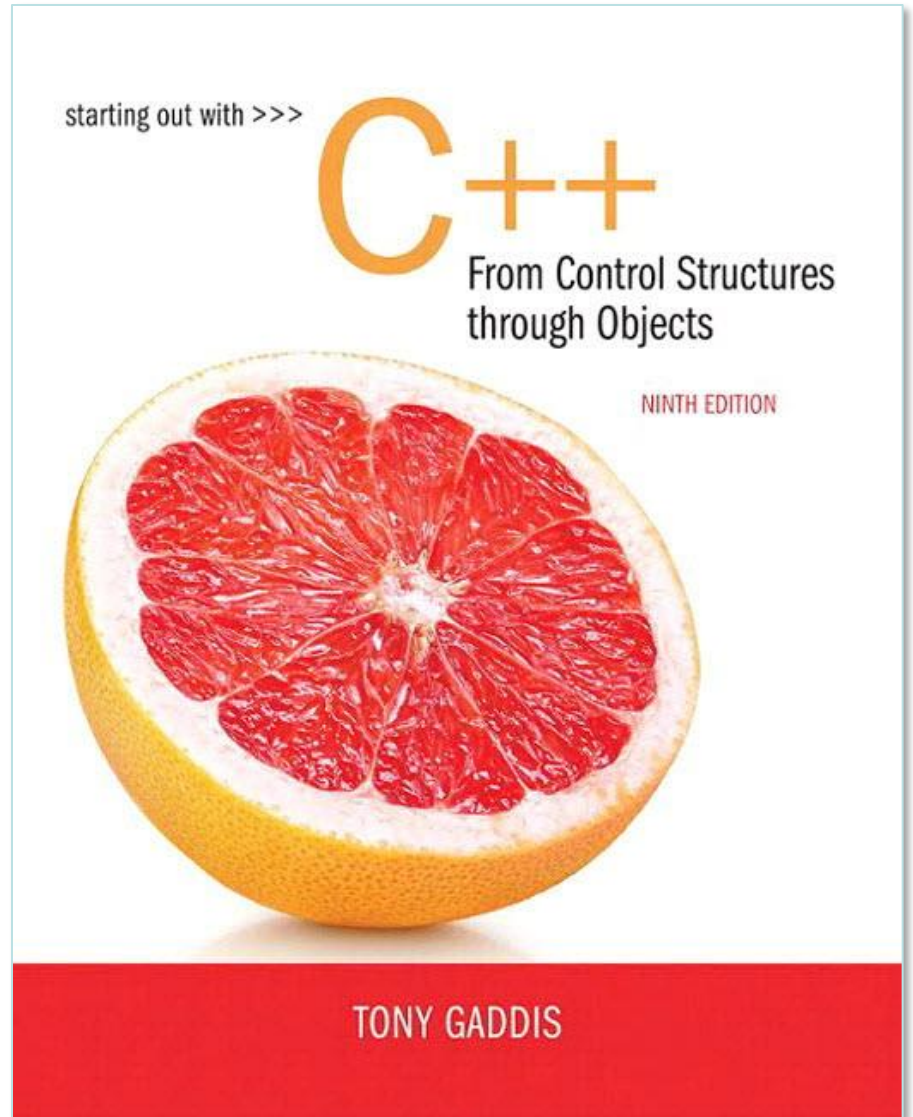
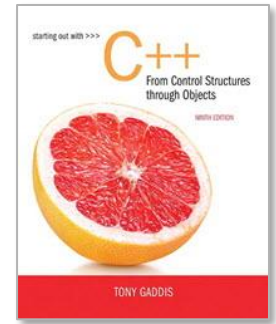


Chapter 4:

Making Decisions





4.1

Relational Operators

Relational Operators

- Used to compare numbers to determine relative order

- Operators:

| | |
|----|--------------------------|
| > | Greater than |
| < | Less than |
| >= | Greater than or equal to |
| <= | Less than or equal to |
| == | Equal to |
| != | Not equal to |

Relational Expressions

- Boolean expressions – `true` or `false`

- Examples:

`12 > 5` **is** `true`

`7 <= 5` **is** `false`

if `x` is 10, then

`x == 10` **is** `true`,

`x != 8` **is** `true`, and

`x == 8` **is** `false`

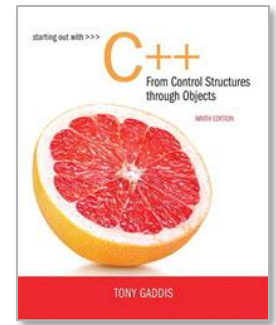
Relational Expressions

- Can be assigned to a variable:

```
result = x <= y;
```

- Assigns 0 for false, 1 for true

- Do not confuse = and ==



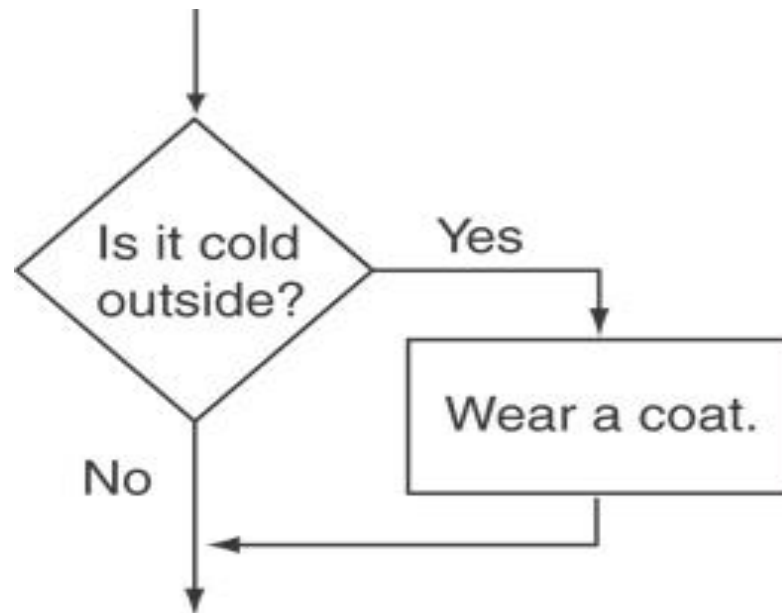
4.2

The `if` Statement

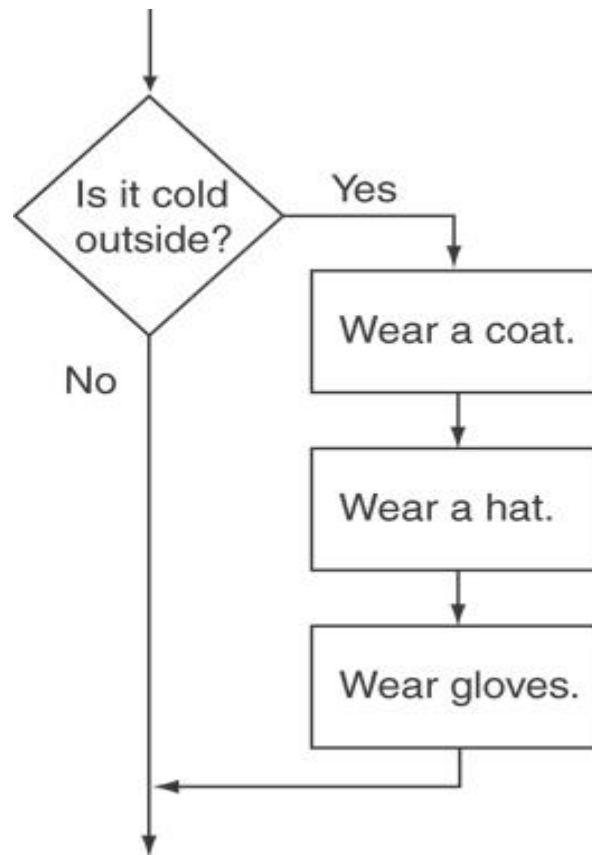
The `if` Statement

- Allows statements to be conditionally executed or skipped over
- Models the way we mentally evaluate situations:
 - "If it is raining, take an umbrella."
 - "If it is cold outside, wear a coat."

Flowchart for Evaluating a Decision



Flowchart for Evaluating a Decision



The `if` Statement

General Format:

```
if (expression)  
    statement;
```

The if Statement-What Happens

To evaluate:

```
if (expression)  
    statement;
```

- If the *expression* is true, then *statement* is executed.
- If the *expression* is false, then *statement* is skipped.

if Statement in Program 4-2

Program 4-2

```
1  // This program averages three test scores
2  #include <iostream>
3  #include <iomanip>
4  using namespace std;
5
6  int main()
7  {
8      int score1, score2, score3; // To hold three test scores
9      double average;             // To hold the average score
10
```

Continued...

if Statement in Program 4-2

Program 4-2 *(continued)*

```
11    // Get the three test scores.
12    cout << "Enter 3 test scores and I will average them: ";
13    cin >> score1 >> score2 >> score3;
14
15    // Calculate and display the average score.
16    average = (score1 + score2 + score3) / 3.0;
17    cout << fixed << showpoint << setprecision(1);
18    cout << "Your average is " << average << endl;
19
20    // If the average is greater than 95, congratulate the user.
21    if (average > 95)
22        cout << "Congratulations! That's a high score!\n";
23    return 0;
24 }
```

Program Output with Example Input Shown in Bold

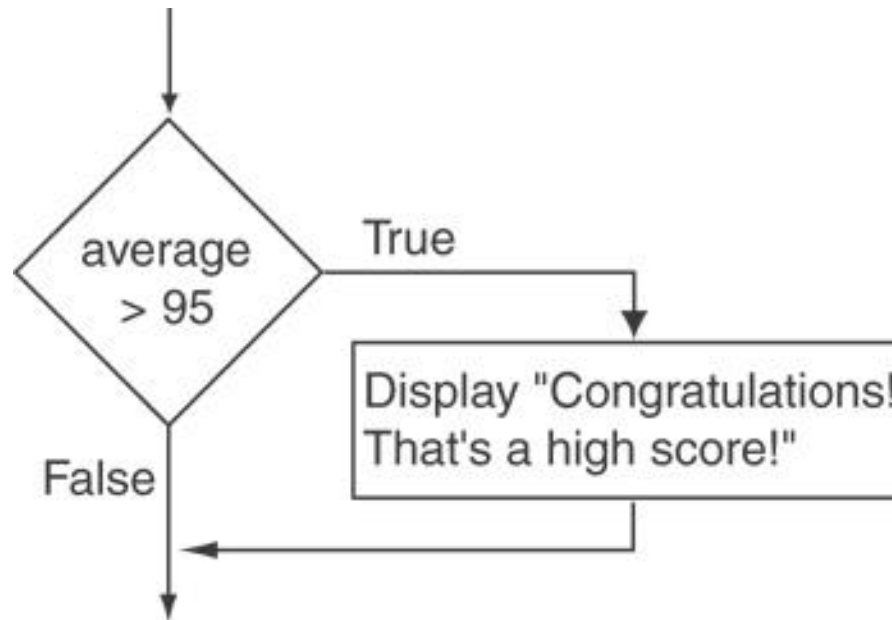
```
Enter 3 test scores and I will average them: 80 90 70 [Enter]
Your average is 80.0
```

