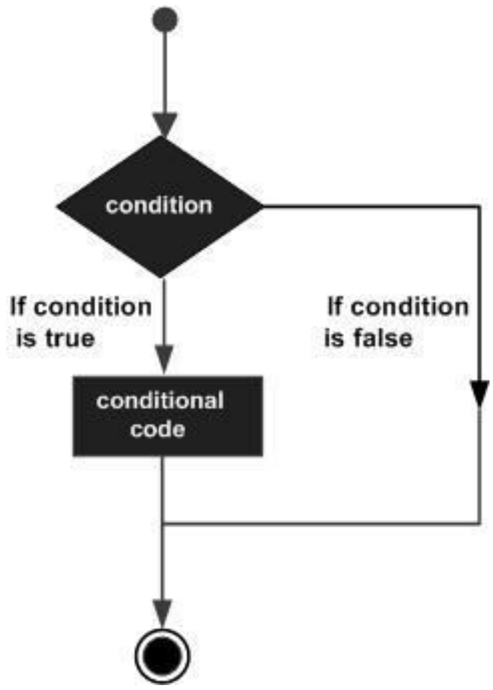
Unit 3: Decision Control Structures in C

Decision Making

Decision making structures require that the programmer specifies one or more conditions to be evaluated or tested by the program, along with a statement or statements to be executed if the condition is determined to be true, and optionally, other statements to be executed if the condition is determined to be false.

Show below is the general form of a typical decision making structure found in most of the programming languages −



C programming language assumes any **non-zero** and **non-null** values as **true**, and if it is either **zero** or **null**, then it is assumed as **false** value.

C programming language provides the following types of decision making statements.

S.N.	Statement & Description
1	if statement An **if statement** consists of a boolean expression followed by one or more statements.
2	if...else statement An **if statement** can be followed by an optional **else statement**, which executes when the Boolean expression is false.
3	nested if statements You can use one **if** or **else if** statement inside another **if** or **else if** statement(s).

4	switch statement A **switch** statement allows a variable to be tested for equality against a list of values.
5	nested switch statements You can use one **switch** statement inside another **switch** statement(s).

if statement

An **if** statement consists of a Boolean expression followed by one or more statements.

Syntax

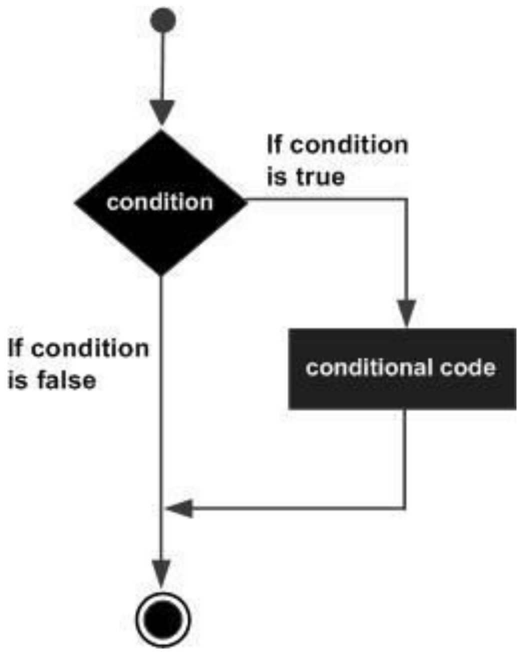
The syntax of an 'if' statement in C programming language is −

```
if(boolean_expression) {
   /* statement(s) will execute if the boolean expression is true */
}
```

If the Boolean expression evaluates to **true**, then the block of code inside the 'if' statement will be executed. If the Boolean expression evaluates to **false**, then the first set of code after the end of the 'if' statement (after the closing curly brace) will be executed.

C programming language assumes any **non-zero** and **non-null** values as **true** and if it is either **zero** or **null**, then it is assumed as **false** value.

Flow Diagram



Example

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

```
int main () {

   /* local variable definition */
   int a = 10;

   /* check the boolean condition using if statement */

   if( a < 20 ) {
      /* if condition is true then print the following */
      printf("a is less than 20\n" );
   }

   printf("value of a is : %d\n", a);

   return 0;
}
```

When the above code is compiled and executed, it produces the following result −

```
a is less than 20;
value of a is : 10
```

if...else statement

An **if** statement can be followed by an optional **else** statement, which executes when the Boolean expression is false.

Syntax

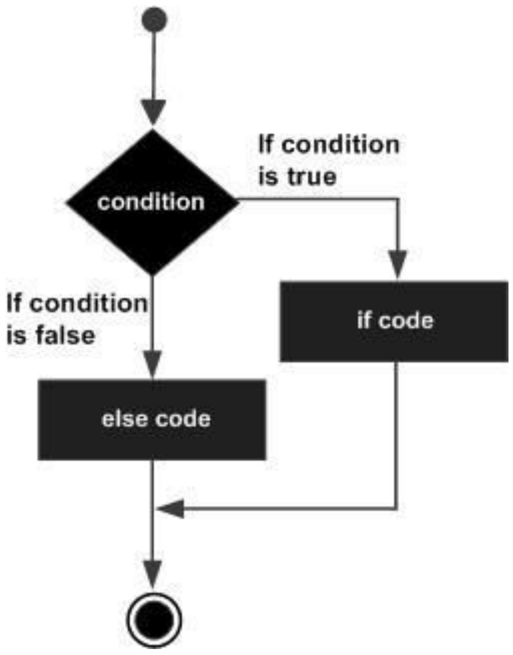
The syntax of an **if...else** statement in C programming language is −

```
if(boolean_expression) {
   /* statement(s) will execute if the boolean expression is true */
}
else {
   /* statement(s) will execute if the boolean expression is false */
}
```

If the Boolean expression evaluates to **true**, then the **if block** will be executed, otherwise, the **else block** will be executed.

C programming language assumes any **non-zero** and **non-null** values as **true**, and if it is either **zero** or **null**, then it is assumed as **false** value.

