Ch4: for, do...while, switch

Logical Operators

Logical Operators

The if, if…else, while, do…while, and for statements each require a condition to determine how to continue a program's flow of control. While relational and equality operators can be used to test whether a particular condition is true or false, they can only test one condition at a time.

Logical Operators provide us with the capability to test multiple simple conditions.
C++ has 3 logical operators:

- && (Logical **AND**)
- || (Logical **OR**)
- ! (Logical **NOT**)

- C++ evaluates to zero (false) or nonzero (true) all expressions that include relational operators, equality operators, or logical operators.

Logical AND (&&) Operator

This binary operator is used to test whether **if and only if both** operands are true.

(expression 1) && (expression 2)

expression1	expression2	expression1 && expression2
false	false	false
false	true	false
true	false	false
true	true	true

Truth Table

Example:

```
#include <iostream>
int main() {
   std::cout << "Enter an integer number: ";
   int value;
   std::cin >> value;

   if (value > 10 && value < 20)
      std::cout << "Your value is between 10 and 20\n";
   else
      std::cout << "Your value is not between 10 and 20";
}
```

Testing more than 2 conditions:

```
if (value > 10 && value < 20 && value != 16)
  std::cout << " 10<value<20, but not 16!";
```

Logical OR (||) Operator

This binary operator is used to test whether **either or both** of two conditions is true.

(expression 1) || (expression 2)

expression1	expression2	expression1 || expression2
false	false	false
false	true	true
true	false	true
true	true	true

Truth Table

Example:

```
#include <iostream>
int main() {
  std::cout << "Enter an integer number: ";
  int value;
  std::cin >> value;

  if (value == 0 || value == 1)
    std::cout << "You picked 0 or 1\n";
  else
    std::cout << "You did not pick 0 or 1";
}
```

Testing more than 2 conditions:

```
if (value == 0 || value == 1 || value == 2 || value == 3)
  std::cout << "You picked 0, 1, 2, or 3!";
```

Logical NOT (!) Operator

This unary operator (!) can be used to flip a condition or Boolean value from true to false, or false to true.

!(expression)

expression	!expression
false	true
true	false

Truth Table

Example:

```
#include <iostream>
int main() {
  int x{5};
  int y{7};
  if (!(x > y))
    std::cout << x << " is not greater than " << y << '\n';
  else
    std::cout << x << " is greater than " << y << '\n';

  if (!x > y) // not the same as (!(x > y)), !x evaluates to 0
    std::cout << x << " is not greater than " << y << '\n';
  else
    std::cout << x << " is greater than " << y << '\n';
}
```

The parentheses around the condition are needed because the NOT operator has a higher precedence than the relational operators. If logical NOT is intended to operate on the result of other operators, use parentheses.

Remarks

- In general, logical AND has higher precedence than logical OR, thus, logical AND operators will be evaluated ahead of logical OR operators.

`value1 || value2 && value3` 〓 `value1 || (value2 && value3)` ≠ `(value1 || value2) && value3`

When mixing logical AND and logical OR in a single expression, explicitly parenthesize each operation to ensure they evaluate how you intend.

- In most cases, logical NOT can be avoided by expressing the condition differently with an appropriate relational or equality operator. For example:

`!(x == y)` 〓 `x != y`

`!(x > y)` 〓 `x <= y`

- De Morgan's law:

`!(x && y)` 〓 `!x || !y`

`!(x || y)` 〓 `!x && !y`

Short-Circuit Evaluation

- Both && and || operators are evaluated from left to right.
- **Short-Circuit Evaluation** is a feature of && and || logical operators in which the second argument (right-hand side) is executed or evaluated only if the first argument (left-hand side) does not suffice to determine the value of the expression.
- That is, when the first argument of the && function evaluates to false, the overall value must be false; and when the first argument of the || function evaluates to true, the overall value must be true.
- This is done to avoid unnecessary calculation for optimization purposes.

```
#include <iostream>
int main() {
  int x{0};
  if ((x != 0) && (10/x == 2)) {
    std::cout << "if's body!\n";
  }
  std::cout << x;
}
```

This feature prevent the possibility of division by zero.

Sample Program: Truth Table

Use logical operators to create truth tables.

