Chapter 3

More Flow of Control

Overview

3.1 Using Boolean Expressions

3.2 Multiway Branches

3.3 More about C++ Loop Statements

3.4 Designing Loops

Flow Of Control

- Flow of control refers to the order in which program statements are performed
  - We have seen the following ways to specify flow of control
    - if-else-statements
    - while-statements
    - do-while-statements
  - New methods described in this chapter include
    - switch-statements
    - for-statements

3.1

Using Boolean Expressions

Using Boolean Expressions

- A Boolean Expression is an expression that is either true or false
  - Boolean expressions are evaluated using relational operations such as
    - = = , < , and >= which produce a boolean value
  - and boolean operations such as
    - &&, | |, and ! which also produce a boolean value
- Type bool allows declaration of variables that carry the value true or false

Evaluating Boolean Expressions

- Boolean expressions are evaluated using values from the Truth Tables in

  - For example, if y is 8, the expression

    !((y < 3) | | (y > 7))

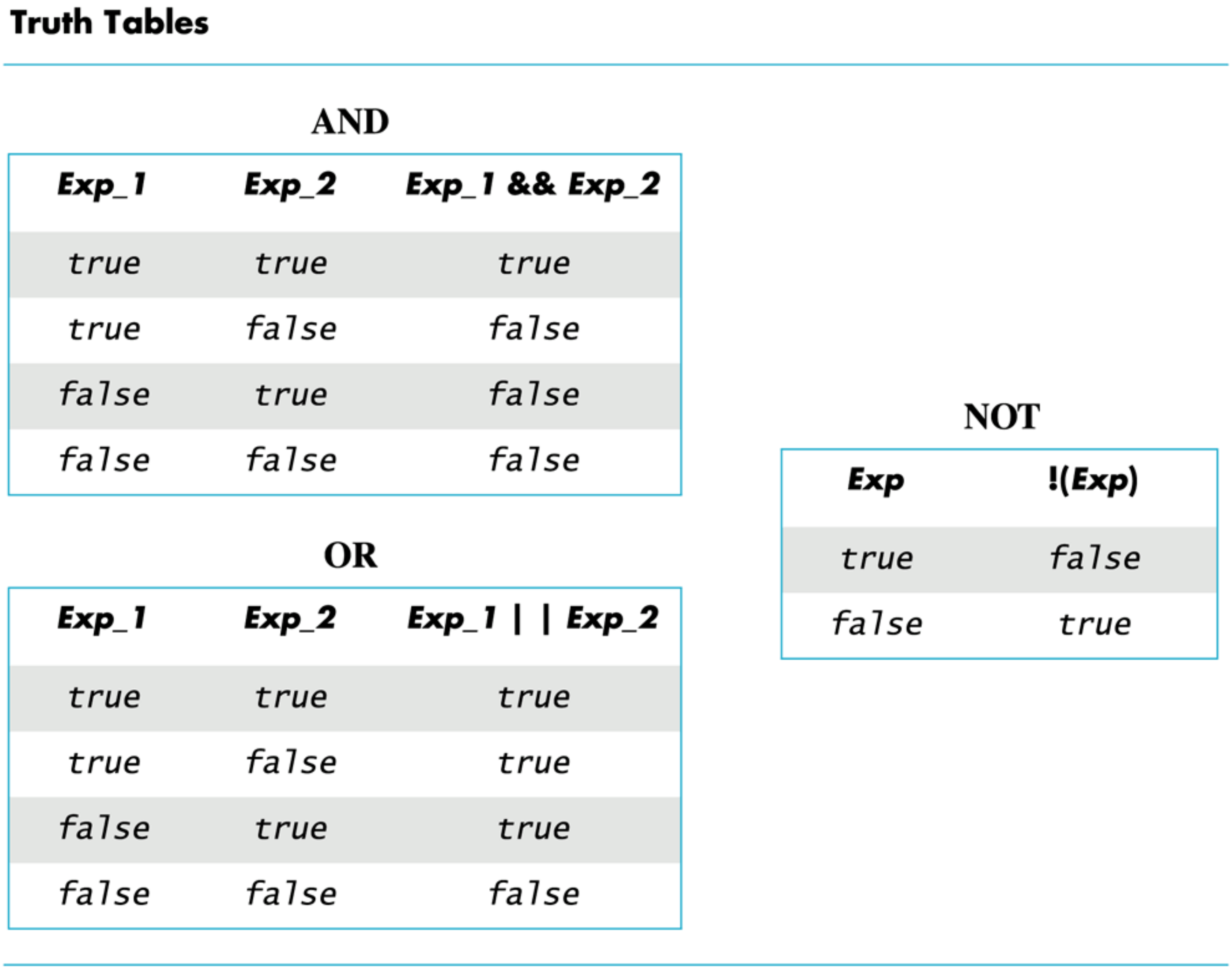
    is evaluated in the following sequence

    ! (false | | true)

    ! (true)

    false

Display 3.1



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

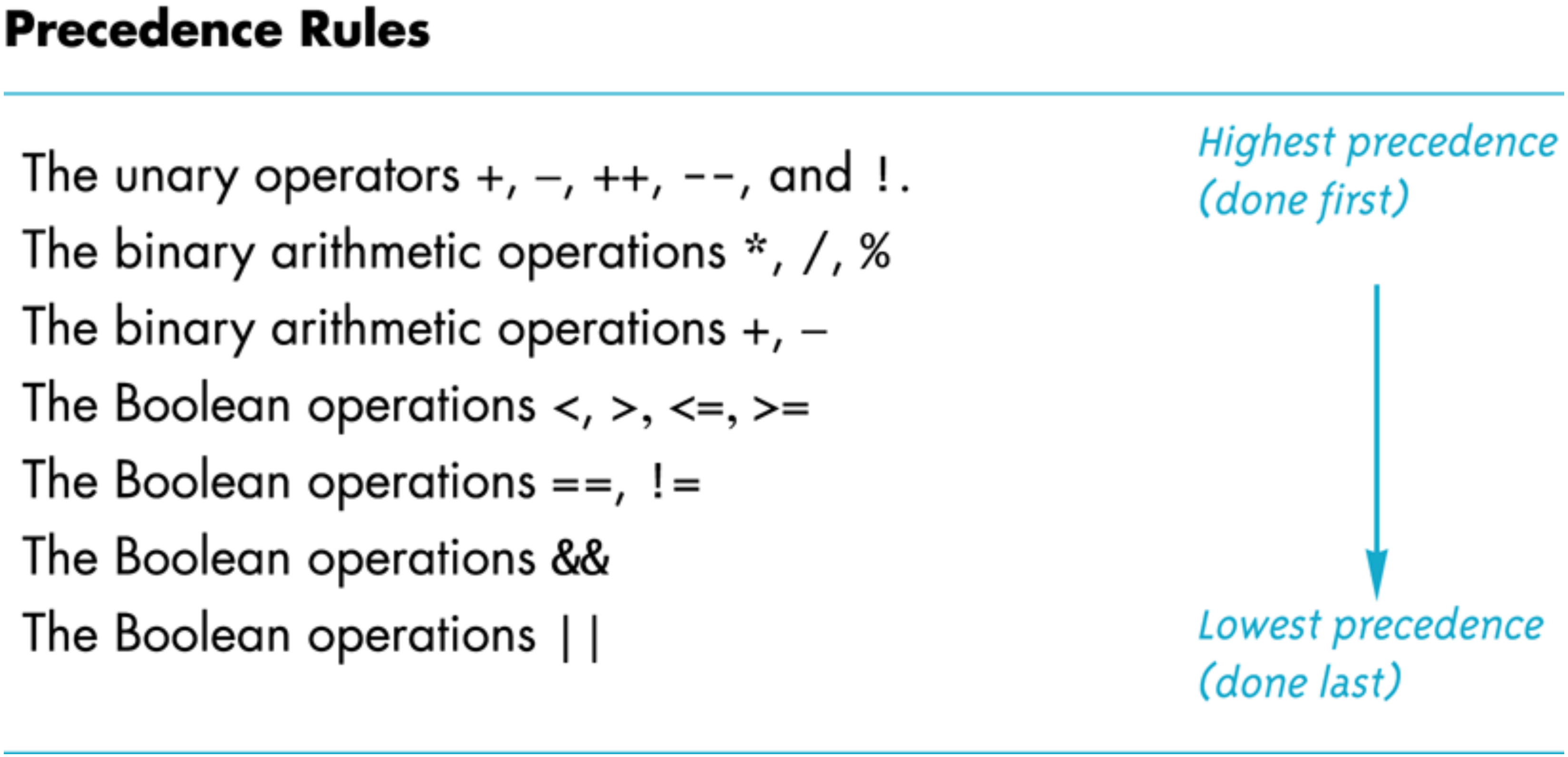
Order of Precedence

- If parenthesis are omitted from boolean expressions, the default precedence of operations is:
  - Perform ! operations first
  - Perform relational operations such as < next
  - Perform && operations next
  - Perform | | operations last

Precedence Rules

- Items in expressions are grouped by precedence rules for arithmetic and boolean operators
    - Operators with higher precedence are performed first
    - Binary operators with equal precedence are performed left to right
    - Unary operators of equal precedence are performed right to left

Display 3.2



Precedence Rules

The unary operators +, –, ++, --, and !.

The binary arithmetic operations *, /, %

The binary arithmetic operations +, –

The Boolean operations <, >, <=, >=

The Boolean operations ==, !=

The Boolean operations &&

The Boolean operations ||

Highest precedence (done first)

Lowest precedence (done last)

Precedence Rule Example

- The expression

  (x+1) > 2 | | (x + 1) < -3

  is equivalent to

  ((x + 1) > 2) | | ((x + 1) < -3)

  - Because > and < have higher precedence than | |

- and is also equivalent to

  x + 1 > 2 | | x + 1 < - 3

Evaluating x + 1 > 2 | | x + 1 < - 3

- Using the precedence rules of Display 3.2
  - First apply the unary –
  - Next apply the +'s
  - Now apply the > and <
  - Finally do the | |

Short-Circuit Evaluation

- Some boolean expressions do not need to be completely evaluated
  - if x is negative, the value of the expression

    ```
    (x >= 0)  && ( y > 1)
    ```

    can be determined by evaluating only (x >= 0)
- C++ uses short-circuit evaluation
  - If the value of the leftmost sub-expression determines the final value of the expression, the rest of the expression is not evaluated

Using Short-Circuit Evaluation

- Short-circuit evaluation can be used to prevent run time errors
  - Consider this if-statement

    ```
    if ((kids != 0) && (pieces / kids >= 2) )
      cout << "Each child may have two pieces!";
    ```

  - If the value of kids is zero, short-circuit evaluation prevents evaluation of (pieces / 0 >= 2)
    - Division by zero causes a run-time error

Type bool and Type int

- C++ can use integers as if they were Boolean values
  - Any non-zero number (typically 1) is true
  - 0 (zero) is false

Problems with !

- The expression (! time > limit), with limit = 60, is evaluated as

  (!time) > limit

- If time is an int with value 36, what is !time?
  - False! Or zero since it will be compared to an integer
  - The expression is further evaluated as

    0 > limit

    false

Correcting the ! Problem

- The intent of the previous expression was most likely the expression

  (! (time > limit))

  which evaluates as

  (! (false))

  true

Avoiding !

- Just as not in English can make things not undifficult to read, the ! operator can make C++ expressions difficult to understand

- Before using the ! operator see if you can express the same idea more clearly without the ! operator

Enumeration Types (Optional)

- An enumeration type is a type with values defined by a list of constants of type int
- Example:

  -
    ```
    enum MonthLength{JAN_LENGTH = 31,
                     FEB_LENGTH = 28,
                     MAR_LENGTH = 31,
                     …
                     DEC_LENGTH = 31};
    ```

Default enum Values

- If numeric values are not specified, identifiers are assigned consecutive values starting with 0

  -
    ```
    enum Direction { NORTH = 0, SOUTH = 1,
                     EAST = 2, WEST = 3};
    ```
    is equivalent to

    ```
    enum Direction {NORTH, SOUTH, EAST,
    WEST};
    ```

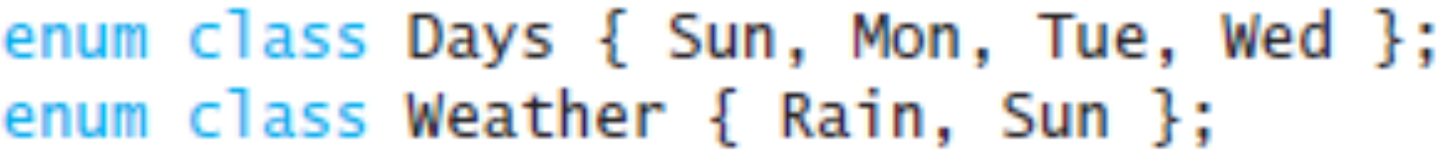
Enumeration Values

- Unless specified, the value assigned an enumeration constant is 1 more than the previous constant
- enum MyEnum{ONE = 17, TWO, THREE,
  FOUR = -3, FIVE};

  results in these values
  - ONE = 17, TWO = 18, THREE = 19, FOUR = -3, FIVE = -2

Strong Enums

- C++11 introduced a new version of enumeration called **strong enums** or **enum classes** that avoids some problems of conventional enums
  - May not want an enum to act like an int
  - Enums are global so you can’t have the same enum value twice
- Define a strong enum as follows:



```
enum class Days { Sun, Mon, Tue, Wed };
enum class Weather { Rain, Sun };
```

Using Strong Enums

- To use our strong enums:

```
Days d = Days::Tue;
Weather w = Weather::Sun;
```

- The variables d and w are not integers so we can’t treat them as such.

