Flow of Control

Contents

- Boolean Expression
- Control Structures
- `if .. else` Statements
- `switch` Statement
- `while` Structure
- `do .. while` Structure
- `for` Structure

Boolean Expressions

Boolean Expression

- Boolean expression: an expression that is either ***true*** or ***false***.

- Comparison Operators: == , !=, <, <=, >, >=

Comparison Operators

MATH SYMBOL	ENGLISH	C++ NOTATION	C++ SAMPLE	MATH EQUIVALENT
=	Equal to	= =	x + 7 = = 2*y	x + 7 = 2y
≠	Not equal to	!=	ans != 'n'	*ans* ≠ *'n'*
<	Less than	<	count < m + 3	*count* < *m* + 3
≤	Less than or equal to	<=	time <= limit	*time* ≤ *limit*
>	Greater than	>	time > limit	*time* > *limit*
≥	Greater than or equal to	>=	age >= 21	*age* ≥ 21

Building Boolean Expressions

- Combine two comparisons using:
  - AND operator: **&&**

    ```
    ( Boolean_Exp_1) && (Boolean_Exp_2)
    ```

  - OR operator: **||**

    ```
    ( Boolean_Exp_1) || (Boolean_Exp_2)
    ```

- Negate a Boolean expression, NOT operator: **!**

  ```
  !( Boolean_Exp)
  ```

Evaluating Boolean Expressions

- Be evaluated the same way as arithmetic expressions.
- Examples:

```
bool result = (x < z) && (z < y);
!( (y < 3) || (y > 7))
```

- Rules: **truth tables**.
- `true`, `false`: predefined constants of type `bool`.

Precedence Rules

- Boolean expression need not be fully parenthesized.

- Default precedence:
  - First: !
  - Next: relational operations (<, >,..)
  - Next: &&
  - Next: ||
- Examples:
  - `(temperature > 80) && (humidity > 0.9) && (poolGate == OPEN)`
  - `temperature > 80 && humidity > 0.9 && poolGate == OPEN`

Precedence of Operators

`::`	Scope resolution operator
`.`	Dot operator
`->`	Member selection
`[]`	Array indexing
`( )`	Function call
`++`	Postfix increment operator (placed after the variable)
`--`	Postfix decrement operator (placed after the variable)
`++`	Prefix increment operator (placed before the variable)
`--`	Prefix decrement operator (placed before the variable)
`!`	Not
`--`	Unary minus
`+`	Unary plus
`*`	Dereference
`&`	Address of
`new`	Create (allocate memory)
`delete`	Destroy (deallocate)
`delete []`	Destroy array (deallocate)
`sizeof`	Size of object
`( )`	Type cast
`*`	Multiply
`/`	Divide
`%`	Remainder (modulo)
`+`	Addition
`-`	Subtraction
`<<`	Insertion operator (console output)
`>>`	Extraction operator (console input)

Highest precedence (done first)

Lower precedence (done later)

Precedence of Operators

<	Less than
>	Greater than
<=	Less than or equal to
>=	Greater than or equal to
==	Equal
!=	Not equal
&&	And
||	Or
=	Assignment
+=	Add and assign
-=	Subtract and assign
*=	Multiply and assign
/=	Divide and assign
%=	Modulo and assign
? :	Conditional operator

Lowest precedence (done last)

Precedence Rules

- **short-circuit evaluation**: if it gets enough information to determine the value, it does not bother to evaluate other expressions.
  - C++ uses this way.

- **complete evaluation**: all the expressions are evaluated before determining.
  - Some of the languages.

- Examples:

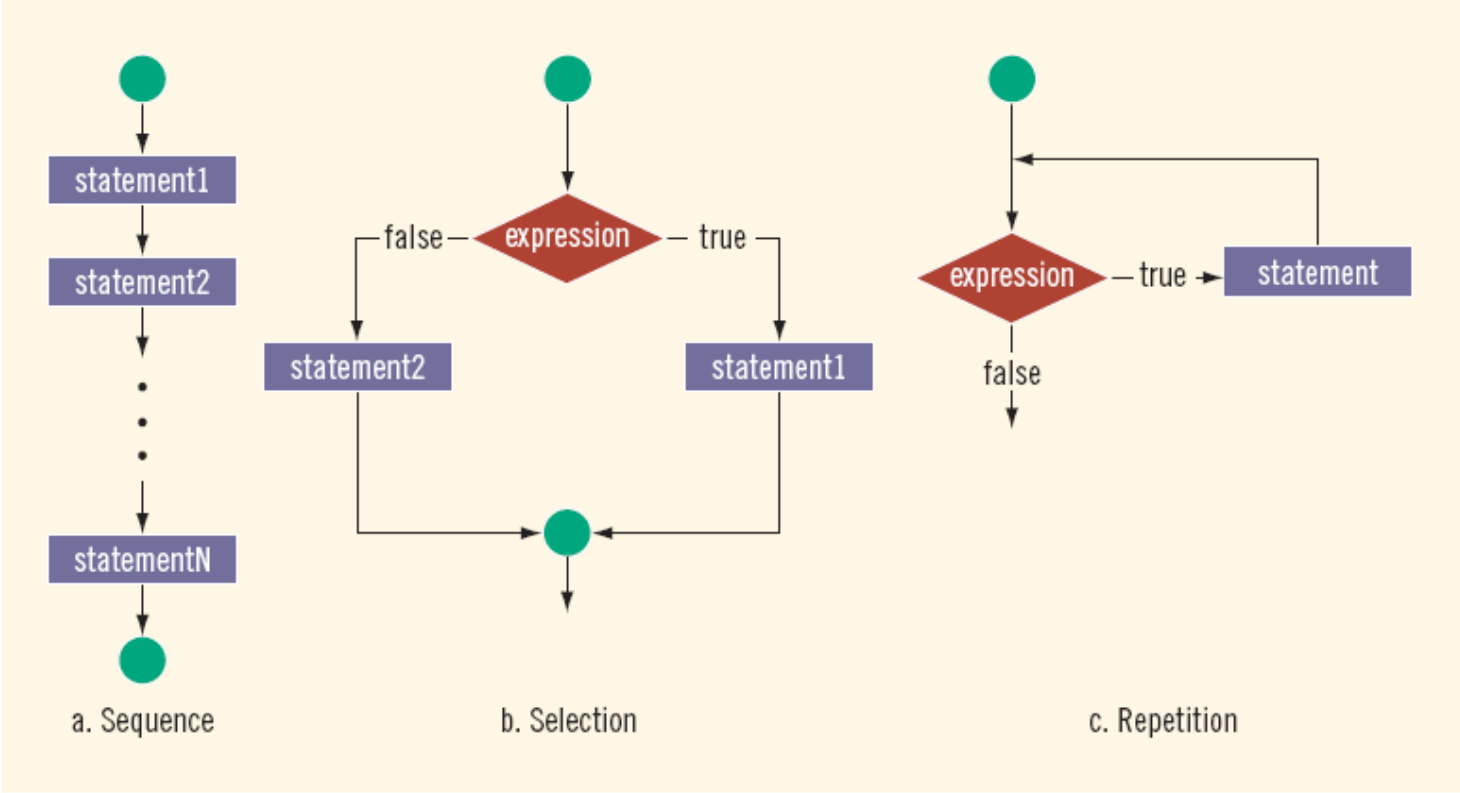
```
(age >= 21) || ( x == 5) //Line 1
(grade == 'A') && (x >= 7)     //Line 2
```

Control Structures

Control Structures

- A computer can proceed:
  - In sequence
  - Selectively (branch) - making a choice
  - Repetitively (iteratively) - looping
- Some statements are executed only if certain conditions are met
- A condition is met if it evaluates to `true`

Control Structures



Selection Structures

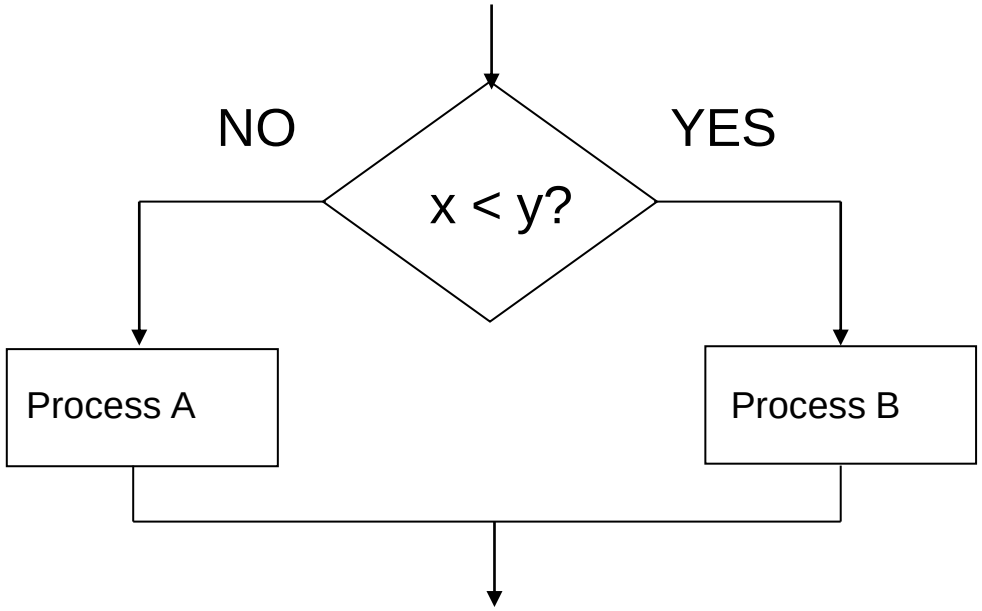
- `if-else` statements
- `switch-case` statements

Repetition Structures

- `while ... do`
- `do ... while`
- `for`

`if-else` Statements

`if-else` Statements



One-Way Selection

- Syntax:

```
if (Boolean_Expression)
    Yes_Statement
```

- The *Yes_Statement* is executed if the value of the *Boolean_Expression* is `true`
- The statement is bypassed if the value is `false`; program goes to the next statement.
- Example:

```
if (score >= 5.0)
    pass = true;
```