Program Output with Other Example Input Shown in Bold

```
Enter 3 test scores and I will average them: 100 100 100 [Enter]
Your average is 100.0
Congratulations! That's a high score!
```



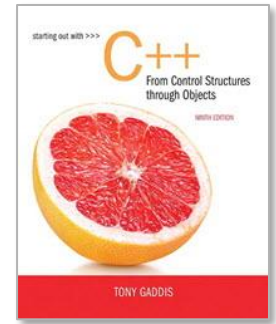
Flowchart for Program 4-2 Lines 21 and 22



if Statement Notes

- Do not place `;` after *(expression)*
- Place *statement;* on a separate line after *(expression)*, indented:

```
if (score > 90)
    grade = 'A';
```
- Be careful testing `floats` and `doubles` for equality
- `0` is `false`; any other value is `true`



4.3

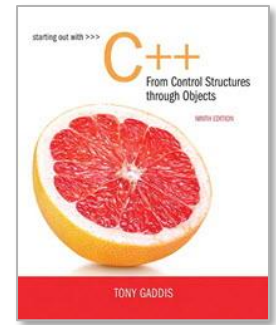
Expanding the `if` Statement

Expanding the `if` Statement

- To execute more than one statement as part of an `if` statement, enclose them in `{ }`:

```
if (score > 90)
{
    grade = 'A';
    cout << "Good Job!\n";
}
```

- `{ }` creates a block of code



4.4

The `if/else` Statement

The `if/else` statement

- Provides two possible paths of execution
- Performs one statement or block if the *expression* is true, otherwise performs another statement or block.

The `if/else` statement

🍊 General Format:

```
if (expression)  
    statement1;    // or block  
else  
    statement2;    // or block
```

if/else-What Happens

To evaluate:

```
if (expression)
    statement1;
else
    statement2;
```

- If the *expression* is true, then *statement1* is executed and *statement2* is skipped.
- If the *expression* is false, then *statement1* is skipped and *statement2* is executed.

The `if/else` statement and Modulus Operator in Program 4-8

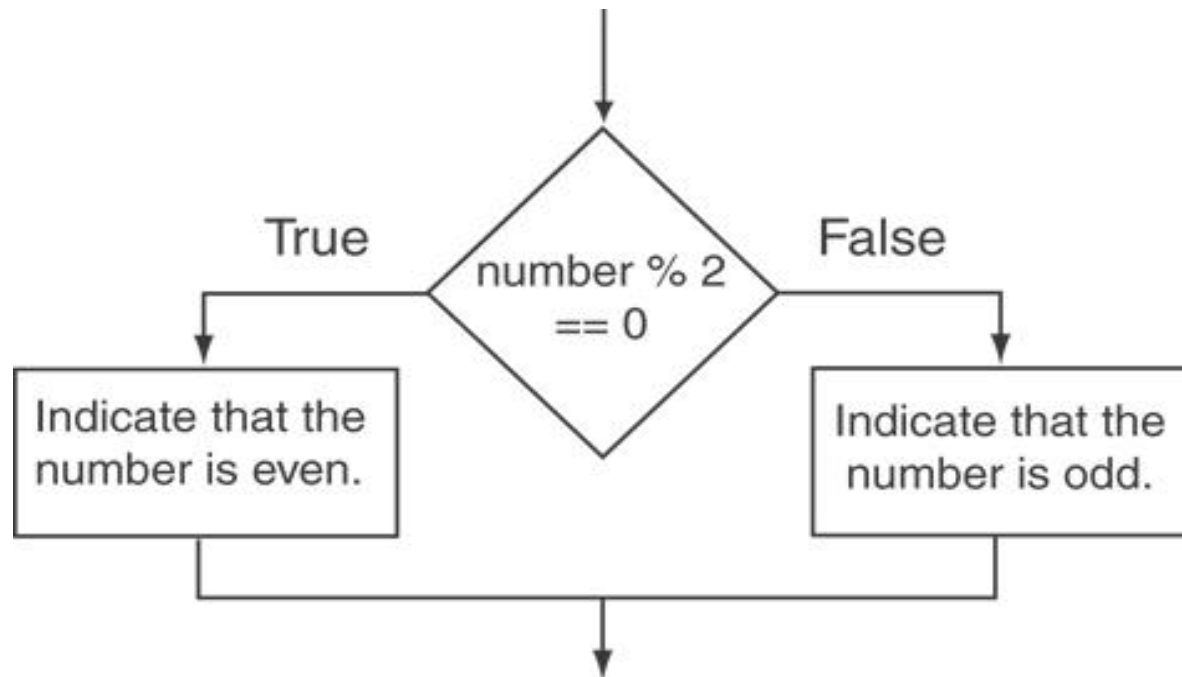
Program 4-8

```
1 // This program uses the modulus operator to determine
2 // if a number is odd or even. If the number is evenly divisible
3 // by 2, it is an even number. A remainder indicates it is odd.
4 #include <iostream>
5 using namespace std;
6
7 int main()
8 {
9     int number;
10
11     cout << "Enter an integer and I will tell you if it\n";
12     cout << "is odd or even. ";
13     cin >> number;
14     if (number % 2 == 0)
15         cout << number << " is even.\n";
16     else
17         cout << number << " is odd.\n";
18     return 0;
19 }
```

Program Output with Example Input Shown in Bold

Enter an integer and I will tell you if it
is odd or even. **17** [Enter]
17 is odd.