Section 3.1 Conclusion

- Can you
  - Write a function definition for a function named in_order that takes three arguments of type int? The function returns true if the arguments are in ascending order; otherwise, it returns false.
  - Determine the value of these Boolean expressions?
    - Assume count = 0 and limit = 10
    - (count == 0) && (limit < 20)
    - !(count == 12)
    - (limit < 0) && ((limit /count) > 7)

3.2

Multiway Branches

Multiway Branches

- A branching mechanism selects one out of a number of alternative actions
  - The if-else-statement is a branching mechanism
- Branching mechanisms can be a subpart of another branching mechanism
  - An if-else-statement can include another if-else-statement as a subpart

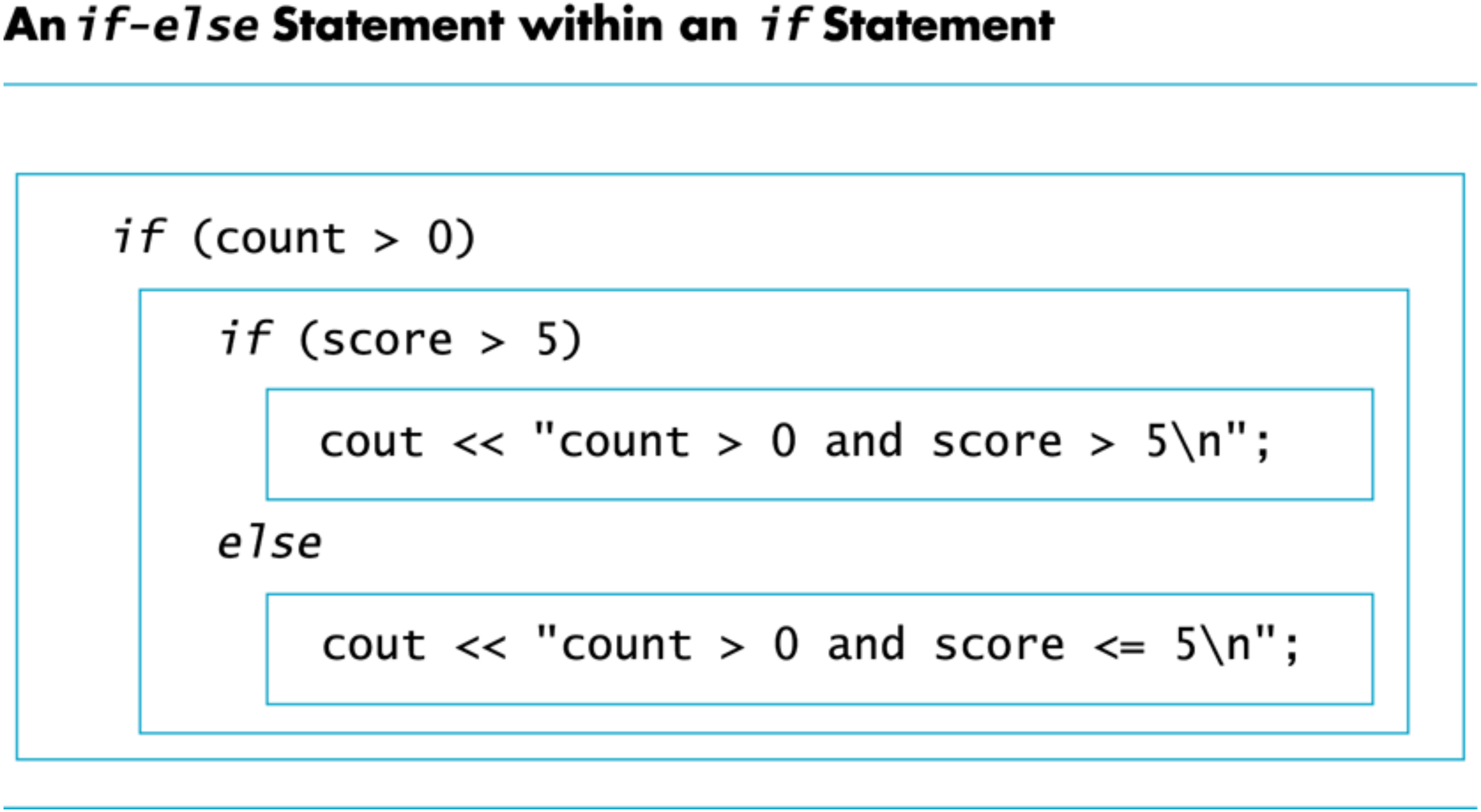
Nested Statements

- A statement that is a subpart of another statement is a nested statement
  - When writing nested statements it is normal to indent each level of nesting
  - Example:

```
if (count < 10)
  if ( x < y)
      cout << x << " is less than " << y;
   else
      cout << y << " is less than " << x;
```

indented

Display 3.3



An *if-else* Statement within an *if* Statement

```
if (count > 0)
    if (score > 5)
        cout << "count > 0 and score > 5\n";
    else
        cout << "count > 0 and score <= 5\n";
```

Nested if-else Statements

- Use care in nesting if-else-statements
- Example: To design an if-else statement to warn a driver when fuel is low, but tells the driver to bypass pit stops if the fuel is close to full. Other wise there should be no output.

  Pseudocode:

```
if fuel gauge is below ¾ then:
        if  fuel gauge is below ¼  then:
                issue a warning
otherwise (gauge > ¾) then:
        output a statement saying don't stop
```

First Try Nested if's

- Translating the previous pseudocode to C++ could yield (if we are not careful)

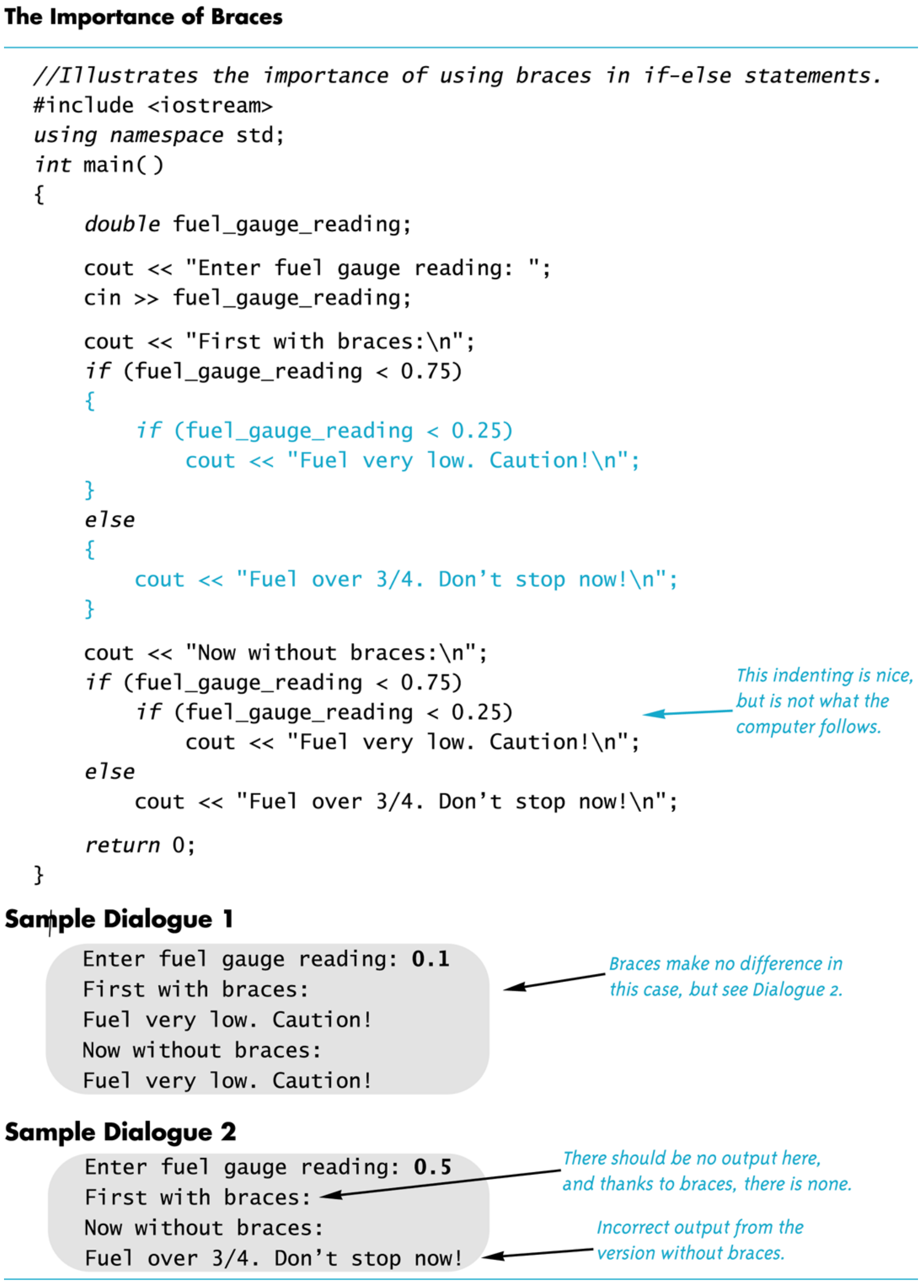
```
      if (fuel_gauge_reading < 0.75)
                  if (fuel_gauge_reading < 0.25)
                              cout << "Fuel very low.  Caution!\n";
      else
                  cout << "Fuel over 3/4.  Don't stop now!\n";
```

  - This would compile and run, but does not produce the desired results
  - The compiler pairs the "else" with the nearest previous "if"

Braces and Nested Statements

- Braces in nested statements are like parenthesis in arithmetic expressions
  - Braces tell the compiler how to group things
- Use braces around substatements
- **Display 3.4** demonstrates the use of braces in nested if-else-statements

Display 3.4



The Importance of Braces

```
//Illustrates the importance of using braces in if-else statements.
#include <iostream>
using namespace std;
int main( )
{
    double fuel_gauge_reading;

    cout << "Enter fuel gauge reading: ";
    cin >> fuel_gauge_reading;

    cout << "First with braces:\n";
    if (fuel_gauge_reading < 0.75)
    {
        if (fuel_gauge_reading < 0.25)
            cout << "Fuel very low. Caution!\n";
    }
    else
    {
        cout << "Fuel over 3/4. Don't stop now!\n";
    }

    cout << "Now without braces:\n";
    if (fuel_gauge_reading < 0.75)
        if (fuel_gauge_reading < 0.25)
            cout << "Fuel very low. Caution!\n";
    else
        cout << "Fuel over 3/4. Don't stop now!\n";

    return 0;
}
```

This indenting is nice, but is not what the computer follows.

Sample Dialogue 1

```
Enter fuel gauge reading: 0.1
First with braces:
Fuel very low. Caution!
Now without braces:
Fuel very low. Caution!
```

Braces make no difference in this case, but see Dialogue 2.

Sample Dialogue 2

```
Enter fuel gauge reading: 0.5
First with braces:
Now without braces:
Fuel over 3/4. Don't stop now!
```

There should be no output here, and thanks to braces, there is none.

Incorrect output from the version without braces.

Multi-way if-else-statements

- An if-else-statement is a two-way branch
- Three or four (or more) way branches can be designed using nested if-else-statements
  - Example: The number guessing game with the number stored in variable number, the guess in variable guess. How do we give hints?