One-Way Selection

```
#include <iostream>

using namespace std;

int main()
{
    int number, temp;

    cout << "Line 1: Enter an integer: ";          //Line 1
    cin >> number;                                 //Line 2
    cout << endl;                                  //Line 3

    temp = number;                                 //Line 4

    if (number < 0)                                //Line 5
        number = -number;                          //Line 6

    cout << "Line 7: The absolute value of "
         << temp << " is " << number << endl;      //Line 7

    return 0;
}
```

One-Way Selection

- Some error examples:

```
//Syntax
• if score >= 60
  grade = 'P’;

//Logical
• if (score >= 60);
  grade = 'P';
```

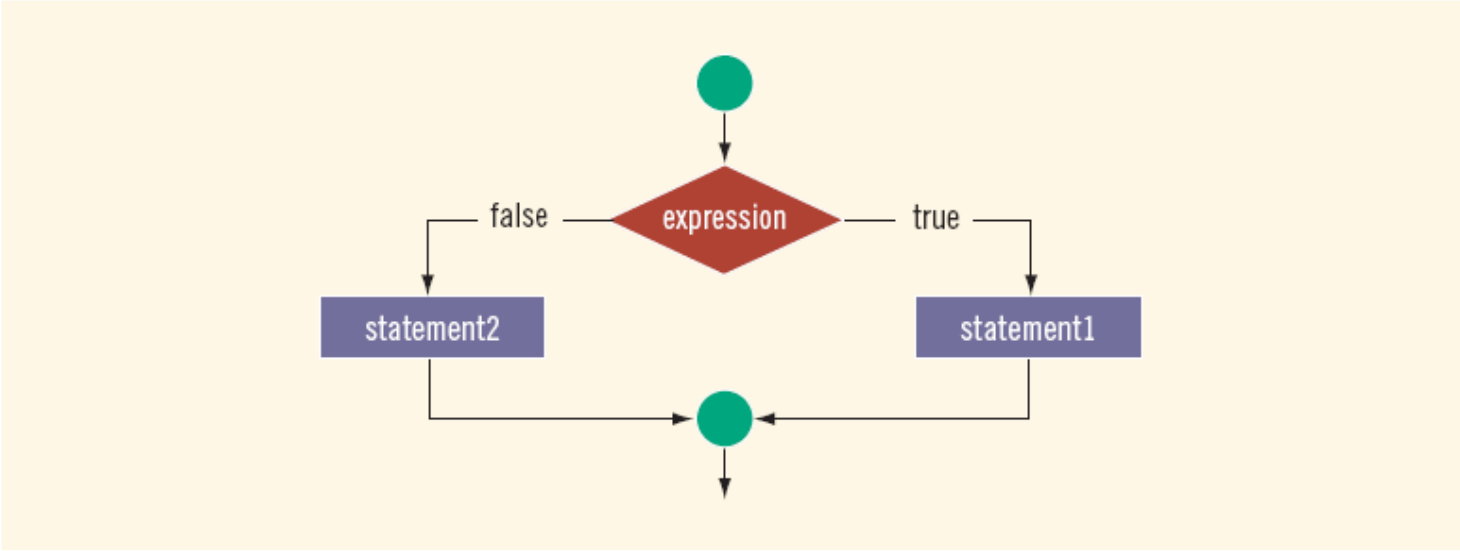
Two-Way Selection

- Two-way selection takes the form:

```
if (Boolean_Expression)
    Yes_Statement
else
    No_Statement
```

- If *Boolean_Expression* is `true`, `Yes_Statement` is executed; otherwise, `No_Statement` is executed
  - `Yes_Statement` and `No_Statement` are any C++ statements

Two-Way Selection



Two-Way Selection

```
if (hours > 40.0)                                    //Line 1
    wages = 40.0 * rate +
            1.5 * rate * (hours - 40.0);             //Line 2
else                                                 //Line 3
    wages = hours * rate;                            //Line 4
```

Compound Statements

- A list of statements enclosed in a pairs of braces.
- Compound statement (block of statements):

```
{
    Statement_1;
    Statement_2;

    ...
    Statement_n;
}
```

- A compound statement is a single statement.

Compound Statements

- Example:

```
if (age > 18)
{
   cout << "Eligible to vote." << endl;
   cout << "No longer a minor." << endl;
}
else
{
   cout << "Not eligible to vote." << endl;
   cout << "Still a minor." << endl;
}
```

Multiple Selections: Nested `if`

- **Nesting:** one control statement in another
- An `else` is associated with the most recent `if` that has not been paired with an `else`
- Syntax:

```
if (Boolean_Expression_1)
    Statement_1
else if (Boolean_Expression_2)
    Statement_2
...
else if (Boolean_Expression_n)
    Statement_n
else
    Statement_For_All_Other_Possibilities
```

Multiple Selections: Nested `if`

Assume that `score` is a variable of type `int`. Based on the value of `score`, the following code outputs the grade:

```
if (score >= 90)
    cout << "The grade is A." << endl;
else if (score >= 80)
    cout << "The grade is B." << endl;
else if (score >= 70)
    cout << "The grade is C." << endl;
else if (score >= 60)
    cout << "The grade is D." << endl;
else
    cout << "The grade is F." << endl;
```

Multiple Selections: Nested `if`

```
if (balance > 50000.00)                    //Line 1
    interestRate = 0.07;                   //Line 2
else                                       //Line 3
    if (balance >= 25000.00)               //Line 4
        interestRate = 0.05;               //Line 5
    else                                   //Line 6
        if (balance >= 1000.00)            //Line 7
            interestRate = 0.03;           //Line 8
        else                               //Line 9
            interestRate = 0.00;           //Line 10
```

