu(void)
{
  printf("\tA- append data\n");
  printf("\tD- delete data\n");
  printf("\tR- replace data\n");

  printf("\n\tQ- to quit\n");
  printf("\n\n\tChoice: ");

  return;
}
```

cont…

```
/*    OUTPUT: switch2.c

                A- append data
                D- delete data
                R- replace data

                Q- to quit


                Choice: r
            Case 'Replace' selected.


                A- append data
                D- delete data
                R- replace data

                Q- to quit


                Choice: D
            Case 'Delete' selected.


                A- append data
                D- delete data
                R- replace data

                Q- to quit


                Choice: q

*/
```

Ex:

```
/*     FILE: tracker.c     */

/* Program to read user input and track changes
   indicated by the user.                        */

#include <stdio.h>

void printMenu(void);
void printStatus(int, int);

int main( )
{
  int x=0, y=0;
  int ch;

  printStatus(x,y);  /* Print current x,y  */

  /* Display menu of choices */
  printMenu( );
  ch =getchar( );

  /* Loop to quit on upper or lower case Q */
  while(ch != 'q' && ch != 'Q'){
    switch(ch){
      case 'u':
      case 'U':
         printf("Case 'Up' selected.\n", ch);
         y++;
         break;
      case 'd':
      case 'D':
         printf("Case 'Down' selected.\n", ch);
         y--;
         break;
      case 'l':
      case 'L':
         printf("Case 'Left' selected.\n", ch);
         x--;
         break;
      case 'r':
      case 'R':
         printf("Case 'Right' selected.\n", ch);
         x++;
         break;
      default:
         printf("Invalid choice- '%c'.\n", ch);
         break;
    }

    getchar( );         /* strip trailing newline */

    printStatus(x,y);   /* Print current x,y  */

    /* Display menu of choices */
    printf("\n\n");
    printMenu( );

    ch =getchar( );
  }

  return 0;
}
```

cont…

```
void printMenu(void)
{
  printf("\tU- Increase y\n");
  printf("\tD- Decrease y\n");
  printf("\tL- Decrease x\n");
  printf("\tR- Increase x\n");

  printf("\n\tQ- to quit\n");
  printf("\n\n\tChoice: ");

  return;
}

void printStatus(int x, int y)
{
  printf("Current location: x = %d, y = %d \n", x, y);
  return;
}


/*    OUTPUT: tracker.c

          Current location: x = 0, y = 0
                U- Increase y
                D- Decrease y
                L- Decrease x
                R- Increase x

                Q- to quit


                Choice: u
          Case 'Up' selected.
          Current location: x = 0, y = 1


                U- Increase y
                D- Decrease y
                L- Decrease x
                R- Increase x

                Q- to quit


                Choice: U
          Case 'Up' selected.
          Current location: x = 0, y = 2


                U- Increase y
                D- Decrease y
                L- Decrease x
                R- Increase x

                Q- to quit


                Choice: r
          Case 'Right' selected.
          Current location: x = 1, y = 2
```

cont…

```
              U- Increase y
              D- Decrease y
              L- Decrease x
              R- Increase x

              Q- to quit


              Choice: r
        Case 'Right' selected.
        Current location: x = 2, y = 2


              U- Increase y
              D- Decrease y
              L- Decrease x
              R- Increase x

              Q- to quit


              Choice: l
        Case 'Left' selected.
        Current location: x = 1, y = 2


              U- Increase y
              D- Decrease y
              L- Decrease x
              R- Increase x

              Q- to quit


              Choice: l
        Case 'Left' selected.
        Current location: x = 0, y = 2


              U- Increase y
              D- Decrease y
              L- Decrease x
              R- Increase x

              Q- to quit


              Choice: l
        Case 'Left' selected.
        Current location: x = -1, y = 2


              U- Increase y
              D- Decrease y
              L- Decrease x
              R- Increase x

              Q- to quit


              Choice: q

    */
```

Ex:

```
/*     FILE: cond_op.c     */

/* conditional operator example. */

#include <stdio.h>

int main( )
{
  int i;

  /* Loop to read integers and quit on non-integer */
  printf("Enter an integer (q to quit): ");
  while(scanf("%d", &i) == 1){  /* scanf returns # of items read. */
    printf("Value entered = %d, absolute value = %d\n",
            i, i<0?-i:i);

    printf("Enter an integer (q to quit): ");
  }

  return 0;
}


/*    OUTPUT: cond_op.c

          Enter an integer (q to quit): 7
          Value entered = 7, absolute value = 7
          Enter an integer (q to quit): -7
          Value entered = -7, absolute value = 7
          Enter an integer (q to quit): 13
          Value entered = 13, absolute value = 13
          Enter an integer (q to quit): -27
          Value entered = -27, absolute value = 27
          Enter an integer (q to quit): q

*/
```

FUNCTIONS – THE DETAILS

- C allows a block of code to be separated from the rest of the program and named.
- These blocks of code or modules are called functions.
- Functions can be passed information thru a parameter list. Any number of parameters can be passed to a function.
- Functions can pass back a result thru a return value. At most one return value can be produced.
- All the C data types are candidates for parameter types and return types.
- Ideally a function can be treated as a black-box. If you know what to pass it and what it will return; you don't need to, or sometimes want to, know how it works.
- C has a special keyword, *void,* that is used to explicitly state that there are no parameters or no return type.
- Using a function takes place in three steps:
    - Defining the function

      The definition is the C code that completely describes the function, what it does, what formal parameters it expects, and what it's return value and type will be.
    - Calling the function

      When the function is needed to do its work, it is "called" by its name and supplied actual parameters for the formal parameters it requires. Its return value is used if provided and needed.
    - Prototyping the function

      A prototype provides the communication information for the function, the parameter types and return value, to the compiler. This allows the compiler to more closely scrutinize your code. (This is a very, very good thing.) A prototype looks like the first line of the function definition, it identifies the parameter types and the return type of the function. A prototype should be placed within the source code at a point before the call is made. Often prototypes are placed near the top of the source code file. More often, the prototypes are placed into a .h file and *#include* is used to include them in the source code file.

Ex:

```
/*     FILE: switch3.c     */

/* A function that displays info. */

#include <stdio.h>

void print_menu(void);        /* Prototype:  - no parameters
                                             - no return value  */

int main( )
{
  int ch;

  /* Display menu of choices */
  print_menu( );
  ch =getchar( );

  /* Loop to quit on upper or lower case Q */
  while(ch != 'q' && ch != 'Q'){
    switch(ch){
      case 'a':
      case 'A':
         printf("Case 'Append' selected.\n", ch);
         break;
      case 'd':
      case 'D':
         printf("Case 'Delete' selected.\n", ch);
         break;
      case 'r':
      case 'R':
         printf("Case 'Replace' selected.\n", ch);
         break;
      default:
         printf("Invalid choice- '%c'.\n", ch);
         break;
    }

    getchar( );         /* strip trailing newline */

    /* Display menu of choices */
    printf("\n\n");
    print_menu( );

    ch =getchar( );
  }

  return 0;
}

void print_menu(void)
{
  printf("\tA- append data\n");
  printf("\tD- delete data\n");
  printf("\tR- replace data\n");

  printf("\n\tQ- to quit\n");
  printf("\n\n\tChoice: ");

  return;
}
```

cont…

```
/*    OUTPUT: switch3.c

                A- append data
                D- delete data
                R- replace data

                Q- to quit


                Choice: r
            Case 'Replace' selected.


                A- append data
                D- delete data
                R- replace data

                Q- to quit


                Choice: D
            Case 'Delete' selected.


                A- append data
                D- delete data
                R- replace data

                Q- to quit


                Choice: q

*/
```

Ex:

```
/*     FILE: binary.c     */

/* A couple functions that get passed a value,
   display some output and return nothing.   */

#include <stdio.h>

void print_binary_int(unsigned int);
void print_binary_char(unsigned char);  /* Prototypes:
                                           - no return values
                                           - one parameter each  */

int main( )
{
  int first;
  char second;

  printf("Enter an integer: ");
  scanf("%d", &first);

  printf("Enter a character: ");
  scanf(" %c", &second);

  printf("Integer %d = ", first);
  print_binary_int(first);

  printf("\n\n");
  printf("Character %c = %d = ", second, second);
  print_binary_char(second);

  printf("\n\n");

  return 0;
}

void print_binary_int(unsigned int x)
{
  unsigned int divisor = 2147483648U;

  while(divisor > 0){
    if(divisor <= x){
      printf("1");
      x = x - divisor;
    }
    else
      printf("0");

    divisor = divisor/2;
  }

  return;
}
```

cont…

```
void print_binary_char(unsigned char c)
{
  unsigned char divisor = 128;

  while(divisor > 0){
    if(divisor <= c){
      printf("1");
      c = c - divisor;
    }
    else
      printf("0");

    divisor = divisor/2;
  }

  return;
}


/*    OUTPUT: binary.c

          Enter an integer: 127
          Enter a character: A
          Integer 127 = 00000000000000000000000001111111

          Character A = 65 = 01000001


*/
```

Ex:

```
/*     FILE: average.c     */

/* A function that is passed two values and returns
   one too. */

#include <stdio.h>

double average(int, int);     /*   Parameters: 2 ints
                                 Return value: a double  */

int main( )
{
  int first, second;
  double avg;

  printf("Enter first integer: ");
  scanf("%d", &first);

  printf("Enter second integer: ");
  scanf("%d", &second);

  avg = average(first, second);

  printf("Average = %f\n", avg);

  return 0;
}

double average(int x, int y)
{
  double temp;

  temp = (x + y)/2.0;

  return temp;
}


/*    OUTPUT: average.c

          Enter first integer: 1
          Enter second integer: 2
          Average = 1.500000

*/
```

Ex:

```
/*     FILE: average2.c     */

/* A function that is passed two values and returns
   one too. Function average( ) with less overhead. */

#include <stdio.h>

double average(int, int);     /*   Parameters: 2 ints
                                 Return value: a double  */

int main( )
{
  int first, second;
  double avg;

  printf("Enter first integer: ");
  scanf("%d", &first);

  printf("Enter second integer: ");
  scanf("%d", &second);

  avg = average(first, second);

  printf("Average = %f\n", avg);

  return 0;
}

double average(int x, int y)
{
  return (x + y)/2.0;
}


/*    OUTPUT: average2.c

          Enter first integer: 1
          Enter second integer: 2
          Average = 1.500000

*/
```

Ex:

```
/*     FILE: recursion.c     */

/* Recursive function to display octal. */

#include <stdio.h>
void printOctal(int x);

int main( )
{
  int value = 71;

  /* Display value in decimal */
  printf("Value = %d decimal\n", value);

  /* Display value in octal */
  printf("Value = ");
  printOctal(value);
  printf(" octal\n");

  return 0;
}

void printOctal(int x)  /* Recursive - printOctal( ) calls  */
{                       /* ... itself.                      */
  if(x < 0){
    printf("-");
    printOctal(-x);
  }
  else {
    if (x > 7)
      printOctal(x/8);
    printf("%d", x%8);
  }

  return;
}


/*    OUTPUT: recursion.c

          Value = 71 decimal
          Value = 107 octal

*/
```

Ex:

```
/*     FILE: recursion2.c     */

/* Recursive functions to display octal and hexadecimal. */

#include <stdio.h>
void printOctal(int x);
void printHex(int x);

int main( )
{
  int value = 175;

  /* Display value in decimal */
  printf("Value = %d decimal\n", value);

  /* Display value in octal */
  printf("Value = ");
  printOctal(value);
  printf(" octal\n");

  /* Display value in hexadecimal */
  printf("Value = ");
  printHex(value);
  printf(" hexadecimal\n");

  return 0;
}

void printOctal(int x)/* Recursive - printOctal( ) calls    */
{                     /* ... itself.                        */
  if(x < 0){
    printf("-");
    printOctal(-x);
  }
  else {
    if (x > 7)
      printOctal(x/8);
    printf("%d", x%8);
  }

  return;
}

void printHex(int x)/* Recursive - printHex( ) calls        */
{                      /* ... itself.                      */
  if(x < 0){
    printf("-");
    printHex(-x);
  }
  else {
    if (x > 15)
      printHex(x/16);
    if((x%16) < 10)
      printf("%d", x%16);
    else
      printf("%c", 'A' + x%16 - 10);
  }

  return;
}


/*    OUTPUT: recursion2.c

          Value = 175 decimal
          Value = 257 octal
          Value = AF hexadecimal

*/
```

POINTERS

- A pointer in C is a data type that can store the address of some other storage location.
- Pointers are used when a variable's location is of interest and not just it's value.
- A pointer is declared by using a data type followed by an asterisk, *.
- To produce the address of a variable, apply the address-of operator, & to a variable.
- Since the contents of a pointer variable are an address you need to dereference the pointer to access the value it references. That will be the value at the address the pointer contains, or the value the pointer references.

Ex:

```
/*     FILE: pointer.c     */

/* A pointer variable. */
#include <stdio.h>

int main( )
{
  int* ptr;
  int i;

  i = 7;

  ptr = &i;     /* ptr now knows where i is. */

  printf("i = %d and is at address %p\n", i, &i);

  printf("i = %d and is at address %p\n", *ptr, ptr);

  return 0;
}


/*    OUTPUT: pointer.c

          i = 7 and is at address 0022FF68
          i = 7 and is at address 0022FF68

*/
```

Ex:

```
/*     FILE: funcPt1.c     */

/* swap( ) function that fails due to pass by value. */

#include <stdio.h>
void swap(int x, int y);

int main( )
{
  int x, y;

  x = 3;
  y = 5;

  printf("Before swap, x = %d, y = %d\n", x, y);
  swap(x,y);
  printf("After swap, x = %d, y = %d\n", x, y);

  return 0;
}

void swap(int x, int y)
{
  int temp;

  printf("In swap before: %d %d\n", x, y);

  temp = x;
  x = y;
  y = temp;

  printf("In swap after: %d %d\n", x, y);

  return;
}


/*    OUTPUT: funcPt1.c

          Before swap, x = 3, y = 5
          In swap before: 3 5
          In swap after: 5 3
          After swap, x = 3, y = 5

*/
```

Ex:

```
/*     FILE: funcPt2.c     */

/* swap( ) function that works due to pointers */

#include <stdio.h>
void swap(int* x, int* y);

int main( )
{
  int x, y;

  x = 3;
  y = 5;

  printf("Before swap, x = %d, y = %d\n", x, y);
  swap(&x,&y);
  printf("After swap, x = %d, y = %d\n", x, y);

  return 0;
}

void swap(int* x, int* y)
{
  int temp;

  printf("In swap before: %d %d\n", *x, *y);

  temp = *x;
  *x = *y;
  *y = temp;

  printf("In swap after: %d %d\n", *x, *y);

  return;
}


/*    OUTPUT: funcPt2.c

          Before swap, x = 3, y = 5
          In swap before: 3 5
          In swap after: 5 3
          After swap, x = 5, y = 3

*/
```

TEXT FILE I/O

- Basic text file I/O is only slightly more difficult than the I/O done to date.
- Every I/O function seen so far has a sister function that will read/write to a file on disk.
- The programmers connection to a file on disk is a file name. The C connection to a file on disk is a file pointer, `FILE *`. The first step in doing file I/O is to translate a filename into a C file pointer using `fopen( )`.
- The file pointer is then passed to the file I/O function we are using so that C can access the appropriate file.
- Finally the connection to the file is severed by calling `fclose( )` with the file pointer as a parameter.

Ex:

```
/*     FILE: FileIO.c     */

/* Basic output using printf( ) */
#include <stdio.h>

int main( )
{
  int x = 7;
  double y =7.25;

  printf("This data will be written to the screen.\n");
  printf("x = %d, y = %f\n", x, y);

  return 0;
}


/*    OUTPUT: FileIO.c

          This data will be written to the screen.
          x = 7, y = 7.250000

*/
```

Ex:

```
/*     FILE: FileIO_2.c     */

/* Basic output to a file using fprintf( ) */
#include <stdio.h>

int main( )
{
  FILE *fptr;
  int x = 7;
  double y =7.25;

  fptr = fopen("FileIO_2.out","w");

  fprintf(fptr,"This data will be written to a file.\n");
  fprintf(fptr,"x = %d, y = %f\n", x, y);

  fclose(fptr);

  return 0;
}


/*   OUTPUT: FileIO_2.out

          This data will be written to a file.
          x = 7, y = 7.250000

*/
```

Ex:

```
/*     FILE: FileIO_3.c     */

/* Text output using fprintf( ) */
#include <stdio.h>

int main( )
{
  FILE *fptr;
  int x= 7;
  double y = 7.25;

  fptr = fopen("FileIO_3.out","w");

  if(fptr != NULL){
    fprintf(fptr,"This data will be written to a file.\n");
    fprintf(fptr,"x = %d, y = %f\n", x, y);

    fclose(fptr);
  }
  else
    printf("Unable to open file.\n");

  return 0;
}


/*   OUTPUT: FileIO_3.out

          This data will be written to a file.
          x = 7, y = 7.250000

*/
```

Ex:

