

Aristides S. Bouras

# C# and Algorithmic Thinking for the Complete Beginner

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Revised  
2nd  
Edition

C# and Algorithmic Thinking for the Complete Beginner  
Learn to Think Like a Programmer

Revised Second Edition

By  
Aristides S. Bouras

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Revised Second Edition

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### **Warning and Disclaimer**

This book is designed to provide information about learning “Algorithmic Thinking”, mainly through the use of C# programming language. Every effort has been taken to make this book compatible with all releases of C#, and it is almost certain to be compatible with any future releases of it.

The information is provided on an “as is” basis. The authors shall have neither liability nor responsibility to any person or entity with respect to any loss or damages arising from the information contained in this book or from the use of the files that may accompany it.

# **Table of Contents**

## Preface

[About the Author](#)

[Acknowledgments](#)

[How This Book is Organized](#)

[Who Should Buy This Book?](#)

[Conventions Used in This Book](#)

[How to Report Errata](#)

[Where to Download Material About this Book](#)

## Section 1 Introductory Knowledge

[Chapter 1 How a Computer Works](#)

[1.1 Introduction](#)

[1.2 What is Hardware?](#)

[1.3 What is Software?](#)

[1.4 How a Computer Executes \(Runs\) a Program](#)

[1.5 Compilers and Interpreters](#)

[1.6 What is Source Code?](#)

[1.7 Review Questions: True/False](#)

[1.8 Review Questions: Multiple Choice](#)

[Chapter 2 C#](#)

[2.1 What is C#?](#)

[2.2 What is the Difference Between a Script and a Program?](#)

[2.3 Why You Should Learn C#](#)

[2.4 How C# Works](#)

[Chapter 3 Software Packages to Install](#)

[3.1 Visual Studio](#)

[3.2 How to Set Up Visual Studio Community on Windows](#)

[3.3 How to Set Up Visual Studio Code on Windows](#)

[3.4 How to Set Up Visual Studio Code on Linux](#)

[Review in “Introductory Knowledge”](#)

[Review Crossword Puzzles](#)

[Review Questions](#)

## Section 2 Getting Started with C#

[Chapter 4 Introduction to Basic Algorithmic Concepts](#)

[4.1 What is an Algorithm?](#)

- 4.2 The Algorithm for Making a Cup of Tea
- 4.3 Properties of an Algorithm
- 4.4 Okay About Algorithms. But What is a Computer Program Anyway?
- 4.5 The Three Parties!
- 4.6 The Three Main Stages Involved in Creating an Algorithm
- 4.7 Flowcharts
  - Exercise 4.7-1 Finding the Average Value of Three Numbers
- 4.8 What are "Reserved Words"?
- 4.9 What is the Difference Between a Statement and a Command?
- 4.10 What is Structured Programming?
- 4.11 The Three Fundamental Control Structures
  - Exercise 4.11-1 Understanding Control Structures Using Flowcharts
- 4.12 Your First C# Program
- 4.13 What is the Difference Between a Syntax Error, a Logic Error, and a Runtime Error?
- 4.14 Commenting Your Code
- 4.15 User-Friendly Programs
- 4.16 Review Questions: True/False
- 4.17 Review Questions: Multiple Choice

## Chapter 5 Variables and Constants

- 5.1 What is a Variable?
- 5.2 What is a Constant?
- 5.3 How Many Types of Variables and Constants Exist?
- 5.4 Rules for Naming Variables and Constants in C#
- 5.5 What Does the Phrase "Declare a Variable" Mean?
- 5.6 How to Declare Variables in C#
- 5.7 How to Declare Constants in C#
- 5.8 Review Questions: True/False
- 5.9 Review Questions: Multiple Choice
- 5.10 Review Exercises

## Chapter 6 Handling Input and Output

- 6.1 Which Statement Outputs Messages and Results on a User's Screen?
- 6.2 How to Output Special Characters
- 6.3 Which Statement Lets the User Enter Data?
- 6.4 Review Questions: True/False

## 6.5 Review Questions: Multiple Choice

### Chapter 7 Operators

7.1 The Value Assignment Operator

7.2 Arithmetic Operators

7.3 What is the Precedence of Arithmetic Operators?

7.4 Compound Assignment Operators

Exercise 7.4-1 Which C# Statements are Syntactically Correct?

Exercise 7.4-2 Finding Variable Types

7.5 Incrementing/Decrementing Operators

7.6 String Operators

Exercise 7.6-1 Concatenating Names

7.7 Review Questions: True/False

7.8 Review Questions: Multiple Choice

7.9 Review Exercises

### Chapter 8 Trace Tables

8.1 What is a Trace Table?

Exercise 8.1-1 Creating a Trace Table

Exercise 8.1-2 Swapping Values of Variables

Exercise 8.1-3 Swapping Values of Variables – An Alternative Approach

Exercise 8.1-4 Creating a Trace Table

Exercise 8.1-5 Creating a Trace Table

8.2 Review Questions: True/False

8.3 Review Exercises

### Chapter 9 Using Visual Studio Community

9.1 Writing and Executing a C# Program in Visual Studio Community

9.2 Writing and Executing a C# Program in Visual Studio Code

9.3 What “Debugging” Means

9.4 Debugging C# Programs with Visual Studio Community

9.5 Debugging C# Programs with Visual Studio Code

9.6 Review Exercises

### Review in “Getting Started with C#

Review Crossword Puzzles

Review Questions

## Section 3 Sequence Control Structures

### Chapter 10 Introduction to Sequence Control Structures

10.1 What is the Sequence Control Structure?

Exercise 10.1-1 Calculating the Area of a Rectangle  
Exercise 10.1-2 Calculating the Area of a Circle  
Exercise 10.1-3 Calculating Fuel Economy  
Exercise 10.1-4 Where is the Car? Calculating Distance Traveled  
Exercise 10.1-5 Kelvin to Fahrenheit  
Exercise 10.1-6 Calculating Sales Tax  
Exercise 10.1-7 Calculating a Sales Discount  
Exercise 10.1-8 Calculating the Sales Tax Rate and Discount

## 10.2 Review Exercises

### Chapter 11 Manipulating Numbers

11.1 Introduction  
11.2 Useful Mathematical Methods (Subprograms), and More  
Exercise 11.2-1 Calculating the Distance Between Two Points  
Exercise 11.2-2 How Far Did the Car Travel?  
11.3 Review Questions: True/False  
11.4 Review Questions: Multiple Choice  
11.5 Review Exercises

### Chapter 12 Complex Mathematical Expressions

12.1 Writing Complex Mathematical Expressions  
Exercise 12.1-1 Representing Mathematical Expressions in C#  
Exercise 12.1-2 Writing a Mathematical Expression in C#  
Exercise 12.1-3 Writing a Complex Mathematical Expression in C#

## 12.2 Review Exercises

### Chapter 13 Exercises With a Quotient and a Remainder

13.1 Introduction  
Exercise 13.1-1 Calculating the Quotient and Remainder of Integer Division  
Exercise 13.1-2 Finding the Sum of Digits  
Exercise 13.1-3 Displaying an Elapsed Time  
Exercise 13.1-4 Reversing a Number

## 13.2 Review Exercises

### Chapter 14 Manipulating Strings

14.1 Introduction  
14.2 The Position of a Character in a String  
14.3 Useful String Methods (Subprograms), and More  
Exercise 14.3-1 Displaying a String Backwards  
Exercise 14.3-2 Switching the Order of Names

Exercise 14.3-3 Creating a Login ID  
Exercise 14.3-4 Creating a Random Word  
Exercise 14.3-5 Finding the Sum of Digits  
14.4 Review Questions: True/False  
14.5 Review Questions: Multiple Choice  
14.6 Review Exercises

Review in “Sequence Control Structures”

Review Crossword Puzzle  
Review Questions

## Section 4 Decision Control Structures

Chapter 15 Making Questions

15.1 Introduction  
15.2 What is a Boolean Expression?  
15.3 How to Write Simple Boolean Expressions  
Exercise 15.3-1 Filling in the Table  
15.4 Logical Operators and Complex Boolean Expressions  
15.5 Assigning the Result of a Boolean Expression to a Variable  
15.6 What is the Order of Precedence of Logical Operators?  
15.7 What is the Order of Precedence of Arithmetic, Comparison, and Logical Operators?

Exercise 15.7-1 Filling in the Truth Table  
Exercise 15.7-2 Calculating the Results of Complex Boolean Expressions  
Exercise 15.7-3 Converting English Sentences to Boolean Expressions

15.8 How to Negate Boolean Expressions  
Exercise 15.8-1 Negating Boolean Expressions  
15.9 Review Questions: True/False  
15.10 Review Questions: Multiple Choice  
15.11 Review Exercises

Chapter 16 The Single-Alternative Decision Structure

16.1 The Single-Alternative Decision Structure  
Exercise 16.1-1 Trace Tables and Single-Alternative Decision Structures  
Exercise 16.1-2 The Absolute Value of a Number  
16.2 Review Questions: True/False  
16.3 Review Questions: Multiple Choice

## 16.4 Review Exercises

### Chapter 17 The Dual-Alternative Decision Structure

#### 17.1 The Dual-Alternative Decision Structure

Exercise 17.1-1 Finding the Output Message

Exercise 17.1-2 Trace Tables and Dual-Alternative Decision Structures

Exercise 17.1-3 Who is the Greatest?

Exercise 17.1-4 Finding Odd and Even Numbers

Exercise 17.1-5 Weekly Wages

#### 17.2 Review Questions: True/False

#### 17.3 Review Questions: Multiple Choice

#### 17.4 Review Exercises

### Chapter 18 The Multiple-Alternative Decision Structure

#### 18.1 The Multiple-Alternative Decision Structure

Exercise 18.1-1 Trace Tables and Multiple-Alternative Decision Structures

Exercise 18.1-2 Counting the Digits

#### 18.2 Review Questions: True/False

#### 18.3 Review Exercises

### Chapter 19 The Case Decision Structure

#### 19.1 The Case Decision Structure

Exercise 19.1-1 The Days of the Week

#### 19.2 Review Questions: True/False

#### 19.3 Review Exercises

### Chapter 20 Nested Decision Control Structures

#### 20.1 What are Nested Decision Control Structures?

Exercise 20.1-1 Trace Tables and Nested Decision Control Structures

Exercise 20.1-2 Positive, Negative or Zero?

#### 20.2 A Mistake That You Will Probably Make!

#### 20.3 Review Questions: True/False

#### 20.4 Review Exercises

### Chapter 21 More about Flowcharts with Decision Control Structures

#### 21.1 Introduction

#### 21.2 Converting C# Programs to Flowcharts

Exercise 21.2-1 Designing the Flowchart

Exercise 21.2-2 Designing the Flowchart

Exercise 21.2-3 Designing the Flowchart

21.3 Converting Flowcharts to C# Programs

Exercise 21.3-1 Writing the C# Program

Exercise 21.3-2 Writing the C# Program

Exercise 21.3-3 Writing the C# Program

21.4 Review Exercises

Chapter 22 Tips and Tricks with Decision Control Structures

22.1 Introduction

22.2 Choosing a Decision Control Structure

22.3 Streamlining the Decision Control Structure

Exercise 22.3-1 “Shrinking” the Algorithm

Exercise 22.3-2 “Shrinking” the C# Program

Exercise 22.3-3 “Shrinking” the Algorithm

22.4 Logical Operators – to Use, or not to Use: That is the Question!

Exercise 22.4-1 Rewriting the Code

Exercise 22.4-2 Rewriting the Code

22.5 Merging Two or More Single-Alternative Decision Structures

Exercise 22.5-1 Merging the Decision Control Structures

Exercise 22.5-2 Merging the Decision Control Structures

22.6 Replacing Two Single-Alternative Decision Structures with a Dual-Alternative One

Exercise 22.6-1 “Merging” the Decision Control Structures

22.7 Put the Boolean Expressions Most Likely to be True First

Exercise 22.7-1 Rearranging the Boolean Expressions

22.8 Why is Code Indentation so Important?

22.9 Review Questions: True/False

22.10 Review Questions: Multiple Choice

22.11 Review Exercises

Chapter 23 More Exercises with Decision Control Structures

23.1 Simple Exercises with Decision Control Structures

Exercise 23.1-1 Both Odds or Both Evens?

Exercise 23.1-2 Is it an Integer?

Exercise 23.1-3 Validating Data Input and Finding Odd and Even Numbers

Exercise 23.1-4 Converting Gallons to Liters, and Vice Versa

Exercise 23.1-5 Converting Gallons to Liters, and Vice Versa (with Data Validation)

**Exercise 23.1-6 Where is the Tollkeeper?**

**Exercise 23.1-7 The Most Scientific Calculator Ever!**

## **23.2 Decision Control Structures in Solving Mathematical Problems**

**Exercise 23.2-1 Finding the Value of y**

**Exercise 23.2-2 Finding the Values of y**

**Exercise 23.2-3 Solving the Linear Equation  $ax + b = 0$**

**Exercise 23.2-4 Solving the Quadratic Equation  $ax^2 + bx + c = 0$**

## **23.3 Finding Minimum and Maximum Values with Decision Control Structures**

**Exercise 23.3-1 Finding the Name of the Heaviest Person**

## **23.4 Exercises with Series of Consecutive Ranges of Values**

**Exercise 23.4-1 Calculating the Discount**

**Exercise 23.4-2 Validating Data Input and Calculating the Discount**

**Exercise 23.4-3 Sending a Parcel**

**Exercise 23.4-4 Finding the Values of y**

**Exercise 23.4-5 Progressive Rates and Electricity Consumption**

**Exercise 23.4-6 Progressive Rates and Text Messaging Services**

## **23.5 Exercises of a General Nature with Decision Control Structures**

**Exercise 23.5-1 Finding a Leap Year**

**Exercise 23.5-2 Displaying the Days of the Month**

**Exercise 23.5-3 Is the Number a Palindrome?**

**Exercise 23.5-4 Checking for Proper Capitalization and Punctuation**

## **23.6 Review Exercises**

**Review in “Decision Control Structures”**

**Review Crossword Puzzle**

**Review Questions**

## **Section 5 Loop Control Structures**

**Chapter 24 Introduction to Loop Control Structures**

**24.1 What is a Loop Control Structure?**

**24.2 From Sequence Control to Loop Control Structures**

**24.3 Review Questions: True/False**

**Chapter 25 Pre-Test, Mid-Test and Post-Test Loop Structures**

**25.1 The Pre-Test Loop Structure**

**Exercise 25.1-1 Designing the Flowchart and Counting the Total Number of Iterations**

**Exercise 25.1-2 Counting the Total Number of Iterations**

**Exercise 25.1-3 Designing the Flowchart and Counting the Total**

## Number of Iterations

Exercise 25.1-4 Counting the Total Number of Iterations

Exercise 25.1-5 Finding the Sum of Four Numbers

Exercise 25.1-6 Finding the Sum of Odd Numbers

Exercise 25.1-7 Finding the Sum of N Numbers

Exercise 25.1-8 Finding the Sum of an Unknown Quantity of Numbers

Exercise 25.1-9 Finding the Product of 20 Numbers

## 25.2 The Post-Test Loop Structure

Exercise 25.2-1 Designing the Flowchart and Counting the Total Number of Iterations

Exercise 25.2-2 Counting the Total Number of Iterations

Exercise 25.2-3 Designing the Flowchart and Counting the Total Number of Iterations

Exercise 25.2-4 Counting the Total Number of Iterations

Exercise 25.2-5 Finding the Product of N Numbers

## 25.3 The Mid-Test Loop Structure

Exercise 25.3-1 Designing the Flowchart and Counting the Total Number of Iterations

## 25.4 Review Questions: True/False

## 25.5 Review Questions: Multiple Choice

## 25.6 Review Exercises

# Chapter 26 The for statement

## 26.1 The for statement

Exercise 26.1-1 Creating the Trace Table

Exercise 26.1-2 Creating the Trace Table

Exercise 26.1-3 Counting the Total Number of Iterations

Exercise 26.1-4 Finding the Sum of Four Numbers

Exercise 26.1-5 Finding the Square Roots from 0 to N

Exercise 26.1-6 Finding the Sum of  $1 + 2 + 3 + \dots + 100$

Exercise 26.1-7 Finding the Product of  $2 \times 4 \times 6 \times 8 \times 10$

Exercise 26.1-8 Finding the Sum of  $2^2 + 4^2 + 6^2 + \dots + (2N)^2$

Exercise 26.1-9 Finding the Sum of  $3^3 + 6^3 + 9^3 + \dots + (3N)^3$

Exercise 26.1-10 Finding the Average Value of Positive Numbers

Exercise 26.1-11 Counting the Vowels

## 26.2 Rules that Apply to For-Loops

Exercise 26.2-1 Counting the Total Number of Iterations

Exercise 26.2-2 Counting the Total Number of Iterations  
Exercise 26.2-3 Counting the Total Number of Iterations  
Exercise 26.2-4 Counting the Total Number of Iterations  
Exercise 26.2-5 Finding the Sum of N Numbers

26.3 Review Questions: True/False  
26.4 Review Questions: Multiple Choice  
26.5 Review Exercises

## Chapter 27 Nested Loop Control Structures

27.1 What is a Nested Loop?  
Exercise 27.1-1 Say “Hello Zeus”. Counting the Total Number of Iterations.  
Exercise 27.1-2 Creating the Trace Table  
27.2 Rules that Apply to Nested Loops  
Exercise 27.2-1 Breaking the First Rule  
Exercise 27.2-2 Counting the Total Number of Iterations  
27.3 Review Questions: True/False  
27.4 Review Questions: Multiple Choice  
27.5 Review Exercises

## Chapter 28 Tips and Tricks with Loop Control Structures

28.1 Introduction  
28.2 Choosing a Loop Control Structure  
28.3 The “Ultimate” Rule  
28.4 Breaking Out of a Loop  
28.5 Cleaning Out Your Loops  
Exercise 28.5-1 Cleaning Out the Loop  
Exercise 28.5-2 Cleaning Out the Loop  
28.6 Endless Loops and How to Avoid Them  
28.7 The “From Inner to Outer” Method  
28.8 Review Questions: True/False  
28.9 Review Questions: Multiple Choice  
28.10 Review Exercises

## Chapter 29 Flowcharts with Loop Control Structures

29.1 Introduction  
29.2 Converting C# Programs to Flowcharts  
Exercise 29.2-1 Designing the Flowchart Fragment  
Exercise 29.2-2 Designing the Flowchart Fragment  
Exercise 29.2-3 Designing the Flowchart

[Exercise 29.2-4 Designing the Flowchart Fragment](#)

[Exercise 29.2-5 Designing the Flowchart](#)

[Exercise 29.2-6 Designing the Flowchart](#)

### [29.3 Converting Flowcharts to C# Programs](#)

[Exercise 29.3-1 Writing the C# Program](#)

[Exercise 29.3-2 Writing the C# Program](#)

[Exercise 29.3-3 Writing the C# Program](#)

[Exercise 29.3-4 Writing the C# Program](#)

### [29.4 Review Exercises](#)

## [Chapter 30 More Exercises with Loop Control Structures](#)

### [30.1 Simple Exercises with Loop Control Structures](#)

[Exercise 30.1-1 Counting the Numbers According to Which is Greater](#)

[Exercise 30.1-2 Counting the Numbers According to Their Digits](#)

[Exercise 30.1-3 How Many Numbers Fit in a Sum](#)

[Exercise 30.1-4 Finding the Total Number of Positive Integers](#)

[Exercise 30.1-5 Iterating as Many Times as the User Wishes](#)

[Exercise 30.1-6 Finding the Sum of the Digits](#)

### [30.2 Exercises with Nested Loop Control Structures](#)

[Exercise 30.2-1 Displaying all Three-Digit Integers that Contain a Given Digit](#)

[Exercise 30.2-2 Displaying all Instances of a Specified Condition](#)

### [30.3 Data Validation with Loop Control Structures](#)

[Exercise 30.3-1 Finding Odd and Even Numbers - Validation Without Error Messages](#)

[Exercise 30.3-2 Finding Odd and Even Numbers - Validation with One Error Message](#)

[Exercise 30.3-3 Finding Odd and Even Numbers - Validation with Individual Error Messages](#)

[Exercise 30.3-4 Finding the Sum of Four Numbers](#)

### [30.4 Using Loop Control Structures to Solve Mathematical Problems](#)

[Exercise 30.4-1 Calculating the Area of as Many Triangles as the User Wishes](#)

[Exercise 30.4-2 Finding x and y](#)

[Exercise 30.4-3 The Russian Multiplication Algorithm](#)

[Exercise 30.4-4 Finding the Number of Divisors](#)

[Exercise 30.4-5 Is the Number a Prime?](#)