To avoid excessive indentation, the code in Example 4-18 can be rewritten as follows:

```
if (balance > 50000.00)                    //Line 1
    interestRate = 0.07;                   //Line 2
else if (balance >= 25000.00)              //Line 3
    interestRate = 0.05;                   //Line 4
else if (balance >= 1000.00)               //Line 5
    interestRate = 0.03;                   //Line 6
else                                       //Line 7
    interestRate = 0.00;                   //Line 8
```

Confusion between == and =

- C++ allows you to use any expression that can be evaluated to either `true` or `false` as an expression in the `if` statement:

```
if (x = 5)
    cout << "The value is five." << endl;
```

- The appearance of = in place of == resembles a *silent killer*
  - It is not a syntax error
  - It is a **logical error**

Conditional Operator (?:)

- Conditional operator (`?:`) takes three arguments
  - Ternary operator

- Syntax for using the conditional operator:

```
expression1 ? expression2 : expression3
```

- If `expression1` is `true`, the result of the conditional expression is `expression2`
  - Otherwise, the result is `expression3`

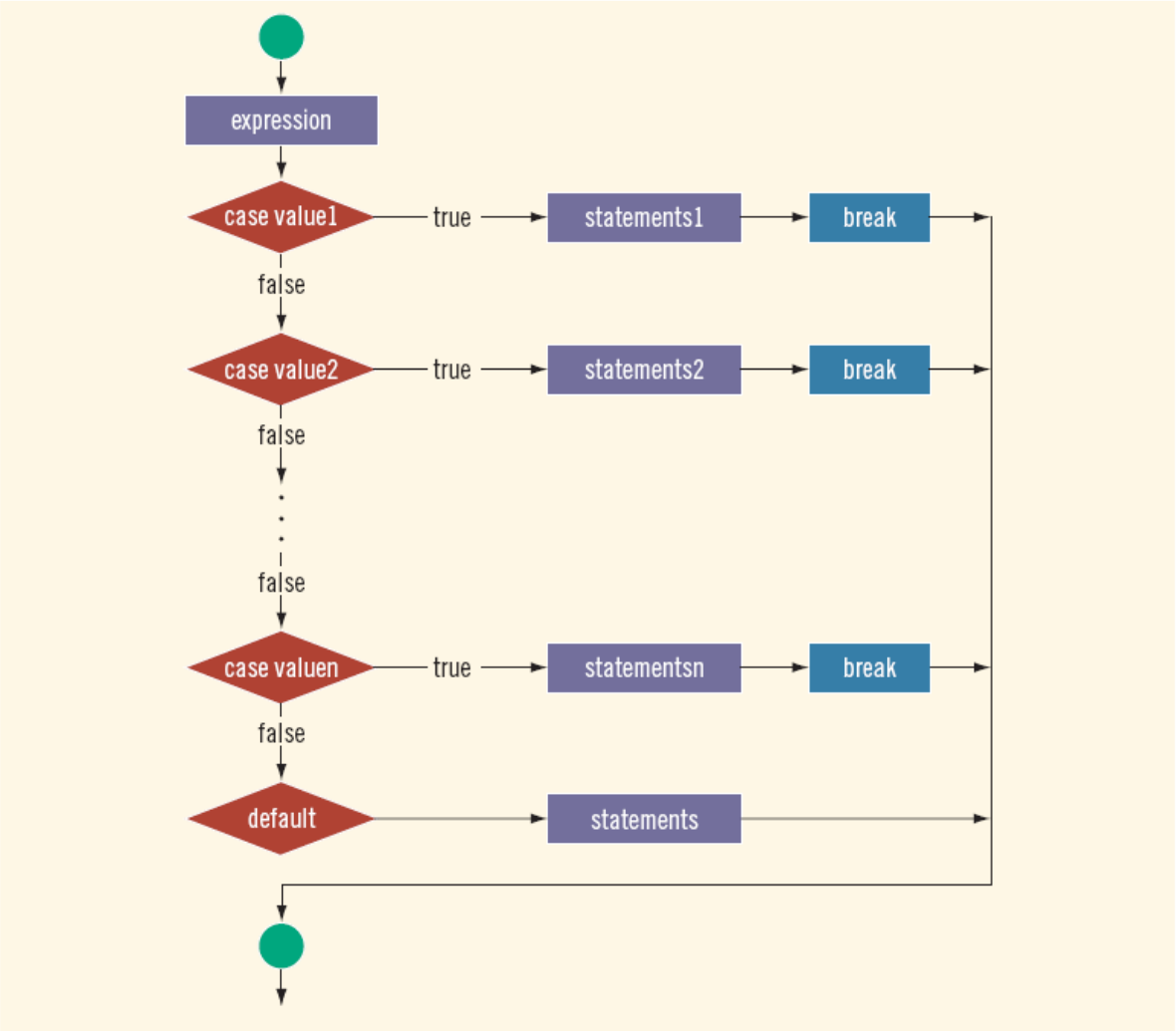
`switch` Statement

`switch` Statement

- `switch` structure: alternate to `if-else`
- `switch` (integral) expression (*controlling expression*) is evaluated first.
- Value of the controlling expression determines which corresponding action is taken.