```
/*     FILE: FileIO_4.c     */

/* Text I/O using fprintf( ) and fscanf( ) */
#include <stdio.h>

int main( )
{
  FILE *fptr;
  int i, x;

  fptr = fopen("FileIO_4.out","w");

  if(fptr != NULL){
    for(i=0; i<5; i++)
      fprintf(fptr,"%d\n", i);

    fclose(fptr);
  }
  else
    printf("Unable to open file.\n");

  fptr = fopen("FileIO_4.out","r");

  if(fptr != NULL){
    for(i=0; i<5; i++){
      fscanf(fptr,"%d", &x);
      printf("Read: %d\n", x);
    }

    fclose(fptr);
  }
  else
    printf("Unable to open file.\n");

  return 0;
}


/*    OUTPUT: FileIO_4.c

          Read: 0
          Read: 1
          Read: 2
          Read: 3
          Read: 4

*/


/*   OUTPUT: FileIO_4.out

          0
          1
          2
          3
          4

*/
```

BINARY FILE I/O

- Binary file I/O writes data from memory to disk in the same format as it is stored in memory.
- Generally is is not going to be human-readable but it should take up less space and can be done faster since it does not need to be translated into text.
- File pointers are used in the same manner as they are in text I/O.

Ex:

```
/*     FILE: FileIO_5.c     */

/* Binary I/O using fwrite( ) and fread( ) */
#include <stdio.h>

int main( )
{
  FILE *fptr;
  int i, x;

  x = 0;
  i = 7;

  printf("i = %d   x = %d\n", i, x);

  fptr = fopen("tmp.dat","w");

  if(fptr != NULL){
    fwrite(&i, 4, 1, fptr);
    fclose(fptr);
  }
  else
    printf("Unable to open file for write.\n");

  fptr = fopen("tmp.dat","r");

  if(fptr != NULL){
    fread(&x, sizeof(int), 1, fptr);
    fclose(fptr);
  }
  else
    printf("Unable to open file for read.\n");

  printf("i = %d   x = %d\n", i, x);

  return 0;
}


/*    OUTPUT: FileIO_5.c

          i = 7   x = 0
          i = 7   x = 7

*/
```

Ex:

```
/*     FILE: FileIO_6.c     */

/* Binary I/O using fwrite( ) and fread( ) */
#include <stdio.h>

int main( )
{
  FILE *fptr;
  int i, ar[5], ar2[5];

  for(i=0; i<5; i++)
    ar[i] = i*11;

  fptr = fopen("tmp.dat","w");

  if(fptr != NULL){
    fwrite(&ar[0], sizeof(int), 5, fptr);
    fclose(fptr);
  }
  else
    printf("Unable to open file for write.\n");

  fptr = fopen("tmp.dat","r");

  if(fptr != NULL){
    fread(ar2, sizeof(int), 5, fptr);
    fclose(fptr);
  }
  else
    printf("Unable to open file for read.\n");

  for(i=0; i<5; i++)
    printf("ar2[%d] = %d\n", i, ar2[i]);

  return 0;
}


/*    OUTPUT: FileIO_6.c

          ar2[0] = 0
          ar2[1] = 11
          ar2[2] = 22
          ar2[3] = 33
          ar2[4] = 44

*/
```

STRINGS

- The C definition of a string is: a set of characters terminated by a null character.
- A set of characters written inside of double quotes indicates to the compiler that it is a string.
- Placement of the null character gets handled by C itself, when C can identify that it is working with strings.
- A programmer can create and manipulate a string as a set of char locations. This set of locations can be created as an array. The programmer must then be sure that the set is used properly so that the terminating null gets placed at the end of the characters so that it represents a legitimate string.

Ex:

```
/*     FILE: string.c     */

/* Basic C string functionality */

#include <stdio.h>

int main( )
{
  char name[81];

  printf("Prompts are strings.\n");
  printf("String - %s", "Please enter a string: ");
  scanf("%s", name);

  printf("\n\nYou entered- %s\n", name);

  return 0;
}


/*    OUTPUT: string.c

          Prompts are strings.
          String - Please enter a string: Jim


          You entered- Jim

*/
```

Ex:

```
/*     FILE: string2.c     */

/* Basic C string functionality */

#include <stdio.h>

int main( )
{
  char name[81];

  name[0] = 'J';
  name[1] = 'i';
  name[2] = 'm';
  name[3] = '\0';

  printf("\n\nYou created: %s\n", name);

  return 0;
}


/*    OUTPUT: string2.c



          You created: Jim

*/
```

Ex:

```
/*     FILE: string3.c     */

/* Standard C string library routines

   Note the inclusion of string.h     */

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

int main( )
{
  char name[81];

  strcpy(name,"Jim");

  printf("You created: %s\n", name);

  return 0;
}


/*    OUTPUT: string3.c

          You created: Jim

*/
```

Ex:

```
/*     FILE: string4.c     */

/* Standard C string library routines */

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

int main( )
{
  char name[81];

  strcpy(name,"Jim");
  strcat(name," Polzin");

  printf("You created: %s\n", name);

  if(strcmp(name,"jim polzin") == 0)
    printf("%s matches %s\n", name, "jim polzin");
  else
    printf("%s doesn't match %s\n", name, "jim polzin");

  if(strcmp(name,"Jim Polzin") == 0)
    printf("%s matches %s\n", name, "Jim Polzin");
  else
    printf("%s doesn't match %s\n", name, "Jim Polzin");


  printf("\n\nString length = %d\n", strlen(name));
  printf("\n\nSize of name  = %d\n", sizeof(name));

  return 0;
}


/*    OUTPUT: string4.c

          You created: Jim Polzin
          Jim Polzin doesn't match jim polzin
          Jim Polzin matches Jim Polzin


          String length = 10


          Size of name  = 81

*/
```

Ex:

```
/*     FILE: stringRead.c     */

/* Reading strings with scanf( ) */

#include <stdio.h>

int main( )
{
  char name[81];

  printf("Enter your name: ");
  scanf("%s", name);



  printf("\n\n");
  printf("You entered: %s\n", name);

  return 0;
}


/*    OUTPUT: stringRead.c

          Enter your name: Jim Polzin


          You entered: Jim

          Enter your name: One Two Three


          You entered: One

*/
```

Ex:

```
/*     FILE: stringRead2.c     */

/* Reading strings with scanf( )
   - it gets more complicated   */

#include <stdio.h>

int main( )
{
  char name[81];
  int age;

  printf("Enter your name: ");
  scanf("%s", name);

  printf("Enter your age: ");
  scanf("%d", &age);



  printf("\n\n");
  printf("Hello %s\n", name);
  printf("you are %d years old.\n", age);

  return 0;
}


/*    OUTPUT: stringRead2.c

          Enter your name: Jim Polzin
          Enter your age:


          Hello Jim
          you are 1 years old.

*/
```

Ex:

```
/*     FILE: stringRead3.c     */

/* Reading strings with scanf( )
   - the rough repair           */

#include <stdio.h>

int main( )
{
  char firstName[81];
  char lastName[81];
  int age;

  /* scanf( ) treats whitespace as a delimiter. So...
     ... you CAN read each separate piece.           */
  printf("Enter your first name: ");
  scanf("%s", firstName);

  printf("Enter your last name: ");
  scanf("%s", lastName);

  printf("Enter your age: ");
  scanf("%d", &age);



  printf("\n\n");
  printf("Hello %s %s\n", firstName, lastName);
  printf("you are %d years old.\n", age);

  return 0;
}


/*    OUTPUT: stringRead3.c

          Enter your first name: Jim
          Enter your last name: Polzin
          Enter your age: 44


          Hello Jim Polzin
          you are 44 years old.

*/
```

Ex:

```
/*     FILE: stringRead4.c     */

/* Reading strings with scanf( )
   - the real fix               */

#include <stdio.h>

int main( )
{
  char name[81];
  int age;

  printf("Enter your name: ");
  gets(name);   /* gets( ) knows all about strings
                   ... it reads all the input through
                   ... the end-of-line.              */

  printf("Enter your age: ");
  scanf("%d", &age);



  printf("\n\n");
  printf("Hello %s\n", name);
  printf("you are %d years old.\n", age);

  return 0;
}


/*    OUTPUT: stringRead4.c

          Enter your name: Jim Polzin
          Enter your age: 44


          Hello Jim Polzin
          you are 44 years old.

*/
```

ARRAYS

- C allows easy creation and access to sets of storage locations with arrays.
- An array is set of storage locations all referred to by the same name. Each individual location is uniquely identified by the array name and an index value, or offset, into the array.
- C arrays are indexed beginning with the value 0 for the index of the first location and ending with the size-1 for the index of the last location.
- Since the only difference between successive locations in an array is the index value, the computer can be used to generate the index values. This allows an entire array to be processed with very little programming effort.
- An array is homogeneous, that is all elements are of the same data type.

Ex:

```
/*     FILE: array1.c     */

/* A simple array example.
   Stores values and displays them. */

#include <stdio.h>

main( )
{
  int ar[10];
  int i;

  for(i=0; i<10; i++)
    ar[i] = 23 - i;

  for(i=0; i<10; i++)
    printf("%d\n", ar[i]);

  return 0;
}



/*    OUTPUT: array1.c

          23
          22
          21
          20
          19
          18
          17
          16
          15
          14

*/
```

Ex:

```
/*     FILE: array2.c     */

/* A simple array example.
   Stores values and displays them.

   The output is a little fancier. */

#include <stdio.h>

main( )
{
  int ar[10];
  int i;

  for(i=0; i<10; i++)
    ar[i] = 23 - i;

  for(i=0; i<10; i++)
    printf("ar[%d] = %d\n", i, ar[i]);

  return 0;
}



/*    OUTPUT: array2.c

          ar[0] = 23
          ar[1] = 22
          ar[2] = 21
          ar[3] = 20
          ar[4] = 19
          ar[5] = 18
          ar[6] = 17
          ar[7] = 16
          ar[8] = 15
          ar[9] = 14

*/
```

Ex:

```
/*     FILE: array3.c     */

/* Reads values and displays them. */

#include <stdio.h>

main( )
{
  int ar[10];
  int i;

  for(i=0; i<10; i++)
  {
    printf("Enter value %d of %d: ", i+1, 10);
    scanf("%d", &ar[i]);
  }

  for(i=0; i<10; i++)
    printf("%d\n", ar[i]);

  return 0;
}



/*    OUTPUT: array3.c

          Enter value 1 of 10: 1
          Enter value 2 of 10: 2
          Enter value 3 of 10: 3
          Enter value 4 of 10: 4
          Enter value 5 of 10: 5
          Enter value 6 of 10: 6
          Enter value 7 of 10: 7
          Enter value 8 of 10: 8
          Enter value 9 of 10: 9
          Enter value 10 of 10: 10
          1
          2
          3
          4
          5
          6
          7
          8
          9
          10

*/
```

Ex:

```
/*     FILE: array4.c     */

/* Reads in values, computes their average, and displays them. */

#include <stdio.h>

main( )
{
  int ar[10];
  int i, sum;
  double avg;

  for(i=0; i<10; i++)
  {
    printf("Enter value %d of %d: ", i+1, 10);
    scanf("%d", &ar[i]);
  }

  sum = 0;
  for(i=0; i<10; i++)
    sum = sum + ar[i];

  avg = (double)sum / 10;
  printf("avg = %f\n", avg);

  return 0;
}



/*    OUTPUT: array4.c

          Enter value 1 of 10: 4
          Enter value 2 of 10: 4
          Enter value 3 of 10: 4
          Enter value 4 of 10: 4
          Enter value 5 of 10: 4
          Enter value 6 of 10: 5
          Enter value 7 of 10: 5
          Enter value 8 of 10: 5
          Enter value 9 of 10: 5
          Enter value 10 of 10: 5
          avg = 4.500000

*/
```

Ex:

```
/*     FILE: array5.c     */

/* Reads in values, computes their average, and displays them.

   Uses a defined constant to simplify future changes and
   increase readability. */

#include <stdio.h>
#define SIZE 10

main( )
{
  int ar[SIZE];
  int i, sum;
  double avg;

  for(i=0; i<SIZE; i++)
  {
    printf("Enter value %d of %d: ", i+1, SIZE);
    scanf("%d", &ar[i]);
  }

  sum = 0;
  for(i=0; i<SIZE; i++)
    sum = sum + ar[i];

  avg = (double)sum / SIZE;
  printf("avg = %f\n", avg);

  return 0;
}



/*    OUTPUT: array5.c

          Enter value 1 of 10: 4
          Enter value 2 of 10: 4
          Enter value 3 of 10: 4
          Enter value 4 of 10: 4
          Enter value 5 of 10: 4
          Enter value 6 of 10: 5
          Enter value 7 of 10: 5
          Enter value 8 of 10: 5
          Enter value 9 of 10: 5
          Enter value 10 of 10: 5
          avg = 4.500000

*/
```

Ex:

```
/*     FILE: max_cnt.c     */

/*
   Loads an array with up to SIZE values.
   Finds the max and the count of values
   greater than 90.
*/

#include <stdio.h>
#define SIZE 50

int main( )
{
  int scores[SIZE];
  int i, n, max, a_count;

  /* Get number of values to read */
  printf("Please enter number of scores (%d or less): ", SIZE);
  scanf("%d", &n);

  /* Validate number entered by user. */
  if (n<=SIZE && n>0){
    /* Read score values into array */
    for(i=0; i<n; i++)
    {
      printf("Enter value %d of %d: ", i+1, n);
      scanf("%d", &scores[i]);
    }

    /* Find maximum of values read. */
    max = scores[0];
    for(i=1; i<n; i++)
    {
      if (scores[i] > max)
        max = scores[i];
    }

    printf("Max score = %d\n", max);

    /* Count number of A's, scores greater than 90 */
    a_count = 0;
    for(i=0; i<n; i++)
    {
      if (scores[i] > 90)
        a_count++;
    }

    printf("A's = %d\n", a_count);
  }

  return 0;

}


/*    OUTPUT: max_cnt.c

          Please enter number of scores (50 or less): 4
          Enter value 1 of 4: 75
          Enter value 2 of 4: 85
          Enter value 3 of 4: 95
          Enter value 4 of 4: 92
          Max score = 95
          A's = 2

*/
```

Ex:

```
/*     FILE: sort1.c     */

/* An example of sorting with selection sort. */

#include <stdio.h>
#define SIZE 10
main( )
{
  int ar[SIZE];
  int pass,item,position,temp;

  for(item=0; item<SIZE; item++)  /* load array with values */
     ar[item] = item*10;

  printf("\nOriginal array:\n");
  for(item=0; item<SIZE; item++)  /* display values in array */
     printf("ar[%d] = %d\n", item, ar[item]);

    /* Selection-sort the values read in. */
    for(pass=0; pass<SIZE-1; pass++){
      position = pass;
      for(item=pass+1; item<SIZE; item++)
        if (ar[position] < ar[item])
          position = item;
      if(pass != position){
        temp = ar[pass];
        ar[pass] = ar[position];
        ar[position] = temp;
      }
    }

  printf("\nSorted array:\n");
  for(item=0; item<SIZE; item++)  /* display values in array */
     printf("ar[%d] = %d\n", item, ar[item]);

  return 0;
}


/*    OUTPUT: sort1.c


          Original array:
          ar[0] = 0
          ar[1] = 10
          ar[2] = 20
          ar[3] = 30
          ar[4] = 40
          ar[5] = 50
          ar[6] = 60
          ar[7] = 70
          ar[8] = 80
          ar[9] = 90

          Sorted array:
          ar[0] = 90
          ar[1] = 80
          ar[2] = 70
          ar[3] = 60
          ar[4] = 50
          ar[5] = 40
          ar[6] = 30
          ar[7] = 20
          ar[8] = 10
          ar[9] = 0

*/
```

Ex:

```
/*     FILE: select.c     */

/* Loads an array with up to 50 values.
   Sorts the values into descending order. */

#include <stdio.h>
#define SIZE 50

int main( )
{
  int scores[SIZE];
  int i, n, pass, item, position, temp;

  /* Get number of values to read */
  printf("Please enter number of scores (%d or less): ", SIZE);
  scanf("%d", &n);

  /* Validate number entered by user. */
  if (n<=SIZE && n>0){
    /* Read score values into array */
    for(i=0; i<n; i++)
    {
      printf("Enter value %d of %d: ", i+1, n);
      scanf("%d", &scores[i]);
    }

    /* Selection-sort the values read in. */
    for(pass=0; pass<n-1; pass++){
      position = pass;
      for(item=pass+1; item<n; item++)
        if (scores[position] < scores[item])
          position = item;
      if(pass != position){
        temp = scores[pass];
        scores[pass] = scores[position];
        scores[position] = temp;
      }
    }

    /* Display scores in sorted order */
    printf("\n\nThe scores in order.\n");
    for(i=0; i<n; i++)
      printf("%d- %d\n", i+1, scores[i]);
  }

  return 0;
}

/*    OUTPUT: select.c

          Please enter number of scores (50 or less): 6
          Enter value 1 of 6: 75
          Enter value 2 of 6: 42
          Enter value 3 of 6: 88
          Enter value 4 of 6: 37
          Enter value 5 of 6: 99
          Enter value 6 of 6: 92