- Exercise 30.4-6 Finding all Prime Numbers from 1 to N
    - Exercise 30.4-7 Heron's Square Root
    - Exercise 30.4-8 Calculating  $\pi$
    - Exercise 30.4-9 Approximating a Real with a Fraction
  - 30.5 Finding Minimum and Maximum Values with Loop Control Structures
    - Exercise 30.5-1 Validating and Finding the Minimum and the Maximum Value
    - Exercise 30.5-2 Validating and Finding the Hottest Planet
    - Exercise 30.5-3 "Making the Grade"
  - 30.6 Exercises of a General Nature with Loop Control Structures
    - Exercise 30.6-1 Fahrenheit to Kelvin, from 0 to 100
    - Exercise 30.6-2 Rice on a Chessboard
    - Exercise 30.6-3 Just a Poll
    - Exercise 30.6-4 Is the Message a Palindrome?
  - 30.7 Review Questions: True/False
  - 30.8 Review Exercises
    - Review in "Loop Control Structures"
      - Review Crossword Puzzle
      - Review Questions
- ## Section 6 Data Structures in C#
- Chapter 31 One-Dimensional Arrays and Dictionaries
    - 31.1 Introduction
    - 31.2 What is an Array?
      - Exercise 31.2-1 Designing an Array
      - Exercise 31.2-2 Designing Arrays
      - Exercise 31.2-3 Designing Arrays
    - 31.3 Creating One-Dimensional Arrays in C#
    - 31.4 How to Get Values from a One-Dimensional Array
      - Exercise 31.4-1 Creating the Trace Table
      - Exercise 31.4-2 Using a Non-Existing Index
    - 31.5 How to Alter the Value of an Array Element
    - 31.6 How to Iterate Through a One-Dimensional Array
      - Exercise 31.6-1 Finding the Sum
    - 31.7 How to Add User-Entered Values to a One-Dimensional Array
      - Exercise 31.7-1 Displaying Words in Reverse Order
      - Exercise 31.7-2 Displaying Positive Numbers in Reverse Order

- Exercise 31.7-3 Finding the Average Value**
- Exercise 31.7-4 Displaying Reals Only**
- Exercise 31.7-5 Displaying Elements with Odd-Numbered Indexes**
- Exercise 31.7-6 Displaying Even Numbers in Odd-Numbered Index Positions**
- 31.8 What is a Dictionary?**
- 31.9 Creating Dictionaries in C#**
- 31.10 How to Get a Value from a Dictionary**
  - Exercise 31.10-1 Using a Non-Existing Key in Dictionaries**
- 31.11 How to Alter the Value of a Dictionary Element**
  - Exercise 31.11-1 Assigning a Value to a Non-Existing Key**
- 31.12 How to Iterate Through a Dictionary**
- 31.13 Review Questions: True/False**
- 31.14 Review Questions: Multiple Choice**
- 31.15 Review Exercises**

## **Chapter 32 Two-Dimensional Arrays**

- 32.1 Creating Two-Dimensional Arrays in C#**
- 32.2 How to Get Values from Two-Dimensional Arrays**
  - Exercise 32.2-1 Creating the Trace Table**
- 32.3 How to Iterate Through a Two-Dimensional Array**
- 32.4 How to Add User-Entered Values to a Two-Dimensional Array**
  - Exercise 32.4-1 Displaying Reals Only**
  - Exercise 32.4-2 Displaying Odd Columns Only**
- 32.5 What's the Story on Variables i and j?**
- 32.6 Square Matrices**
  - Exercise 32.6-1 Finding the Sum of the Elements of the Main Diagonal**
  - Exercise 32.6-2 Finding the Sum of the Elements of the Antidiagonal**
  - Exercise 32.6-3 Filling in the Array**
- 32.7 Review Questions: True/False**
- 32.8 Review Questions: Multiple Choice**
- 32.9 Review Exercises**

## **Chapter 33 Tips and Tricks with Arrays**

- 33.1 Introduction**
- 33.2 Processing Each Row Individually**
  - Exercise 33.2-1 Finding the Average Value**

### 33.3 Processing Each Column Individually

Exercise 33.3-1 Finding the Average Value

### 33.4 How to Use More Than One Data Structures in a Program

Exercise 33.4-1 Finding the Average Value of Two Grades

Exercise 33.4-2 Finding the Average Value of More than Two Grades

Exercise 33.4-3 Using an Array Along with a Dictionary

### 33.5 Creating a One-Dimensional Array from a Two-Dimensional Array

### 33.6 Creating a Two-Dimensional Array from a One-Dimensional Array

### 33.7 Review Questions: True/False

### 33.8 Review Questions: Multiple Choice

### 33.9 Review Exercises

## Chapter 34 More Exercises with Arrays

### 34.1 Simple Exercises with Arrays

Exercise 34.1-1 Creating an Array that Contains the Average Values of its Neighboring Elements

Exercise 34.1-2 Creating an Array with the Greatest Values

Exercise 34.1-3 Merging One-Dimensional Arrays

Exercise 34.1-4 Merging Two-Dimensional Arrays

Exercise 34.1-5 Creating Two Arrays – Separating Positive from Negative Values

Exercise 34.1-6 Creating an Array with Those who Contain Digit 5

### 34.2 Data Validation with Arrays

Exercise 34.2-1 Displaying Odds in Reverse Order – Validation Without Error Messages

Exercise 34.2-2 Displaying Odds in Reverse Order – Validation with One Error Message

Exercise 34.2-3 Displaying Odds in Reverse Order – Validation with Individual Error Messages

### 34.3 Finding Minimum and Maximum Values in Arrays

Exercise 34.3-1 Which Depth is the Greatest?

Exercise 34.3-2 Which Lake is the Deepest?

Exercise 34.3-3 Which Lake, in Which Country, Having Which Average Area, is the Deepest?

Exercise 34.3-4 Which Students Have got the Greatest Grade?

**Exercise 34.3-5 Finding the Minimum Value of a Two-Dimensional Array**

**Exercise 34.3-6 Finding the City with the Coldest Day**

**Exercise 34.3-7 Finding the Minimum and the Maximum Value of Each Row**

### **34.4 Sorting Arrays**

**Exercise 34.4-1 The Bubble Sort Algorithm – Sorting One-Dimensional Arrays with Numeric Values**

**Exercise 34.4-2 Sorting One-Dimensional Arrays with Alphanumeric Values**

**Exercise 34.4-3 Sorting One-Dimensional Arrays While Preserving the Relationship with a Second Array**

**Exercise 34.4-4 Sorting Last and First Names**

**Exercise 34.4-5 Sorting a Two-Dimensional Array**

**Exercise 34.4-6 The Modified Bubble Sort Algorithm – Sorting One-Dimensional Arrays**

**Exercise 34.4-7 The Five Best Scorers**

**Exercise 34.4-8 The Selection Sort Algorithm – Sorting One-Dimensional Arrays**

**Exercise 34.4-9 Sorting One-Dimensional Arrays While Preserving the Relationship with a Second Array**

**Exercise 34.4-10 The Insertion Sort Algorithm – Sorting One-Dimensional Arrays**

**Exercise 34.4-11 The Three Worst Elapsed Times**

### **34.5 Searching Elements in Data Structures**

**Exercise 34.5-1 The Linear Search Algorithm – Searching in a One-Dimensional Array that may Contain the Same Value Multiple Times**

**Exercise 34.5-2 Display the Last Names of All Those People Who Have the Same First Name**

**Exercise 34.5-3 The Linear Search Algorithm – Searching in a One-Dimensional Array that Contains Unique Values**

**Exercise 34.5-4 Searching for a Given Social Security Number**

**Exercise 34.5-5 The Linear Search Algorithm – Searching in a Two-Dimensional Array that May Contain the Same Value Multiple Times**

**Exercise 34.5-6 Searching for Wins, Losses and Ties**

Exercise 34.5-7 The Linear Search Algorithm – Searching in a Two-Dimensional Array that Contains Unique Values

Exercise 34.5-8 Checking if a Value Exists in all Columns

Exercise 34.5-9 The Binary Search Algorithm – Searching in a Sorted One-Dimensional Array

Exercise 34.5-10 Display all the Historical Events for a Country

Exercise 34.5-11 Searching in Each Column of a Two-Dimensional Array

### 34.6 Exercises of a General Nature with Arrays

Exercise 34.6-1 On Which Days was There a Possibility of Snow?

Exercise 34.6-2 Was There Any Possibility of Snow?

Exercise 34.6-3 In Which Cities was There a Possibility of Snow?

Exercise 34.6-4 Display from Highest to Lowest Grades by Student, and in Alphabetical Order

Exercise 34.6-5 Archery at the Summer Olympics

### 34.7 Review Questions: True/False

### 34.8 Review Exercises

Review in “Data Structures in C#

Review Crossword Puzzle

Review Questions

## Section 7 Subprograms

Chapter 35 Introduction to Subprograms

35.1 What Exactly is a Subprogram?

35.2 What is Procedural Programming?

35.3 What is Modular Programming?

35.4 Review Questions: True/False

Chapter 36 User-Defined Subprograms

36.1 Subprograms that Return Values

36.2 How to Make a Call to a Method

36.3 Subprograms that Return no Values

36.4 How to Make a Call to a void Method

36.5 Formal and Actual Arguments

36.6 How Does a Method Execute?

Exercise 36.6-1 Back to Basics – Calculating the Sum of Two Numbers

Exercise 36.6-2 Calculating the Sum of Two Numbers Using Fewer Lines of Code!

## 36.7 How Does a void Method Execute?

Exercise 36.7-1 Back to Basics – Displaying the Absolute Value of a Number

## 36.8 Review Questions: True/False

## 36.9 Review Exercises

# Chapter 37 Tips and Tricks with Subprograms

37.1 Can Two Subprograms use Variables of the Same Name?

37.2 Can a Subprogram Call Another Subprogram?

37.3 Passing Arguments by Value and by Reference

Exercise 37.3-1 Finding the Logic Error

37.4 Passing and/or Returning an Array

37.5 Default Argument Values (Optional Arguments) and Named Arguments

37.6 Overloading Methods

37.7 The Scope of a Variable

37.8 Converting Parts of Code into Subprograms

37.9 Recursion

Exercise 37.9-1 Calculating the Fibonacci Sequence Recursively

37.10 Review Questions: True/False

37.11 Review Exercises

# Chapter 38 More Exercises with Subprograms

## 38.1 Simple Exercises with Subprograms

Exercise 38.1-1 Designing the Flowchart

Exercise 38.1-2 Designing the Flowchart

Exercise 38.1-3 A Simple Currency Converter

Exercise 38.1-4 A More Complete Currency Converter

Exercise 38.1-5 Finding the Average Values of Positive Integers

Exercise 38.1-6 Finding the Sum of Odd Positive Integers

Exercise 38.1-7 Finding the Values of y

## 38.2 Exercises of a General Nature with Subprograms

Exercise 38.2-1 Validating Data Input Using a Subprogram

Exercise 38.2-2 Sorting an Array Using a Subprogram

Exercise 38.2-3 Progressive Rates and Electricity Consumption

Exercise 38.2-4 Roll, Roll, Roll the... Dice!

Exercise 38.2-5 How Many Times Does Each Number of the Dice Appear?

## 38.3 Review Exercises

Review in “Subprograms”

Review Crossword Puzzle

Review Questions

## Section 8 Object-Oriented Programming

Chapter 39 Introduction to Object-Oriented Programming

39.1 What is Object-Oriented Programming?

39.2 Classes and Objects in C#

39.3 The Constructor and the Keyword this

39.4 Passing Initial Values to the Constructor

Exercise 39.4-1 Historical Events

39.5 Getter and Setter Methods vs Properties

Exercise 39.5-1 The Roman Numerals

39.6 Can a Method Call Another Method of the Same Class?

Exercise 39.6-1 Doing Math

39.7 Class Inheritance

39.8 Review Questions: True/False

39.9 Review Exercises

Review in “Object-Oriented Programming”

Review Crossword Puzzle

Review Questions

Some Final Words from the Author

# Preface

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## About the Author

Aristides<sup>[1]</sup> S. Bouras was born in 1973. During his early childhood, he discovered a love of computer programming. He got his first computer at the age of 12, a Commodore 64, which incorporated a ROM-based version of the BASIC programming language and 64 kilobytes of RAM!!!

He holds a degree in Computer Engineering from the Technological Educational Institute of Piraeus, and a Dipl. Eng. degree in Electrical and Computer Engineering from the Democritus University of Thrace.

He worked as a software developer at a company that specialized in industrial data flow and labelling of products. His main job was to develop software applications for data terminals, as well as PC software applications for collecting and storing data on a Microsoft SQL Server®.

He has developed many applications such as warehouse managing systems and websites for companies and other organizations. Nowadays, he works as a high school teacher. He mainly teaches courses in computer networks, programming tools for the Internet/intranets, and databases.

He has written a number of books, mainly about algorithmic and computational thinking through the use of Python, C#, Java, C++, PHP, and Visual Basic programming languages.

He is married and he has two children.

## Acknowledgments

I would like to thank, with particular gratefulness, my friend and senior editor Victoria (Vicki) Austin for her assistance in copy editing. Without her, this book might not have reached its full potential. With her patient guidance and valuable and constructive suggestions, she helped me bring this book up to a higher level!

## How This Book is Organized

The book you hold in your hands follows the spiral curriculum teaching approach, a method proposed in 1960 by Jerome Bruner, an American psychologist. According to this method, as a subject is being taught, basic ideas are revisited at intervals—at a more sophisticated level each time—until the reader achieves a complete understanding of the subject. First, the reader learns the basic elements without worrying about the details. Later, more details are taught and basic elements are mentioned again and again, eventually being stored in the brain's long term memory.

According to Jerome Bruner, learning requires the student's active participation, experimentation, exploration, and discovery. This book contains many examples, most of which can be practically performed. This gives the reader the opportunity to get his or her hands on C# and become capable of creating his or her own programs.

## Who Should Buy This Book?

Thoroughly revised for the latest version of C#, this book explains basic concepts in a clear and explicit way that takes very seriously one thing for granted—that the reader knows nothing about computer programming.

Addressed to anyone who has no prior programming knowledge or experience, but a desire to learn programming with C#, it teaches the first thing that every novice programmer needs to learn, which is *Algorithmic Thinking*. Algorithmic Thinking involves more than just learning code. It is a problem-solving process that involves learning *how to code*.

This edition contains all the popular features of the previous edition and adds a significant number of exercises, as well as extensive revisions and updates. Apart from C# 's arrays, it now also covers dictionaries, while a brand new section provides an effective introduction to the next field that a

programmer needs to work with, which is Object Oriented Programming (OOP).

This book has a class course structure with questions and exercises at the end of each chapter so you can test what you have learned right away and improve your comprehension. With 250 solved and 450 unsolved exercises, 475 True/False, about 150 multiple choice, and 200 review questions and crosswords (the solutions and the answers to which can be found on the Internet), this book is ideal for

- ▶ novices or average programmers, for self-study
- ▶ high school students
- ▶ first-year college or university students
- ▶ teachers
- ▶ professors
- ▶ anyone who wants to start learning or teaching computer programming using the proper conventions and techniques

## Conventions Used in This Book

Following are some explanations on the conventions used in this book. “Conventions” refer to the standard ways in which certain parts of the text are displayed.

### C# Statements

This book uses plenty of examples written in C# language. C# statements are shown in a typeface that looks like this.

| This is a C# statement

### Keywords, Variables, Methods, and Arguments Within the Text of a Paragraph

Keywords, variables, methods (subprograms), and arguments are sometimes shown within the text of a paragraph. When they are, the special text is shown in a typeface different from that of the rest of the paragraph. For instance, `first_name = 5` is an example of a C# statement within the paragraph text.

### Words in Italics

You may notice that some of the special text is also displayed in italics. In this book, italicized words are general types that must be replaced with the specific name appropriate for your data. For example, the general form of a C# statement may be presented as

| `static void name(type1 arg1, type2 arg2 )`

In order to complete the statement, the keywords `name`, `type1`, `arg1`, `type2`, and `arg2` must be replaced with something meaningful. When you use this statement in your program, you might use it in the following form.

| `static void display_rectangle(int width, int height)`

### Three dots (...): an Ellipsis

In the general form of a statement you may also notice three dots ( ... ), also known as an “ellipsis”, following a list in an example. They are not part of the statement. An ellipsis indicates that you can have as many items in the list as you want. For example, the ellipsis in the general form of the statement

| `display_messages(arg1, arg2, ... );`

indicates that the list may contain more than two arguments. When you use

this statement in your program, your statement might be something like this.

```
display_messages(message1, "Hello", message2, "Hi!");
```

## Square Brackets

The general form of some statements or methods (subprograms) may contain “square brackets” [ ], which indicate that the enclosed section is optional. For example, the general form of the statement

```
str.Substring(beginIndex [, endIndex] )
```

indicates that the section [, endIndex] can be omitted.

The following two statements produce different results but they are both syntactically correct.

```
a = str.Substring(3);  
b = str.Substring(3, 9);
```

## The Dark Header

Most of this book's examples are shown in a typeface that looks like this.

□ project\_29\_2\_3

```
static void Main(string[] args) {  
    int a, b;  
  
    a = 1;  
    b = 2;  
    Console.WriteLine(a + b);  
}
```

The header □ project\_29\_2\_3 on top indicates the filename that you must open to test the program. All the examples that contain this header can be found free of charge on my website.

## Notices

Very often this book uses notices to help you better understand the meaning of a concept. Notices look like this.

✎ This typeface designates a note.

## Something Already Known or Something to Remember

Very often this book can help you recall something you have already learned (probably in a previous chapter). Other times, it will draw your attention to something you should memorize. Reminders look like this.

 This typeface designates something to recall or something that you should memorize.

## How to Report Errata

Although I have taken great care to ensure the accuracy of the content of this book, mistakes do occur. If you find a mistake in this book, either in the text or the code, I encourage you to report it to me. By doing so, you can save other readers from frustration and, of course, help me to improve the next release of this book. If you find any errata, please feel free to report them by visiting the following address:

<https://www.bouraspage.com/report-errata>

Once your errata are verified, your submission will be accepted and the errata will be uploaded to my website, and added to any existing list of errata.

## Where to Download Material About this Book

Material about this book, such as:

- ▶ a list of verified errata (if any);
- ▶ the answers to all of the review questions, as well as the solutions to all review exercises; and
- ▶ all of this book's examples that have a header like this  **project\_29\_2\_3** on top

can be downloaded free of charge from the following address:

<https://bit.ly/2Xi8dCQ>

# **Section 1**

## **Introductory Knowledge**

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# **Chapter 1**

## **How a Computer Works**

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### **1.1 Introduction**

In today's society, almost every task requires the use of a computer. In schools, students use computers to search the Internet and to send emails. At work, people use them to make presentations, to analyze data, and to communicate with customers. At home, people use computers to play games, to connect to social networks and to chat with other people all over the world. Of course, don't forget smartphones such as iPhones. They are computers as well!

Computers can perform so many different tasks because of their ability to be programmed. In other words, a computer can perform any job that a program tells it to. A *program* is a set of *statements* (often called *instructions* or *commands*) that a computer follows in order to perform a specific task.

Programs are essential to a computer, because without them a computer is a dummy machine that can do nothing at all. It is the program that actually tells the computer what to do and when to do it. On the other hand, the *programmer* or the *software developer* is the person who designs, creates, and often tests computer programs.

This book introduces you to the basic concepts of computer programming using the C# language.

### **1.2 What is Hardware?**

The term *hardware* refers to all devices or components that make up a computer. If you have ever opened the case of a computer or a laptop you have probably seen many of its components, such as the microprocessor (CPU), the memory, and the hard disk. A computer is not a device but a system of devices that all work together. The basic components of a typical computer system are discussed here.

#### **► The Central Processing Unit (CPU)**

This is the part of a computer that actually performs all the tasks defined in a program (basic arithmetic, logical, and input/output operations).

### ► **Main Memory (RAM – Random Access Memory)**

This is the area where the computer holds the program (while it is being executed/run) as well as the data that the program is working with. All programs and data stored in this type of memory are lost when you shut down your computer or you unplug it from the wall outlet.

### ► **Main Memory (ROM – Read Only Memory)**

ROM or Read Only Memory is a special type of memory which can only be *read* by the computer (but cannot be changed). All programs and data stored in this type of memory are **not** lost when the computer is switched off. ROM usually contains manufacturer's instructions as well as a program called the *bootstrap loader* whose function is to start the operation of computer system once the power is turned on.

### ► **Secondary Storage Devices**

This is usually the hard disk or the SSD (Solid State Drive), and sometimes (but more rarely) the CD/DVD drive. In contrast to main memory, this type of memory can hold data for a longer period of time, even if there is no power to the computer. However, programs stored in this memory cannot be directly executed. They must be transferred to a much faster memory; that is, the main memory.'

### ► **Input Devices**

Input devices are all those devices that collect data from the outside world and enter them into the computer for further processing.