switch Statement

```
switch (Controlling_Expression)
{
        case Constant_1:
                Statement_Sequence_1
                break;
        case Constant_2:
                Statement_Sequence_n
                break;
        ...
        case Constant_n:
                Statement_Sequence_n
                break;
        default:
                Default_Statement_Sequence
}
```


expression
case value1
true
statements1
break
false
case value2
true
statements2
break
false
false
case valuen
true
statementsn
break
false
default
statements

`switch` Statement

- One or more statements may follow a **`case`** label.
- Braces are not needed to turn multiple statements into a single compound statement.
- The `break` statement may or may not appear after each statement.
- `switch`, `case`, `break`, and `default` are reserved words.

switch Statement

```
switch (grade)
{
case 'A':
    cout << "The grade is 4.0.";
    break;
case 'B':
    cout << "The grade is 3.0.";
    break;
case 'C':
    cout << "The grade is 2.0.";
    break;
case 'D':
    cout << "The grade is 1.0.";
    break;
case 'F':
    cout << "The grade is 0.0.";
    break;
default:
    cout << "The grade is invalid.";
}
```

switch Statement

```
int vehicleClass;
double toll;
cout << "Enter vehicle class: ";
cin >> vehicleClass;

switch (vehicleClass)
{
    case 1:
        cout << "Passenger car.";
        toll = 0.50;
        break;
    case 2:
        cout << "Bus.";
        toll = 1.50;
        break;
    case 3:
        cout << "Truck.";
        toll = 2.00;
        break;
    default:
        cout << "Unknown vehicle class!";
}
```

If you forget this `break`*, then passenger cars will pay $ 1.50.*

Enumeration Types

- Enumeration type: a type whose values are defined by a list of constants type `int`.
- Syntax:

```
enum Name {enumerator_1, enumerator_2,...};
enum Name {enumerator_1 = constant_1, enumerator_2 = constant_2,...};
```

- Examples:
  - `enum Direction {NORTH, SOUTH, EAST, WEST};`
  - `enum Direction {NORTH=0, SOUTH=1, EAST=2, WEST=3};`
  - `enum MyNum {ONE = 17, TWO, THREE, FOUR = -3, FIVE}`

Enumeration Types

- Example:

```
enum Color { red, green, blue };
Color r = red;
switch(r)
{
    case red   : std::cout << "red\n";   break;
    case green: std::cout << "green\n"; break;
    case blue  : std::cout << "blue\n";  break;
}
```

`assert` function

Terminating a Program with the `assert` Function

Terminating a Program with the `assert` Function

- Certain types of errors that are very difficult to catch can occur in a program
  - Example: division by zero can be difficult to catch using any of the programming techniques examined so far

- The predefined function, `assert`, is useful in stopping program execution when certain elusive errors occur.

The `assert` Function

- Syntax:

```
assert(expression);
```

  `expression` is any logical expression

- If `expression` evaluates to `true`, the next statement executes
- If `expression` evaluates to `false`, the program terminates and indicates where in the program the error occurred
- To use `assert`, include `cassert` header file.

The `assert` Function

- `assert` is useful for enforcing programming constraints during program development.
- After developing and testing a program, remove or disable *assert* statements.
- The preprocessor directive `#define NDEBUG` must be placed before the directive `#include <cassert>` to disable the assert statement.

Programming Example

Cable Company Billing

- This programming example **calculates a customer's bill for a local cable company.**
- There are two types of customers:
  - Residential
  - Business
- Two rates for calculating a cable bill:
  - One for residential customers
  - One for business customers

Cable Company Billing - Rates

- For residential customer:
  - Bill processing fee: $4.50
  - Basic service fee: $20.50
  - Premium channel: $7.50 per channel

- For business customer:
  - Bill processing fee: $15.00
  - Basic service fee: $75.00 for first 10 connections and $5.00 for each additional connection
  - Premium channel cost: $50.00 per channel for any number of connections

Cable Company Billing - Requirements

- Ask user for account number and customer code
- Assume `R` or `r` stands for residential customer and `B` or `b` stands for business customer.
- The program should print the billing amount to two decimal places

Cable Company Billing - Input/Output

- Input:
  - Customer account number
  - Customer code
  - Number of premium channels
  - For business customers, number of basic service connections

- Output:
  - Customer's account number
  - Billing amount

Repetition Structures

Why Is Repetition Needed?