Flow Diagram



Example

```
#include <stdio.h>

int main () {

   /* local variable definition */
   int a = 100;

   /* check the boolean condition */
   if( a < 20 ) {
      /* if condition is true then print the following */
      printf("a is less than 20\n" );
   }
   else {
      /* if condition is false then print the following */
      printf("a is not less than 20\n" );
   }

   printf("value of a is : %d\n", a);

   return 0;
}
```

When the above code is compiled and executed, it produces the following result −

```
a is not less than 20;
value of a is : 100
```

If...else if...else Statement

An **if** statement can be followed by an optional **else if...else** statement, which is very useful to test various conditions using single if...else if statement.

When using if...else if..else statements, there are few points to keep in mind −

- An if can have zero or one else's and it must come after any else if's.

- An if can have zero to many else if's and they must come before the else.
- Once an else if succeeds, none of the remaining else if's or else's will be tested.

Syntax

The syntax of an **if...else if...else** statement in C programming language is −

```
if(boolean_expression 1) {
   /* Executes when the boolean expression 1 is true */
}
else if( boolean_expression 2) {
   /* Executes when the boolean expression 2 is true */
}
else if( boolean_expression 3) {
   /* Executes when the boolean expression 3 is true */
}
else  {
   /* executes when the none of the above condition is true */
}
```

Example

```
#include <stdio.h>

int main () {

   /* local variable definition */
   int a = 100;

   /* check the boolean condition */
   if( a == 10 ) {
      /* if condition is true then print the following */
      printf("Value of a is 10\n" );
   }
   else if( a == 20 ) {
      /* if else if condition is true */
      printf("Value of a is 20\n" );
   }
   else if( a == 30 ) {
      /* if else if condition is true  */
      printf("Value of a is 30\n" );
   }
   else {
      /* if none of the conditions is true */
      printf("None of the values is matching\n" );
   }

   printf("Exact value of a is: %d\n", a );

   return 0;
}
```

When the above code is compiled and executed, it produces the following result −

```
None of the values is matching
Exact value of a is: 100
```

nested if statements

It is always legal in C programming to **nest** if-else statements, which means you can use one if or else if statement inside another if or else if statement(s).

Syntax

The syntax for a **nested if** statement is as follows −

```
if( boolean_expression 1) {

   /* Executes when the boolean expression 1 is true */
   if(boolean_expression 2) {
      /* Executes when the boolean expression 2 is true */
   }
}
```

You can nest **else if...else** in the similar way as you have nested *if* statements.

Example

```
#include <stdio.h>

int main () {

   /* local variable definition */
   int a = 100;
   int b = 200;

   /* check the boolean condition */
   if( a == 100 ) {

      /* if condition is true then check the following */
      if( b == 200 ) {
         /* if condition is true then print the following */
         printf("Value of a is 100 and b is 200\n" );
      }
   }

   printf("Exact value of a is : %d\n", a );
   printf("Exact value of b is : %d\n", b );

   return 0;
}
```

When the above code is compiled and executed, it produces the following result −

```
Value of a is 100 and b is 200
Exact value of a is : 100
Exact value of b is : 200
```

switch statement

A **switch** statement allows a variable to be tested for equality against a list of values. Each value is called a case, and the variable being switched on is checked for each **switch case**.

Syntax

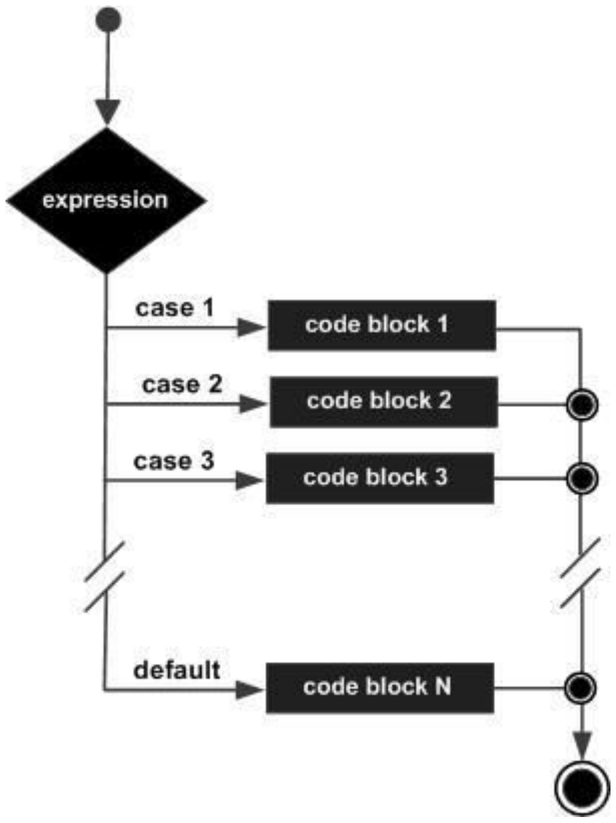
The syntax for a **switch** statement in C programming language is as follows −

```
switch(expression) {

   case constant-expression  :
      statement(s);
      break; /* optional */

   case constant-expression  :
      statement(s);
      break; /* optional */

   /* you can have any number of case statements */
   default : /* Optional */
   statement(s);
}
```

The following rules apply to a **switch** statement −

- The **expression** used in a **switch** statement must have an integral or enumerated type, or be of a class type in which the class has a single conversion function to an integral or enumerated type.
- You can have any number of case statements within a switch. Each case is followed by the value to be compared to and a colon.
- The **constant-expression** for a case must be the same data type as the variable in the switch, and it must be a constant or a literal.
- When the variable being switched on is equal to a case, the statements following that case will execute until a **break** statement is reached.
- When a **break** statement is reached, the switch terminates, and the flow of control jumps to the next line following the switch statement.
- Not every case needs to contain a **break**. If no **break** appears, the flow of control will *fall through* to subsequent cases until a break is reached.
- A **switch** statement can have an optional **default** case, which must appear at the end of the switch. The default case can be used for performing a task when none of the cases is true. No **break** is needed in the default case.