Keyboards, mice, and microphones are all input devices.

### ► **Output Devices**

Output devices are all those devices that output data to the outside world. Monitors (screens) and printers are output devices.

## **1.3 What is Software?**

Everything that a computer does is controlled by software. There are two categories of software: system software and application software.

- *System software* is the program that controls and manages the basic operations of a computer. For example, system software controls the computer's internal operations. It manages all devices that are connected to it, and it saves data, loads data, and allows other programs

to be executed. The three main types of system software are:

- ▶ the *operating system*. Windows, Linux, macOS, Android, and iOS are all examples of operating systems.
- ▶ the *utility software*. This type of software is usually installed with the operating system. It is used to make the computer run as efficiently as possible. Antivirus utilities and backup utilities are considered utility software.
- ▶ the *device driver software*. A device driver controls a device that is attached to your computer, such as a mouse or a graphic card. A device driver is a program that acts like a translator. It translates the instructions of the operating system to instructions that a device can actually understand.
- ▶ *Application software* refers to all the other programs that you use for your everyday tasks, such as browsers, word processors, notepads, games, and many more.

## 1.4 How a Computer Executes (Runs) a Program

When you turn on your computer, the main memory (RAM) is completely empty. The first thing the computer needs to do is to transfer the operating system from the hard disk to the main memory.

After the operating system is loaded to main memory, you can execute (run) any program (application software) you like. This is usually done by clicking, double clicking, or tapping the program's corresponding icon. For example, let's say you click on the icon of your favorite word processor. This action orders your computer to copy (or load) the word processing program from your hard disk to the main memory (RAM) so the CPU can execute it.

 Programs are stored on secondary storage devices such as hard disks. When you install a program on your computer, the program is copied to your hard disk. Then, when you execute a program, the program is copied (loaded) from your hard disk to the main memory (RAM), and that copy of the program is executed.

 The terms “run” and “execute” are synonymous.

## 1.5 Compilers and Interpreters

Computers can execute programs that are written in a strictly defined computer language. You cannot write a program using a natural language such as English or Greek, because your computer won't understand you!

But what does a computer actually understand? A computer can understand a specific low-level language called the *machine language*. In a machine language all statements (or commands) are made up of zeros and ones. The following is an example of a program written in a machine language, that calculates the sum of two numbers.

```
0010 0001 0000 0100  
0001 0001 0000 0101  
0011 0001 0000 0110  
0111 0000 0000 0001
```

Shocked? Don't worry, you are not going to write programs this way. Hopefully, no one writes computer programs this way anymore. Nowadays, all programmers write their programs in a high-level language and then they use a special program to translate them into a machine language.

 A *high-level language* is one that is not limited to a particular type of computer.

There are two types of programs that programmers use to perform translation: compilers and interpreters.

A *compiler* is a program that translates statements written in a high-level language into a separate machine language program. You can then execute the machine language program any time you wish. After the translation, there is no need to run the compiler again unless you make changes in the high-level language program.

An *interpreter* is a program that simultaneously translates and executes the statements written in a high-level language. As the interpreter reads each individual statement in the high-level language program, it translates it into a machine language code and then directly executes it. This process is repeated for every statement in the program.

## 1.6 What is Source Code?

The statements (often called instructions or commands) that the programmer

writes in a high-level language are called *source code* or simply *code*. The programmer first types the source code into a program known as a *code editor*, and then uses either a compiler to translate it into a machine language program, or an interpreter to translate and execute it at the same time.

Visual Studio® is an example of an Integrated Development Environment (IDE) that enables programmers to both write and execute their source code. You will learn more about Visual Studio in [Chapter 3](#).

 *C# programs can even be written in a simple text editor!*

## 1.7 Review Questions: True/False

Choose **true** or **false** for each of the following statements.

1. Modern computers can perform so many different tasks because they have many gigabytes of RAM.
2. A computer can operate without a program.
3. A hard disk is an example of hardware.
4. Data can be stored in main memory (RAM) for a long period of time, even if there is no power to the computer.
5. Data is stored in main memory (RAM), but programs are not.
6. Speakers are an example of an output device.
7. Windows and Linux are examples of software.
8. A media player is an example of system software.
9. When you turn on your computer, the main memory (RAM) already contains the operating system.
10. When you open your word processing application, it is actually copied from a secondary storage device to the main memory (RAM).
11. In a machine language, all statements (commands) are a sequence of zeros and ones.
12. Nowadays, a computer cannot understand zeros and ones.
13. Nowadays, software is written in a language composed of ones and zeros.
14. Software refers to the physical components of a computer.
15. The compiler and the interpreter are software.

16. The compiler translates source code to an executable file.
17. The interpreter creates a machine language program.
18. After the translation, the interpreter is not required anymore.
19. Source code can be written using a simple text editor.
20. Source code can be executed by a computer without compilation or interpretation.
21. A program written in machine language requires compilation (translation).
22. A compiler translates a program written in a high-level language.

## 1.8 Review Questions: Multiple Choice

Select the correct answer for each of the following statements.

1. Which of the following is **not** computer hardware?
  - a. a hard disk
  - b. a DVD disc
  - c. a sound card
  - d. the main memory (RAM)
2. Which of the following is **not** a secondary storage device?
  - a. a DVD reader/writer device
  - b. a Solid State Drive (SSD)
  - c. a USB flash drive
  - d. RAM
3. Which one of the following operations **cannot** be performed by the CPU?
  - a. Transfer data to the main memory (RAM).
  - b. Display data to the user.
  - c. Transfer data from the main memory (RAM).
  - d. Perform arithmetic operations.
4. A touch screen is
  - a. an input device.
  - b. an output device.

- c. both of the above
5. Which of the following is **not** software?
- a. Windows
  - b. Linux
  - c. iOS
  - d. a video game
  - e. a web browser
  - f. All of the above are software.
6. Which of the following statements is correct?
- a. Programs are stored on the hard disk.
  - b. Programs are stored on DVD discs.
  - c. Programs are stored in main memory (RAM).
  - d. All of the above are correct.
7. Which of the following statements is correct?
- a. Programs can be executed directly from the hard disk.
  - b. Programs can be executed directly from a DVD disc.
  - c. Programs can be executed directly from the main memory (RAM).
  - d. All of the above are correct.
  - e. None of the above is correct.
8. Programmers **cannot** write computer programs in
- a. machine language.
  - b. natural language such as English, Greek, and so on.
  - c. C#.
9. A compiler translates
- a. a program written in machine language into a high-level language program.
  - b. a program written in a natural language (English, Greek, etc.) into a machine language program.
  - c. a program written in high-level computer language into a machine language program.

- d. none of the above
  - e. all of the above
10. Machine language is
- a. a language that machines use to communicate with each other.
  - b. a language made up of numerical instructions that is used directly by a computer.
  - c. a language that uses English words for operations.
11. In a program written in high-level computer language, if two identical statements are one after the other, the interpreter
- a. translates the first one and executes it, then it translates the second one and executes it.
  - b. translates the first one, then translates the second one, and then executes them both.
  - c. translates only the first one (since they are identical) and then executes it two times.

# Chapter 2

## C#

---

### 2.1 What is C#?

C# (pronounced as “C sharp”) is a widely used general-purpose, high-level computer programming language that allows programmers to create desktop or mobile applications, large-scale applications, embedded systems, client-server applications, web pages, and many other types of software. C# is an extension of its predecessor, the C programming language.

C# is designed to be a platform-independent language. It is intended to let programmers “write once, run anywhere (WORA)”, meaning that code is written once but can run on any combination of hardware and operating system without being re-compiled.

### 2.2 What is the Difference Between a Script and a Program?

Technically speaking, a script is *interpreted* whereas a program is *compiled*, but this is actually not their major difference. There is another more important difference between them!

The main purpose of a script written in a scripting language such as JavaScript, or VBA (Visual Basic for Applications) is to control another application. So you can say that, in some ways JavaScript controls the web browser, and VBA controls a Microsoft® Office application such as MS Word or MS Excel.

On the other hand, a program written in a programming language such as C#, or C++ executes independently of any other application. A program is compiled into a separate set of machine language instructions that can then be executed as stand-alone any time the user wishes.

☞ *Macros of Microsoft Office are scripts written in VBA. Their purpose is to automate certain functions within Microsoft Office.*

☞ *A lot of people think that JavaScript is a simplified version of Java but in fact the similarity of the names is just a coincidence.*

☞ *A script cannot be executed as stand-alone. It requires a hosting application in order to execute.*

## 2.3 Why You Should Learn C#

C# is what is known as a “high-level” computer language. C#’s coding style is similar to C; it is quite easy to understand and it is very efficient on multiple platforms such as Windows, Linux, and Unix. C# is a very flexible and powerful language, making it very suitable for developing large-scale applications, embedded systems, drivers, client-server applications, art applications, music players, or even video games.

C# is everywhere! It is on desktop computers, laptops, mobile devices, and even in data centers costing millions of dollars. With a huge community of developers worldwide, C# enables efficient development of many exciting applications and services. This huge availability of C# programmers is a major reason why organizations choose C# for new development over any other programming language. This is also a very good reason why you should actually learn C#!

## 2.4 How C# Works

Computers do not understand natural languages such as English or Greek, so you need a computer language such as C# to communicate with them. C# is a very powerful high-level computer language. The C# compiler (or, actually, a combination of two compilers) converts C# language to a language that computers can actually understand, and that is known as the “machine language”.

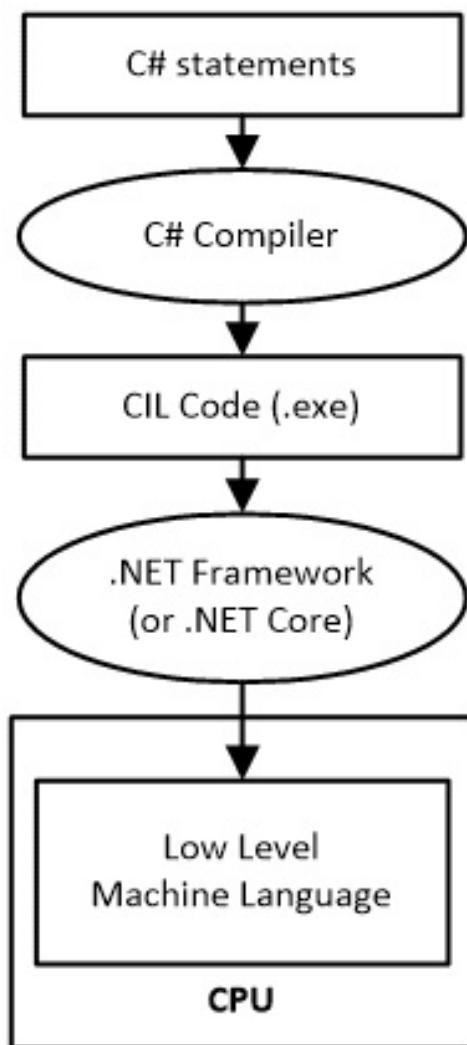
In the past, computer languages made use of either an interpreter or a compiler. Nowadays however, many computer languages including C# use two compilers. In C#, the first compiler translates statements into an intermediate language called Common Intermediate Language (CIL), which is a language similar to Java’s bytecode. The CIL code is stored on disk in an executable file called an *assembly*, typically with an extension of .exe. Later, when a user wants to execute the file, .NET (pronounced as "dot net") performs a Just In Time (JIT) compilation to convert the CIL code into low-level machine language code for direct execution on the hardware.

 *.NET Framework is a version of .NET for building any type of app that runs on Windows.*

 *.NET Core is a version of .NET for building websites, services, and console apps that run on Windows, Linux, or macOS*

 Instead of two compilers, some languages use a compiler and an interpreter. In Java, for example, the compiler translates Java statements into bytecode statements and saves them in a .class file. Later, when a user wants to execute a .class file, the Java Virtual Machine (JVM)—which is actually a combination of a compiler and an interpreter—reads the .class file and executes it, initially using interpretation. During interpretation, however, the JVM monitors which sequences of bytecode are frequently executed and translates them (compiles them) into low-level machine language code for direct execution on the hardware.

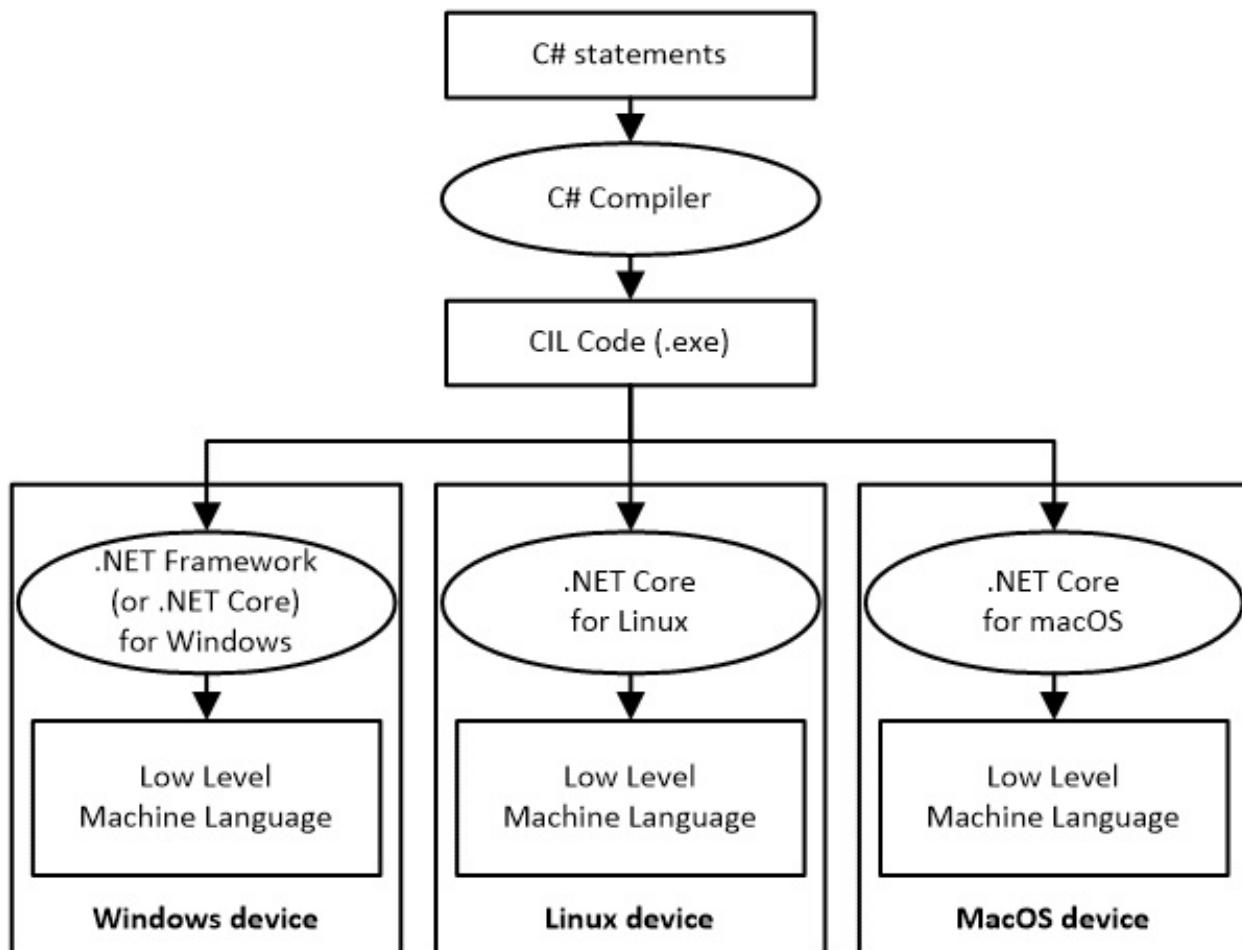
In **Figure 2–1** you can see how statements written in C# are compiled into CIL code and how CIL code is then compiled and executed using the .NET.



**Figure 2–1** Executing C# statements using the .NET

Now come some reasonable questions: *Why all this trouble? Why does C#*

*and other languages translate twice? Why are C# statements not directly translated into low-level machine language code?* The answer lies in the fact that C# is designed to be a platform-independent programming language. This means that a program is written once but it can be executed on any device, regardless of its operating system or its architecture, as long as the appropriate version of .NET is installed on it. In the past, programs had to be recompiled, or even rewritten, for each computer platform. One of the biggest advantages of C# is that you only have to write and compile a program once! In **Figure 2–2** you can see how statements written in C# are compiled into CIL code and how CIL code can then be executed on any platform that has the corresponding .NET installed on it.



**Figure 2–2** Executing C# statements on different platforms

# **Chapter 3**

## **Software Packages to Install**

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### **3.1 Visual Studio**

Microsoft Visual Studio is an Integrated Development Environment (IDE) that provides a great set of tools for many programming languages (via extensions installed separately) and lets you easily create applications for Android, iOS, Mac, Windows, and the cloud, as well as websites, web applications ,and web services.

Visual Studio is much more than a text editor. It can indent lines, match words and brackets, and highlight source code that is written incorrectly. It also provides automatic code (IntelliSense®), which means that as you type, it displays a list of possible completions. The IDE also provides hints to help you analyze your code and find any potential problems. It even suggests some simple solutions to fix those problems. You can use the Visual Studio not only to write but also to execute your programs directly from the IDE.

Visual Studio has a large community of users all around the world and this is why it comes in so many different flavors. To be more specific, in Microsoft's download page you can download:

- ▶ **Visual Studio** (Community, Professional, or Enterprise), which runs on Windows
- ▶ **Visual Studio for Mac**, which runs on macOS
- ▶ **Visual Studio Code**, which runs on Windows, macOS, and Linux

This book explains how to install and use both Visual Studio Community and Visual Studio Code. Visual Studio Community is easy to install but runs only on Windows. On the other hand, Visual Studio Code runs on Windows, macOS, and Linux, but it needs more effort to install.

### **3.2 How to Set Up Visual Studio Community on Windows**

Before you start, keep in mind that this paragraph explains the process of installing Visual Studio Community on Windows. If you want to install Visual Studio Code, skip this paragraph and go directly to the next one ([paragraph 3.3](#)).

To install Visual Studio Community, you can download it free of charge

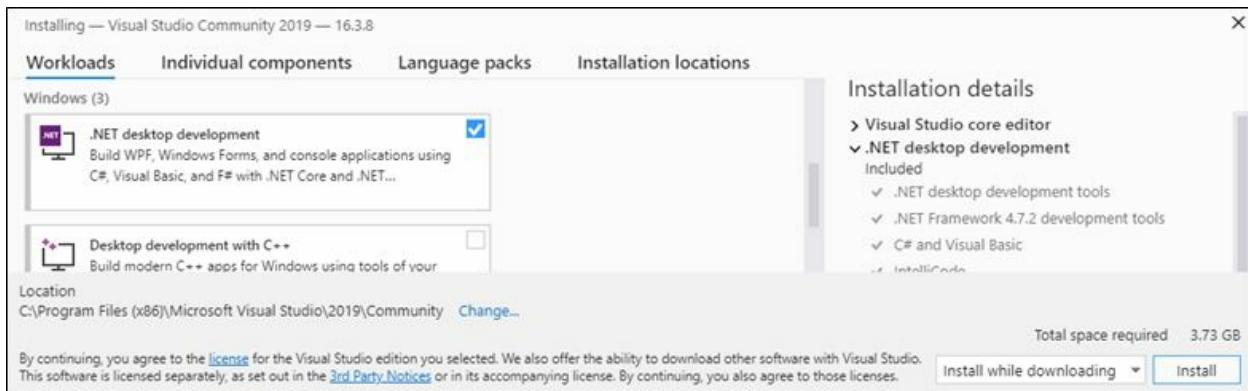
from the following address:

<https://visualstudio.microsoft.com/>

Download the edition called “Visual Studio Community”. When the download is complete, run the corresponding installer.

The Visual Studio installer informs you that it needs to set up a few things so that you can configure your installation. Click on the “Continue” button and wait for the process to complete.

Next, the installer (as shown in **Figure 3–1**) prompts you to select Workloads. Check the box for “.NET desktop development” and read the license for the edition you have selected.