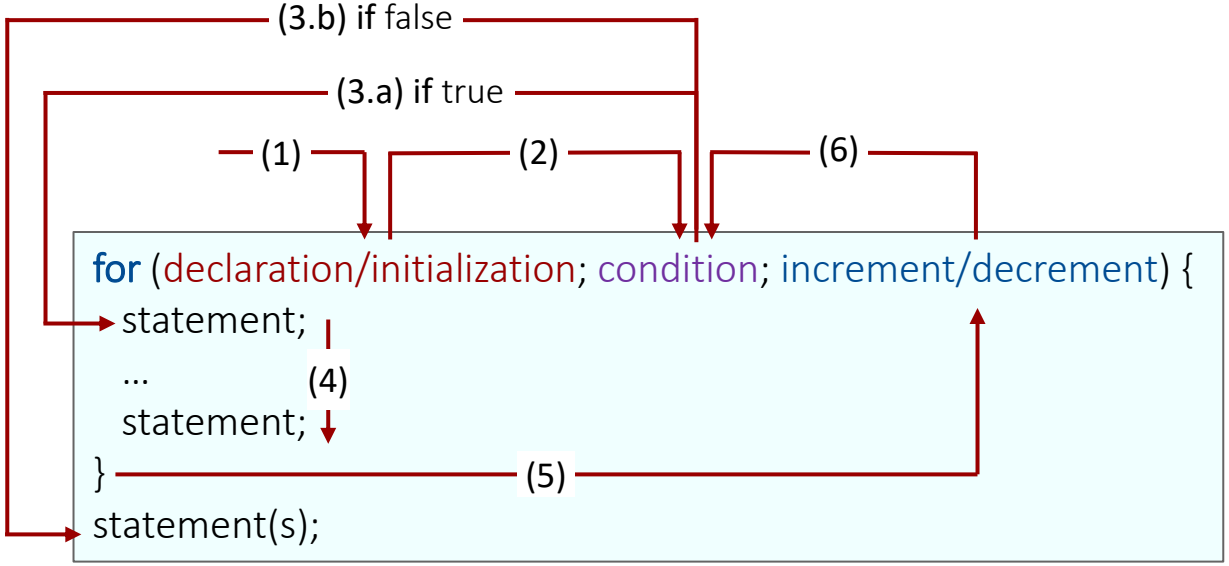
By default, bool values are displayed as 1 and 0. We can use stream manipulator boolalpha (a sticky manipulator) to specify that the value of each bool expression should be displayed as either the word "**true**" or the word "**false**."

```
#include <iostream>
int main() {
   std::cout << std::boolalpha;
  // create truth table for && (logical AND) operator
  std::cout << "Logical AND (&&)"
    << "\nfalse && false: " << (false && false)
    << "\nfalse && true: " << (false && true)
    << "\ntrue && false: " << (true && false)
    << "\ntrue && true: " << (true && true) << "\n\n";
  // create truth table for || (logical OR) operator
  std::cout << "Logical OR (||)"
    << "\nfalse || false: " << (false || false)
    << "\nfalse || true: " << (false || true)
    << "\ntrue || false: " << (true || false)
    << "\ntrue || true: " << (true || true) << "\n\n";
  // create truth table for ! (logical NOT) operator
  std::cout << "Logical NOT (!)"
    << "\n!false: " << (!false)
    << "\n!true: " << (!true) << std::endl;
}
```

for **Iteration Statement**

for **Iteration Statement**

for statements repeat an action (or group of actions) in their bodies while a condition remains true. When the condition is false, the iteration terminates, and the first statement after the body of for will execute. If the condition is initially false, the action (or group of actions) will not execute. Conditions are usually formed by using the relational and equality operators.

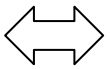


Corresponding while statement:

```
declaration & initialization;
while (condition) {
  statement(s);
  increment/decrement;
}
statement(s);
```

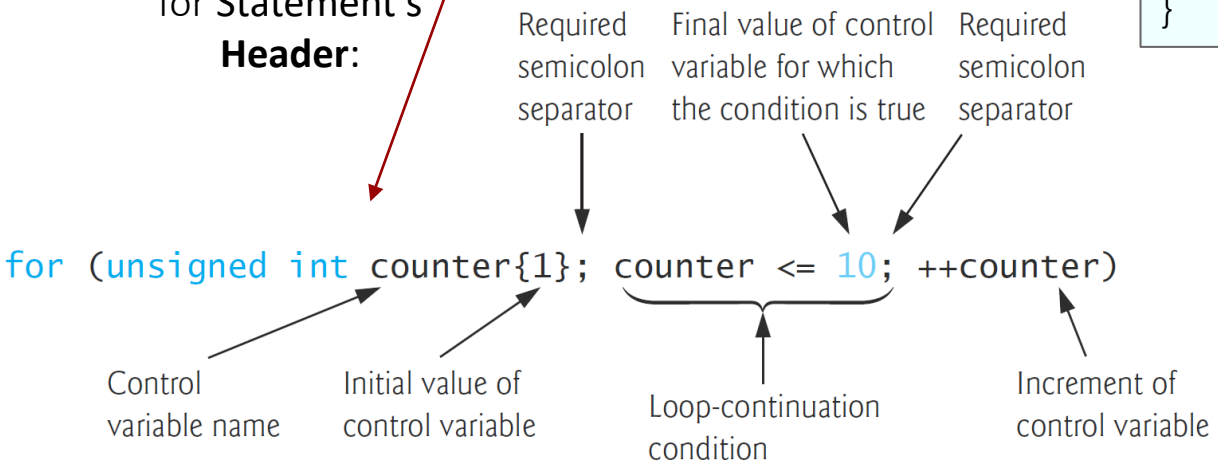
Example: Using for and while to Display Numbers from 1 to 10

```
#include <iostream>
int main() {
  for (unsigned int counter{1}; counter <= 10; ++counter) {
    std::cout << counter << "  ";
  }
}
```



```
#include <iostream>
int main() {
  unsigned int counter{1};
  while (counter <= 10) {
    std::cout << counter << "  ";
    ++counter;
  }
}
```

for **Statement's Header**:



- while can be used in most (but not all) cases in place of for. Typically, for statements are used for counter-controlled iteration and while statements for sentinel-controlled iteration.

Expressions in a for Header

- If a for statement's control variable is declared in the initialization section of the for's header, it can be used only in that for's body, not beyond it (variable's scope).

- If the program declares/initializes the control variable before the loop, declaration/initialization can be omitted.

- If the program calculates the increment/decrement in the loop's body or if no increment/decrement is needed, this expression can be omitted.

```
#include <iostream>
int main() {
   unsigned int counter{1};
   for ( ; counter <= 10; ) {
      std::cout << counter << "  ";
      ++ counter;
   }
}
```

- If the loop-continuation condition is omitted, C++ assumes that the condition is always true, thus, creating an **infinite loop**.

Expressions in a for Header (cont.)

- The increment/decrement expression in a for acts as if it were a standalone statement at the end of the for's body. Therefore, the following increment/decrement expressions are equivalent in a for statement:

```
i = i + 1
i += 1
++i
i++
```

or

```
i = i - 1
i -= 1
--i
i--
```

(preferred)

- While using decrement expression, the loop **counts downward**. In this case, using unsigned int may result in an infinite loop.