Flow Diagram



Example

```
#include <stdio.h>

int main () {

   /* local variable definition */
   char grade = 'B';

   switch(grade) {
      case 'A' :
         printf("Excellent!\n" );
         break;
      case 'B' :
      case 'C' :
         printf("Well done\n" );
         break;
      case 'D' :
         printf("You passed\n" );
         break;
      case 'F' :
         printf("Better try again\n" );
         break;
      default :
         printf("Invalid grade\n" );
   }

   printf("Your grade is  %c\n", grade );

   return 0;
}
```

When the above code is compiled and executed, it produces the following result −

```
Well done
Your grade is B
```

nested switch statements

It is possible to have a switch as a part of the statement sequence of an outer switch. Even if the case constants of the inner and outer switch contain common values, no conflicts will arise.

Syntax

The syntax for a **nested switch** statement is as follows −

```
switch(ch1) {

   case 'A':
      printf("This A is part of outer switch" );

      switch(ch2) {
         case 'A':
            printf("This A is part of inner switch" );
            break;
         case 'B': /* case code */
      }

      break;
   case 'B': /* case code */
}
```

Example

```
#include <stdio.h>

int main () {

   /* local variable definition */
   int a = 100;
   int b = 200;

   switch(a) {

      case 100:
         printf("This is part of outer switch\n", a );
         switch(b) {
            case 200:
               printf("This is part of inner switch\n", a );
         }
   }

   printf("Exact value of a is : %d\n", a );
   printf("Exact value of b is : %d\n", b );

   return 0;
}
```

When the above code is compiled and executed, it produces the following result −

```
This is part of outer switch
This is part of inner switch
Exact value of a is : 100
Exact value of b is : 200
```

The ? : Operator

We have covered **conditional operator ? :** in the previous chapter which can be used to replace **if...else** statements. It has the following general form −

```
Exp1 ? Exp2 : Exp3;
```

Where Exp1, Exp2, and Exp3 are expressions. Notice the use and placement of the colon.

The value of a ? expression is determined like this −

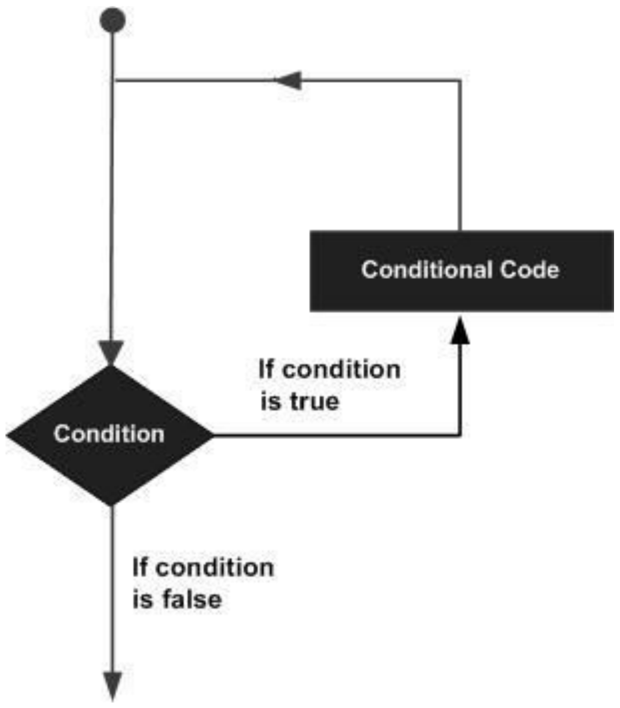
- Exp1 is evaluated. If it is true, then Exp2 is evaluated and becomes the value of the entire ? expression.
- If Exp1 is false, then Exp3 is evaluated and its value becomes the value of the expression.

Loops

You may encounter situations, when a block of code needs to be executed several number of times. In general, statements are executed sequentially: The first statement in a function is executed first, followed by the second, and so on.

Programming languages provide various control structures that allow for more complicated execution paths.

A loop statement allows us to execute a statement or group of statements multiple times. Given below is the general form of a loop statement in most of the programming languages −



C programming language provides the following types of loops to handle looping requirements.

S.N.	Loop Type & Description
1	while loop

	Repeats a statement or group of statements while a given condition is true. It tests the condition before executing the loop body.
2	for loop Executes a sequence of statements multiple times and abbreviates the code that manages the loop variable.
3	do...while loop It is more like a while statement, except that it tests the condition at the end of the loop body.
4	nested loops You can use one or more loops inside any other while, for, or do..while loop.

while loop in C

A **while** loop in C programming repeatedly executes a target statement as long as a given condition is true.

Syntax

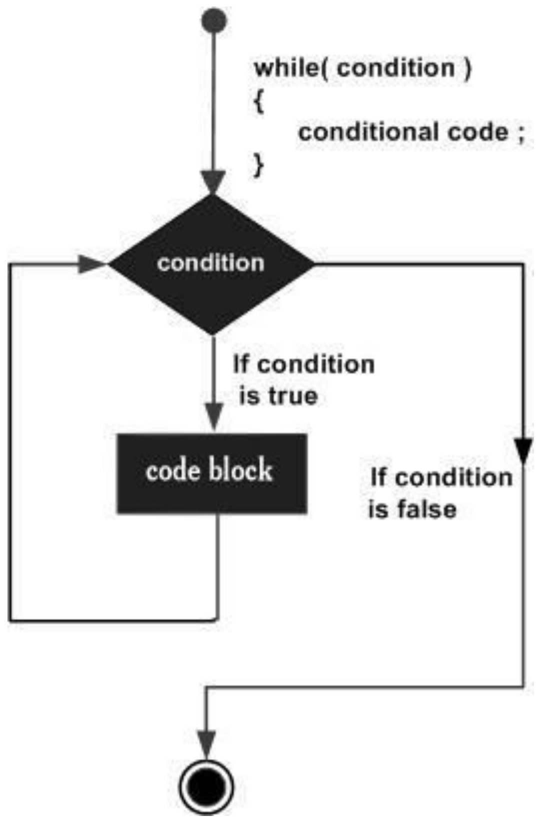
The syntax of a **while** loop in C programming language is −

```
while(condition) {
   statement(s);
}
```

Here, **statement(s)** may be a single statement or a block of statements. The **condition** may be any expression, and true is any nonzero value. The loop iterates while the condition is true.

When the condition becomes false, the program control passes to the line immediately following the loop.

