Chapter 2

Flow of Control

Learning Objectives

- Boolean Expressions
  - Building, Evaluating & Precedence Rules
- Branching Mechanisms
  - if-else
  - switch
  - Nesting if-else
- Loops
  - While, do-while, for
  - Nesting loops

Boolean Expressions:

- Logical Operators
  - Logical AND (&&)
  - Logical OR (||)

Display 2.1 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

Evaluating Boolean Expressions

- Data type bool
  - Returns true or false
  - true, false are predefined library consts
- Truth tables

Evaluating Boolean Expressions: **Display 2.2** Truth Tables

Display 2.2 Truth Tables

AND

Exp_1	*Exp_2*	*Exp_1* && *Exp_2*
true	true	true
true	false	false
false	true	false
false	false	false

OR

Exp_1	*Exp_2*	*Exp_1* || *Exp_2*
true	true	true
true	false	true
false	true	true
false	false	false

NOT

Exp	!(*Exp*)
true	false
false	true

Display 2.3
Precedence of Operators (1 of 4)

Display 2.3 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

Highest precedence (done first)

Display 2.3
Precedence of Operators (2 of 4)

*	Multiply
/	Divide
%	Remainder (modulo)
+	Addition
–	Subtraction
<<	Insertion operator (console output)
>>	Extraction operator (console input)

Lower precedence (done later)

Display 2.3
Precedence of Operators (3 of 4)

Display 2.3 Precedence of Operators

All operators in part 2 are of lower precedence than those in part 1.

<	Less than
>	Greater than
<=	Less than or equal to
>=	Greater than or equal to
==	Equal
!=	Not equal
&&	And
||	Or

Display 2.3
Precedence of Operators (4 of 4)

=	Assignment
+=	Add and assign
−=	Subtract and assign
*=	Multiply and assign
/=	Divide and assign
%=	Modulo and assign
? :	Conditional operator
throw	Throw an exception
,	Comma operator

Lowest precedence (done last)

Precedence Examples

- Arithmetic before logical
  - x + 1 > 2 || x + 1 < -3 means:
    - ((x + 1) > 2) || ((x + 1) < -3)
- Short-circuit evaluation
  - (x >= 0) && (y > 1)
  - Be careful with increment operators!
    - (x > 1) && (y++)
- Integers as boolean values
  - All non-zero values → true
  - Zero value → false

Branching Mechanisms

- if-else statements
  - Choice of two alternate statements based on condition expression
  - Example:

```
if (hrs > 40)
  grossPay = rate*40 + 1.5*rate*(hrs-40);
else
  grossPay = rate*hrs;
```

if-else Statement Syntax

- Formal syntax:
  if (<boolean_expression>)
  <yes_statement>
  else
  <no_statement>
- Note each alternative is only ONE statement!
- To have multiple statements execute in either branch → use compound statement

Compound/Block Statement

- Only "get" one statement per branch
- Must use compound statement { }
  for multiples
  - Also called a "block" stmt
- Each block should have block statement
  - Even if just one statement
  - Enhances readability

Compound Statement in Action

- Note indenting in this example:

```
if (myScore > yourScore)
{
      cout << "I win!\n";
      wager = wager + 100;
}
else
{
      cout << "I wish these were golf scores.\n";
      wager = 0;
}
```

The Optional else

- else clause is optional
  - If, in the false branch (else), you want "nothing" to happen, leave it out
  - Example:

```
if (sales >= minimum)
    salary = salary + bonus;
cout << "Salary = %" << salary;
```

  - Note: nothing to do for false condition, so there is no else clause!
  - Execution continues with cout statement

Nested Statements

- if-else statements contain smaller statements
  - Compound or simple statements (we've seen)
  - Can also contain any statement at all, including another if-else stmt!
  - Example:

```
if (speed > 55)
    if (speed > 80)
        cout << "You're really speeding!";
    else
        cout << "You're speeding.";
```

    - Note proper indenting!

