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Third Edition

Programming in ANSI C

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E Balagurusamy

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1

Overview of C

1.1 HISTORY OF C

'C' seems a strange name for a programming language. But this strange sounding language is one of the most popular computer languages today because it is a structured, high-level, machine independent language. It allows software developers to develop programs without worrying about the hardware platforms where they will be implemented.

The root of all modern languages is ALGOL, introduced in the early 1960s. ALGOL was the first computer language to use a block structure. Although it never became popular in USA, it was widely used in Europe. ALGOL gave the concept of structured programming to the computer science community. Computer scientists like Corrado Bohm, Guiseppe Jacopini and Edsger Dijkstra popularized this concept during 1960s. Subsequently, several languages were announced.

In 1967, Martin Richards developed a language called BCPL (Basic Combined Programming Language) primarily for writing system software. In 1970, Ken Thompson created a language using many features of BCPL and called it simply B. B was used to create early versions of UNIX operating system at Bell Laboratories. Both BCPL and B were "typeless" system programming languages.

C was evolved from ALGOL, BCPL and B by Dennis Ritchie at Bell Laboratories in 1972. C uses many concepts from these languages and added the concept of data types and other powerful features. Since it was developed along with the UNIX operating system, it is strongly associated with UNIX. This operating system, which was also developed at Bell Laboratories, was coded almost entirely in C. UNIX is one of the most popular network operating systems in use today and the heart of the Internet data superhighway.

For many years, C was used mainly in academic environments, but eventually with the release of many C compilers for commercial use and the increasing popularity of UNIX, it began to gain widespread support among computer professionals. Today, C is running under a variety of operating system and hardware platforms.

During 1970s, C had evolved into what is now known as "traditional C". The language became more popular after publication of the book *'The C Programming Language'* by Brian Kerningham and Dennis Ritchie in 1978. The book was so popular that the language came to be known as "K&R C" among the programming community. The rapid growth of C led to the development of different

versions of the language that were similar but often incompatible. This posed a serious problem for system developers.

To assure that the C language remains standard, in 1983, American National Standards Institute (ANSI) appointed a technical committee to define a standard for C. The committee approved a version of C in 1989 which is now known as ANSI C. It was then approved by the International Standards Organization (ISO) in 1990. The standard was updated in 1999. The history of ANSI C is illustrated in Fig. 1.1.

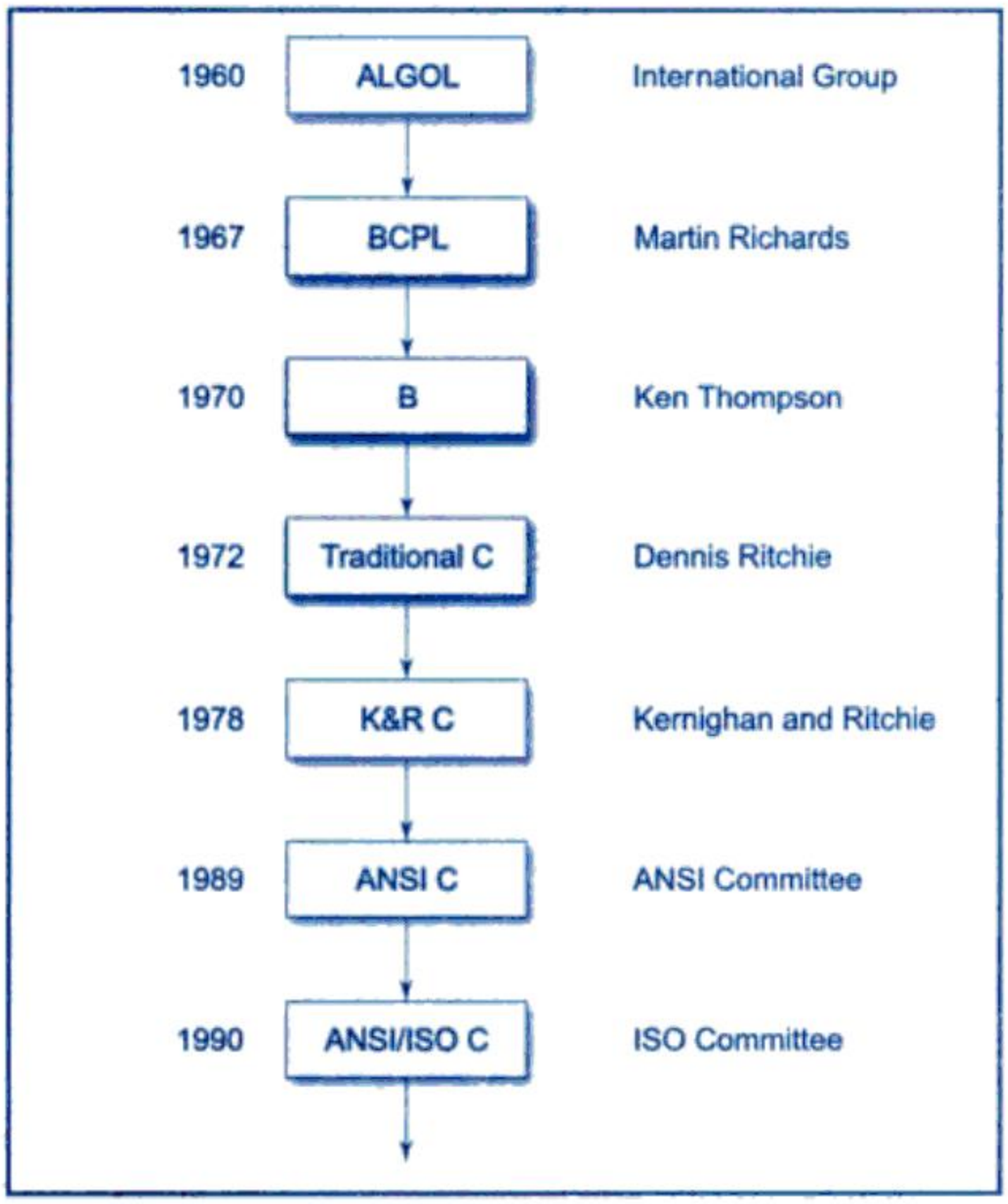

Fig. 1.1 *History of ANSI C*

1.2 IMPORTANCE OF C

The increasing popularity of C is probably due to its many desirable qualities. It is a robust language whose rich set of built-in functions and operators can be used to write any complex program. The C compiler combines the capabilities of an assembly language with the features of a high-level language and therefore it is well suited for writing both system software and business packages. In fact, many of the C compilers available in the market are written in C.

Programs written in C are efficient and fast. This is due to its variety of data types and powerful operators. It is many times faster than BASIC. For example, a program to increment a variable from 0 to 15000 takes about one second in C while it takes more than 50 seconds in an interpreter BASIC.

There are only 32 keywords and its strength lies in its built-in functions. Several standard functions are available which can be used for developing programs.

C is highly portable. This means that C programs written for one computer can be run on another with little or no modification. Portability is important if we plan to use a new computer with a different operating system.

C language is well suited for structured programming, thus requiring the user to think of a problem in terms of function modules or blocks. A proper collection of these modules would make a complete program. This modular structure makes program debugging, testing and maintenance easier.

Another important feature of C is its ability to extend itself. A C program is basically a collection of functions that are supported by the C library. We can continuously add our own functions to C library. With the availability of a large number of functions, the programming task becomes simple.

Before discussing specific features of C, we shall look at some sample C programs, and analyze and understand how they work.

1.3 SAMPLE PROGRAM 1: PRINTING A MESSAGE

Consider a very simple program given in Fig. 1.2.

```
main( )
{
/*.....printing begins.....*/
    printf("I see, I remember");
/*.....printing ends.....*/
}
```

Fig. 1.2 *A program to print one line of text*

This program when executed will produce the following output:

```
I see, I remember
```

Let us have a close look at the program. The first line informs the system that the name of the program is **main** and the execution begins at this line. The **main( )** is a special function used by the C system to tell the computer where the program starts. Every program must have *exactly one main* function. If we use more than one **main** function, the compiler cannot tell which one marks the beginning of the program.

The empty pair of parentheses immediately following **main** indicates that the function **main** has no *arguments* (or parameters). The concept of arguments will be discussed in detail later when we discuss functions (in Chapter 9).

The opening brace "{ " in the second line marks the beginning of the function **main** and the closing brace "}" in the last line indicates the end of the function. In this case, the closing brace also marks the end of the program. All the statements between these two braces form the *function body*. The function body contains a set of instructions to perform the given task.

In this case, the function body contains three statements out of which only the **printf** line is an executable statement. The lines beginning with /* and ending with */ are known as *comment* lines. These are used in a program to enhance its readability and understanding. Comment lines are not executable statements and therefore anything between /* and */ is ignored by the compiler. In general, a comment can be inserted wherever blank spaces can occur—at the beginning, middle or end of a line—"but never in the middle of a word ".

Although comments can appear anywhere, they cannot be nested in C. That means, we cannot have comments inside comments. Once the compiler finds an opening token, it ignores everything until it finds a closing token. The comment line

```
/* = = = =/* = = = = */ = = = = */
```

is not valid and therefore results in an error.

Since comments do not affect the execution speed and the size of a compiled program, we should use them liberally in our programs. They help the programmers and other users in understanding the various functions and operations of a program and serve as an aid to debugging and testing. We shall see the use of comment lines more in the examples that follow.

Let us now look at the **printf( )** function, the only executable statement of the program.

```
printf("I see, I remember");
```

printf is a predefined standard C function for printing output. *Predefined* means that it is a function that has already been written and compiled, and linked together with our program at the time of linking. The concepts of compilation and linking are explained later in this chapter. The **printf** function causes everything between the starting and the ending quotation marks to be printed out. In this case, the output will be:

```
I see, I remember
```

Note that the print line ends with a semicolon. *Every statement in C should end with a semicolon (;) mark.*

Suppose we want to print the above quotation in two lines as

```
I see,
I remember!
```

This can be achieved by adding another **printf** function as shown below:

```
printf(I see, \n");
printf("I remember !");
```

The information contained between the parentheses is called the *argument* of the function. This argument of the first **printf** function is " I see, \n" and the second is "I remember!". These arguments are simply strings of characters to be printed out.

Notice that the argument of the first **printf** contains a combination of two characters \ and **n** at the end of the string. This combination is collectively called the *newline* character. A newline character instructs the computer to go to the next (new) line. It is similar in concept to the carriage return key on a typewriter. After printing the character comma (,) the presence of the newline character **\n** causes the string "I remember!" to be printed on the next line. No space is allowed between \ and n.

If we omit the newline character from the first **printf** statement, then the output will again be a single line as shown below.

```
I see,I remember !
```

This is similar to the output of the program in Fig. 1.2. However, note that there is no space between , and I.

It is also possible to produce two or more lines of output by one **printf** statement with the use of newline character at appropriate places. For example, the statement

```
printf("I see,\n I remember !");
```

will output

```
I see,
I remember!
```

while the statement

```
printf( "I\n.. see,\n… … … I\n… … … remember !");
```

will print out

```
I
.. see
… … … I
… … … remember !
```

NOTE: Some authors recommend the inclusion of the statement

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

at the beginning of all programs that use any input/output library functions. However, this is not necessary for the functions *printf* and *scanf* which have been defined as a part of the C language. See Chapter 4 for more on input and output functions.

Before we proceed to discuss further examples, we must note one important point. C does make a distinction between *uppercase* and *lowercase* letters. For example, **printf** and **PRINTF** are not the same. In C, everything is written in lowercase letters. However, uppercase letters are used for symbolic names representing constants. We may also use uppercase letters in output strings like "I SEE" and "I REMEMBER"

The above example that printed **I see, I remember** is one of the simplest programs. Figure 1.3 highlights the general format of such simple programs. All C programs need a **main** function.

The main Function

The main is a part of every C program. C permits different forms of main statement. Following forms are allowed.

- main()
- int main()
- void main()
- main(void)
- void main(void)
- int main(void)

The empty pair of parentheses indicates that the function has no arguments. This may be explicitly indicated by using the keyword **void** inside the parentheses. We may also specify the keyword **int** or **void** before the word **main**. The keyword **void** means that the function does not return any information to the operating system and **int** means that the function returns an integer value to the operating system. When **int** is specified, the last statement in the program must be "return 0". For the sake of simplicity, we use the first form in our programs.

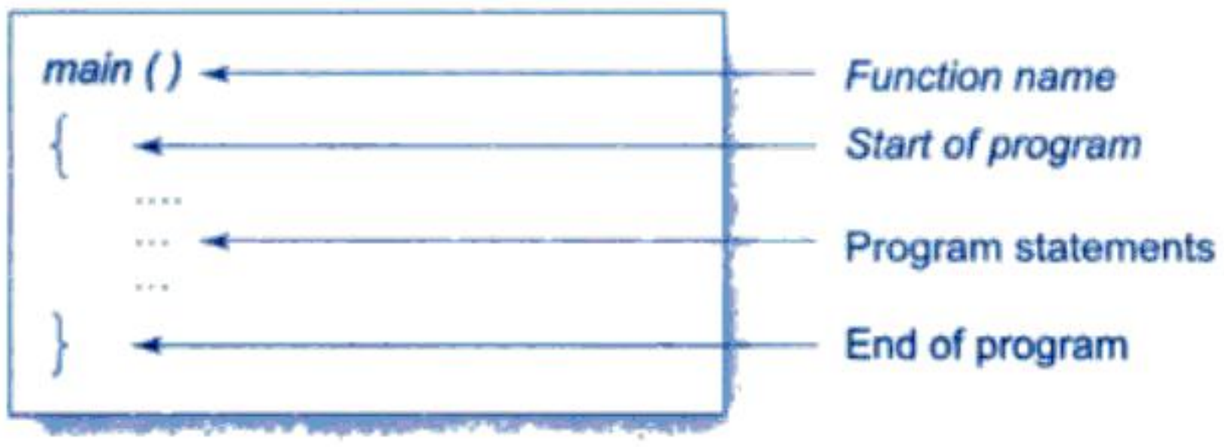

Fig. 1.3 *Format of simple C programs*

1.4 SAMPLE PROGRAM 2: ADDING TWO NUMBERS

Consider another program, which performs addition on two numbers and displays the result. The complete program is shown in Fig. 1.4.

```
/* Programm ADDITION                                    line-1 */
/* Written by EBG                                       line-2 */
main()                                                  /*  line-3 */
{                                                       /*  line-4 */
        int number;                                     /*  line-5 */
        float amount;                                   /*  line-6 */
                                                        /*  line-7 */
        number = 100;                                   /*  line-8 */
                                                        /*  line-9 */
        amount = 30.75 + 75.35;                         /* line-10 */
        printf("%d\n",number);                          /* line-11 */
        printf("%5.2f",amount);                         /* line-12 */
}                                                       /* line-13 */
```

Fig. 1.4 *Program to add two numbers*

This program when executed will produce the following output:

```
100
106.10
```

The first two lines of the program are comment lines. It is a good practice to use comment lines in the beginning to give information such as name of the program, author, date, etc. Comment characters are also used in other lines to indicate line numbers.

The words **number** and **amount** are *variable names* that are used to store numeric data. The numeric data may be either in *integer* form or in *real* form. In C, *all variables should be declared* to tell the compiler what the ***variable names*** are and what ***type of data*** they hold. The variables must be declared before they are used. In lines 5 and 6, the declarations

```
int number;
float amount;
```

tell the compiler that **number** is an integer (**int** is the abbreviation for integer) and **amount** is a floating (**float**) point number. Declaration statements must appear at the beginning of the functions as shown in Fig.1.4. All declaration statements end with a semicolon. C supports many other data types and they are discussed in detail in Chapter 2.

The words such as **int** and **float** are called the *keywords* and cannot be used as *variable* names. A list of keywords is given in Chapter 2.

Data is stored in a variable by *assigning* a data value to it. This is done in lines 8 and 10. In line-8, an integer value 100 is assigned to the integer variable **number** and in line-10, the result of addition of two real numbers 30.75 and 75.35 is assigned to the floating point variable **amount.** The statements

```
number = 100;
amount = 30.75 + 75.35;
```

are called the *assignment* statements. Every assignment statement must have a semicolon at the end.

The next statement is an output statement that prints the value of **number**. The print statement

```
printf("%d\n", number);
```

contains two arguments. The first argument "%d" tells the compiler that the value of the second argument **number** should be printed as a *decimal integer*. Note that these arguments are separated by a comma. The newline character \n causes the next output to appear on a new line.

The last statement of the program

```
printf("%5.2f", amount);
```

prints out the value of **amount** in floating point format. The format specification *%5.2f* tells the compiler that the output must be in *floating point*, with five places in all and two places to the right of the decimal point.

1.5 SAMPLE PROGRAM 3: INTEREST CALCULATION

The program in Fig. 1.5 calculates the value of money at the end of each year of investment, assuming an interest rate of 11 percent and prints the year, and the corresponding amount, in two columns. The output is shown in Fig. 1.6 for a period of 10 years with an initial investment of 5000.00. The program uses the following formula:

Value at the end of year = Value at start of year (1 + interest rate)

In the program, the variable **value** represents the value of money at the end of the year while **amount** represents the value of money at the start of the year. The statement

```
amount = value ;
```

makes the value at the end of the *current* year as the value at start of the *next* year.

```
/*———————— INVESTMENT PROBLEM ————————*/
#define PERIOD  10
#define PRINCIPAL  5000.00
/*————————— MAIN PROGRAM BEGINS —————————*/
main()
```

```
{ /*———————— DECLARATION STATEMENTS ————————*/
    int year;
    float amount, value, inrate;
/*———————— ASSIGNMENT STATEMENTS ————————*/
    amount = PRINCIPAL;
    inrate = 0.11;
    year = 0;
/*———————— COMPUTATION STATEMENTS ————————*/
/*———————— COMPUTATION USING While LOOP ————————*/
    while(year <= PERIOD)
    {   printf("%2d        %8.2f\n",year, amount);
        value  = amount + inrate * amount;
        year   = year + 1;
        amount = value;
    }
/*———————— while LOOP ENDS ————————*/
}
/*———————— PROGRAM ENDS ————————*/
```

Fig. 1.5 *Program for investment problem*

Let us consider the new features introduced in this program. The second and third lines begin with **#define** instructions. A **#define** instruction defines value to a *symbolic constant* for use in the program. Whenever a symbolic name is encountered, the compiler substitutes the value associated with the name automatically. To change the value, we have to simply change the definition. In this example, we have defined two symbolic constants **PERIOD** and **PRINCIPAL** and assigned values 10 and 5000.00 respectively. These values remain constant throughout the execution of the program.

```
0       5000.00
1       5550.00
2       6160.50
3       6838.15
4       7590.35
5       8425.29
6       9352.07
7       10380.00
8       11522.69
9       12790.00
10      14197.11
```

Fig. 1.6 *Output of the investment program*

The **#define** Directive

A **#define** is a preprocessor compiler directive and not a statement. Therefore **#define** lines should not end with a semicolon. Symbolic constants are generally written in uppercase so that they are easily distinguished from lowercase variable names. **#define** instructions are usually placed at the beginning before the **main()** function. Symbolic constants are not declared in declaration section. Preprocessor directions are discussed in Chapter 14.

We must note that the defined constants are not variables. We may not change their values within the program by using an assignment statement. For example, the statement

```
PRINCIPAL = 10000.00;
```

is illegal.

The declaration section declares **year** as integer and **amount, value** and **inrate** as floating point numbers. Note all the floating-point variables are declared in one statement. They can also be declared as

```
float amount;
float value;
float inrate;
```

When two or more variables are declared in one statement, they are separated by a comma.

All computations and printing are accomplished in a **while** loop. **while** is a mechanism for evaluating repeatedly a statement or a group of statements. In this case as long as the value of **year** is less than or equal to the value of **PERIOD**, the four statements that follow **while** are executed. Note that these four statements are grouped by braces. We exit the loop when **year** becomes greater than **PERIOD**. The concept and types of loops are discussed in Chapter 6.

C supports the basic four arithmetic operators (–, +, *, /) along with several others. They are discussed in Chapter 3.

1.6 SAMPLE PROGRAM 4: USE OF SUBROUTINES

So far, we have used only **printf** function that has been provided for us by the C system. The program shown in Fig. 1.7 uses a user-defined function. A function defined by the user is equivalent to a subroutine in FORTRAN or subprogram in BASIC.

```
/*———————— PROGRAM USING FUNCTION ————————*/
int mul (int a, int b); /*—— DECLARATION ———*/
/*————————— MAIN PROGRAM BEGINS —————————*/
    main ()
    {
        int a, b, c;

        a = 5;
```

```
        b = 10;
        c = mul (a,b);

        printf ("multiplication of %d and %d is %d",a,b,c);
    }
/* ————————        MAIN PROGRAM ENDS
                    MUL() FUNCTION STARTS ————————————*/
    int mul (int x, int y)
    int p;
    {
            p = x*y;
            return(p);
    }
/* ———————————— MUL () FUNCTION ENDS ————————————*/
```

Fig. 1.7 *A program using a user-defined function*

Figure 1.7 presents a very simple program that uses a **mul** ( ) function. The program will print the following output.