**Figure 3–1** Selecting workloads and the installation folder in the Visual Studio installer

 *The installation folder (location) proposed on your computer may differ from that in **Figure 3–1** depending on the versions of the Visual Studio or Windows that you have.*

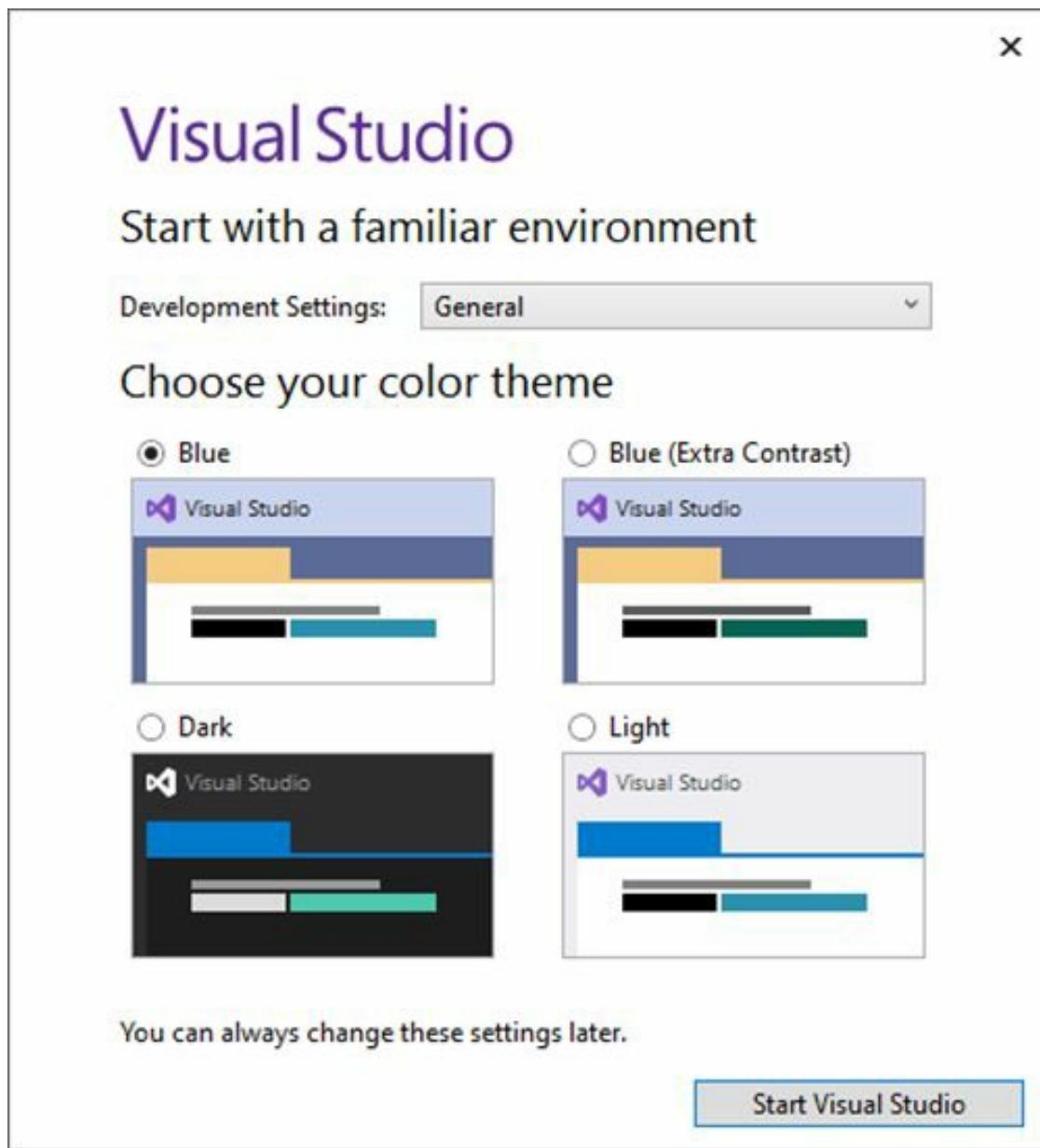
Next, click on the “Install” button in the bottom right-hand corner of the installation window.

When the installation process is complete, you can launch Visual Studio. You will see a Welcome screen, as shown in **Figure 3–2**. You can sign in or you can just click on the “Not now, maybe later” link.



**Figure 3–2** The Visual Studio welcome screen

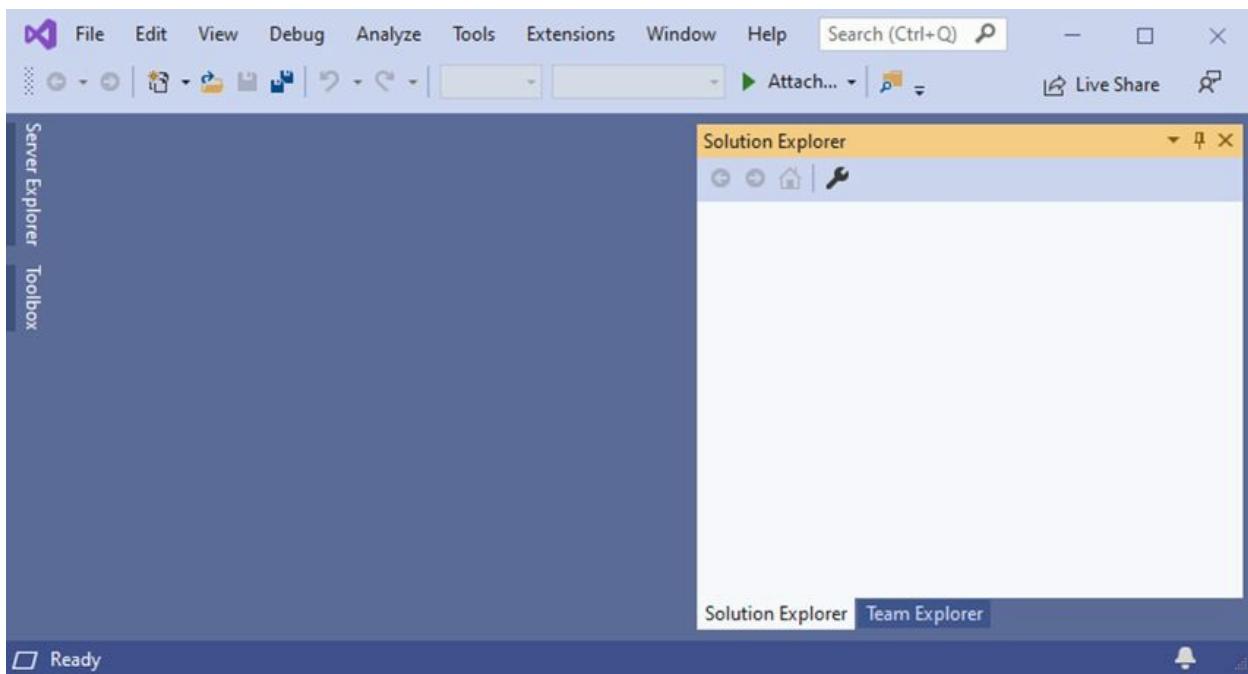
On the next screen, set the “Development Settings” to “General” and choose a color theme of your choice, as shown in **Figure 3–3**. This book uses the blue color theme.



**Figure 3–3** Selecting the Development Settings and color theme

Click on the “Start Visual Studio” button in the bottom right-hand corner of the Visual Studio window.

In the window that opens, click on “Continue without code”. The Visual Studio Community environment opens and should look like the one shown in **Figure 3–4**.



**Figure 3–4** The Visual Studio IDE

One thing that this book does in order to save paper is to decrease the number of spaces per indent to two. From the main menu in the Visual Studio window, select Tools → Options. In the popup window that appears, click on the dropdown arrow to expand the Text Editor → C# → Tabs. This will open the “Tabs” Options for C#, as shown in **Figure 3–5**. Make sure that the Indenting option is selected as “Smart”. Set the fields “Tab size” and “Indent size” to 2. Then, make sure that “Insert spaces” is selected (instead of “Keep tabs”).

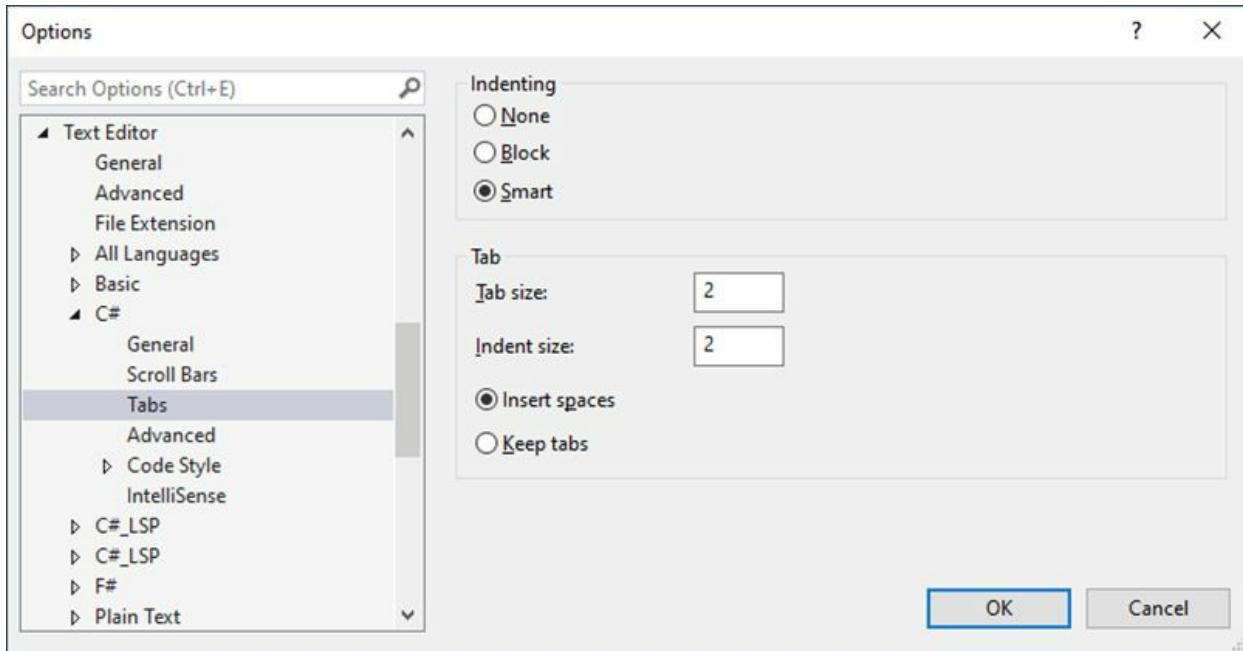


Figure 3–5 The Editor's “Options” dialog box

While still in the “Options” dialog box, click on the dropdown arrow on the left to expand the “Text Editor → C# → Code Style → Formatting → New Lines”. This will open the “New line options” for C#, in which you will uncheck all the new line options for braces and expressions and check all the new line options for keywords, as shown in **Figure 3–6**.

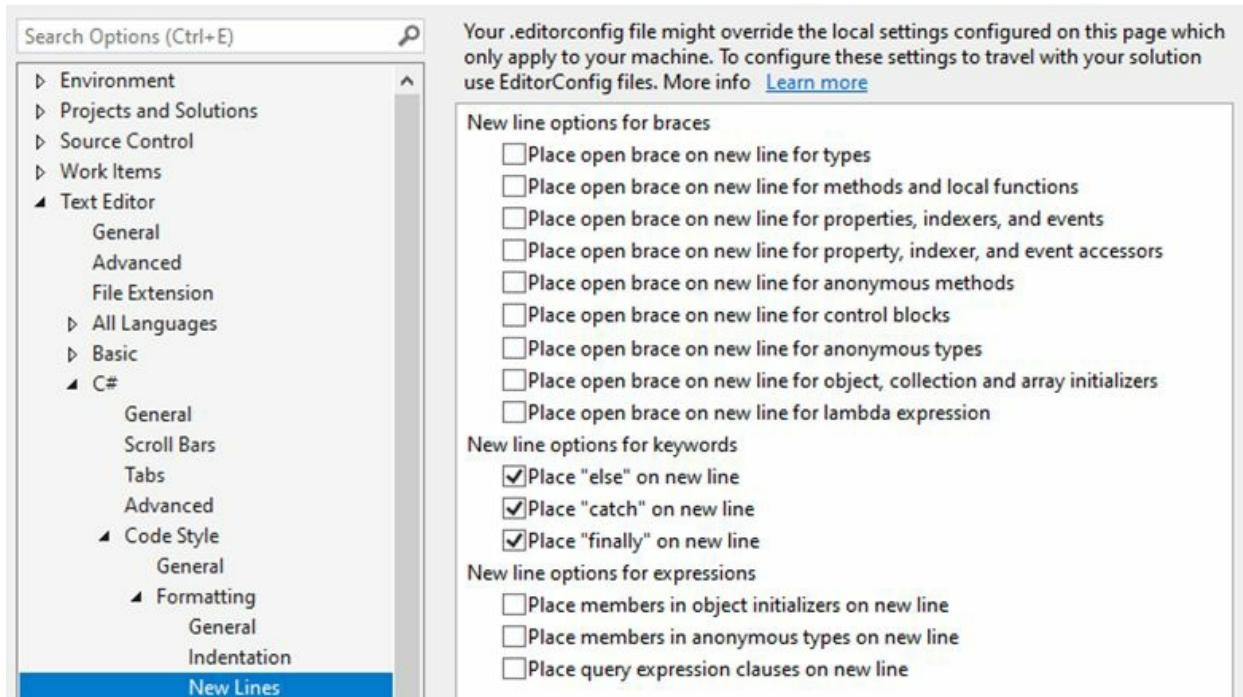


Figure 3–6 The Editor's “Options” dialog box

Click on the “OK” button at the bottom of the Options screen.

Visual Studio Community has been configured properly! Now it's time to conquer the world of C#! In the upcoming chapters, you will learn all about how to create C# projects, how to write C# programs, and so many tips and tricks useful in your first steps as a budding programmer!

### 3.3 How to Set Up Visual Studio Code on Windows

This paragraph explains how to install .NET Core SDK and Visual Studio Code on Windows. If you want to install them on Linux, skip this paragraph and go directly to the next one ([paragraph 3.4](#)).

Before installing Visual Studio Code on Windows, you need to install .NET Core SDK. Download it from the following address:

<https://dotnet.microsoft.com/download>

When the download is complete, run the corresponding installer and complete the installation process.

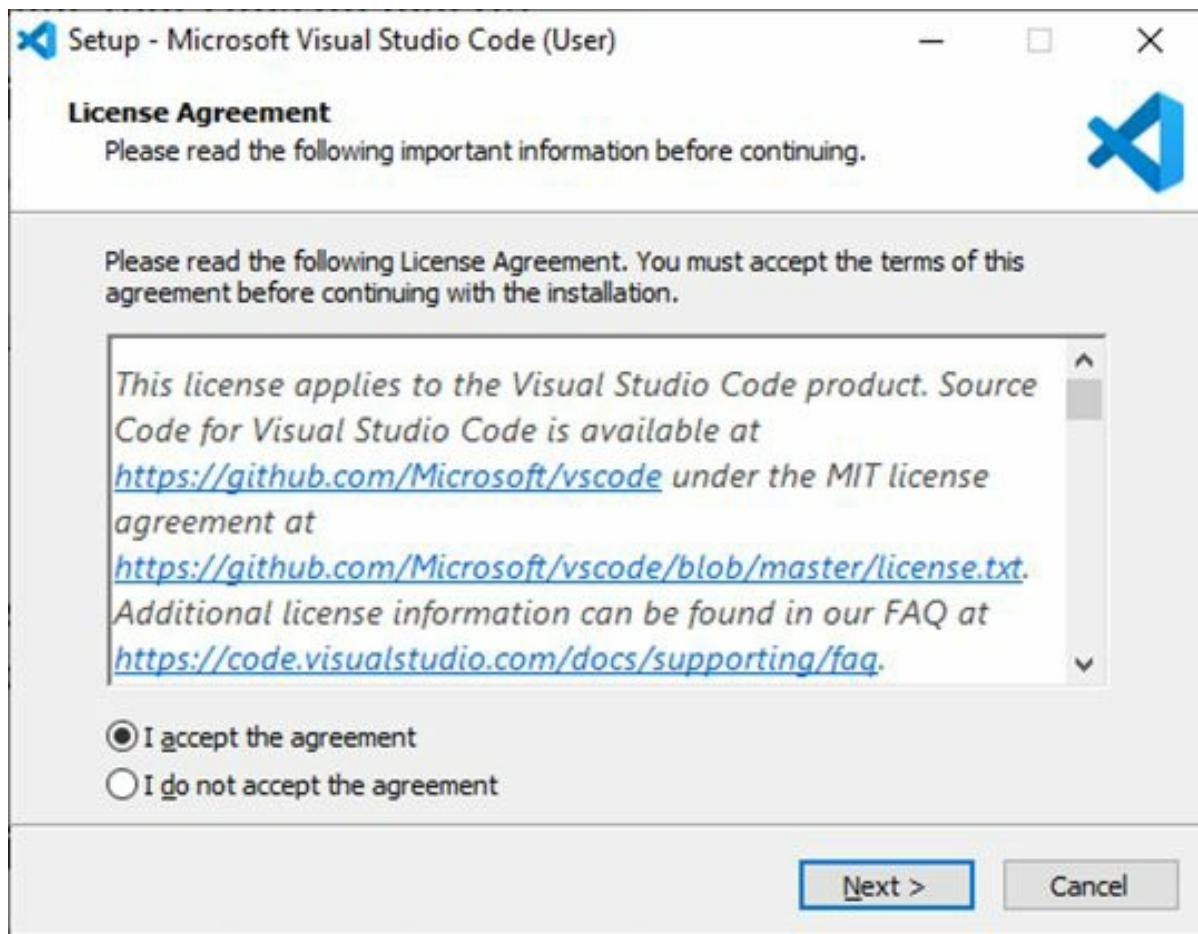
 *.NET Core must be installed on your system, as it performs a Just In Time (JIT) compilation to convert the CIL code into low-level machine language code for direct execution on the hardware (see [paragraph 2.4](#)).*

Next, you have to install Visual Studio Code. From the following address:

<https://visualstudio.microsoft.com/>

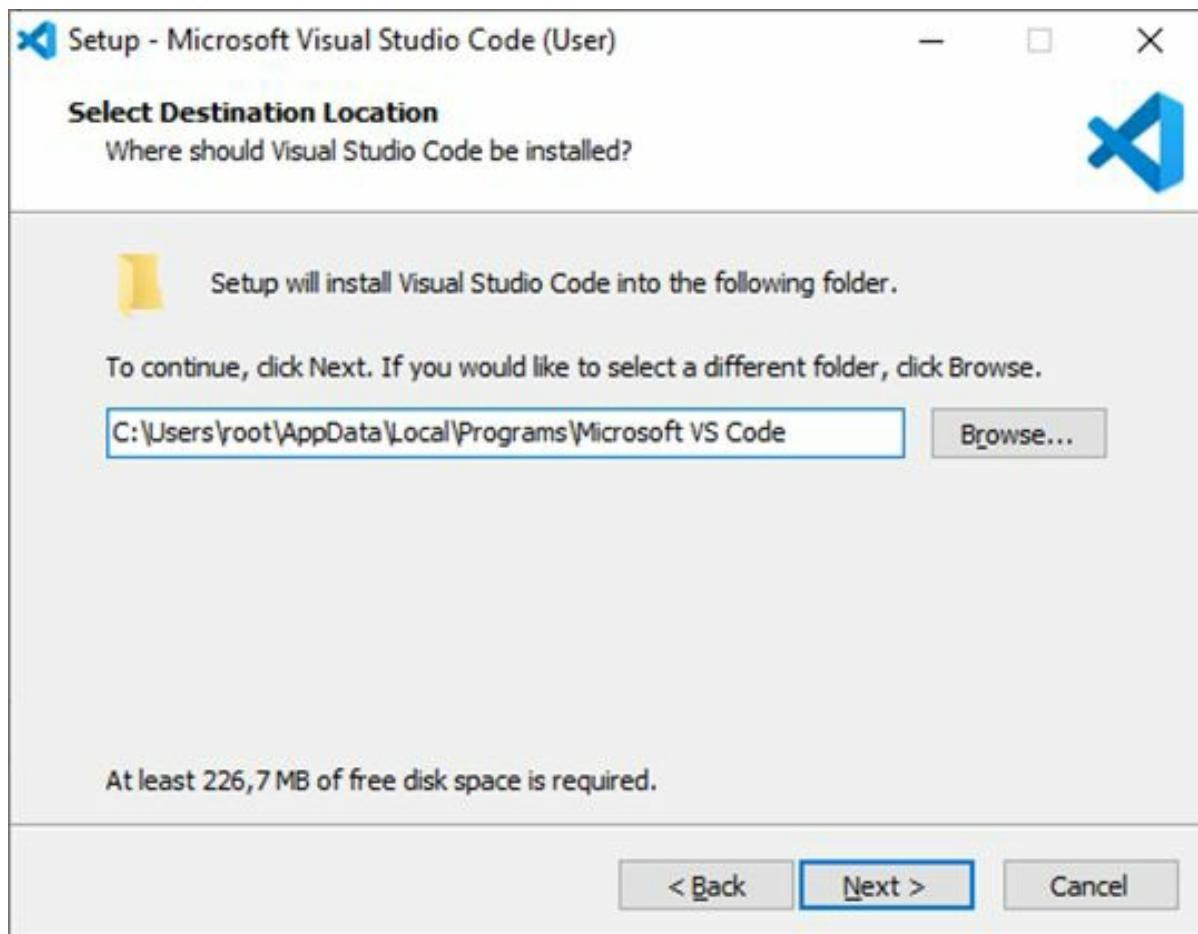
download (free of charge) the edition called “Visual Studio Code (Windows x64)”. When the download is complete, run the corresponding installer.