- Repetition allows you to efficiently use variables
- Can input, add, and average multiple numbers using a limited number of variables.
- For example, to add five numbers:
  - Declare a variable for each number, input the numbers and add the variables together
  - Create a loop that reads a number into a variable and adds it to a variable that contains the sum of the numbers

Repetition Structures

- Three loop statements:
  - `while ... do`
  - `do ... while`
  - `for`
- **loop body**: the code repeated in a loop.
- **iteration**: each repetition of a loop.
- **Infinite loop:** continues to execute endlessly
  - Avoided by including statements in loop body that assure exit condition is eventually `false`

`while` Structures

`while` Structure

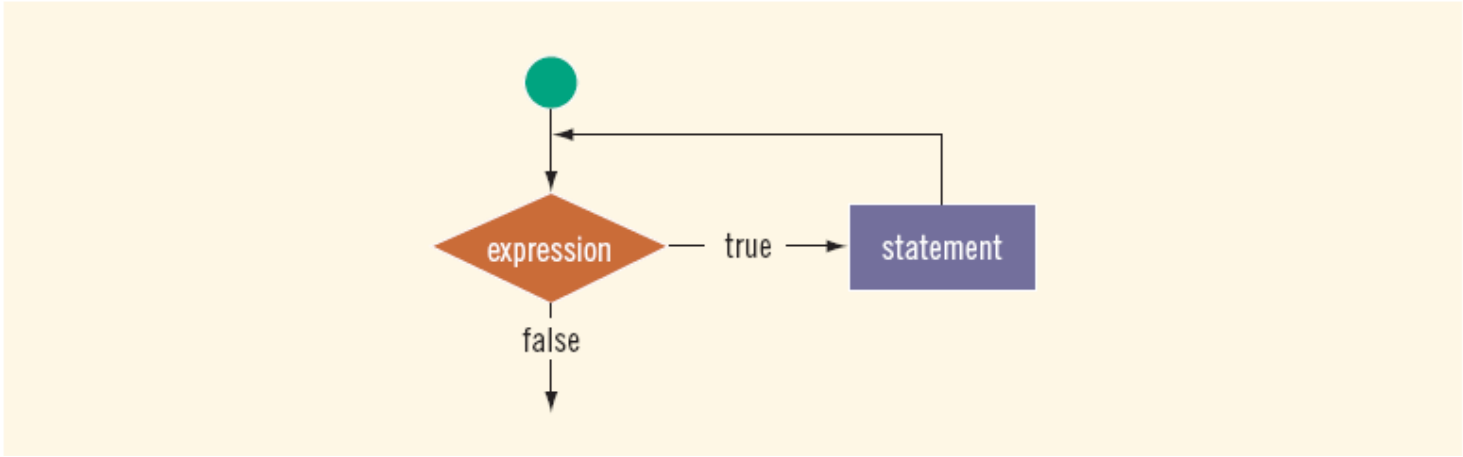
- Single-statement body:

```
while (expression)
    statement
```

- Multi-statement body:

```
while (expression)
{
    Statement_1
    Statement_2
    ...
    Statement_Last
}
```

`while` Structure



while Structure

- Example:

```
int i = 0;
while (i <= 20)
{
    cout << i << " ";
    i = i + 5;
}
```

- Example:

```
int i = 20;
while (i < 20)
{
    cout << i << " ";
    i = i + 5;
}
```

do..while Structure

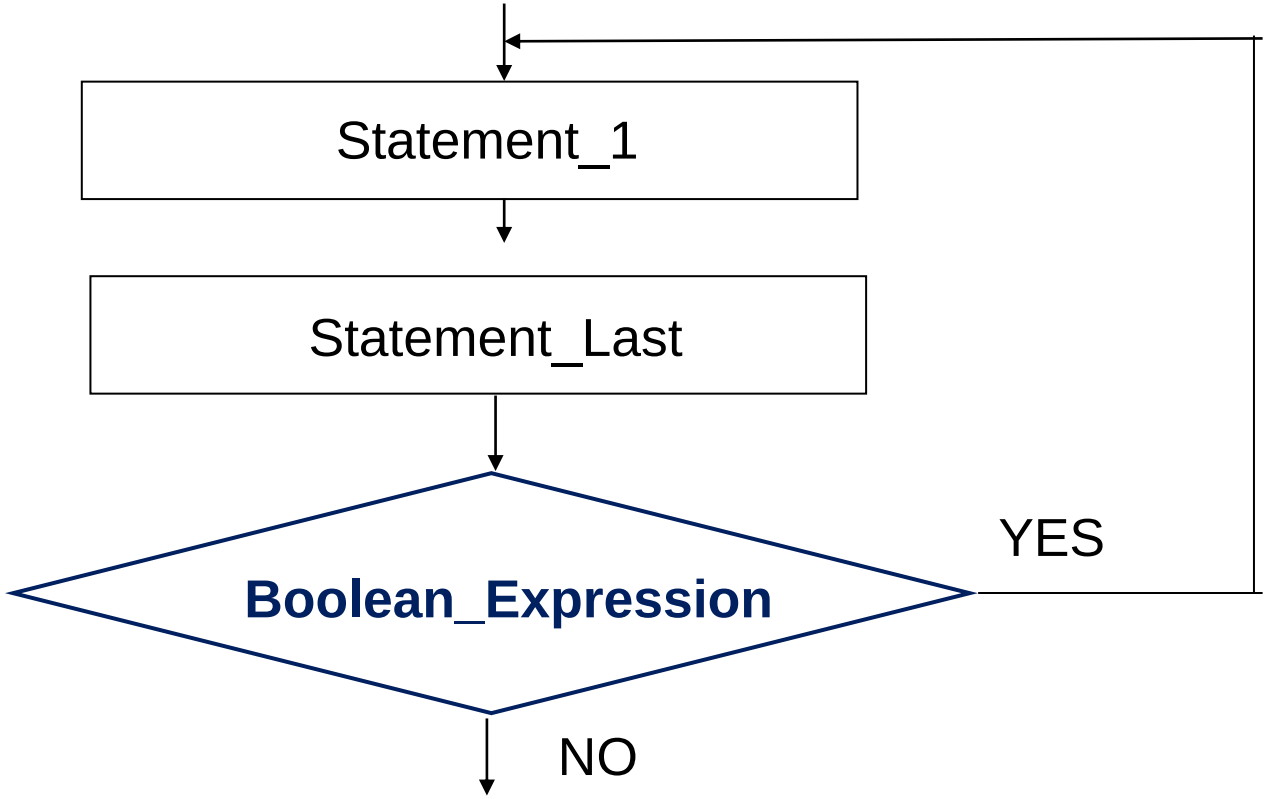
- Single-statement body:

```
do
    Statement
while (Boolean_Expression);
```