Multiway if-else

- Not new, just different indenting
- Avoids "excessive" indenting
  - Syntax:

Multiway if-else Statement

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
```

Multiway if-else Example

EXAMPLE

```
if ((temperature < –10) && (day == SUNDAY))
    cout << "Stay home.";
else if (temperature < –10) //and day != SUNDAY
    cout << "Stay home, but call work.";
else if (temperature <= 0) //and temperature >= –10
    cout << "Dress warm.";
else //temperature > 0
    cout << "Work hard and play hard.";
```

The Boolean expressions are checked in order until the first `true` Boolean expression is encountered, and then the corresponding statement is executed. If none of the Boolean expressions is *true*, then the *Statement_For_All_Other_Possibilities* is executed.

The switch Statement

- A new stmt for controlling multiple branches
- Uses controlling expression which returns bool data type (true or false)

switch Statement Syntax

switch Statement

SYNTAX

```
switch (Controlling_Expression)
{
    case Constant_1:
        Statement_Sequence_1
        break;
    case Constant_2:
        Statement_Sequence_2
        break;
                    .
                    .
                    .
    case Constant_n:
        Statement_Sequence_n
        break;
    default:
        Default_Statement_Sequence
}
```

You need not place a `break` *statement in each case. If you omit a* `break`*, that case continues until a* `break` *(or the end of the* `switch` *statement) is reached.*

The switch Statement in Action

EXAMPLE

```
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*

switch Menu Example

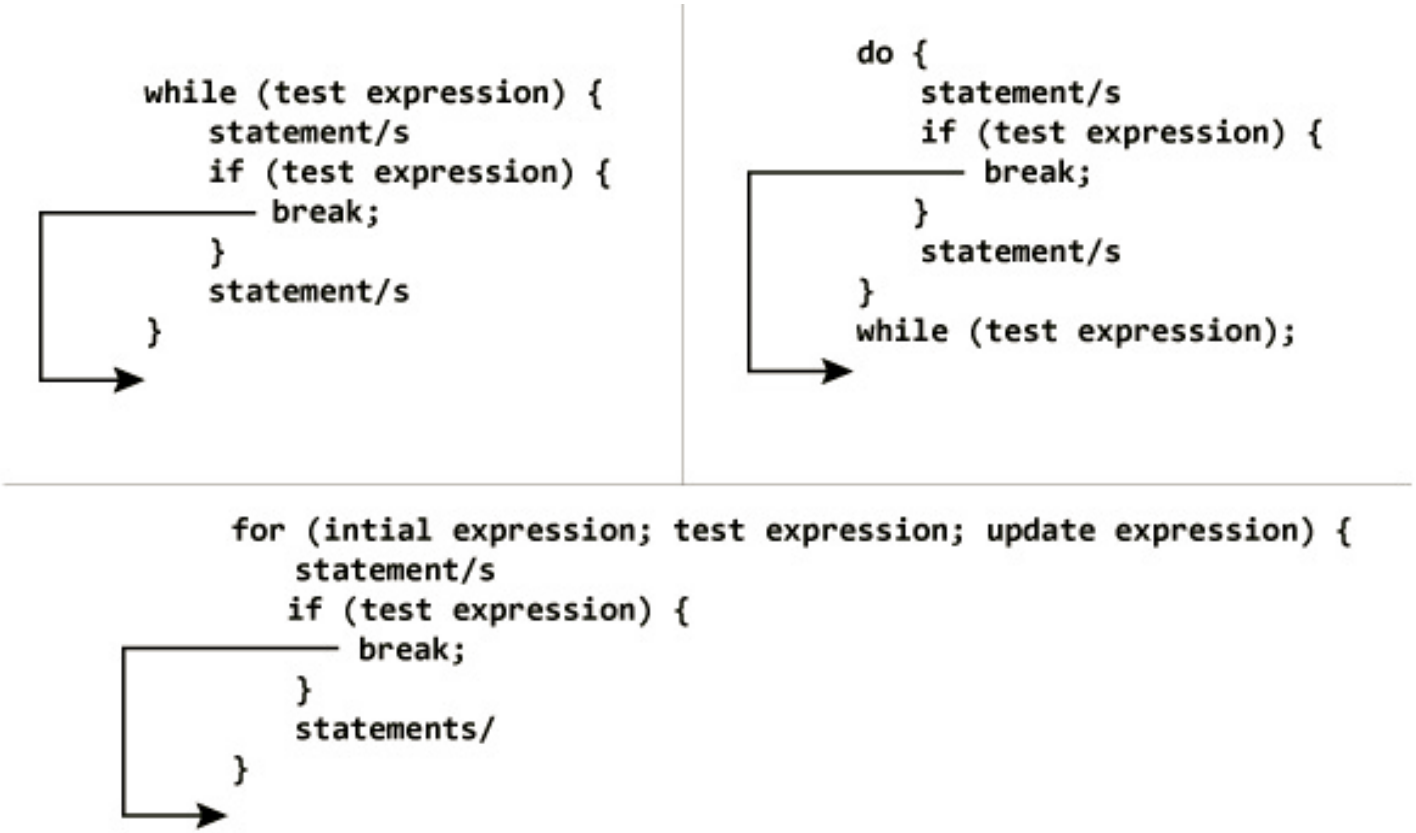
- Switch stmt "perfect" for menus:

```
switch (response)
{
        case "1":
                // Execute menu option 1
                break;
        case "2":
                // Execute menu option 2
                break;
        case "3":
                // Execute menu option 3
                break;
        default:
                cout << "Please enter valid response.";
}
```