Flow Diagram



Here, the key point to note is that a while loop might not execute at all. When the condition is tested and the result is false, the loop body will be skipped and the first statement after the while loop will be executed.

Example

```
#include <stdio.h>

int main () {

   /* local variable definition */
   int a = 10;

   /* while loop execution */
   while( a < 20 ) {
      printf("value of a: %d\n", a);
      a++;
   }

   return 0;
}
```

When the above code is compiled and executed, it produces the following result −

```
value of a: 10
value of a: 11
value of a: 12
value of a: 13
value of a: 14
value of a: 15
value of a: 16
value of a: 17
value of a: 18
value of a: 19
```

for loop in C

A **for** loop is a repetition control structure that allows you to efficiently write a loop that needs to execute a specific number of times.

Syntax

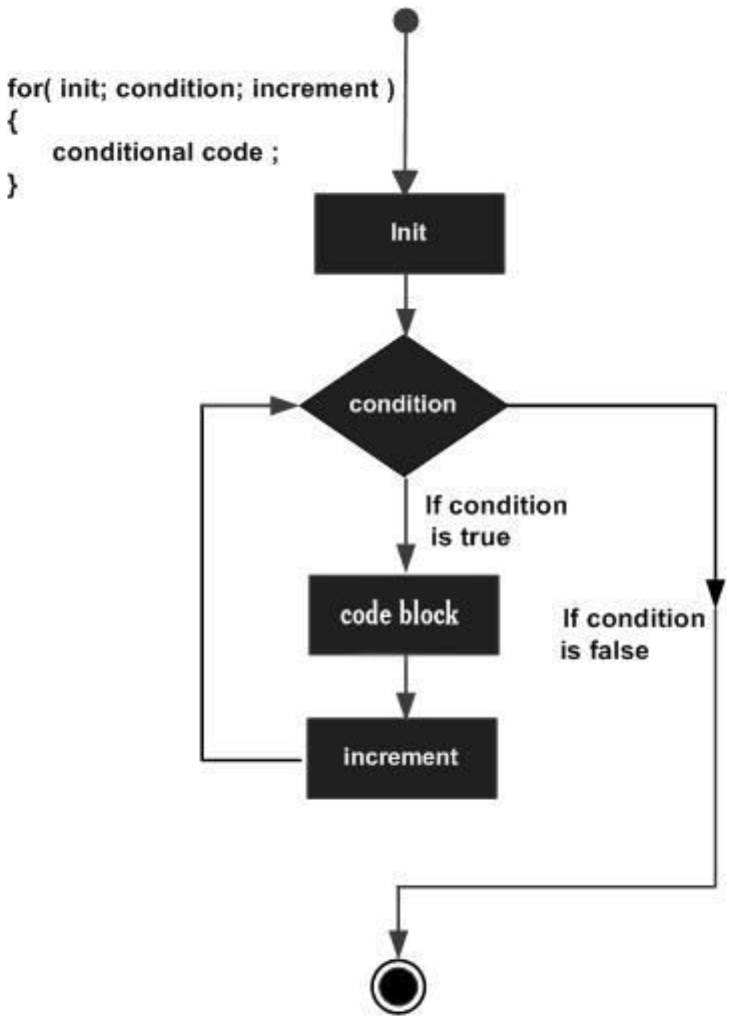
The syntax of a **for** loop in C programming language is −

```
for ( init; condition; increment ) {
   statement(s);
}
```

Here is the flow of control in a 'for' loop −

- The **init** step is executed first, and only once. This step allows you to declare and initialize any loop control variables. You are not required to put a statement here, as long as a semicolon appears.
- Next, the **condition** is evaluated. If it is true, the body of the loop is executed. If it is false, the body of the loop does not execute and the flow of control jumps to the next statement just after the 'for' loop.
- After the body of the 'for' loop executes, the flow of control jumps back up to the **increment** statement. This statement allows you to update any loop control variables. This statement can be left blank, as long as a semicolon appears after the condition.
- The condition is now evaluated again. If it is true, the loop executes and the process repeats itself (body of loop, then increment step, and then again condition). After the condition becomes false, the 'for' loop terminates.

Flow Diagram



Example

```
#include <stdio.h>

int main () {

   int a;

   /* for loop execution */
   for( a = 10; a < 20; a = a + 1 ){
      printf("value of a: %d\n", a);
   }

   return 0;
}
```

When the above code is compiled and executed, it produces the following result −

```
value of a: 10
value of a: 11
value of a: 12
value of a: 13
value of a: 14
value of a: 15
value of a: 16
value of a: 17
value of a: 18
value of a: 19
```

do...while loop in C

Unlike **for** and **while** loops, which test the loop condition at the top of the loop, the **do...while** loop in C programming checks its condition at the bottom of the loop.

A **do...while** loop is similar to a while loop, except the fact that it is guaranteed to execute at least one time.

Syntax

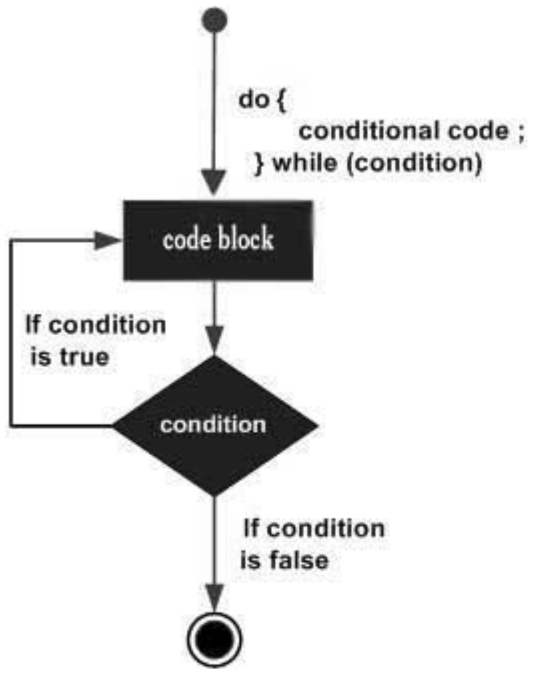
The syntax of a **do...while** loop in C programming language is −

```
do {
   statement(s);
} while( condition );
```

Notice that the conditional expression appears at the end of the loop, so the statement(s) in the loop executes once before the condition is tested.