Flowchart for Program 4-8 Lines 14 through 18



Testing the Divisor in Program 4-9

Program 4-9

```
1  // This program asks the user for two numbers, num1 and num2.
2  // num1 is divided by num2 and the result is displayed.
3  // Before the division operation, however, num2 is tested
4  // for the value 0. If it contains 0, the division does not
5  // take place.
6  #include <iostream>
7  using namespace std;
8
9  int main()
10 {
11     double num1, num2, quotient;
12
```

Continued...

Testing the Divisor in Program 4-9

Program 4-9 *(continued)*

```
13     // Get the first number.
14     cout << "Enter a number: ";
15     cin >> num1;
16
17     // Get the second number.
18     cout << "Enter another number: ";
19     cin >> num2;
20
21     // If num2 is not zero, perform the division.
22     if (num2 == 0)
23     {
24         cout << "Division by zero is not possible.\n";
25         cout << "Please run the program again and enter\n";
26         cout << "a number other than zero.\n";
27     }
28     else
29     {
30         quotient = num1 / num2;
31         cout << "The quotient of " << num1 << " divided by ";
32         cout << num2 << " is " << quotient << ".\n";
33     }
34     return 0;
35 }
```

Program Output with Example Input Shown in Bold

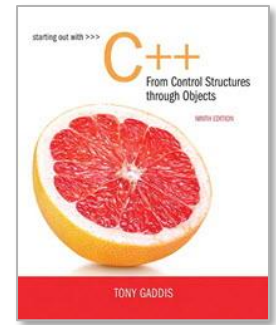
(When the user enters 0 for num2)

Enter a number: **10 [Enter]**

Enter another number: **0 [Enter]**

Division by zero is not possible.

Please run the program again and enter
a number other than zero.



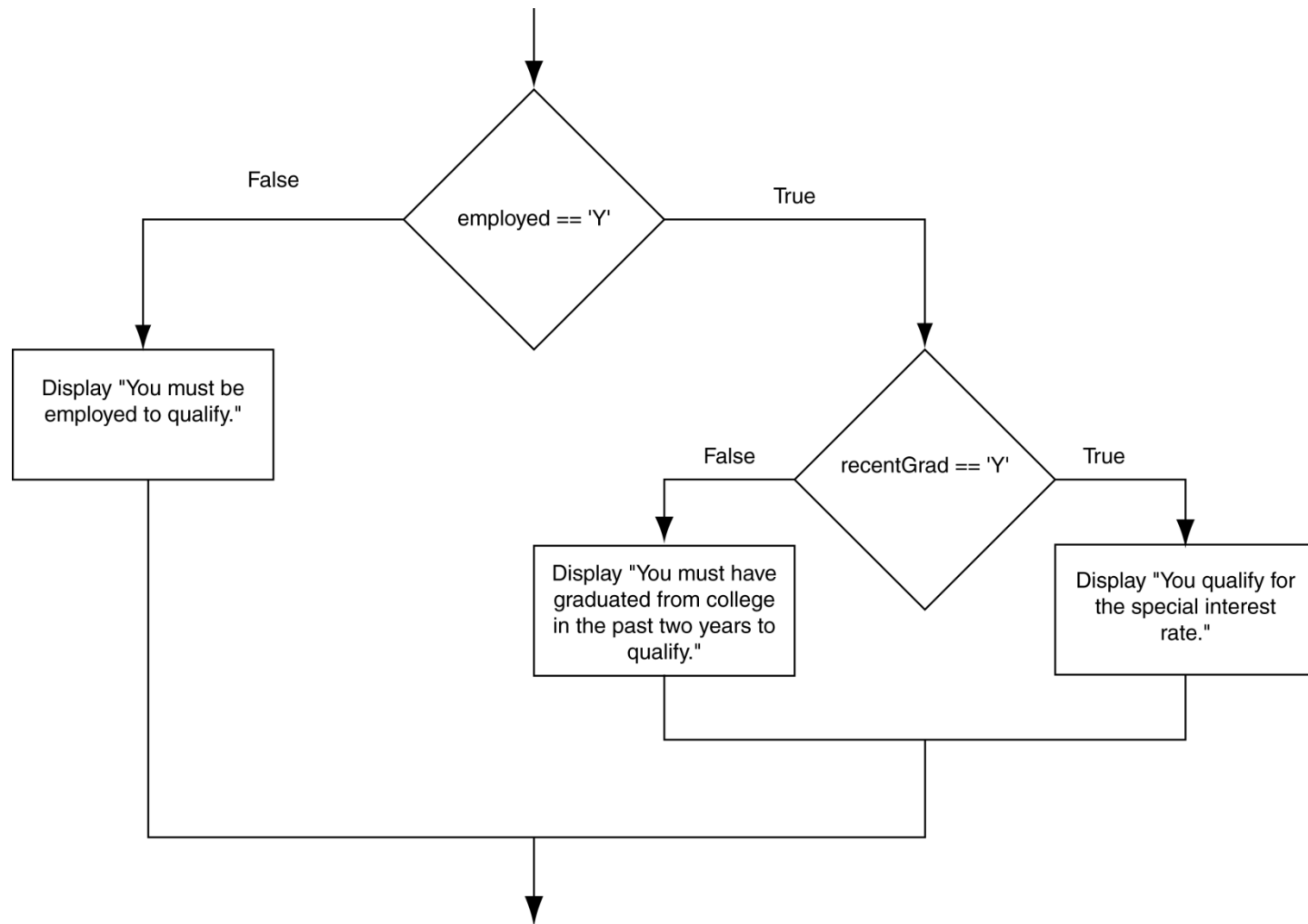
4.5

Nested `if` Statements

Nested `if` Statements

- An `if` statement that is nested inside another `if` statement
- Nested `if` statements can be used to test more than one condition