          The scores in order.
          1- 99
          2- 92
          3- 88
          4- 75
          5- 42
          6- 37
*/
```

Ex:

```
/*     FILE: arrayString.c     */

/* Strings are arrays */

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

int main( )
{
  char name[81];

  strcpy(name,"Jim");
  strcat(name," Polzin");

  printf("You created: %s\n", name);

  name[6] = 'L';

  printf("It was changed to: %s\n", name);

  return 0;
}


/*    OUTPUT: arrayString.c

          You created: Jim Polzin
          It was changed to: Jim PoLzin

*/
```

Ex:

```
/*     FILE: arrayString2.c     */

/* Strings are arrays */

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

int main( )
{
  int i;
  char name[81];

  strcpy(name,"Jim");
  strcat(name," Polzin");

  printf("You created: ");

  for(i=0; name[i] != '\0'; i++)
    putchar(name[i]);

  putchar('\n');

  return 0;
}


/*    OUTPUT: arrayString2.c

          You created: Jim Polzin

*/
```

Ex:

```
/*     FILE: arrayString3.c     */

/* Strings as parameters */

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

void myPuts(char [ ]);
void myStrcpy(char [ ], char[ ]);

int main( )
{
  int i;
  char name[81];

  myStrcpy(name,"Jim");
  strcat(name," Polzin");

  printf("You created: ");

  myPuts(name);

  return 0;
}

void myPuts(char s[ ])
{
  int i;

  for(i=0; s[i] != '\0'; i++)
    putchar(s[i]);

  putchar('\n');

  return;
}

void myStrcpy(char dest[ ], char src[ ])
{
  int i;

  for(i=0; src[i] != '\0'; i++)
    dest[i] = src[i];

  dest[i] = '\0';

  return;
}


/*    OUTPUT: arrayString3.c

          You created: Jim Polzin

*/
```

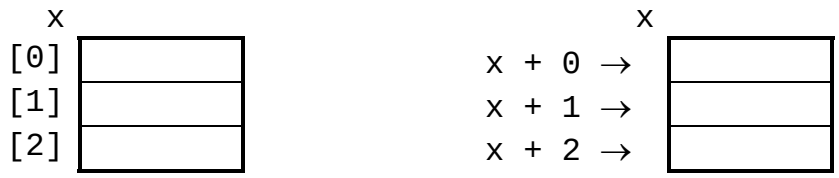
Ex:

```
/*     FILE: arrayString4.c     */

/* Strings as parameters

   myStrcpy - altered       */

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

void myPuts(char [ ]);
void myStrcpy(char [ ], char[ ]);

int main( )
{
  int i;
  char name[81];

  myStrcpy(name,"Jim");
  strcat(name," Polzin");

  printf("You created: ");

  myPuts(name);

  return 0;
}

void myPuts(char s[ ])
{
  int i;

  for(i=0; s[i] != '\0'; i++)
    putchar(s[i]);

  putchar('\n');

  return;
}

void myStrcpy(char dest[ ], char src[ ])  /* C style, streamlined! */
{
  int i;

  for(i=0; (dest[i]=src[i]) != '\0'; i++)
  ;

  return;
}


/*    OUTPUT: arrayString4.c

          You created: Jim Polzin

*/
```

ARRAYS AND POINTERS

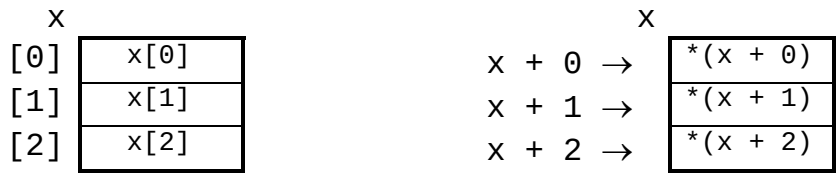
- With a 1-D array the array name is the address of the first thing in the array.

```
int  x[3];
```




```
   x  - address of the first thing in the integer array
x + 1- address of the second thing in the integer array
x + 2- address of the third thing in the integer array
```

- With a 1-D array dereferencing once, or indexing into the array once using the array access operator, gives a value in the array.




```
*x == x[0]
      - value of the first element in the array
*(x + 1)== x[1]
      - value of the second element in the array
*(x + 2)== x[2]
      - value of the third element in the array
```

Ex:

```
/*     FILE: pointer2.c     */

/* Array names are addresses. */
#include <stdio.h>

int main( )
{
  int* ptr;
  int i;
  int ar[5];

  for (i=0; i<5; i++)
    ar[i] = i+1;

  ptr = ar;     /* ptr now knows where ar is. */

  printf("ar[0] = %d and is at address %p\n", ar[0], ar);

  printf("*ptr = %d and is at address %p\n\n", *ptr, ptr);

  for (i=0; i<5; i++)
    printf("ar[%d] = %d and is at address %p\n", i, ar[i], ar+i);

  printf("\n");
  for (i=0; i<5; i++)
    printf("*(ptr+i) = %d and is at address %p\n", *(ptr+i), ptr+i);

  return 0;
}


/*    OUTPUT: pointer2.c

          ar[0] = 1 and is at address 0022FF38
          *ptr = 1 and is at address 0022FF38

          ar[0] = 1 and is at address 0022FF38
          ar[1] = 2 and is at address 0022FF3C
          ar[2] = 3 and is at address 0022FF40
          ar[3] = 4 and is at address 0022FF44
          ar[4] = 5 and is at address 0022FF48

          *(ptr+i) = 1 and is at address 0022FF38
          *(ptr+i) = 2 and is at address 0022FF3C
          *(ptr+i) = 3 and is at address 0022FF40
          *(ptr+i) = 4 and is at address 0022FF44
          *(ptr+i) = 5 and is at address 0022FF48

*/
```

Ex:

```
/*     FILE: array6.c     */

/* Passing an array to a function.
   Array name/pointer equivalence.*/

#include <stdio.h>
#define SIZE 5
void print_array(int a[ ], int length);
void print_array2(int* a, int length);

main( )
{
  int ar[SIZE];
  int i;

  for(i=0; i<SIZE; i++)
  {
    printf("Enter value %d of %d: ", i+1, SIZE);
    scanf("%d", ar + i);
  }

  printf("\n");
  print_array(ar, SIZE);

  printf("\n");
  print_array2(ar, SIZE);

  return 0;
}

void print_array(int a[ ], int length)
{
  int i;
  for(i=0; i<length; i++)
    printf("a[%d] = %d\n", i, a[i]);

  return;
}

void print_array2(int* a, int length)
{
  int i;
  for(i=0; i<length; i++)
    printf("a[%d] = %d\n", i, a[i]);

  return;
}

/*    OUTPUT: array6.c

          Enter value 1 of 5: 11
          Enter value 2 of 5: 22
          Enter value 3 of 5: 33
          Enter value 4 of 5: 44
          Enter value 5 of 5: 55

          a[0] = 11
          a[1] = 22
          a[2] = 33
          a[3] = 44
          a[4] = 55

          a[0] = 11
          a[1] = 22
          a[2] = 33
          a[3] = 44
          a[4] = 55
*/
```

Ex:

```
/*     FILE: string5.c     */

/* Passing a string to a function - pointer */
#include <stdio.h>
#include <string.h>

void myPuts(char *str);

int main( )
{
  char name[81];

  strcpy(name,"Jim");
  strcat(name," Polzin");

  printf("You created: %s\n", name);
/* Another way */
  myPuts("You created: ");
  myPuts(name);
  myPuts("\n");

  return 0;
}

void myPuts(char *str)
{
  while(*str != '\0')
    putchar(*str++);

  return;
}


/*    OUTPUT: string5.c

          You created: Jim Polzin
          You created: Jim Polzin

*/
```

Ex:

```
/*     FILE: string6.c     */

/* Passing a string to a function - pointers */
#include <stdio.h>
#include <string.h>

void myPuts(char *str);
void myStrcpy(char *dest, char *src);
char * myStrcpy2(char *dest, char *src);

int main( )
{
  char name[81];

  myStrcpy(name,"Jim Polzin");

  myPuts("You created: ");
  myPuts(name);
  myPuts("\n");

  myPuts("You created: ");
  myPuts(myStrcpy2(name,"C Programming Language."));
  myPuts("\n");

  return 0;
}

void myPuts(char *str)
{
  while(*str)
    putchar(*str++);

  return;
}

void myStrcpy(char *dest, char *src)
{
  while(*src != '\0'){
    *dest = *src;
    dest++;
    src++;
  }
  *dest = *src;

  return;
}

char * myStrcpy2(char *dest, char *src)
{
  char * ret = src;

  while(*dest++ = *src++);

  return ret;
}


/*    OUTPUT: string6.c

          You created: Jim Polzin
          You created: C Programming Language.

*/
```

BASIC MULTI-DIMENSIONAL ARRAYS

- Basically, a 2-dimensional array can be thought of as a 2-D table of storage locations. The first index determines a row in the table and the second the column in that row.

```
int  x[2][3];   /* a 2-D set of ints */
```

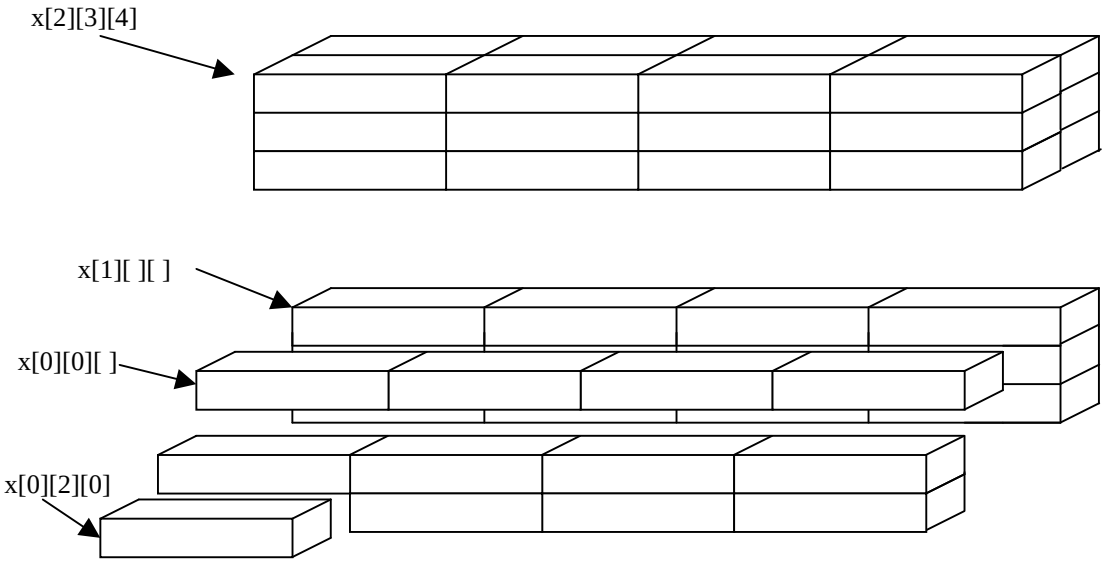
x	[ ][0]	[ ][1]	[ ][2]
[0][ ]			
[1][ ]			

- To access a particular location 2 index values must be provided.

x	[ ][0]	[ ][1]	[ ][2]
[0][ ]	x[0][0]	x[0][1]	x[0][2]
[1][ ]	x[1][0]	x[1][1]	x[1][2]

- A 3-dimensional array can be thought of as a 3-D set of storage locations. The first index determines a layer in the set, the second, a row in that layer, and the third, a particular element in that layer and row.

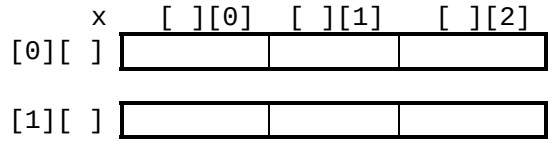
```
int  x[2][3][4];   /* a 3-D set of ints */
```



cont…

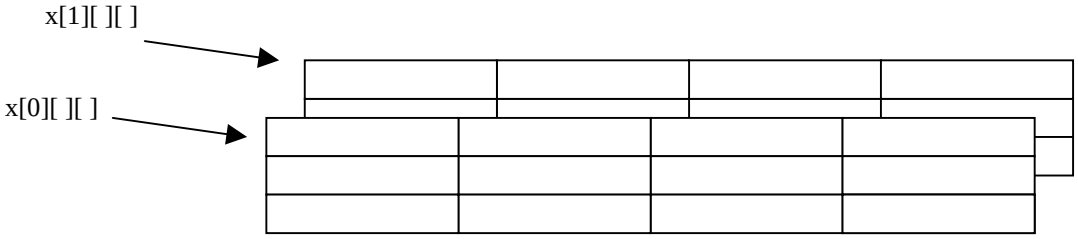
- Equivalently a 2-D array can be thought of as a set of 1-D arrays. Each row being a 1-D array of values.

```
int  x[2][3];    /* a set of 2, 1-D arrays containing 3 ints */
```



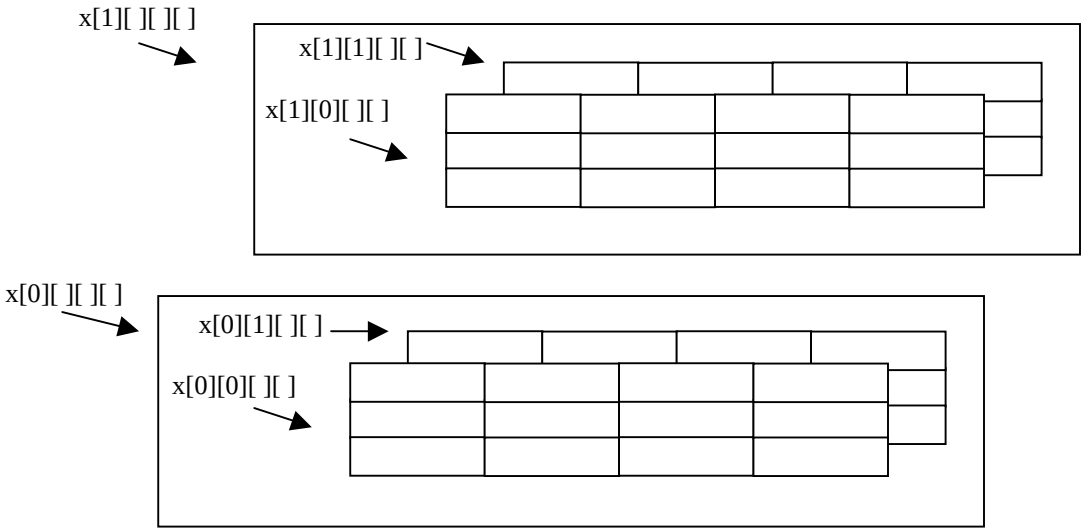
- A 3-D array can be thought of as a set of 2-D arrays. Each layer being a 2-D array of values.

```
int  x[2][3][4];    /* a set of 2, 3x4 2-D arrays */
```



- This conceptualization of arrays, as sets of sets, allows us to easily comprehend arrays of greater-than 3 dimensions. It also is a better model for understanding the relationship of pointers with n-dimensional arrays.