If the condition is true, the flow of control jumps back up to do, and the statement(s) in the loop executes again. This process repeats until the given condition becomes false.

Flow Diagram



Example

```
#include <stdio.h>

int main () {

   /* local variable definition */
   int a = 10;
   /* do loop execution */
   do {
      printf("value of a: %d\n", a);
      a = a + 1;
   }while( a < 20 );

   return 0;
}
```

When the above code is compiled and executed, it produces the following result −

```
value of a: 10
value of a: 11
value of a: 12
value of a: 13
value of a: 14
value of a: 15
value of a: 16
value of a: 17
value of a: 18
value of a: 19
```

nested loops in C

C programming allows to use one loop inside another loop. The following section shows a few examples to illustrate the concept.

Syntax

The syntax for a **nested for loop** statement in C is as follows −

```
for ( init; condition; increment ) {

   for ( init; condition; increment ) {
      statement(s);
   }

   statement(s);
}
```

The syntax for a **nested while loop** statement in C programming language is as follows −

```
while(condition) {

   while(condition) {
      statement(s);
   }

   statement(s);
}
```

The syntax for a **nested do...while loop** statement in C programming language is as follows −

```
do {

   statement(s);

   do {
      statement(s);
   }while( condition );

}while( condition );
```

A final note on loop nesting is that you can put any type of loop inside any other type of loop. For example, a 'for' loop can be inside a 'while' loop or vice versa.

Example

The following program uses a nested for loop to find the prime numbers from 2 to 100 −

```
#include <stdio.h>

int main () {

   /* local variable definition */
   int i, j;

   for(i = 2; i<100; i++) {

      for(j = 2; j <= (i/j); j++)
         if(!(i%j)) break; // if factor found, not prime
         if(j > (i/j)) printf("%d is prime\n", i);
   }

   return 0;
}
```

When the above code is compiled and executed, it produces the following result −

```
2 is prime
3 is prime
5 is prime
7 is prime
11 is prime
13 is prime
17 is prime
19 is prime
23 is prime
29 is prime
31 is prime
37 is prime
41 is prime
43 is prime
47 is prime
53 is prime
59 is prime
61 is prime
67 is prime
71 is prime
73 is prime
79 is prime
83 is prime
89 is prime
97 is prime
```

Loop Control Statements

Loop control statements change execution from its normal sequence. When execution leaves a scope, all automatic objects that were created in that scope are destroyed.

C supports the following control statements.

S.N.	Control Statement & Description
1	break statement Terminates the **loop** or **switch** statement and transfers execution to the statement immediately following the loop or switch.
2	continue statement Causes the loop to skip the remainder of its body and immediately retest its condition prior to reiterating.
3	goto statement Transfers control to the labeled statement.

break statement in C

The **break** statement in C programming has the following two usages −

- When a **break** statement is encountered inside a loop, the loop is immediately terminated and the program control resumes at the next statement following the loop.
- It can be used to terminate a case in the **switch** statement (covered in the next chapter).

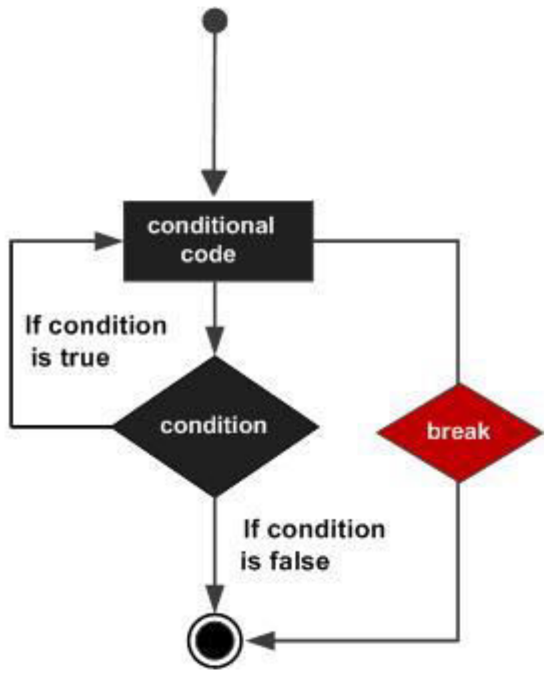
If you are using nested loops, the break statement will stop the execution of the innermost loop and start executing the next line of code after the block.

Syntax

The syntax for a **break** statement in C is as follows −

```
break;
```

Flow Diagram



Example

```
#include <stdio.h>

int main () {

   /* local variable definition */
   int a = 10;

   /* while loop execution */
   while( a < 20 ) {

      printf("value of a: %d\n", a);
      a++;

      if( a > 15) {
         /* terminate the loop using break statement */
         break;
      }

   }

   return 0;
}
```

When the above code is compiled and executed, it produces the following result −

```
value of a: 10
value of a: 11
value of a: 12
value of a: 13
value of a: 14
value of a: 15
```

continue statement in C

The **continue** statement in C programming works somewhat like the **break** statement. Instead of forcing termination, it forces the next iteration of the loop to take place, skipping any code in between.

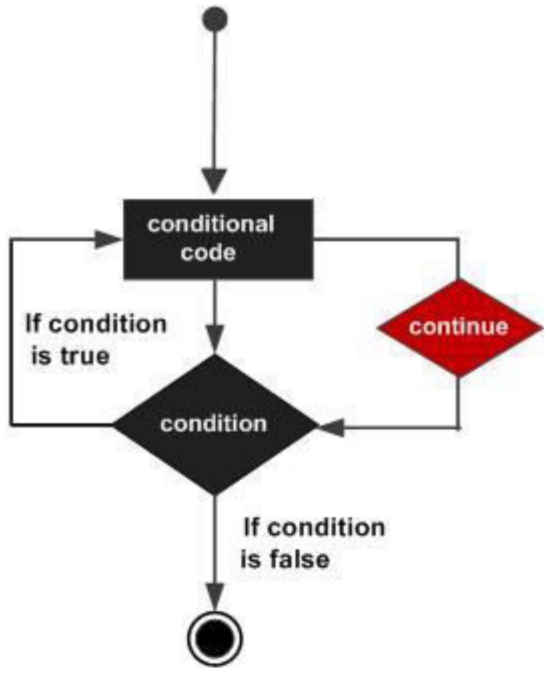
For the **for** loop, **continue** statement causes the conditional test and increment portions of the loop to execute. For the **while** and **do...while** loops, **continue** statement causes the program control to pass to the conditional tests.