In the popup window that appears (see **Figure 3–7**), you must accept the terms of the License Agreement and click on the “Next” button.



**Figure 3–7** Accepting the terms of the License Agreement

The Visual Studio Code installer (as shown in **Figure 3–8**) prompts you to select where Visual Studio Code should be installed. Keep the proposed folder and click on the “Next” button.

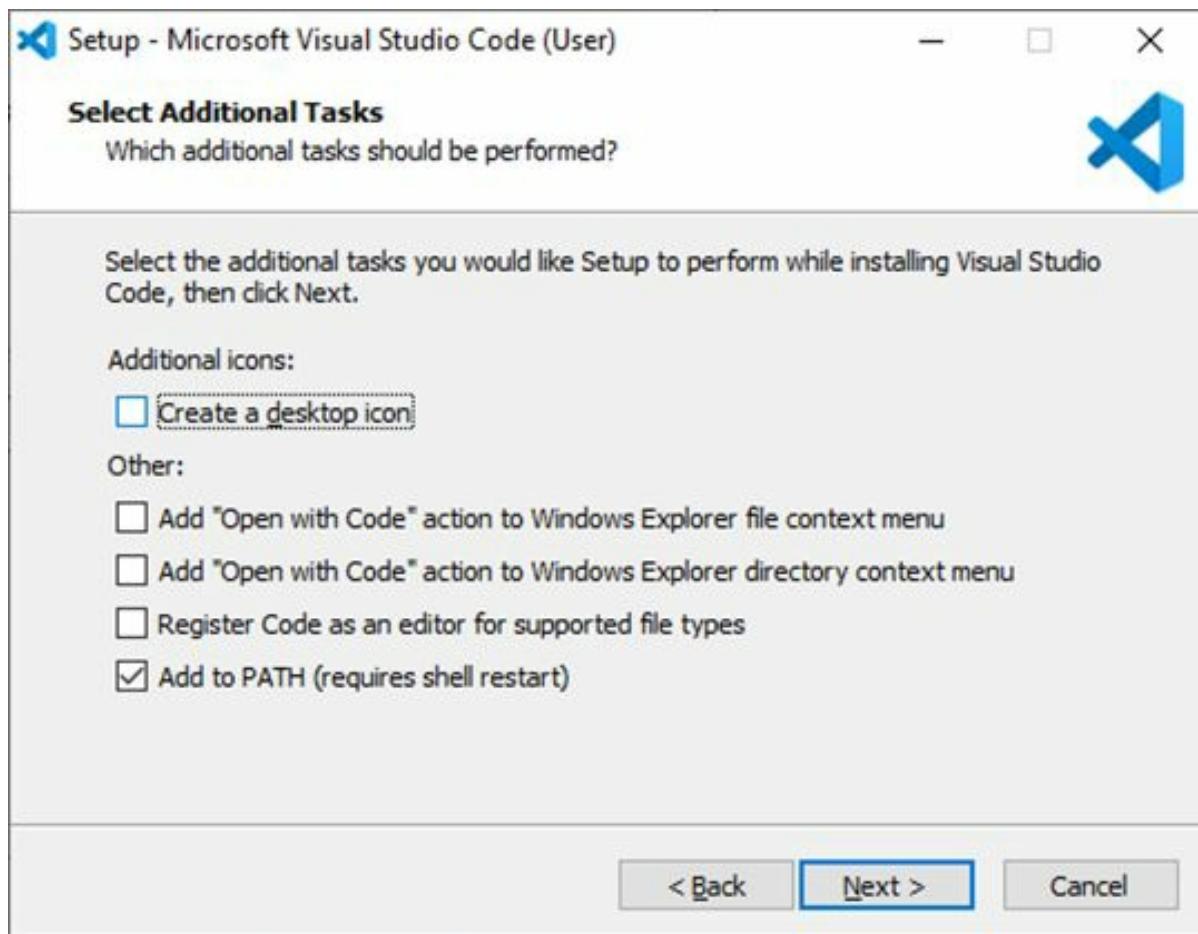


**Figure 3–8** Selecting the Destination Location

 *The installation folder (Destination Location) proposed on your computer may differ from that in **Figure 3–8** depending on the versions of the Visual Studio or Windows that you have.*

On the next screen, you can select where the installer should place the program's shortcuts. Click on the “Next” button.

On the next screen, you can select the additional tasks you would like the installer to perform. Make sure that the “add to PATH (requires shell restart)” option is checked (as shown in **Figure 3–9**), and click on the “Next” button.



**Figure 3–9** Selecting Additional Tasks

On the next screen, click on the “Install” button.

When the installation process is complete, launch Visual Studio Code and click on the “Extensions” / button in the Activity Bar on the left. Search for “C# for Visual Studio Code” as shown in **Figure 3–10** and click on the “Install” button.



**Figure 3–10** Searching for the C# extension in Visual Studio Code

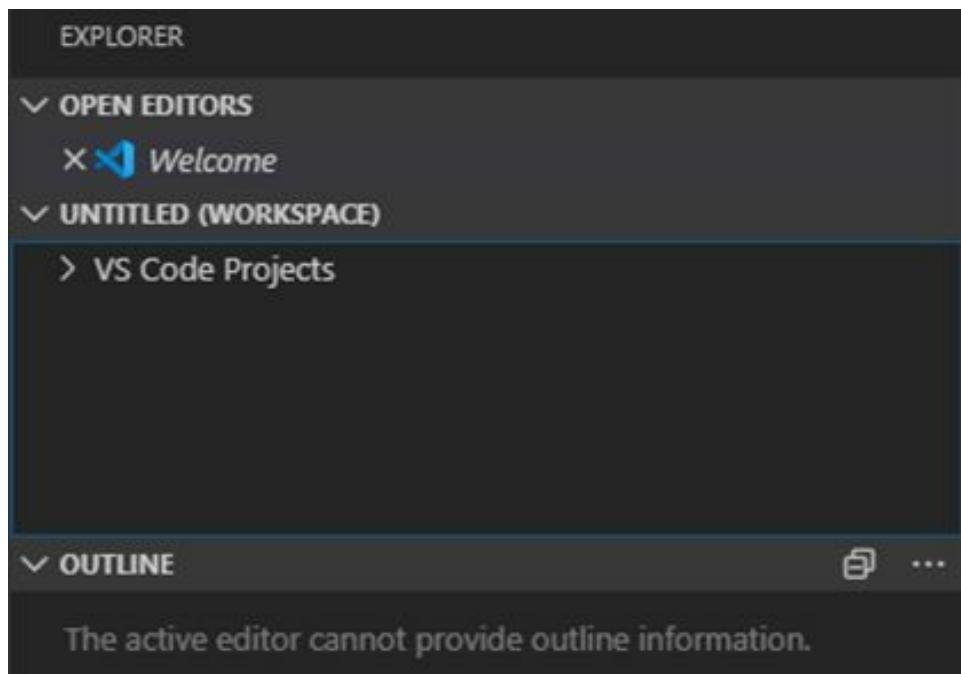
Once the C# for Visual Studio Extension is installed, you will notice (in the output window shown in **Figure 3–11**) that the dependencies (OmniSharp, .NET Core Debugger, etc.) are being installed automatically. Wait until the entire process finishes.

PROBLEMS    **OUTPUT**    DEBUG CONSOLE    TERMINAL    C# ▾   

Installing C# dependencies...  
Platform: win32, x86\_64  
  
Downloading package 'OmniSharp for Windows (.NET 4.6 / x64)' (32059 KB) ....|

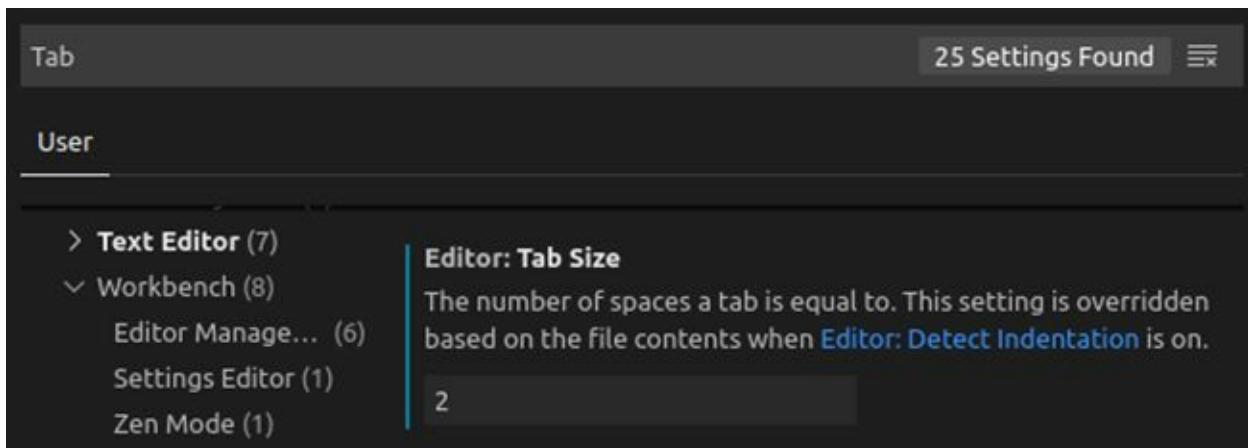
**Figure 3–11** Installing C# dependencies

Next, you have to add a folder to the workspace. In the Side Bar on the left of the screen, click on the “Add Folder” button and add (select) an empty folder where your projects should be stored. One good idea is to create a folder named “VS Code Projects” in your Documents folder and add that folder to the workspace, as shown in **Figure 3–12**.



**Figure 3–12** Adding the “VS Code Projects” folder to the workspace

One thing that this book does in order to save paper is to decrease the number of spaces per indent to two. Click on the “Manage” / icon in the Activity Bar. In the menu that appears, click on “Settings” and search for the keyword “Tab”. Select “Text Editor” on the left, as shown in **Figure 3–13**, and set the field “Editor: Tab Size” to 2.



**Figure 3–13** The Editor’s “Settings” dialog box

One additional thing that this book does in order to save paper is to decrease the number of new lines in source code. Unfortunately, the current edition of Visual Studio Code doesn't include a field in the “Settings” form for you to easily change these settings. It is possible that a future edition of Visual Studio Code will include one, but for now, you have to do this the hard way!

Use a text editor (such as Notepad, Notepad++, etc.) to edit the file “omnisharp.json” located at ”%USERPROFILE%\omnisharp\omnisharp.json”. If there is no such file, create a new one and type the following settings:

```
{  
    "FormattingOptions": {  
        "NewLinesForBracesInLambdaExpressionBody": false,  
        "NewLinesForBracesInAnonymousMethods": false,  
        "NewLinesForBracesInAnonymousTypes": false,  
        "NewLinesForBracesInControlBlocks": false,  
        "NewLinesForBracesInTypes": false,  
        "NewLinesForBracesInMethods": false,  
        "NewLinesForBracesInProperties": false,  
        "NewLinesForBracesInObjectCollectionArrayInitializers": false,  
        "NewLinesForBracesInAccessors": false  
    }  
}
```

Save the file and close the text editor.

 In Windows 10, the environment variable %USERPROFILE% is an alias for the current user's profile folder. For example, for the user “mitsos”, the file “c:\users\mitsos\.omnisharp\omnisharp.json” can also be denoted by “%USERPROFILE%\omnisharp\omnisharp.json”.

 If there is no directory (folder) .omnisharp, you will need to create a new one.

Visual Studio Code has been configured properly! Now it's time to conquer the world of C#! In the upcoming chapters, you will learn all about how to create C# projects, how to write C# programs, and so many tips and tricks useful in your first steps as a budding programmer!

### 3.4 How to Set Up Visual Studio Code on Linux

This paragraph explains the process of installing Visual Studio Code and .NET Core SDK on Linux. If you have already installed Visual Studio Community or Visual Studio Code on Windows, skip this paragraph.

Microsoft offers Visual Studio Code for Linux as a .deb, .rpm, or .tar.gz file. From the following address:

<https://visualstudio.microsoft.com/>

choose and download (free of charge) the version that is suitable for your Linux distribution. When the download is complete, run the corresponding installer.

 Instead of downloading Visual Studio Code directly from Microsoft, you could try downloading it from your Linux's Software Center (Ubuntu Software, GNOME Software, etc.)

When the installation process is complete, launch Visual Studio Code and click on the “Extensions” / icon in the Activity Bar on the left. Search for “C# for Visual Studio Code” as shown in **Figure 3–14** and click on the “Install” button.

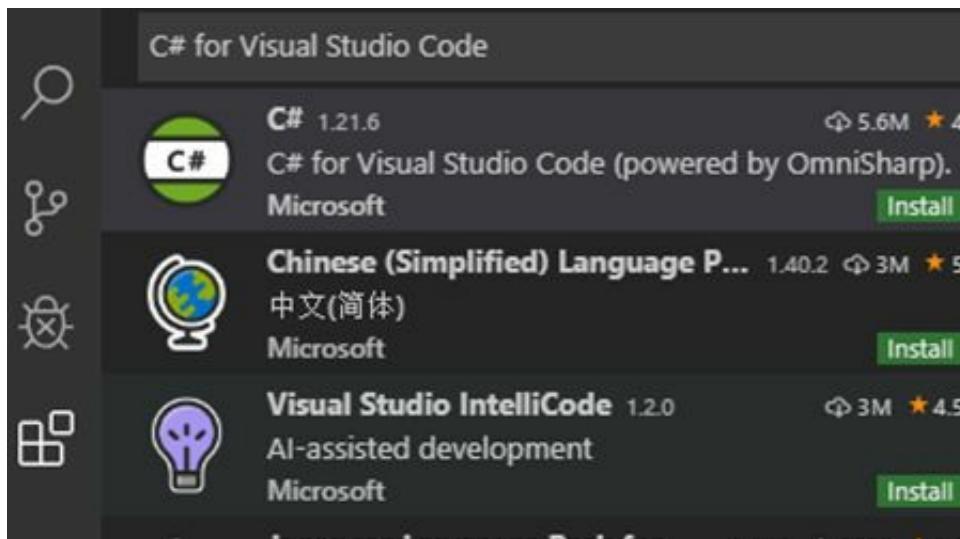
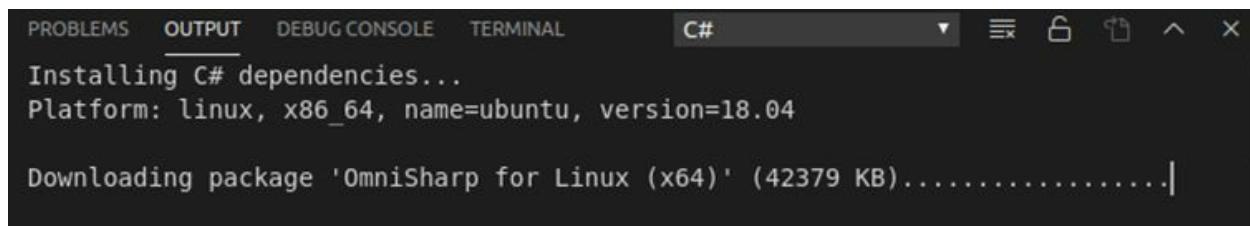


Figure 3–14 Searching for the C# extension in Visual Studio Code

Once the C# for Visual Studio Extension is installed, you will notice (in the output window shown in **Figure 3–15**) that dependencies (OmniSharp, .NET Core Debugger, etc.) are being installed automatically. Wait until the entire process finishes.

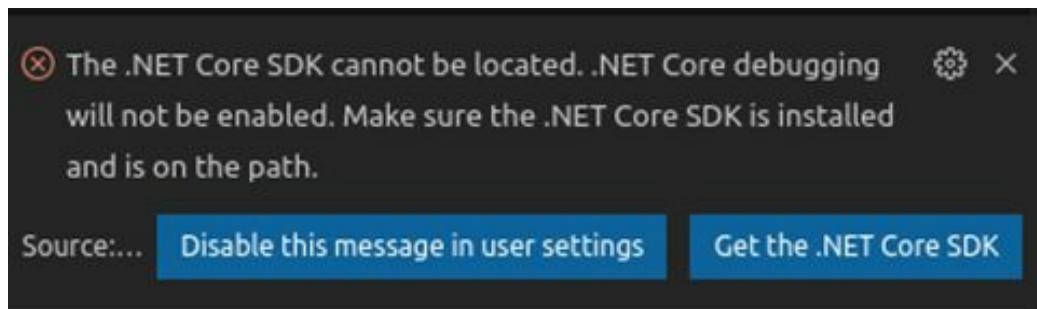


```
PROBLEMS OUTPUT DEBUG CONSOLE TERMINAL C#
Installing C# dependencies...
Platform: linux, x86_64, name=ubuntu, version=18.04
Downloading package 'OmniSharp for Linux (x64)' (42379 KB).....|
```

Figure 3–15 Installing C# dependencies

At the end of this process, you may receive the message “Failed to spawn ‘dotnet --info’” in the output window and the following popup message (shown in **Figure 3–16**) may appear. This message appears because the

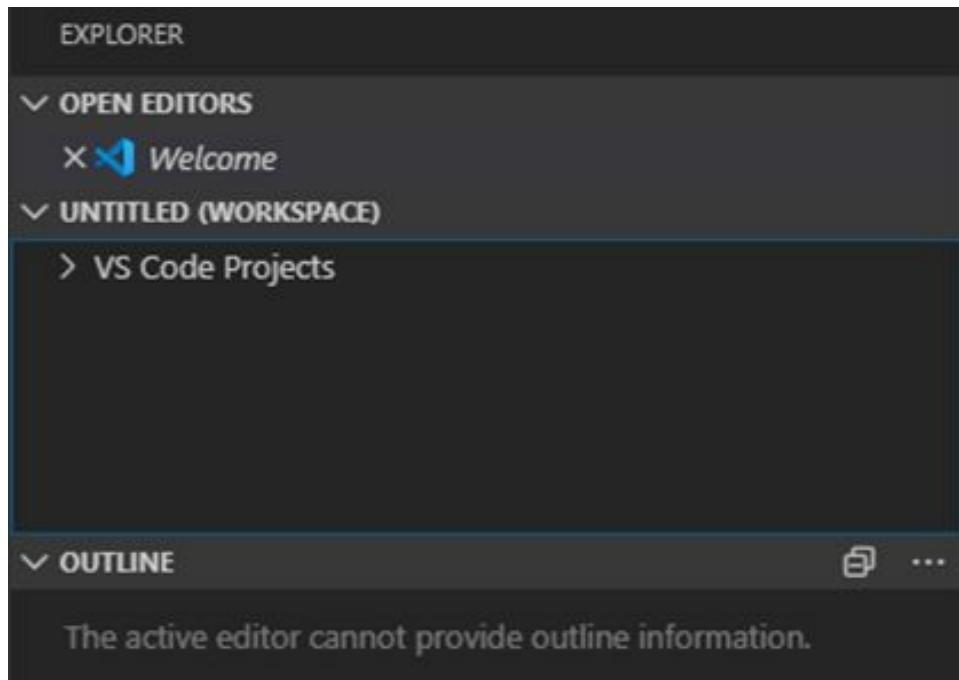
.NET Core SDK cannot be located on your system.



**Figure 3–16** The .NET Core SDK cannot be located on your system

Click on the “Get the .Net Core SDK” button. In the popup window that appears, click on the “Open Link” button and then, in the webpage that opens, click on the “Install for Linux” button. Choose your Linux distribution and read and follow the directions on how to install .Net Core SDK on your system.

Next, you have to add a folder to the workspace. In the Side Bar on the left, click on the “Add Folder” button and add (select) an empty folder where your projects should be stored. One good idea is to create a folder named “VS Code Projects” in your Home folder (directory) and add that folder to the workspace, as shown in **Figure 3–17**.



**Figure 3–17** Adding the “VS Code Projects” folder to the workspace

One thing that this book does in order to save paper is to decrease the number of spaces per indent to two. Click on the “Manage” / icon in the

Activity Bar. In the menu that appears, click on “Settings” and search for the keyword “Tab”. Select “Text Editor” on the left of the screen (as shown in **Figure 3–18**), and set the field “Editor: Tab Size” to 2.