Number Guessing

- The following nested statements implement the hints for our number guessing game

  -
    ```
    if (guess> number)
        cout << "Too high.";
    else
          if (guess < number)
              cout << "Too low.");
          else
              if (guess == number)
                   cout << "Correct!";
    ```

Indenting Nested if-else

- Notice how the code on the previous slide crept across the page leaving less and less space
  - Use this alternative for indenting several nested if-else-statements:

```
if (guess> number)
          cout << "Too high.";
else if (guess < number)
           cout << "Too low.");
else if (guess == number)
          cout << "Correct!";
```

The Final if-else-statement

- When the conditions tested in an if-else-statement are mutually exclusive, the final if-else can sometimes be omitted.
  - The previous example can be written as

```
if (guess> number)
   cout << "Too high.";
else if (guess < number)
   cout << "Too low.");
else // (guess == number)
   cout << "Correct!";
```

Nested if-else Syntax

- A Multiway if-else statement is written as

  ```
  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
  ```

Program Example: State Income Tax

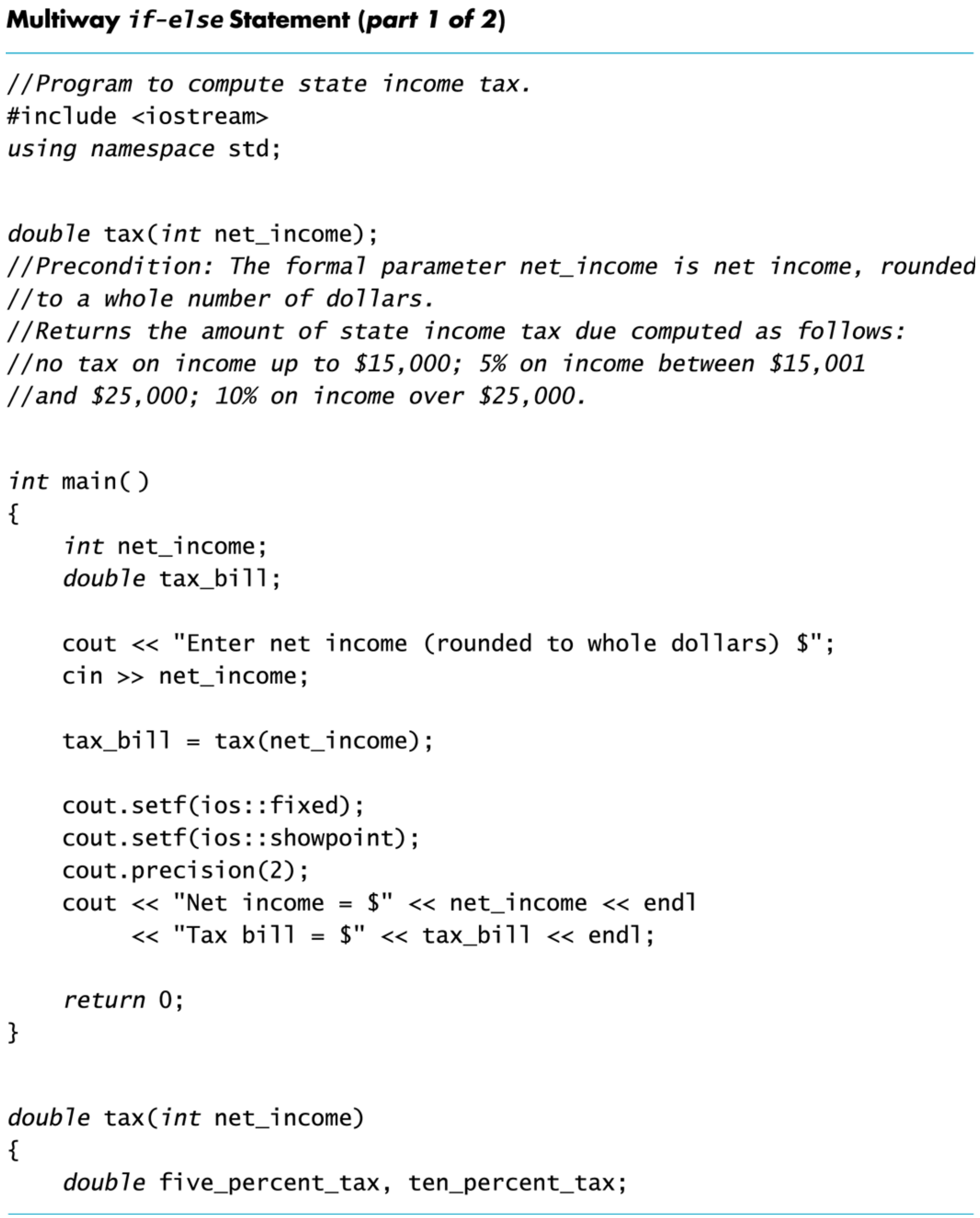
- Write a program for a state that computes tax according to the rate schedule:

  No tax on first $15,000 of income

  5% tax on each dollar from $15,001
  to $25,000

  10% tax on each dollar over $25,000

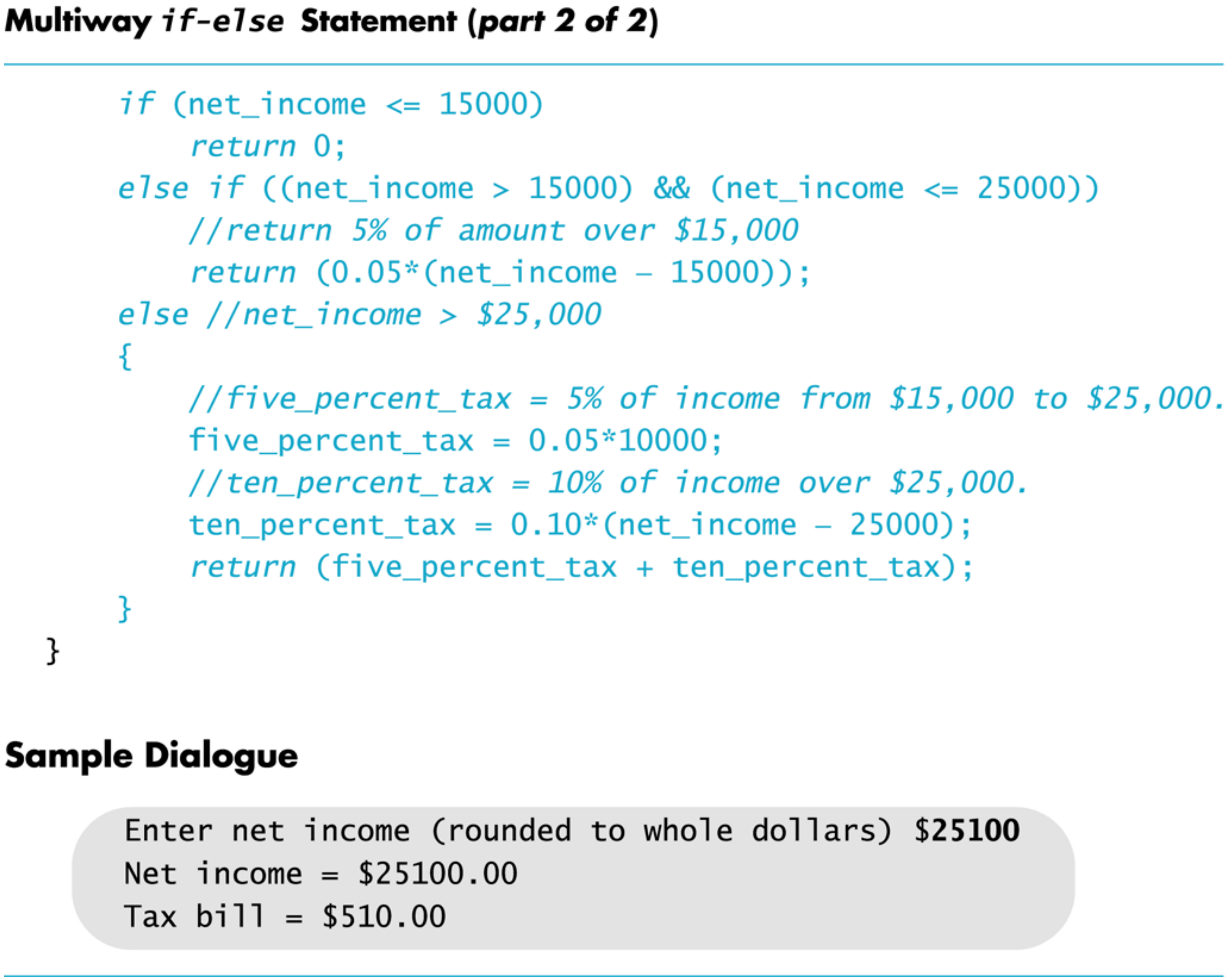
Display 3.5 (1/2)



Multiway *if-else* Statement (*part 1 of 2*)

```
//Program to compute state income tax.
#include <iostream>
using namespace std;


double tax(int net_income);
//Precondition: The formal parameter net_income is net income, rounded
//to a whole number of dollars.
//Returns the amount of state income tax due computed as follows:
//no tax on income up to $15,000; 5% on income between $15,001
//and $25,000; 10% on income over $25,000.


int main( )
{
    int net_income;
    double tax_bill;

    cout << "Enter net income (rounded to whole dollars) $";
    cin >> net_income;

    tax_bill = tax(net_income);

    cout.setf(ios::fixed);
    cout.setf(ios::showpoint);
    cout.precision(2);
    cout << "Net income = $" << net_income << endl
         << "Tax bill = $" << tax_bill << endl;

    return 0;
}


double tax(int net_income)
{
    double five_percent_tax, ten_percent_tax;
```

Display 3.5
(2/2)



Multiway *if-else* Statement (*part 2 of 2*)

```
    if (net_income <= 15000)
        return 0;
    else if ((net_income > 15000) && (net_income <= 25000))
        //return 5% of amount over $15,000
        return (0.05*(net_income - 15000));
    else //net_income > $25,000
    {
        //five_percent_tax = 5% of income from $15,000 to $25,000.
        five_percent_tax = 0.05*10000;
        //ten_percent_tax = 10% of income over $25,000.
        ten_percent_tax = 0.10*(net_income - 25000);
        return (five_percent_tax + ten_percent_tax);
    }
}
```

Sample Dialogue

```
Enter net income (rounded to whole dollars) $25100
Net income = $25100.00
Tax bill = $510.00
```

Refining if-else-statements

- Notice that the line

  ```
  else if (( net_income > 15000
                  && net_income < = 25000))
  ```

  can be replaced with

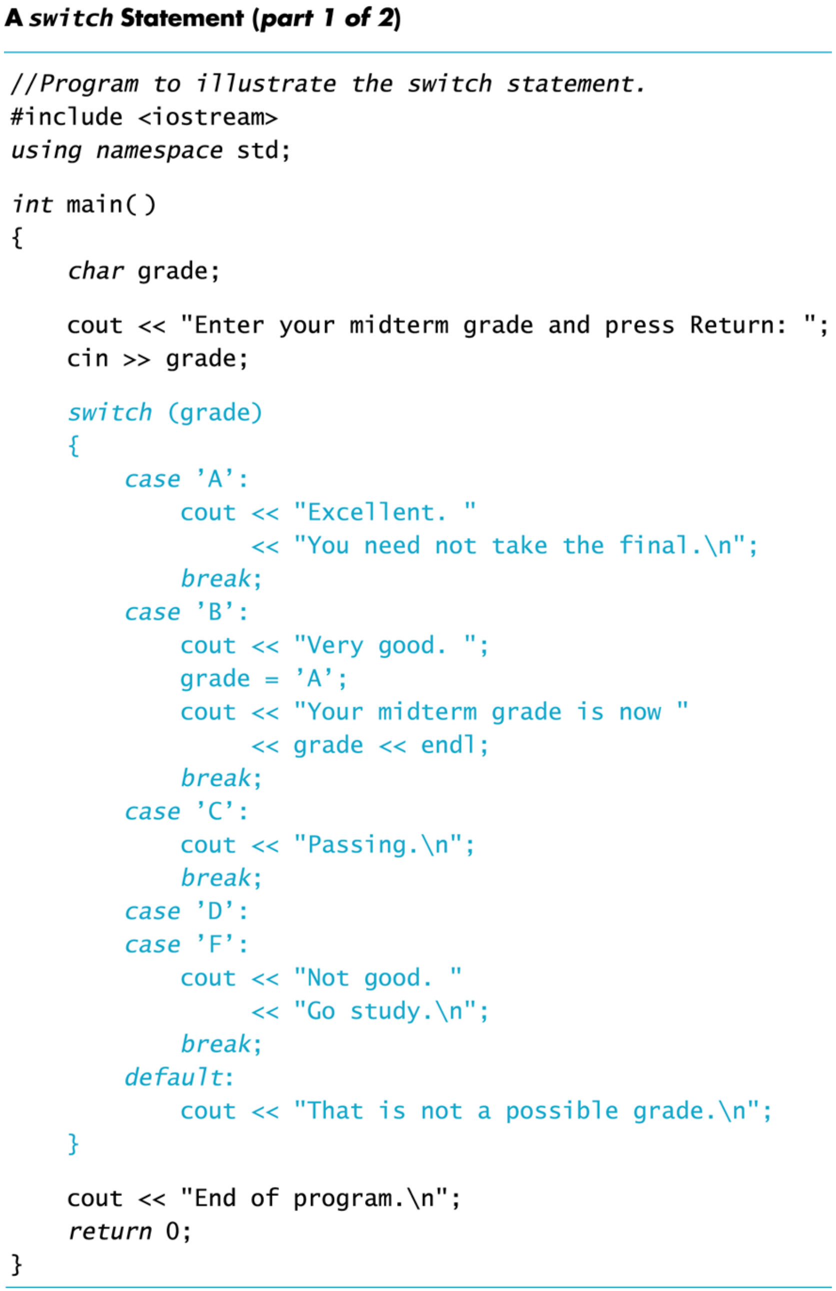
  ```
  else if (net_income <= 25000)
  ```

  - The computer will not get to this line unless it is already determined that net_income > 15000

The switch-statement

- The switch-statement is an alternative for constructing multi-way branches
    - The example in Display 3.6 determines output based on a letter grade
        - Grades 'A', 'B', and 'C' each have a branch
        - Grades 'D' and 'F' use the same branch
        - If an invalid grade is entered, a default branch is used

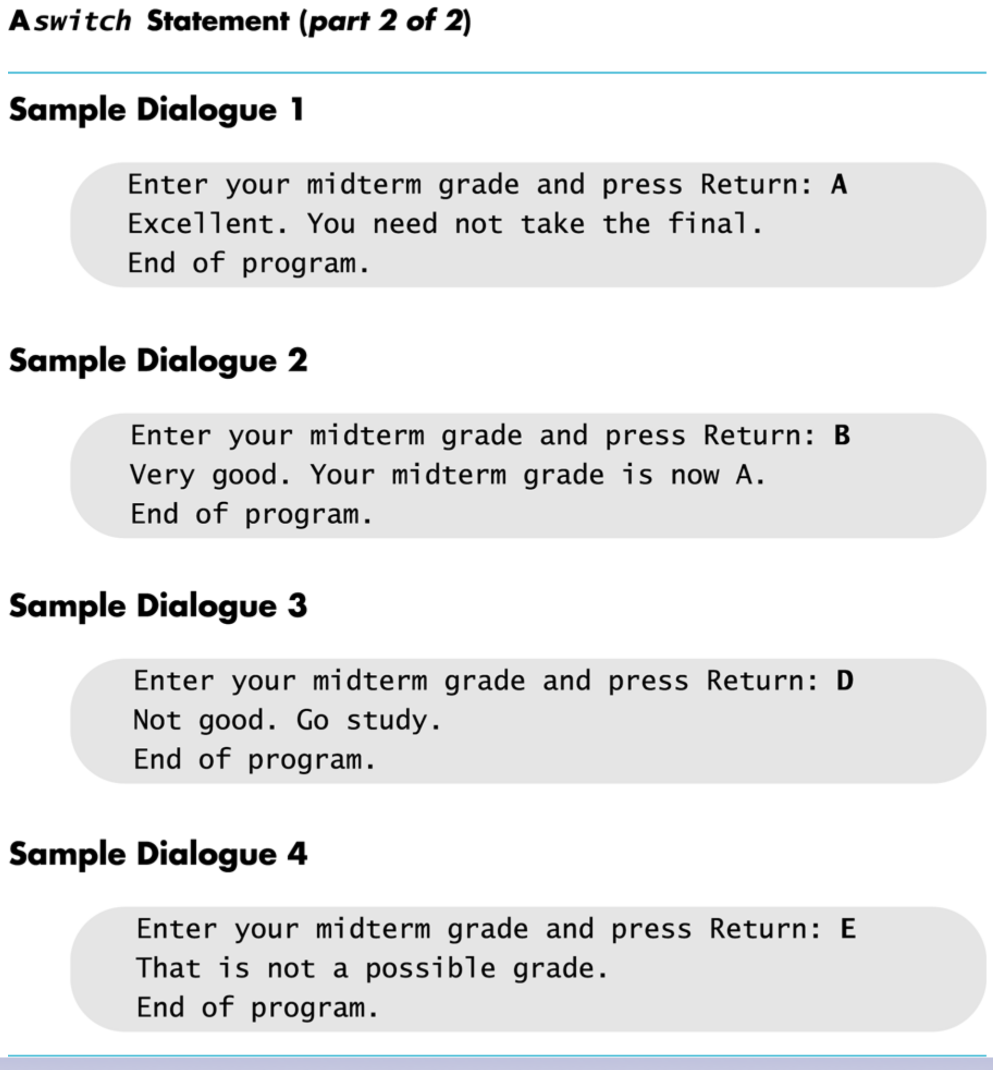
Display 3.6 (1/2)



A *switch* Statement (*part 1 of 2*)