Syntax

The syntax for a **continue** statement in C is as follows −

```
continue;
```

Flow Diagram



Example

```
#include <stdio.h>

int main () {

   /* local variable definition */
   int a = 10;

   /* do loop execution */
   do {

      if( a == 15) {
         /* skip the iteration */
         a = a + 1;
         continue;
      }
      printf("value of a: %d\n", a);
      a++;

   } while( a < 20 );

   return 0;
}
```

When the above code is compiled and executed, it produces the following result −

```
value of a: 10
value of a: 11
value of a: 12
value of a: 13
value of a: 14
value of a: 16
value of a: 17
value of a: 18
value of a: 19
```

goto statement in C

A **goto** statement in C programming provides an unconditional jump from the 'goto' to a labeled statement in the same function.

NOTE − Use of **goto** statement is highly discouraged in any programming language because it makes difficult to trace the control flow of a program, making the program hard to understand and hard to modify. Any program that uses a goto can be rewritten to avoid them.

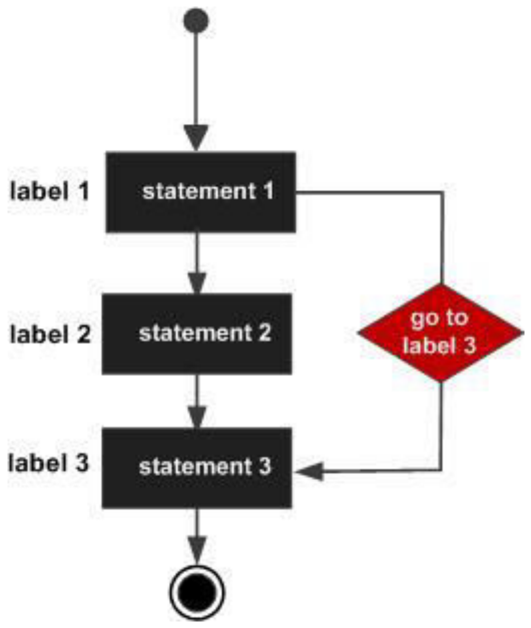
Syntax

The syntax for a **goto** statement in C is as follows −

```
goto label;
..
.
label: statement;
```

Here **label** can be any plain text except C keyword and it can be set anywhere in the C program above or below to **goto** statement.

Flow Diagram



Example

```
#include <stdio.h>

int main () {

   /* local variable definition */
   int a = 10;

   /* do loop execution */
   LOOP:do {

      if( a == 15) {
         /* skip the iteration */
         a = a + 1;
         goto LOOP;
      }

      printf("value of a: %d\n", a);
      a++;

   }while( a < 20 );

   return 0;
}
```

When the above code is compiled and executed, it produces the following result −

```
value of a: 10
value of a: 11
value of a: 12
value of a: 13
value of a: 14
value of a: 16
value of a: 17
value of a: 18
value of a: 19
```

The Infinite Loop

A loop becomes an infinite loop if a condition never becomes false. The **for** loop is traditionally used for this purpose. Since none of the three expressions that form the 'for' loop are required, you can make an endless loop by leaving the conditional expression empty.

```
#include <stdio.h>

int main () {

   for( ; ; ) {
      printf("This loop will run forever.\n");
   }

   return 0;
}
```

When the conditional expression is absent, it is assumed to be true. You may have an initialization and increment expression, but C programmers more commonly use the for(;;) construct to signify an infinite loop.

NOTE − You can terminate an infinite loop by pressing Ctrl + C keys.

UNIT 3: C - Pointers

Pointers in C are easy and fun to learn. Some C programming tasks are performed more easily with pointers, and other tasks, such as dynamic memory allocation, cannot be performed without using pointers. So it becomes necessary to learn pointers to become a perfect C programmer. Let's start learning them in simple and easy steps.

As you know, every variable is a memory location and every memory location has its address defined which can be accessed using ampersand (&) operator, which denotes an address in memory. Consider the following example, which prints the address of the variables defined −

```
#include <stdio.h>

int main () {

   int  var1;
   char var2[10];

   printf("Address of var1 variable: %x\n", &var1  );
   printf("Address of var2 variable: %x\n", &var2  );

   return 0;
}
```

When the above code is compiled and executed, it produces the following result −

```
Address of var1 variable: bff5a400
Address of var2 variable: bff5a3f6
```

What are Pointers?

A **pointer** is a variable whose value is the address of another variable, i.e., direct address of the memory location. Like any variable or constant, you must declare a pointer before using it to store any variable address. The general form of a pointer variable declaration is −

```
type *var-name;
```

Here, **type** is the pointer's base type; it must be a valid C data type and **var-name** is the name of the pointer variable. The asterisk * used to declare a pointer is the same asterisk used for multiplication. However, in this statement the asterisk is being used to designate a variable as a pointer. Take a look at some of the valid pointer declarations −

```
int    *ip;    /* pointer to an integer */
double *dp;    /* pointer to a double */
float  *fp;    /* pointer to a float */
char   *ch     /* pointer to a character */
```

The actual data type of the value of all pointers, whether integer, float, character, or otherwise, is the same, a long hexadecimal number that represents a memory address. The only difference between pointers of different data types is the data type of the variable or constant that the pointer points to.

How to Use Pointers?