Multiplication of 5 and 10 is 50

The **mul** ( ) function multiplies the values of **x** and **y** and the result is returned to the **main** ( ) function when it is called in the statement

```
c = mul (a, b);
```

The **mul** ( ) has two *arguments* **x** and **y** that are declared as integers. The values of **a** and **b** are passed on to **x** and **y** respectively when the function **mul** ( ) is called. User-defined functions are considered in detail in Chapter 9.

1.7 SAMPLE PROGRAM 5: USE OF MATH FUNCTIONS

We often use standard mathematical functions such as cos, sin, exp, etc. We shall see now the use of a mathematical function in a program. The standard mathematical functions are defined and kept as a part of C **math library**. If we want to use any of these mathematical functions, we must add an **#include** instruction in the program. Like **#define,** it is also a compiler directive that instructs the compiler to link the specified mathematical functions from the library. The instruction is of the form

```
#include <math.h>
```

math.h is the filename containing the required function. Figure 1.8 illustrates the use of cosine function. The program calculates cosine values for angles 0, 10, 20.....180 and prints out the results with headings.

Another **#include** instruction that is often required is

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

stdio.h refers to the *standard* I/O header file containing standard input and output functions

```
/*———— PROGRAM USING COSINE FUNCTION ———— */
#include <math.h>
#define     PI      3.1416
#define     MAX     180

main ( )
{

     int angle;
     float x,y;

     angle = 0;
     printf("    Angle     Cos(angle)\n\n");

     while(angle <= MAX)
     {
          x = (PI/MAX)*angle;
          y = cos(x);
          printf("%15d %13.4f\n", angle, y);
          angle = angle + 10;
     }
}
```

Output

```
          Angle                Cos(angle)
          0                     1.0000
          10                    0.9848
          20                    0.9397
          30                    0.8660
          40                    0.7660
          50                    0.6428
          60                    0.5000
          70                    0.3420
          80                    0.1736
          90                   -0.0000
          100                  -0.1737
          110                  -0.3420
          120                  -0.5000
          130                  -0.6428
          140                  -0.7660
          150                  -0.8660
          160                  -0.9397
          170                  -0.9848
          180                  -1.0000
```

Fig. 1.8 *Program using a math function*

The **#include** Directive

As mentioned earlier, C programs are divided into modules or functions. Some functions are written by users like us and many others are stored in the C library. Library functions are grouped category-wise and stored in different files known as header files. If we want to access the functions stored in the library, it is necessary to tell the compiler about the files to be accessed.

This is achieved by using the preprocessor directive **#include** as follows:

#include<filename>

filename is the name of the library file that contains the required function definition. Preprocessor directives are placed at the beginning of a program.

A list of library functions and header files containing them are given in Appendix III.

1.8 BASIC STRUCTURE OF C PROGRAMS

The examples discussed so far illustrate that a C program can be viewed as a group of building blocks called *functions*. A function is a subroutine that may include one or more *statements* designed to perform a *specific task*. To write a C program, we first create functions and then put them together. A C program may contain one or more sections shown in Fig. 1.9.

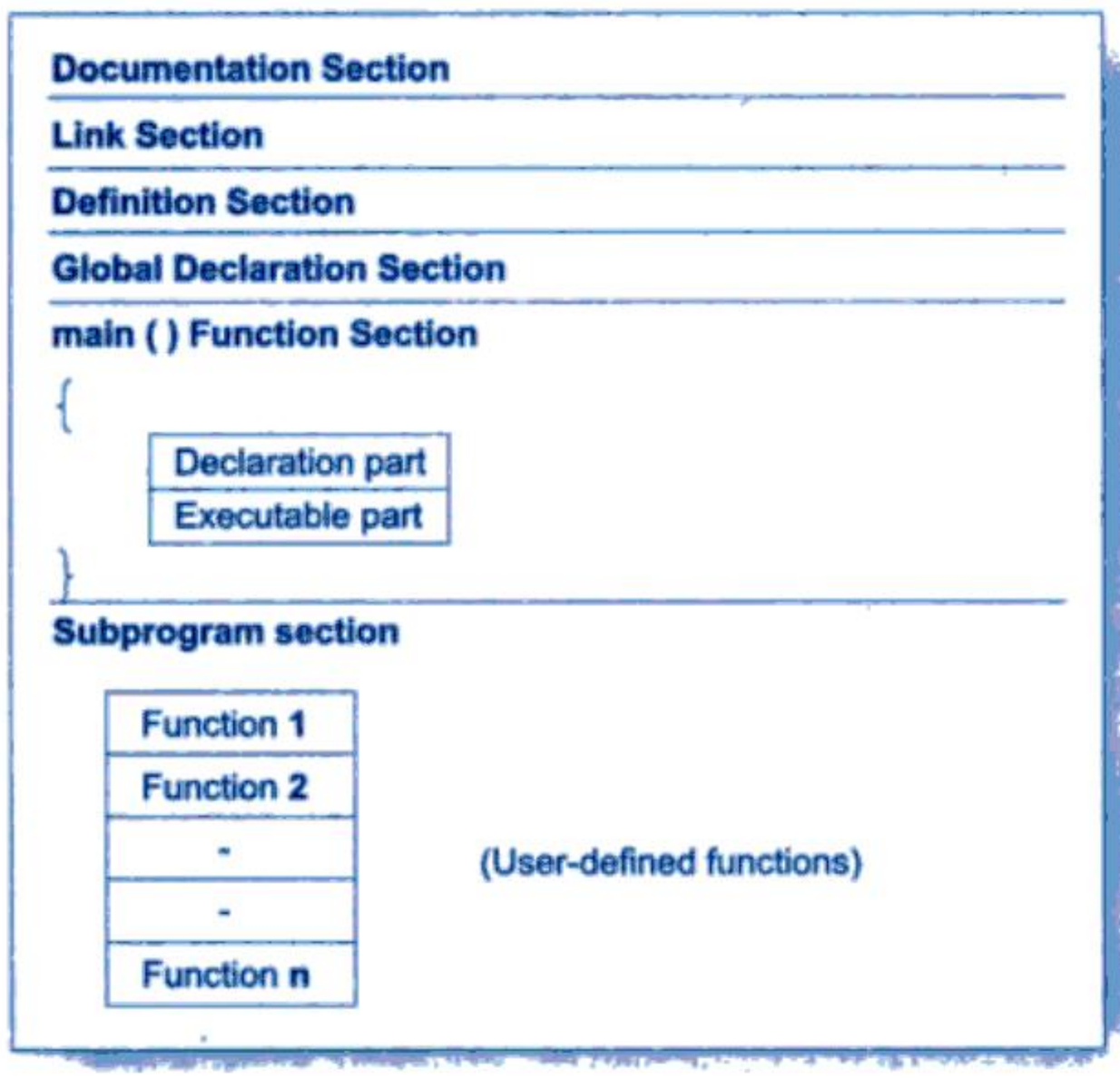

Fig. 1.9 *An overview of a C program*

The documentation section consists of a set of comment lines giving the name of the program, the author and other details, which the programmer would like to use later. The link section provides instructions to the compiler to link functions from the system library. The definition section defines all symbolic constants.

There are some variables that are used in more than one function. Such variables are called *global* variables and are declared in the *global* declaration section that is outside of all the functions. This section also declares all the user-defined functions.

Every C program must have one **main**() function section. This section contains two parts, declaration part and executable part. The declaration part declares all the variables used in the executable part. There is at least one statement in the executable part. These two parts must appear between the opening and the closing braces. The program execution begins at the opening brace and ends at the closing brace. The closing brace of the main function section is the logical end of the program. All statements in the declaration and executable parts end with a semicolon.

The subprogram section contains all the user-defined functions that are called in the **main** function. User-defined functions are generally placed immediately after the **main** function, although they may appear in any order.

All sections, except the **main** function section may be absent when they are not required.

1.9 PROGRAMMING STYLE

Unlike some other programming languages (COBOL, FORTRAN, etc.,) C is a *free-form* language. That is, the C compiler does not care, where on the line we begin typing. While this may be a licence for bad programming, we should try to use this fact to our advantage in developing readable programs. Although several alternative styles are possible, we should select one style and use it with total consistency.

First of all, we must develop the habit of writing programs in lowercase letters. C program statements are written in lowercase letters. Uppercase letters are used only for symbolic constants.

Braces group program statements together and mark the beginning and the end of functions. A proper indentation of braces and statements would make a program easier to read and debug. Note how the braces are aligned and the statements are indented in the program of Fig. 1.5.

Since C is a free-form language, we can group statements together on one line. The statements

```
a = b;
x = y + 1;
z = a + x;
```

can be written on one line as

```
a = b; x = y+1; z = a+x;
```

The program

```
main( )
{
     printf("hello C");
}
```

may be written in one line like

```
main( ) {printf("Hello C")};
```

However, this style make the program more difficult to understand and should not be used. In this book, each statement is written on a separate line.

The generous use of comments inside a program cannot be overemphasized. Judiciously inserted comments not only increase the readability but also help to understand the program logic. This is very important for debugging and testing the program.

1.10 EXECUTING A 'C' PROGRAM

Executing a program written in C involves a series of steps. These are:

1. Creating the program
2. Compiling the program
3. Linking the program with functions that are needed from the C library
4. Executing the program.

Figure 1.10 illustrates the process of creating, compiling and executing a C program. Although these steps remain the same irrespective of the *operating system*, system commands for implementing the steps and conventions for naming *files* may differ on different systems.

An operating system is a program that controls the entire operation of a computer system. All input/out operations are channeled through the operating system. The operating system, which is an interface between the hardware and the user, handles the execution of user programs.

The two most popular operating systems today are UNIX (for minicomputers) and MS-DOS (for microcomputers). We shall discuss briefly the procedure to be followed in executing C programs under both these operating systems in the following sections.

1.11 UNIX SYSTEM

Creating the program

Once we load the UNIX operating system into the memory, the computer is ready to receive program. The program must be entered into a file. The file name can consist of letters, digits and special characters, followed by a dot and a letter **c**. Examples of valid file names are:

```
hello.c
program.c
ebg1.c
```

The file is created with the help of a *text editor*, either **ed** or **vi.** The command for calling the editor and creating the file is

```
ed filename
```

If the file existed before, it is loaded. If it does not yet exist, the file has to be created so that it is ready to receive the new program. Any corrections in the program are done under the editor. (The name of your system's editor may be different. Check your system manual.)

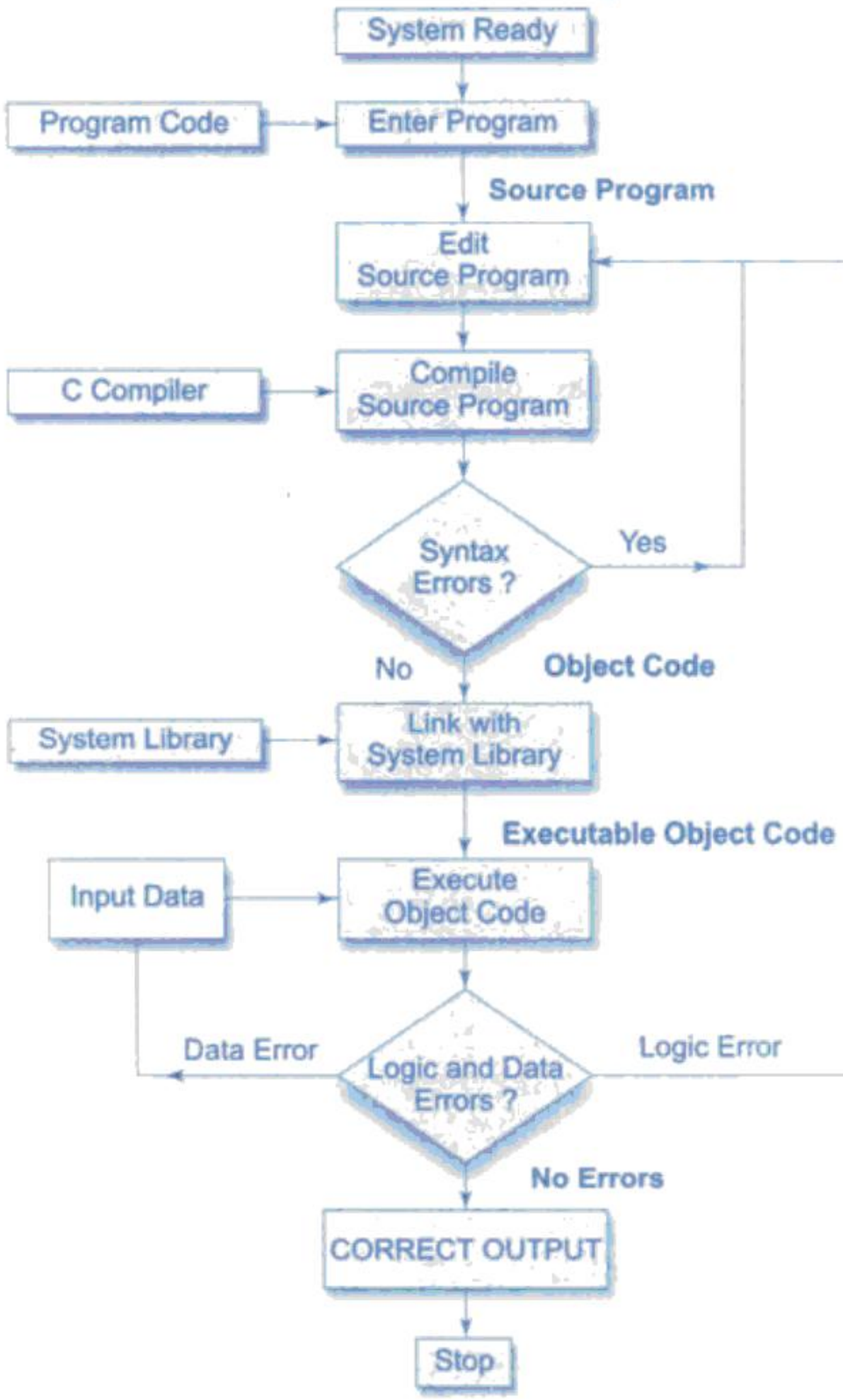

Fig. 1.10 *Process of compiling and running a C program*

When the editing is over, the file is saved on disk. It can then be referenced any time later by its file name. The program that is entered into the file is known as the *source program*, since it represents the original form of the program.

Compiling and Linking

Let us assume that the source program has been created in a file named *ebg1.c*. Now the program is ready for compilation. The compilation command to achieve this task under UNIX is

```
cc ebg1.c
```

The source program instructions are now translated into a form that is suitable for execution by the computer. The translation is done after examining each instruction for its correctness. If everything is

alright, the compilation proceeds silently and the translated program is stored on another file with the name *ebg1.o*. This program is known as *object code*.

Linking is the process of putting together other program files and functions that are required by the program. For example, if the program is using **exp()** function, then the object code of this function should be brought from the **math library** of the system and linked to the main program. Under UNIX, the linking is automatically done (if no errors are detected) when the **cc** command is used.

If any mistakes in the *syntax* and *semantics* of the language are discovered, they are listed out and the compilation process ends right there. The errors should be corrected in the source program with the help of the editor and the compilation is done again.

The compiled and linked program is called the *executable object code* and is stored automatically in another file named **a.out.**

Note that some systems use different compilation command for linking mathematical functions.

```
cc filename - lm
```

is the command under UNIPLUS SYSTEM V operating system.

Executing the Program

Execution is a simple task. The command

```
a.out
```

would load the executable object code into the computer memory and execute the instructions. During execution, the program may request for some data to be entered through the keyboard. Sometimes the program does not produce the desired results. Perhaps, something is wrong with the program *logic* or *data*. Then it would be necessary to correct the source program or the data. In case the source program is modified, the entire process of compiling, linking and executing the program should be repeated.

Creating Your Own Executable File

Note that the linker always assigns the same name **a.out**. When we compile another program, this file will be overwritten by the executable object code of the new program. If we want to prevent from happening, we should rename the file immediately by using the command.

```
mv a.out name
```

We may also achieve this by specifying an option in the cc command as follows:

```
cc -o name source-file
```

This will store the executable object code in the file name and prevent the old file **a.out** from being destroyed.

Multiple Source Files

To compile and link multiple source program files, we must append all the files names to the **cc** command.

```
cc filename-1.c .... filename-n.c
```

These files will be separately compiled into object files called

```
filename-i.o
```

and then linked to produce an executable program file **a.out** as shown in Fig. 1.11.

It is also possible to compile each file separately and link them later. For example, the commands

```
cc -c mod1.c
cc -c mod2.c
```

will compile the source files *mod1.c* and *mod2.c* into objects files *mod1.o* and *mod2.o*. They can be linked together by the command

```
cc mod1.o mod2.o
```

we may also combine the source files and object files as follows:

```
cc mod1.c mod2.o
```

Only *mod1.c* is compiled and then linked with the object file mod2.o. This approach is useful when one of the multiple source files need to be changed and recompiled or an already existing object files is to be used along with the program to be compiled.

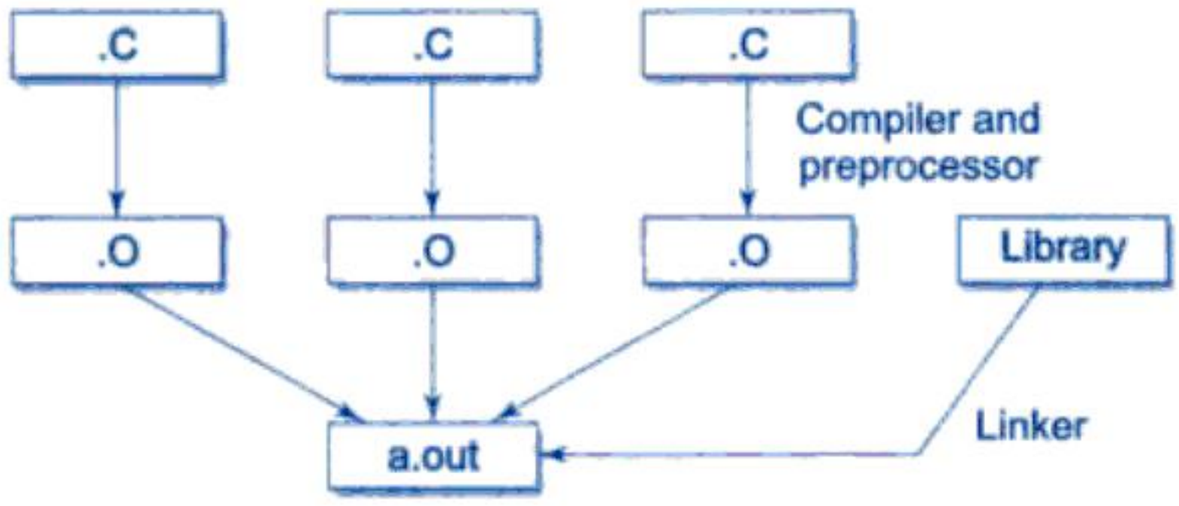

Fig. 1.11 *Compilation of multiple files*

1.12 MS-DOS SYSTEM

The program can be created using any word processing software in non-document mode. The file name should end with the characters ".c" like **program.c, pay.c,** etc. Then the command

```
MSC pay.c
```

under MS-DOS operating system would load the program stored in the file **pay.c** and generate the **object code.** This code is stored in another file under name **pay.obj**. In case any language errors are found, the compilation is not completed. The program should then be corrected and compiled again.

The linking is done by the command

```
LINK pay.obj
```

which generates the **executable code** with the filename **pay.exe**. Now the command

```
pay
```

would execute the program and give the results.

Just Remember

- Every C program requires a **main()** function (Use of more than one **main()** is illegal). The place **main** is where the program execution begins.
- The execution of a function begins at the opening brace of the function and ends at the corresponding closing brace.
- C programs are written in lowercase letters. However, uppercase letters are used for symbolic names and output strings.
- All the words in a program line must be separated from each other by at least one space, or a tab, or a punctuation mark.
- Every program statement in a C language must end with a semicolon.
- All variables must be declared for their types before they are used in the program.
- We must make sure to include header files using **#include** directive when the program refers to special names and functions that it does not define.
- Compiler directives such as **define** and **include** are special instructions to the compiler to help it compile a program. They do not end with a semicolon.
- The sign # of compiler directives must appear in the first column of the line.
- When braces are used to group statements, make sure that the opening brace has a corresponding closing brace.
- C is a free-form language and therefore a proper form of indentation of various sections would improve legibility of the program.
- A comment can be inserted almost anywhere a space can appear. Use of appropriate comments in proper places increases readability and understandability of the program and helps users in debugging and testing. Remember to match the symbols /* and */ appropriately.

REVIEW QUESTIONS

1.1 State whether the following statements are *true* or *false*.
   (a) Every line in a C program should end with a semicolon.
   (b) In C language lowercase letters are significant.
   (c) Every C program ends with an END word.
   (d) **main( )** is where the program begins its execution.
   (e) A line in a program may have more than one statement.
   (f) A **printf** statement can generate only one line of output.
   (g) The closing brace of the **main( )** in a program is the logical end of the program.
   (h) The purpose of the header file such as **stdio.h** is to store the source code of a program.
   (i) Comments cause the computer to print the text enclosed between /* and */ when executed.
   (j) Syntax errors will be detected by the compiler.

1.2 Which of the following statements are *true*?
   (a) Every C program must have at least one user-defined function.

(b) Only one function may be named **main( )**.
(c) Declaration section contains instructions to the computer.