```
int  x[2][2][3][4];      /* a set of 2, 2x3x4 3-D arrays */
```



Ex:

```
/*     FILE: marray1.c     */

/*
    Multidimensional arrays:

    A 2-D array representing a table of
    exam scores

*/

#include <stdio.h>

#define ROWS 10       /* Preprocessor directives to */
#define COLS 3        /* ...allow easy adjustment   */
                      /* ...table dimensions.       */
int main( )
{
  int row, col;       /* Variables for visiting/processing   */
                      /* ...every row & column in the table. */
  int scores[ROWS][COLS];

  for(row=0; row < ROWS; row++)  /* Zero out the table. */
    for(col=0; col < COLS; col++)
      scores[row][col] = 0;

  scores[0][0] = 90;  /* Place some sample values in the */
  scores[0][1] = 92;  /* ...for testing.                 */
  scores[0][2] = 93;

  scores[1][0] = 70;
  scores[1][1] = 89;
  scores[1][2] = 100;

  scores[2][0] = 85;
  scores[2][1] = 90;
  scores[2][2] = 95;

  for(row=0; row < ROWS; row++)    /* Nested loops to display */
  {                                /* ... the table.          */
    for(col=0; col < COLS; col++)
    {
      printf("  %d", scores[row][col]);
    }
    printf("\n");                  /* Add a newline after each */
  }                                /* ... row in the table.    */

  return 0;
}

/*    OUTPUT: marray1.c

            90  92  93
            70  89  100
            85  90  95
            0  0  0
            0  0  0
            0  0  0
            0  0  0
            0  0  0
            0  0  0
            0  0  0
*/
```

Ex:

```
/*     FILE: marray2.c     */

/*
    Multidimensional arrays:

    A 2-D array representing a table of
    exam scores

*/

#include <stdio.h>

#define ROWS 10       /* Preprocessor directives to */
#define COLS 3        /* ...allow easy adjustment   */
                      /* ...table dimensions.       */
int main( )
{
  int row, col;       /* Variables for visiting/processing   */
                      /* ...every row & column in the table. */
  int scores[ROWS][COLS];

  for(row=0; row < ROWS; row++)  /* Zero out the table. */
    for(col=0; col < COLS; col++)
      scores[row][col] = 0;

  scores[0][0] = 90;  /* Place some sample values in the */
  scores[0][1] = 92;  /* ...for testing.                 */
  scores[0][2] = 93;

  scores[1][0] = 70;
  scores[1][1] = 89;
  scores[1][2] = 100;

  scores[2][0] = 85;
  scores[2][1] = 90;
  scores[2][2] = 95;

  for(row=0; row < ROWS; row++)    /* Nested loops to display */
  {                                /* ... the table.          */
    for(col=0; col < COLS; col++)
    {
      printf(" %5d", scores[row][col]);
    }
    printf("\n");                  /* Add a newline after each */
  }                                /* ... row in the table.    */

  return 0;
}


/*    OUTPUT: marray2.c

               90    92    93
               70    89   100
               85    90    95
                0     0     0
                0     0     0
                0     0     0
                0     0     0
                0     0     0
                0     0     0
                0     0     0

*/
```

Ex:

```
/*     FILE: marray3.c     */

/*
    Multidimensional arrays:

    A 2-D array representing a table of
    exam scores

*/

#include <stdio.h>

#define ROWS 10       /* Preprocessor directives to */
#define COLS 3        /* ...allow easy adjustment   */
                      /* ...table dimensions.       */
int main( )
{
  int row, col;       /* Variables for visiting/processing   */
                      /* ...every row & column in the table. */
  int j, sum;         /* Additional integer variables. */
  float avg;

  int scores[ROWS][COLS];

  for(row=0; row < ROWS; row++)  /* Zero out the table. */
    for(col=0; col < COLS; col++)
      scores[row][col] = 0;

  scores[0][0] = 90;  /* Place some sample values in the */
  scores[0][1] = 92;  /* ...for testing.                 */
  scores[0][2] = 93;

  scores[1][0] = 70;
  scores[1][1] = 89;
  scores[1][2] = 100;

  scores[2][0] = 85;
  scores[2][1] = 90;
  scores[2][2] = 95;

  for(row=0; row < ROWS; row++)    /* Nested loops to display */
  {                                /* ... the table.          */
    for(col=0; col < COLS; col++)
    {
      printf(" %5d", scores[row][col]);
    }

    for(sum=0, j=0; j<COLS; j++)    /* Compute and print average */
    {                               /* ...for each row.          */
      sum += scores[row][j];
    }
    avg = (float)sum/COLS;
    printf(" %.2f", avg);

    printf("\n");                 /* Add a newline after each */
  }                               /* ... row in the table.    */

  return 0;
}
```

cont…

```
/*    OUTPUT: marray3.c

              90    92    93 91.67
              70    89   100 86.33
              85    90    95 90.00
               0     0     0 0.00
               0     0     0 0.00
               0     0     0 0.00
               0     0     0 0.00
               0     0     0 0.00
               0     0     0 0.00
               0     0     0 0.00

*/
```

Ex:

```
/*     FILE: marray4.c     */

/*
    Multidimensional arrays:

    A 2-D array representing a table of
    exam scores

*/

#include <stdio.h>

#define ROWS 10       /* Preprocessor directives to */
#define COLS 3        /* ...allow easy adjustment   */
                      /* ...table dimensions.       */
int main( )
{
  int row, col;       /* Variables for visiting/processing   */
                      /* ...every row & column in the table. */
  int j, sum;         /* Additional integer variables. */
  float avg;

  int scores[ROWS][COLS];

  for(row=0; row < ROWS; row++)  /* Zero out the table. */
    for(col=0; col < COLS; col++)
      scores[row][col] = 0;

  scores[0][0] = 90;  /* Place some sample values in the */
  scores[0][1] = 92;  /* ...for testing.                 */
  scores[0][2] = 93;

  scores[1][0] = 70;
  scores[1][1] = 89;
  scores[1][2] = 100;

  scores[2][0] = 85;
  scores[2][1] = 90;
  scores[2][2] = 95;

  for(row=0; row < ROWS; row++)    /* Nested loops to display */
  {                                /* ... the table.          */
    for(col=0; col < COLS; col++)
    {
      printf(" %5d", scores[row][col]);
    }

    for(sum=0, j=0; j<COLS; j++)    /* Compute and print average */
    {                               /* ...for each row.          */
      sum += scores[row][j];
    }
    avg = (float)sum/COLS;
    printf(" %10.2f", avg);        /* Adjust format for alignment. */

    printf("\n");                  /* Add a newline after each */
  }                                /* ... row in the table.    */

  return 0;
}
```

cont…

```
/*    OUTPUT: marray4.c

              90    92    93      91.67
              70    89   100      86.33
              85    90    95      90.00
               0     0     0       0.00
               0     0     0       0.00
               0     0     0       0.00
               0     0     0       0.00
               0     0     0       0.00
               0     0     0       0.00
               0     0     0       0.00

*/
```

Ex:

```
/*     FILE: marray5.c     */

/*
    Multidimensional arrays:

    A 2-D array representing a table of
    exam scores

*/

#include <stdio.h>

#define ROWS 10       /* Preprocessor directives to */
#define COLS 3        /* ...allow easy adjustment   */
                      /* ...table dimensions.       */
int main( )
{
  int row, col;       /* Variables for visiting/processing   */
                      /* ...every row & column in the table. */
  int j, sum;         /* Additional integer variables. */
  float avg;

  int scores[ROWS][COLS];

  for(row=0; row < ROWS; row++)  /* Zero out the table. */
    for(col=0; col < COLS; col++)
      scores[row][col] = 0;

  scores[0][0] = 90;  /* Place some sample values in the */
  scores[0][1] = 92;  /* ...for testing.                 */
  scores[0][2] = 93;

  scores[1][0] = 70;
  scores[1][1] = 89;
  scores[1][2] = 100;

  scores[2][0] = 85;
  scores[2][1] = 90;
  scores[2][2] = 95;

  for(col=0; col < COLS; col++)    /* Add column headings. */
  {
    printf("%5s%d", "S", col+1);
  }
  printf(" %10s", "Average");
  printf("\n");

  for(row=0; row < ROWS; row++)    /* Nested loops to display */
  {                                /* ... the table.          */
    for(col=0; col < COLS; col++)
    {
      printf(" %5d", scores[row][col]);
    }

    for(sum=0, j=0; j<COLS; j++)    /* Compute and print average */
    {                               /* ...for each row.          */
      sum += scores[row][j];
    }
    avg = (float)sum/COLS;
    printf(" %10.2f", avg);

    printf("\n");                  /* Add a newline after each */
  }                                /* ... row in the table.    */

  return 0;
}
```

cont…

```
/*    OUTPUT: marray5.c

              S1    S2    S3    Average
              90    92    93      91.67
              70    89   100      86.33
              85    90    95      90.00
               0     0     0       0.00
               0     0     0       0.00
               0     0     0       0.00
               0     0     0       0.00
               0     0     0       0.00
               0     0     0       0.00
               0     0     0       0.00

*/
```

Ex:

```
/*     FILE: marray6.c     */

/*
    Multidimensional arrays:

    A 2-D array representing a table of
    exam scores

*/

#include <stdio.h>

#define ROWS 10       /* Preprocessor directives to */
#define COLS 3        /* ...allow easy adjustment   */
                      /* ...table dimensions.       */
int main( )
{
  int row, col;       /* Variables for visiting/processing   */
                      /* ...every row & column in the table. */
  int j, sum;         /* Additional integer variables. */
  float avg;

  int scores[ROWS][COLS];

  for(row=0; row < ROWS; row++)  /* Zero out the table. */
    for(col=0; col < COLS; col++)
      scores[row][col] = 0;

  scores[0][0] = 90;  /* Place some sample values in the */
  scores[0][1] = 92;  /* ...for testing.                 */
  scores[0][2] = 93;

  scores[1][0] = 70;
  scores[1][1] = 89;
  scores[1][2] = 100;

  scores[2][0] = 85;
  scores[2][1] = 90;
  scores[2][2] = 95;

  for(col=0; col < COLS; col++)    /* Dress-up headings. */
  {
    printf("%5s%d", "S", col+1);
  }
  printf(" %10s", "Average");
  printf("\n");

  for(col=0; col < COLS; col++)
  {
    printf(" %5s", "-----");
  }
  printf(" %10s", "-------");
  printf("\n");
```

cont…

```
  for(row=0; row < ROWS; row++)    /* Nested loops to display */
  {                                /* ... the table.          */
    for(col=0; col < COLS; col++)
    {
      printf(" %5d", scores[row][col]);
    }

    for(sum=0, j=0; j<COLS; j++)    /* Compute and print average */
    {                               /* ...for each row.          */
      sum += scores[row][j];
    }
    avg = (float)sum/COLS;
    printf(" %10.2f", avg);

    printf("\n");                  /* Add a newline after each */
  }                                /* ... row in the table.    */

  return 0;
}


/*    OUTPUT: marray6.c

            S1    S2    S3    Average
         ----- ----- -----    -------
            90    92    93      91.67
            70    89   100      86.33
            85    90    95      90.00
             0     0     0       0.00
             0     0     0       0.00
             0     0     0       0.00
             0     0     0       0.00
             0     0     0       0.00
             0     0     0       0.00
             0     0     0       0.00

*/
```

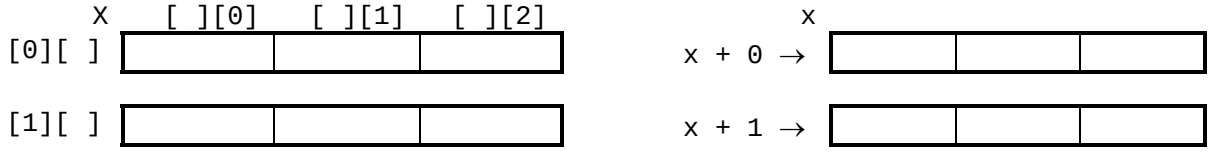
Ex:

```
/*     FILE: mArray7.c     */

/*
   3-D array: A 3-D "set" of storage locations.

   int [2][3][4] - is two sets, of three sets,
   of four integers.
                                              */

#include <stdio.h>

int main( )
{
  int depth, row, col;
  int x[2][3][4];

  for(depth = 0; depth < 2; depth++)
    for(row = 0; row < 3; row++)
      for(col = 0; col < 4; col++)
        x[depth][row][col] = depth*100 + row*10 + col;

  printf("\n\n                    Array is:  int x[2][3][4]\n");
  printf("                   -------------------------\n");

  for(depth = 0; depth < 2; depth++){
    printf("\n Layer %d:\n", depth);
    printf(" ========\n");

    for(row = 0; row < 3; row++)
    {
      for(col = 0; col < 4; col++)
        printf(" x[%d][%d][%d] = %3.3d  ",
                    depth, row, col, x[depth][row][col]);

      printf("\n");
    }
  }

  return 0;
}



/*    OUTPUT: mArray7.c


                            Array is:  int x[2][3][4]
                            -------------------------

          Layer 0:
          ========
          x[0][0][0] = 000   x[0][0][1] = 001   x[0][0][2] = 002   x[0][0][3] = 003
          x[0][1][0] = 010   x[0][1][1] = 011   x[0][1][2] = 012   x[0][1][3] = 013
          x[0][2][0] = 020   x[0][2][1] = 021   x[0][2][2] = 022   x[0][2][3] = 023

          Layer 1:
          ========
          x[1][0][0] = 100   x[1][0][1] = 101   x[1][0][2] = 102   x[1][0][3] = 103
          x[1][1][0] = 110   x[1][1][1] = 111   x[1][1][2] = 112   x[1][1][3] = 113
          x[1][2][0] = 120   x[1][2][1] = 121   x[1][2][2] = 122   x[1][2][3] = 123

*/
```

MULTIDIMENSIONAL ARRAYS AND POINTERS

- With a 2-D array the array name is the address of the first thing in the array. In this case the first thing in the array is a 1-D array:

```
int  x[2][3];  /* a set of 2 1-D arrays containing 3 ints */
```



- So the array name of this [2][3] array is the address of a set of 3 integers.

  `x` - address of the first array in the set of 2, 3 integer arrays.
  `x + 1`- address of the second array in the set of 2, 3 integer arrays.

  `*x == x[0]`
  - address of the first element in the first array
    (same as a 1-D array now that `x` has been dereferenced once.)

  `*(x + 1) == x[1]`
  - address of the first element in the second array
    (same as a 1-D array now that `x` has been dereferenced once.)

  `*(*(x + 0) + 1) == x[0][1]`
  - `x + 0` is the address of the first array
  - `*(x + 0)` is the address of the first element in the first array
  - `*(x + 0) + 1` is the address of the second element in the first array
  - `*(*(x + 0) + 1)` is the value of the second element in the first array

  `*(*(x + 1) + 2) == x[1][2]`
  - `x + 1` is the address of the second array
  - `*(x + 1)` is the address of the first element in the second array
  - `*(x + 1) + 2` is the address of the third element in the second array
  - `*(*(x + 1) + 2)` is the value of the third element in the second array

- With a 2-D array, dereferencing once, or indexing into the array once using the array access operator, gives an address. Dereferencing twice, or indexing into the array twice using the array access operator, gives a value from the array.
- Unless you dereference or index as many times as you have dimensions in an array, you still have an address, just a different kind of address.

Ex:

```
/*     FILE: pointer3.c     */

/* Arrays are sets of storage locations.

   Multidimensional arrays are sets of sets
   of storage locations.

   An array name is the address of the first
   thing (or set) in the array.               */

#include <stdio.h>
void displayArray(int ar[ ][3], int length);

int main( )
{
  int *ptr;          /* pointer to a integer  */
  int  (*ptr2)[3];   /* pointer to a set of 3
                        ... integers.         */
  int i, j;
  int x[5][3];       /* 5x3 array - or a set
                        ... of 5, 3 integer   */
  ptr = x[0];        /* ... arrays.           */
  ptr2 = x;

  for (i=0; i<5; i++)   /* Load array with         */
    for (j=0; j<3; j++) /* ...recognizable values. */
      x[i][j] = i*10 + j;


  for (i=0; i<5; i++)   /* Display address of each row. */
      printf("x + %d is at address %p\n",
              i, x + i);
  for (i=0; i<5; i++)   /* Display address of 1st integer in */
      printf("x[%d] is  at address %p\n",  /* ... each row.  */
              i, x[i]);

  printf("\n");
  for (i=0; i<3; i++)   /* Compute address of next item in    */
      printf("x + %d is  at address %p\n",  /* ... the array. */
              i, x + i);

  for (i=0; i<3; i++)   /* Compute address of next item in the */
      printf("x[%d]+%d is at address %p\n", /* ... particular  */
              0, i, x[0] + i);              /* ... set.        */

  printf("\n");

  displayArray(x, 5);  /* Display array contents. */
  return 0;
}

void displayArray(int ar[ ][3], int length)
{
  int i,j;
  for (i=0; i<length; i++){

    for (j=0; j<3; j++)
      printf("ar[%d][%d] = %2.2d ", i, j, ar[i][j]);

    printf("\n");
  }
}
```

cont…

```
/*    OUTPUT: pointer3.c

          x + 0 is at address 0022FEF0
          x + 1 is at address 0022FEFC
          x + 2 is at address 0022FF08
          x + 3 is at address 0022FF14
          x + 4 is at address 0022FF20
          x[0] is  at address 0022FEF0
          x[1] is  at address 0022FEFC
          x[2] is  at address 0022FF08
          x[3] is  at address 0022FF14
          x[4] is  at address 0022FF20

          x + 0 is  at address 0022FEF0
          x + 1 is  at address 0022FEFC
          x + 2 is  at address 0022FF08
          x[0]+0 is at address 0022FEF0
          x[0]+1 is at address 0022FEF4
          x[0]+2 is at address 0022FEF8

          ar[0][0] = 00 ar[0][1] = 01 ar[0][2] = 02
          ar[1][0] = 10 ar[1][1] = 11 ar[1][2] = 12
          ar[2][0] = 20 ar[2][1] = 21 ar[2][2] = 22
          ar[3][0] = 30 ar[3][1] = 31 ar[3][2] = 32
          ar[4][0] = 40 ar[4][1] = 41 ar[4][2] = 42

*/
```

Ex:

```
/*     FILE: pointer4.c     */

/* 3-D array name, what does it represent?
                                          */
/* Arrays are sets of storage locations.

   Multidimensional arrays are sets of sets
   of storage locations.