- Multi-statement body:

```
do
{
    Statement_1
    Statement_2
    ...
    Statement_Last
} while (Boolean_Expression);
```

do..while Structure



do..while Structure

- Example:

```
int i = 0;
do
{
    cout << i << " ";
    i = i + 5;
} while (i <= 20);
```

- Example:

```
int i = 20;
do
{
    cout << i << " ";
    i = i + 5;
} while (i < 20);
```

Counter-Controlled `while` Loops

- If you know exactly how many pieces of data need to be read, the `while` loop becomes a counter-controlled loop.

```
counter = 0;          //initialize the loop control variable

while (counter < N) //test the loop control variable
{
     .
     .
     .
     counter++;       //update the loop control variable
     .
     .
     .
}
```

Sentinel-Controlled `while` Loops

- *Sentinel variable* is tested in the condition and loop ends when sentinel is encountered.

```
cin >> variable;              //initialize the loop control variable

while (variable != sentinel)  //test the loop control variable
{
     .
     .
     .
     cin >> variable;       //update the loop control variable
     .
     .
     .
}
```

- Example:
  - Read some positive numbers and average them, but you do not have the preset number of data items in mind. Suppose ***-999*** marks the end of the data.

Flag-Controlled `while` Loops

- A flag-controlled `while` loop uses a `bool` variable to control the loop.
- The flag-controlled `while` loop takes the form:

```
found = false;       //initialize the loop control variable

while (!found)       //test the loop control variable
{
    .
    .
    .
    if (expression)
        found = true; //update the loop control variable
    .
    .
    .
}
```

- Example: **Number guessing game**.

Infinite Loop

- Example:

```
int x = 1;
while (x != 12)
{
   cout << x << endl;
   x = x + 2;
}
```

Infinite Loop

- Example:

```
int x = 1;
while (x != 12)
{
   cout << x << endl;
   x = x + 2;
}
```

How to fix this loop?

The Comma Operator

- **Comma operator** (,)
  - evaluates a list of expressions
  - returns the value of the last expression.

- Examples - What are the value of these variables after running:
  - `result = (first = 2, second = first + 1);`
  - `result = (first = 2, second = first + 1, first = second + 7);`
  - `result = ((first = 2, second = first + 1), third = second + 1);`

for Structure

for Structure

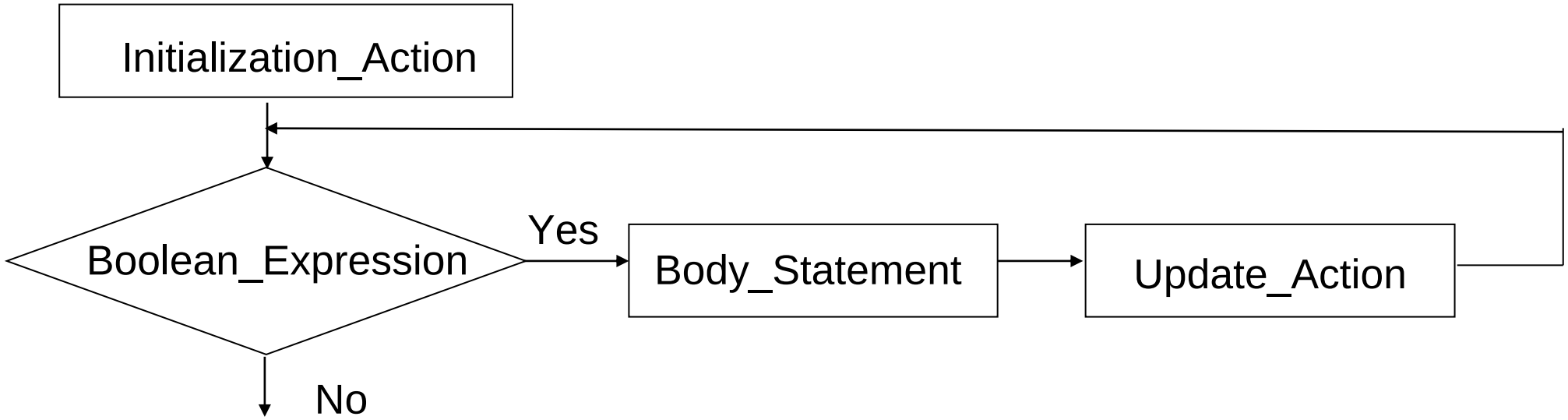
- The general form of the `for` statement is:

```
for (Initialization_Action; Boolean_Expression; Update_Action)

  Body_Statement
```