Flowchart for a Nested `if` Statement



Nested `if` Statements

🍊 From Program 4-10

```
20      // Determine the user's loan qualifications.
21      if (employed == 'Y')
22      {
23          if (recentGrad == 'Y') //Nested if
24          {
25              cout << "You qualify for the special ";
26              cout << "interest rate.\n";
27          }
28      }
```

Nested `if` Statements

Another example, from Program 4-1

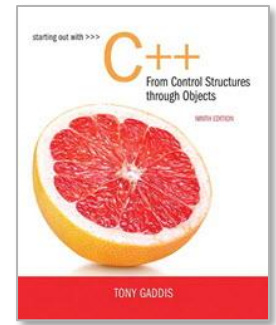
```
20      // Determine the user's loan qualifications.
21      if (employed == 'Y')
22      {
23          if (recentGrad == 'Y') // Nested if
24          {
25              cout << "You qualify for the special ";
26              cout << "interest rate.\n";
27          }
28          else // Not a recent grad, but employed
29          {
30              cout << "You must have graduated from ";
31              cout << "college in the past two\n";
32              cout << "years to qualify.\n";
33          }
34      }
35      else // Not employed
36      {
37          cout << "You must be employed to qualify.\n";
38      }
```

Use Proper Indentation!

This if and else go together.

```
if (employed == 'Y')
{
    if (recentGrad == 'Y') // Nested if
    {
        cout << "You qualify for the special ";
        cout << "interest rate.\n";
    }
    else // Not a recent grad, but employed
    {
        cout << "You must have graduated from ";
        cout << "college in the past two\n";
        cout << "years to qualify.\n";
    }
}
else // Not employed
{
    cout << "You must be employed to qualify.\n";
}
```

This if and else go together.



4.6

The `if/else if` Statement

The `if/else if` Statement

- Tests a series of conditions until one is found to be true
- Often simpler than using nested `if/else` statements
- Can be used to model thought processes such as:

"If it is raining, take an umbrella,
else, if it is windy, take a hat,
else, take sunglasses"

if/else if Format

```
if (expression)  
    statement1;    // or block  
else if (expression)  
    statement2;    // or block  
.  
. // other else ifs  
.  
else if (expression)  
    statementn;    // or block
```

The `if/else if` Statement in Program 4-13

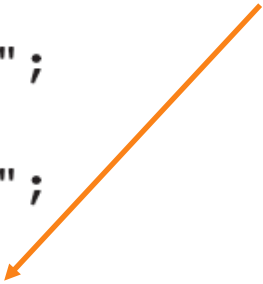
```
21      // Determine the letter grade.
22      if (testScore >= A_SCORE)
23          cout << "Your grade is A.\n";
24      else if (testScore >= B_SCORE)
25          cout << "Your grade is B.\n";
26      else if (testScore >= C_SCORE)
27          cout << "Your grade is C.\n";
28      else if (testScore >= D_SCORE)
29          cout << "Your grade is D.\n";
30      else
31          cout << "Your grade is F.\n";
```

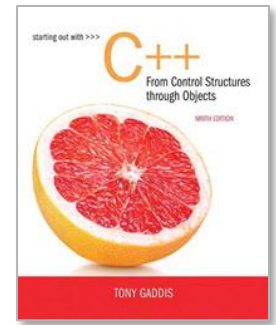
Using a Trailing `else` to Catch Errors in Program 4-14

- The trailing `else` clause is optional, but it is best used to catch errors.

```
21    // Determine the letter grade.
22    if (testScore >= A_SCORE)
23        cout << "Your grade is A.\n";
24    else if (testScore >= B_SCORE)
25        cout << "Your grade is B.\n";
26    else if (testScore >= C_SCORE)
27        cout << "Your grade is C.\n";
28    else if (testScore >= D_SCORE)
29        cout << "Your grade is D.\n";
30    else if (testScore >= 0)
31        cout << "Your grade is F.\n";
32    else
33        cout << "Invalid test score.\n";
```

This trailing
`else`
catches
invalid test
scores



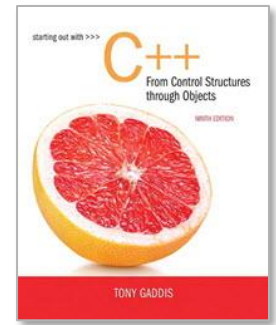


4.7

Flags

Flags

- Variable that signals a condition
- Usually implemented as a `bool` variable
- Can also be an integer
 - The value `0` is considered `false`
 - Any nonzero value is considered `true`
- As with other variables in functions, must be assigned an initial value before it is used



4.8

Logical Operators

Logical Operators

- Used to create relational expressions from other relational expressions
- Operators, meaning, and explanation:

| | | |
|-----|-----|---|
| & & | AND | New relational expression is true if both expressions are true |
| | OR | New relational expression is true if either expression is true |
| ! | NOT | Reverses the value of an expression – true expression becomes false, and false becomes true |