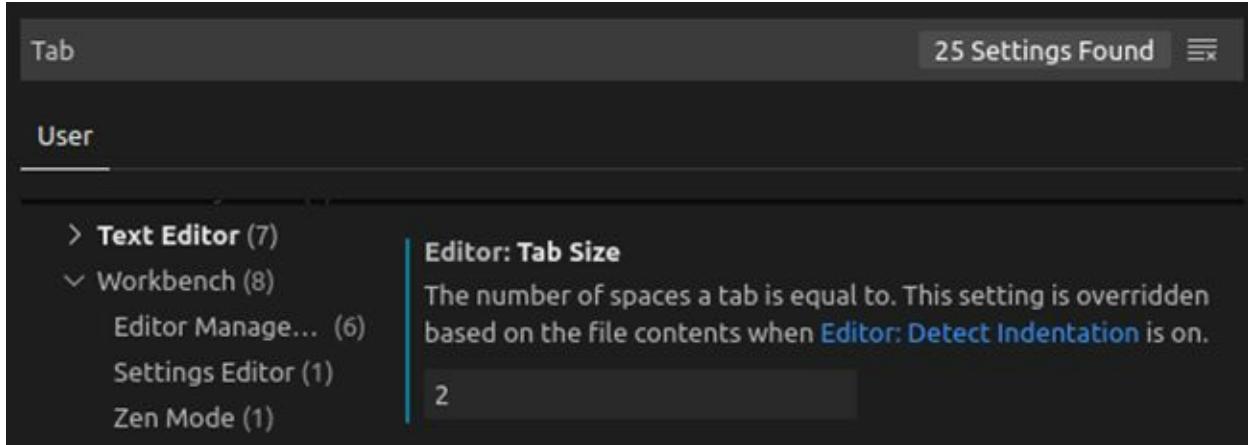


Figure 3–18 The Editor’s “Settings” dialog box

One additional thing that this book does in order to save paper is to decrease the number of new lines in source code. Unfortunately, the current edition of Visual Studio Code doesn't include a field in the “Settings” form for you to easily change these settings. It is possible that a future edition of Visual Studio Code will include one, but for now, you have to do this the hard way!

Use a text editor (such as Notepad++, Vim, etc.) to edit the file “omnisharp.json” located at: “`~/.omnisharp/omnisharp.json`”. If there is no such file, create a new one, and type the following settings:

```
{  
  "FormattingOptions": {  
    "NewLinesForBracesInLambdaExpressionBody": false,  
    "NewLinesForBracesInAnonymousMethods": false,  
    "NewLinesForBracesInAnonymousTypes": false,  
    "NewLinesForBracesInControlBlocks": false,  
    "NewLinesForBracesInTypes": false,  
    "NewLinesForBracesInMethods": false,  
    "NewLinesForBracesInProperties": false,  
    "NewLinesForBracesInObjectCollectionArrayInitializers": false,  
    "NewLinesForBracesInAccessors": false  
  }  
}
```

Save the file and close the text editor.

 In Linux, the tilde (~) character is an alias for the current user's home directory. For example, for the user “mitsos”, the file

`"/home/mitsos/.omnisharp/omnisharp.json"` can also be denoted by  
`"~/omnisharp/omnisharp.json"`.

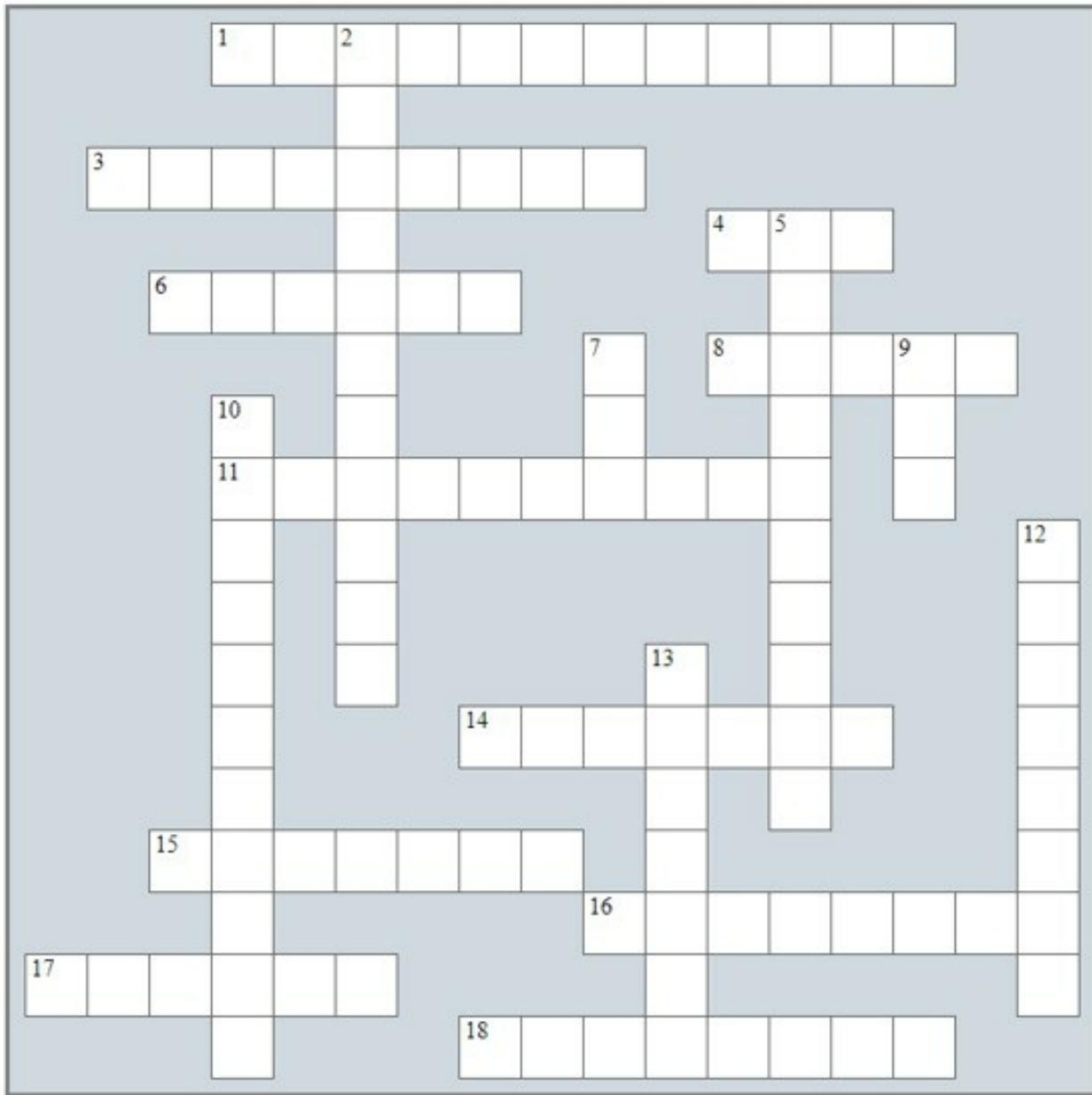
 If there is no directory (folder) `.omnisharp`, you will need to create a new one.

Visual Studio Code has been configured properly! Now it's time to conquer the world of C#! In the upcoming chapters, you will learn all about how to create C# projects, how to write C# programs, and so many tips and tricks useful in your first steps as a budding programmer!

## **Review in “Introductory Knowledge”**

### **Review Crossword Puzzles**

1. Solve the following crossword puzzle.



#### **Across**

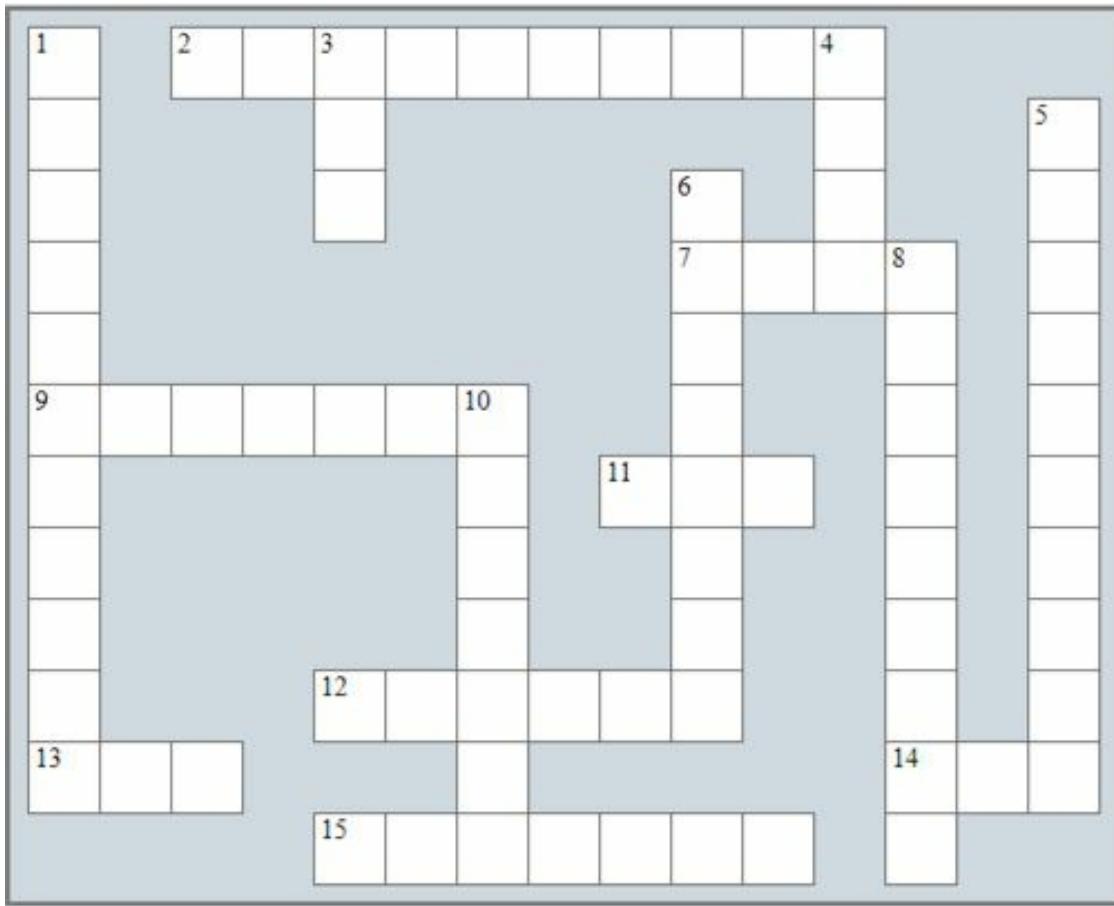
1. Statements or commands.
3. Windows is such a system.
4. A computer component.

6. A category of software.
8. An input device.
11. It's the person who designs computer programs.
14. An output device.
15. Antivirus is such a software.
16. In today's society, almost every task requires the use of this device.
17. A computer component.
18. All these devices make up a computer.

### **Down**

---

2. These devices are also computers.
  5. Computers can perform so many different tasks because of their ability to be \_\_\_\_\_.
  7. Special memory that can only be read.
  9. A secondary storage device.
  10. A browser is this type of software.
  12. An input device.
  13. An operating system.
2. Solve the following crossword puzzle.

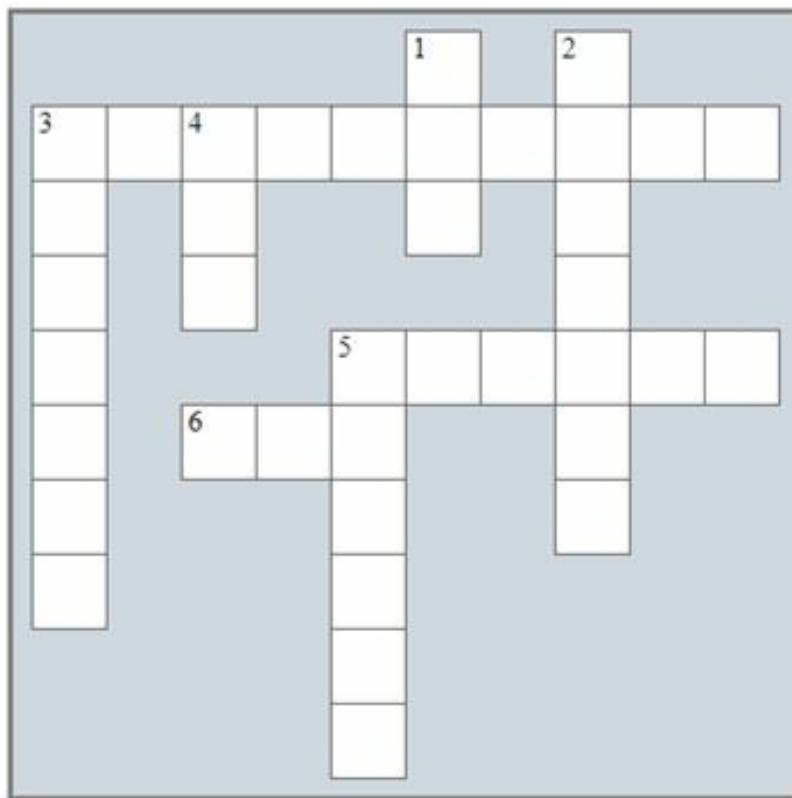


### **Across**

2. The CPU performs one of these basic operations.
7. In a machine language all statements are made up of zeros and \_\_\_\_\_.
9. A set of statements.
11. \_\_\_\_\_ is a language executed by the .NET
12. This software controls a device that is attached to your computer.
13. All data stored in this type of memory are lost when you shut down your computer.
14. \_\_\_\_\_ converts the bytecode into low-level machine language code
15. Run a program.

### **Down**

1. A program that simultaneously translates and executes the statements written in a high-level language.
  3. Visual Studio is such a software.
  4. The statements that a programmer writes to solve a problem.
  5. A scripting language.
  6. A program that translates statements written in a high-level language into a separate machine language program.
  8. A category of programming languages.
  10. A low-level language.
3. Solve the following crossword puzzle.



### **Across**

---

3. An input device.
5. C# is suitable for developing \_\_\_\_\_ applications.
6. A scripting language that can control Microsoft Word.

### **Down**

---

1. It performs logical operations.

2. A script requires a \_\_\_\_\_ application in order to execute.
3. It displays data to the user.
4. An intermediate language that C# uses.

## Review Questions

Answer the following questions.

1. What is hardware?
2. List the five basic components of a typical computer system.
3. Which part of the computer actually executes the programs?
4. Which part of the computer holds the program and its data while the program is running?
5. Which part of the computer holds data for a long period of time, even when there is no power to the computer?
6. How do you call the device that collects data from the outside world and enters them into the computer?
7. List some examples of input devices.
8. How do you call the device that outputs data from the computer to the outside world?
9. List some examples of output devices.
10. What is software?
11. How many software categories are there, and what are their names?
12. A word processing program belongs to what category of software?
13. What is a compiler?
14. What is an interpreter?
15. What is meant by the term “machine language”?
16. What is source code?
17. What is C#?
18. What is CIL code?
19. What is the difference between a script and a program?
20. What are some of the possible uses of C#?
21. What is Visual Studio?

## **Section 2**

### **Getting Started with C#**

---

# Chapter 4

## Introduction to Basic Algorithmic Concepts

---

### 4.1 What is an Algorithm?

In technical terms, an *algorithm*<sup>[2]</sup> is a strictly defined finite sequence of well-defined statements (often called instructions or commands) that provides the solution to a problem or to a specific class of problems for any acceptable set of input values (if there are any inputs). In other words, an algorithm is a step-by-step procedure to solve a given problem. The term *finite* means that the algorithm must reach an end point and cannot run forever.

You can find algorithms everywhere in your real life, not just in computer science. For example, the process for preparing toast or a cup of tea can be expressed as an algorithm. Certain steps, in a certain order, must be followed in order to achieve your goal.

### 4.2 The Algorithm for Making a Cup of Tea

The following is an algorithm for making a cup of tea.

1. Put the teabag in a cup.
2. Fill the kettle with water.
3. Boil the water in the kettle.
4. Pour some of the boiled water into the cup.
5. Add milk to the cup.
6. Add sugar to the cup.
7. Stir the tea.
8. Drink the tea.

As you can see, certain steps must be followed. These steps are in a specific order, even though some of the steps could be rearranged. For example, steps 5 and 6 can be reversed. You could add the sugar first, and the milk afterwards.

 *Keep in mind that the order of some steps can probably be changed but you can't move them far away from where they should be. For example, you can't move step 3 ("Boil the water in the kettle.") to the end of the*

*algorithm, because you will end up drinking a cup of iced tea (and not a warm one) which is totally different from your initial goal!*

### 4.3 Properties of an Algorithm

An algorithm must satisfy the following properties:

- ▶ **Input:** The algorithm must have input values from a specified set.
- ▶ **Output:** The algorithm must produce the output values from a specified set of input values. The output values are the solution to a problem.
- ▶ **Finiteness:** For any input, the algorithm must terminate after a finite number of steps.
- ▶ **Definiteness:** All steps of the algorithm must be precisely defined.
- ▶ **Effectiveness:** It must be possible to perform each step of the algorithm correctly and in a finite amount of time. That is, its steps must be basic enough so that, for example, someone using a pencil and a paper could carry them out exactly, and in a finite amount of time. It is not enough that each step is definite (or precisely defined), but it must also be feasible.

### 4.4 Okay About Algorithms. But What is a Computer Program Anyway?

A *computer program* is nothing more than an algorithm that is written in a language that computers can understand, like C#, Python, C++, or Java.

A computer program cannot actually *make* you a cup of tea or cook your dinner, although an algorithm can guide you through the steps to do it yourself. However, programs can (for example) be used to calculate the average value of a set of numbers, or to find the maximum value among them. Artificial intelligence programs can even play chess or solve logic puzzles.

### 4.5 The Three Parties!

There are always three parties involved in an algorithm—the one that writes the algorithm, the one that executes it, and the one that uses or enjoys it.

Let's take an algorithm for preparing a meal, for example. Someone writes the algorithm (the author of the recipe book), someone executes it (probably your mother, who prepared the meal following the steps from the recipe

book), and someone uses it (probably you, who enjoys the meal).

Now consider a real computer program. Let's take a video game, for example. Someone writes the algorithm in a computer language (the programmer), someone or something executes it (usually a laptop or a computer), and someone else uses it or plays with it (the user).

Be careful however, because sometimes the terms “programmer” and “user” can be confusing. When you *write* a computer program, for that period of time you are “the programmer” but when you *use* your own program, you are “the user”.

## 4.6 The Three Main Stages Involved in Creating an Algorithm

An algorithm should consist of three stages: *data input*, *data processing*, and *results output*. This order is specific and cannot be changed.

Consider a computer program that finds the average value of three numbers. First, the program must prompt (ask) the user to enter the numbers (the data input stage). Next, the program must calculate the average value of the numbers (the data processing stage). Finally, the program must display the result on the computer's screen (the results output stage).

Let's take a look at these stages in more detail.

### First stage – Data input

1. Prompt the user to enter a number.
2. Prompt the user to enter a second number.
3. Prompt the user to enter a third number.

### Second stage – Data processing

4. Calculate the sum of the three numbers.
5. Divide the sum by 3.

### Third stage – Results output

6. Display the result on the screen.

In some rare situations, the input stage may be absent and the computer program may consist of only two stages. For example, consider a computer program that is written to calculate the following sum.

$$1+2+3+4+5$$

In this example, the user must enter no values at all because the computer

program knows exactly what to do. It must calculate the sum of the numbers 1 to 5 and then display the value of 15 on the user's screen. The two required stages (data processing and results output) are shown here.

### **First stage – Data input**

Nothing to do

### **Second stage - Data processing**

1. Calculate the sum of  $1 + 2 + 3 + 4 + 5$ .

### **Third stage – Results output**

2. Display the result on the screen.

However, what if you want to let the user decide the upper limit of that sum? What if you want to let the user decide whether to sum the numbers 1 to 5 or the numbers 1 to 20? In that case, the program must include an input stage at the beginning of the program to let the user enter that upper limit. Once the user enters that upper limit, the computer can calculate the result. The three required stages are shown here.

### **First stage – Data input**

1. Prompt the user to enter a number.

### **Second stage – Data processing**

2. Calculate the sum  $1 + 2 + \dots$  (up to and including the upper limit the user entered).

### **Third stage – Results output**

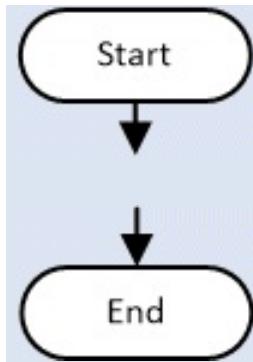
3. Display the results on the screen.

For example, if the user enters the number 6 as the upper limit, the computer would find the result of  $1 + 2 + 3 + 4 + 5 + 6$ .