Can we use unsigned int here?

```
#include <iostream>
int main() {
  for (int i{10}; i >= 0; i -= 1) {
    std::cout << i << "  ";
  }
}
```

Reason:

```
#include <iostream>
#include<climits>
int main() {
  unsigned int i{1};
  std::cout << i << "\n";
  i = -1; // A wrap-around to the max value
  std::cout << i << "\n";
  std::cout << "UINT_MAX: " << UINT_MAX;
}
```

- Placing a semicolon immediately to the right of the right parenthesis of a for header makes that for's body an empty statement. This is normally a logic error.

Expressions in a for Header (cont.)

- Arithmetic expressions can be placed everywhere in a for statement's header.

```
int y{10};
int x{2};
for (int j = x; j <= 4 * x * y; j += y / x)
```

- Using an incorrect relational operator or an incorrect final value of a loop counter in the loop-continuation condition of for statement can cause a common logic error called an **off-by-one** error. For example:

```
for (unsigned int i{1}; i < 11; ++i)
```
=
```
for (unsigned int i{1}; i <= 10; ++i)
```
=
```
for (unsigned int i{0}; i < 10; ++i)
```
(10 iterations)

≠

```
for (unsigned int i{1}; i < 10; ++i)
```
(9 iterations)

- If a program must modify the control variable's value in the loop's body, use while rather than for.

Sample Program: Compound-Interest Calculations (Floating-Point-Based Calculations)

A person invests $1,000 in a savings account yielding 5% annual interest rate. Assuming that all the interest is left on deposit, calculate and print the amount of money in the account at the end of each year for 10 years. Use the following formula:

$$a = p(1 + r)^n$$

p: original amount invested (i.e., the principal)
r: annual interest rate (e.g., use 0.05 for 5%)
n: number of years
a: amount on deposit at the end of the nth year.

```
#include <iostream>
#include <iomanip>
#include <cmath> // for pow function
int main() {
  // set floating-point number format
  std::cout << std::fixed << std::setprecision(2);
  double principal{1000}; // initial amount before interest
  double rate{0.05}; // interest rate
  std::cout << "Initial principal: " << principal << "\n";
  std::cout << "    Interest rate:    " << rate << "\n";
  // display headers
  std::cout << "\nYear" << std::setw(20) << "Amount on deposit" << "\n";
  // calculate on deposit for each of ten years
  for (unsigned int year{1}; year <= 10; year++) {
    double amount{principal * std::pow(1 + rate, year)};
    // display the year and the amount
    std::cout << std::setw(4) << year << std::setw(20) << amount << "\n";
  }
}
```

- Standard Library Function pow(x, y) from header <cmath> calculates the value of x^y.

Formatting with setw and Justification with left, right

setw(n) is a parameterized stream manipulator which specifies that the next value output should appear in a field width of at least n character positions.

- If the output value is less than n character positions wide, the value is right justified in the field by default.
- If the output value is more than n character positions wide, the field width is extended with additional character positions to the right to accommodate the entire value.

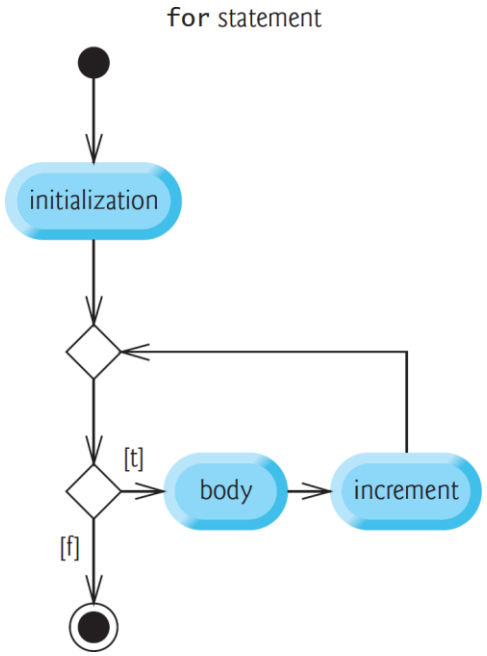
```
#include <iostream>
#include <iomanip>
int main() {
  std::cout << "Default positioning:\n"
        << std::setw(9) << "Print" << '\n';

  std::cout << "Left positioning:\n" << std::left
        << std::setw(9) << "Print" << '\n';

  std::cout << "Right positioning:\n" << std::right
        << std::setw(9) << "Print" << '\n';
}
```

```
Default positioning:
   Print
Left positioning:
Print
Right positioning:
   Print
```

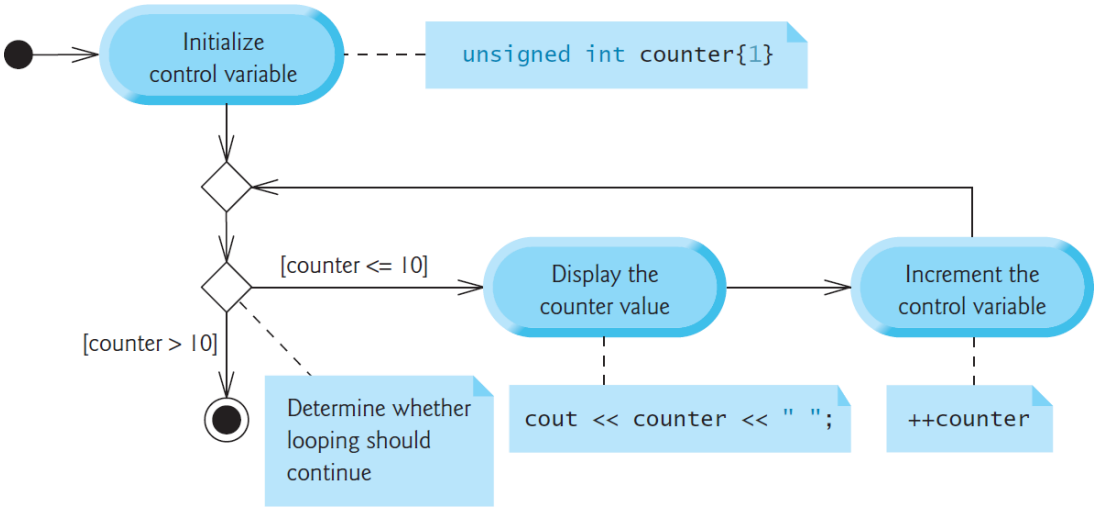
- To indicate that values should be output left justified, simply output stream manipulator left.
- Right justification can be restored by outputting stream manipulator right.