```
//Program to illustrate the switch statement.
#include <iostream>
using namespace std;

int main( )
{
    char grade;

    cout << "Enter your midterm grade and press Return: ";
    cin >> grade;

    switch (grade)
    {
        case 'A':
            cout << "Excellent. "
                 << "You need not take the final.\n";
            break;
        case 'B':
            cout << "Very good. ";
            grade = 'A';
            cout << "Your midterm grade is now "
                 << grade << endl;
            break;
        case 'C':
            cout << "Passing.\n";
            break;
        case 'D':
        case 'F':
            cout << "Not good. "
                 << "Go study.\n";
            break;
        default:
            cout << "That is not a possible grade.\n";
    }

    cout << "End of program.\n";
    return 0;
}
```

Display 3.6 (2/2)



A *switch* Statement (*part 2 of 2*)

Sample Dialogue 1

```
Enter your midterm grade and press Return: A
Excellent. You need not take the final.
End of program.
```

Sample Dialogue 2

```
Enter your midterm grade and press Return: B
Very good. Your midterm grade is now A.
End of program.
```

Sample Dialogue 3

```
Enter your midterm grade and press Return: D
Not good. Go study.
End of program.
```

Sample Dialogue 4

```
Enter your midterm grade and press Return: E
That is not a possible grade.
End of program.
```

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
  }
  ```

The Controlling Statement

- A switch statement's controlling statement must return one of these types
  - A bool value
  - An enum constant
  - An integer type
  - A character
- The value returned is compared to the constant values after each "case"
  - When a match is found, the code for that case is used

The break Statement

- The break statement ends the switch-statement
  - Omitting the break statement will cause the code for the next case to be executed!
  - Omitting a break statement allows the use of multiple case labels for a section of code

    -
      ```
      case 'A':
      case 'a':
                    cout << "Excellent.";
                     break;
      ```
    - Runs the same code for either 'A' or 'a'

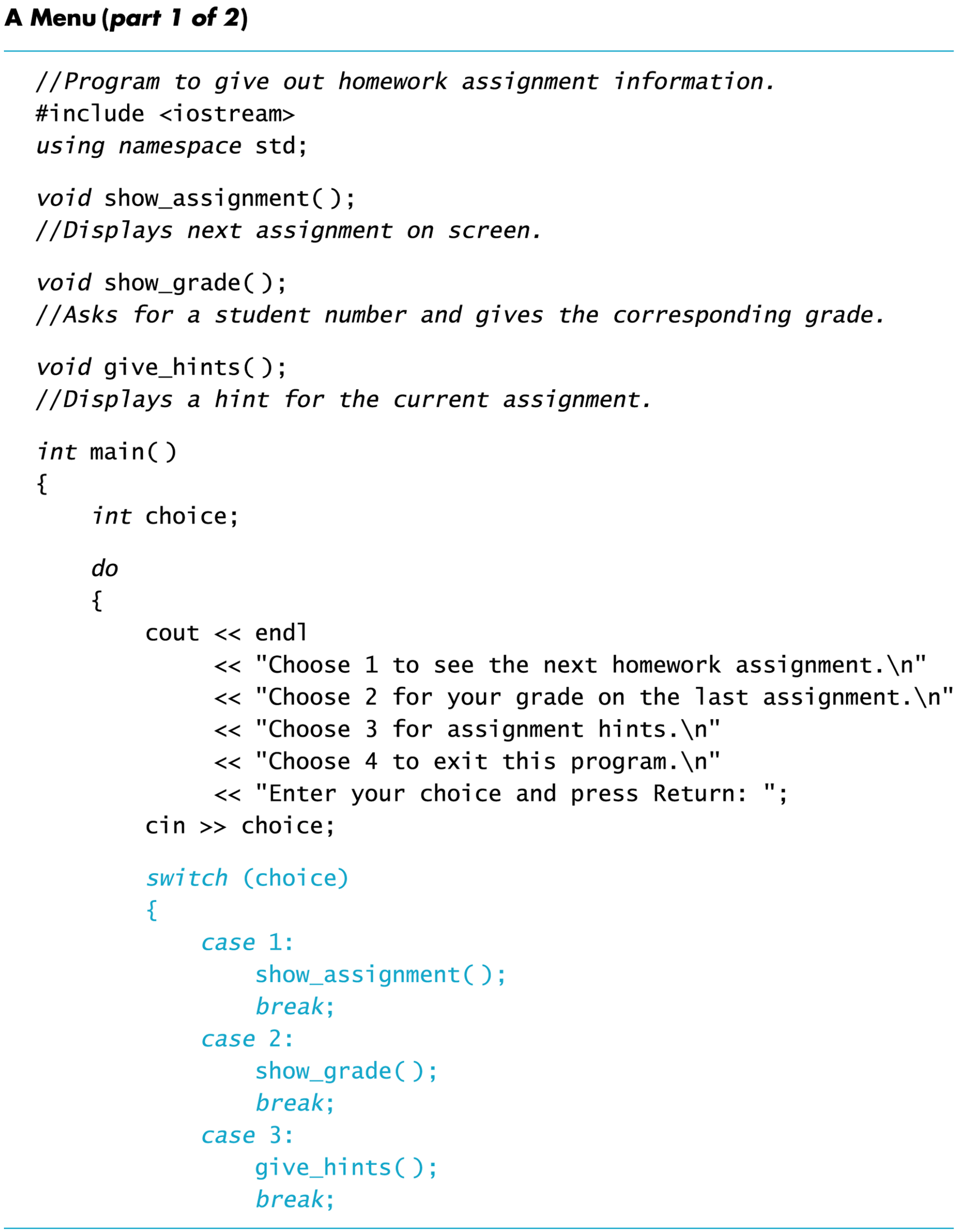
The default Statement

- If no case label has a constant that matches the controlling expression, the statements following the default label are executed
  - If there is no default label, nothing happens when the switch statement is executed
  - It is a good idea to include a default section

Switch-statements and Menus

- Nested if-else statements are more versatile than a switch statement
- Switch-statements can make some code more clear
  - A menu is a natural application for a switch-statement

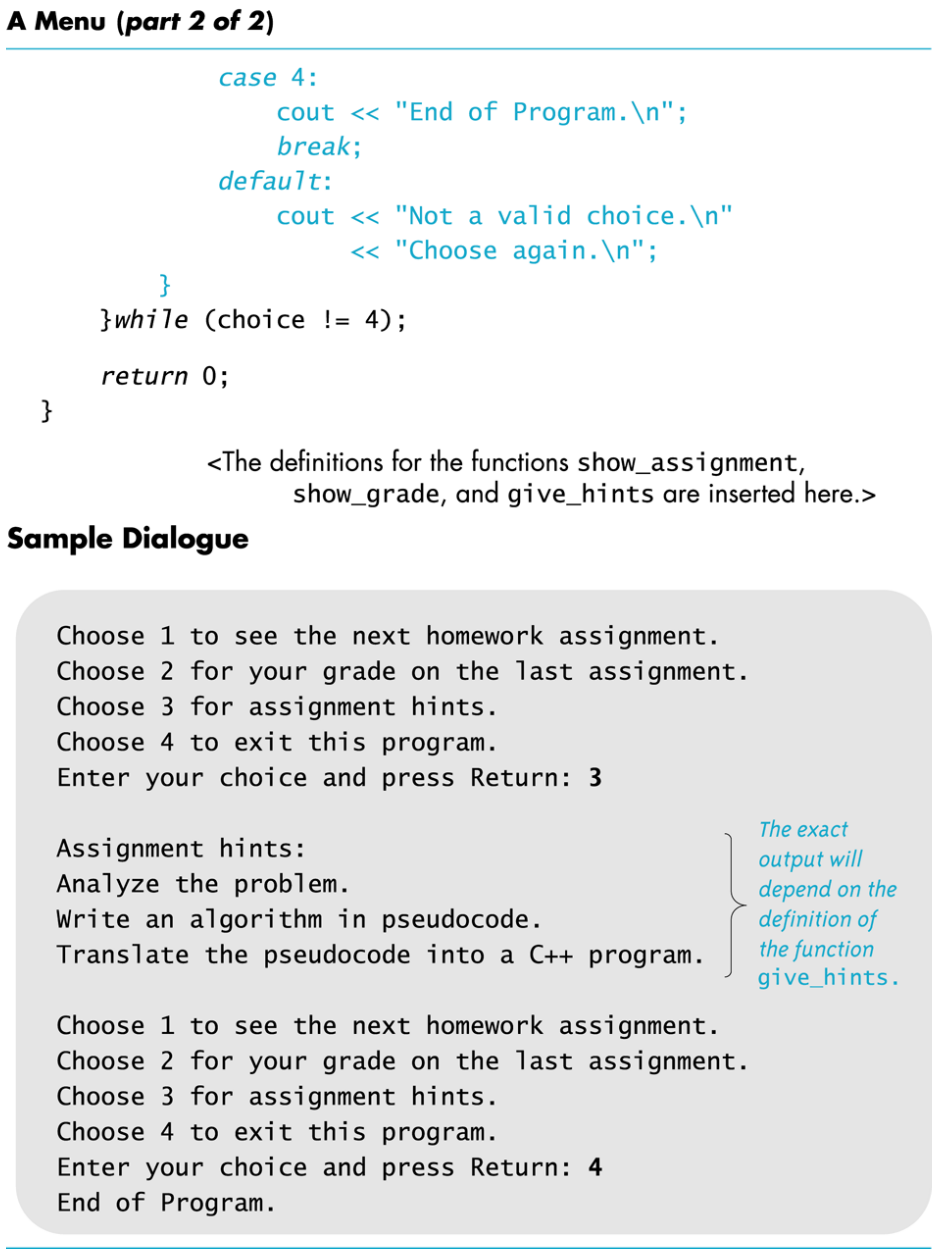
Display 3.7 (1/2)



A Menu (*part 1 of 2*)

```
//Program to give out homework assignment information.
#include <iostream>
using namespace std;

void show_assignment( );
//Displays next assignment on screen.

void show_grade( );
//Asks for a student number and gives the corresponding grade.

void give_hints( );
//Displays a hint for the current assignment.

int main( )
{
    int choice;

    do
    {
        cout << endl
             << "Choose 1 to see the next homework assignment.\n"
             << "Choose 2 for your grade on the last assignment.\n"
             << "Choose 3 for assignment hints.\n"
             << "Choose 4 to exit this program.\n"
             << "Enter your choice and press Return: ";
        cin >> choice;

        switch (choice)
        {
            case 1:
                show_assignment( );
                break;
            case 2:
                show_grade( );
                break;
            case 3:
                give_hints( );
                break;
```

Display 3.7 (2/2)



A Menu (*part 2 of 2*)

```
            case 4:
                cout << "End of Program.\n";
                break;
            default:
                cout << "Not a valid choice.\n"
                     << "Choose again.\n";
        }
    }while (choice != 4);

    return 0;
}
```

<The definitions for the functions show_assignment,
show_grade, and give_hints are inserted here.>

Sample Dialogue

```
Choose 1 to see the next homework assignment.
Choose 2 for your grade on the last assignment.
Choose 3 for assignment hints.
Choose 4 to exit this program.
Enter your choice and press Return: 3

Assignment hints:
Analyze the problem.
Write an algorithm in pseudocode.
Translate the pseudocode into a C++ program.

Choose 1 to see the next homework assignment.
Choose 2 for your grade on the last assignment.
Choose 3 for assignment hints.
Choose 4 to exit this program.
Enter your choice and press Return: 4
End of Program.
```

The exact output will depend on the definition of the function give_hints.