   An array name is the address of the first
   thing (or set) in the array.             */

#include <stdio.h>

int main( )
{
  int depth, row, col;
  int x[2][3][4];

  for(depth = 0; depth < 2; depth++)  /* Load array with        */
    for(row = 0; row < 3; row++)      /* ...recognizable values */
      for(col = 0; col < 4; col++)
        x[depth][row][col] = depth*100 + row*10 + col;

/*  Display "sets" within the 3-D array with their addresses. */
  printf("\n\n                     Array is:  int x[2][3][4]\n");
  printf("                    ------------------------\n");
  for(depth = 0; depth < 2; depth++){
    printf("\n x + %d = %p\n",             /* Layer address */
                     depth, x + depth);
    printf(" ================", depth, x + depth);
    for(row = 0; row < 3; row++)
    {
      printf("\n x[%d] + %d = %p\n",        /* Row address */
                       depth, row, x[depth] + row);
      printf(" -------------------\n", depth, row, x[depth] + row);
      for(col = 0; col < 4; col++)
        printf(" x[%d][%d]+%d=%p",          /* Integer address */
                      depth, row, col, x[depth][row] + col);
      printf("\n");
      for(col = 0; col < 4; col++)
        printf(" x[%d][%d][%d] = %3.3d  ",     /* Value */
                     depth, row, col, x[depth][row][col]);

      printf("\n");
    }
    printf("\n\n");
  }

  return 0;
}
```

cont…

```
/*    OUTPUT: pointer4.c


                          Array is:  int x[2][3][4]
                          -------------------------

          x + 0 = 0022FED0
          ================
          x[0] + 0 = 0022FED0
          -------------------
          x[0][0]+0=0022FED0 x[0][0]+1=0022FED4 x[0][0]+2=0022FED8 x[0][0]+3=0022FEDC
          x[0][0][0] = 000   x[0][0][1] = 001   x[0][0][2] = 002   x[0][0][3] = 003

          x[0] + 1 = 0022FEE0
          -------------------
          x[0][1]+0=0022FEE0 x[0][1]+1=0022FEE4 x[0][1]+2=0022FEE8 x[0][1]+3=0022FEEC
          x[0][1][0] = 010   x[0][1][1] = 011   x[0][1][2] = 012   x[0][1][3] = 013

          x[0] + 2 = 0022FEF0
          -------------------
          x[0][2]+0=0022FEF0 x[0][2]+1=0022FEF4 x[0][2]+2=0022FEF8 x[0][2]+3=0022FEFC
          x[0][2][0] = 020   x[0][2][1] = 021   x[0][2][2] = 022   x[0][2][3] = 023



          x + 1 = 0022FF00
          ================
          x[1] + 0 = 0022FF00
          -------------------
          x[1][0]+0=0022FF00 x[1][0]+1=0022FF04 x[1][0]+2=0022FF08 x[1][0]+3=0022FF0C
          x[1][0][0] = 100   x[1][0][1] = 101   x[1][0][2] = 102   x[1][0][3] = 103

          x[1] + 1 = 0022FF10
          -------------------
          x[1][1]+0=0022FF10 x[1][1]+1=0022FF14 x[1][1]+2=0022FF18 x[1][1]+3=0022FF1C
          x[1][1][0] = 110   x[1][1][1] = 111   x[1][1][2] = 112   x[1][1][3] = 113

          x[1] + 2 = 0022FF20
          -------------------
          x[1][2]+0=0022FF20 x[1][2]+1=0022FF24 x[1][2]+2=0022FF28 x[1][2]+3=0022FF2C
          x[1][2][0] = 120   x[1][2][1] = 121   x[1][2][2] = 122   x[1][2][3] = 123


*/
```

Ex:

```
/*     FILE: MultiArray.c     */

/* Program with multiple strings containing the
   names of the months.                          */

#include <stdlib.h>

int main( )
{
  char jan[8] = "January";
  char feb[9] = "February";
  char mar[6] = "March";
  char apr[6] = "April";
  char may[4] = "May";
  char jun[5] = "June";
  char jul[5] = "July";
  char aug[7] = "August";
  char sep[10] = "September";
  char oct[8] = "October";
  char nov[9] = "November";
  char dec[9] = "December";


  printf("The months of the year: \n");

  printf("%s \n", jan);
  printf("%s \n", feb);
  printf("%s \n", mar);
  printf("%s \n", apr);
  printf("%s \n", may);
  printf("%s \n", jun);
  printf("%s \n", jul);
  printf("%s \n", aug);
  printf("%s \n", sep);
  printf("%s \n", oct);
  printf("%s \n", nov);
  printf("%s \n", dec);

  return 0;
}


/*    OUTPUT: MultiArray.c

          The months of the year:
          January
          February
          March
          April
          May
          June
          July
          August
          September
          October
          November
          December

*/
```

Ex:

```
/*     FILE: MultiArray2.c     */

/* Program with multiple strings containing the
   names of the months.

   Simplified initialization.                  */

#include <stdlib.h>

int main( )
{
  char jan[ ] = "January";   /* Compiler computes necessary */
  char feb[ ] = "February";  /* ... size from initializers. */
  char mar[ ] = "March";
  char apr[ ] = "April";
  char may[ ] = "May";
  char jun[ ] = "June";
  char jul[ ] = "July";
  char aug[ ] = "August";
  char sep[ ] = "September";
  char oct[ ] = "October";
  char nov[ ] = "November";
  char dec[ ] = "December";


  printf("The months of the year: \n");

  printf("%s \n", jan);
  printf("%s \n", feb);
  printf("%s \n", mar);
  printf("%s \n", apr);
  printf("%s \n", may);
  printf("%s \n", jun);
  printf("%s \n", jul);
  printf("%s \n", aug);
  printf("%s \n", sep);
  printf("%s \n", oct);
  printf("%s \n", nov);
  printf("%s \n", dec);

  return 0;
}


/*    OUTPUT: MultiArray2.c

          The months of the year:
          January
          February
          March
          April
          May
          June
          July
          August
          September
          October
          November
          December
*/
```

Ex:

```
/*     FILE: MultiArray3.c     */

/* Program with multiple strings containing the
   names of the months.

   Since a multi-dimensional array is an "array
   of arrays", we can use here for our sets of
   sets of characters.                          */

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

int main( )
{
  char months[12][10];
  int i;

  strcpy(months[0], "January");
  strcpy(months[1], "February");
  strcpy(months[2], "March");
  strcpy(months[3], "April");
  strcpy(months[4], "May");
  strcpy(months[5], "June");
  strcpy(months[6], "July");
  strcpy(months[7], "August");
  strcpy(months[8], "September");
  strcpy(months[9], "October");
  strcpy(months[10], "November");
  strcpy(months[11], "December");


  printf("The months of the year: \n");

  for (i=0; i<12; i++)
    printf("%s \n", months[i]);

  return 0;
}


/*    OUTPUT: MultiArray3.c

          The months of the year:
          January
          February
          March
          April
          May
          June
          July
          August
          September
          October
          November
          December

*/
```

Ex:

```
/*     FILE: MultiArray4.c     */

/* Program with multiple strings containing the
   names of the months.

   Since a multi-dimensional array is an "array
   of arrays", we can use here for our sets of
   sets of characters.                          */

#include <stdlib.h>

int main( )
{
  char months[12][10] = {"January",  /* Using an initilaization list. */
                         "February",
                         "March",
                         "April",
                         "May",
                         "June",
                         "July",
                         "August",
                         "September",
                         "October",
                         "November",
                         "December"};
  int i;

  printf("The months of the year: \n");

  for (i=0; i<12; i++)
    printf("%s \n", months[i]);

  return 0;
}


/*    OUTPUT: MultiArray4.c

          The months of the year:
          January
          February
          March
          April
          May
          June
          July
          August
          September
          October
          November
          December

*/
```

Ex:

```
/*     FILE: MultiArray5.c     */

/* Program with multiple strings containing the
   names of the months.

   Since month lengths vary, each array of chars can
   be of a different length. However, each array of
   characters can be tracked by the address of the first
   character in the array. An array of pointers can be
   used to track each of those addresses.                    */

#include <stdlib.h>

int main( )
{
  char* months[12] = {"January",  /* Using an initilaization list.   */
                      "February", /* Compiler is doing a lot here.   */
                      "March",    /* Each "string" is a char address */
                      "April",
                      "May",
                      "June",
                      "July",
                      "August",
                      "September",
                      "October",
                      "November",
                      "December"};
  int i;

  printf("The months of the year: \n");

  for (i=0; i<12; i++)
    printf("%s \n", months[i]);

  return 0;
}


/*    OUTPUT: MultiArray5.c

          The months of the year:
          January
          February
          March
          April
          May
          June
          July
          August
          September
          October
          November
          December
*/
```

COMMAND-LINE ARGUMENTS

- Information can be passed to a C program from the operating system's command line.
- The command-line arguments are packaged up into an array of strings, and the count of the number of strings and the array of strings are passed to *main( )*.
- The first line of the definition of *main( )* will now look like:

*int main(int argc, char *argv[ ])*

- *argc* is the argument count, *argv* is the array strings.
- Each comand-line argument can now be accessed within the program.

Ex:

```
/*     FILE: cmdLine1.c     */

/* Program echoes all the command line arguments given. */

#include <stdio.h>

int main(int argc, char *argv[ ])
{
 int i;

 for(i=0; i<argc; i++)
   printf("argv[%d] = %s\n", i, argv[i]);

 return 0;
}


/*    OUTPUT: cmdLine1.c

  argv[0] = cmdLine1
  argv[1] = one
  argv[2] = two
  argv[3] = three

   COMMAND LINE: cmdLine1 one two three



  argv[0] = cmdLine1
  argv[1] = one
  argv[2] = 1
  argv[3] = two
  argv[4] = 2
  argv[5] = three
  argv[6] = 3

   COMMAND LINE: cmdLine1 one 1 two 2 three 3



  argv[0] = cmdLine1
  argv[1] = Jim Polzin
  argv[2] = Teaches C, sometimes.

   COMMAND LINE: cmdLine1 "Jim Polzin" "Teaches C, sometimes."


*/
```

C STORAGE CLASSES

Automatic

* variables defined in a function or block of code are automatic by default
    * can be explicitly declared using the *auto* keyword
    * known only in the function or block of code they are defined in
    * exist only while the function or block is executing
    * not initialized by default

External

* variables defined outside any function
* known to all functions defined in the source file after the variable definition
* *extern* keyword declares an external and makes it known to a function or file regardless of where the external variable is actually defined
* exist for the entire duration of the program
* initialized to zero by default

Static automatic

* known only to the function in which they are defined
* *static* keyword defines a static automatic variable
* exist for the entire duration of the program
* initialized once, to zero by default
* retain their value between function calls

Static External

* external variable restricted to the file it is defined in
* *static* keyword declares an external variable to be static external

Dynamic memory

* allocated using *malloc( )*
* exists until released by *free( )*
* accessed by address

Function scope

External

* function that can be accessed by other files
* functions are external by default

Static

* function accessible only in the defining file
* *static* keyword declares a function to be static

Ex:

```
/*     FILE: extern.c     */

/* Uses an external set of variables and a static variable. */

#include <stdio.h>

void change_char(void);

char str[81] = "Hello world!";
int position;

int main( )
{

  printf("str = %s\n", str);

  position = 11;
  change_char( );

  printf("str = %s\n", str);

  for(position=10; position>5; position --)
    change_char( );

  printf("str = %s\n", str);

  return 0;
}

void change_char(void)
{
  static int calls;
  if(calls != 0)
    printf("I've been called %d time%c before.\n",
                            calls, calls==1?' ':'s');
  else
    printf("I've never been called before.\n");

  str[position] = 'X';

  calls++;

  return;
}


/*    OUTPUT: extern.c

          str = Hello world!
          I've never been called before.
          str = Hello worldX
          I've been called 1 time  before.
          I've been called 2 times before.
          I've been called 3 times before.
          I've been called 4 times before.
          I've been called 5 times before.
          str = Hello XXXXXX

*/
```

Ex:

```
/*     FILE: extern2.c     */

/* Functions that use an external set of variables */

extern char str[81];
extern int position;

void change_char(void)
{
  static int calls;
  if(calls != 0)
    printf("I've been called %d time%c before.\n",
                            calls, calls==1?' ':'s');
  else
    printf("I've never been called before.\n");

  str[position] = 'X';

  calls++;

  return;
}



/*     FILE: extern3.c     */

/* Uses an external set of variables and a static variable. */
/* Calls function found in another file.                    */

#include <stdio.h>

void change_char(void);

char str[81] = "Hello world!";
int position;

int main( )
{

  printf("str = %s\n", str);

  position = 11;
  change_char( );

  printf("str = %s\n", str);

  for(position=10; position>5; position --)
    change_char( );

  printf("str = %s\n", str);

  return 0;
}

/*    OUTPUT: extern3.c

          str = Hello world!
          I've never been called before.
          str = Hello worldX
          I've been called 1 time  before.
          I've been called 2 times before.
          I've been called 3 times before.
          I've been called 4 times before.
          I've been called 5 times before.
          str = Hello XXXXXX

*/
```

STRUCTURES

- An array in C is a set or group of storage locations that are all of the same type.
- A structure in C allows a group of storage locations that are of different types to be created and treated as single unit.
- Structures are termed a data "aggregate", since pieces of differing types are grouped together in a structure. These pieces are referred to as "members" of the structure.
- Structures are NOT the same as arrays because a structure itself is treated as a single entity and a structure's name refers to the entire structure. (With an array, the array name is just the address of the first element in the set.)
- A structure definition creates the equivalent of a new data type. Any place you use a basic C data type you can use a structure. They can be passed as parameters, used as return values, you can take the address of one, C can compute the *sizeof* one.
- Since a structure we define is essentially a new data type, no existing C functions or operators were designed with our definitions in mind. So printf( ) and scanf( ) have no conversion specifiers for them, and the arithmetic operators won't operate on them. But we can write our own functions to perform any of these operations.
- Some basic operators do still work with structures, & address-of, sizeof( ), * dereference, = assignment, (*type*) type cast.
- There are also two operators just for structure operations. The . member access operator and the –> member access thru a pointer operator.

Ex:

```
/*     FILE: struct1.c     */

/* Defining and using a structure. */

#include <stdio.h>

int main( )
{
  struct part{
    char name[124];
    long no;
    double price;
  };

  struct part board;

  strcpy(board.name,"I/O card");
  board.no = 127356;
  board.price = 99.50;

  printf("Product: %s\n", board.name);
  printf("Part No.: %ld\n", board.no);
  printf("Unit price: %.2f\n", board.price);

  return 0;
}


/*    OUTPUT: struct1.c

          Product: I/O card
          Part No.: 127356
          Unit price: 99.50

*/
```

Ex:

```
/*     FILE: struct2.c     */

/* Defining and using a structure. */

#include <stdio.h>

struct part{
  char name[124];
  long no;
  double price;
};

int main( )
{
  struct part board;

  strcpy(board.name,"I/O card");
  board.no = 127356;
  board.price = 99.50;

  printf("Product: %s\n", board.name);
  printf("Part No.: %ld\n", board.no);
  printf("Unit price: %.2f\n", board.price);

  printf("\n\n");
  printf("struct part size: %d\n", sizeof(struct part));
  printf("board size: %d\n", sizeof(board));
  printf("      board at: %p\n", &board);
  printf(" board.name at: %p\n", &board.name);
  printf("   board.no at: %p\n", &board.no);
  printf("                %p = %X + %X \n",
          &board.no, &board.name, sizeof(board.name));
  printf("board.price at: %p\n", &board.price);
  printf("                %p = %X + %X \n",
          &board.price, &board.no, sizeof(board.no));

  return 0;
}


/*    OUTPUT: struct2.c

          Product: I/O card
          Part No.: 127356
          Unit price: 99.50


          struct part size: 136
          board size: 136
                board at: 0022FED8
           board.name at: 0022FED8
             board.no at: 0022FF54
                          0022FF54 = 22FED8 + 7C
          board.price at: 0022FF58
                          0022FF58 = 22FF54 + 4

*/
```

Ex:

```
/*     FILE: struct3.c     */

/* Structures are like basic data types. */

#include <stdio.h>

struct part{
  char name[124];
  long no;
  double price;
};

int main( )
{
  struct part board;
  struct part board2;

  strcpy(board.name,"I/O card");
  board.no = 127356;
  board.price = 99.50;

  board2 = board;          /* assign one structure to another. */

  printf("Product: %s\n", board.name);
  printf("Part No.: %ld\n", board.no);
  printf("Unit price: %.2f\n", board.price);

  printf("\n\n");
  printf("Board2 - Product: %s\n", board2.name);
  printf("Board2 - Part No.: %ld\n", board2.no);
  printf("Board2 - Unit price: %.2f\n", board2.price);

  return 0;
}


/*    OUTPUT: struct3.c

          Product: I/O card
          Part No.: 127356
          Unit price: 99.50


          Board2 - Product: I/O card
          Board2 - Part No.: 127356
          Board2 - Unit price: 99.50

*/
```

Ex:

```
/*     FILE: struct4.c     */

/* Structures are like basic data types. You can pass them
   to a function and the entire structure is passed.       */