1.3 Which of the following statements about comments are *false*?
(a) Use of comments reduces the speed of execution of a program.
(b) Comments serve as internal documentation for programmers.
(c) A comment can be inserted in the middle of a statement.
(d) In C, we can have comments inside comments.

1.4 Fill in the blanks with appropriate words in each of the following statements.
(a) Every program statement in a C program must end with a _____
(b) The _____ Function is used to display the output on the screen.
(c) The _____ header file contains mathematical functions.
(d) The escape sequence character _____ causes the cursor to move to the next line on the screen.

1.5 Remove the semicolon at the end of the **printf** statement in the program of Fig. 1.2 and execute it. What is the output?

1.6 In the Sample Program 2, delete line-5 and execute the program. How helpful is the error message?

1.7 Modify the Sample Program 3 to display the following output:

Year	Amount
1	5500.00
2	6160.00
-	_____
-	_____
10	14197.11

1.8 Find errors, if any, in the following program:

```
/* A simple program
int main( )
{
     /* Does nothing */
}
```

1.9 Find errors, if any, in the following program:

```
#include (stdio.h)
void main(void)
{
     print("Hello C");
}
```

1.10 Find errors, if any, in the following program:

```
Include <math.h>
main { }
(
     FLOAT X;
     X = 2.5;
     Y = exp(x);
```

```
                Print(x,y);
            )
```

1.11 Why and when do we use the **#define** directive?
1.12 Why and when do we use the **#include** directive?
1.13 What does **void main(void)** mean?
1.14 Distinguish between the following pairs:
  (a) main( ) and void main(void)
  (b) int main( ) and void main( )
1.15 Why do we need to use comments in programs?
1.16 Why is the look of a program is important?
1.17 Where are blank spaces permitted in a C program?
1.18 Describe the structure of a C program.
1.19 Describe the process of creating and executing a C program under UNIX system.
1.20 How do we implement multiple source program files?

PROGRAMMING EXERCISES

1.1 Write a program that will print your mailing address in the following form:

First line	:	Name
Second line	:	Door No, Street
Third line	:	City, Pin code

1.2 Modify the above program to provide border lines to the address.
1.3 Write a program using one print statement to print the pattern of asterisks as shown below:

```
*
*   *
*   *   *
*   *   *   *
```

1.4 Write a program that will print the following figure using suitable characters.

1.5 Given the radius of a circle, write a program to compute and display its area. Use a symbolic constant to define the π value and assume a suitable value for radius.
1.6 Write a program to output the following multiplication table:

$5 \times 1 = 5$
$5 \times 2 = 10$
$5 \times 3 = 15$
. .
. .
$5 \times 10 = 50$

1.7 Given two integers 20 and 10, write a program that uses a function add( ) to add these two numbers and sub( ) to find the difference of these two numbers and then display the sum and difference in the following form:

$$20 + 10 = 30$$

$$20 - 10 = 10$$

1.8 Given the values of three variables a, b and c, write a program to compute and display the value of x, where

$$x = \frac{a}{b - c}$$

Execute your program for the following values:

(a) a = 250, b = 85, c = 25

(b) a = 300, b = 70, c = 70

Comment on the output in each case.

Chapter

2

Constants, Variables, and Data Types

2.1 INTRODUCTION

A programming language is designed to help process certain kinds of *data* consisting of numbers, characters and strings and to provide useful output known as *information*. The task of processing of data is accomplished by executing a sequence of precise instructions called a *program*. These instructions are formed using certain symbols and words according to some rigid rules known as *syntax rules* (or *grammar*). Every program instruction must confirm precisely to the syntax rules of the language.

Like any other language, C has its own vocabulary and grammar. In this chapter, we will discuss the concepts of constants and variables and their types as they relate to C programming language.

2.2 CHARACTER SET

The characters that can be used to form words, numbers and expressions depend upon the computer on which the program is run. However, a subset of characters is available that can be used on most personal, micro, mini and mainframe computers. The characters in C are grouped into the following categories:

1. Letters
2. Digits
3. Special characters
4. White spaces

The entire character set is given in Table 2.1.

The compiler ignores white spaces unless they are a part of a string constant. White spaces may be used to separate words, but are prohibited between the characters of keywords and identifiers.

Trigraph Characters

Many non-English keyboards do not support all the characters mentioned in Table 2.1. ANSI C introduces the concept of "trigraph" sequences to provide a way to enter certain characters that are not available on some keyboards. Each trigraph sequence consists of three characters (two question marks followed by another character) as shown in Table 2.2. For example, if a keyboard does not support square brackets, we can still use them in a program using the trigraphs ??(and ??).

Table 2.1 *C Character Set*

Letters	*Digits*
Uppercase A.....Z	All decimal digits 0 9
Lowercase a.....z	

Special Characters

, comma	& ampersand
. period	^ caret
; semicolon	* asterisk
: colon	– minus sign
? question mark	+ plus sign
‘ apostrophe	< opening angle bracket
“ quotation mark	(or less than sign)
! exclamation mark	> closing angle bracket
| vertical bar	(or greater than sign)
/ slash	(left parenthesis
\ backslash	) right parenthesis
~ tilde	[left bracket
_ under score	] right bracket
$ dollar sign	{ left brace
% percent sign	} right brace
	# number sign

White Spaces

Blank space
Horizontal tab
Carriage return
New line
Form feed

Table 2.2 *ANSI C Trigraph Sequences*

Trigraph sequence	*Translation*
??=	# number sign
??(	[left bracket
??)	] right bracket
??<	{ left brace
??>	} right brace
??!	| vetical bar
??/	\ back slash
??/	^ caret
??-	~ tilde

2.3 C TOKENS

In a passage of text, individual words and punctuation marks are called *tokens*. Similarly, in a C program the smallest individual units are known as C tokens. C has six types of tokens as shown in Fig. 2.1. C programs are written using these tokens and the syntax of the language.

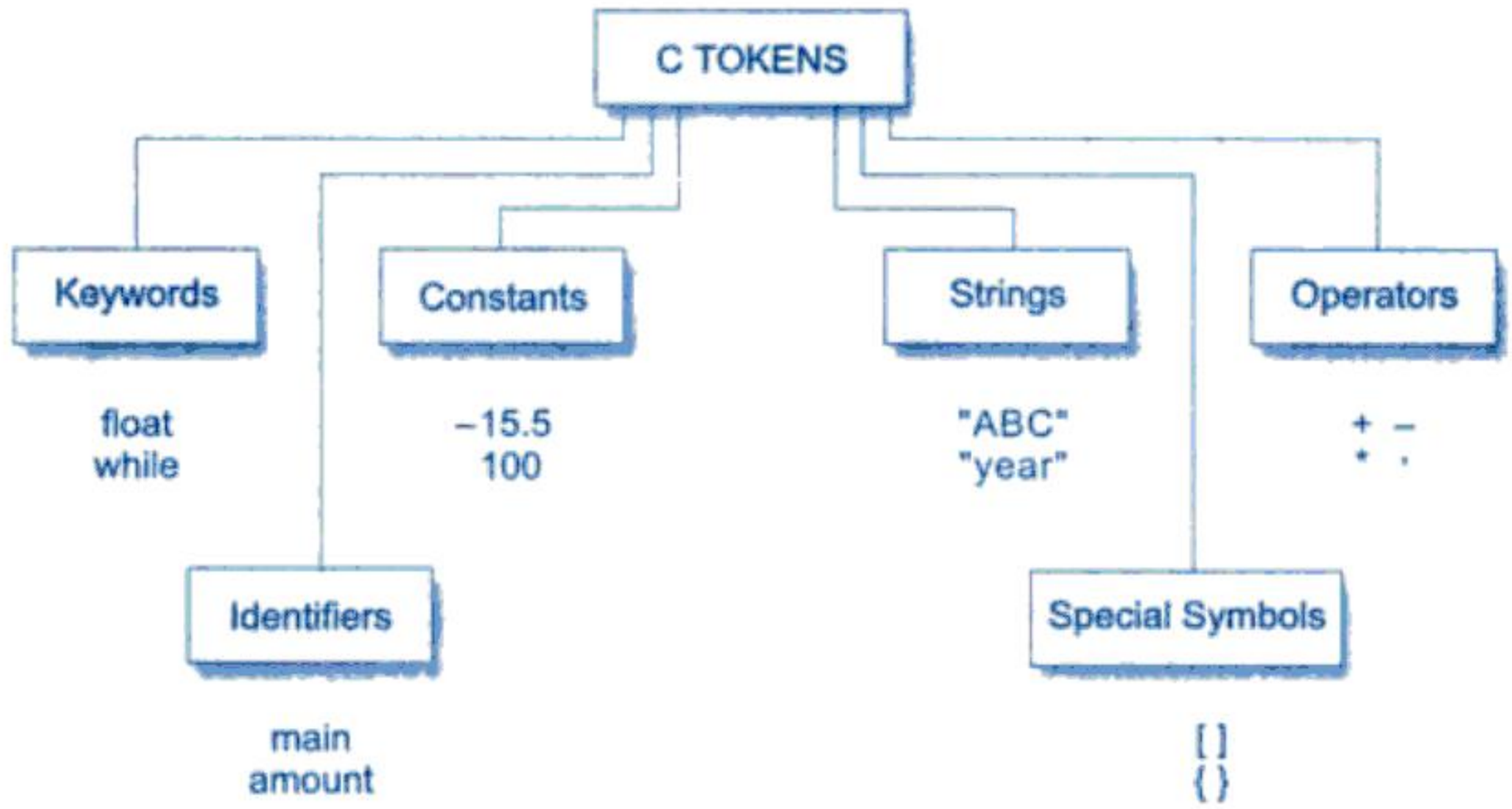

Fig. 2.1 *C tokens and examples*

2.4 KEYWORDS AND IDENTIFIERS

Every C word is classified as either a *keyword* or an *identifier*. All keywords have fixed meanings and these meanings cannot be changed. Keywords serve as basic building blocks for program statements. The list of all keywords of ANSI C are listed in Table 2.3. All keywords must be written in lowercase. Some compilers may use additional keywords that must be identified from the C manual.

Table 2.3 *ANSI C Keywords*

auto	double	int	struct
break	else	long	switch
case	enum	register	typedef
char	extern	return	union
const	float	short	unsigned
continue	for	signed	void
default	goto	sizeof	volatile
do	if	static	while

Identifiers refer to the names of variables, functions and arrays. These are user-defined names and consist of a sequence of letters and digits, with a letter as a first character. Both uppercase and lowercase letters are permitted, although lowercase letters are commonly used. The underscore character is also permitted in identifiers. It is usually used as a link between two words in long identifiers.

Rules for Identifiers

1. First character must be an alphabet (or underscore).
2. Must consist of only letters, digits or underscore.
3. Only first 31 characters are significant.
4. Cannot use a keyword.
5. Must not contain white space.

2.5 CONSTANTS

Constants in C refer to fixed values that do not change during the execution of a program. C supports several types of constants as illustrated in Fig. 2.2.

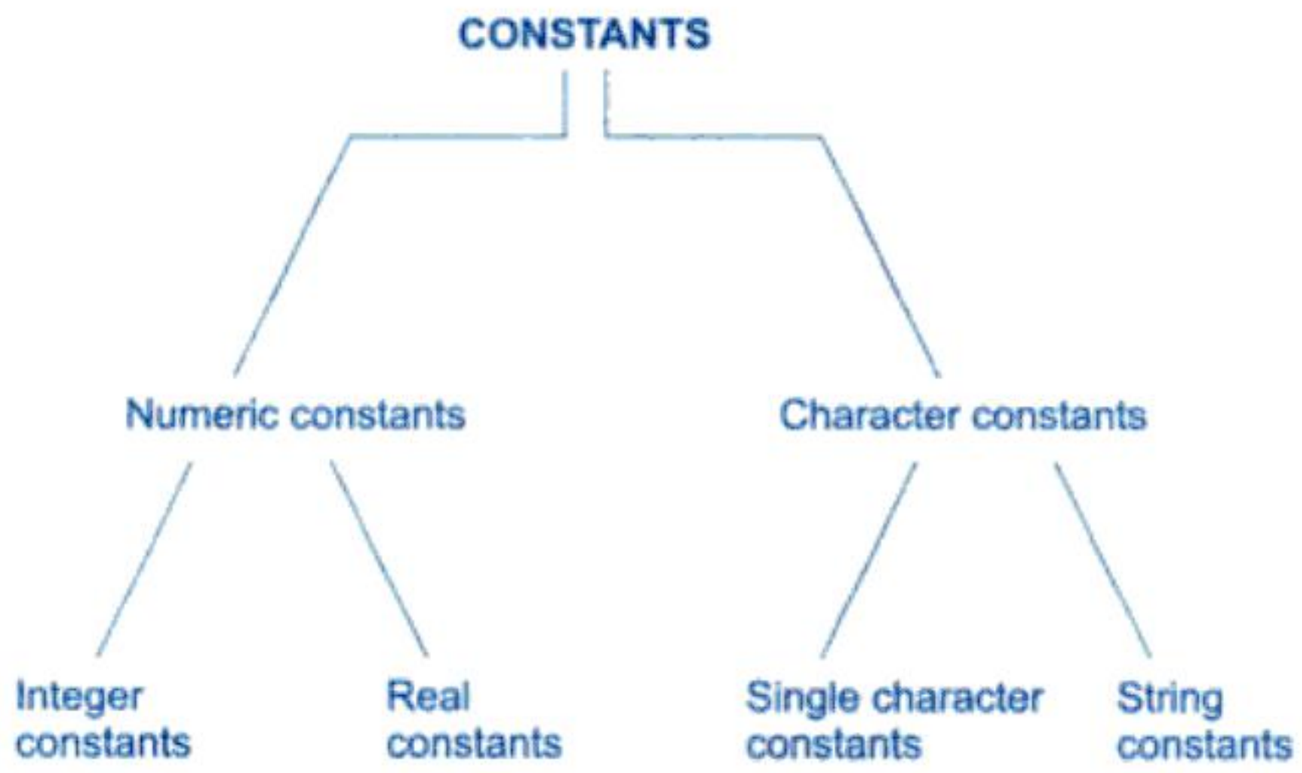

Fig. 2.2 *Basic types of C constants*

Integer Constants

An *integer* constant refers to a sequence of digits. There are three types of integers, namely, *decimal* integer, *octal* integer and *hexadecimal* integer.

Decimal integers consist of a set of digits, 0 through 9, preceded by an optional – or + sign. Valid examples of decimal integer constants are:

123 – 321 0 654321 +78

Embedded spaces, commas, and non-digit characters are not permitted between digits. For example,

15 750 20,000 $1000

are illegal numbers. Note that ANSI C supports *unary plus* which was not defined earlier.

An *octal* integer constant consists of any combination of digits from the set 0 through 7, with a leading 0. Some examples of octal integer are:

037 0 0435 0551

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Table 2.5 *(Contd.)*

Constant	*Meaning*
'\v'	vertical tab
'\''	single quote
'\"'	double quote
'\?'	question mark
'\\'	backslash
'\0'	null

2.6 VARIABLES

A *variable* is a data name that may be used to store a data value. Unlike constants that remain unchanged during the execution of a program, a variable may take different values at different times during execution. In Chapter 1, we used several variables. For instance, we used the variable **amount** in Sample Program 3 to store the value of money at the end of each year (after adding the interest earned during that year).

A variable name can be chosen by the programmer in a meaningful way so as to reflect its function or nature in the program. Some examples of such names are:

Average
height
Total
Counter_1
class_strength

As mentioned earlier, variable names may consist of letters, digits, and the underscore(_) character, subject to the following conditions:

1. They must begin with a letter. Some systems permit underscore as the first character.
2. ANSI standard recognizes a length of 31 characters. However, length should not be normally more than eight characters, since only the first eight characters are treated as significant by many compilers.
3. Uppercase and lowercase are significant. That is, the varible **Total** is not the same as **total** or **TOTAL**.
4. It should not be a keyword.
5. White space is not allowed.

Some examples of valid variable names are:

John	Value	T_raise
Delhi	x1	ph_value
mark	sum1	distance

Invalid examples include:

123	(area)
%	25th

Further examples of variable names and their correctness are given in Table 2.6.

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Void Types

The **void** type has no values. This is usually used to specify the type of functions. The type of a function is said to be **void** when it does not return any value to the calling function. It can also play the role of a generic type, meaning that it can represent any of the other standard types.

Character Types

A single character can be defined as a character(**char**) type data. Characters are usually stored in 8 bits (one byte) of internal storage. The qualifier **signed** or **unsigned** may be explicitly applied to char. While **unsigned chars** have values between 0 and 255, **signed chars** have values from –128 to 127.

2.8 DECLARATION OF VARIABLES

After designing suitable variable names, we must declare them to the compiler. Declaration does two things:

1. It tells the compiler what the variable name is.
2. It specifies what type of data the variable will hold.

The declaration of variables must be done before they are used in the program.

Primary Type Declaration

A variable can be used to store a value of any data type. That is, the name has nothing to do with its type. The syntax for declaring a variable is as follows:

```
data-type v1,v2,....vn ;
```

v1, v2, ...vn are the names of variables. Variables are separated by commas. A declaration statement must end with a semicolon. For example, valid declarations are:

```
int count;
int number, total;
double ratio;
```

int and **double** are the keywords to represent integer type and real type data values respectively. Table 2.9 shows various data types and their keyword equivalents.

Table 2.9 *Data Types and Their Keywords*

Data type	*Keyword equivalent*
Character	char
Unsigned character	unsigned char
Signed character	signed char
Signed integer	signed int (or int)

(Contd.)

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```
{
   int i;
   float balance;
   ....
   ....
   function1();
}
function1()
{
   int i;
   float sum;
   ....
   ....
}
```

The variable **m** which has been declared before the **main** is called *global* variable. It can be used in all the functions in the program. It need not be declared in other functions. A global variable is also known as an *external* variable.

The variables **i**, **balance** and **sum** are called *local* variables because they are declared inside a function. Local variables are visible and meaningful only inside the functions in which they are declared. They are not known to other functions. Note that the variable **i** has been declared in both the functions. Any change in the value of **i** in one function does not affect its value in the other.

C provides a variety of storage class specifiers that can be used to declare explicitly the scope and lifetime of variables. The concepts of scope and lifetime are important only in multifunction and multiple file programs and therefore the storage classes are considered in detail later when functions are discussed. For now, remember that there are four storage class specifiers (**auto, register, static**, and **extern**) whose meanings are given in Table 2.10.

The storage class is another qualifier (like **long** or **unsigned)** that can be added to a variable declaration as shown below:

```
auto int count;
register char ch;
static int x;
extern long total;
```

Static and external (**extern**) variables are automatically initialized to zero. Automatic (**auto**) variables contain undefined values (known as 'garbage') unless they are initialized explicitly.

Table 2.10 *Storage Classes and Their Meaning*

Storage class	*Meaning*
auto	Local variable known only to the function in which it is declared. *Default is auto.*
static	Local variable which exists and retains its value even after the control is transferred to the calling function.
extern	Global variable known to all functions in the file.
register	Local variable which is stored in the register.

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Example 2.3 The program in Fig. 2.9 illustrates the use of **scanf** function.

The first executable statement in the program is a **printf,** requesting the user to enter an integer number. This is known as "prompt message" and appears on the screen like

Enter an integer number

As soon as the user types in an integer number, the computer proceeds to compare the value with 100. If the value typed in is less than 100, then a message

Your number is smaller than 100

is printed on the screen. Otherwise, the message

Your number contains more than two digits

is printed. Outputs of the program run for two different inputs are also shown in Fig. 2.9.