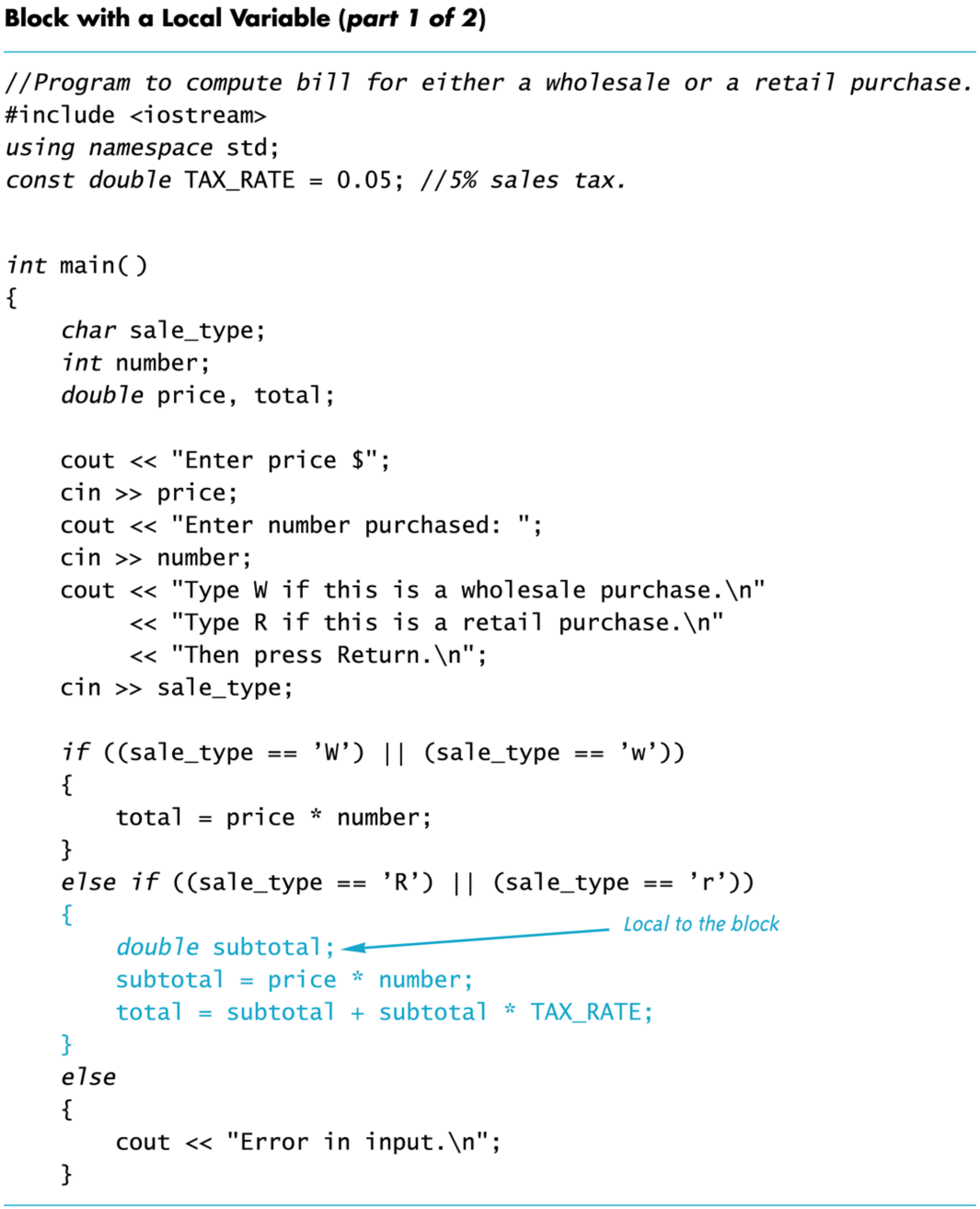
Function Calls in Branches

- Switch and if-else-statements allow the use of multiple statements in a branch
  - Multiple statements in a branch can make the switch or if-else-statement difficult to read
  - Using function calls (as shown in Display 3.7) instead of multiple statements can make the switch or if-else-statement much easier to read

Blocks

- Each branch of a switch or if-else statement is a separate sub-task
  - If the action of a branch is too simple to warrant a function call, use multiple statements between braces
  - A block is a section of code enclosed by braces
  - Variables declared within a block, are local to the block or have the block as their scope.
    - Variable names declared in the block can be reused outside the block

Display 3.8 (1/2)

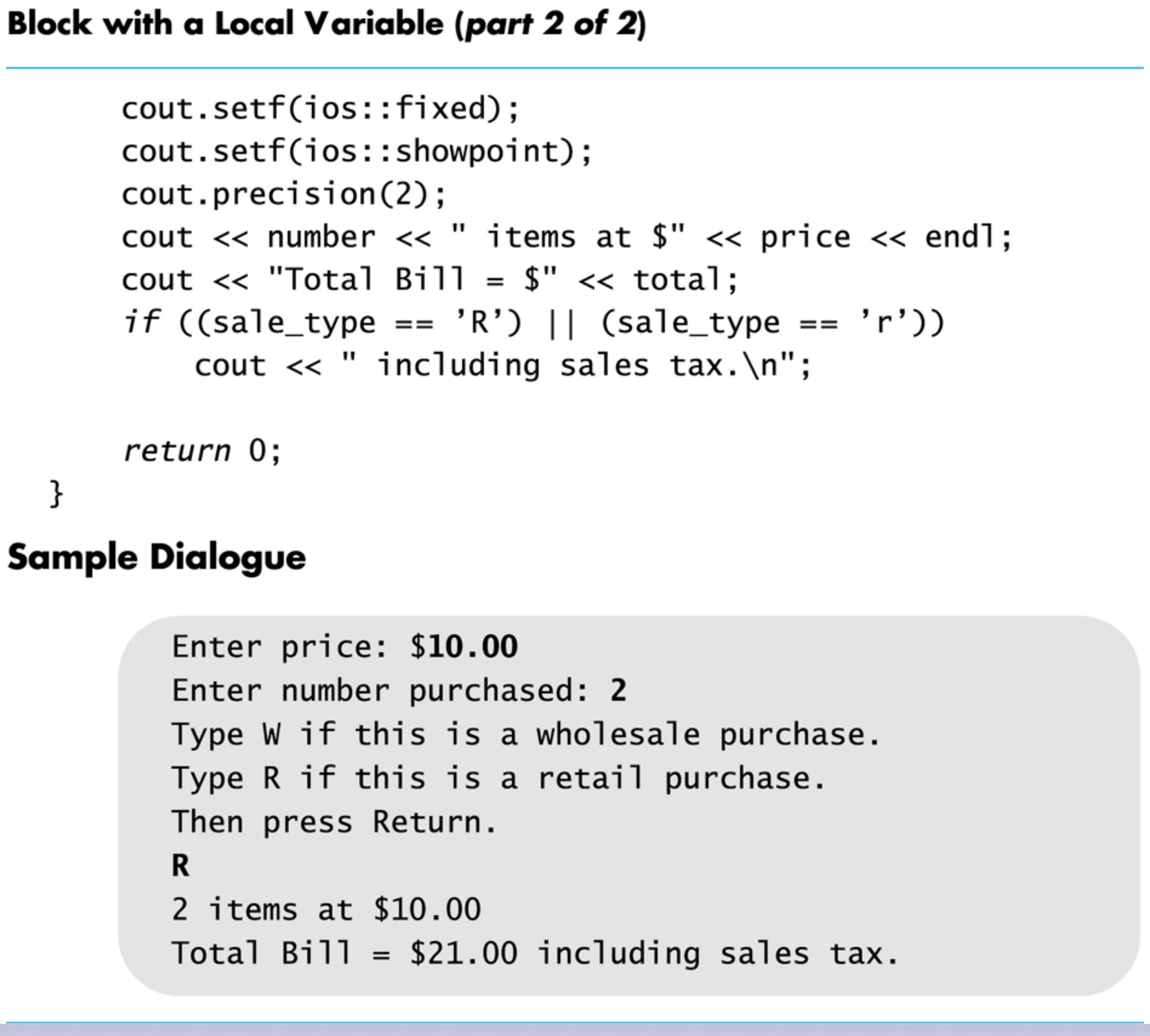


Block with a Local Variable (*part 1 of 2*)

```
//Program to compute bill for either a wholesale or a retail purchase.
#include <iostream>
using namespace std;
const double TAX_RATE = 0.05; //5% sales tax.


int main( )
{
    char sale_type;
    int number;
    double price, total;

    cout << "Enter price $";
    cin >> price;
    cout << "Enter number purchased: ";
    cin >> number;
    cout << "Type W if this is a wholesale purchase.\n"
         << "Type R if this is a retail purchase.\n"
         << "Then press Return.\n";
    cin >> sale_type;

    if ((sale_type == 'W') || (sale_type == 'w'))
    {
        total = price * number;
    }
    else if ((sale_type == 'R') || (sale_type == 'r'))
    {
        double subtotal;
        subtotal = price * number;
        total = subtotal + subtotal * TAX_RATE;
    }
    else
    {
        cout << "Error in input.\n";
    }
```

Local to the block

Display 3.8 (2/2)



Block with a Local Variable (*part 2 of 2*)

```
    cout.setf(ios::fixed);
    cout.setf(ios::showpoint);
    cout.precision(2);
    cout << number << " items at $" << price << endl;
    cout << "Total Bill = $" << total;
    if ((sale_type == 'R') || (sale_type == 'r'))
        cout << " including sales tax.\n";

    return 0;
}
```

Sample Dialogue

```
Enter price: $10.00
Enter number purchased: 2
Type W if this is a wholesale purchase.
Type R if this is a retail purchase.
Then press Return.
R
2 items at $10.00
Total Bill = $21.00 including sales tax.
```

Statement Blocks

- A statement block is a block that is not a function body or the body of the main part of a program
- Statement blocks can be nested in other statement blocks
  - Nesting statement blocks can make code difficult to read
  - It is generally better to create function calls than to nest statement blocks

Scope Rule for Nested Blocks

- If a single identifier is declared as a variable in each of two blocks, one within the other, then these are two different variables with the same name
  - One of the variables exists only within the inner block and cannot be accessed outside the inner block
  - The other variable exists only in the outer block and cannot be accessed in the inner block

Section 3.2 Conclusion

- Can you

  - Give the output of this code fragment?

```
{
   int x = 1;
   cout << x << endl;
   {
         cout << x << endl;
         int x = 2;
         cout << x << endl;
    }
   cout << x << endl;
```