There are a few important operations, which we will do with the help of pointers very frequently. **(a)** We define a pointer variable, **(b)** assign the address of a variable to a pointer and **(c)** finally access the value at the address available in the pointer variable. This is done by using unary operator ***** that returns the value of the variable located at the address specified by its operand. The following example makes use of these operations −

```
#include <stdio.h>

int main () {

   int  var = 20;   /* actual variable declaration */
   int  *ip;        /* pointer variable declaration */

   ip = &var;  /* store address of var in pointer variable*/

   printf("Address of var variable: %x\n", &var  );

   /* address stored in pointer variable */
   printf("Address stored in ip variable: %x\n", ip );

   /* access the value using the pointer */
   printf("Value of *ip variable: %d\n", *ip );

   return 0;
}
```

When the above code is compiled and executed, it produces the following result −

```
Address of var variable: bffd8b3c
Address stored in ip variable: bffd8b3c
Value of *ip variable: 20
```

NULL Pointers

It is always a good practice to assign a NULL value to a pointer variable in case you do not have an exact address to be assigned. This is done at the time of variable declaration. A pointer that is assigned NULL is called a **null** pointer.

The NULL pointer is a constant with a value of zero defined in several standard libraries. Consider the following program −

```
#include <stdio.h>

int main () {

   int  *ptr = NULL;

   printf("The value of ptr is : %x\n", ptr  );

   return 0;
}
```

When the above code is compiled and executed, it produces the following result −

```
The value of ptr is 0
```

In most of the operating systems, programs are not permitted to access memory at address 0 because that memory is reserved by the operating system. However, the memory address 0 has special significance; it signals that the pointer is not intended to point to an accessible memory location. But by convention, if a pointer contains the null (zero) value, it is assumed to point to nothing.

To check for a null pointer, you can use an 'if' statement as follows −

```
if(ptr)     /* succeeds if p is not null */
if(!ptr)    /* succeeds if p is null */
```

Pointers in Detail

Pointers have many but easy concepts and they are very important to C programming. The following important pointer concepts should be clear to any C programmer −

S.N.	Concept & Description
1	Pointer arithmetic There are four arithmetic operators that can be used in pointers: ++, --, +, -
2	Array of pointers You can define arrays to hold a number of pointers.
3	Pointer to pointer C allows you to have pointer on a pointer and so on.

Passing pointers to functions in C

4 Passing an argument by reference or by address enable the passed argument to be changed in the calling function by the called function.

Return pointer from functions in C

5 C allows a function to return a pointer to the local variable, static variable, and dynamically allocated memory as well.

C - Pointer arithmetic

A pointer in c is an address, which is a numeric value. Therefore, you can perform arithmetic operations on a pointer just as you can on a numeric value. There are four arithmetic operators that can be used on pointers: ++, --, +, and -

To understand pointer arithmetic, let us consider that **ptr** is an integer pointer which points to the address 1000. Assuming 32-bit integers, let us perform the following arithmetic operation on the pointer −

```
ptr++
```

After the above operation, the **ptr** will point to the location 1004 because each time ptr is incremented, it will point to the next integer location which is 4 bytes next to the current location. This operation will move the pointer to the next memory location without impacting the actual value at the memory location. If **ptr** points to a character whose address is 1000, then the above operation will point to the location 1001 because the next character will be available at 1001.

Incrementing a Pointer

We prefer using a pointer in our program instead of an array because the variable pointer can be incremented, unlike the array name which cannot be incremented because it is a constant pointer. The following program increments the variable pointer to access each succeeding element of the array −

```
#include <stdio.h>

const int MAX = 3;

int main () {

   int  var[] = {10, 100, 200};
   int  i, *ptr;

   /* let us have array address in pointer */
   ptr = var;

   for ( i = 0; i < MAX; i++) {

      printf("Address of var[%d] = %x\n", i, ptr );
      printf("Value of var[%d] = %d\n", i, *ptr );

      /* move to the next location */
      ptr++;
   }

   return 0;
}
```

When the above code is compiled and executed, it produces the following result −

```
Address of var[0] = bf882b30
Value of var[0] = 10
Address of var[1] = bf882b34
Value of var[1] = 100
Address of var[2] = bf882b38
Value of var[2] = 200
```

Decrementing a Pointer

The same considerations apply to decrementing a pointer, which decreases its value by the number of bytes of its data type as shown below −

```
#include <stdio.h>

const int MAX = 3;

int main () {

   int  var[] = {10, 100, 200};
   int  i, *ptr;

   /* let us have array address in pointer */
   ptr = &var[MAX-1];

   for ( i = MAX; i > 0; i--) {

      printf("Address of var[%d] = %x\n", i-1, ptr );
      printf("Value of var[%d] = %d\n", i-1, *ptr );

      /* move to the previous location */
      ptr--;
   }

   return 0;
}
```

When the above code is compiled and executed, it produces the following result −

```
Address of var[2] = bfedbcd8
Value of var[2] = 200
Address of var[1] = bfedbcd4
Value of var[1] = 100
Address of var[0] = bfedbcd0
Value of var[0] = 10
```

Pointer Comparisons

Pointers may be compared by using relational operators, such as ==, <, and >. If p1 and p2 point to variables that are related to each other, such as elements of the same array, then p1 and p2 can be meaningfully compared.

The following program modifies the previous example − one by incrementing the variable pointer so long as the address to which it points is either less than or equal to the address of the last element of the array, which is &var[MAX - 1] −

```
#include <stdio.h>

const int MAX = 3;

int main () {

   int  var[] = {10, 100, 200};
   int  i, *ptr;

   /* let us have address of the first element in pointer */
   ptr = var;
   i = 0;

   while ( ptr <= &var[MAX - 1] ) {

      printf("Address of var[%d] = %x\n", i, ptr );
      printf("Value of var[%d] = %d\n", i, *ptr );

      /* point to the previous location */
      ptr++;
      i++;
   }

   return 0;
}
```

When the above code is compiled and executed, it produces the following result −

```
Address of var[0] = bfdbcb20
Value of var[0] = 10
Address of var[1] = bfdbcb24
Value of var[1] = 100
Address of var[2] = bfdbcb28
Value of var[2] = 200
```

C - Array of pointers

Before we understand the concept of arrays of pointers, let us consider the following example, which uses an array of 3 integers −

```
#include <stdio.h>

const int MAX = 3;

int main () {

   int  var[] = {10, 100, 200};
   int i;

   for (i = 0; i < MAX; i++) {
      printf("Value of var[%d] = %d\n", i, var[i] );
   }

   return 0;
}
```

When the above code is compiled and executed, it produces the following result −

```
Value of var[0] = 10
Value of var[1] = 100
Value of var[2] = 200
```