## **4.7 Flowcharts**

A *flowchart* is a graphical method of presenting an algorithm, usually on paper. It is the visual representation of the algorithm's flow of execution. In other words, it visually represents how the flow of execution proceeds from one statement to the next until the end of the algorithm is reached. The basic symbols that flowcharts use are shown in **Table 4-1**.

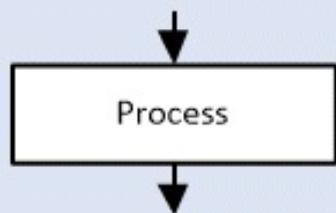
Flowchart Symbols	Description



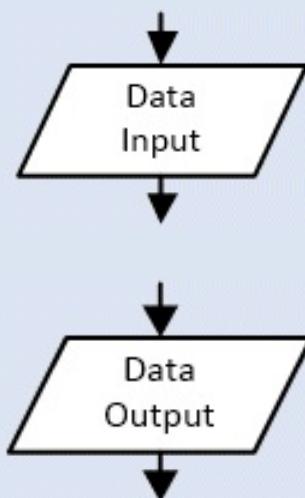
**Start/End:** Represents the beginning or the end of an algorithm. The Start symbol has one exit and the End symbol has one entrance.



**Arrow:** Shows the flow of execution. An arrow coming from one symbol and ending at another symbol shows that control passes to the symbol that the arrow is pointing to. Arrows are always drawn as straight lines going up and down or sideways (never at an angle).

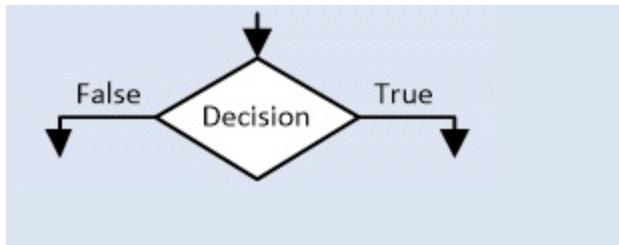


**Process:** Represents a process or mathematical (formula) calculation. The Process symbol has one entrance and one exit.

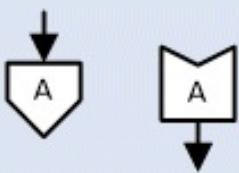


**Data Input/Output:** Represents the data input or the results output. In most cases, data comes from a keyboard and results are displayed on a screen. The Data input/output symbol has one entrance and one exit.

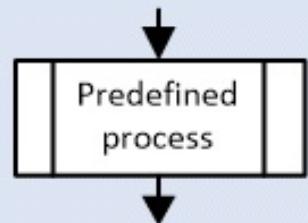
**Decision:** Indicates the point at which a decision is made. Based on a given condition (which can be true



or false), the algorithm will follow either the right or the left path. The Decision symbol has one entrance and two (and always only two) exits.



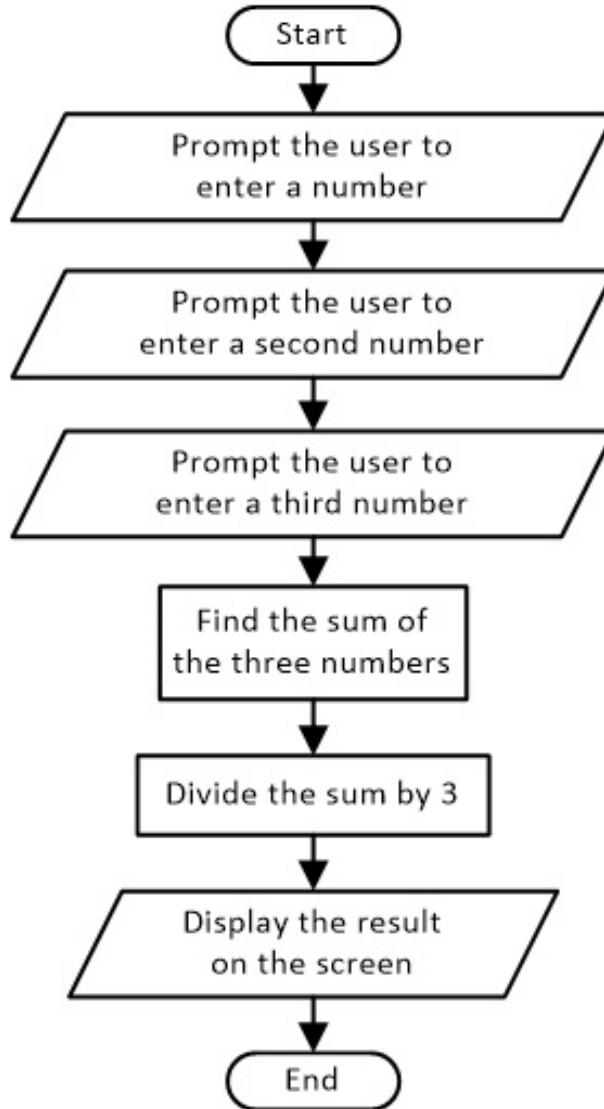
**Off-page connectors:** Show continuation of a flowchart onto another page. They are used to connect segments on multiple pages when a flowchart gets too big to fit onto one sheet of paper. The outgoing off-page connector symbol has one entrance and the incoming off-page connector symbol has one exit.



**Subprogram (predefined process):** Depicts a call to a subprogram that is formally defined elsewhere, such as in a separate flowchart. The Predefined process symbol has one entrance and one exit.

**Table 4-1** Flowchart Symbols and Their Functions

An example of a flowchart is shown in **Figure 4-1**. The algorithm prompts the user to enter three numbers and then calculates their average value and displays it on the computer screen.



**Figure 4–1** Flowchart for an algorithm that calculates and displays the average of three numbers

*A flowchart always begins and ends with a Start/End symbol!*

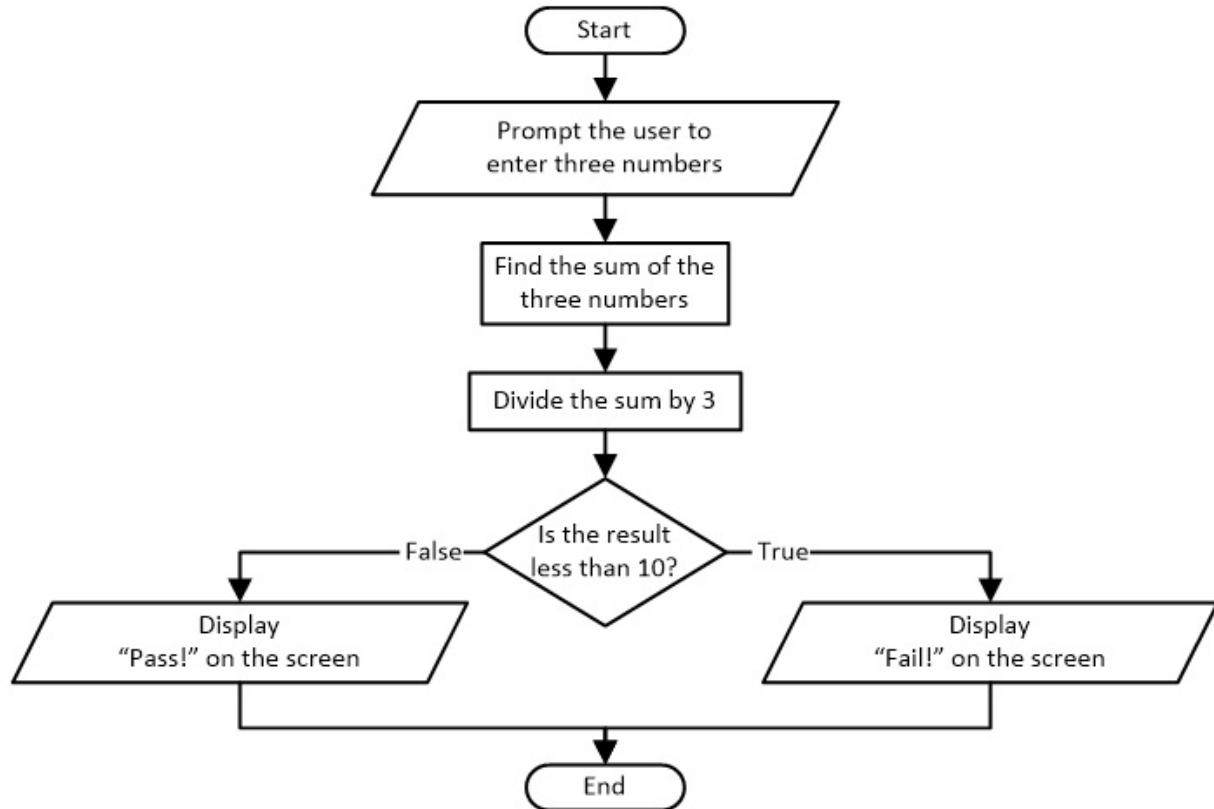
### Exercise 4.7-1 Finding the Average Value of Three Numbers

*Design an algorithm that calculates the average value of three numbers. Whenever the average value is below 10, a message “Fail!” must be displayed. Otherwise, if the average value is 10 or above, a message “Pass!” must be displayed.*

#### Solution

In this problem, two different messages must be displayed, but only one can appear each time the algorithm is executed; the wording of the message

depends on the average value. The flowchart for the algorithm is presented here.



To save paper, you can prompt the user to enter all three numbers using one single oblique parallelogram.

A Decision symbol always has one entrance and two exit paths!

Of course it is very soon for you to start creating your own algorithms. This particular exercise is quite simple and is presented in this chapter as an exception, just for demonstration purposes. You need to learn more before you start creating your own algorithms or even C# programs. Just be patient! In a few chapters the big moment will come!

## 4.8 What are "Reserved Words"?

In a computer language, a *reserved word* (or *keyword*) is a word that has a strictly predefined meaning—it is reserved for special use and cannot be used for any other purpose. For example, the words `Start`, `End`, `Read`, and `Write` in flowcharts have a predefined meaning. They are used to represent the beginning, the end, the data input, and the results output, respectively.

Reserved words exist in all high-level computer languages as well. In C#, there are many reserved words such as `if`, `while`, `else`, and `for`. Their meanings are predefined, so these words cannot be used for any other purposes.

 *Reserved words exist in all high-level computer languages. However, each language has its own reserved words. For example, the reserved words `else if` in C# are written as `elif` in Python.*

## 4.9 What is the Difference Between a Statement and a Command?

There is a big discussion on the Internet about whether there is, or is not, any difference between a statement and a command. Some people prefer to use the term “statement”, and some others the term “command”. For a novice programmer, there is no difference; both are instructions to the computer!

## 4.10 What is Structured Programming?

*Structured programming* is a software development method that uses modularization and structured design. Large programs are broken down into smaller modules and each individual module uses structured code, which means that the statements are organized in a specific manner that minimizes errors and misinterpretation. As its name suggests, structured programming is done in a structured programming language and C# is one such language.

The structured programming concept was formalized in 1966 by Corrado Böhm<sup>[4]</sup> and Giuseppe Jacopini<sup>[5]</sup>. They demonstrated theoretical computer program design using sequences, decisions, and iterations.

## 4.11 The Three Fundamental Control Structures

There are three fundamental control structures in structured programming.

- ▶ **Sequence Control Structure:** This refers to the line-by-line execution, in which statements are executed sequentially, in the same order in which they appear in the program, without skipping any of them. It is also known as a *sequential control structure*.
- ▶ **Decision Control Structure:** Depending on whether a condition is true or false, the decision control structure may skip the execution of an entire block of statements or even execute one block of statements

instead of another. It is also known as a *selection control structure*.

- **Loop Control Structure:** This is a control structure that allows the execution of a block of statements multiple times until a specified condition is met. It is also known as an *iteration control structure* or a *repetition control structure*.

 Every computer program around the world is written in terms of only these three control structures!

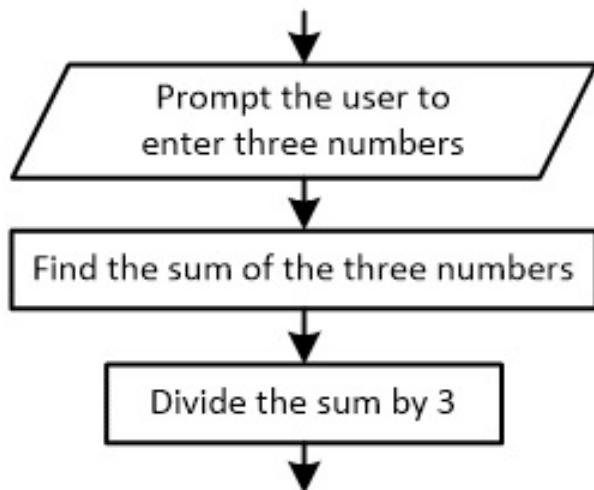
If you didn't quite understand the deeper meaning of these three control structures, don't worry, because upcoming chapters will analyze them very thoroughly. Patience is a virtue. All you have to do for now is wait!

### Exercise 4.11-1 Understanding Control Structures Using Flowcharts

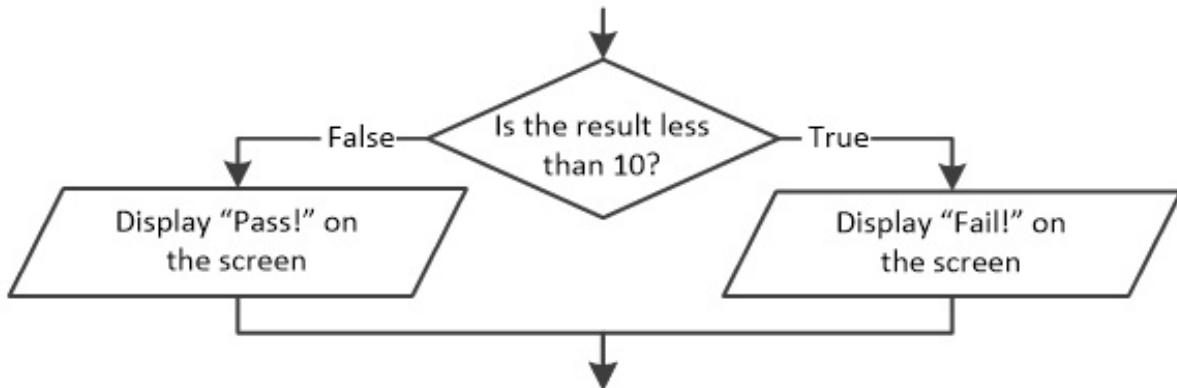
Using flowcharts, give an example for each type of control structure.

#### Solution

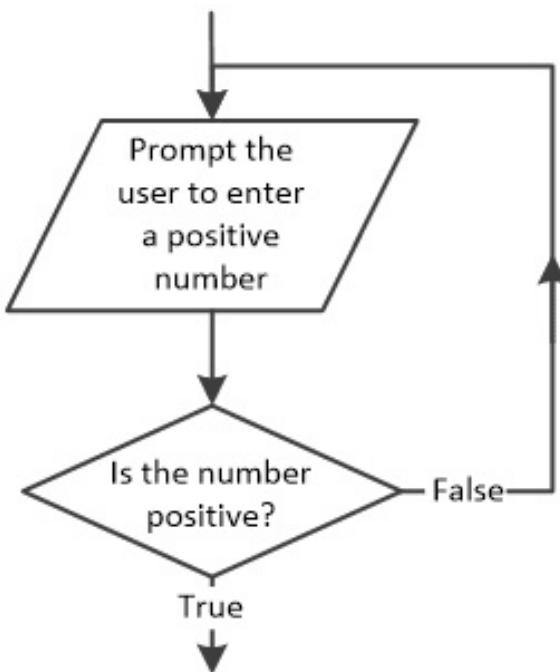
##### **Example of a Sequence Control Structure**



##### **Example of a Decision Control Structure**



### Example of a Loop Control Structure



## 4.12 Your First C# Program

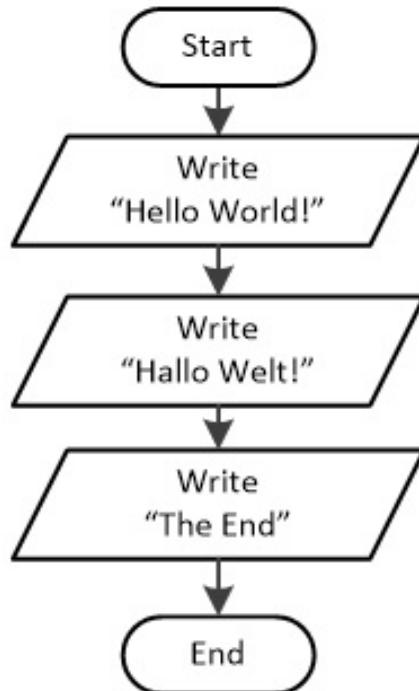
Converting a flowchart to a computer language such as C# results in a C# program. A C# program is nothing more than a text file including C# statements. C# programs can even be written in your text editor application! Keep in mind, though, that using Visual Studio to write C# programs is a much better solution due to all of its included features that can make your life easier.

 A C# source code is saved on your hard disk with the default .cs file extension.

A C# program must always contain a Main method, as shown here.

```
static void Main(string[] args) {  
    // C# code goes here  
}
```

Here is a very simple algorithm that displays three messages on the screen.



This algorithm can also be written as a C# program as follows.

```
static void Main(string[] args) {  
    Console.WriteLine("Hello World!");  
    Console.WriteLine("Hallo Welt!");  
    Console.WriteLine("The End");  
}
```

 Note that C# requires that all statements be terminated with a semicolon.

## 4.13 What is the Difference Between a Syntax Error, a Logic Error, and a Runtime Error?

When programmers write code in a high-level language there are three types of errors that might happen: syntax errors, logic errors, and runtime errors.

A *syntax error* is a mistake such as a misspelled keyword, a missing

punctuation character, or a missing closing bracket. The syntax errors are detected by the compiler or the interpreter. If you try to execute a C# program that contains a syntax error, you will get an error message on your screen and the program won't execute. You must correct any errors and then try to execute the program again.

 *Some IDEs, such as Visual Studio, detect these errors as you type and underline the erroneous statements with a wavy red line.*

A *logic error* is an error that prevents your program from doing what you expected it to do. With logic errors you get no warning at all. Your code compiles and runs but the result is not the expected one. Logic errors are hard to detect. You must review your program thoroughly to find out where your error is. For example, consider a C# program that prompts the user to enter three numbers, and then calculates and displays their average value. In this program, however, the programmer made a typographical error (a “typo”); one of his or her statements divides the sum of the three numbers by 5, and not by 3 as it should. Of course the C# program executes as normal, without any error messages, prompting the user to enter three numbers and displaying a result, but obviously not the correct one! It is the programmer who has to find and correct the erroneously written C# statement, not the computer or the interpreter! Computers are not that smart after all!

A *runtime error* is an error that occurs during the execution of a program. A runtime error can cause a program to end abruptly or even cause system shut-down. Such errors are the most difficult errors to detect. There is no way to be sure, before executing the program, whether this error is going to happen, or not. You can suspect that it may happen though! For example, running out of memory or a division by zero causes a runtime error.

 *A logic error can be the cause of a runtime error!*

 *Logic errors and runtime errors are commonly referred to as "bugs", and are often found before the software is released. When errors are found after a software has been released to the public, programmers often release patches, or small updates, to fix the errors.*

## 4.14 Commenting Your Code

When you write a small and easy program, anyone can understand how it

works just by reading it line-by-line. However, long programs are difficult to understand, sometimes even by the same person who wrote them.

*Comments* are extra information that can be included in a program to make it easier to read and understand. You can add explanations and other pieces of information, including:

- ▶ who wrote the program
- ▶ when the program was created or last modified
- ▶ what the program does
- ▶ how the program works

 *Comments are for human readers. Compilers and interpreters ignore any comments you may add to your programs.*

However, you should not over-comment. There is no need to explain every line of your program. Add comments only when a particular portion of your program is hard to follow.

In C#, you can add comments using one of the following methods:

- ▶ double slashes //.....
- ▶ slash-asterisk, asterisk-slash delimiters /\* ..... \*/

The following program demonstrates how to use both types of commenting. Usually double slashes ( // ) are used for commenting one single line, whereas the slash-asterisk, asterisk-slash delimiters /\* ..... \*/ are used for commenting multiple lines at once.

```
/*
   Created By Bouras Aristides
   Date created: 12/25/2003
   Date modified: 04/03/2008
   Description: This program displays some messages on the screen
*/



static void Main(string[] args) {
    Console.WriteLine("Hello Zeus!"); //It displays a message on the screen

    //Display a second message on the screen
    Console.WriteLine("Hello Hera!");

    /* Display a third message on screen */ Console.WriteLine("Γεια σας");
```

```
//This is a comment      Console.WriteLine("The End");  
}
```

As you can see in the preceding program, you can add comments above a statement or at the end of it, but not in front of it. Look at the last statement, which is supposed to display the message “The End”. This statement is never executed because it is considered part of the comment.