- setw is defined in <iomanip> header file and left, right are defined in <iostream> header file.

UML Activity Diagram for for Statement



Example:




```
#include <iostream>
int main() {
  for (int counter{1}; counter <= 10; counter++) {
    std::cout << counter << "  ";
  }
  std::cout << std::endl;
}
```

Comma Operator

Comma as a Separator and Operator

- **Comma as a Separator** is used to separate multiple variables in a variable declarations, multiple elements in array declaration and initialization, and multiple arguments/ parameters in function calls and definitions, enum declarations, and constructs.

```
int a{1}, b{2}, c;
```

```
void setNumbers(int X, int Y, int Z)
```

- **Comma as an Operator** between the expressions allows to evaluate multiple expressions wherever a single expression is allowed. It guarantees that a list of expressions evaluates from left to right (and returns the value/type of the rightmost expression, if required).

```
int a{1}, b{2}, c{3}; // Comma as a Separator
int i = (a, b); // Comma as an Operator, Result: i=2
int j = (a, b, c); // Comma as an Operator, Result: j=3
int k = (a += 2, a + b); // Comma as an Operator, Result: k=5
int l = a, b; // evaluates as "(l=a), b", i.e., l gets assigned
              // the value of a, and b is evaluated and discarded.
```

```
#include <iostream>
int main() {
   int x{ 1 };
   int y{ 2 };
   std::cout << (++x, ++y) << '\n';
  // increment x and y, evaluates to the right operand
}
```

Applications of Comma Operator

- Application in Condition: It can be used within a condition (of an if, while, do…while, or for) to allow auxiliary computations, e.g., doing arithmetic operations or calling a function and using the result by a comma-separated list.

```
if (y = f(x), y > x) {
    ... // statements involving x and y
}
```

⇔

```
if ( (y = f(x)) > x) {
    ... // statements involving x and y
}
```

- Application in for Statements: It can be used to allow multiple initialization expressions and/or multiple increment/decrement expressions by comma-separated lists.

```
for (int lower{0}, upper{10}; lower < upper; ++lower, --upper){
   ... // statements involving lower and upper
}
```

- Application in Avoiding a Block and Its Associated Braces:

```
if (condition)
   x = 2, y = 3;
```

⇔

```
if (condition) {
   x = 2;
   y = 3;
}
```

Sample Program: Summing Even Integers

Problem: Using a for statement, write a program to sum the even integers from 2 to 20 and print the result.

```
// Summing integers with the for statement.
#include <iostream>
int main() {
   unsigned int total{0};
   // total even integers from 2 through 20
   for (unsigned int number{2}; number <= 20; number += 2) {
      total += number;
   }
   std::cout << "Sum is " << total << std::endl;
}
```

You could merge the statement's body into the increment portion by using a **comma operator**. Although it is **not the best practice**.

```
#include <iostream>
int main() {
   unsigned int total{0};
   for (unsigned int number{2}; number <= 20; total += number, number += 2){
   }
   std::cout << "Sum is " << total << std::endl;
}
```

do…while **Iteration Statement**

do...while **Iteration Statement**

do...while **statements** are similar to the while statements, however, the do...while statements test the loop-continuation condition after executing the loop's body; thus, the body always executes at least once. When the condition is false, the iteration terminates, and the first statement after the body of do...while will execute. Conditions are usually formed by using the relational and equality operators.

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

";" here.

Example: Using a do...while to output the numbers 1–10:

```
#include <iostream>
int main() {
  unsigned int counter{1};

  do {
    std::cout << counter << "  ";
    ++counter;
  } while (counter <= 10);

  std::cout << std::endl;
}
```

- Not providing in the body of a do...while statement an action that eventually causes the condition to become false results in a logic error called an **infinite loop** (the loop never terminates).

do…while **Iteration Statement**

Note: Since scope of a variable declared in a block {} is just within the block, a variable declared in body of a do…while cannot be used in the loop condition, which is outside that scope.

j declared inside do…while's body. Thus, it cannot be used in condition.

```
#include <iostream>
int main() {
  int i{0};
  do {
    int j;
    j = i * 2;
    std::cout << j << " ";
    i++;
  } while (j < 100);
}
```

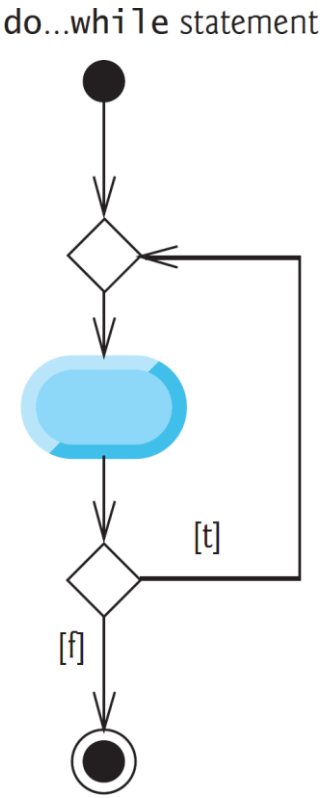
✗

```
#include <iostream>
int main() {
  int i{0};
  int j;
  do {
    j = i * 2;
    std::cout << j << " ";
    i++;
  } while (j < 100);
}
```