```
Program
  main()
  {
       int number;

       printf("Enter an integer number\n");
       scanf ("%d", &number);

       if ( number < 100 )
         printf("Your number is smaller than 100\n\n");
       else
         printf("Your number contains more than two digits\n");
  }

Output
  Enter an integer number
  54
  Your number is smaller than 100
  Enter an integer number
  108
  Your number contains more than two digits
```

Fig. 2.9 *Use of scanf function for interactive computing*

Some compilers permit the use of the 'prompt message' as a part of the control string in **scanf,** like

```
scanf("Enter a number %d",&number);
```

We discuss more about **scanf** in Chapter 4.

In Fig. 2.9 we have used a decision statement **if...else** to decide whether the number is less than 100. Decision statements are discussed in depth in Chapter 5.

Example 2.4 Sample program 3 discussed in Chapter 1 can be converted into a more flexible interactive program using **scanf** as shown in Fig. 2.10.

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2.13 DECLARING A VARIABLE AS VOLATILE

ANSI standard defines another qualifier **volatile** that could be used to tell explicitly the compiler that a variable's value may be changed at any time by some external sources (from outside the program). For example:

```
volatile int date;
```

The value of **date** may be altered by some external factors even if it does not appear on the left-hand side of an assignment statement. When we declare a variable as **volatile**, the compiler will examine the value of the variable each time it is encountered to see whether any external alteration has changed the value.

Remember that the value of a variable declared as **volatile** can be modified by its own program as well. If we wish that the value must not be modified by the program while it may be altered by some other process, then we may declare the variable as both **const** and **volatile** as shown below:

```
volatile const int location = 100;
```

2.14 OVERFLOW AND UNDERFLOW OF DATA

Problem of data overflow occurs when the value of a variable is either too big or too small for the data type to hold. The largest value that a variable can hold also depends on the machine. Since floating-point values are rounded off to the number of significant digits allowed (or specified), an overflow normally results in the largest possible real value, whereas an underflow results in zero.

Integers are always exact within the limits of the range of the integral data types used. However, an overflow which is a serious problem may occur if the data type does not match the value of the constant. C does not provide any warning or indication of integer overflow. It simply gives incorrect results. (Overflow normally produces a negative number.) We should therefore exercise a greater care to define correct data types for handling the input/output values.

Just Remember

- Do not use the underscore as the first character of identifiers (or variable names) because many of the identifiers in the system library start with underscore.
- Use only 31 or less characters for identifiers. This helps ensure portability of programs.
- Do not use keywords or any system library names for identifiers.
- Use meaningful and intelligent variable names.
- Do not create variable names that differ only by one or two letters.
- Each variable used must be declared for its type at the beginning of the program or function.
- All variables must be initialized before they are used in the program.
- Integer constants, by default, assume **int** types. To make the numbers **long** or **unsigned**, we must append the letters L and U to them.
- Floating point constants default to **double**. To make them to denote **float** or **long double**, we must append the letters F or L to the numbers.

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(c) A global variable is also known as _____ variable.
(d) A variable can be made constant by declaring it with the qualifier _____ at the time of initialization.

2.3 What are trigraph characters? How are they useful?
2.4 Describe the four basic data types. How could we extend the range of values they represent?
2.5 What is an unsigned integer constant? What is the significance of declaring a constant unsigned?
2.6 Describe the characteristics and purpose of escape sequence characters.
2.7 What is a variable and what is meant by the "value" of a variable?
2.8 How do variables and symbolic names differ?
2.9 State the differences between the declaration of a variable and the definition of a symbolic name.
2.10 What is initialization? Why is it important?
2.11 What are the qualifiers that an **int** can have at a time?
2.12 A programmer would like to use the word DPR to declare all the double-precision floating point values in his program. How could he achieve this?
2.13 What are enumeration variables? How are they declared? What is the advantage of using them in a program?
2.14 Describe the purpose of the qualifiers **const** and **volatile**.
2.15 When dealing with very small or very large numbers, what steps would you take to improve the accuracy of the calculations?
2.16 Which of the following are invalid constants and why?

0.0001	5x1.5	99999	
+100	75.45 E-2	"15.75"	
–45.6	–1.79 e + 4	0.00001234	

2.17 Which of the following are invalid variable names and why?

Minimum	First.name	n1+n2	&name
doubles	3rd_row	n$	Row1
float	Sum Total	Row Total	Column-total

2.18 Find errors, if any, in the following declaration statements.

```
Int x;
float letter,DIGIT;
double = p,q
exponent alpha,beta;
m,n,z: INTEGER
short char c;
long int m; count;
long float temp;
```

2.19 What would be the value of x after execution of the following statements?

```
int x, y = 10;
char z = 'a';
x = y + z;
```

2.20 Identify syntax errors in the following program. After corrections, what output would you expect when you execute it?

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Example 3.1 The program in Fig. 3.1 shows the use of integer arithmetic to convert a given number of days into months and days.

```
Program
   main ()
   {
      int months, days ;

      printf("Enter days\n") ;
      scanf("%d", &days) ;

      months = days / 30 ;
      days = days % 30 ;
      printf("Months = %d Days = %d", months, days) ;
   }

Output
   Enter days
   265
   Months = 8 Days = 25
   Enter days
   364
   Months = 12 Days = 4
   Enter days
   45
   Months = 1 Days = 15
```

Fig. 3.1 *Illustration of integer arithmetic*

The variables months and days are declared as integers. Therefore, the statement

```
months = days/30;
```

truncates the decimal part and assigns the integer part to months. Similarly, the statement

```
days = days%30;
```

assigns the remainder part of the division to days. Thus the given number of days is converted into an equivalent number of months and days and the result is printed as shown in the output.

Real Arithmetic

An arithmetic operation involving only real operands is called *real arithmetic*. A real operand may assume values either in decimal or exponential notation. Since floating point values are rounded to the number of significant digits permissible, the final value is an approximation of the correct result. If **x, y,** and **z** are **floats**, then we will have:

$$x = 6.0/7.0 = 0.857143$$
$$y = 1.0/3.0 = 0.333333$$

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The shorthand operator += means 'add y+1 to x' or 'increment x by y+1'. For y = 2, the above statement becomes

```
x += 3;
```

and when this statement is executed, 3 is added to x. If the old value of x is, say 5, then the new value of x is 8. Some of the commonly used shorthand assignment operators are illustrated in Table 3.4.

Table 3.4 *Shorthand Assignment Operators*

Statement with simple assignment operator	*Statement with shorthand operator*
a = a + 1	a += 1
a = a – 1	a –= 1
a = a * (n+1)	a *= n+1
a = a / (n+1)	a /= n+1
a = a % b	a %= b

The use of shorthand assignment operators has three advantages:

1. What appears on the left-hand side need not be repeated and therefore it becomes easier to write.
2. The statement is more concise and easier to read.
3. The statement is more efficient.

These advantages may be appreciated if we consider a slightly more involved statement like

```
value(5*j–2) = value(5*j–2) + delta;
```

With the help of the += operator, this can be written as follows:

```
value(5*j–2) += delta;
```

It is easier to read and understand and is more efficient because the expression 5*j–2 is evaluated only once.

Example 3.2 Program of Fig. 3.2 prints a sequence of squares of numbers. Note the use of the shorthand operator *= .

The program attempts to print a sequence of squares of numbers starting from 2. The statement

```
a *= a;
```

which is identical to

```
a = a*a;
```

replaces the current value of **a** by its square. When the value of **a** becomes equal or greater than **N** (=100) the **while** is terminated. Note that the output contains only three values 2, 4 and 16.

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In **while** loops:

```
while (c = getchar( ), c != '10')
```

Exchanging values:

```
t = x, x = y, y = t;
```

The sizeof Operator

The **sizeof** is a compile time operator and, when used with an operand, it returns the number of bytes the operand occupies. The operand may be a variable, a constant or a data type qualifier.

Examples:
m = **sizeof**(sum);
n = **sizeof**(long int);
k = **sizeof**(235L);

The **sizeof** operator is normally used to determine the lengths of arrays and structures when their sizes are not known to the programmer. It is also used to allocate memory space dynamically to variables during execution of a program.

Example 3.3 In Fig. 3.3, the program employs different kinds of operators. The results of their evaluation are also shown for comparison.

Notice the way the increment operator ++ works when used in an expression. In the statement

```
c = ++a - b;
```

new value of **a** (= 16) is used thus giving the value 6 to c. That is, a is incremented by 1 before it is used in the expression. However, in the statement

```
d = b++ + a;
```

the old value of **b** (=10) is used in the expression. Here, b is incremented by 1 after it is used in the expression.

We can print the character % by placing it immediately after another % character in the control string. This is illustrated by the statement

```
printf("a%%b = %d\n", a%b);
```

The program also illustrates that the expression

```
c > d ? 1 : 0
```

assumes the value 0 when c is less than d and 1 when c is greater than d.

Program

```
main()
{
    int a, b, c, d;

    a = 15;
    b = 10;
    c = ++a - b;

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

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Whenever parentheses are used, the expressions within parentheses assume highest priority. If two or more sets of parentheses appear one after another as shown above, the expression contained in the left-most set is evaluated first and the right-most in the last. Given below are the new steps.

First pass

Step1: 9-12/6 * (2-1)
Step2: 9-12/6 * 1

Second pass

Step3: 9-2 * 1
Step4: 9-2

Third pass

Step5: 7

This time, the procedure consists of three left-to-right passes. However, the number of evaluation steps remains the same as 5 (i.e equal to the number of arithmetic operators).

Parentheses may be nested, and in such cases, evaluation of the expression will proceed outward from the innermost set of parentheses. Just make sure that every opening parenthesis has a matching closing parenthesis. For example

$$9 - (12/(3+3) * 2) - 1 = 4$$

whereas

$$9 - ((12/3) + 3 * 2) - 1 = -2$$

While parentheses allow us to change the order of priority, we may also use them to improve understandability of the program. When in doubt, we can always add an extra pair just to make sure that the priority assumed is the one we require.

Rules for Evaluation of Expression

- First, parenthesized sub expression from left to right are evaluated.
- If parentheses are nested, the evaluation begins with the innermost sub-expression.
- The precedence rule is applied in determining the order of application of operators in evaluating sub-expressions
- The associativity rule is applied when two or more operators of the same precedence level appear in a sub-expression.
- Arithmetic expressions are evaluated from left to right using the rules of precedence.
- When parentheses are used, the expressions within parentheses assume highest priority.

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Since **female_number** and **male_number** are declared as integers in the program, the decimal part of the result of the division would be lost and **ratio** would represent a wrong figure. This problem can be solved by converting locally one of the variables to the floating point as shown below:

ratio = (**float**) female_number/male_number

The operator (**float**) converts the **female_number** to floating point for the purpose of evaluation of the expression. Then using the rule of automatic conversion, the division is performed in floating point mode, thus retaining the fractional part of result.

Note that in no way does the operator (**float**) affect the value of the variable **female number.** And also, the type of **female number** remains as **int** in the other parts of the program.

The process of such a local conversion is known as *explicit conversion* or *casting a value.* The general form of a cast is:

(**type-name**) expression

Where *type-name* is one of the standard C data types. The expression may be a constant, variable or an expression. Some examples of casts and their actions are shown in Table 3.7.

Table 3.7 *Use of Casts*

Example	*Action*
x = (**int**) 7.5	7.5 is converted to integer by truncation.
a = (**int**) 21.3/(int)4.5	Evaluated as 21/4 and the result would be 5.
b = (**double**)sum/n	Division is done in floating point mode.
y = (**int**) (a+b)	The result of a+b is converted to integer.
z = (**int**)a+b	a is converted to integer and then added to b.
p = cos((**double**)x)	Converts x to double before using it.

Casting can be used to round-off a given value. Consider the following statement:

```
x = (int) (y+0.5);
```

If **y** is 27.6, **y**+0.5 is 28.1 and on casting, the result becomes 28, the value that is assigned to **x**. Of course, the expression, being cast is not changed.

Example 3.6 Figure 3.8 shows a program using a cast to evaluate the equation

$$sum = \sum_{i=1}^{n} (1/i)$$

Program

```
main()
{
     float  sum ;
     int    n ;

     sum = 0 ;
```

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As pointed out earlier in Chapter 1, to use any of these functions in a program, we should include the line:

```
#include <math.h>
```

in the beginning of the program.

Just Remember

- Use *decrement* and *increment* operators carefully. Understand the difference between **postfix** and **prefix** operations before using them.
- Add parentheses wherever you feel they would help to make the evaluation order clear.
- Be aware of side effects produced by some expressions.
- Avoid any attempt to divide by zero. It is normally undefined. It will either result in a fatal error or in incorrect results.
- Do not forget a semicolon at the end of an expression.
- Understand clearly the precedence of operators in an expression. Use parentheses, if necessary.
- Associativity is applied when more than one operator of the same precedence are used in an expression. Understand which operators associate from right to left and which associate from left to right.
- Do not use *increment* or *decrement* operators with any expression other than a *variable identifier*.
- It is illegal to apply modules operator % with anything other than integers.
- Do not use a variable in an expression before it has been assigned a value.
- Integer division always truncates the decimal part of the result. Use it carefully. Use casting where necessary.
- The result of an expression is converted to the type of the variable on the left of the assignment before assigning the value to it. Be careful about the loss of information during the conversion.
- All mathematical functions implement *double* type parameters and return *double* type values.
- It is an error if any space appears between the two symbols of the operators ==, !=, <= and >=.
- It is an error if the two symbols of the operators !=, <= and >= are reversed.
- Use spaces on either side of binary operator to improve the readability of the code.
- Do not use increment and decrement operators to floating point variables.
- Do not confuse the equality operator == with the assignment operator =.

CASE STUDIES

1. Salesman's Salary

A computer manufacturing company has the following monthly compensation policy to their salespersons:

Minimum base salary : 1500.00

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(e) The statement ++a++; gives the value 12 to a
(f) The statement a = 1/b; assigns the value 0.5 to a

3.4 Declared **a** as *int* and **b** as *float*, state whether the following statements are true or false.
(a) The statement a = 1/3 + 1/3 + 1/3; assigns the value 1 to a.
(b) The statement b = 1.0/3.0 + 1.0/3.0 + 1.0/3.0; assigns a value 1.0 to b.
(c) The statement b = 1.0/3.0 * 3.0 gives a value 1.0 to b.
(d) The statement b = 1.0/3.0 + 2.0/3.0 assigns a value 1.0 to b.
(e) The statement a = 15/10.0 + 3/2; assigns a value 3 to a.

3.5 Which of the following expressions are true?
(a) !(5 + 5 >=10)
(b) 5 + 5 = = 10 || 1 + 3 = = 5
(c) 5 > 10 || 10 < 20 && 3 < 5
(d) 10 ! = 15 && !(10<20) || 15 > 30

3.6 Which of the following arithmetic expressions are valid ? If valid, give the value of the expression; otherwise give reason.

(a) 25/3 % 2	(e) –14 % 3
(b) +9/4 + 5	(f) 15.25 + – 5.0
(c) 7.5 % 3	(g) (5/3) * 3 + 5 % 3
(d) 14 % 3 + 7 % 2	(h) 21 % (int)4.5

3.7 Write C assignment statements to evaluate the following equations:
(a) Area = $\pi r^2 + 2 \pi rh$
(b) Torque = $\frac{2m_1m_2}{m_1 + m_2} \cdot g$
(c) Side = $\sqrt{a^2 + b^2 - 2ab\cos(x)}$
(d) Energy = mass $\left[\text{acceleration} \times \text{height} + \frac{(\text{velocity})^2}{2}\right]$

3.8 Identify unnecessary parentheses in the following arithmetic expressions.
(a) ((x–(y/5)+z)%8) + 25
(b) ((x–y) * p)+q
(c) (m*n) + (–x/y)
(d) x/(3*y)

3.9 Find errors, if any, in the following assignment statements and rectify them.
(a) `x = y = z = 0.5, 2.0. –5.75;`
(b) `m = ++a * 5;`
(c) `y = sqrt(100);`
(d) `p * = x/y;`
(e) `s = /5;`
(f) `a = b++ –c*2`

3.10 Determine the value of each of the following logical expressions if a = 5, b = 10 and c = –6
(a) a > b && a < c
(b) a < b && a > c
(c) a == c || b > a

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The file name **stdio.h** is an abbrevation for *standard input-output header* file. The instruction **#include <*stdio.h*>** tells the compiler 'to search for a file named **stdio.h** and place its contents at this point in the program'. The contents of the header file become part of the source code when it is compiled.

4.2 READING A CHARACTER

The simplest of all input/output operations is reading a character from the 'standard input' unit (usually the keyboard) and writing it to the 'standard output' unit (usually the screen). Reading a single character can be done by using the function **getchar.** (This can also be done with the help of the **scanf** function which is discussed in Section 4.4.) The **getchar** takes the following form:

variable_name = **getchar( );**

variable_name is a valid C name that has been declared as **char** type. When this statement is encountered, the computer waits until a key is pressed and then assigns this character as a value to **getchar** function. Since **getchar** is used on the right-hand side of an assignment statement, the character value of **getchar** is in turn assigned to the variable name on the left. For example

```
char name;
name = getchar();
```

will assign the character 'H' to the variable **name** when we press the key H on the keyboard. Since **getchar** is a function, it requires a set of parentheses as shown.

Example 4.1 The program in Fig. 4.1 shows the use of **getchar** function in an interactive environment.

The program displays a question of YES/NO type to the user and reads the user's response in a single character (Y or N). If the response is Y, it outputs the message

My name is BUSY BEE

otherwise, outputs.

You are good for nothing

Note: There is one line space between the input text and output message.

Program

```
#include <stdio.h>
main()
{
   char answer;
   printf("Would you like to know my name?\n");
   printf("Type Y for YES and N for NO: ");
   answer = getchar(); /* .... Reading a character...*/
   if(answer == 'Y' || answer == 'y')
     printf("\n\nMy name is BUSY BEE\n");
   else
```

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```
a
A
Enter an alphabet
Q
q
Enter an alphabet
z
Z
```

Fig. 4.3 *Reading and writing of alphabets in reverse case*

4.4 FORMATTED INPUT

Formatted input refers to an input data that has been arranged in a particular format. For example, consider the following data:

```
15.75 123 John
```

This line contains three pieces of data, arranged in a particular form. Such data has to be read conforming to the format of its appearance. For example, the first part of the data should be read into a variable **float**, the second into **int**, and the third part into **char**. This is possible in C using the **scanf** function. (**scanf** means *scan* formatted.)

We have already used this input function in a number of examples. Here, we shall explore all of the options that are available for reading the formatted data with **scanf** function. The general form of **scanf** is

scanf ("*control string*", *arg1*, *arg2*, ... *argn*);

The *control string* specifies the field format in which the data is to be entered and the arguments *arg*1, *arg2*, ..., *argn* specify the address of locations where the data is stored. Control string and arguments are separated by commas.

Control string (also known as *format string*) contains field specifications, which direct the interpretation of input data. It may include:

- Field (or format) specifications, consisting of the conversion character %, a data type character (or type specifier), and an *optional* number, specifying the field width.
- Blanks, tabs, or newlines.

Blanks, tabs and newlines are ignored. The data type character indicates the type of data that is to be assigned to the variable associated with the corresponding argument. The field width specifier is optional. The discussions that follow will clarify these concepts.

Inputting Integer Numbers

The field specification for reading an integer number is:

```
% w d
```

The percent sign (%) indicates that a conversion specification follows. *w* is an integer number that specifies the *field width* of the number to be read and d, known as data type character, indicates that the number to be read is in integer mode. Consider the following example:

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```
a = 12    b = 3.450000     c = A
Enter values of a, b and c
23 78 9
a = 23    b = 78.000000    c = 9
Enter values of a, b and c
8 A 5.25
Error in input.
Enter values of a, b and c
Y 12 67
Error in input.
Enter values of a, b and c
15.75 23 X
a = 15    b = 0.750000     c = 2
```

Fig. 4.8 *Detection of errors in* ***scanf*** *input*

Commonly used **scanf** format codes are given in Table 4.2

Table 4.2 *Commonly used scanf Format Codes*

Code	*Meaning*
%c	read a single character
%d	read a decimal integer
%e	read a floating point value
%f	read a floating point value
%g	read a floating point value
%h	read a short integer
%i	read a decimal, hexadecimal or octal integer
%o	read an octal integer
%s	read a string
%u	read an unsigned decimal integer
%x	read a hexadecimal integer
%[..]	read a string of word(s)

The following letters may be used as prefix for certain conversion characters.

- h for short integers
- l for long integers or double
- L for long double

Points to Remember While Using scanf

If we do not plan carefully, some 'crazy' things can happen with **scanf**. Since the I/O routines are not a part of C language, they are made available either as a separate module of the C library or as a part of the operating system (like UNIX). New features are added to these routines from time to time as new versions of systems are released. We should consult the system reference manual before using these routines. Given below are some of the general points to keep in mind while writing a **scanf** statement.

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sion). The value, when displayed, is *rounded to p decimal places* and printed *right-justified* in the field of *w* columns. Leading blanks and trailing zeros will appear as necessary. The default precision is 6 decimal places. The negative numbers will be printed with the minus sign. The number will be displayed in the form [–] mmm-nnn.

We can also display a real number in exponential notation by using the specification

% *w.p* e

The display takes the form

[-] m.nnnne[±]xx

where the length of the string of n's is specified by the precision *p*. The default precision is 6. The field width **w** should satisfy the condition.

$$w \geq p+7$$

The value will be rounded off and printed right justified in the field of **w** columns.

Padding the leading blanks with zeros and printing with *left-justification* are also possible by using flags 0 or – before the field width specifier **w**.

The following examples illustrate the output of the number y = 98.7654 under different format specifications:

Format	*Output*
printf("%7.4f",y)	9 8 . 7 6 5 4
printf("%7.2f",y)	9 8 . 7 7
printf("%-7.2f",y)	9 8 . 7 7
printf("%f",y)	9 8 . 7 6 5 4
printf("%10.2e",y)	9 . 8 8 e + 0 1
printf("%11.4e",-y)	– 9 . 8 7 6 5 e + 0 1
printf("%-10.2e",y)	9 . 8 8 e + 0 1
printf("%e",y)	9 . 8 7 6 5 4 0 e + 0 1

Some systems also support a special field specification character that lets the user define the field size at run time. This takes the following form:

```
printf("%*.*f", width, precision, number);
```

In this case, both the field width and the precision are given as arguments which will supply the values for **w** and **p**. For example,

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Code	*Meaning*
%f	print a floating point value without exponent
%g	print a floating point value either e-type or f-type depending on value
%i	print a signed decimal integer
%o	print an octal integer, without leading zero
%s	print a string
%u	print an unsigned decimal integer
%x	print a hexadecimal integer, without leading Ox

The following letters may be used as prefix for certain conversion characters.

h for short integers
l for long integers or double
L for long double.

Table 4.4 *Commonly used* ***Output*** *Format Flags*

Flag	*Meaning*
–	Output is left-justified within the field. Remaining field will be blank.
+	+ or – will precede the signed numeric item.
0	Causes leading zeros to appear.
#(with o or x)	Causes octal and hex items to be preceded by O and Ox, respectively.
#(with e, f or g)	Causes a decimal point to be present in all floating point numbers, even if it is whole number. Also prevents the truncation of trailing zeros in g-type conversion.