There may be a situation when we want to maintain an array, which can store pointers to an int or char or any other data type available. Following is the declaration of an array of pointers to an integer −

```
int *ptr[MAX];
```

It declares **ptr** as an array of MAX integer pointers. Thus, each element in ptr, holds a pointer to an int value. The following example uses three integers, which are stored in an array of pointers, as follows −

```
#include <stdio.h>

const int MAX = 3;

int main () {

   int  var[] = {10, 100, 200};
   int i, *ptr[MAX];

   for ( i = 0; i < MAX; i++) {
      ptr[i] = &var[i]; /* assign the address of integer. */
   }

   for ( i = 0; i < MAX; i++) {
      printf("Value of var[%d] = %d\n", i, *ptr[i] );
   }

   return 0;
}
```

When the above code is compiled and executed, it produces the following result −

```
Value of var[0] = 10
Value of var[1] = 100
Value of var[2] = 200
```

You can also use an array of pointers to character to store a list of strings as follows −

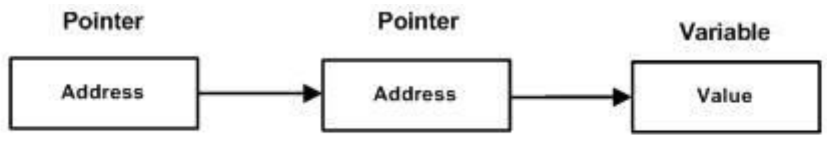
```
#include <stdio.h>

const int MAX = 4;

int main () {

   char *names[] = {
      "Zara Ali",
      "Hina Ali",
      "Nuha Ali",
      "Sara Ali",
   };

   int i = 0;

   for ( i = 0; i < MAX; i++) {
      printf("Value of names[%d] = %s\n", i, names[i] );
   }
   return 0;
}
```

When the above code is compiled and executed, it produces the following result −

```
Value of names[0] = Zara Ali
Value of names[1] = Hina Ali
Value of names[2] = Nuha Ali
Value of names[3] = Sara Ali
```

C - Pointer to Pointer

A pointer to a pointer is a form of multiple indirection, or a chain of pointers. Normally, a pointer contains the address of a variable. When we define a pointer to a pointer, the first pointer contains the address of the second pointer, which points to the location that contains the actual value as shown below.



A variable that is a pointer to a pointer must be declared as such. This is done by placing an additional asterisk in front of its name. For example, the following declaration declares a pointer to a pointer of type int −

```
int **var;
```

When a target value is indirectly pointed to by a pointer to a pointer, accessing that value requires that the asterisk operator be applied twice, as is shown below in the example −

```
#include <stdio.h>

int main () {

   int  var;
   int  *ptr;
   int  **pptr;

   var = 3000;

   /* take the address of var */
   ptr = &var;

   /* take the address of ptr using address of operator & */
   pptr = &ptr;

   /* take the value using pptr */
   printf("Value of var = %d\n", var );
   printf("Value available at *ptr = %d\n", *ptr );
   printf("Value available at **pptr = %d\n", **pptr);

   return 0;
}
```

When the above code is compiled and executed, it produces the following result −

```
Value of var = 3000
Value available at *ptr = 3000
Value available at **pptr = 3000
```

Passing pointers to functions in C

C programming allows passing a pointer to a function. To do so, simply declare the function parameter as a pointer type.

Following is a simple example where we pass an unsigned long pointer to a function and change the value inside the function which reflects back in the calling function −

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

void getSeconds(unsigned long *par);

int main () {

   unsigned long sec;
   getSeconds( &sec );

   /* print the actual value */
   printf("Number of seconds: %ld\n", sec );

   return 0;
}

void getSeconds(unsigned long *par) {
   /* get the current number of seconds */
   *par = time( NULL );
   return;
}
```

When the above code is compiled and executed, it produces the following result −

```
Number of seconds :1294450468
```

The function, which can accept a pointer, can also accept an array as shown in the following example −

```
#include <stdio.h>

/* function declaration */
double getAverage(int *arr, int size);

int main () {

   /* an int array with 5 elements */
   int balance[5] = {1000, 2, 3, 17, 50};
   double avg;

   /* pass pointer to the array as an argument */
   avg = getAverage( balance, 5 ) ;

   /* output the returned value  */
   printf("Average value is: %f\n", avg );
   return 0;
}

double getAverage(int *arr, int size) {

   int  i, sum = 0;
   double avg;

   for (i = 0; i < size; ++i) {
      sum += arr[i];
   }

   avg = (double)sum / size;
   return avg;
}
```

When the above code is compiled together and executed, it produces the following result −

```
Average value is: 214.40000
```

Return pointer from functions in C

We have seen in the last chapter how C programming allows to return an array from a function. Similarly, C also allows to return a pointer from a function. To do so, you would have to declare a function returning a pointer as in the following example −

```
int * myFunction() {
   .
   .
   .
}
```

Second point to remember is that, it is not a good idea to return the address of a local variable outside the function, so you would have to define the local variable as **static** variable.

Now, consider the following function which will generate 10 random numbers and return them using an array name which represents a pointer, i.e., address of first array element.

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

/* function to generate and retrun random numbers. */
int * getRandom( ) {

   static int  r[10];
   int i;

   /* set the seed */
   srand( (unsigned)time( NULL ) );

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

   return r;
}

/* main function to call above defined function */
int main () {

   /* a pointer to an int */
   int *p;
   int i;

   p = getRandom();
   for ( i = 0; i < 10; i++ ) {
      printf("*(p + [%d]) : %d\n", i, *(p + i) );
   }

   return 0;
}
```

When the above code is compiled together and executed, it produces the following result −

```
1523198053
1187214107
1108300978
430494959
1421301276
930971084
123250484
106932140
1604461820
149169022
*(p + [0]) : 1523198053
*(p + [1]) : 1187214107
*(p + [2]) : 1108300978
*(p + [3]) : 430494959
*(p + [4]) : 1421301276
*(p + [5]) : 930971084
*(p + [6]) : 123250484
*(p + [7]) : 106932140
*(p + [8]) : 1604461820
*(p + [9]) : 149169022
```