Logical Operators-Examples

```
int x = 12, y = 5, z = -4;
```

| | |
|---|-------|
| <code>(x > y) && (y > z)</code> | true |
| <code>(x > y) && (z > y)</code> | false |
| <code>(x <= z) (y == z)</code> | false |
| <code>(x <= z) (y != z)</code> | true |
| <code>! (x >= z)</code> | false |

The logical && operator in Program 4-15

```
21    // Determine the user's loan qualifications.
22    if (employed == 'Y' && recentGrad == 'Y')
23    {
24        cout << "You qualify for the special "
25            << "interest rate.\n";
26    }
27    else
28    {
29        cout << "You must be employed and have\n"
30            << "graduated from college in the\n"
31            << "past two years to qualify.\n";
32    }
```

The logical || Operator in Program 4-16

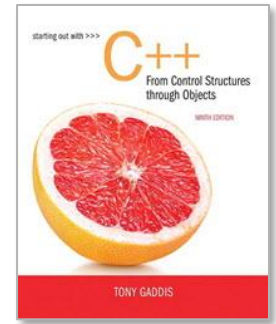
```
23     // Determine the user's loan qualifications.
24     if (income >= MIN_INCOME || years > MIN_YEARS)
25         cout << "You qualify.\n";
26     else
27     {
28         cout << "You must earn at least $"
29             << MIN_INCOME << " or have been "
30             << "employed more than " << MIN_YEARS
31             << " years.\n";
32     }
```

The logical ! Operator in Program 4-17

```
23     // Determine the user's loan qualifications.
24     if (!(income >= MIN_INCOME || years > MIN_YEARS))
25     {
26         cout << "You must earn at least $"
27             << MIN_INCOME << " or have been "
28             << "employed more than " << MIN_YEARS
29             << " years.\n";
30     }
31     else
32         cout << "You qualify.\n";
```

Logical Operator-Notes

- ! has highest precedence, followed by & &, then | |
- If the value of an expression can be determined by evaluating just the sub-expression on left side of a logical operator, then the sub-expression on the right side will not be evaluated (*short circuit evaluation*)



4.9

Checking Numeric Ranges with Logical Operators

Checking Numeric Ranges with Logical Operators

- Used to test to see if a value falls **inside** a range:

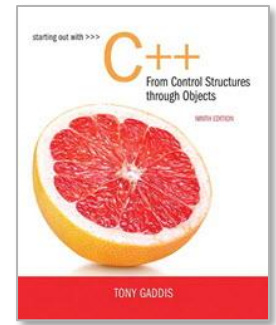
```
if (grade >= 0 && grade <= 100)
    cout << "Valid grade";
```

- Can also test to see if value falls **outside** of range:

```
if (grade <= 0 || grade >= 100)
    cout << "Invalid grade";
```

- Cannot use mathematical notation:

```
if (0 <= grade <= 100) //doesn't work!
```



4.10

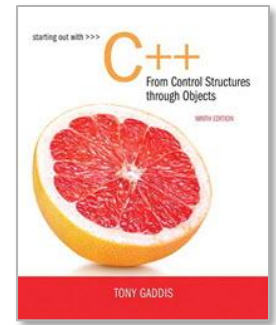
Menus

Menus

- Menu-driven program: program execution controlled by user selecting from a list of actions
- Menu: list of choices on the screen
- Menus can be implemented using `if/else if` statements

Menu-Driven Program Organization

- Display list of numbered or lettered choices for actions
- Prompt user to make selection
- Test user selection in *expression*
 - if a match, then execute code for action
 - if not, then go on to next *expression*



4.11

Validating User Input

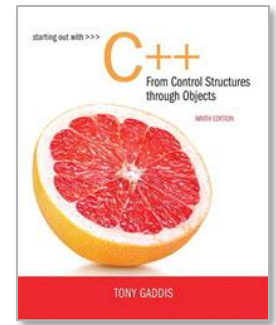
Validating User Input

- Input validation: inspecting input data to determine whether it is acceptable
- Bad output will be produced from bad input
- Can perform various tests:
 - Range
 - Reasonableness
 - Valid menu choice
 - Divide by zero

Input Validation in Program 4-19

```
16     int testScore; // To hold a numeric test score
17
18     // Get the numeric test score.
19     cout << "Enter your numeric test score and I will\n"
20           << "tell you the letter grade you earned: ";
21     cin >> testScore;
22
23     // Validate the input and determine the grade.
24     if (testScore >= MIN_SCORE && testScore <= MAX_SCORE)
25     {
26         // Determine the letter grade.
27         if (testScore >= A_SCORE)
28             cout << "Your grade is A.\n";
29         else if (testScore >= B_SCORE)
30             cout << "Your grade is B.\n";
31         else if (testScore >= C_SCORE)
32             cout << "Your grade is C.\n";
33         else if (testScore >= D_SCORE)
34             cout << "Your grade is D.\n";
35         else
36             cout << "Your grade is F.\n";
37     }
38     else
39     {
40         // An invalid score was entered.
41         cout << "That is an invalid score. Run the program\n"
42              << "again and enter a value in the range of\n"
43              << MIN_SCORE << " through " << MAX_SCORE << ".\n";
44     }
```





4.12

Comparing Characters and Strings

Comparing Characters

- Characters are compared using their ASCII values
- 'A' < 'B'
 - The ASCII value of 'A' (65) is less than the ASCII value of 'B' (66)
- '1' < '2'
 - The ASCII value of '1' (49) is less than the ASCII value of '2' (50)
- Lowercase letters have higher ASCII codes than uppercase letters, so 'a' > 'Z'