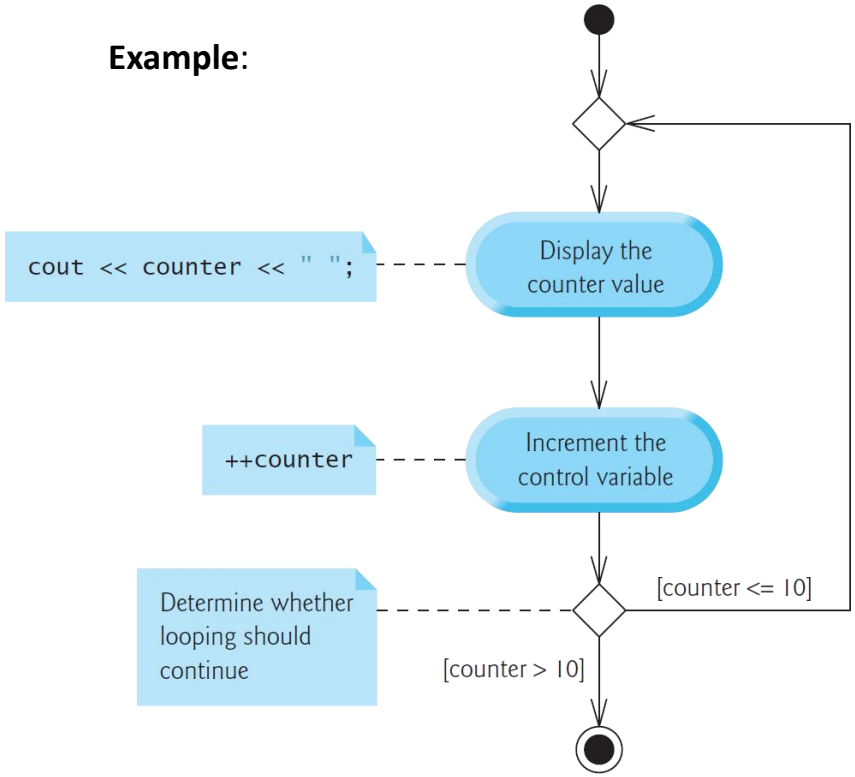
✓

j declared outside do…while's body. Thus, it can be used in condition.

UML Activity Diagram for do...while Statement



Example:




```
#include <iostream>
int main() {
  unsigned int counter{1};

  do {
    std::cout << counter << "  ";
    ++counter;
  } while (counter <= 10);

  std::cout << std::endl;
}
```

switch Multiple-Selection Statement

switch **Multiple-Selection Statement**

switch **Multiple-Selection Statement** selects among many different actions (or groups of actions), depending on the value of a variable or expression.

break statement at the end of a case causes control to exit the switch statement immediately.

break statement is not required for the last case (or the optional default case, when it appears last).

```
switch (an expression or variable) {
  case label1:
    statement(s);
    break;
  case label2:
    statement(s);
    break;
  ...
  default:
    statement(s);
    break;
}
```

switch statement does not require braces ({}) around multiple statements in a case.

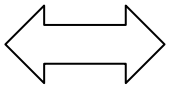
switch's controlling expression/variable is evaluated to produce a value.

- If the expression's value is equal to the value after any of the case **labels**, the statements after the matching case label are executed.
- If no matching value can be found and a default **case** exists, the statements after the default case are executed instead, otherwise, execution continues after the end of the switch block.

switch vs if...else

```
#include <iostream>
int main() {
  int x;
  std::cout << "Enter a Number: ";
  std::cin >> x;
  if (x == 1)
    std::cout << "One";
  else if (x == 2)
    std::cout << "Two";
  else if (x == 3)
    std::cout << "Three";
  else
    std::cout << "Unknown";
}
```

x is evaluated up to three times, which is inefficient.



```
#include <iostream>
int main() {
  int x;
  std::cout << "Enter a Number: ";
  std::cin >> x;
  switch (x) {
    case 1:
      std::cout << "One";
      break;
    case 2:
      std::cout << "Two";
      break;
    case 3:
      std::cout << "Three";
      break;
    default:
      std::cout << "Unknown";
      break;
  }
}
```

x is evaluated only once, which is more efficient.

Remarks

- The **controlling expression/variable** must evaluate to a signed or unsigned integral type (bool, char, int, long, long long, or enumerated types that evaluates to a constant integer value), but not floating-point types or strings.
- The value after the case labels must either match the type of the controlling expression /variable or must be convertible to that type.
- There is no practical limit to the number of case labels you can have, but all case labels in switch statement must be unique.

```
switch (x) {
  case 54:
    ...
  case 54:  // error: already used value 54!
    ...
  case '6': // error: '6' converts to integer value 54, which is already used
    ...
}
```

- The default label is **optional**, and there can only be one default label per switch statement. By convention, the default case is placed last in the switch statement.

Remarks

- switch statement does not provide a mechanism for testing ranges of values. Therefore, every value you need to test must be listed in a separate case label.
- When break statement is omitted for a case, each time a match occurs, the statements for that case and subsequent cases execute until a break statement or the end of the switch is encountered. This is called "**falling through**" to the statements in subsequent cases.

```
#include <iostream>
int main() {
  char n{'B'};
  switch (n) {
    case 'A':
      std::cout << 'A' << "\n"; // Skipped
    case 'B': // Match!
      std::cout << 'B' << "\n"; // Execution begins here
      std::cout << 'B' << "\n";
    case 'C':
      std::cout << 'C' << "\n"; // This is also executed
      break;
    case 'D':
      std::cout << 'D' << "\n"; // Skipped
      break;
    default:
      std::cout << 'E' << "\n"; // Skipped
      break;
  }
}
```