3.3

More About C++ Loop Statements

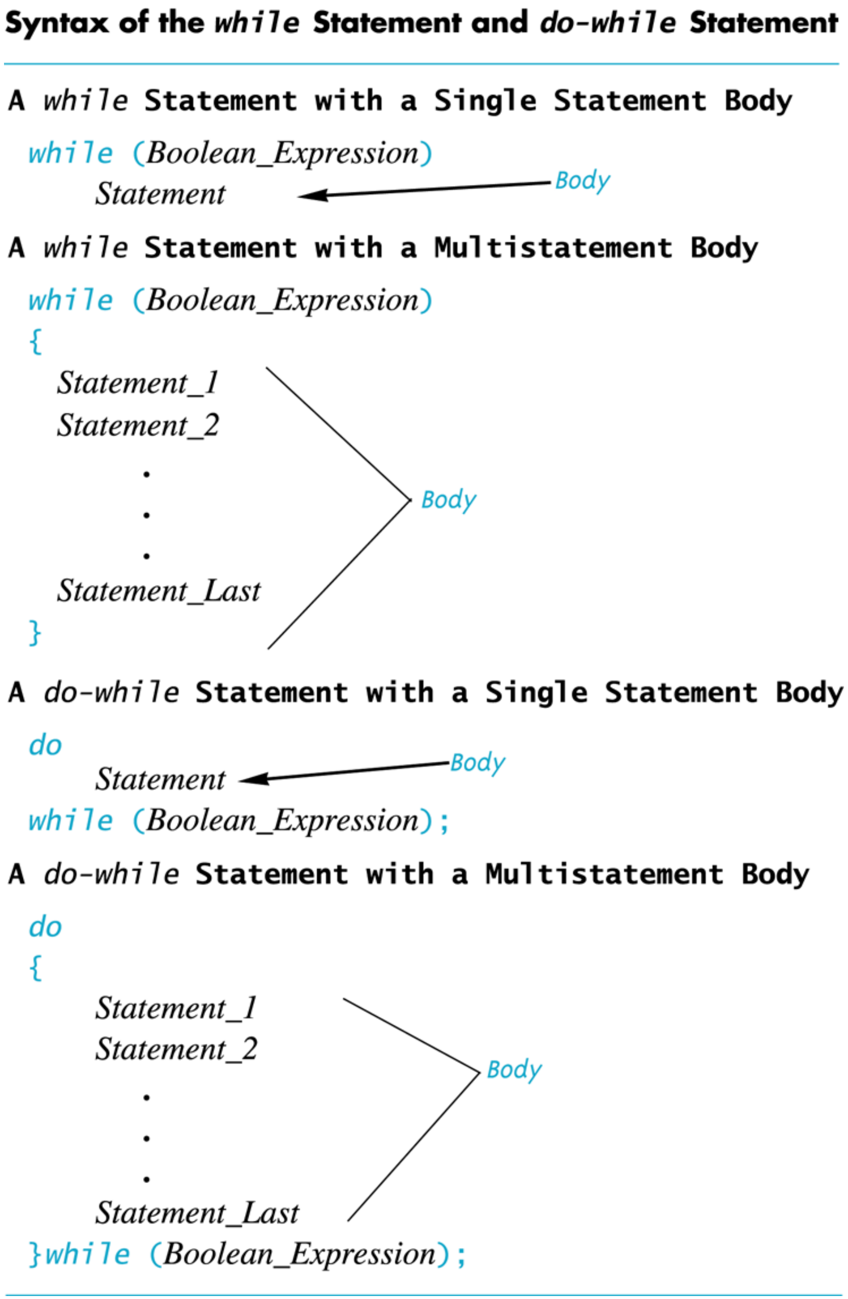
More About
C++ Loop Statements

- A loop is a program construction that repeats a statement or sequence of statements a number of times
  - The body of the loop is the statement(s) repeated
  - Each repetition of the loop is an iteration
- Loop design questions:
  - What should the loop body be?
  - How many times should the body be iterated?

while and do-while

- An important difference between while and do-while loops:
  - A while loop checks the Boolean expression at the beginning of the loop
    - A while loop might never be executed!
  - A do-while loop checks the Boolean expression at the end of the loop
    - A do-while loop is always executed at least once
- Review while and do-while syntax in

Display 3.9



Syntax of the *while* Statement and *do-while* Statement

A *while* Statement with a Single Statement Body

```
while (Boolean_Expression)
    Statement                 Body
```

A *while* Statement with a Multistatement Body

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

A *do-while* Statement with a Single Statement Body

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

A *do-while* Statement with a Multistatement Body

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

The Increment Operator

- We have used the increment operator in statements such as

```
number++;
```

  to increase the value of number by one
- The increment operator can also be used in expressions:

```
int number = 2;
int value_produced = 2 * (number++);
```

  - (number++) first returns the value of number (2) to be multiplied by 2, then increments number to three

number++ vs ++number

- (number++) returns the current value of number, then increments number
  - An expression using (number++) will use the value of number BEFORE it is incremented
- (++number) increments number first and returns the new value of number
  - An expression using (++number) will use the value of number AFTER it is incremented
- Number has the same value after either version!

++ Comparisons

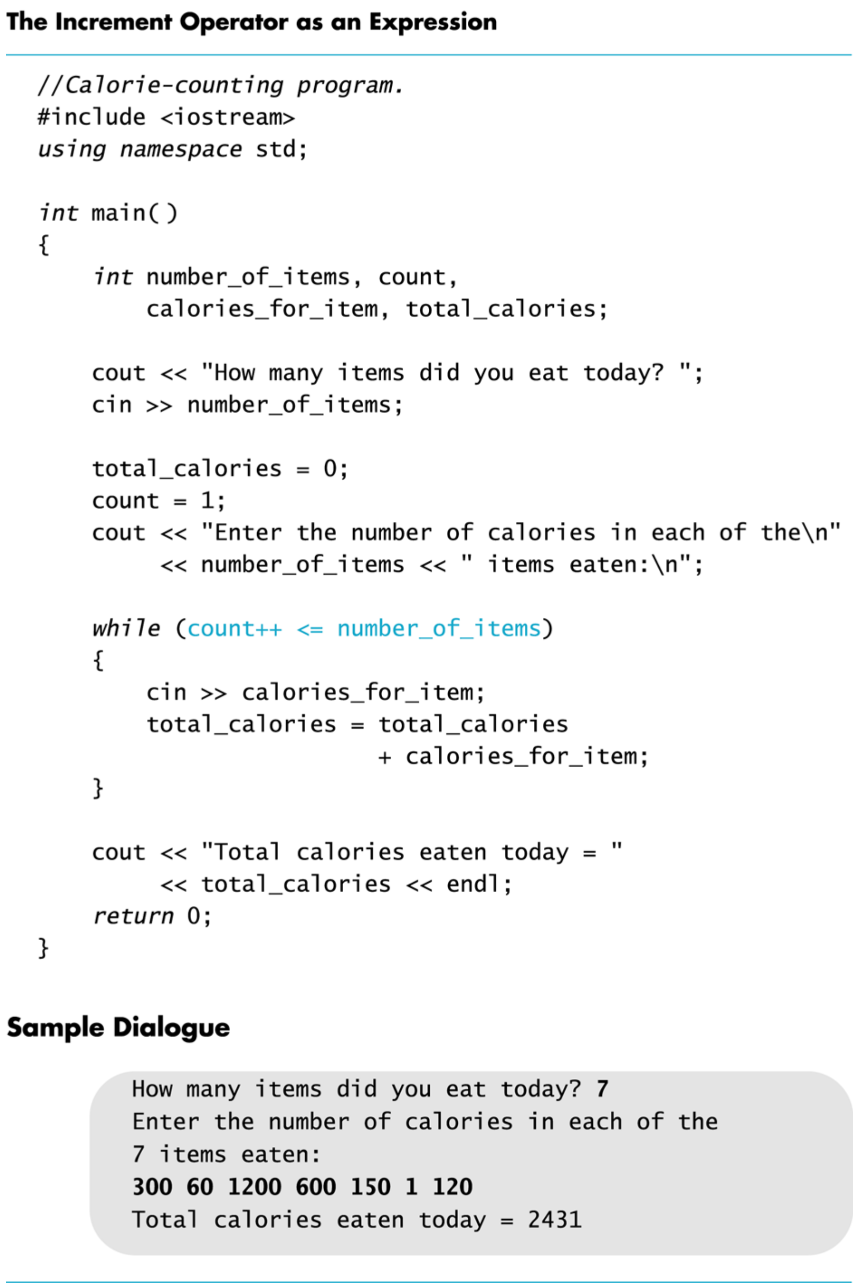
-
  ```
  int number = 2;
  int value_produced = 2 * (number++);
  cout << value_produced << " " << number;
  ```

  displays 4 3

-
  ```
  int number = 2;
  int value_produced = 2* (++number);
  cout << value_produced << " " number;
  ```

  displays 6 3

Display 3.10



The Increment Operator as an Expression

```
//Calorie-counting program.
#include <iostream>
using namespace std;

int main( )
{
    int number_of_items, count,
        calories_for_item, total_calories;

    cout << "How many items did you eat today? ";
    cin >> number_of_items;

    total_calories = 0;
    count = 1;
    cout << "Enter the number of calories in each of the\n"
         << number_of_items << " items eaten:\n";

    while (count++ <= number_of_items)
    {
        cin >> calories_for_item;
        total_calories = total_calories
                         + calories_for_item;
    }

    cout << "Total calories eaten today = "
         << total_calories << endl;
    return 0;
}
```

Sample Dialogue

```
How many items did you eat today? 7
Enter the number of calories in each of the
7 items eaten:
300 60 1200 600 150 1 120
Total calories eaten today = 2431
```

The Decrement Operator

- The decrement operator (--) decreases the value of the variable by one

-
  ```
                      int number = 8;
              int value_produced = number--;
              cout << value_produced << "  " << number;
  ```

  displays 8 7
- Replacing "number--" with "--number" displays 7 7

The for-Statement

- A for-Statement (for-loop) is another loop mechanism in C++
  - Designed for common tasks such as adding numbers in a given range
  - Is sometimes more convenient to use than a while loop
  - Does not do anything a while loop cannot do

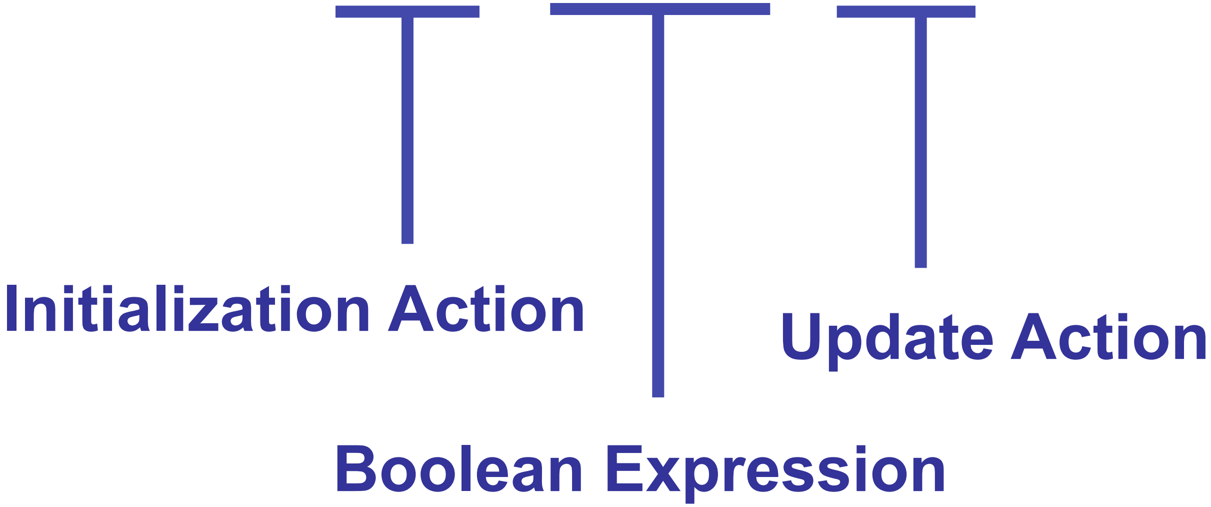
for/while Loop Comparison

-
  ```
  sum = 0;
  n = 1;
  while(n <= 10)  // add the numbers 1 - 10
   {
      sum = sum + n;
      n++;
    }
  ```

-
  ```
  sum = 0;
  for (n = 1; n <= 10; n++)  //add the numbers 1 - 10
    sum = sum + n;
  ```

For Loop Dissection

- The for loop uses the same components as the while loop in a more compact form
  - for (n = 1; n <= 10; n++)



Initialization Action

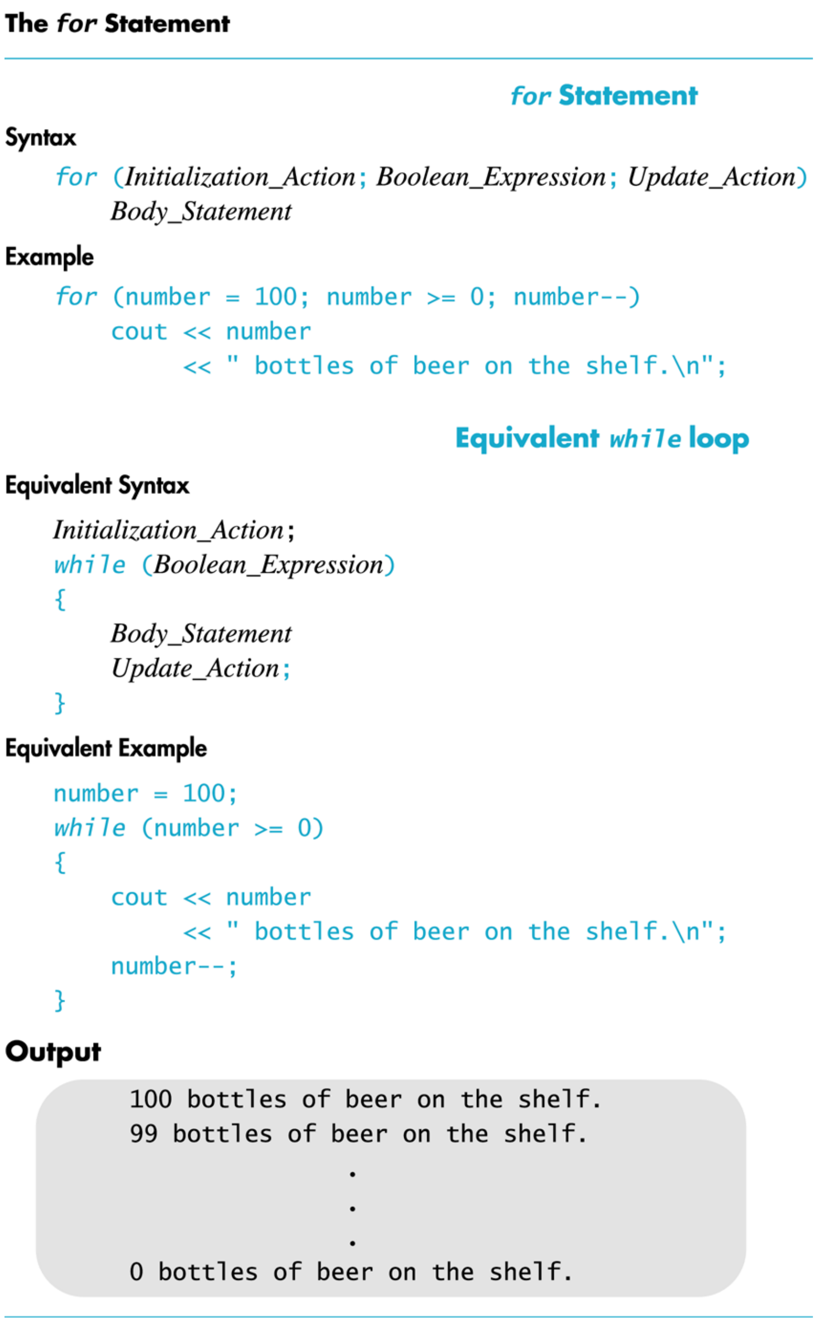
Update Action

Boolean Expression

for Loop Alternative

- A for loop can also include a variable declaration in the initialization action
  - for (int n = 1; n < = 10; n++)
    This line means
    - Create a variable, n, of type int and initialize it with 1
    - Continue to iterate the body as long as n <= 10
    - Increment n by one after each iteration
- For-loop syntax and while loop comparison are found in