Relational Operators Compare Characters in Program 4-20

```
10    // Get a character from the user.
11    cout << "Enter a digit or a letter: ";
12    ch = cin.get();
13
14    // Determine what the user entered.
15    if (ch >= '0' && ch <= '9')
16        cout << "You entered a digit.\n";
17    else if (ch >= 'A' && ch <= 'Z')
18        cout << "You entered an uppercase letter.\n";
19    else if (ch >= 'a' && ch <= 'z')
20        cout << "You entered a lowercase letter.\n";
21    else
22        cout << "That is not a digit or a letter.\n";
```


Comparing `string` Objects

- Like characters, strings are compared using their ASCII values

```
string name1 = "Mary";  
string name2 = "Mark";
```

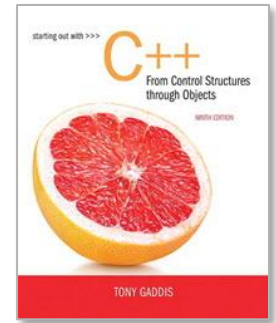
The characters in each string must match before they are equal

```
name1 > name2 // true  
name1 <= name2 // false  
name1 != name2 // true
```

```
name1 < "Mary Jane" // true
```

Relational Operators Compare Strings in Program 4-21

```
26      // Determine and display the correct price
27      if (partNum == "S-29A")
28          cout << "The price is $" << PRICE_A << endl;
29      else if (partNum == "S-29B")
30          cout << "The price is $" << PRICE_B << endl;
31      else
32          cout << partNum << " is not a valid part number.\n";
```

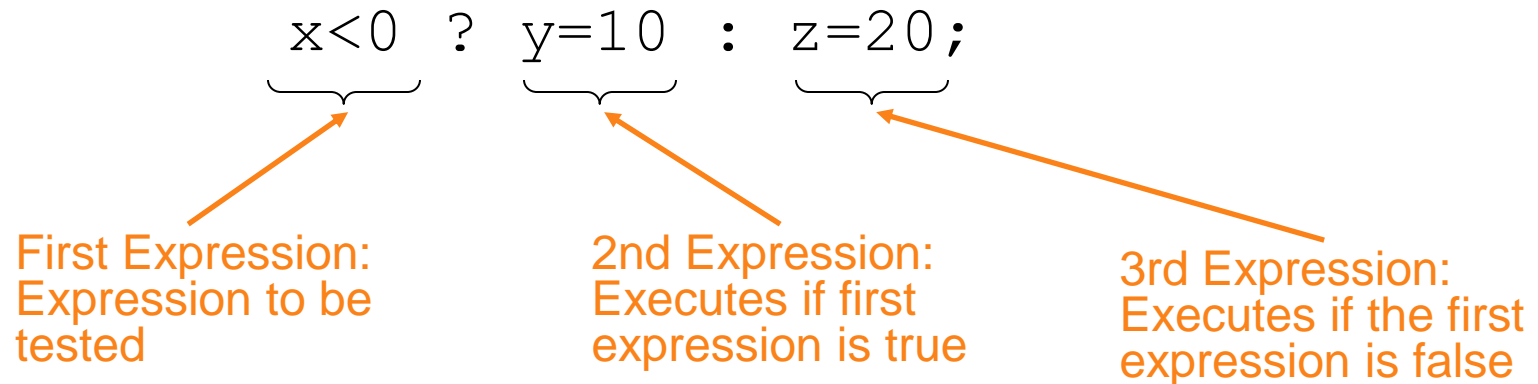


4.13

The Conditional Operator

The Conditional Operator

- Can use to create short `if/else` statements
- Format: `expr ? expr : expr;`



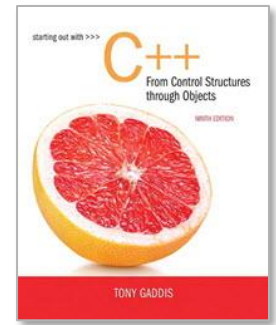
The Conditional Operator

- The value of a conditional expression is
 - The value of the second expression if the first expression is true
 - The value of the third expression if the first expression is false
- Parentheses () may be needed in an expression due to precedence of conditional operator

The Conditional Operator in Program 4-22

```
1 // This program calculates a consultant's charges at $50
2 // per hour, for a minimum of 5 hours. The ?: operator
3 // adjusts hours to 5 if less than 5 hours were worked.
4 #include <iostream>
5 #include <iomanip>
6 using namespace std;
7
8 int main()
9 {
10     const double PAY_RATE = 50.0; // Hourly pay rate
11     const int MIN_HOURS = 5;      // Minimum billable hours
12     double hours,                 // Hours worked
13           charges;                // Total charges
14
15     // Get the hours worked.
16     cout << "How many hours were worked? ";
17     cin >> hours;
18
19     // Determine the hours to charge for.
20     hours = hours < MIN_HOURS ? MIN_HOURS : hours;
21
22     // Calculate and display the charges.
23     charges = PAY_RATE * hours;
24     cout << fixed << showpoint << setprecision(2)
25           << "The charges are $" << charges << endl;
26     return 0;
27 }
```





4.14

The `switch` Statement

The `switch` Statement

- Used to select among statements from several alternatives
- In some cases, can be used instead of `if/else if` statements

switch Statement Format

```
switch (expression) //integer
{
    case exp1: statement1;
    case exp2: statement2;
    ...
    case expn: statementn;
    default:    statementn+1;
}
```

The `switch` Statement in Program 4-23

Program 4-23

```
1  // The switch statement in this program tells the user something
2  // he or she already knows: the data just entered!
3  #include <iostream>
4  using namespace std;
5
6  int main()
7  {
8      char choice;
9
10     cout << "Enter A, B, or C: ";
11     cin >> choice;
12     switch (choice)
13     {
14         case 'A': cout << "You entered A.\n";
15                 break;
16         case 'B': cout << "You entered B.\n";
17                 break;
18         case 'C': cout << "You entered C.\n";
19                 break;
20         default:  cout << "You did not enter A, B, or C!\n";
21     }
22     return 0;
23 }
```

Program Output with Example Input Shown in Bold

Enter A, B, or C: **B** [Enter]
You entered B.