ASCII Character Set

	0	1	2	3	4	5	6	7	8	9
0	nul	soh	stx	etx	eot	enq	ack	bel	bs	ht
1	nl	vt	ff	cr	so	si	dle	dc1	dc2	dc3
2	dc4	nak	syn	etb	can	em	sub	esc	fs	gs
3	rs	us	sp	!	"	#	$	%	&	‘
4	(	)	*	+	,	-	.	/	0	1
5	2	3	4	5	6	7	8	9	:	;
6	<	=	>	?	@	A	B	C	D	E
7	F	G	H	I	J	K	L	M	N	O
8	P	Q	R	S	T	U	V	W	X	Y
9	Z	[	\	]	^	_	’	a	b	c
10	d	e	f	g	h	i	j	k	l	m
11	n	o	p	q	r	s	t	u	v	w
12	x	y	z	{	|	}	~	del		

The digits at the left of the table are the left digits of the decimal equivalents (0–127) of the character codes, and the digits at the top of the table are the right digits of the character codes. For example, the character code for “F” is 70, and the character code for “&” is 38.

Sample Program: Using a switch Statement in Member Function of a Class

Day.h file

```
class Day {
public:
  void set_data() {
    std::cout<<"Enter number of day: ";
    std::cin>>day;
  }
  void display_day()  {
    switch (day) {
      case 1:
        std::cout<<"MONDAY";
        break;
      case 2:
        std::cout<<"TUESDAY";
        break;
      case 3:
        std::cout<<"WEDNESDAY";
        break;
      case 4:
        std::cout<<"THURSDAY";
        break;
      case 5:
        std::cout<<"FRIDAY";
        break;
      case 6:
        std::cout<<"SATURDAY";
        break;
      case 7:
        std::cout<<"SUNDAY";
        break;
      default:
        std::cout<<"INVALID INPUT";
        break;
    }
  }
private:
  int day;
};
```

main.cpp file

```
#include<iostream>
#include"Day.h"
int main() {
   Day d;
   d.set_data();
   d.display_day();
}
```

Sample Program: Using a switch Statement to Count Letter Grades

Problem: Calculate the class average of a set of numeric grades entered by the user, and uses a switch statement to determine the number of students who received an A, B, C, D, or F.

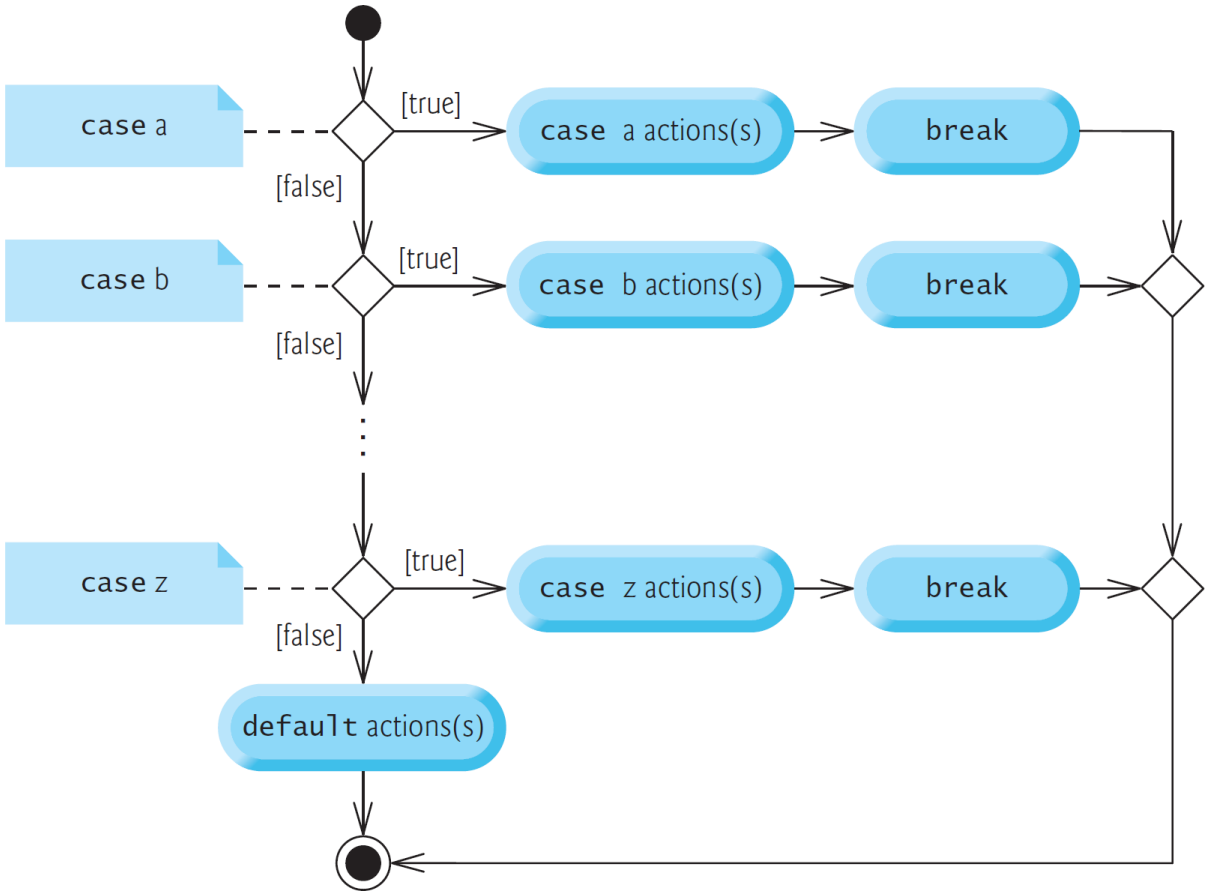
```
// Using a switch statement to count letter grades.
#include <iostream>
#include <iomanip>

int main() {
   int total{0}; // sum of grades
   unsigned int gradeCounter{0}; // number of grades entered
   unsigned int aCount{0}; // count of A grades
   unsigned int bCount{0}; // count of B grades
   unsigned int cCount{0}; // count of C grades
   unsigned int dCount{0}; // count of D grades
   unsigned int fCount{0}; // count of F grades

   std::cout << "Enter the integer grades in the range 0-100.\n"
      << "Type the end-of-file indicator to terminate input:\n"
      << "   On UNIX/Linux/Mac OS X type <Ctrl> d then press Enter\n"
      << "   On Windows type <Ctrl> z then press Enter\n";

   int grade;
```

```
// loop until user enters the end-of-file indicator
   while (std::cin >> grade) {
      total += grade; // add grade to total
      ++gradeCounter; // increment number of grades

      //  increment appropriate letter-grade counter
      switch (grade / 10) {
         case 10:  // grade was 100
         case 9: // grade was between 90 and 99
            ++aCount;
            break; // exits switch
         case 8: // grade was between 80 and 89
            ++bCount;
            break; // exits switch
         case 7: // grade was between 70 and 79
            ++cCount;
            break; // exits switch
         case 6: // grade was between 60 and 69
            ++dCount;
            break; // exits switch
         default: // grade was less than 60
            ++fCount;
            break; // optional; exits switch anyway
      } // end switch
   } // end while
```