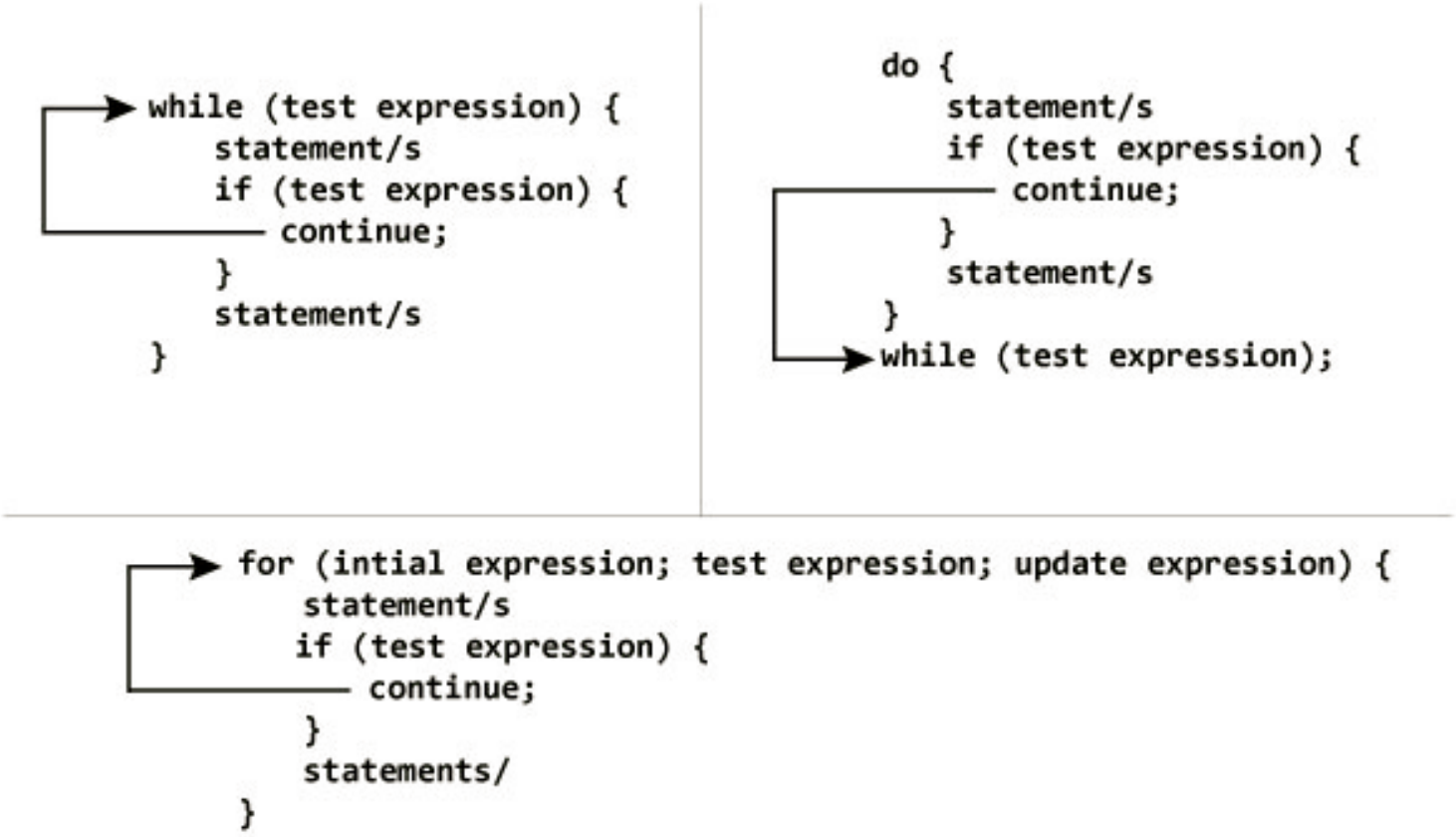
The break and continue Statements

- Flow of Control
  - Recall how loops provide "graceful" and clear flow of control in and out
  - In RARE instances, can alter natural flow
- break;
  - Forces loop to exit immediately.
- continue;
  - Skips rest of loop body
- These statements violate natural flow
  - Only used when absolutely necessary!

How “break” works



How “continue” works



Conditional Operator

- Also called "ternary operator"
  - Allows embedded conditional in expression
  - Essentially "shorthand if-else" operator
  - Example:

```
if (n1 > n2)
    max = n1;
else
    max = n2;
```

  - Can be written:

```
max = (n1 > n2) ? n1 : n2;
```

    - "?" and ":" form this "ternary" operator

Loops

- 3 Types of loops in C++
  - while
    - Most flexible
    - No "restrictions"
  - do-while
    - Least flexible
    - Always executes loop body at least once
  - for
    - Natural "counting" loop

while Loops Syntax

Syntax for `while` and `do-while` Statements

A `while` STATEMENT WITH A SINGLE STATEMENT BODY

```
while (Boolean_Expression)
    Statement
```

A `while` STATEMENT WITH A MULTISTATEMENT BODY

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

while Loop Example

- Consider:

```
count = 0;                  // Initialization
while (count < 3)                   // Loop Condition
{
      cout << "Hi ";                 // Loop Body
      count++;                      // Update expression
}
```

  - Loop body executes how many times?

do-while Loop Syntax

A do-while STATEMENT WITH A SINGLE-STATEMENT BODY

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

A do-while STATEMENT WITH A MULTISTATEMENT BODY

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

Do not forget the final semicolon.

do-while Loop Example

```
count = 0;          // Initialization