Enhancing the Readability of Output

Computer outputs are used as information for analysing certain relationships between variables and for making decisions. Therefore the correctness and clarity of outputs are of utmost importance. While the correctness depends on the solution procedure, the clarity depends on the way the output is presented. Following are some of the steps we can take to improve the clarity and hence the readability and understandability of outputs.

1. Provide enough blank space between two numbers.
2. Introduce appropriate headings and variable names in the output.
3. Print special messages whenever a peculiar condition occurs in the output.
4. Introduce blank lines between the important sections of the output.

The system usually provides two blank spaces between the numbers. However, this can be increased by selecting a suitable field width for the numbers or by introducing a 'tab' character between the specifications. For example, the statement

```
printf("a = %d\t b = %d", a, b);
```

will provide four blank spaces between the two fields. We can also print them on two separate lines by using the statement

```
printf("a = %d\n b = %d", a, b);
```

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Problem

```
#include <math.h>
#define LAMBDA 0.001
main()
{
   double t;
   float r;
   int i, R;
   for (i=1; i<=27; ++i)
   {
     printf("--");
   }
printf("\n");
for (t=0; t<=3000; t+=150)
{
   r = exp(-LAMBDA*t);
   R = (int)(50*r+0.5);
   printf(" |");
   for (i=1; i<=R; ++i)
   {
      printf("*");
   }
   printf("#\n");
   }
   for (i=1; i<3; ++i)
   {
      printf(" |\n");
   }
}
```

Output

```
-----------------------------------------------------
|**************************************************#
|*************************************************#
|************************************#
|**********************************#
|*****************************#
|************************#
|*******************#
|*****************#
|***************#
|*************#
|**********#
|********#
|*******#
|
```

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Ratio = –3.181818

```
Program
  main()
  {
       int a, b, c, d;
       float ratio;

       printf("Enter four integer values\n");
       scanf("%d %d %d %d", &a, &b, &c, &d);

       if (c-d != 0) /* Execute statement block */
       {
            ratio = (float)(a+b)/(float)(c-d);
            printf("Ratio = %f\n", ratio);
       }
  }
```

Output

```
Enter four integer values
12 23 34 45
Ratio = -3.181818

Enter four integer values
12  23  34  34
```

Fig. 5.3 *Illustration of simple* ***if*** *statement*

The second run has neither produced any results nor any message. During the second run, the value of (c–d) is equal to zero and therefore the statements contained in the statement-block are skipped. Since no other statement follows the statement-block, program stops without producing any output.

Note the use of **float** conversion in the statement evaluating the **ratio**. This is necessary to avoid truncation due to integer division. Remember, the output of the first run –3.181818 is printed correct to six decimal places. The answer contains a round off error. If we wish to have higher accuracy, we must use **double** or **long double** data type.

The simple **if** is often used for counting purposes. The Example 5.2 illustrates this.

Example 5.2 The program in Fig. 5.4 counts the number of boys whose weight is less than 50 kg and height is greater than 170 cm.

The program has to test two conditions, one for weight and another for height. This is done using the compound relation

```
if (weight < 50 && height > 170)
```

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Here, if the code is equal to 1, the statement **boy = boy + 1;** is executed and the control is transferred to the statement **xxxxxx**, after skipping the else part. If the code is not equal to 1, the statement **boy = boy + 1**; is skipped and the statement in the **else** part **girl = girl + 1**; is executed before the control reaches the statement **xxxxxxxx.**

Consider the program given in Fig. 5.3. When the value (c–d) is zero, the ratio is not calculated and the program stops without any message. In such cases we may not know whether the program stopped due to a zero value or some other error. This program can be improved by adding the **else** clause as follows:

```
.....
.....
if (c-d != 0)
   {
      ratio = (float)(a+b)/(float)(c-d);
      printf("Ratio = %f\n", ratio);
   }
else
   printf("c-d is zero\n");
.....
.....
```

Example 5.3 A program to evaluate the power series

$$e^x = 1 + x + \frac{x^2}{2!} + \frac{x^3}{3!} + \ldots + \frac{x^n}{n!}, \quad 0 < x < 1$$

is given in Fig. 5.6. It uses **if.....else** to test the accuracy.

The power series contains the recurrence relationship of the type

$$T_n = T_{n-1}\left(\frac{x}{n}\right) \text{ for } n > 1$$

$$T_1 = x \text{ for } n = 1$$

$$T_0 = 1$$

If T_{n-1} (usually known as *previous term*) is known, then T_n (known as *present term*) can be easily found by multiplying the previous term by x/n. Then

$$e^x = T_0 + T_1 + T_2 + \ldots\ldots + T_n = \text{sum}$$

Program

```
#define ACCURACY 0.0001
main()
{
   int n, count;
   float x, term, sum;
   printf("Enter value of x:");
```

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Example 5.4 The program in Fig. 5.8 selects and prints the largest of the three numbers using nested **if....else** statements.

```
Program
   main()
   {
   float A, B, C;

   printf("Enter three values\n");
   scanf("%f %f %f", &A, &B, &C);

   printf("\nLargest value is ");
   if (A>B)
   {
      if (A>C)
         printf("%f\n", A);
      else
         printf("%f\n", C);
   }
   else
   {
      if (C>B)
         printf("%f\n", C);
      else
         printf("%f\n", B);
   }
Output
      Enter three values
      23445 67379 88843

      Largest value is 88843.000000
```

Fig 5.8 *Selecting the largest of three numbers*

Dangling Else Problem

One of the classic problems encountered when we start using nested **if....else** statements is the dangling else. This occurs when a matching **else** is not available for an **if**. The answer to this problem is very simple. Always match an **else** to the most recent unmatched **if** in the current block. In some cases, it is possible that the false condition is not required. In such situations, **else** statement may be omitted

"**else** is always paired with the most recent unpaired **if**"

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Output

```
Enter CUSTOMER NO. and UNITS consumed 101 150
Customer No:101 Charges = 75.00

Enter CUSTOMER NO. and UNITS consumed 202 225
Customer No:202 Charges = 116.25

Enter CUSTOMER NO. and UNITS consumed 303 375
Customer No:303 Charges = 213.75

Enter CUSTOMER NO. and UNITS consumed 404 520
Customer No:404 Charges = 326.00

Enter CUSTOMER NO. and UNITS consumed 505 625
Customer No:505 Charges = 415.00
```

Fig. 5.10 *Illustration of* ***else..if*** *ladder*

Rules for Indentation

When using control structures, a statement often controls many other statements that follow it. In such situations it is a good practice to use *indentation* to show that the indented statements are dependent on the preceding controlling statement. Some guidelines that could be followed while using indentation are listed below:

- Indent statements that are dependent on the previous statements; provide at least three spaces of indentation.
- Align vertically else clause with their matching if clause.
- Use braces on separate lines to identify a block of statements.
- Indent the statements in the block by at least three spaces to the right of the braces.
- Align the opening and closing braces.
- Use appropriate comments to signify the beginning and end of blocks.
- Indent the nested statements as per the above rules.
- Code only one clause or statement on each line.

5.7 THE SWITCH STATEMENT

We have seen that when one of the many alternatives is to be selected, we can use an **if** statement to control the selection. However, the complexity of such a program increases dramatically when the number of alternatives increases. The program becomes difficult to read and follow. At times, it may confuse even the person who designed it. Fortunately, C has a built-in multiway decision statement known as a **switch.** The **switch** statement tests the value of a given variable (or expression) against a list of **case** values and when a match is found, a block of statements associated with that **case** is executed. The general form of the **switch** statement is as shown below:

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- The **break** statement transfers the control out of the **switch** statement.
- The **break** statement is optional. That is, two or more case labels may belong to the same statements.
- The **default** label is optional. If present, it will be executed when the expression does not find a matching case label.
- There can be at most one **default** label.
- The **default** may be placed anywhere but usually placed at the end.
- It is permitted to nest **switch** statements.

5.8 THE ? : OPERATOR

The C language has an unusual operator, useful for making two-way decisions. This operator is a combination of ? and :, and takes three operands. This operator is popularly known as the *conditional operator*. The general form of use of the conditional operator is as follows:

conditional expression ? expression1 : expression2

The *conditional expression* is evaluated first. If the result is nonzero, *expression1* is evaluated and is returned as the value of the conditional expression. Otherwise, *expression2* is evaluated and its value is returned. For example, the segment

```
if (x < 0)
   flag = 0;
else
   flag = 1;
```

can be written as

```
flag = ( x < 0 ) ? 0 : 1;
```

Consider the evaluation of the following function:

$y = 1.5x + 3$ for $x \leq 2$

$y = 2x + 5$ for $x > 2$

This can be evaluated using the conditional operator as follows:

```
y = ( x > 2 ) ? (2 * x + 5) : (1.5 * x + 3);
```

The conditional operator may be nested for evaluating more complex assignment decisions. For example, consider the weekly salary of a salesgirl who is selling some domestic products. If x is the number of products sold in a week, her weekly salary is given by

$$\text{salary} = \begin{cases} 4x + 100 & \text{for } x < 40 \\ 300 & \text{for } x = 40 \\ 4.5x + 150 & \text{for } x > 40 \end{cases}$$

This complex equation can be written as

```
salary = (x != 40) ? ((x < 40) ? (4*x+100) : (4.5*x+150)) : 300;
```

The same can be evaluated using **if...else** statements as follows:

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Due to the unconditional **goto** statement at the end, the control is always transferred back to the input statement. In fact, this program puts the computer in a permanent loop known as an *infinite loop*. The computer goes round and round until we take some special steps to terminate the loop. Such infinite loops should be avoided. Example 5.7 illustrates how such infinite loops can be eliminated.

Example 5.7 Program presented in Fig. 5.13 illustrates the use of the **goto** statement. The program evaluates the square root for five numbers. The variable count keeps the count of numbers read. When count is less than or equal to 5, **goto read**; directs the control to the label **read**; otherwise, the program prints a message and stops.

Program

```
#include <math.h>
main()
{
     double x, y;
     int count;
     count = 1;
     printf("Enter FIVE real values in a LINE \n");
read:
     scanf("%lf", &x);
     printf("\n");
     if (x < 0)
       printf("Value - %d is negative\n",count);
     else
     {
       y = sqrt(x);
       printf("%lf\t %lf\n", x, y);
     }
     count = count + 1;
     if (count <= 5)
goto read;
     printf("\nEnd of computation");
}
```

Output

```
Enter FIVE real values in a LINE
50.70 40 -36 75 11.25
50.750000     7.123903
40.000000     6.324555
Value -3 is negative
75.000000     8.660254
11.250000     3.354102
End of computation
```

Fig. 5.13 *Use of the goto statement*

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An executive's gross salary includes basic pay, house rent allowance at 25% of basic pay and other perks. Income tax is withheld from the salary on a percentage basis as follows:

Gross salary	*Tax rate*
Gross <= 2000	No tax deduction
2000 < Gross <= 4000	3%
4000 < Gross <= 5000	5%
Gross > 5000	8%

Write a program that will read an executive's job number, level number, and basic pay and then compute the net salary after withholding income tax.

Problem analysis:

Gross salary = basic pay + house rent allowance + perks

Net salary = Gross salary – income tax.

The computation of perks depends on the level, while the income tax depends on the gross salary. The major steps are:

1. Read data.
2. Decide level number and calculate perks.
3. Calculate gross salary.
4. Calculate income tax.
5. Compute net salary.
6. Print the results.

Program: A program and the results of the test data are given in Fig. 5.15. Note that the last statement should be an executable statement. That is, the label **stop:** cannot be the last line.

```
Program
   #define CA1 1000
   #define CA2 750
   #define CA3 500
   #define CA4 250
   #define EA1 500
   #define EA2 200
   #define EA3 100
   #define EA4 0
   main()
   {
      int level, jobnumber;
      float  gross,
             basic,
             house_rent,
             perks,
             net,
             incometax;
      input:
      printf("\nEnter level, job number, and basic pay\n");
      printf("Enter 0 (zero) for level to END\n\n");
      scanf("%d", &level);
```

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```
        z = 0;
(c) if (x)
      if (y)
        z = 10;
    else
        z = 0;
(d) if (x = = 0 || x & & y)
      if (!y)
        z = 0;
    else
        y = 1;
```

5.10 Assuming that x = 2, y = 1 and z = 0 initially, what will be their values after executing the following code segments?

```
(a) switch (x)
    {
        case 2:
            x = 1;
            y = x + 1;
        case 1:
            x = 0;
            break;
        default:
            x = 1;
            y = 0;
    }
(b) switch (y)
    {
        case 0:
            x = 0;
            y = 0;
        case 2:
            x = 2;
            z = 2;
        default:
            x = 1;
            y = 2;
}
```

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Chapter 6

Decision Making and Looping

6.1 INTRODUCTION

We have seen in the previous chapter that it is possible to execute a segment of a program repeatedly by introducing a counter and later testing it using the **if** statement. While this method is quite satisfactory for all practical purposes, we need to initialize and increment a counter and test its value at an appropriate place in the program for the completion of the loop. For example, suppose we want to calculate the sum of squares of all integers between 1 and 10. We can write a program using the **if** statement as follows:

```
            ------------
            ------------
            sum = 0;
            n = 1;
     ┌────► loop:
  L  │      sum = sum + n*n;
     │      if (n == 10)
  o  │          goto print;──┐
  o  │      else             │
     │      {                │  n = 10,
  p  │          n = n+1;     │  end of loop
     └───────   goto loop;   │
            }                │
            print: ◄─────────┘
            ------------
            ------------
```

This program does the following things:

1. Initializes the variable **n**.
2. Computes the square of **n** and adds it to **sum**.
3. Tests the value of **n** to see whether it is equal to 10 or not. If it is equal to 10, then the program prints the results.

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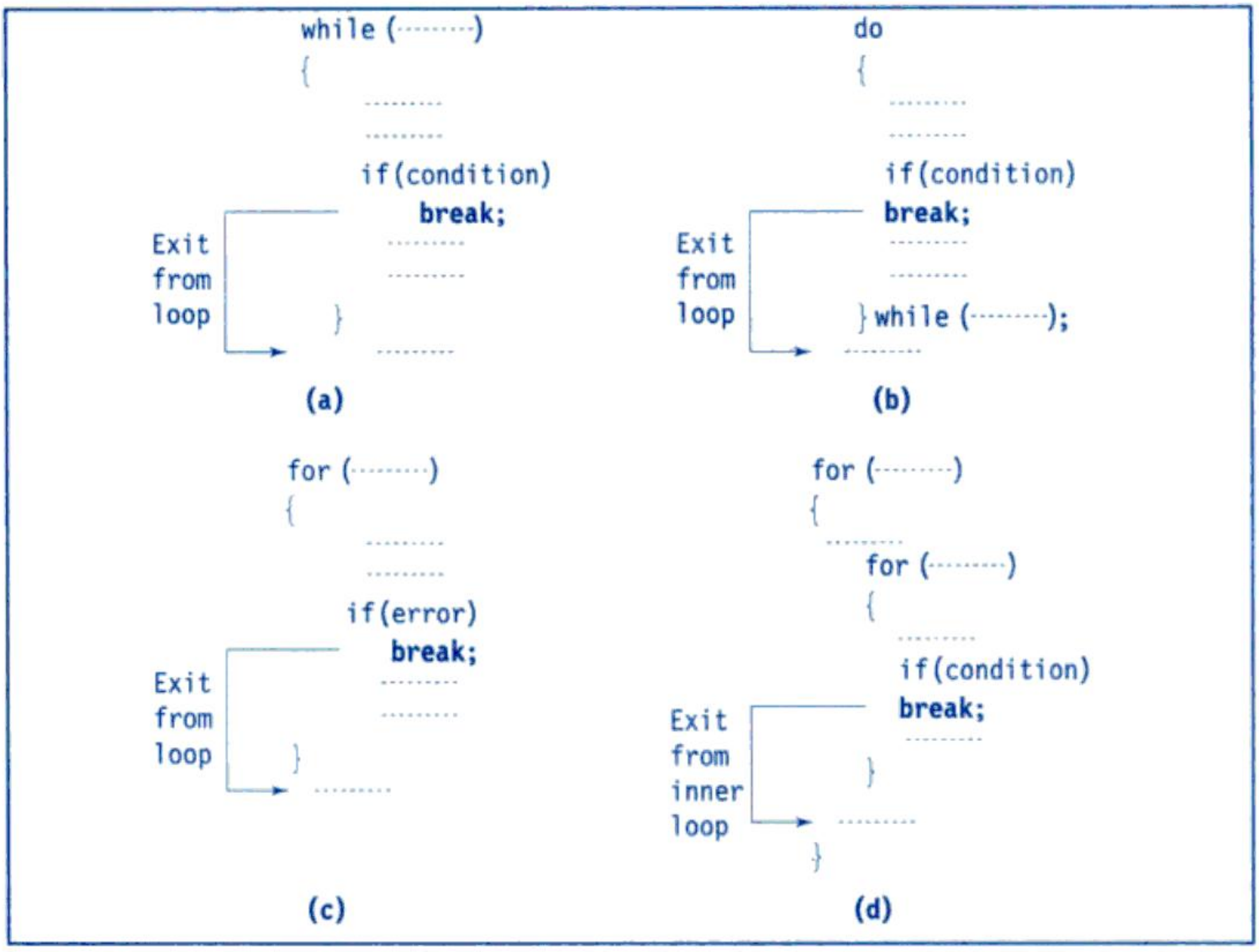

Fig. 6.6 *Exiting a loop with* ***break*** *statement*

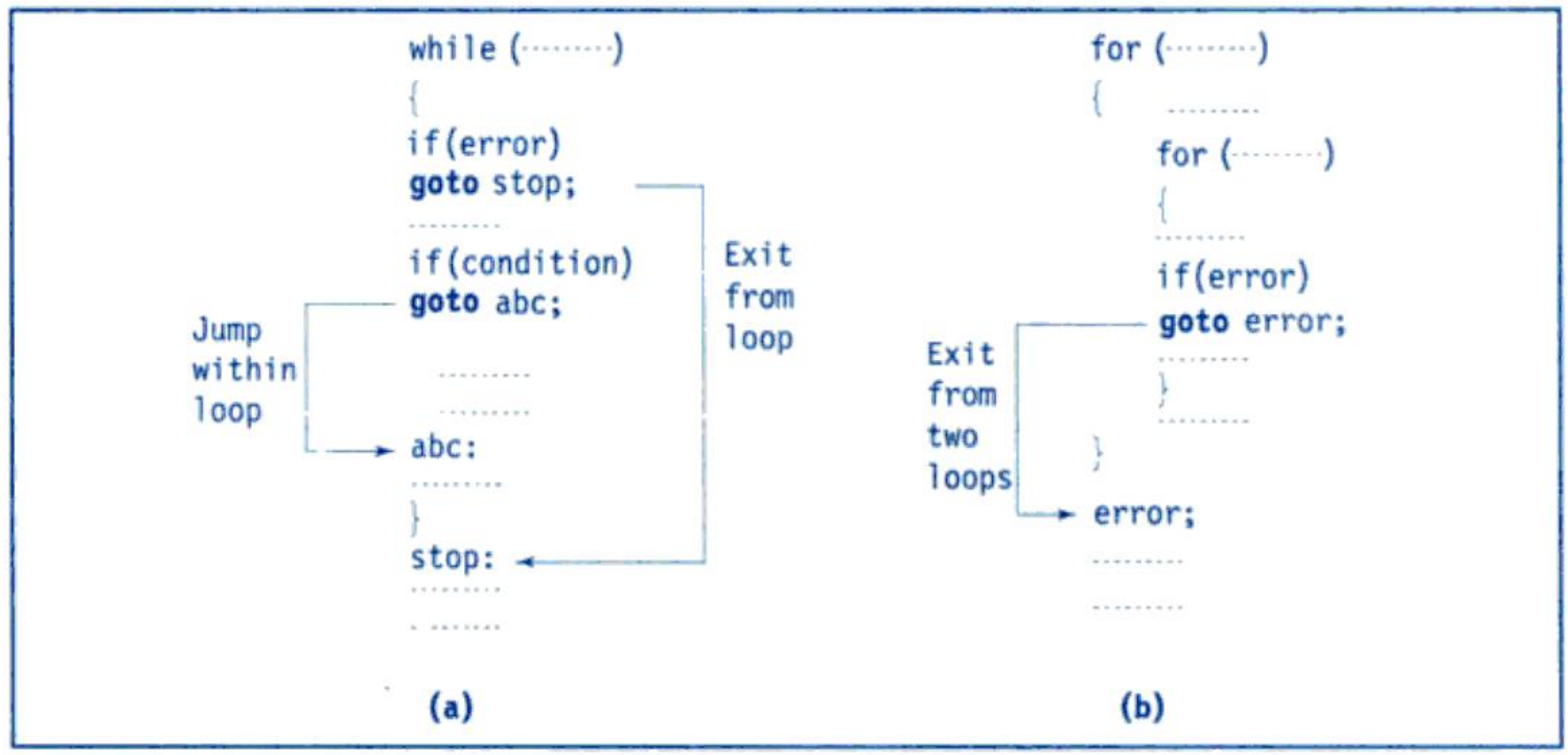

Fig. 6.7 *Jumping within and exiting from the loops with* ***goto*** *statement*

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The third feature is that the test-condition may have any compound relation and the testing need not be limited only to the loop control variable. Consider the example below:

```
sum = 0;
for (i = 1; i < 20 && sum < 100; ++i)
{
     sum = sum+i;
     printf("%d %d\n", i, sum);
}
```

The loop uses a compound test condition with the counter variable **i** and sentinel variable **sum**. The loop is executed as long as both the conditions i < 20 and sum < 100 are true. The **sum** is evaluated inside the loop.

It is also permissible to use expressions in the assignment statements of initialization and increment sections. For example, a statement of the type

```
for (x = (m+n)/2; x > 0; x = x/2)
```

is perfectly valid.

Another unique aspect of **for** loop is that one or more sections can be omitted, if necessary. Consider the following statements:

```
-------
m = 5;
for ( ; m != 100 ; )
{
     printf("%d\n", m);
     m = m+5;
}
-------
```

Both the initialization and increment sections are omitted in the **for** statement. The initialization has been done before the **for** statement and the control variable is incremented inside the loop. In such cases, the sections are left 'blank'. However, the semicolons separating the sections must remain. If the test-condition is not present, the **for** statement sets up an *'infinite'* loop. Such loops can be broken using **break** or **goto** statements in the loop.

We can set up *time delay loops* using the null statement as follows:

```
for  ( j = 1000; j > 0; j = j-1)
     ;
```

This loop is executed 1000 times without producing any output; it simply causes a time delay. Notice that the body of the loop contains only a semicolon, known as a *null* statement. This can also be written as

```
for (j=1000; j > 0; j = j-1)
```

This implies that the C compiler will not give an error message if we place a semicolon by mistake at the end of a **for** statement. The semicolon will be considered as a *null statement* and the program may produce some nonsense.

Nesting of for Loops

Nesting of loops, that is, one **for** statement within another **for** statement, is allowed in C. For example, two loops can be nested as follows:

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Output

MULTIPLICATION TABLE

1	2	3	4	5	6	7	8	9	10
2	4	6	8	10	12	14	16	18	20
3	6	9	12	15	18	21	24	27	30
4	8	12	16	20	24	28	32	36	40
5	10	15	20	25	30	35	40	45	50
6	12	18	24	30	36	42	48	54	60
7	14	21	28	35	42	49	56	63	70
8	16	24	32	40	48	56	64	72	80
9	18	27	36	45	54	63	72	81	90
10	20	30	40	50	60	70	80	90	100
11	22	33	44	55	66	77	88	99	110
12	24	36	48	60	72	84	96	108	120

Fig. 6.3 *Printing of a multiplication table using* ***do...while*** *loop*

Notice that the **printf** of the inner loop does not contain any new line character (\n). This allows the printing of all row values in one line. The empty **printf** in the outer loop initiates a new line to print the next row.

6.4 THE FOR STATEMENT

Simple 'for' Loops

The **for** loop is another *entry-controlled* loop that provides a more concise loop control structure. The general form of the **for** loop is

```
for ( initialization ; test-condition ; increment)
{
    body of the loop
}
```

The execution of the **for** statement is as follows:

1. *Initialization* of the *control variables* is done first, using assignment statements such as i = 1 and count = 0. The variables **i** and **count** are known as loop-control variables.
2. The value of the control variable is tested using the test-condition. The *test-condition* is a relational expression, such as i < 10 that determines when the loop will exit. If the condition is *true*, the body of the loop is executed; otherwise the loop is terminated and the execution continues with the statement that immediately follows the loop.
3. When the body of the loop is executed, the control is transferred back to the **for** statement after evaluating the last statement in the loop. Now, the control variable is *incremented* using an assignment statement such as i = i+1 and the new value of the control variable is again tested to see whether it satisfies the loop condition. If the condition is satisfied, the body of the loop is again executed. This process continues till the value of the control variable fails to satisfy the test-condition.

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When a function is defined in one file and accessed in another, the later file must include a function *declaration*. The declaration identifies the function as an external function whose definition appears elsewhere. We usually place such declarations at the beginning of the file, before all functions. Although all functions are assumed to be external, it would be a good practice to explicitly declare such functions with the storage class **extern.**

Just Remember

- It is a syntax error if the types in the declaration and function definition do not match.
- It is a syntax error if the number of actual parameters in the function call do not match the number in the declaration statement.
- It is a logic error if the parameters in the function call are placed in the wrong order.
- It is illegal to use the name of a formal argument as the name of a local variable.
- Using **void** as return type when the function is expected to return a value is an error.
- Trying to return a value when the function type is marked **void** is an error.
- Variables in the parameter list must be individually declared for their types. We cannot use multiple declarations (like we do with local or global variables).
- A **return** statement is required if the return type is anything other than **void.**
- If a function does not return any value, the return type must be declared **void.**
- If a function has no parameters, the parameter list must be declared **void.**
- Placing a semicolon at the end of header line is illegal.
- Forgetting the semicolon at the end of a prototype declaration is an error.
- Defining a function within the body of another function is not allowed.
- It is an error if the type of data returned does not match the return type of the function.
- It will most likely result in logic error if there is a mismatch in data types between the actual and formal arguments.
- Functions return integer value by default.
- A function without a return statement cannot return a value, when the parameters are passed by value.
- A function that returns a value can be used in expressions like any other C variable.
- When the value returned is assigned to a variable, the value will be converted to the type of the variable receiving it.
- Function cannot be the target of an assignment.
- A function with void return type cannot be used in the right-hand side of an assignment statement. It can be used only as a stand-alone statement.
- A function that returns a value cannot be used as a stand-alone statement.
- A **return** statement can occur anywhere within the body of a function.
- A function can have more than one return statement.
- A function definition may be placed either after or before the **main** function.

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(c) int product (int m, 10)
(d) double minimum (double x; double y;)
(e) int mul (int x, y)
(f) exchange (int *a, int *b)
(g) void sum (int a, int b, int &c)

9.10 Find errors, if any, in the following function definitions:

(a)
```
void abc (int a, int b)
    {
            int c;
            . . . .
            return (c);
    }
```
(b)
```
int abc (int a, int b)
    {
            . . . .
            . . . .
    }
```
(c)
```
int abc (int a, int b)
    {
            double c = a + b;
            return (c);
    }
```
(d)
```
void abc (void)
    {
            . . . .
            . . . .
            return;
    }
```
(e)
```
int abc(void)
    {
            . . . .
            . . . .
            return;
    }
```

9.11 Find errors in the following function calls:

(a) void xyz ( );
(b) xyx (void);
(c) xyx (int x, int y);
(d) xyzz ( );
(e) xyz ( ) + xyz ( );

9.12 A function to divide two floating point numbers is as follows:

```
divide (float x, float y)
{
    return (x / y);
}
```

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Arrays Vs Structures

Both the arrays and structures are classified as structured data types as they provide a mechanism that enable us to access and manipulate data in a relatively easy manner. But they differ in a number of ways.

1. An array is a collection of related data elements of same type. Structure can have elements of different types.
2. An array is derived data type whereas a structure is a programmer-defined one.
3. Any array behaves like a built-in data type. All we have to do is to declare an array variable and use it. But in the case of a structure, first we have to design and declare a data structure before the variables of that type are declared and used.

10.3 DECLARING STRUCTURE VARIABLES

After defining a structure format we can declare variables of that type. A structure variable declaration is similar to the declaration of variables of any other data types. It includes the following elements.

1. The keyword **struct**
2. The structure tag name
3. List of variable names separated by commas
4. A terminating semicolon

For example, the statement

```
struct book_bank, book1, book2, book3;
```

declares **book1, book2**, and **book3** as variables of type **struct book_bank.**

Each one of these variables has four members as specified by the template. The complete declaration might look like this:

```
struct book_bank
{
   char  title[20];
   char  author[15];
   int   pages;
   float price;
};
struct book_bank book1, book2, book3;
```

Remember that the members of a structure themselves are not variables. They do not occupy any memory until they are associated with the structure variables such as **book1.** When the compiler comes across a declaration statement, it reserves memory space for the structure variables. It is also allowed to combine both the structure definition and variables declaration in one statement.

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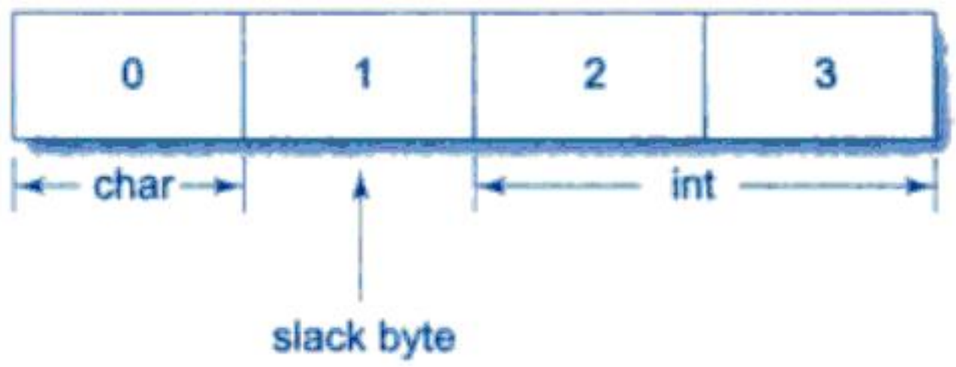
Word Boundaries and Slack Bytes

Computer stores structures using the concept of "word boundary". The size of a word boundary is machine dependent. In a computer with two bytes word boundary, the members of a structure are stored left_aligned on the word boundary as shown below. A character data takes one byte and an integer takes two bytes. One byte between them is left unoccupied. This unoccupied byte is known as the *slack byte*.



When we declare structure variables, each one of them may contain slack bytes and the values stored in such slack bytes are undefined. Due to this, even if the members of two variables are equal, their structures do not necessarily compare equal. C, therefore, does not permit comparison of structures. However, we can design our own function that could compare individual members to decide whether the structures are equal or not.

10.7 OPERATIONS ON INDIVIDUAL MEMBERS

As pointed out earlier, the individual members are identified using the member operator, the dot. A member with the dot operator along with its structure variable can be treated like any other variable name and therefore can be manipulated using expressions and operators. Consider the program in Fig. 10.2. We can perform the following operations:

```
if (student1.number == 111)
        student1.marks += 10.00;

float sum = student1.marks + student2.marks;
student2.marks * = 0.5;
```

We can also apply increment and decrement operators to numeric type members. For example, the following statements are valid:

```
student1.number ++;
++ student1.number;
```

The precedence of the member operator is higher than all arithmetic and relational operators and therefore no parentheses are required.

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therefore, necessary for the function to return the entire structure back to the calling function. All compilers may not support this method of passing the entire structure as a parameter.

3. The third approach employs a concept called *pointers* to pass the structure as an argument. In this case, the address location of the structure is passed to the called function. The function can access indirectly the entire structure and work on it. This is similar to the way arrays are passed to function. This method is more efficient as compared to the second one.

In this section, we discuss in detail the second method, while the third approach using pointers is discussed in the next chapter, where pointers are dealt in detail.

The general format of sending a copy of a structure to the called function is:

```
function_name (structure_variable_name);
```

The called function takes the following form:

```
data_type function_name(struct_type st_name)
{
   ......
   ......
   return(expression);
}
```

The following points are important to note:

1. The called function must be declared for its type, appropriate to the data type it is expected to return. For example, if it is returning a copy of the entire structure, then it must be declared as **struct** with an appropriate tag name.
2. The structure variable used as the actual argument and the corresponding formal argument in the called function must be of the same **struct** type.
3. The **return** statement is necessary only when the function is returning some data back to the calling function. The *expression* may be any simple variable or structure variable or an expression using simple variables.
4. When a function returns a structure, it must be assigned to a structure of identical type in the calling function.
5. The called functions must be declared in the calling function appropriately.

Example 10.5 Write a simple program to illustrate the method of sending an entire structure as a parameter to a function.

A program to update an item is shown in Fig. 10.6. The function **update** receives a copy of the structure variable **item** as one of its parameters. Note that both the function **update** and the formal parameter **product** are declared as type **struct stores.** It is done so because the function uses the parameter **product** to receive the structure variable **item** and also to return the updated values of **item**.

The function **mul** is of type **float** because it returns the product of **price** and **quantity.** However, the parameter **stock,** which receives the structure variable **item** is declared as type **struct stores.**

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- When accessing a member with a pointer and dot notation, parentheses are required around the pointer, like (*ptr).number.
- The selection operator (->) is a single token. Any space between the symbols – and > is an error.
- When using **scanf** for reading values for members, we must use address operator & with non-string members.
- Forgetting to include the array subscript when referring to individual structures of an array of structures is an error.
- A union can store only one of its members at a time. We must exercise care in accessing the correct member. Accessing a wrong data is a logic error.
- It is an error to initialize a union with data that does not match the type of the first member.
- Always provide a structure tag name when creating a structure. It is convenient to use tag name to declare new structure variables later in the program.
- Use short and meaningful structure tag names.
- Avoid using same names for members of different structures (although it is not illegal).
- Passing structures to functions by pointers is more efficient than passing by value. (Passing by pointers are discussed in Chapter 11.)
- We cannot take the address of a bit field. Therefore, we cannot use **scanf** to read values in bit fields. We can neither use pointer to access the bit fields.
- Bit fields cannot be arrayed.

CASE STUDY

Book Shop Inventory

A book shop uses a personal computer to maintain the inventory of books that are being sold at the shop. The list includes details such as author, title, price, publisher, stock position, etc. Whenever a customer wants a book, the shopkeeper inputs the title and author of the book and the system replies whether it is in the list or not. If it is not, an appropriate message is displayed. If book is in the list, then the system displays the book details and asks for number of copies. If the requested copies are available, the total cost of the books is displayed; otherwise the message "Required copies not in stock" is displayed.

A program to accomplish this is shown in Fig. 10.8. The program uses a template to define the structure of the book. Note that the date of publication, a member of **record** structure, is also defined as a structure.

When the title and author of a book are specified, the program searches for the book in the list using the function

look_up(table, s1, s2, m)

The parameter **table** which receives the structure variable **book** is declared as type **struct record.** The parameters **s1** and **s2** receive the string values of **title** and **author** while **m** receives the total number of books in the list. Total number of books is given by the expression

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11.2 UNDERSTANDING POINTERS

The computer's memory is a sequential collection of 'storage cells' as shown in Fig. 11.1. Each cell, commonly known as a *byte,* has a number called *address* associated with it. Typically, the addresses are numbered consecutively, starting from zero. The last address depends on the memory size. A computer system having 64 K memory will have its last address as 65,535.

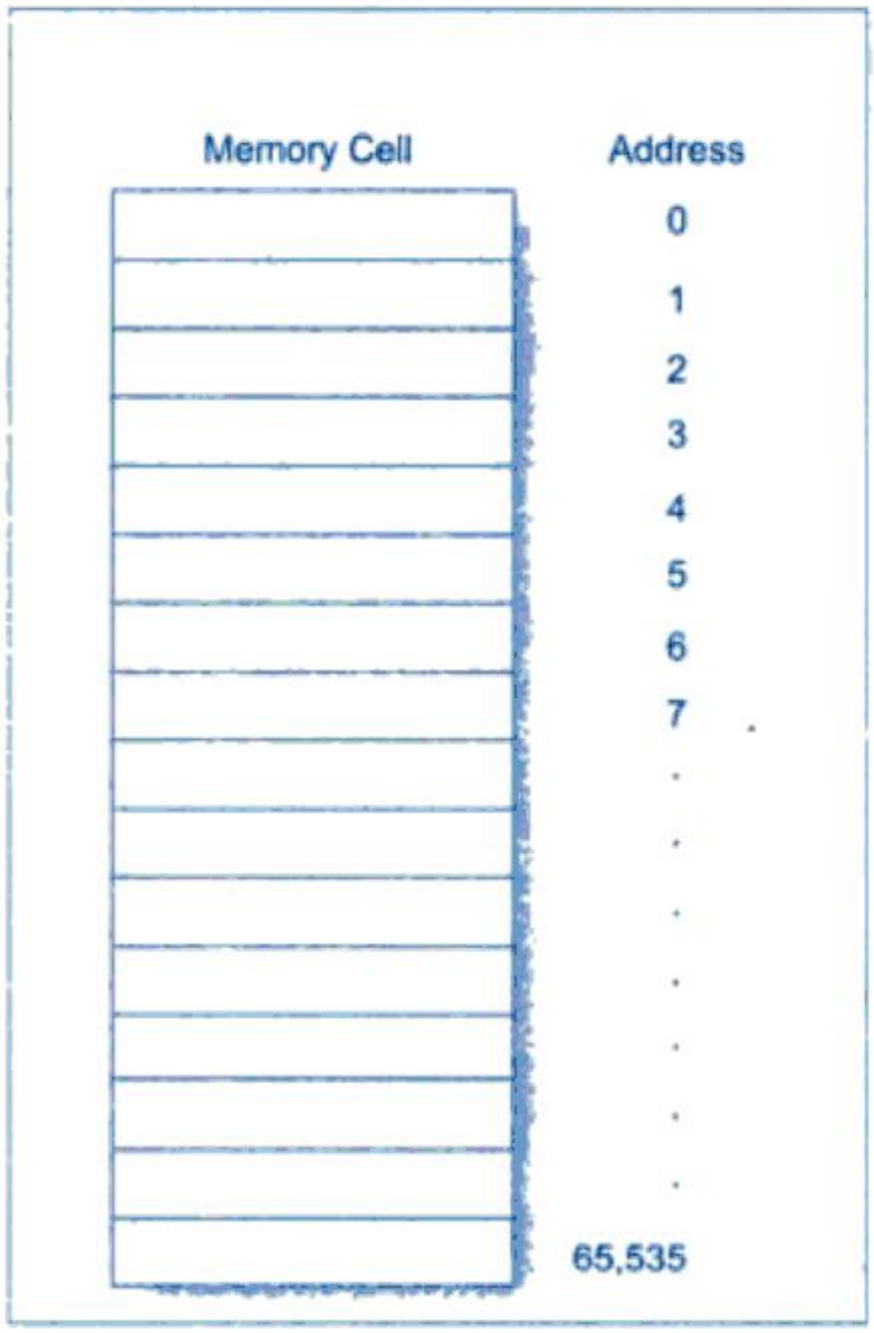

Fig. 11.1 *Memory organisation*

Whenever we declare a variable, the system allocates, somewhere in the memory, an appropriate location to hold the value of the variable. Since, every byte has a unique address number, this location will have its own address number. Consider the following statement:

```
int quantity = 179;
```

This statement instructs the system to find a location for the integer variable **quantity** and puts the value 179 in that location. Let us assume that the system has chosen the address location 5000 for **quantity.** We may represent this as shown in Fig. 11.2. (Note that the address of a variable is the address of the first bye occupied by that variable.)

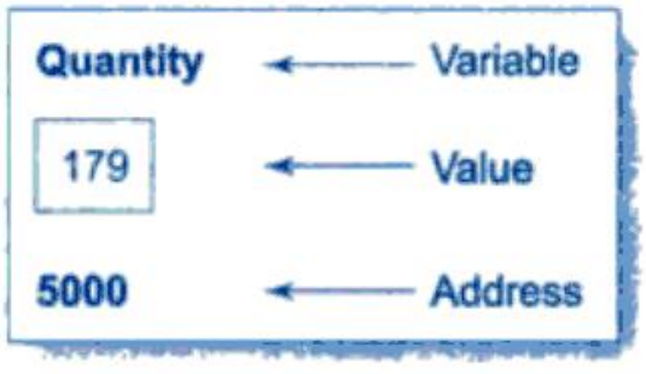

Fig. 11.2 *Representation of a variable*

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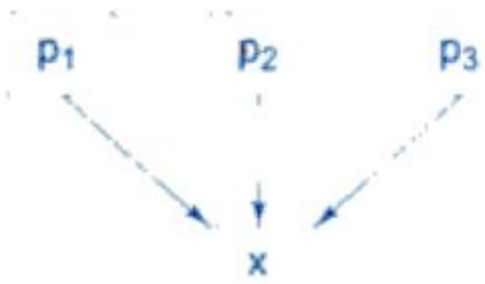
We can also use different pointers to point to the same data variable. Example.