Sample Program: Using a switch Statement to Count Letter Grades (cont.)

```
  // set floating-point number format
  std::cout << std::fixed << std::setprecision(2);

  // display grade report
  std::cout << "\nGrade Report:\n";

  // if user entered at least one grade...
  if (gradeCounter != 0) {
    // calculate average of all grades entered
    double average{static_cast<double>(total) / gradeCounter};

    // output summary of results
    std::cout << "Total of the " << gradeCounter << " grades entered is "
      << total << "\nClass average is " << average
      << "\nNumber of students who received each grade:"
      << "\nA: " << aCount << "\nB: " << bCount << "\nC: " << cCount
      << "\nD: " << dCount << "\nF: " << fCount << std::endl;
  }
  else { // no grades were entered, so output appropriate message
    std::cout << "No grades were entered" << std::endl;
  }
}
```

UML Activity Diagram for switch Statement



break **and** continue **Statements**

break Statement

The break statement, when executed in a while, for, do…while, or switch, causes immediate exit from that loop, and execution continues with the first statement after the control statement.

- Common uses of the break statement are to escape early from a loop or to skip the remainder of a switch.

```
#include <iostream>
int main() {
   for (unsigned int count{1}; count <= 10; ++count) { // loop 10 times
      if (count == 5) {
         break; // terminates loop if count is 5
      }
      std::cout << count << " ";
   }
   std::cout << "\nBroke out of loop at count = 5" << std::endl;
}
```

```
1 2 3 4
```

continue **Statement**

The continue statement, when executed in a while, for, or do…while, skips the remaining statements in the loop body and proceeds with the next iteration of the loop.

- In while and do…while statements, after the continue statement executes, the program evaluates the loop-continuation test immediately.
- In a for statement, after the continue statement executes, the increment/decrement expression executes, then the program evaluates the loop-continuation test.

```
#include <iostream>
int main() {
  for (unsigned int count{1}; count <= 10; ++count) { // loop 10 times
    if (count == 5) {
      continue; // skip remaining code in loop body if count is 5
    }
    std::cout << count << " ";
  }
  std::cout << "\nUsed continue to skip printing 5" << std::endl;
}
```

```
1 2 3 4 6 7 8 9 10
```

while **does not execute in the same manner as** for

```
#include <iostream>
int main() {
  for (unsigned int count{1}; count <= 10; ++count) {
    if (count == 5) {
      continue;
    }
    std::cout << count << " ";
  }
}
```

1 2 3 4 6 7 8 9 10

```
#include <iostream>
int main() {
  unsigned int count{1};
  while (count <= 10) {
    if (count == 5) {
      continue;
    }
    std::cout << count << " ";
    ++count;
  }
}
```

infinite loop!

```
#include <iostream>
int main() {
  unsigned int count{1};
  while (count <= 10) {
    ++count;
    if (count == 5) {
      continue;
    }
    std::cout << count << " ";
  }
}
```

2 3 4 6 7 8 9 10 11

```
#include <iostream>
int main() {
  unsigned int count{0};
  while (count <= 9) {
    ++count;
    if (count == 5) {
      continue;
    }
    std::cout << count << " ";
  }
}
```

1 2 3 4 6 7 8 9 10

Constants

Literal Constants

Literal Constants are unnamed values inserted directly into the code. All literals have a type. The type of a literal is deduced from the literal's value by compiler.

Literal Value	Examples	Default Literal Type
integer value	5, 0, -3	int
Boolean value	true, false	bool
floating point value	1.2, 0.0, 3.4	double (not float!)
character	'a', '\n'	char
C-style string	"Hello, world!"	const char*

- If the default type of a literal is not as desired, you can change the type of a literal by adding a **suffix**:

Data type	Literal Suffix	Meaning
integral	u or U	unsigned int
integral	l or L	long
integral	ul, uL, Ul, UL, lu, lU, Lu, or LU	unsigned long
integral	ll or LL	long long
integral	ull, uLL, Ull, ULL, llu, llU, LLu, or LLU	unsigned long long
integral	z or Z	The signed version of std::size_t (C++23)
integral	uz or UZ	std::size_t (C++23)
floating point	f or F	float
floating point	l or L	long double
string	s	std::string
string	sv	std::string_view

- Suffixes are not case sensitive.