do
{
    cout << "Hi ";      // Loop Body
    count++;            // Update expression
} while (count < 3);    // Loop Condition
```

- Loop body executes how many times?
- do-while loops always execute body at least once!

while vs. do-while

- Very similar, but…
  - One important difference
    - Issue is "WHEN" boolean expression is checked
    - while: checks BEFORE body is executed
    - do-while: checked AFTER body is executed
- After this difference, they're essentially identical!
- while is more common, due to it's ultimate "flexibility"

for Loop Syntax

```
for (Init_Action; Bool_Exp; Update_Action)
    Body_Statement
```

- Like if-else, Body_Statement can be a block statement
  - Much more typical

for Loop Example

- for (count=0;count<3;count++)
  {
  cout << "Hi "; // Loop Body
  }
- How many times does loop body execute?
- Initialization, loop condition and update all "built into" the for-loop structure!
- A natural "counting" loop

Nested Loops

- Recall: ANY valid C++ statements can be inside body of loop
- This includes additional loop statements!
  - Called "nested loops"
- Requires careful indenting:

```
for (outer=0; outer<5; outer++)
    for (inner=7; inner>2; inner--)
        cout << outer << inner;
```

  - Notice no { } since each body is one statement
  - Good style dictates we use { } anyway

An example: Matrix Multiplication

$$\begin{bmatrix} * & * & * & * \\ 0 & 1 & 2 & 3 \\ * & * & * & * \\ * & * & * & * \end{bmatrix} \times \begin{bmatrix} * & 0 & * & * \\ * & 1 & * & * \\ * & 2 & * & * \\ * & 3 & * & * \end{bmatrix} = \begin{bmatrix} * & * & * & * \\ * & 14 & * & * \\ * & * & * & * \\ * & * & * & * \end{bmatrix}$$

```
for(i = 0; i < n; i++){
    for(j = 0; j < n; j++){
        for(k = 0; k < n; k++){
            c[i*n + j] += a[i*n + k] * b[k*n + j];
        }
    }
}
```