```
int x;
int *p1 = &x;
int *p2 = &x;
int *p3 = &x;
. . . . .
. . . . .
```



11.6 ACCESSING A VARIABLE THROUGH ITS POINTER

Once a pointer has been assigned the address of a variable, the question remains as to how to access the value of the variable using the pointer. This is done by using another unary operator * (asterisk), usually known as the *indirection operator*. Another name for the indirection operator is the *dereferencing operator*. Consider the following statements:

```
int quantity, *p, n;
quantity = 179;
p = &quantity;
n = *p;
```

The first line declares **quantity** and **n** as integer variables and **p** as a pointer variable pointing to an integer. The second line assigns the value 179 to **quantity** and the third line assigns the address of **quantity** to the pointer variable **p**. The fourth line contains the indirection operator *. When the operator * is placed before a pointer variable in an expression (on the right-hand side of the equal sign), the pointer returns the value of the variable of which the pointer value is the address. In this case, ***p** returns the value of the variable **quantity**, because **p** is the address of **quantity.** The * can be remembered as 'value at address'. Thus the value of **n** would be 179. The two statements

```
p = &quantity;
n = *p;
```

are equivalent to

```
n = *&quantity;
```

which in turn is equivalent to

```
n = quantity;
```

In C, the assignment of pointers and addresses is always done symbolically, by means of symbolic names. You cannot access the value stored at the address 5368 by writing *5368. It will not work. Example 11.2 illustrates the distinction between pointer value and the value it points to.

Example 11.2 Write a program to illustrate the use of indirection operator '*' to access the value pointed to by a printer.

The program and output are shown in Fig.11.5. The program clearly shows how we can access the value of a variable using a pointer. You may notice that the value of the pointer **ptr** is 4104 and the value it points to is 10. Further, you may also note the following equivalences:

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```
*(x+i) or *(p+i)
```

represents the element **x[i]**. Similarly, an element in a two-dimensional array can be represented by the pointer expression as follows:

```
*(*(a+i)+j) or *(*(p+i)+j)
```

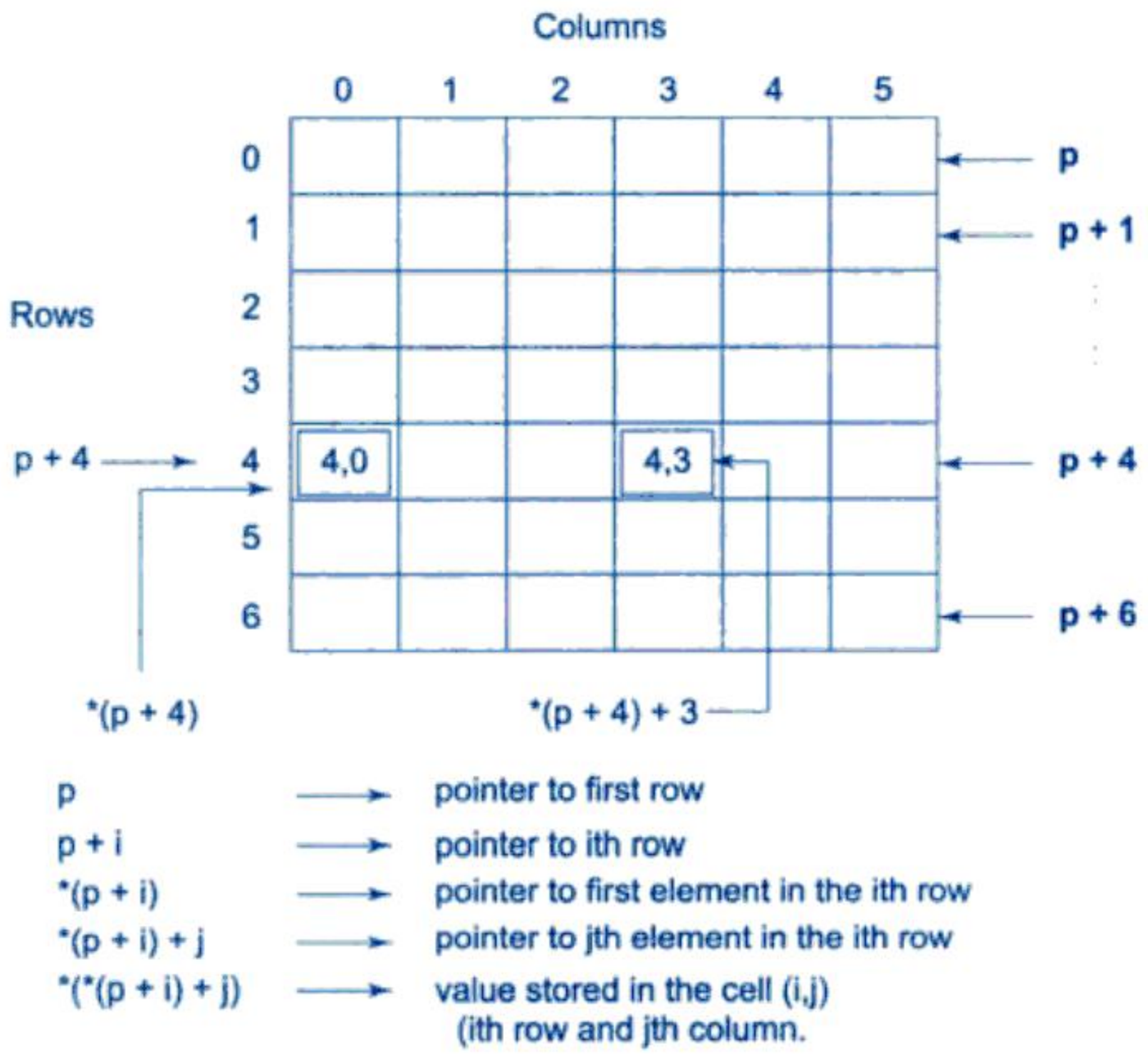
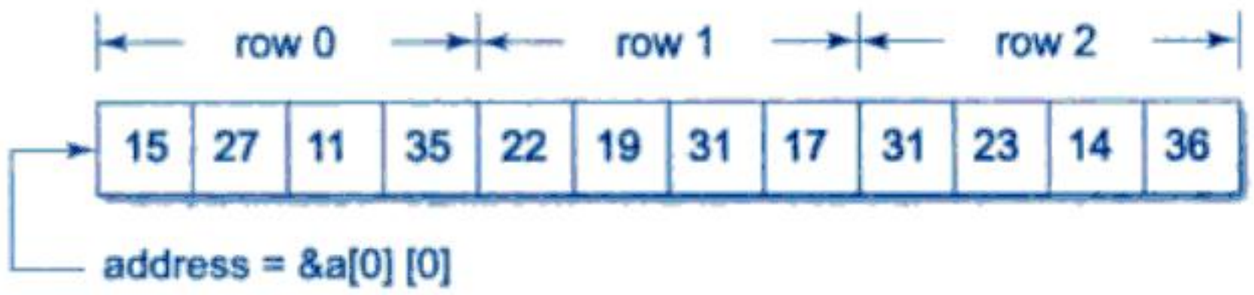


Fig. 11.9 *Pointers to two-dimensional arrays*

Figure 11.9 illustrates how this expression represents the element **a[i][j]**. The base address of the array **a** is &a[0][0] and starting at this address, the compiler allocates contiguous space for all the elements, *row-wise*. That is, the first element of the second row is placed immediately after the last element of the first row, and so on. Suppose we declare an array **a** as follows:

```
int a[3][4] = { {15,27,11,35},
                {22,19,31,17},
                {31,23,14,36}
              };
```

The elements of **a** will be stored as:



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declares **name** to be an *array of three pointers* to characters, each pointer pointing to a particular name as:

This declaration allocates only 28 bytes, sufficient to hold all the characters as shown

N	e	w		Z	e	a	l	a	n	d	\0
A	u	s	t	r	a	l	i	a	\0		
I	n	d	i	a	\0						

The following statement would print out all the three names:

```
for(i = 0; i <= 2; i++)
    printf("%s\n", name[i]);
```

To access the jth character in the ith name, we may write as

***(name[i]+j)**

The character arrays with the rows of varying length are called 'ragged arrays' and are better handled by pointers.

Remember the difference between the notations ***p[3]** and **(*p)[3].** Since * has a lower precedence than [ ], *p[3] declares p as an array of 3 pointers while **(*p)**[3] declares **p** as a pointer to an array of three elements.

11.13 POINTERS AS FUNCTION ARGUMENTS

We have noted earlier that when an array is passed to a function as an argument, only the address of the first element of the array is passed, but not the actual values of the array elements. If **x** is an array, when we call **sort(x),** the address of **x[0]** is passed to the function **sort**. The function uses this address for manipulating the array elements. Similarly, we can pass the address of a variable as an argument to a function in the normal fashion. We used this method when discussing functions that return multiple values (see Chapter 9).

When we pass addresses to a function, the parameters receiving the addresses should be pointers. The process of calling a function using pointers to pass the addresses of variables is known as '*call by reference*'. (You know, the process of passing the actual value of variables is known as "call by value".) The function which is called by 'reference' can change the value of the variable used in the call.

Consider the following code:

```
main()
{
    int x;
```

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Compatibility and Casting

A variable declared as a pointer is not just a *pointer type* variable. It is also a pointer to a *specific* fundamental data type, such as a character. A pointer therefore always has a type associated with it. We cannot assign a pointer of one type to a pointer of another type, although both of them have memory addresses as their values. This is known as *incompatibility* of pointers.

All the pointer variables store memory addresses, which are compatible, but what is not compatible is the underlying data type to which they point to. We cannot use the assignment operator with the pointers of different types. We can however make explicit assignment between incompatible pointer types by using **cast** operator, as we do with the fundamental types. Example:

```
int x;
char *p;
p = (char *) & x;
```

In such cases, we must ensure that all operations that use the pointer **p** must apply casting properly.

We have an exception. The exception is the void pointer (void *). The void pointer is a ***generic pointer*** that can represent any pointer type. All pointer types can be assigned to a void pointer and a void pointer can be assigned to any pointer without casting. A void pointer is created as follows:

```
void *vp;
```

Remember that since a void pointer has no object type, it cannot be de-referenced.

11.16 POINTERS AND STRUCTURES

We know that the name of an array stands for the address of its zeroth element. The same thing is true of the names of arrays of structure variables. Suppose **product** is an array variable of **struct** type. The name **product** represents the address of its zeroth element. Consider the following declaration:

```
struct inventory
{
   char   name[30];
   int    number;
   float  price;
} product[2], *ptr;
```

This statement declares **product** as an array of two elements, each of the type **struct inventory** and **ptr** as a pointer to data objects of the type **struct inventory.** The assignment

```
ptr = product;
```

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```
            }
    }
    /*      Print out the ranked list                */
    print_list(char *string[ ],
               int array [] [SUBJECTS + 1],
               int m,
               int n)
    {
        int  i, j, (*rowptr)[SUBJECTS+1] = array;
        for(i = 0; i < m; i++)
        {
            printf("%-20s", string[i]);
            for(j = 0; j < n; j++)
                printf("%5d", (*(rowptr + i))[j]);
                printf("\n");
        }
    }
    /*      Exchange of integer values               */
    swap_int(int *p, int *q)
    {
        int  temp;
        temp = *p;
        *p   = *q;
        *q   = temp;
    }

    /*      Exchange of strings          */
    swap_string(char s1[ ], char s2[ ])
    {
        char  swaparea[256];
        int   i;
        for(i = 0; i < 256; i++)
            swaparea[i] = '\0';
        i = 0;
        while(s1[i] != '\0' && i < 256)
        {
            swaparea[i] = s1[i];
            i++;
        }
        i = 0;
        while(s2[i] != '\0' && i < 256)
        {
            s1[i] = s2[i];
            s1[++i] = '\0';
        }
        i = 0;
```

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information about the file is subsequently used as a communication link between the system and the program.

The second statement also specifies the purpose of opening this file. The mode does this job. Mode can be one of the following:

r open the file for reading only.
w open the file for writing only.
a open the file for appending (or adding) data to it.

Note that both the filename and mode are specified as strings. They should be enclosed in double quotation marks.

When trying to open a file, one of the following things may happen:

1. When the mode is 'writing', a file with the specified name is created if the file does not exist. The contents are deleted, if the file already exists.
2. When the purpose is 'appending', the file is opened with the current contents safe. A file with the specified name is created if the file does not exist.
3. If the purpose is 'reading', and if it exists, then the file is opened with the current contents safe otherwise an error occurs.

Consider the following statements:

```
FILE *p1, *p2;
p1 = fopen("data", "r");
p2 = fopen("results", "w");
```

The file **data** is opened for reading and **results** is opened for writing. In case, the **results** file already exists, its contents are deleted and the file is opened as a new file. If **data** file does not exist, an error will occur.

Many recent compilers include additional modes of operation. They include:

r+ The existing file is opened to the beginning for both reading and writing.
w+ Same as **w** except both for reading and writing.
a+ Same as **a** except both for reading and writing.

We can open and use a number of files at a time. This number however depends on the system we use.

12.3 CLOSING A FILE

A file must be closed as soon as all operations on it have been completed. This ensures that all outstanding information associated with the file is flushed out from the buffers and all links to the file are broken. It also prevents any accidental misuse of the file. In case, there is a limit to the number of files that can be kept open simultaneously, closing of unwanted files might help open the required files. Another instance where we have to close a file is when we want to reopen the same file in a different mode. The I/O library supports a function to do this for us. It takes the following form:

```
fclose(file_pointer);
```

This would close the file associated with the **FILE** pointer **file_pointer.** Look at the following segment of a program.

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```
Contents of ODD file
111 333 555 777 999 121 343 565

Contents of EVEN file
222 444 666 888   0 232 454
```

Fig. 12.2 *Operations on integer data*

The fprintf and fscanf Functions

So far, we have seen functions, which can handle only one character or integer at a time. Most compilers support two other functions, namely **fprintf** and **fscanf**, that can handle a group of mixed data simultaneously.

The functions **fprintf** and **fscanf** perform I/O operations that are identical to the familar **printf** and **scanf** functions, except of course that they work on files. The first argument of these functions is a file pointer which specifies the file to be used. The general form of **fprintf** is

```
fprintf(fp, "control string", list);
```

where *fp* is a file pointer associated with a file that has been opened for writing. The *control string* contains output specifications for the items in the list. The *list* may include variables, constants and strings. Example:

```
fprintf(f1, "%s %d %f", name, age, 7.5);
```

Here, **name** is an array variable of type char and **age** is an **int** variable.

The general format of **fscanf** is

```
fprintf(fp, "control string", list);
```

This statement would cause the reading of the items in the list from the file specified by fp, according to the specifications contained in the *control string*. Example:

```
fscanf(f2, "%s %d", item, &quantity);
```

Like **scanf, fscanf** also returns the number of items that are successfully read. When the end of file is reached, it returns the value **EOF.**

Example 12.3 Write a program to open a file named INVENTORY and store in it the following data:

Item name	Number	Price	Quantity
AAA-1	111	17.50	115
BBB-2	125	36.00	75
C-3	247	31.75	104

Extend the program to read this data from the file INVENTORY and display the inventory table with the value of each item.

The program is given in Fig.12.3. The filename INVENTORY is supplied through the keyboard. Data is read using the function **fscanf** from the file **stdin,** which refers to the terminal and it is then written to the file that is being pointed to by the file pointer **fp.** Remember that the file pointer **fp** points to the file INVENTORY.

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```
main()
{
    struct invent_record item;
    char  filename[10];
    int   response;
    FILE  *fp;
    long  n;
    void append (struct invent_record *x, file *y);
    printf("Type filename:");
    scanf("%s", filename);

    fp = fopen(filename, "a+");
    do
    {
       append(&item, fp);
       printf("\nItem %s appended.\n",item.name);
       printf("\nDo you want to add another item\
           (1 for YES /0 for NO)?");
       scanf("%d", &response);
    }  while (response == 1);

    n = ftell(fp);       /* Position of last character  */
    fclose(fp);

    fp = fopen(filename, "r");

    while(ftell(fp) < n)
    {
       fscanf(fp,"%s %d %f %d",
       item.name, &item.number, &item.price, &item.quantity);
       fprintf(stdout,"%-8s %7d %8.2f %8d\n",
       item.name, item.number, item.price, item.quantity);
    }
    fclose(fp);
}
void append(struct invent_record *product, File *ptr)
{
    printf("Item name:");
    scanf("%s", product->name);
    printf("Item number:");
    scanf("%d", &product->number);
    printf("Item price:");
    scanf("%f", &product->price);
    printf("Quantity:");
    scanf("%d", &product->quantity);
    fprintf(ptr, "%s %d %.2f %d",
```

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PROGRAMMING EXERCISES

12.1 Write a program to copy the contents of one file into another.

12.2 Two files DATA1 and DATA2 contain sorted lists of integers. Write a program to produce a third file DATA which holds a single sorted, merged list of these two lists. Use command line arguments to specify the file names.

12.3 Write a program that compares two files and returns 0 if they are equal and 1 is they are not.

12.4 Write a program that appends one file at the end of another.

12.5 Write a program that reads a file containing integers and appends at its end the sum of all the integers.

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```
    printf("malloc failed.\n");
    exit(1);
}
printf("Buffer of size %d created \n",_msize(buffer));
strcpy(buffer, "HYDERABAD");
printf("\nBuffer contains: %s \n ", buffer);
/* Reallocation */
if((buffer = (char *)realloc(buffer, 15)) == NULL)
{
    printf("Reallocation failed. \n");
    exit(1);
}
printf("\nBuffer size modified. \n");
printf("\nBuffer still contains: %s \n",buffer);
strcpy(buffer, "SECUNDERABAD");
printf("\nBuffer now contains: %s \n",buffer);
/* Freeing memory */
free(buffer);
 }
```

Output

```
Buffer of size 10 created
Buffer contains: HYDERABAD
Buffer size modified
Buffer still contains: HYDERABAD
Buffer now contains: SECUNDERABAD
```

Fig. 13.3 *Reallocation and release of memory space*

13.7 CONCEPTS OF LINKED LISTS

We know that a list refers to a set of items organized sequentially. An array is an example of list. In an array, the sequential organization is provided implicitly by its index. We use the index for accessing and manipulation of array elements. One major problem with the arrays is that the size of an array must be specified precisely at the beginning. As pointed out earlier, this may be a difficult task in many real-life applications.

A completely different way to represent a list is to make each item in the list part of a structure that also contains a "link" to the structure containing the next item, as shown in Fig. 13.4. This type of list is called a *linked list* because it is a list whose order is given by links from one item to the next.

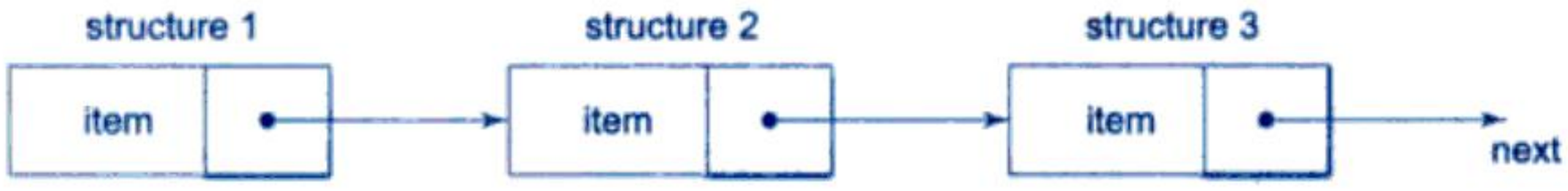

Fig. 13.4 *A linked list*

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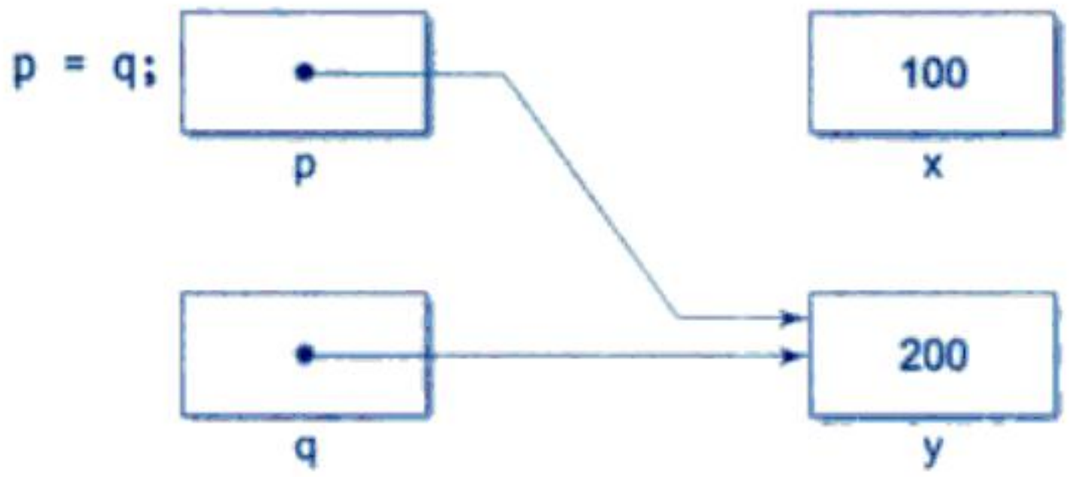
The pointer **p** contains the address of **x** and **q** contains the address of y.

***p =100 and *q = 200 and p<>q**

(b) Assignment p = q

The assignment **p = q** assigns the address of the variable **y** to the pointer variable **p** and therefore **p** now points to the variable y.

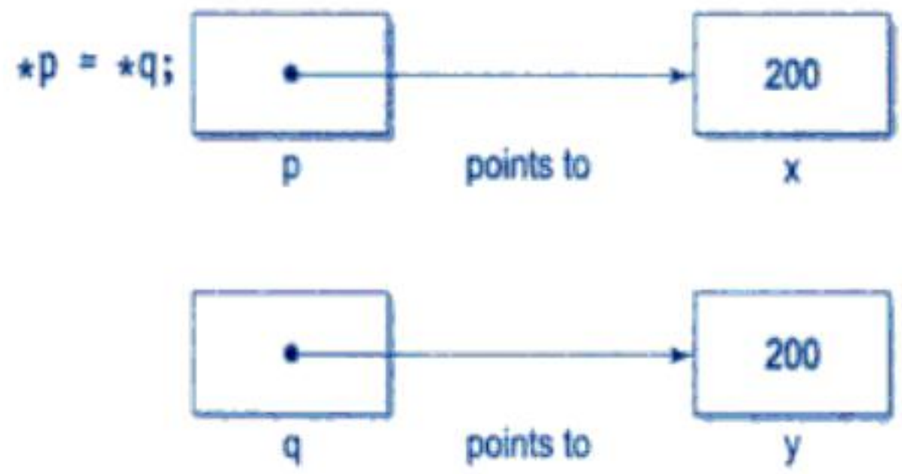


Both the pointer variables point to the same variable.