Literal Constants

```
#include <iostream>

int main() {
   std::cout << 5 << '\n'; // 5 (no suffix) is type int (by default)
   std::cout << 5u << '\n'; // 5u is type unsigned int
   std::cout << 5L << '\n'; // 5L is type long
   std::cout << 5.0 << '\n'; // 5.0 (no suffix) is type double (by default)
   std::cout << 5.0f << std::endl; // 5.0f is type float
   float f{4.1f}; // use 'f' suffix so the literal is a float and matches variable type of float
   double d{4.1}; // type double matches the literal type double
}
```

const Variables

A variable whose value can not be changed is called a **constant variable**. Defining a variable as a constant (using const keyword in the variable's declaration) helps ensure that this value is not accidentally changed.

`const var_type var_name` or `var_type const var_name`

(preferred style)

- Constant variables must be initialized when declaring them, and then, that value can not be changed, e.g., via assignment.

```
#include <iostream>
int main() {
  std::cout << "Enter your age: ";
  int age{};
  std::cin >> age;
  const int constAge {age}; // initialize const variable using non-const value
  // int const constAge {age}; // "east const" style, okay but not preferred
  age = 5; // age is non-const, so we can change its value
  constAge = 6; // error: constAge is const, so we cannot change its value
}
```

Compile-time Constants

Depending on the initializer, const variables could end up as either a **compile-time** const or a **runtime** const.

- A **Compile-time Constant** is a constant whose value is known at compile-time. Examples:
  - Literals (e.g., 1, 2.3, 'A', and "Hello, world!").
  - A const variable only if its initializer is a constant expression.

An expression that all the values in it are known at compile-time, and it is evaluated by the compiler at compile-time.

For example, in `int x{3+4};`

3+4 is a constant expression, and a modern compiler will replace it with the resulting value 7 at compile-time.

```
#include <iostream>
int main() {
  const int x { 3 };  // x is a compile-time const
  const int y { 4 };  // y is a compile-time const
  const int z { x + y }; // x + y is a constant expression, so z is compile-time const
  const int a { 1 + 2 }; // 1 + 2 is a constant expression, so a is compile-time const
}
```

Run-time Constants

Runtime Constants are const variable whose initialization values are not known until run-time (i.e., they are initialized with a non-constant or run-time expression).

```
#include <iostream>
int getNumber() {
    std::cout << "Enter a number: ";
    int y{};
    std::cin >> y;
    return y;
}
int main() {
    const int x{ 3 };          // x is a compile time constant
    const int y{ getNumber() }; // y is a runtime constant
    const int z{ x + y };      // x + y is a runtime expression
    std::cout << z << '\n';    // a runtime expression
}
```

constexpr Variables

There are a few cases where C++ requires a compile-time constant instead of a run-time constant.

By using the constexpr (short for "constant expression") keyword instead of const in a variable's declaration, we can ensure that the variable is a compile-time constant. Thus, if the initialization value of a constexpr variable is not a constant expression, the compiler will error.

```
#include <iostream>
int five() {
   return 5;
}
int main() {
   constexpr double gravity { 9.8 }; // ok: 9.8 is a constant expression
   constexpr int a { 4 + 5 };      // ok: 4 + 5 is a constant expression
   constexpr int b { a};  // ok: a is a constant expression
   std::cout << "Enter your age: ";
   int age{};
   std::cin >> age;
   constexpr int myAge { age }; // compile error: age is not a compile-time constant expression
   constexpr int f { five() }; // compile error: return value of five() is not a compile-time constant expression
}
```

Type Deduction (auto keyword)

Type Deduction

Because C++ is a strongly-typed language, we are required to provide an explicit type for all objects. **Type Deduction** (also sometimes called **Type Inference**) is a feature that allows the compiler to deduce the type of an object from the object's initializer. To use type deduction, the auto keyword is used in place of the variable's type.

```
int add(int x, int y) {
  return x + y;
}
int main() {
  auto d{ 5.0 }; // 5.0 is a double literal, so d will be type double
  auto i{ 1 + 2 }; // 1 + 2 evaluates to an int, so i will be type int
  auto x{ i }; // i is an int, so x will be type int too
  auto sum{ add(5, 6) }; // add() returns an int, so sum's type will be deduced to int

  const int a{ 5 };  // a has type const int
  auto b{ a };       // b will be type int (const is dropped)
  const auto c{ a }; // c will be type const int (const is reapplied)

  auto z1; // Error: The compiler is unable to deduce the type of z1
  auto z2{ }; // Error: The compiler is unable to deduce the type of z2
}
```

Type deduction will drop the const qualifier from deduced types. If you want a deduced type to be const, you must use the const keyword in conjunction with the auto keyword.

Type Deduction Using Literal Suffixes

```
#include <iostream>

int main() {
    auto x1{0}; // int (by default)
    auto x2{0L}; // long
    auto x3{0LL}; // long long
    auto x4{0.0f}; // float
    auto x5{0.0}; // double (by default)
    auto x6{0.0L}; // long double
    std::cout << "x1 is " << sizeof(x1) << " bytes\n";
    std::cout << "x2 is " << sizeof(x2) << " bytes\n";
    std::cout << "x3 is " << sizeof(x3) << " bytes\n";
    std::cout << "x4 is " << sizeof(x4) << " bytes\n";
    std::cout << "x5 is " << sizeof(x5) << " bytes\n";
    std::cout << "x6 is " << sizeof(x6) << " bytes\n";
}
```

Type Deduction for String Literals

If you want the type deduced from a string literal to be std::string or std::string_view, you must use the s or sv literal suffixes:

```
#include <string>
#include <string_view> // Since C++17
int main() {
   auto a { "Hello" }; // a will be type const char*, not std::string

   using namespace std::literals; // easiest way to access the s and sv suffixes, since C++14
   auto a1 { "Hello"s };  // "Hello"s is a std::string literal, so a1 will be deduced as a std::string

   // Since C++17:
   auto a2 { "Hello"sv }; // "Hello"sv is a std::string_view literal, so a2 will be deduced as a std::string_view
}
```