- The *Initialization_Action*, *Boolean_Expression*, and *Update_Action* are called `for` loop control statements
  - `Initialization_Action` usually initializes a variable (called the `for` **loop control**, or `for` **indexed**, **variable**)
- In C++, `for` is a reserved word

for Structure




```
for (Initialization_Action; Boolean_Expression; Update_Action)
        Body_Statement
```

Examples

- Example:

```
for (int i = 0; i < 10; i ++)
   cout << i << " ";

cout << end;
```

Examples

- Example:

```
int i = 0;
for ( ; i < 10; i ++)
   cout << i << " ";

cout << end;
```

Examples

- Example:

```
for (int i = 1; i <= 5; i++)
{
   cout << "Hello !" << endl;
   cout << "*" << endl;
}
```

- Example:

```
for (int i = 1; i <= 5; i++)
   cout << "Hello !" << endl;
cout << "*" << endl;
```

Examples

- Example:

```
for (int i = 1; i <= 5; i++);
   cout << "Hello !" << endl;
```

- Example:

```
for ( ; ; )
   cout << "Hello !" << endl;
```

Examples

- Example:

```
for (int i = 10; i >= 0; i--)
   cout << " " << i;
cout << endl;
```

- Example:

```
for (int i = 1; i <= 20; i = i+2)
   cout << " " << i;
cout << endl;
```

Choosing the Right Loop Structure

- All three loops have their place in C++
  - If you know or can determine in advance the number of repetitions needed, the **`for`** loop is the correct choice.
  - If you do not know and cannot determine in advance the number of repetitions needed, and it could be zero, use a **`while`** loop.
  - If you do not know and cannot determine in advance the number of repetitions needed, and it is at least one, use a **`do...while`** loop

Nested Loops

- It is legal to nest one loop statement inside another loop statement.
- Example:

```
for (i = 1; i <= 5 ; i++)
{
        for (j = 1; j <= i; j++)
            cout << "*";
        cout << endl;
}
```

`break` and `continue`

`break` and `continue` Statements

- **`break`** and **`continue`** alter the flow of control.
- **`break`** statement is used for two purposes:
  - To exit early from a loop
    - Can eliminate the use of certain (flag) variables
  - To skip the remainder of the **`switch`** structure

- After the **`break`** statement executes, the program continues with the first statement after the structure.

`break` and `continue` Statements

- **`continue`** is used in **`while`**, **`for`**, and **`do...while`** structures.
- When executed in a loop
  - It skips remaining statements and proceeds with the next iteration of the loop

Examples

```
1  #include <iostream>
2  using namespace std;

3  int main( )
4  {
5      int number, sum = 0, count = 0;
6      cout << "Enter 4 negative numbers:\n";

7      while (++count <= 4)
8      {
9          cin >> number;

10         if (number >= 0)
11         {
12             cout << "ERROR: positive number"
13                  << " or zero was entered as the\n"
14                  << count << "th number! Input ends "
15                  << "with the " << count << "th number.\n"
16                  << count << "th number was not added in.\n";
17             break;
18         }

19         sum = sum + number;
20     }

21     cout << sum << " is the sum of the first "
22          << (count - 1) << " numbers.\n";

23     return 0;
24 }
```

Examples

```
1   #include <iostream>
2   using namespace std;

3   int main( )
4   {
5       int number, sum = 0, count = 0;
6       cout << "Enter 4 negative numbers, ONE PER LINE:\n";

7       while (count < 4)
8       {
9           cin >> number;

10          if (number >= 0)
11          {
12              cout << "ERROR: positive number (or zero)!\n"
13                   << "Reenter that number and continue:\n";
14              continue;
15          }
16          sum = sum + number;
17          count++;
18      }

19      cout << sum << " is the sum of the "
20           << count << " numbers.\n";
21      return 0;
22  }
```

Programming Example

Checking Account Balance

- A local bank in your town needs a program to calculate a customer's checking account balance at the end of each month
- Data are stored in a file in the following form:

```
467343 23750.40
W 250.00
D 1200
W 75.00
I 120.74
```

Checking Account Balance

- The first line of data shows the account number followed by the account balance at the beginning of the month
- Thereafter each line has two entries:
  - Transaction code
  - Transaction amount
- Transaction codes
  - `W` or `w` means withdrawal
  - `D` or `d` means deposit
  - `I` or `i` means interest paid by the bank

Checking Account Balance

- Program updates balance after each transaction
- During the month, if at any time the balance goes below $1000.00, a $25.00 service fee is charged.

Checking Account Balance

- Program prints the following information:
  - Account number
  - Balance at the beginning of the month
  - Balance at the end of the month
  - Interest paid by the bank
  - Total amount of deposit
  - Number of deposits
  - Total amount of withdrawal
  - Number of withdrawals
  - Service charge if any

Checking Account Balance

- **Input:** file consisting of data in the previous format
- **Output** is of the following form:

```
Account Number: 467343
Beginning Balance: $23750.40
Ending Balance: $24611.49
Interest Paid: $366.24
Amount Deposited: $2230.50
Number of Deposits: 3
Amount Withdrawn: $1735.65
Number of Withdrawals: 6
```

Questions and Answers