Program Output with Example Input Shown in Bold

Enter A, B, or C: **F** [Enter]
You did not enter A, B, or C!

switch Statement Requirements

- 1) *expression* must be an integer variable or an expression that evaluates to an integer value
- 2) *exp1* through *expn* must be constant integer expressions or literals, and must be unique in the `switch` statement
- 3) `default` is optional but recommended

switch Statement-How it Works

- 1) *expression* is evaluated
- 2) The value of *expression* is compared against *exp1* through *expn*.
- 3) If *expression* matches value *expi*, the program branches to the statement following *expi* and continues to the end of the `switch`
- 4) If no matching value is found, the program branches to the statement after `default`:

break Statement

- Used to exit a `switch` statement
- If it is left out, the program "falls through" the remaining statements in the `switch` statement

break and default statements in Program 4-25

Program 4-25

```
1  // This program is carefully constructed to use the "fall through"
2  // feature of the switch statement.
3  #include <iostream>
4  using namespace std;
5
6  int main()
7  {
8      int modelNum;  // Model number
9
10     // Get a model number from the user.
11     cout << "Our TVs come in three models:\n";
12     cout << "The 100, 200, and 300. Which do you want? ";
13     cin >> modelNum;
14
15     // Display the model's features.
16     cout << "That model has the following features:\n";
17     switch (modelNum)
18     {
19         case 300: cout << "\tPicture-in-a-picture.\n";
20         case 200: cout << "\tStereo sound.\n";
21         case 100: cout << "\tRemote control.\n";
22                 break;
23         default:  cout << "You can only choose the 100,";
24                 cout << "200, or 300.\n";
25     }
26     return 0;
27 }
```

Continued...

break and default statements in Program 4-25

Program Output with Example Input Shown in Bold

Our TVs come in three models:

The 100, 200, and 300. Which do you want? **100 [Enter]**

That model has the following features:

Remote control.

Program Output with Example Input Shown in Bold

Our TVs come in three models:

The 100, 200, and 300. Which do you want? **200 [Enter]**

That model has the following features:

Stereo sound.

Remote control.

Program Output with Example Input Shown in Bold

Our TVs come in three models:

The 100, 200, and 300. Which do you want? **300 [Enter]**

That model has the following features:

Picture-in-a-picture.

Stereo sound.

Remote control.

Program Output with Example Input Shown in Bold

Our TVs come in three models:

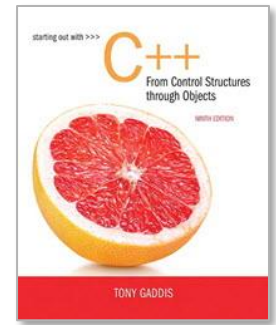
The 100, 200, and 300. Which do you want? **500 [Enter]**

That model has the following features:

You can only choose the 100, 200, or 300.

Using `switch` in Menu Systems

- `switch` statement is a natural choice for menu-driven program:
 - display the menu
 - then, get the user's menu selection
 - use user input as `expression` in `switch` statement
 - use menu choices as `expr` in `case` statements



4.15

More About Blocks and Scope

More About Blocks and Scope

- Scope of a variable is the block in which it is defined, from the point of definition to the end of the block
- Usually defined at beginning of function
- May be defined close to first use

Inner Block Variable Definition in Program 4-29

```
16     if (income >= MIN_INCOME)
17     {
18         // Get the number of years at the current job.
19         cout << "How many years have you worked at "
20             << "your current job? ";
21         int years;      // Variable definition
22         cin >> years;
23
24         if (years > MIN_YEARS)
25             cout << "You qualify.\n";
26         else
27         {
28             cout << "You must have been employed for\n"
29                 << "more than " << MIN_YEARS
30                 << " years to qualify.\n";
31         }
32     }
```

Variables with the Same Name

- Variables defined inside { } have local or block scope
- When inside a block within another block, can define variables with the same name as in the outer block.
 - When in inner block, outer definition is not available
 - Not a good idea

Two Variables with the Same Name in Program 4-30

Program 4-30

```
1 // This program uses two variables with the name number.
2 #include <iostream>
3 using namespace std;
4
5 int main()
6 {
7     // Define a variable named number.
8     int number;
9
10    cout << "Enter a number greater than 0: ";
11    cin >> number;
12    if (number > 0)
13    {
14        int number; // Another variable named number.
15        cout << "Now enter another number: ";
16        cin >> number;
17        cout << "The second number you entered was "
18             << number << endl;
19    }
20    cout << "Your first number was " << number << endl;
21    return 0;
22 }
```

Program Output with Example Input Shown in Bold

```
Enter a number greater than 0: 2 [Enter]
Now enter another number: 7 [Enter]
The second number you entered was 7
Your first number was 2
```