#include <stdio.h>

struct part{
  char name[124];
  long no;
  double price;
};

void print_part(struct part p);

int main( )
{
  struct part board;
  struct part board2;

  strcpy(board.name,"I/O card");
  board.no = 127356;
  board.price = 99.50;

  board2 = board;          /* assign one structure to another. */

  print_part(board);       /* Print part structures with a function. */

  printf("\n\n");

  print_part(board2);

  return 0;
}

void print_part(struct part p)
{
  printf("Product: %s\n", p.name);
  printf("Part No.: %ld\n", p.no);
  printf("Unit price: %.2f\n", p.price);

  return;
}


/*    OUTPUT: struct4.c

          Product: I/O card
          Part No.: 127356
          Unit price: 99.50


          Product: I/O card
          Part No.: 127356
          Unit price: 99.50

*/
```

Ex:

```
/*     FILE: struct5.c     */

/* Arrays can be used with structures just like any other
   C data type.                                          */

#include <stdio.h>

#define SIZE 5

struct part{
  char name[124];
  long no;
  double price;
};

void print_part(struct part p);

int main( )
{
  struct part board;              /* One "part" */
  struct part inventory[SIZE];    /* Array to hold SIZE "part"s */

  int i;

  for(i=0; i < SIZE; i++){        /* Load the array of structures. */
    sprintf(board.name,"I/O card #%d", i);
    board.no = 127356 + i;
    board.price = 99.50 + i*3;

    inventory[i] = board;
  }

  for(i=0; i < SIZE; i++){        /* Display the array of structures. */
    print_part(inventory[i]);
    printf("\n");
  }

  return 0;
}

void print_part(struct part p)
{
  printf("Product: %s\n", p.name);
  printf("Part No.: %ld\n", p.no);
  printf("Unit price: %.2f\n", p.price);

  return;
}
```

cont…

```
/*    OUTPUT: struct5.c

          Product: I/O card #0
          Part No.: 127356
          Unit price: 99.50

          Product: I/O card #1
          Part No.: 127357
          Unit price: 102.50

          Product: I/O card #2
          Part No.: 127358
          Unit price: 105.50

          Product: I/O card #3
          Part No.: 127359
          Unit price: 108.50

          Product: I/O card #4
          Part No.: 127360
          Unit price: 111.50


*/
```

Ex:

```
/*     FILE: struct6.c     */

/* The address of a structure can be passed to a function
   just like any other C data type.                        */

#include <stdio.h>

#define SIZE 5

struct part{
  char name[124];
  long no;
  double price;
};

void print_part(struct part* p);

int main( )
{
  struct part board;              /* One "part" */
  struct part inventory[SIZE];    /* Array to hold SIZE "part"s */

  int i;

  for(i=0; i < SIZE; i++){        /* Load the array of structures. */
    sprintf(board.name,"I/O card #%d", i);
    board.no = 127356 + i;
    board.price = 99.50 + i*3;

    inventory[i] = board;
  }

  print_part(&board);             /* print_part( ) expects an address. */
  printf("\n");

  for(i=0; i < SIZE; i++){        /* Display the array of structures. */
    print_part(&inventory[i]);
    printf("\n");
  }

  return 0;
}

void print_part(struct part* p)
{
  printf("Product: %s\n", (*p).name);
  printf("Part No.: %ld\n", (*p).no);
  printf("Unit price: %.2f\n", (*p).price);

  return;
}
```

cont…

```
/*    OUTPUT: struct6.c

          Product: I/O card #4
          Part No.: 127360
          Unit price: 111.50

          Product: I/O card #0
          Part No.: 127356
          Unit price: 99.50

          Product: I/O card #1
          Part No.: 127357
          Unit price: 102.50

          Product: I/O card #2
          Part No.: 127358
          Unit price: 105.50

          Product: I/O card #3
          Part No.: 127359
          Unit price: 108.50

          Product: I/O card #4
          Part No.: 127360
          Unit price: 111.50


*/
```

Ex:

```
/*     FILE: struct7.c     */

/* The address of a structure can be passed to a function
   just like any other C data type.                       */

#include <stdio.h>

#define SIZE 5

struct part{
  char name[124];
  long no;
  double price;
};

void print_part(struct part* p);

int main( )
{
  struct part board;              /* One "part" */
  struct part inventory[SIZE];    /* Array to hold SIZE "part"s */

  int i;

  for(i=0; i < SIZE; i++){        /* Load the array of structures. */
    sprintf(board.name,"I/O card #%d", i);
    board.no = 127356 + i;
    board.price = 99.50 + i*3;

    inventory[i] = board;
  }

  print_part(&board);             /* print_part( ) expects an address. */
  printf("\n");

  for(i=0; i < SIZE; i++){        /* Display the array of structures. */
    print_part(inventory + i);    /* Don't need to ask for the address  */
    printf("\n");                 /* ... since an array name is already */
  }                               /* ... an address.                    */

  return 0;
}

void print_part(struct part* p)   /* -> operator simplifies access thru */
{                                 /* ... a pointer.                     */
  printf("Product: %s\n", p->name);
  printf("Part No.: %ld\n", p->no);
  printf("Unit price: %.2f\n", p->price);

  return;
}
```

cont…

```
/*    OUTPUT: struct7.c

          Product: I/O card #4
          Part No.: 127360
          Unit price: 111.50

          Product: I/O card #0
          Part No.: 127356
          Unit price: 99.50

          Product: I/O card #1
          Part No.: 127357
          Unit price: 102.50

          Product: I/O card #2
          Part No.: 127358
          Unit price: 105.50

          Product: I/O card #3
          Part No.: 127359
          Unit price: 108.50

          Product: I/O card #4
          Part No.: 127360
          Unit price: 111.50


*/
```

Ex:

```
/*     FILE:  struct8.c     */

/* Reading data into a structure.

   More functions.                        */

#include <stdio.h>

#define SIZE 5

struct part{
  char name[124];
  long no;
  double price;
};

void print_part(struct part* p);
struct part read_part(void);

int main( )
{
  struct part inventory[SIZE];    /* Array to hold SIZE "part"s */

  int i;

  for(i=0; i < SIZE; i++){        /* Load the array of structures. */
    inventory[i] = read_part( );
  }

  for(i=0; i < SIZE; i++){        /* Display the array of structures. */
    print_part(inventory + i);    /* Don't need to ask for the address  */
    printf("\n");                 /* ... since an array name is already */
  }                               /* ... an address.                    */

  return 0;
}

void print_part(struct part* p)   /* -> operator simplifies access thru */
{                                 /* ... a pointer.                     */
  printf("Product: %s\n", p->name);
  printf("Part No.: %ld\n", p->no);
  printf("Unit price: %.2f\n", p->price);

  return;
}

struct part read_part(void)  /* returns the structure. */
{
  struct part temp;

  gets(temp.name);
  scanf("%ld", &temp.no);
  scanf("%lf", &temp.price);
  getchar( );                  /* Strip trailing newline */

  return temp;
}
```

cont…

```
/*    OUTPUT: struct8.c

          Product: I/O card #0
          Part No.: 127356
          Unit price: 99.50

          Product: Network card #1
          Part No.: 127357
          Unit price: 102.50

          Product: USB card #2
          Part No.: 127358
          Unit price: 105.50

          Product: Fax card #3
          Part No.: 127359
          Unit price: 108.50

          Product: Modem card #4
          Part No.: 127360
          Unit price: 111.50


       INPUT:

          I/O card #0
          127356
          99.50
          Network card #1
          127357
          102.50
          USB card #2
          127358
          105.50
          Fax card #3
          127359
          108.50
          Modem card #4
          127360
          111.50

*/
```

Ex:

```
/*     FILE:  struct9.c     */

/* Reading data into a structure.

   Passing the address to store into.  */

#include <stdio.h>

#define SIZE 5

struct part{
  char name[124];
  long no;
  double price;
};

void print_part(struct part* p);
void read_part(struct part*);

int main( )
{
  struct part inventory[SIZE];    /* Array to hold SIZE "part"s */

  int i;

  for(i=0; i < SIZE; i++){        /* Load the array of structures. */
    read_part(inventory+i);
  }

  for(i=0; i < SIZE; i++){        /* Display the array of structures. */
    print_part(inventory + i);    /* Don't need to ask for the address  */
    printf("\n");                 /* ... since an array name is already */
  }                               /* ... an address.                    */

  return 0;
}

void print_part(struct part* p)   /* -> operator simplifies access thru */
{                                 /* ... a pointer.                     */
  printf("Product: %s\n", p->name);
  printf("Part No.: %ld\n", p->no);
  printf("Unit price: %.2f\n", p->price);

  return;
}

void read_part(struct part* temp)  /* returns the structure. */
{
  gets(temp->name);
  scanf("%ld", &temp->no);
  scanf("%lf", &temp->price);
  getchar( );                 /* Strip trailing newline */

  return;
}
```

cont…

```
/*    OUTPUT: struct9.c

          Product: I/O card #0
          Part No.: 127356
          Unit price: 99.50

          Product: Network card #1
          Part No.: 127357
          Unit price: 102.50

          Product: USB card #2
          Part No.: 127358
          Unit price: 105.50

          Product: Fax card #3
          Part No.: 127359
          Unit price: 108.50

          Product: Modem card #4
          Part No.: 127360
          Unit price: 111.50


       INPUT:

          I/O card #0
          127356
          99.50
          Network card #1
          127357
          102.50
          USB card #2
          127358
          105.50
          Fax card #3
          127359
          108.50
          Modem card #4
          127360
          111.50

*/
```

Ex:

```
/*     FILE:  struct10.c     */

/* Reading data into a structure.

   Monitor input for success.  */

#include <stdio.h>

#define SIZE 5

struct part{
  char name[124];
  long no;
  double price;
};

void print_part(struct part* p);
int read_part(struct part*);

int main( )
{
  struct part inventory[SIZE];    /* Array to hold SIZE "part"s */

  int i;
  int count = 0;

  for(i=0; i < SIZE && read_part(inventory+i) != EOF; i++)       /* Load the array of
structures. */
     count++;

  for(i=0; i < count; i++){        /* Display the array of structures. */
    print_part(inventory + i);    /* Don't need to ask for the address  */
    printf("\n");                 /* ... since an array name is already */
  }                               /* ... an address.                    */

  return 0;
}

void print_part(struct part* p)   /* -> operator simplifies access thru */
{                                 /* ... a pointer.                     */
  printf("Product: %s\n", p->name);
  printf("Part No.: %ld\n", p->no);
  printf("Unit price: %.2f\n", p->price);

  return;
}

int read_part(struct part* temp)  /* returns the structure. */
{
  int result = 1;

  if(gets(temp->name) == NULL)
    result = EOF;
  if(result == 1 && scanf("%ld", &temp->no) != 1)
    result = EOF;
  if(result == 1 && scanf("%lf", &temp->price) != 1)
    result = EOF;
  if(result == 1)
    getchar( );                  /* Strip trailing newline */

  return result;
}
```

cont…

```
/*    OUTPUT: struct10.c

          Product: I/O card #0
          Part No.: 127356
          Unit price: 99.50

          Product: Network card #1
          Part No.: 127357
          Unit price: 102.50

          Product: USB card #2
          Part No.: 127358
          Unit price: 105.50

          Product: Fax card #3
          Part No.: 127359
          Unit price: 108.50

          Product: Modem card #4
          Part No.: 127360
          Unit price: 111.50


        INPUT:

          I/O card #0
          127356
          99.50
          Network card #1
          127357
          102.50
          USB card #2
          127358
          105.50
          Fax card #3
          127359
          108.50
          Modem card #4
          127360
          111.50

          Product: Network card #1
          Part No.: 127357
          Unit price: 102.50

          Product: USB card #2
          Part No.: 127358
          Unit price: 105.50


        INPUT:

          Network card #1
          127357
          102.50
          USB card #2
          127358
          105.50
*/
```

Ex:

```
/*     FILE:  struct11.c     */

/* Reading data into a structure.

   Monitor input for success.

   Capitalize on for loop features and comma operator*/

#include <stdio.h>

#define SIZE 5

struct part{
  char name[124];
  long no;
  double price;
};

void print_part(struct part* p);
int read_part(struct part*);

int main( )
{
  struct part inventory[SIZE];    /* Array to hold SIZE "part"s */

  int i;
  int count;
                                  /* Load the array of structures. */
  for(i=0, count=0; i < SIZE && read_part(inventory+i) != EOF; i++, count++)
    ;

  for(i=0; i < count; i++){        /* Display the array of structures. */
    print_part(inventory + i);    /* Don't need to ask for the address  */
    printf("\n");                 /* ... since an array name is already */
  }                               /* ... an address.                    */

  return 0;
}

void print_part(struct part* p)   /* -> operator simplifies access thru */
{                                 /* ... a pointer.                     */
  printf("Product: %s\n", p->name);
  printf("Part No.: %ld\n", p->no);
  printf("Unit price: %.2f\n", p->price);

  return;
}

int read_part(struct part* temp)  /* returns the structure. */
{
  int result = 1;

  if(gets(temp->name) == NULL)
    result = EOF;
  if(result == 1 && scanf("%ld", &temp->no) != 1)
    result = EOF;
  if(result == 1 && scanf("%lf", &temp->price) != 1)
    result = EOF;
  if(result == 1)
    getchar( );                  /* Strip trailing newline */

  return result;
}
```

cont…

```
/*    OUTPUT: struct11.c

          Product: I/O card #0
          Part No.: 127356
          Unit price: 99.50

          Product: Network card #1
          Part No.: 127357
          Unit price: 102.50

          Product: USB card #2
          Part No.: 127358
          Unit price: 105.50

          Product: Fax card #3
          Part No.: 127359
          Unit price: 108.50

          Product: Modem card #4
          Part No.: 127360
          Unit price: 111.50


        INPUT:

          I/O card #0
          127356
          99.50
          Network card #1
          127357
          102.50
          USB card #2
          127358
          105.50
          Fax card #3
          127359
          108.50
          Modem card #4
          127360
          111.50

          Product: Network card #1
          Part No.: 127357
          Unit price: 102.50

          Product: USB card #2
          Part No.: 127358
          Unit price: 105.50


        INPUT:

          Network card #1
          127357
          102.50
          USB card #2
          127358
          105.50
*/
```

Ex:

```
/*     FILE: struct12.c     */

/* Binary file I/O - Reading/writing structs  */

#include <stdio.h>

#define SIZE 5

struct part{
  char name[124];
  long no;
  double price;
};

void print_part(const struct part * const);

int main( )
{
  struct part board;              /* One "part" */
  struct part inventory[SIZE];    /* Array to hold SIZE "part"s */

  FILE * fp;
  char * filename = "structBin.bin";
  int i;

  for(i=0; i < SIZE; i++){        /* Load the array of structures. */
    sprintf(board.name,"I/O card #%d", i);
    board.no = 127356 + i;
    board.price = 99.50 + i*3;

    inventory[i] = board;
  }

  fp = fopen(filename,"w");

  if(fp != NULL){
    for(i=0; i < SIZE; i++)         /* Write the structures. */
      fwrite(inventory + i, sizeof(struct part), 1, fp);

    fclose(fp);

    fp = fopen(filename,"r");

    if(fp != NULL){
      for(i=SIZE-1; i >= 0; i--)         /* Read the structures. */
        fread(inventory + i, sizeof(struct part), 1, fp);

      fclose(fp);

      for(i=0; i < SIZE; i++){      /* Display the array of structures. */
        print_part(inventory + i);
        printf("\n");
      }
    }
    else
      fprintf(stderr,"Unable to open file %s for read.\n", filename);
  }
  else
    fprintf(stderr,"Unable to open file %s for write.\n", filename);

  return 0;
}
```

cont…

```
void print_part(const struct part * const p)  /* Display function */
{
  printf("Product: %s\n", p->name);
  printf("Part No.: %ld\n", p->no);
  printf("Unit price: %.2f\n", p->price);

  return;
}


/*    OUTPUT: struct12.c

          Product: I/O card #4
          Part No.: 127360
          Unit price: 111.50

          Product: I/O card #3
          Part No.: 127359
          Unit price: 108.50

          Product: I/O card #2
          Part No.: 127358
          Unit price: 105.50

          Product: I/O card #1
          Part No.: 127357
          Unit price: 102.50

          Product: I/O card #0
          Part No.: 127356
          Unit price: 99.50


*/
```

Ex:

```
/*     FILE: struct13.c     */

/* Binary file I/O - Reading/writing structs

   - writing sets/blocks of data              */

#include <stdio.h>

#define SIZE 5

struct part{
  char name[124];
  long no;
  double price;
};

void print_part(const struct part * const);

int main( )
{
  struct part board;              /* One "part" */
  struct part inventory[SIZE];    /* Array to hold SIZE "part"s */