***p = *q = 200 but x <> y**

(c) Assignment *p = *q

This assignment statement puts the value of the variable pointed to by **q** in the location of the variable pointed to by **p**.



The pointer **p** still points to the same variable **x** but the old value of **x** is replaced by 200 (which is pointed to by **q**).

x = y = 200 but p <> q

(d) NULL pointers

A special constant known as NULL pointer (0) is available in C to initialize pointers that point to nothing. That is the statements

p = 0; (or p = NULL;) p → 0

q = 0; (q = NULL;) q → 0

make the pointers **p** and **q** point to nothing. They can be later used to point any values.

We know that a pointer must be initialized by assigning a memory address before using it. There are two ways of assigning memory address to a pointer.

1. Assigning an existing variable address (static assignment)

```
ptr = &count;
```

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Inserting a new item, say X, into the list has three situations:

1. Insertion at the front of the list.
2. Insertion in the middle of the list.
3. Insertion at the end of the list.

The process of insertion precedes a search for the place of insertion. The search involves in locating a node after which the new item is to be inserted.

A general algorithm for insertion is as follows:

Begin
if the list is empty or
the new node comes before the head node *then*,
insert the new node as the head node,
else
if the new node comes after the last node, *then*,
insert the new node as the end node,
else
insert the new node in the body of the list.
End

Algorithm for placing the new item at the beginning of a linked list:

1. Obtain space for new node.
2. Assign data to the item field of new node.
3. Set the *next* field of the new node to point to the start of the list.
4. Change the head pointer to point to the new node.

Algorithm for inserting the new node X between two existing nodes, say, N1 and N2;

1. Set space for new node X.
2. Assign value to the item field of X.
3. Set the *next* field of X to point to node N2.
4. Set the *next* field of N1 to point to X.

Algorithm for inserting an item at the end of the list is similar to the one for inserting in the middle, except the *next* field of the new node is set to NULL (or set to point to a dummy or sentinel node, if it exists).

Example 13.4 Write a function to insert a given item *before* a specified node known as key node.

The function **insert** shown in Fig. 13.8 requests for the item to be inserted as well as the "key node". If the insertion happens to be at the beginning, then memory space is created for the new node, the value of new item is assigned to it and the pointer **head** is assigned to the next member. The pointer **new** which indicates the beginning of the new node is assigned to **head.** Note the following statements:

```
new->number = x;
new->next = head;
head = new;
```

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has time to clear the files, he takes it off from the top. That is, files are added at the top and removed from the top (see Fig. 13.10b). Stacks are sometimes referred to as "last in, first out" (LIFO) structure.

Lists, queues and stacks are all inherently one-dimensional. A *tree* represents a two-dimensional linked list. Trees are frequently encountered in everyday life. One example is the organizational chart of a large company. Another example is the chart of sports tournaments.

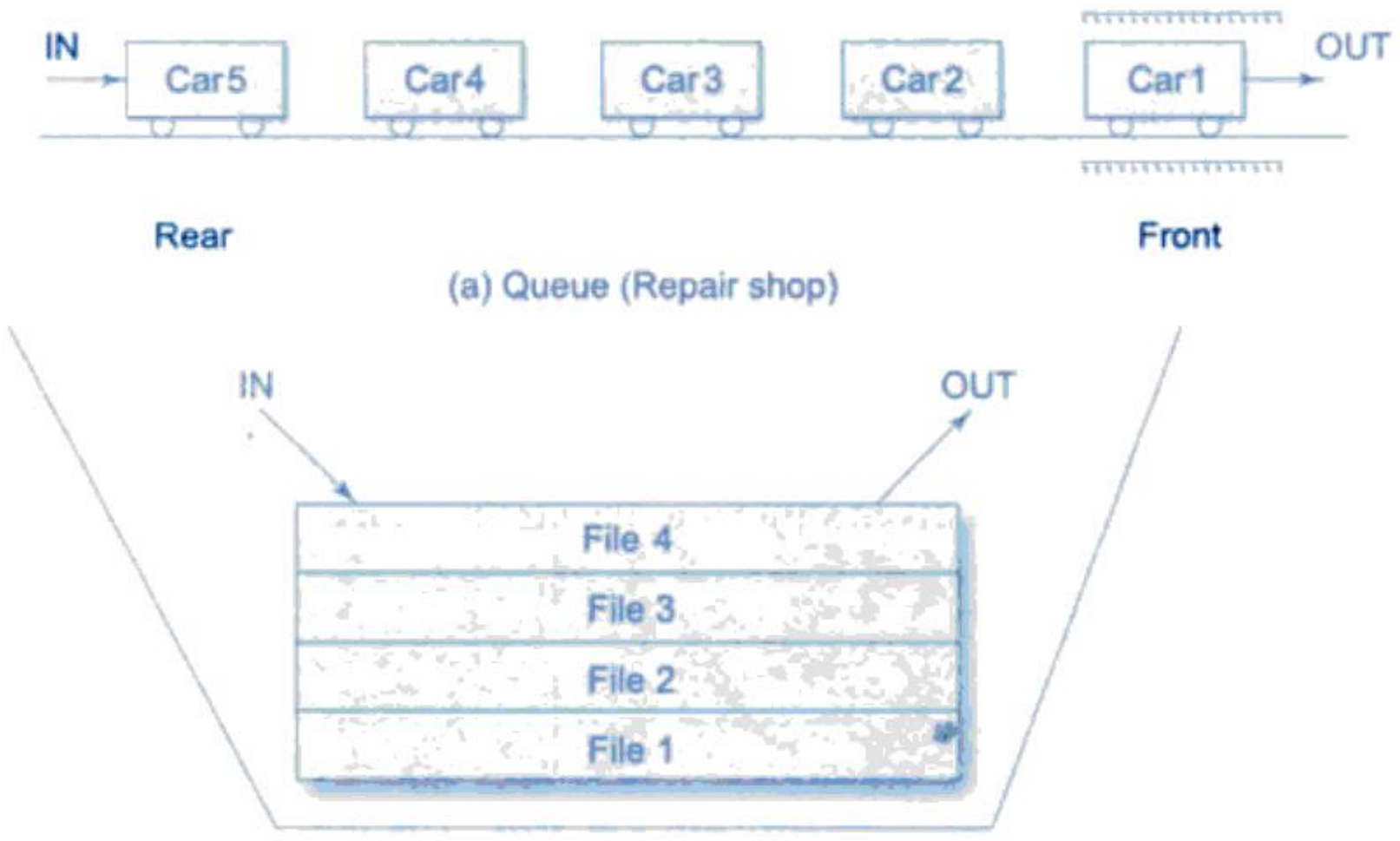

Fig. 13.10 *Application of linked lists*

Just Remember

- Use the **sizeof** operator to determine the size of a linked list.
- When using memory allocation functions **malloc** and **calloc,** test for a NULL pointer return value. Print appropriate message if the memory allocation fails.
- Never call memory allocation functions with a zero size.
- Release the dynamically allocated memory when it is no longer required to avoid any possible "memory leak".
- Using **free** function to release the memory not allocated dynamically with **malloc** or **calloc** is an error.
- Use of a invalid pointer with **free** may cause problems and, sometimes, system crash.
- Using a pointer after its memory has been released is an error.
- It is an error to assign the return value from **malloc** or **calloc** to anything other than a pointer.
- It is a logic error to set a pointer to NULL before the node has been released. The node is irretrievably lost.

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```
                head = insert_sort(head,n);
              }
                scanf("%d", &n);
            }
            printf("\n");
            print(head);
            print("\n");
}
node *insert_sort(node *list, int x)
{
            node *p1, *p2, *p;
            p1 = NULL;
            p2 = list; /* p2 points to first node */

            for( ; p2->number < x ; p2 = p2->next)
            {
              p1 = p2;

              if(p2->next == NULL)
              {
                p2 = p2->next;          /* p2 set to NULL */
                break;          /* insert new node at end */
              }
            }

/* key node found */
p = (node *)malloc(sizeof(node)); /* space for new node */
p->number = x;      /* place value in the new node */
p->next = p2;       /* link new node to key node */
if (p1 == NULL)
          list = p;       /* new node becomes the first node */
else
          p1->next = p;  /* new node inserted after 1st node */


     return (list);
}
void print(node *list)
{
            if (list == NULL)
              printf("NULL");
            else
            {
              printf("%d-->",list->number);
              print(list->next);
```

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which would obviously not produce the correct results. This is because the preprocessor performs a blind test substitution of the argument a+b in place of x. This shortcoming can be corrected by using parentheses for each occurrence of a formal argument in the *string*.
Example:

```
#define        CUBE(x)        ( (x) * (x) *(x) )
```

This would result in correct expansion of **CUBE(a+b)** as:

```
volume = ( (a+b) * (a+b) * (a+b));
```

Remember to use parentheses for each occurrence of a formal argument, as well as the whole *string*.

Some commonly used definitions are:

```
#define        MAX(a,b)        (((a) > (b)) ? (a) : (b))
#define        MIN(a,b)        (((a) < (b)) ? (a) : (b))
#define        ABS(x)          (((x) > 0) ? (x) : (–(x)))
#define        STREQ(s1,s2)    (strcmp((s1,) (s2)) == 0)
#define        STRGT(s1,s2)    (strcmp((s1,) (s2)) > 0)
```

The argument supplied to a macro can be any series of characters. For example, the definition

```
#define PRINT(variable, format)    printf("variable = %format \n", variable)
```

can be called-in by

```
PRINT(price x quantity, f);
```

The preprocessor will expand this as

```
printf( "price x quantity = %f\n", price x quantity);
```

Note that the actual parameters are substituted for formal parameters in a macro call, although they are within a string. This definition can be used for printing integers and character strings as well.

Nesting of Macros

We can also use one macro in the definition of another macro. That is, macro definitions may be nested. For instance, consider the following macro definitions.

```
#define        M          5
#define        N          M+1
#define        SQUARE(x)  ( (x) * (x) )
#define        CUBE(x)    (SQUARE (x) * (x))
#define        SIXTH(x)   (CUBE(x) * CUBE(x))
```

The preprocessor expands each **#define** macro, until no more macros appear in the text. For example, the last definition is first expanded into

```
((SQUARE(x) * (x)) * (SQUARE(x) * (x)))
```

Since **SQUARE (x)** is still a macro, it is further expanded into

```
( ( ((x)*(x)) * (x) ) * ( ((x) * (x)) * (x)) )
```

which is finally evaluated as x^6.

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elif Directive

The #elif enables us to establish an "if..else..if.." sequence for testing multiple conditions. The general form of use of **#elif** is:

```
#if   expression 1
        statement sequence 1
#elif  expression 2
        statement sequence 2
      . . . . .
      . . . . .
        #elif expression N
          statement sequence N
#endif
```

For example:

```
#if  MACHINE == HCL
     #define FILE "hcl.h"
          #elif     MACHINE == WIPRO
               #define FILE "wipro.h"

               #elif     MACHINE == DCM
                    #define FILE "dcm.h"
#endif
#include FILE
```

#pragma Directive

The **#pragma** is an implementation oriented directive that allows us to specify various instructions to be given to the compiler. It takes the following form

#pragma *name*

where *name* is the name of the **pragma** we want. For example, under Microsoft C,

#pragma loop_opt(on)

causes loop optimization to be performed. It is ignored, if the compiler does not recognize it.

#error Directive

The **#error** directive is used to produce diagnostic messages during debugging. The general form is

#error *error message*

When the **#error** directive is encountered, it displays the error message and terminates processing. Example.

```
#if !defined(FILE_G)
#error NO GRAPHICS FACILITY
#endif
```

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Algorithm Development

After we have decided a solution procedure and an overall outline of the program, the next step is to work out a detailed definite, step-by-step procedure, known as *algorithm* for each function. The most common method of describing an algorithm is through the use of *flowcharts*. The other method is to write what is known as *pseudocode*. The flow chart presents the algorithm pictorially, while the pseudocode describe the solution steps in a logical order. Either method involves concepts of logic and creativity.

Since algorithm is the key factor for developing an efficient program, we should devote enough attention to this step. A problem might have many different approaches to its solution. For example, there are many sorting techniques available to sort a list. Similarly, there are many methods of finding the area under a curve. We must consider all possible approaches and select the one, which is simple to follow, takes less execution time, and produces results with the required accuracy.

Control Structures

A complex solution procedure may involve a large number of control statements to direct the flow of execution. In such situations, indiscriminate use of control statements such as **goto** may lead to unreadable and uncomprehensible programs. It has been demonstrated that any algorithm can be structured, using the three basic control structure, namely, sequence structure, selection structure, and looping structure.

Sequence structure denotes the execution of statements sequentially one after another. Selection structure involves a decision, based on a condition and may have two or more branches, which usually join again at a later point. **if . . . .else** and **switch** statements in C can be used to implement a selection structure. Looping structure is used when a set of instructions is evaluated repeatedly. This structure can be implemented using **do**, **while**, or **for** statements.

A well-designed program would provide the following benefits:

1. Coding is easy and error-free.
2. Testing is simple.
3. Maintenance is easy.
4. Good documentation is possible.
5. Cost estimates can be made more accurately.
6. Progress of coding may be controlled more precisely.

15.3 PROGRAM CODING

The algorithm developed in the previous section must be translated into a set of instructions that a computer can understand. The major emphasis in coding should be simplicity and clarity. A program written by one may have to be ready by others later. Therefore, it should be readable and simple to understand. Complex logic and tricky coding should be avoided. The elements of coding style include:

- internal documentation.
- construction of statements.
- generality of the program.
- input/output formats.

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```
        m = 5;
        p1 = m;
        printf("%d\n", *p1);
}
```

This will print some unknown value because the pointer assignment

```
p1 =m;
```

is wrong. It should be:

```
p1 = &m;
```

Consider the following expression:

```
y = p1 + 10;
```

Perhaps, **y** was expected to be assigned the value at location **p1** plus 10. But it does not happen. **y** will contain some unknown address value. The above expression should be rewritten as

```
y = *p1 + 10;
```

Missing Parentheses in Pointer Expressions

The following two statements are not the same:

```
x = *p1 + 1;
x = *(p1 + 1);
```

The first statement would assign the value at location **p1** plus 1 to **x** while the second would assign the value at location **p1 + 1**.

Omitting Parentheses around Arguments in Macro Definitions

This would cause incorrect evaluation of expression when the macro definition is substituted.
Example: **# define** f(x) x * x + 1
The call **y = f(a+b);**
will be evaluated as **y = a+b * a+b+1;** which is wrong.
Some other mistakes that we commonly make are:

- Wrong indexing of loops.
- Wrong termination of loops.
- Unending loops.
- Use of incorrect relational test.
- Failure to consider all possible conditions of a variable.
- Trying to divide by zero.
- Mismatching of data specifications and variables in **scanf** and **printf** statements.
- Forgetting truncation and rounding off errors.

15.5 PROGRAM TESTING AND DEBUGGING

Testing and debugging refer to the tasks of detecting and removing errors in a program, so that the program produces the desired results on all occasions. Every programmer should be aware of the fact

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The following program tests whether a given number is odd or even.

```
main()
{
        int test = 1;
        int number;

        printf("Input a number \n");
        scanf("%d", &number);

        while (number != -1)
        {
            if(number & test)
                print("Number is odd\n\n");
            else
                printf("Number is even\n\n");

                printf("Input a number \n");
                scanf("%d", &number);
        }
}
```

Output

```
Input a number
20
Number is even

Input a number
9
Number is odd

Input a number
-1
```

Bitwise OR

The bitwise OR is represented by the symbol | (vertical bar) and is surrounded by two integer operands. The result of OR operation is 1 if *at least* one of the bits has a value of 1; otherwise it is zero. Consider the variables **x** and **y** discussed above.

```
x - - ->      0000 0000 0000 1101
y - - ->      0000 0000 0001 1001

              ---------------------
x|y - - ->    0000 0000 0001 1101
              ---------------------
```

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Function	*Data type returned*	*Task*
<ctype.h>		
isalnum(c)	int	Determine if argument is alphanumeric. Return nonzero value if true; 0 otherwise.
isalpha(c)	int	Determine if argument is alphabetic. Return nonzero value if true; 0 otherwise.
isascii(c)	int	Determine if argument is an ASCII character. Return nonzero value if true; 0 otherwise.
iscntrl(c)	int	Determine if argument is an ASCII control character. Return nonzero value if true; 0 otherwise.
isdigit(c)	int	Determine if argument is a decimal digit. Return nonzero value if true; 0 otherwise.
isgraph(c)	int	Determine if argument is a graphic printing ASCII character. Return nonzero value if true; 0 otherwise.
islower(c)	int	Determine if argument is lowercase. Return nonzero value if true; 0 otherwise.
isodigit(c)	int	Determine if argument is an octal digit. Return nonzero value if true; 0 otherwise.
isprint(c)	int	Determine if argument is a printing ASCII character. Return nonzero value if true; 0 otherwise.
ispunct(c)	int	Determine if argument is a punctuation character. Return non-zero value if true; 0 otherwise.
isspace(c)	int	Determine if argument is a whitespace character. Return non-zero value if true; 0 otherwise.
isupper(c)	int	Determine if argument is uppercase. Return nonzero value if true; 0 otherwise.
isxdigit(c)	int	determine if argument is a hexadecimal digit. Return nonzero value if true; 0 otherwise.
toascii(c)	int	Convert value of argument to ASCII.
tolower(c)	int	Convert letter to lowercase.
toupper(c)	int	Convert letter to uppercase.
<math.h>		
acos(d)	double	Return the arc cosine of d.
asin(d)	double	Return the arc sine of d.
atan(d)	double	Return the arc tangent of d.
atan2(d1,d2)	double	Return the arc tangent of d1/d2.
ceil(d)	double	Return a value rounded up to the next higher integer.
cos(d)	double	Return the cosine of d.
cosh(d)	double	Return the hyperbolic cosine of d.
exp(d)	double	Raise e to the power d.
fabs(d)	double	Return the absolute value of d.
floor(d)	double	Return a value rounded down to the next lower integer.

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```
28 int phone_found,room_found;
29 int del_entry; /* counts del entry at a given time */
30 int tot_del_entry=0; /* master del counter */
31 int ListAll(void);
32 int SortAllEntries(char);
33 int GeTotalEntries(void);
34 int chkstrdig (char str[], int range);
35 char menu(void);
36 void LoadDB(void); /* load database from file function */
37 void exitmenu(void);
38 void drawscreen(void);
39 void refreshscreen(void);
40
41 char dbload[80]; /* loaded database */
42
43 void main(void)
44 {
45 char iroom[80],iphone[80],add_quit;
46 char option,sortopt,exit_opt; /* menu,sort and exit option*/
47 int phone_check,room_check,delete_check,sort_check,list_check;
48 int iroom_search,iroom_del;
49 int int_iroom,total_entries;
50 int error_iphone,error_iroom; /* used to check inputs error's */
51 long int longint_iphone;
52 long int iphone_search;
53 long int iphone_del;
54
55 /* Init while no valid database file is loaded program will work in RAM! */
56 strcpy(dbload, "No database file loaded (RAM MODE!).");
57
58 /* MAIN MENU */
59 do
60  {
61   do
62    { option = menu();
63      if (option == '1') /* AddEntry Option */
64       {  current_e_add=0; /*init current entries added to zero.*/
65   for (i=add_count; i < MAXDB; i++)
66   {   clrscr();
67       refreshscreen();
68       drawscreen();
69       gotoxy(1,4);
70       printf(">> Add Entry <<");
71       gotoxy(1,25);
72       cprintf("Please Add Your Entry, leave blank to quit to Main Menu");
73       gotoxy(1,6);
```

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```
                    cprintf("Successful: There are currently %d entries in the data
                    base,
248   ",add_count);
249                 /* room_found is globe it counts room no. found in FindRoom
                    function */
250                 cprintf("found %d.",room_found);
251                 getch();
252           }
253           if (room_check == -1) /* return = -1 Room was not found */
254           {   gotoxy(1,25);
255              cprintf("Error: The Room No. Your looking for was Not Found.");
256              getch();
257           }
258
259         }
260         else
261         if (option == '5') /* ListAll option */
262         {  clrscr();
263            refreshscreen();
264            drawscreen();
265            gotoxy(1,4);
266            printf(">> ListAll <<\n\n");
267
268           list_check = ListAll();
269
270           if (list_check == 0) /* return 0 if entries are in database */
271           {   gotoxy(1,25);
272              cprintf("List Sucuessful");
273              getch();
274           }
275           if (list_check == -1) /* return -1 - emptylist */
276           {
277               gotoxy(1,25);
278               cprintf("Empty List");
279               getch();
280      }
281        }
282         else
283         if (option == '6') /* Getotalentries option */
284         {  total_entries = GeTotalEntries();
285   gotoxy(1,25);
      cprintf("There are currently %d entries stored in the
286   Database.",total_entries);
287          getch();
288       }
289       else
```

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