Display 3.11



The *for* Statement

for Statement

Syntax

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

Example

```
for (number = 100; number >= 0; number--)
    cout << number
         << " bottles of beer on the shelf.\n";
```

Equivalent _while_ loop

Equivalent Syntax

```
Initialization_Action;
while (Boolean_Expression)
{
    Body_Statement
    Update_Action;
}
```

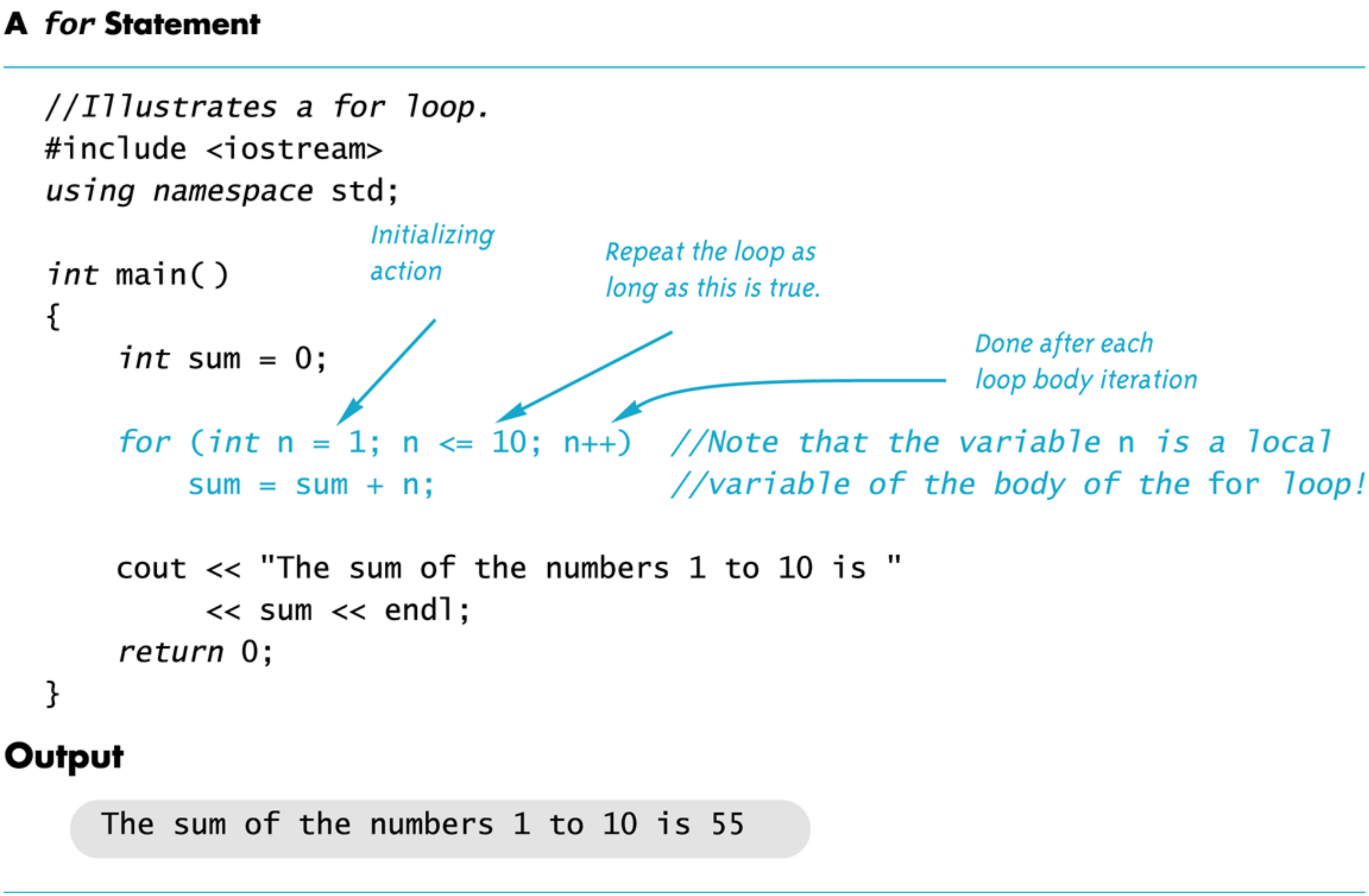
Equivalent Example

```
number = 100;
while (number >= 0)
{
    cout << number
         << " bottles of beer on the shelf.\n";
    number--;
}
```

Output

```
100 bottles of beer on the shelf.
99 bottles of beer on the shelf.
               .
               .
               .
0 bottles of beer on the shelf.
```

Display 3.12



A *for* Statement

```
//Illustrates a for loop.
#include <iostream>
using namespace std;

int main( )
{
    int sum = 0;

    for (int n = 1; n <= 10; n++)  //Note that the variable n is a local
        sum = sum + n;             //variable of the body of the for loop!

    cout << "The sum of the numbers 1 to 10 is "
         << sum << endl;
    return 0;
}
```

Initializing action

Repeat the loop as long as this is true.

Done after each loop body iteration

Output

```
The sum of the numbers 1 to 10 is 55
```

for-loop Details

- Initialization and update actions of for-loops often contain more complex expressions
  - Here are some samples

```
for (n = 1; n < = 10; n = n + 2)

for(n = 0 ; n > -100 ; n = n -7)

for(double x = pow(y,3.0);  x > 2.0;  x = sqrt(x) )
```

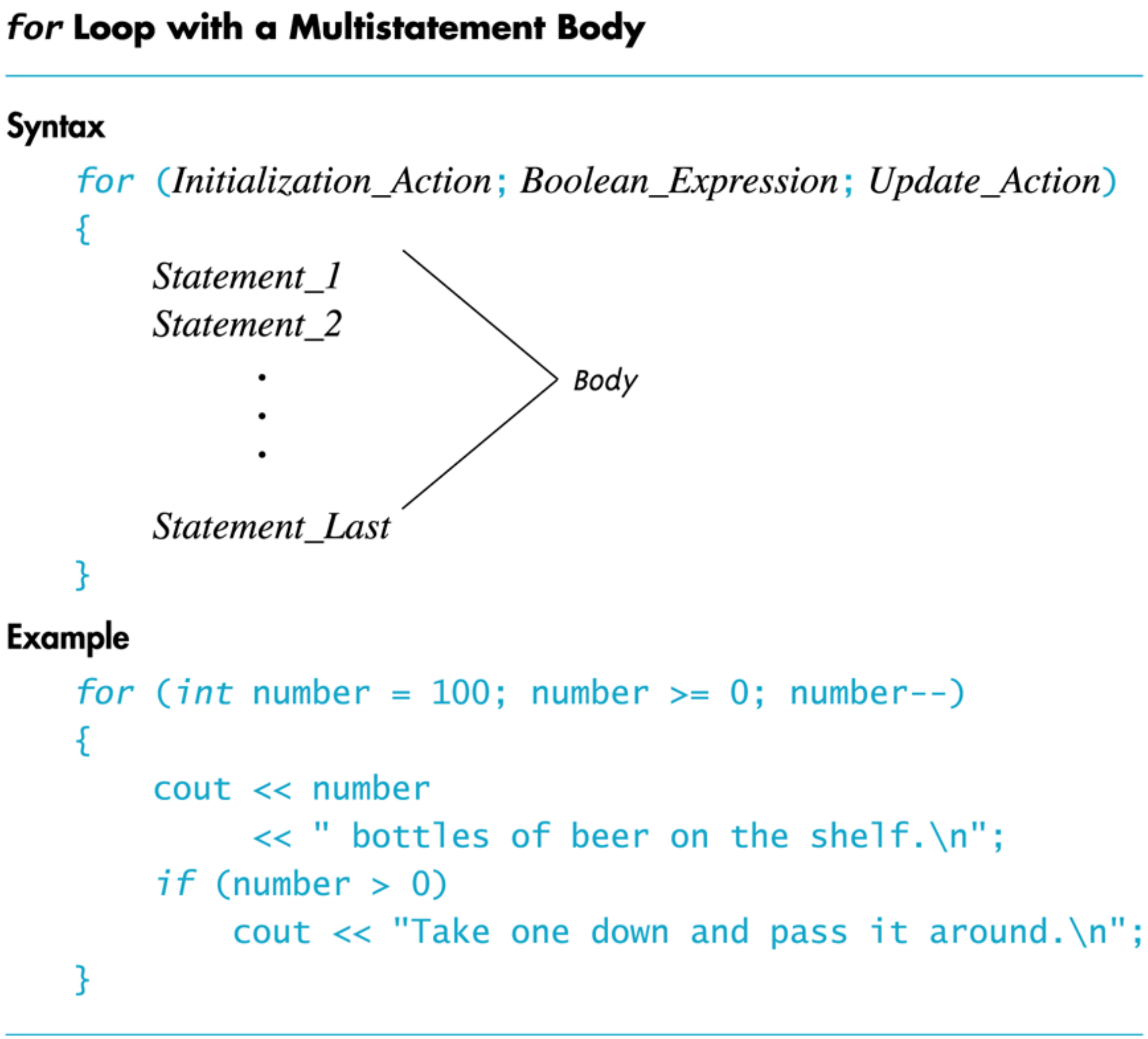
The for-loop Body

- The body of a for-loop can be
  - A single statement
  - A compound statement enclosed in braces
    - Example:

```
for(int number = 1; number >= 0; number--)
{
    // loop body statements
}
```

- Next slide shows the syntax for a for-loop with a multi-statement body

Display 3.13



for Loop with a Multistatement Body

Syntax

```
for (Initialization_Action; Boolean_Expression; Update_Action)
{
     Statement_1
     Statement_2
          .
          .
          .
     Statement_Last
}
```

Body

Example

```
for (int number = 100; number >= 0; number--)
{
    cout << number
         << " bottles of beer on the shelf.\n";
    if (number > 0)
        cout << "Take one down and pass it around.\n";
}
```

The Empty Statement

- A semicolon creates a C++ statement
  - Placing a semicolon after x++ creates the statement

    x++;
  - Placing a semicolon after nothing creates an empty statement that compiles but does nothing

```
cout << "Hello" << endl;
;
cout << "Good Bye"<< endl;
```

Extra Semicolon

- Placing a semicolon after the parentheses of a for loop creates an empty statement as the body of the loop
  - Example:

    ```
    for(int count = 1; count <= 10; count++);
        cout << "Hello\n";
    ```

    prints one "Hello", but not as part of the loop!
    - The empty statement is the body of the loop
    - cout << "Hello\n"; is not part of the loop body!

Local Variable Standard

- ANSI C++ standard requires that a variable declared in the for-loop initialization section be local to the block of the for-loop
- Find out how your compiler treats these variables!
- If you want your code to be portable, do not depend on all compilers to treat these variables as local to the for-loop!

Which Loop To Use?