  FILE * fp;
  char * filename = "structBin.bin";
  int i;

  fp = fopen(filename,"w");

  if(fp != NULL){
    for(i=0; i < SIZE; i++){        /* Write the structures. */
      sprintf(board.name,"I/O card #%d", i);
      board.no = 127356 + i;
      board.price = 99.50 + i*3;

      fwrite(&board, sizeof(struct part), 1, fp);
    }

    fclose(fp);

    fp = fopen(filename,"r");

    if(fp != NULL){     /* Read the structures. */
      fread(inventory, sizeof(struct part), SIZE, fp);

      fclose(fp);

      for(i=0; i < SIZE; i++){      /* Display the array of structures. */
        print_part(inventory + i);
        printf("\n");
      }
    }
    else
      fprintf(stderr,"Unable to open file %s for read.\n", filename);
  }
  else
    fprintf(stderr,"Unable to open file %s for write.\n", filename);

  return 0;
}
```

cont…

```
void print_part(const struct part * const p)  /* Display function */
{
  printf("Product: %s\n", p->name);
  printf("Part No.: %ld\n", p->no);
  printf("Unit price: %.2f\n", p->price);

  return;
}


/*    OUTPUT: struct13.c

          Product: I/O card #0
          Part No.: 127356
          Unit price: 99.50

          Product: I/O card #1
          Part No.: 127357
          Unit price: 102.50

          Product: I/O card #2
          Part No.: 127358
          Unit price: 105.50

          Product: I/O card #3
          Part No.: 127359
          Unit price: 108.50

          Product: I/O card #4
          Part No.: 127360
          Unit price: 111.50


*/
```

ENUMERATED TYPES

- enumerated types can be created to give symbolic names to integer values and enlist the compiler for type checking.

Ex:

```
/*     FILE: enum.c     */

/* Enumerated types give symbolic constants with type
           checking.                                          */

#include <stdio.h>

enum GPA{F,D,C,B,A};

int main( )
{
          enum GPA grade;

          grade = A;
          printf("Score for an 'A': %d\n", grade);

          grade = B;
          printf("Score for an 'B': %d\n", grade);

          grade = C;
          printf("Score for an 'C': %d\n", grade);

          grade = D;
          printf("Score for an 'D': %d\n", grade);

          grade = F;
          printf("Score for an 'F': %d\n", grade);

          return 0;
}


/*    OUTPUT: enum.c

          Score for an 'A': 4
          Score for an 'B': 3
          Score for an 'C': 2
          Score for an 'D': 1
          Score for an 'F': 0

*/
```

Ex:

```
/*     FILE: enum2.c     */

/* Enumerated types give symbolic constants with type
           checking.                                          */

#include <stdio.h>

enum GPA{F,D,C,B,A};

int main( )
{
          enum GPA grade;

          grade = A;
          printf("Score for an 'A': %d\n", grade);

          grade = Q;
          printf("Score for an 'Q': %d\n", grade);

          return 0;
}



/*    OUTPUT: enum2.c

          enum2.c: In function `main':
          enum2.c:15: `Q' undeclared (first use in this function)
          enum2.c:15: (Each undeclared identifier is reported only once
          enum2.c:15: for each function it appears in.)

*/
```

Ex:

```
/*     FILE: enum3.c     */

/* Enumerated types give symbolic constants with type
           checking.                                          */

#include <stdio.h>

enum Direction{North=1, South, East, West};

int main( )
{
          enum Direction dir;

          dir = North;
          printf("Direction 'North': %d\n", dir);

          dir = South;
          printf("Direction 'South': %d\n", dir);

          dir = East;
          printf("Direction  'East': %d\n", dir);

          dir = West;
          printf("Direction  'West': %d\n", dir);

          return 0;
}


/*    OUTPUT: enum3.c

          Direction 'North': 1
          Direction 'South': 2
          Direction  'East': 3
          Direction  'West': 4

*/
```

Ex:

```
/*     FILE: enum4.c     */

/* Enumerated types give symbolic constants with type
           checking.                                          */

#include <stdio.h>

enum Direction{North=1, South, East, West};

int main( )
{
          enum Direction dir;

          dir = South;

          switch(dir)
          {
            case North:
            printf("Direction %d is %s\n", dir, "North");
            break;

            case South:
            printf("Direction %d is %s\n", dir, "South");
            break;

            case East:
            printf("Direction %d is %s\n", dir, "East");
            break;

            case West:
            printf("Direction %d is %s\n", dir, "West");
            break;
  }

          return 0;
}


/*    OUTPUT: enum4.c

          Direction 2 is South

*/
```

Ex:

```
/*     FILE: enum5.c     */

/* Enumerated types give symbolic constants with type
           checking.                                          */

#include <stdio.h>

enum Direction{North=1, South, East, West};
char * directionString(enum Direction);

int main( )
{
          enum Direction dir;

          dir = East;
          printf("Direction %d is %s\n",
                         dir, directionString(dir));

          return 0;
}

char * directionString(enum Direction d)
{
  static char * dirs[ ] = { "North",
                            "South",
                            "East",
                            "West" };
          return dirs[d-1];
}


/*    OUTPUT: enum5.c

          Direction 3 is East

*/
```

UNIONS

- A union allows multiple mappings of the same piece of storage.
- Only one is in effect at any given time, but the same piece of memory can be utilized differently using a different mapping defined by the union.

Ex:

```
/*     FILE: union.c     */

/* A union that be either an array of
   ints or an array of floats, as
   needed.                              */

#include <stdio.h>
union intFloatArray{
  int iarray[5];
  float farray[5];
};

int main( )
{
  union intFloatArray ar;
  int i;

  for(i=0; i<5; i++)
    ar.iarray[i] = i*11;

  for(i=0; i<5; i++)
    printf("int[%d] = %d\n", i, ar.iarray[i]);

  for(i=0; i<5; i++)
    ar.farray[i] = i*1.1;

  for(i=0; i<5; i++)
    printf("float[%d] = %f\n", i, ar.farray[i]);

  printf("size of union int_float_array = %d\n",
                    sizeof(union intFloatArray));
  printf("size of ar = %d\n",sizeof(ar));

  return 0;
}


/*    OUTPUT: union.c

          int[0] = 0
          int[1] = 11
          int[2] = 22
          int[3] = 33
          int[4] = 44
          float[0] = 0.000000
          float[1] = 1.100000
          float[2] = 2.200000
          float[3] = 3.300000
          float[4] = 4.400000
          size of union int_float_array = 20
          size of ar = 20

*/
```

Ex:

```
/*     FILE: union2.c     */

/* A union that allows byte-wise inspection of
   a storage location.                          */

#include <stdio.h>
union intFloatArrayByte{
  int i;
  float f;
  unsigned char byte[4];
};

int main( )
{
  union intFloatArrayByte map;
  int i;

  map.i = 7;

  printf("int = %d\n", map.i);

  for(i=0; i<4; i++)
    printf("char[%d] = %X\n", i, map.byte[i]);

  return 0;
}


/*    OUTPUT: union2.c

          int = 7
          char[0] = 7
          char[1] = 0
          char[2] = 0
          char[3] = 0

*/
```

Ex:

```
/*     FILE: union3.c     */

/* A union that allows byte-wise inspection of
   a storage location.                          */

#include <stdio.h>
union intFloatArrayByte{
  int i;
  float f;
  unsigned char byte[4];
};

int main( )
{
  union intFloatArrayByte map;
  int i;

  map.f = 7.0;

  printf("float = %f\n", map.f);

  for(i=0; i<4; i++)
    printf("char[%d] = %X\n", i, map.byte[i]);

  return 0;
}


/*    OUTPUT: union3.c

          float = 7.000000
          char[0] = 0
          char[1] = 0
          char[2] = E0
          char[3] = 40

*/
```

TYPEDEF

- C allows a type name to be defined using the *typedef* mechanism.
- The type defined used in situations where a standard C type would be used.
- *typedef* is often used to shorten the *struct name* type associated with a structure definition.

Ex:

```
/*     FILE: struct14.c     */

/* Typedef - simplified naming */

#include <stdio.h>

#define SIZE 5

struct part{
  char name[124];
  long no;
  double price;
};

typedef struct part part;     /* part becomes the type of "struct part" */

void print_part(const struct part * const);

int main( )
{
  part board;              /* One "part" */
  part inventory[SIZE];    /* Array to hold SIZE "part"s */

  FILE * fp;
  char * filename = "structBin.bin";
  int i;

  fp = fopen(filename,"w");

  if(fp != NULL){
    for(i=0; i < SIZE; i++){        /* Write the structures. */
      sprintf(board.name,"I/O card #%d", i);
      board.no = 127356 + i;
      board.price = 99.50 + i*3;

      fwrite(&board, sizeof(part), 1, fp);
    }

    fclose(fp);

    fp = fopen(filename,"r");
```

cont…

```
    if(fp != NULL){     /* Read the structures. */
      fread(inventory, sizeof(part), SIZE, fp);

      fclose(fp);

      for(i=0; i < SIZE; i++){      /* Display the array of structures. */
        print_part(inventory + i);
        printf("\n");
      }
    }
    else
      fprintf(stderr,"Unable to open file %s for read.\n", filename);
  }
  else
    fprintf(stderr,"Unable to open file %s for write.\n", filename);

  return 0;
}

void print_part(const part * const p)  /* Display function */
{
  printf("Product: %s\n", p->name);
  printf("Part No.: %ld\n", p->no);
  printf("Unit price: %.2f\n", p->price);

  return;
}


/*    OUTPUT: struct14.c

          Product: I/O card #0
          Part No.: 127356
          Unit price: 99.50

          Product: I/O card #1
          Part No.: 127357
          Unit price: 102.50

          Product: I/O card #2
          Part No.: 127358
          Unit price: 105.50

          Product: I/O card #3
          Part No.: 127359
          Unit price: 108.50

          Product: I/O card #4
          Part No.: 127360
          Unit price: 111.50


*/
```

BIT OPERATORS

- C has a set of operators that can be used to perform bit-level operations.
- There are a pair of shift operators, and bitwise OR, AND, XOR, and NOT.
- All the operators are applied to each bit in the entire bit pattern. That is, all bits get shifted, all bits get ANDed, etc.

Ex:

```
/*     FILE: bitop.c     */

/* Exercises several C bit operators */

#include <stdio.h>

void setOneBit(int* ptr, int bit);
void setBit(int* ptr, int bit);
void clearBit(int* ptr, int bit);

int main( )
{
  int x;

  setOneBit(&x, 3);
  printf("x = %8.8X\n", x);

  clearBit(&x, 3);
  printf("x = %8.8X\n", x);

  x = 3;
  printf("\nx = %8.8X\n", x);
  setBit(&x, 3);
  printf("x = %8.8X\n", x);

  clearBit(&x, 3);
  printf("x = %8.8X\n", x);

  return 0;
}

void setOneBit(int* ptr, int bit)  /* sets the specified bit on,  */
{                                  /* ... all others will be off. */
    *ptr = 1 << bit;
}

void setBit(int* ptr, int bit) /* sets specified bit on and    */
{                              /* ... leaves all others as-is. */
    *ptr = (*ptr)| (1 << bit);
}

void clearBit(int* ptr, int bit) /* turns specified bit off. */
{
    *ptr = (*ptr)&(~(1 << bit));
}
```

cont…

```
/*    OUTPUT: bitop.c

          x = 00000008
          x = 00000000

          x = 00000003
          x = 0000000B
          x = 00000003

*/
```

Ex:

```
/*     FILE: bitop2.c     */

/* Exercises several C bit operators

   Don't waste the return value.      */

#include <stdio.h>

int setOneBit(int* ptr, int bit);
int setBit(int* ptr, int bit);
int clearBit(int* ptr, int bit);

int main( )
{
  int x;

  printf("x = %8.8X\n", setOneBit(&x, 3));

  printf("x = %8.8X\n", clearBit(&x, 3));

  printf("\nx = %8.8X\n", x = 3);

  printf("x = %8.8X\n", setBit(&x, 3));

  printf("x = %8.8X\n", clearBit(&x, 3));

  return 0;
}

int setOneBit(int* ptr, int bit)   /* sets the specified bit on,  */
{                                  /* ... all others will be off. */
    *ptr = 1 << bit;

    return *ptr;
}

int setBit(int* ptr, int bit)  /* sets specified bit on and    */
{                                /* ... leaves all others as-is. */
    *ptr = (*ptr)| (1 << bit);

    return *ptr;
}

int clearBit(int* ptr, int bit) /* turns specified bit off. */
{
    *ptr = (*ptr)&(~(1 << bit));

    return *ptr;
}


/*    OUTPUT: bitop2.c

          x = 00000008
          x = 00000000

          x = 00000003
          x = 0000000B
          x = 00000003

*/
```

DYNAMIC MEMORY ALLOCATION

- Up until now, the storage requirements of a C program needed to be established at compile time. Variables needed to be defined so that their storage requirements would be known. Arrays needed to be sized so that their storage requirements would be known.
- Dynamic memory allocation allows storage requirements to be determined at run-time.
- When the requirements are known, a request is made for the required amount of storage and the program can then proceed. This allows the program to tailor its storage use to exactly fit its needs during each run, or at any given point in time during a run.
- There is a cost. There is overhead incurred while the request for storage is being met.
- The key to dynamic memory allocation is pointers and the appropriate allocation function.
- *malloc( )* is the basic m-emory alloc-ation function. *Malloc* is told how many bytes of storage are needed and if the allocation can be satisfied *malloc* returns the address of the storage. If the allocation fails, *NULL* is returned.
- Dynamically allocated memory can and should be deallocated using *free( ).*

Ex:

```
/*     FILE: dynamic1.c     */

/* Dynamic memory allocation using malloc( ).
   Note: #include stdlib.h for memory allocation
         functions.                              */

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

int main( )
{
  int* ptr;
  int size, i;

  printf("Please enter number of integers to be read: ");
  scanf("%d", &size);

  ptr = malloc(size * sizeof(int));   /* allocation is requested in bytes */

                                      /* Once the storage is allocated, ptr
                                         can be treated like an array.    */
  for(i=0; i<size; i++){
    printf("Enter integer %d of %d: ", i+1, size);
    scanf("%d", &ptr[i]);
  }

  for(i=0; i<size; i++)
    printf("ptr[%d] = %d\n", i, ptr[i]);

  free(ptr);

  return 0;
}


/*    OUTPUT: dynamic1.c

          Please enter number of integers to be read: 5
          Enter integer 1 of 5: 11
          Enter integer 2 of 5: 22
          Enter integer 3 of 5: 33
          Enter integer 4 of 5: 44
          Enter integer 5 of 5: 55
          ptr[0] = 11
          ptr[1] = 22
          ptr[2] = 33
          ptr[3] = 44
          ptr[4] = 55

*/
```

Ex:

```
/*     FILE: dynamic2.c     */

/* Dynamic memory allocation using malloc( ).
   Note: #include stdlib.h for memory allocation
         functions.

   Error handling for dynamic memory allocation. */

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

int main( )
{
  int* ptr;
  int size, i;

  printf("Please enter number of integers to be read: ");
  scanf("%d", &size);

  ptr = malloc(size * sizeof(int));   /* allocation is requested in bytes */

                                      /* Once the storage is allocated, ptr
                                         can be treated like an array.    */
  if(ptr != NULL){
    for(i=0; i<size; i++){
      printf("Enter integer %d of %d: ", i+1, size);
      scanf("%d", &ptr[i]);
    }

    for(i=0; i<size; i++)
      printf("ptr[%d] = %d\n", i, ptr[i]);

    free(ptr);
  }
  else
    printf("FAILURE: Unable to allocate storage.\n");

  return 0;
}


/*    OUTPUT: dynamic2.c

          Please enter number of integers to be read: 5
          Enter integer 1 of 5: 511
          Enter integer 2 of 5: 522
          Enter integer 3 of 5: 533
          Enter integer 4 of 5: 544
          Enter integer 5 of 5: 555
          ptr[0] = 511
          ptr[1] = 522
          ptr[2] = 533
          ptr[3] = 544
          ptr[4] = 555

*/
```

Ex:

```
/*     FILE: max_cnt.c     */

/*
   Loads an array with up to SIZE values.
   Finds the max and the count of values
   greater than 90.
*/

#include <stdio.h>
#define SIZE 50

int main( )
{
  int scores[SIZE];
  int i, n, max, a_count;

  /* Get number of values to read */
  printf("Please enter number of scores (%d or less): ", SIZE);
  scanf("%d", &n);

  /* Validate number entered by user. */
  if (n<=SIZE && n>0){
    /* Read score values into array */
    for(i=0; i<n; i++)
    {
      printf("Enter value %d of %d: ", i+1, n);
      scanf("%d", &scores[i]);
    }

    /* Find maximum of values read. */
    max = scores[0];
    for(i=1; i<n; i++)
    {
      if (scores[i] > max)
        max = scores[i];
    }

    printf("Max score = %d\n", max);

    /* Count number of A's, scores greater than 90 */
    a_count = 0;
    for(i=0; i<n; i++)
    {
      if (scores[i] > 90)
        a_count++;
    }

    printf("A's = %d\n", a_count);
  }

  return 0;

}


/*    OUTPUT: max_cnt.c

          Please enter number of scores (50 or less): 4
          Enter value 1 of 4: 75
          Enter value 2 of 4: 85
          Enter value 3 of 4: 95
          Enter value 4 of 4: 92
          Max score = 95
          A's = 2

*/
```

Ex:

```
/*     FILE: dynamic3.c     */

/* Prompts the user for the number of scores
   and uses malloc( ) to allocate the appropriate
   amount of storage.

   Finds the max and the count of values
   greater than 90.                              */

#include <stdio.h>
#include <limits.h>
#include <stdlib.h>

int main( )
{
  int* scores;             /* tracks malloc-ed score storage */
  int i, n, max, a_count;

  /* Get number of values to malloc( ) and read */
  printf("Please enter number of scores: ");
  scanf("%d", &n);

  /* Validate number entered by user. */
  if (n<=INT_MAX && n>0){
    /* Allocate the appropriate number of bytes */
    scores = (int *)malloc(sizeof(int)*n);

    if (scores != NULL){
      /* Read score values into array */
      for(i=0; i<n; i++)
      {
        printf("Enter value %d of %d: ", i+1, n);
        scanf("%d", &scores[i]);
      }

      /* Find maximum of values read. */
      max = scores[0];
      for(i=1; i<n; i++)
      {
        if (scores[i] > max)
          max = scores[i];
      }

      printf("Max score = %d\n", max);

      /* Count number of A's, scores greater than 90 */
      a_count = 0;
      for(i=0; i<n; i++)
      {
        if (scores[i] > 90)
          a_count++;
      }

      printf("A's = %d\n", a_count);

      free(scores);
    }
    else
      printf("Malloc( ) request failed!\n");
  }
  else
    printf("Invalid allocation request: %d\n", n);

  return 0;

}
```

cont…

```
/*    OUTPUT: dynamic3.c

          Please enter number of scores: 4
          Enter value 1 of 4: 75
          Enter value 2 of 4: 85
          Enter value 3 of 4: 95
          Enter value 4 of 4: 92
          Max score = 95
          A's = 2

          Please enter number of scores: 7
          Enter value 1 of 7: 75
          Enter value 2 of 7: 76
          Enter value 3 of 7: 85
          Enter value 4 of 7: 86
          Enter value 5 of 7: 92
          Enter value 6 of 7: 97
          Enter value 7 of 7: 99
          Max score = 99
          A's = 3

*/
```

Ex:

```
/*     FILE: dynamic4.c     */

/*
   Prompts the user for the number of values
   and uses malloc( ) to allocate the appropriate
   amount of storage.

   Passes the array/allocation to functions
   for reading, displaying and for sorting.       */

#include <stdio.h>
#include <stdlib.h>
#include <limits.h>

int * selectionSort(int [ ], int);
int * printArray(int [ ], int);
int * readArray(int [ ], int);

int main(int argc, char *argv[ ])
{
  int *ar;
  int n;

  /* Get number of values to malloc( ) and read */
  printf("Please enter number of values: ");
  scanf("%d", &n);

  /* Validate number entered by user. */
  if (n<=INT_MAX && n>0){
    /* Allocate the appropriate number of bytes */
    ar = (int *)malloc(sizeof(int)*n);

    if (ar != NULL){

      readArray(ar, n);

      printf("\nOriginal array:\n");
      printArray(ar, n);

      selectionSort(ar, n);

      printf("\nSorted array:\n");
      printArray(ar, n);

      free(ar);
    }
    else
      printf("Malloc( ) request failed!\n");
  }
  else
    printf("Invalid allocation request: %d\n", n);

  return 0;
}
```

cont…

```
int * selectionSort(int array[ ], int size)
{
  int pass,item,position,temp;

  /* Selection-sort the values read in. */
  for(pass=0; pass<size-1; pass++){
    position = pass;
    for(item=pass+1; item<size; item++)
      if (array[position] < array[item])
        position = item;
    if(pass != position){
      temp = array[pass];
      array[pass] = array[position];
      array[position] = temp;
    }
  }

  return array;
}

int * printArray(int a[ ], int s)
{
  int i;

  for(i=0; i<s; i++)  /* display values in array */
     printf("%d\n", a[i]);

  return a;
}

int * readArray(int a[ ], int s)
{
  int i;
        /* Read score values into array */
  for(i=0; i<s; i++)
  {
    printf("Enter value %d of %d: ", i+1, s);
    scanf("%d", &a[i]);
  }

  return a;
}


/*    OUTPUT: dynamic4.c

          Please enter number of values: 4
          Enter value 1 of 4: 75
          Enter value 2 of 4: 85
          Enter value 3 of 4: 95
          Enter value 4 of 4: 92

          Original array:
          75
          85
          95
          92

          Sorted array:
          95
          92
          85
          75
```

cont…

```
Please enter number of values: 7
Enter value 1 of 7: 75
Enter value 2 of 7: 76
Enter value 3 of 7: 85
Enter value 4 of 7: 86
Enter value 5 of 7: 92
Enter value 6 of 7: 97
Enter value 7 of 7: 99

Original array:
75
76
85
86
92
97
99

Sorted array:
99
97
92
86
85
76
75

*/
```

DYNAMIC MULTIDIMENSIONAL ARRAYS

- Multidimensional arrays can be allocated dynamically.
- Pointers of the correct type must be defined in order to utilize the multidimensional array using standard array notation.
- Only the first dimension of a dynamic multidimensional array can be variable.
- *Truly dynamic multidimensional arrays can be created; but then the compiler cannot be as helpful with the offsets computed when indexing. The programmer is therefore completely responsible for computing positions from indices. (We will not look at these types of arrays here.)*

Ex:

```
/*     FILE: dynamic5.c     */
/*
   Dynamically allocating a 2-D array.

   Notice the pointer definitions and the
   cast from malloc.
                                          */
#include <stdio.h>
#include <stdlib.h>
#include <limits.h>

void printArray(int ar[ ][2], int s);

int main(int argc, char *argv[ ])
{
  int (*ar)[2];
  int rows, r, c;

  /* Get number of rows for the n x 2 2-D array */
  printf("Please enter number of rows: ");
  scanf("%d", &rows);

  /* Validate number entered by user. */
  if (rows<=INT_MAX && rows>0){
    /* Allocate the appropriate number of bytes */
    ar = (int (*)[2])malloc(sizeof(int)*rows * 2);

    if (ar != NULL){
      for(r=0; r<rows; r++)
        for(c=0; c<2; c++)
          ar[r][c] = (2*r) + c;    /* Use the 2-D array */

      printArray(ar, rows);

      free(ar);
    }
    else
      printf("Malloc( ) request failed!\n");
  }
  else
    printf("Invalid allocation request: %d\n", rows);

  return 0;
}

void printArray(int ar[ ][2], int rows)
{
  int r, c;

  printf("           ");
  for(c=0; c<2; c++)
    printf(" [ ][%d]", c);
  printf("\n");

  for(r=0; r<rows; r++)
  {
    printf("ar[%d][ ] =", r);
    for(c=0; c<2; c++)
    {
      printf("   %3d ", ar[r][c]);
    }
    printf("\n");
  }

  return;
}
```

cont…

```
/*    OUTPUT: dynamic5.c

          Please enter number of rows: 3
                       [ ][0] [ ][1]
          ar[0][ ] =     0      1
          ar[1][ ] =     2      3
          ar[2][ ] =     4      5

          Please enter number of rows: 7
                       [ ][0] [ ][1]
          ar[0][ ] =     0      1
          ar[1][ ] =     2      3
          ar[2][ ] =     4      5
          ar[3][ ] =     6      7
          ar[4][ ] =     8      9
          ar[5][ ] =    10     11
          ar[6][ ] =    12     13

*/
```

Ex:

```
/*     FILE: dynamic6.c     */

/*
   Dynamically allocating a 2-D array.

   Notice the pointer definitions and the
   cast from malloc.
                                        */
#include <stdio.h>
#include <stdlib.h>
#include <limits.h>

#define COLUMNS 4

void printArray(int ar[ ][COLUMNS], int s);

int main(int argc, char *argv[ ])
{
  int (*ar)[COLUMNS];
  int rows, r, c;

  /* Get number of rows for the n x COLUMNS 2-D array */
  printf("Please enter number of rows: ");
  scanf("%d", &rows);

  /* Validate number entered by user. */
  if (rows<=INT_MAX && rows>0){
    /* Allocate the appropriate number of bytes */
    ar = (int (*)[COLUMNS])malloc(sizeof(int)*rows * COLUMNS);

    if (ar != NULL){
      for(r=0; r<rows; r++)
        for(c=0; c<COLUMNS; c++)
          ar[r][c] = (COLUMNS*r) + c;    /* Use the 2-D array */

      printArray(ar, rows);

      free(ar);
    }
    else
      printf("Malloc( ) request failed!\n");
  }
  else
    printf("Invalid allocation request: %d\n", rows);

  return 0;
}
```

cont…

```
void printArray(int ar[ ][COLUMNS], int rows)
{
  int r, c;

  printf("           ");
  for(c=0; c<COLUMNS; c++)
    printf(" [ ][%d]", c);
  printf("\n");

  for(r=0; r<rows; r++)
  {
    printf("ar[%d][ ] =", r);
    for(c=0; c<COLUMNS; c++)
    {
      printf("   %3d ", ar[r][c]);
    }
    printf("\n");
  }

  return;
}



/*    OUTPUT: dynamic6.c

          Please enter number of rows: 3
                       [ ][0] [ ][1] [ ][2] [ ][3]
          ar[0][ ] =     0      1      2      3
          ar[1][ ] =     4      5      6      7
          ar[2][ ] =     8      9     10     11

          Please enter number of rows: 7
                       [ ][0] [ ][1] [ ][2] [ ][3]
          ar[0][ ] =     0      1      2      3
          ar[1][ ] =     4      5      6      7
          ar[2][ ] =     8      9     10     11
          ar[3][ ] =    12     13     14     15
          ar[4][ ] =    16     17     18     19
          ar[5][ ] =    20     21     22     23
          ar[6][ ] =    24     25     26     27

*/
```

Ex:

```
/*     FILE: dynamic7.c     */

/*
   Dynamically allocating a 2-D array.

   Notice the pointer definitions and the
   cast from malloc.

                                          */

#include <stdio.h>
#include <stdlib.h>
#include <limits.h>

#define COLUMNS 10

void printArray(int ar[ ][COLUMNS], int s);

int main(int argc, char *argv[ ])
{
  int (*ar)[COLUMNS];
  int rows, r, c;

  /* Get number of rows for the n x COLUMNS 2-D array */
  printf("Please enter number of rows: ");
  scanf("%d", &rows);

  /* Validate number entered by user. */
  if (rows<=INT_MAX && rows>0){
    /* Allocate the appropriate number of bytes */
    ar = (int (*)[COLUMNS])malloc(sizeof(int)*rows * COLUMNS);

    if (ar != NULL){
      for(r=0; r<rows; r++)
        for(c=0; c<COLUMNS; c++)
          ar[r][c] = (COLUMNS*r) + c;    /* Use the 2-D array */

      printArray(ar, rows);

      free(ar);
    }
    else
      printf("Malloc( ) request failed!\n");
  }
  else
    printf("Invalid allocation request: %d\n", rows);

  return 0;
}
```

cont…

```
void printArray(int ar[ ][COLUMNS], int rows)
{
  int r, c;

  printf("           ");
  for(c=0; c<COLUMNS; c++)
    printf(" [ ][%d]", c);
  printf("\n");

  for(r=0; r<rows; r++)
  {
    printf("ar[%d][ ] =", r);
    for(c=0; c<COLUMNS; c++)
    {
      printf("   %3d ", ar[r][c]);
    }
    printf("\n");
  }

  return;
}



/*    OUTPUT: dynamic7.c

          Please enter number of rows: 3
                        [ ][0] [ ][1] [ ][2] [ ][3] [ ][4] [ ][5] [ ][6] [ ][7] [ ][8] [ ][9]
          ar[0][ ] =     0      1      2      3      4      5      6      7      8      9
          ar[1][ ] =    10     11     12     13     14     15     16     17     18     19
          ar[2][ ] =    20     21     22     23     24     25     26     27     28     29

          Please enter number of rows: 7
                        [ ][0] [ ][1] [ ][2] [ ][3] [ ][4] [ ][5] [ ][6] [ ][7] [ ][8] [ ][9]
          ar[0][ ] =     0      1      2      3      4      5      6      7      8      9
          ar[1][ ] =    10     11     12     13     14     15     16     17     18     19
          ar[2][ ] =    20     21     22     23     24     25     26     27     28     29
          ar[3][ ] =    30     31     32     33     34     35     36     37     38     39
          ar[4][ ] =    40     41     42     43     44     45     46     47     48     49
          ar[5][ ] =    50     51     52     53     54     55     56     57     58     59
          ar[6][ ] =    60     61     62     63     64     65     66     67     68     69

*/
```

Ex:

```
/*     FILE: dynamic8.c     */

/*
   Dynamically allocating a 3-D array.

   Notice the pointer definitions and the
   cast from malloc.

                                          */

#include <stdio.h>
#include <stdlib.h>
#include <limits.h>

#define COLUMNS 4
#define ROWS 3


void printArray(int ar[ ][ROWS][COLUMNS], int layers);

int main(int argc, char *argv[ ])
{
  int (*ar)[ROWS][COLUMNS];
  int layers, r, c, l;

  /* Get number of rows for the n x ROWS x COLUMNS 3-D array */
  printf("Please enter number of %d x %d layers: ", ROWS, COLUMNS);
  scanf("%d", &layers);

  /* Validate number entered by user. */
  if (layers<=INT_MAX && layers>0){
    /* Allocate the appropriate number of bytes */
    ar = (int (*)[ROWS][COLUMNS])malloc(sizeof(int)*layers * ROWS * COLUMNS);

    if (ar != NULL){
      for(l=0; l<layers; l++)
        for(r=0; r<ROWS; r++)
          for(c=0; c<COLUMNS; c++)
            ar[l][r][c] = r + c + l*10;    /* Use the 3-D array */

      printArray(ar, layers);

      free(ar);
    }
    else
      printf("Malloc( ) request failed!\n");
  }
  else
    printf("Invalid allocation request: %d\n", layers);

  return 0;
}
```

cont…

```
void printArray(int ar[ ][ROWS][COLUMNS], int layers)
{
  int r, c, l;

  for(l=0; l<layers; l++)
  {
    printf("\n");
    printf("              ");
    for(c=0; c<COLUMNS; c++)
      printf(" [%d][ ][%d]", l, c);
    printf("\n");

    for(r=0; r<ROWS; r++)
    {
      printf("ar[%d][%d][ ] =", l, r);
      for(c=0; c<COLUMNS; c++)
      {
        printf("      %3.2d ", ar[l][r][c]);
      }
      printf("\n");
    }
  }

  return;
}


/*    OUTPUT: dynamic8.c

          Please enter number of 3 x 4 layers: 3

                          [0][ ][0] [0][ ][1] [0][ ][2] [0][ ][3]
          ar[0][0][ ] =       00        01        02        03
          ar[0][1][ ] =       01        02        03        04
          ar[0][2][ ] =       02        03        04        05

                          [1][ ][0] [1][ ][1] [1][ ][2] [1][ ][3]
          ar[1][0][ ] =       10        11        12        13
          ar[1][1][ ] =       11        12        13        14
          ar[1][2][ ] =       12        13        14        15

                          [2][ ][0] [2][ ][1] [2][ ][2] [2][ ][3]
          ar[2][0][ ] =       20        21        22        23
          ar[2][1][ ] =       21        22        23        24
          ar[2][2][ ] =       22        23        24        25
```

cont…

```
Please enter number of 3 x 4 layers: 7

                [0][ ][0] [0][ ][1] [0][ ][2] [0][ ][3]
ar[0][0][ ] =       00        01        02        03
ar[0][1][ ] =       01        02        03        04
ar[0][2][ ] =       02        03        04        05

                [1][ ][0] [1][ ][1] [1][ ][2] [1][ ][3]
ar[1][0][ ] =       10        11        12        13
ar[1][1][ ] =       11        12        13        14
ar[1][2][ ] =       12        13        14        15

                [2][ ][0] [2][ ][1] [2][ ][2] [2][ ][3]
ar[2][0][ ] =       20        21        22        23
ar[2][1][ ] =       21        22        23        24
ar[2][2][ ] =       22        23        24        25

                [3][ ][0] [3][ ][1] [3][ ][2] [3][ ][3]
ar[3][0][ ] =       30        31        32        33
ar[3][1][ ] =       31        32        33        34
ar[3][2][ ] =       32        33        34        35

                [4][ ][0] [4][ ][1] [4][ ][2] [4][ ][3]
ar[4][0][ ] =       40        41        42        43
ar[4][1][ ] =       41        42        43        44
ar[4][2][ ] =       42        43        44        45

                [5][ ][0] [5][ ][1] [5][ ][2] [5][ ][3]
ar[5][0][ ] =       50        51        52        53
ar[5][1][ ] =       51        52        53        54
ar[5][2][ ] =       52        53        54        55

                [6][ ][0] [6][ ][1] [6][ ][2] [6][ ][3]
ar[6][0][ ] =       60        61        62        63
ar[6][1][ ] =       61        62        63        64
ar[6][2][ ] =       62        63        64        65

*/
```

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