- Choose the type of loop late in the design process
  - First design the loop using pseudocode
  - Translate the pseudocode into C++
  - The translation generally makes the choice of an appropriate loop clear
  - While-loops are used for all other loops when there might be occassions when the loop should not run
  - Do-while loops are used for all other loops when the loop must always run at least once

Choosing a for-loop

- for-loops are typically selected when doing numeric calculations, especially when using a variable changed by equal amounts each time the loop iterates

Choosing a while-loop

- A while-loop is typically used
  - When a for-loop is not appropriate
  - When there are circumstances for which the loop body should not be executed at all

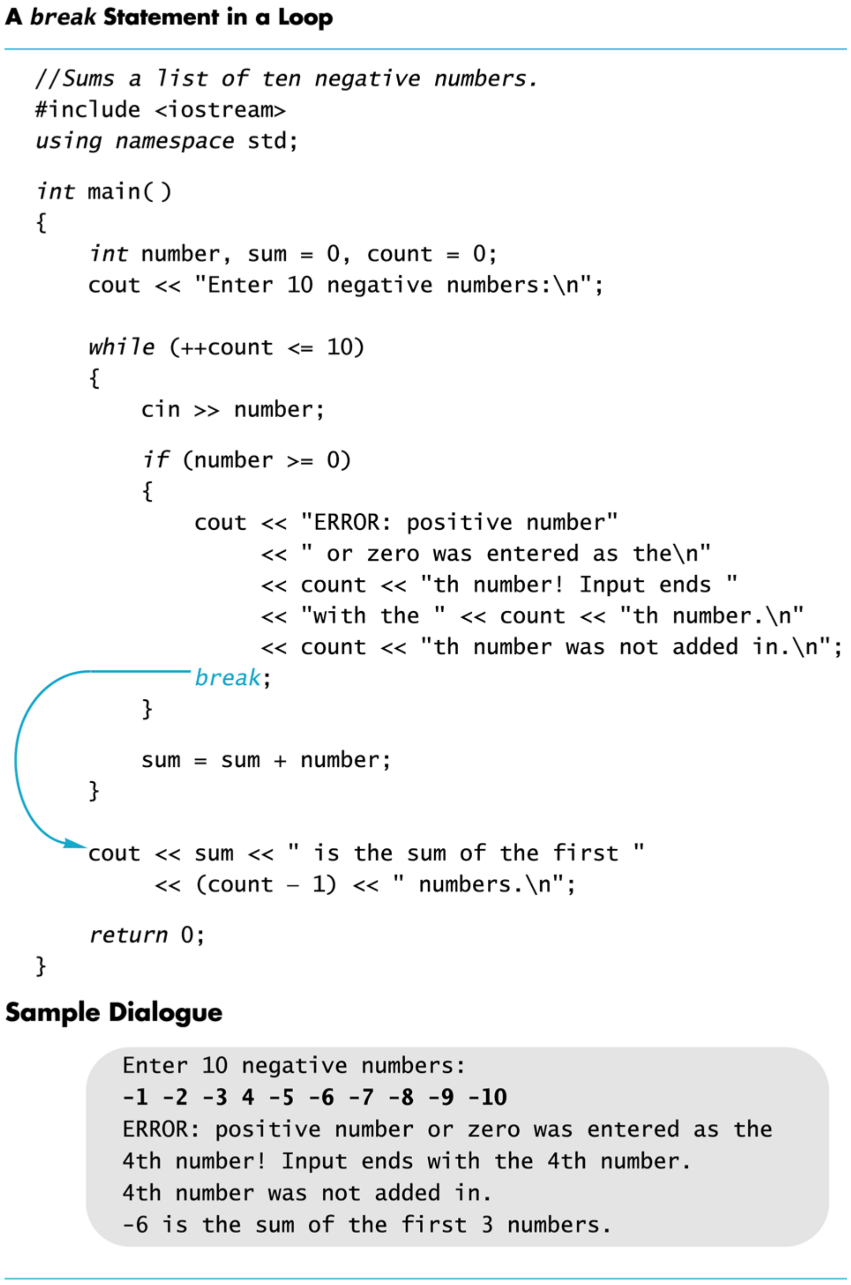
Choosing a do-while Loop

- A do-while-loop is typically used
  - When a for-loop is not appropriate
  - When the loop body must be executed at least once

The break-Statement

- There are times to exit a loop before it ends
  - If the loop checks for invalid input that would ruin a calculation, it is often best to end the loop
- The break-statement can be used to exit a loop before normal termination
  - Be careful with nested loops! Using break only exits the loop in which the break-statement occurs

Display 3.14



A *break* Statement in a Loop

```
//Sums a list of ten negative numbers.
#include <iostream>
using namespace std;

int main( )
{
    int number, sum = 0, count = 0;
    cout << "Enter 10 negative numbers:\n";

    while (++count <= 10)
    {
        cin >> number;

        if (number >= 0)
        {
            cout << "ERROR: positive number"
                 << " or zero was entered as the\n"
                 << count << "th number! Input ends "
                 << "with the " << count << "th number.\n"
                 << count << "th number was not added in.\n";
            break;
        }

        sum = sum + number;
    }

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

    return 0;
}
```

Sample Dialogue

```
Enter 10 negative numbers:
-1 -2 -3 4 -5 -6 -7 -8 -9 -10
ERROR: positive number or zero was entered as the
4th number! Input ends with the 4th number.
4th number was not added in.
-6 is the sum of the first 3 numbers.
```

Section 3.3 Conclusion

- Can you
  - Determine the output of the following?

    ```
    for(int count = 1; count < 5; count++)
      cout << (2 * count) << "  " ;
    ```

  - Determine which type of loop is likely to be best for
    - Summing a series such as 1/2 + 1/3 + 1/4 + … + 1/10?
    - Reading a list of exam scores for one student?
    - Testing a function to see how it performs with different values of its arguments

3.4

Designing Loops

Designing Loops

- Designing a loop involves designing
  - The body of the loop
  - The initializing statements
  - The conditions for ending the loop

Sums and Products

- A common task is reading a list of numbers and computing the sum
  - Pseudocode for this task might be:

```
sum = 0;
repeat the following this_many times
    cin >> next;
    sum = sum + next;
end of loop
```

  - This pseudocode can be implemented with a for-loop as shown on the next slide

for-loop for a sum

- The pseudocode from the previous slide is implemented as

```
int sum = 0;
for(int count=1; count <= this_many; count++)
   {
        cin >> next;
        sum = sum + next;
   }
```

  - sum must be initialized prior to the loop body!

Repeat "this many times"

- Pseudocode containing the line

  ```
  repeat the following "this many times"
  ```

  is often implemented with a for-loop
- A for-loop is generally the choice when there is a predetermined number of iterations
  - Example:

    ```
    for(int count = 1; count <= this_many; count++)
        Loop_body
    ```

for-loop For a Product

- Forming a product is very similar to the sum example seen earlier

```
int product = 1;
for(int count=1; count <= this_many; count++)
{
        cin >> next;
        product = product * next;
}
```

  - product must be initialized prior to the loop body
  - Notice that product is initialized to 1, not 0!

Ending a Loop

- The are four common methods to terminate an input loop
  - List headed by size
    - When we can determine the size of the list beforehand
  - Ask before iterating
    - Ask if the user wants to continue before each iteration
  - List ended with a sentinel value
    - Using a particular value to signal the end of the list
  - Running out of input
    - Using the eof function to indicate the end of a file

List Headed By Size

- The for-loops we have seen provide a natural implementation of the list headed by size method of ending a loop
  - Example:

```
int items;
cout << "How many items in the list?";
cin >> items;
for(int count  = 1; count <= items; count++)
{
        int number;
        cout << "Enter number " << count;
        cin >> number;
        cout << endl;
        // statements to process the number
 }
```

Ask Before Iterating

- A while loop is used here to implement the ask before iterating method to end a loop

```
sum = 0;
cout << "Are there numbers in the list (Y/N)?";
char ans;
cin >> ans;

while (( ans = 'Y')  || (ans = 'y'))
{
        //statements to read and process the number
        cout << "Are there more numbers(Y/N)? ";
        cin >> ans;
 }
```

List Ended With a Sentinel Value

- A while loop is typically used to end a loop using the list ended with a sentinel value method

```
cout << "Enter a list of nonnegative integers.\n"
      << "Place a negative integer after the list.\n";
sum = 0;
cin >> number;
while (number > 0)
{
          //statements to process the number
          cin >> number;
}
```

  - Notice that the sentinel value is read, but not processed

Running Out of Input

- The while loop is typically used to implement the running out of input method of ending a loop

```
ifstream infile;
infile.open("data.dat");
while (! infile.eof( ) )
{
        // read and process items from the file
        // File I/O covered in Chapter 6
}
infile.close( );
```

General Methods To Control Loops

- Three general methods to control any loop
  - Count controlled loops
  - Ask before iterating
  - Exit on flag condition

Count Controlled Loops

- Count controlled loops are loops that determine the number of iterations before the loop begins
    - The list headed by size is an example of a count controlled loop for input

Exit on Flag Condition

- Loops can be ended when a particular flag condition exists
  - A variable that changes value to indicate that some event has taken place is a flag
  - Examples of exit on a flag condition for input
    - List ended with a sentinel value
    - Running out of input

Exit on Flag Caution

- Consider this loop to identify a student with a grade of 90 or better

```
 int n = 1;
 grade = compute_grade(n);
while (grade < 90)
 {
       n++;
      grade = compute_grade(n);
  }
 cout << "Student number " << n
            << " has a score of "  << grade << endl;
```

The Problem

- The loop on the previous slide might not stop at the end of the list of students if no student has a grade of 90 or higher
    - It is a good idea to use a second flag to ensure that there are still students to consider
    - The code on the following slide shows a better solution

The Exit On Flag Solution

- This code solves the problem of having no student grade at 90 or higher

```
int n=1;
grade = compute_grade(n);
while (( grade < 90) && ( n < number_of_students))
{
            // same as before
}
if (grade > 90)
             // same output as before
else
            cout << "No student has a high score.";
```

Nested Loops

- The body of a loop may contain any kind of statement, including another loop
  - When loops are nested, all iterations of the inner loop are executed for each iteration of the outer loop
  - Give serious consideration to making the inner loop a function call to make it easier to read your program
- Display 3.15 show two versions of a program with nested loops

Display 3.15

```
//DISPLAY 3.15 Explicitly Nested Loops
//Determines the total number of green-necked vulture eggs
//counted by all conservationists in the conservation district.
#include <iostream>
using namespace std;

int main()
{
cout << "This program tallies conservationist reports\n"
     << "on the green-necked vulture.\n"
     << "Each conservationist's report consists of\n"
     << "a list of numbers. Each number is the count of\n"
     << "the eggs observed in one "
     << "green-necked vulture nest.\n"
     << "This program then tallies "
     << "the total number of eggs.\n";

  int number_of_reports;
  cout << "How many conservationist reports are there? ";
  cin >> number_of_reports;

  int grand_total = 0, subtotal, count;
  for (count = 1; count <= number_of_reports; count++)
  {
    cout << endl << "Enter the report of "
       << "conservationist number " << count << endl;
    cout << "Enter the number of eggs in each nest.\n"
       << "Place a negative integer at the end of your list.\n";
    subtotal = 0;
    int next;
    cin >> next;
    while (next >=0)
    {
      subtotal = subtotal + next;
      cin >> next;
    }
    cout << "Total egg count for conservationist "
       << " number " << count << " is "
       << subtotal << endl;
    grand_total = grand_total + subtotal;
  }
  cout << endl << "Total egg count for all reports = "
     << grand_total << endl;

  return 0;
}
```

Debugging Loops

- Common errors involving loops include
  - Off-by-one errors in which the loop executes one too many or one too few times
  - Infinite loops usually result from a mistake in the Boolean expression that controls the loop

Fixing Off By One Errors

- Check your comparison:
  should it be < or <=?

- Check that the initialization uses the correct value

- Does the loop handle the zero iterations case?

Fixing Infinite Loops

- Check the direction of inequalities:
  < or > ?
- Test for < or > rather than equality (==)
  - Remember that doubles are really only approximations

More
Loop Debugging Tips

- Be sure that the mistake is really in the loop
- Trace the variable to observe how the variable changes
  - Tracing a variable is watching its value change during execution
    - Many systems include utilities to help with this
  - cout statements can be used to trace a value

Debugging Example

- The following code is supposed to conclude with the variable product containing the product of the numbers 2 through 5

```
int next = 2, product = 1;
while (next < 5)
{
        next++;
        product = product * next;
}
```

Tracing Variables

- Add temporary cout statements to trace variables

```
int next = 2, product = 1;
while (next < 5)
{
        next++;
        product = product * next;
         cout << "next = " << next
             << "product = " << product
             << endl;
}
```

First Fix

- The cout statements added to the loop show us that the loop never multiplied by 2
  - Solve the problem by moving the statement next++

```
int next = 2, product = 1;
while (next < 5)
{
     product = product * next;
     next++;

      cout << "next = " << next
                << "product = " << product
                << endl;
}
```

  - There is still a problem!

Second Fix

- Re-testing the loop shows us that now the loop never multiplies by 5
  - The fix is to use <= instead of < in our comparison

```
int next = 2, product = 1;
while (next <= 5)
{
      product = product * next;
      next++;
}
```

Loop Testing Guidelines

- Every time a program is changed, it must be retested
  - Changing one part may require a change to another
- Every loop should at least be tested using input to cause:
  - Zero iterations of the loop body
  - One iteration of the loop body
  - One less than the maximum number of iterations
  - The maximum number of iteratons

Starting Over

- Sometimes it is more efficient to throw out a buggy program and start over
  - The new program will be easier to read
  - The new program is less likely to be as buggy
  - You may develop a working program faster than if you repair the bad code
    - The lessons learned in the buggy code will help you design a better program faster

Chapter 3.4 Conclusion

- Can you
  - Describe how to trace a variable?
  - List possible solutions to an off-by-one error?
  - Determine the number of fence posts needed for a 100 meter long fence?

Chapter 3 -- End