 If you add comments using the delimiters `/* ..... */` in front of a statement, the statement is still executed. In the preceding example, the Greek message “Γεια σας”, even though it is written next to some comments, is still executed. It is advisable, however, not to follow this writing style because it can make your code difficult to read.

 Comments are not visible to the user of a program while the program runs.

## 4.15 User-Friendly Programs

What is a *user-friendly* program? It's one the user considers a friend instead of an enemy, one that is easy for a novice user.

If you want to write user-friendly programs you have to put yourself in the shoes of the user. Users want the computer to do their job their way, with a minimum of effort. Hidden menus, unclear labels and directions, and misleading error messages can all make a program user-unfriendly!

The law that best defines user-friendly designs is the *Law of Least Astonishment*: “*The program should act in a way that least astonishes the user*”. This law is also commonly referred to as the *Principle of Least Astonishment (POLA)*.

## 4.16 Review Questions: True/False

Choose **true** or **false** for each of the following statements.

1. The process for preparing a meal is actually an algorithm.
2. Algorithms are used only in computer science.
3. An algorithm can run forever.
4. In an algorithm, you can relocate a step in any position you wish.
5. An algorithm must produce the correct output values for at least one set of input values.

6. Computers can play chess.
7. An algorithm can always become a computer program.
8. Programming is the process of creating a computer program.
9. There are always three parties involved in a computer program: the programmer, the computer, and the user.
10. The programmer and the user can sometimes be the same person.
11. It is possible for a computer program to output no results.
12. A flowchart is a computer program.
13. A flowchart is composed of a set of geometric shapes.
14. A flowchart is a method used to represent an algorithm.
15. To represent an algorithm, you can design a flowchart without using any Start/End symbols.
16. You can design a flowchart without using any Process symbols.
17. You can design a flowchart without using any Data input/output symbols.
18. A flowchart must always include at least one Decision symbol.
19. In a flowchart, a Decision symbol can have one, two, or three exit paths, depending on the given problem.
20. Reserved words are all those words that have a strictly predefined meaning.
21. Structured programming includes structured design.
22. C# is a structured computer language.
23. The basic principle of structured programming is that it includes only four fundamental control structures.
24. One statement, written ten times, is considered a loop control structure.
25. Decision control structure refers to the line-by-line execution.
26. A misspelled keyword is considered a logic error.
27. A C# program can be executed even though it contains logic errors.
28. If you leave an exclamation mark at the end of a C# statement, it is considered a syntax error.
29. If you leave an exclamation mark at the end of a C# statement, it cannot

prevent the whole C# program from being executed.

30. One of the advantages of structured programming is that no errors are made while writing a computer program.
31. Logic errors are caught during compilation.
32. Runtime errors are caught during compilation.
33. Syntax errors are the most difficult errors to detect.
34. A program that calculates the area of a triangle but outputs the wrong results contains logic errors.
35. When a program includes no output statements, it contains syntax errors.
36. A program must always contain comments.
37. If you add comments to a program, the computer can more easily understand it.
38. You cannot add comments above a statement.
39. Comments are not visible to the users of a program.
40. A program is called user-friendly if it can be used easily by a novice user.
41. The acronym POLA stands for “Principle of Least Amusement”.

#### **4.17 Review Questions: Multiple Choice**

Select the correct answer for each of the following statements.

1. An algorithm is a strictly defined finite sequence of well-defined statements that provides the solution to
  - a. a problem.
  - b. a specific class of problems.
  - c. both of the above
2. Which of the following is **not** a property that an algorithm must satisfy?
  - a. effectiveness
  - b. fittingness
  - c. definiteness
  - d. input

3. A computer program is
  - a. an algorithm.
  - b. a sequence of instructions.
  - c. both of the above
  - d. none of the above
4. When someone prepares a meal, he or she is the
  - a. “programmer”
  - b. “user”
  - c. none of the above
5. Which of the following does **not** belong in the three main stages involved in creating an algorithm?
  - a. data protection
  - b. data input
  - c. results output
  - d. data processing
6. A flowchart can be
  - a. presented on a piece of paper.
  - b. entered directly into a computer as is.
  - c. both of the above
7. A rectangle in a flowchart represents
  - a. an input/output operation.
  - b. a processing operation.
  - c. a decision.
  - d. none of the above
8. Which of the following is/are control structures?
  - a. a decision
  - b. a sequence
  - c. a loop
  - d. All of the above are control structures.
9. Which of the following C# statements contains a syntax error?

- a. Console.WriteLine("Hello Poseidon")
  - b. Console.WriteLine("It's me! I contain a syntax error!!!!");
  - c. Console.WriteLine("Hello Athena");
  - d. none of the above
10. Which of the following `Console.WriteLine` statements is actually executed?
- a. `Console.WriteLine("Hello Apollo");`
  - b. `/* Console.WriteLine("Hello Artemis"); */`
  - c. `//This will be executed// Console.WriteLine("Hello Ares");`
  - d. `/* This will be executed */ Console.WriteLine("Hello Aphrodite");`
  - e. none of the above

# Chapter 5

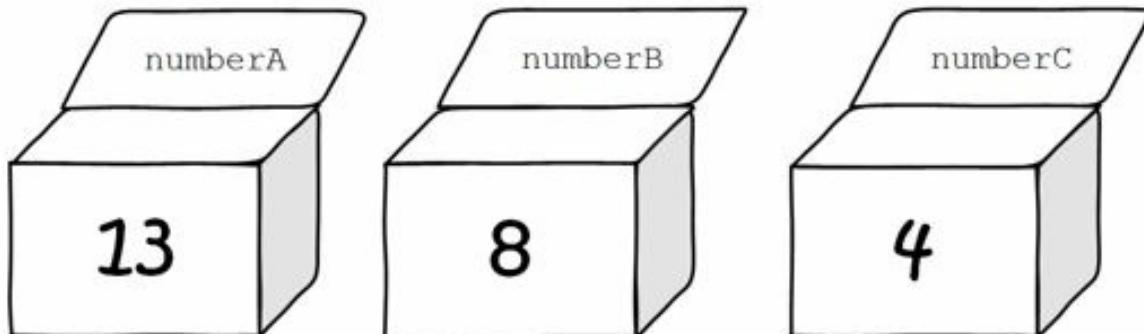
## Variables and Constants

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### 5.1 What is a Variable?

In computer science, a *variable* is a location in the computer's main memory (RAM) where a program can store a value and change it as the program executes.

Picture a variable as a transparent box in which you can insert and hold one thing at a time. Because the box is transparent, you can also see what it contains. Also, if you have two or more boxes you can give each box a unique name. For example, you could have three boxes, each containing a different number, and you could name the boxes `numberA`, `numberB`, and `numberC`.

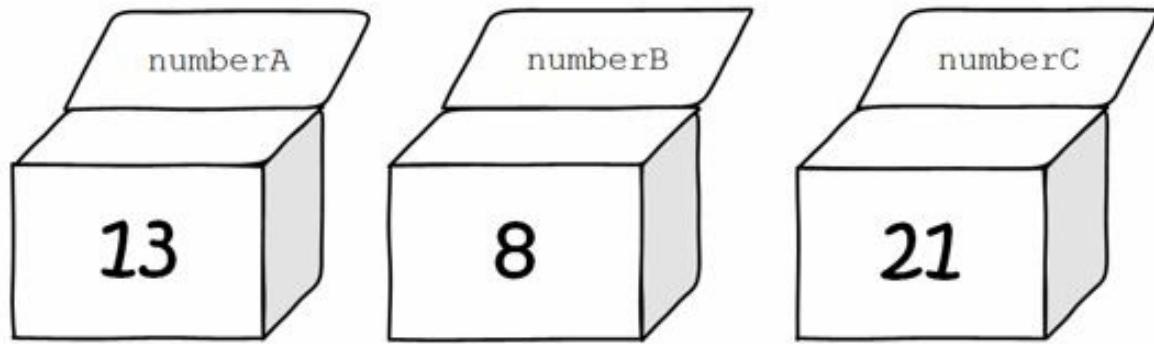


The boxes named `numberA`, `numberB` and `numberC` in the example contain the numbers 13, 8, and 4, respectively. Of course, you can examine or even alter the contained value of each one of these boxes at any time.

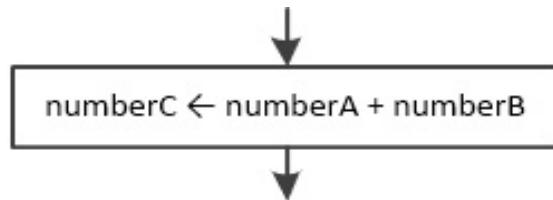
Now, let's say that someone asks you to find the sum of the values of the first two boxes and then store the result in the last box. The steps you must follow are:

1. Look at the first two boxes and examine the values they contain.
2. Use your CPU (this is your brain) to calculate the sum (the result).
3. Insert the result in the last box. However, since each box can contain only one single value at a time, the value 4 is actually replaced by the number 21.

The boxes now look like this.



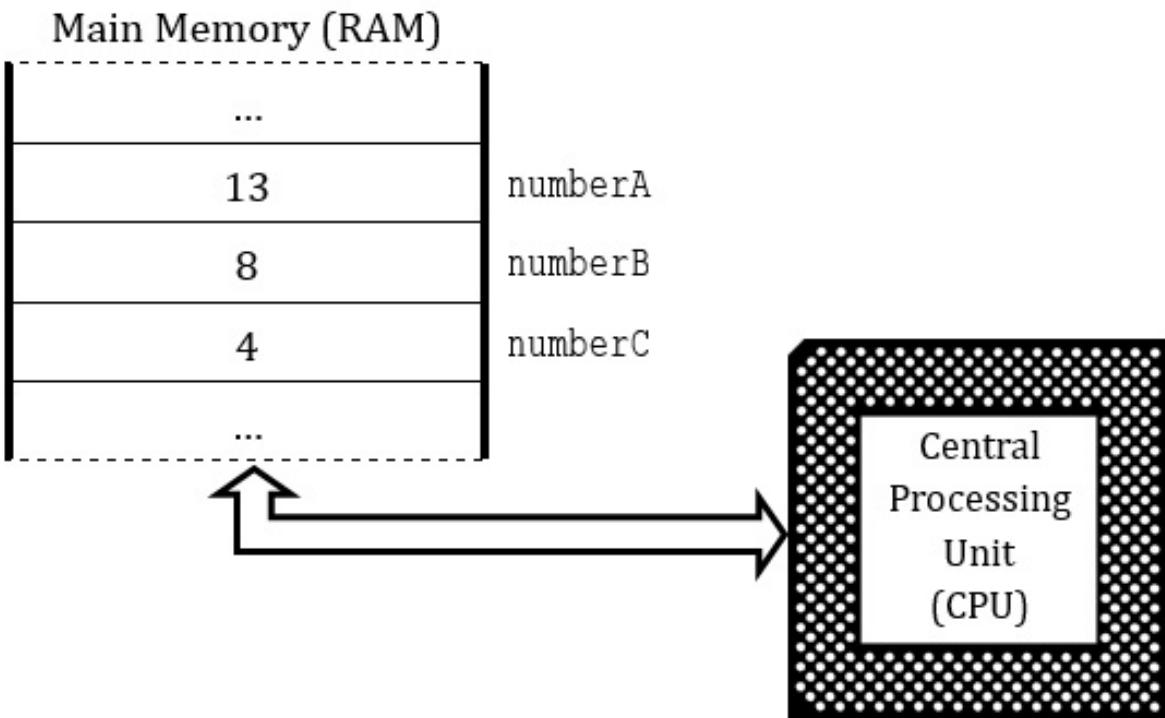
In a flowchart, the action of storing a value in a variable is represented by a left arrow



This action is usually expressed as “Assign a value, or the result of an expression, to a variable”. The left arrow is called the *value assignment operator*.

 Note that this arrow always points to the left. You are not allowed to use right arrows. Also, on the left side of the arrow only one single variable must exist.

In real computer science, the three boxes are actually three individual regions in main memory (RAM), named numberA, numberB and numberC.



When a program instructs the CPU to execute the statement

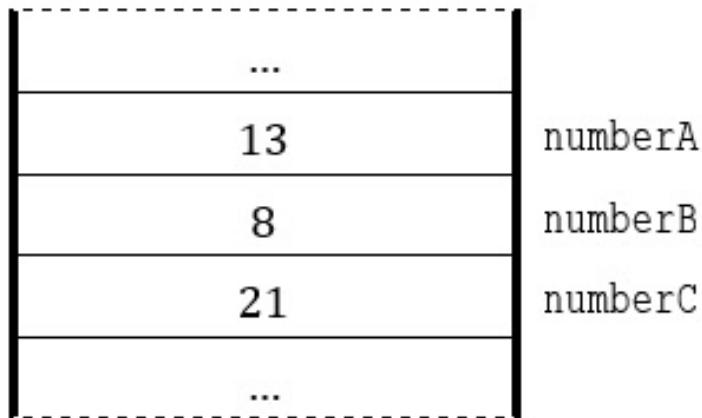
$$\text{numberC} \leftarrow \text{numberA} + \text{numberB}$$

it follows the same three-step process as in the previous example.

1. The numbers 13 and 8 are transferred from the RAM's regions named `numberA` and `numberB` to the CPU.  
(This is the first step, in which you examined the values contained in the first two boxes).
2. The CPU calculates the sum of  $13 + 8$ .  
(This is the second step, in which you used your brain to calculate the sum, or result).
3. The result, 21, is transferred from the CPU to the RAM's region named `numberC`, replacing the existing number 4.  
(This is the third step, in which you inserted the result in the last box).

After execution, the RAM looks like this.

## Main Memory (RAM)



☞ While a C# program is running, a variable can hold various values, but only one value at a time. When you assign a value to a variable, this value remains stored until you assign a new value replacing the old one.

☞ The content of a variable can change to different values, but its name will always be the same because the name is just an identifier of a location in memory.

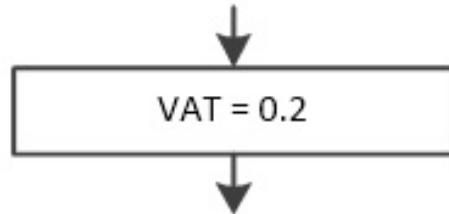
A variable is one of the most important elements in computer science because it helps you interact with data stored in the main memory (RAM). Soon, you will learn all about how to use variables in C#.

## 5.2 What is a Constant?

Sometimes you may need to use a value that cannot change while the program is running. Such a value is called a *constant*. In simple terms, you could say that a constant is a locked variable. This means that when a program begins to run and a value is assigned to the constant, nothing can change the value of the constant while the program is running. For example, in a financial program an interest rate can be declared as a constant.

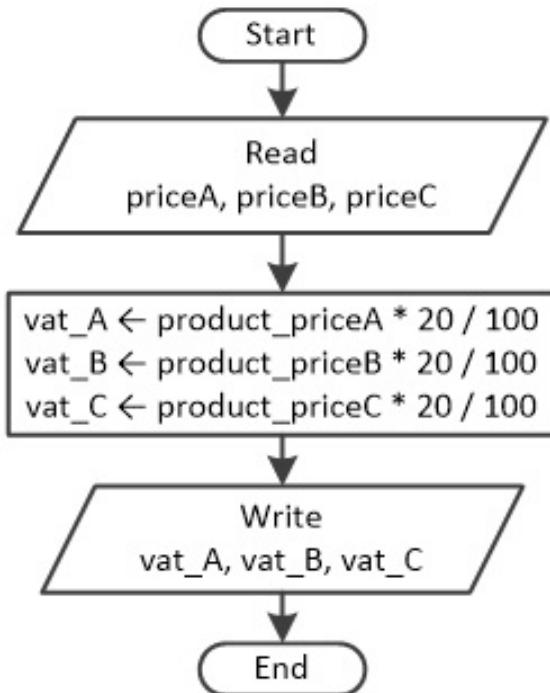
A descriptive name for a constant can also improve the readability of your program and help you avoid some errors. For example, let's say that you are using the value 3.14159265 (but not as a constant) at many points throughout your program. If you make a typographic error when typing the number, this will produce the wrong results. But, if this value is given a name, any typographical error in the name is detected by the compiler, and you are notified with an error message.

In a flowchart, you can represent the action of setting a constant equal to a value with the equals ( $=$ ) sign.



This book uses uppercase characters to distinguish a constant from a variable.

Consider an algorithm that lets the user enter the prices of three different products and then calculates and displays the 20% Value Added Tax (known as VAT) for each product. The flowchart in **Figure 5–1** shows this process when no constant is used.



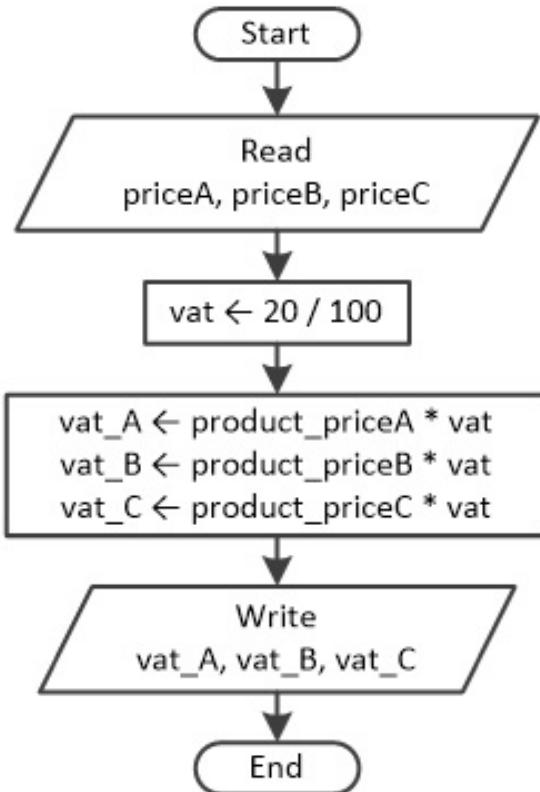
**Figure 5–1** Calculating the 20% VAT for three products without the use of a constant

Even though this algorithm is absolutely correct, the problem is that the author used the 20% VAT (20/100) three times. If this were an actual computer program, the CPU would be forced to calculate the result of the division (20/100) three individual times.

Generally speaking, division and multiplication are CPU-time

*consuming operations that must be avoided when possible.*

A much better solution would be to use a variable, as shown in **Figure 5–2**. This reduces the number of division operations and also decreases the potential for typographical errors.

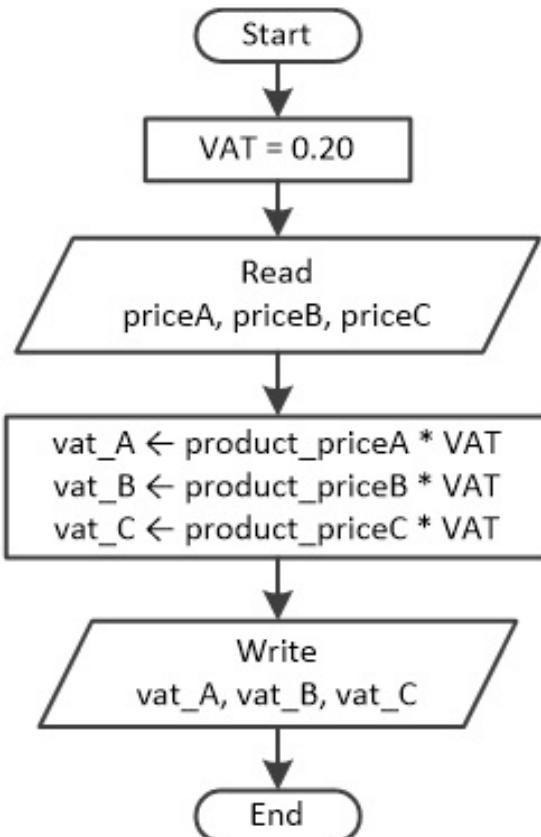


**Figure 5–2** Calculating the 20% VAT for three products using a variable, vat

This time the division ( $20/100$ ) is calculated only once, and then its result is used to calculate the VAT of each product.

But even now, the algorithm (which might later become a computer program) isn't perfect; vat is a variable and any programmer could accidentally change its value below in the program.

The ideal solution would be to change the variable vat to a constant VAT, as shown in **Figure 5–3**.



**Figure 5–3** Calculating the 20% VAT for three products using a constant, VAT

Note that when a constant is declared in a flowchart, the equals (=) sign is used instead of the left arrow.

This last solution is the best choice for many reasons.

- ▶ No one, including the programmer, can change the value of constant VAT just by accidentally writing a statement such as `VAT ← 0.60` in any position of the program.
- ▶ The potential for typographical errors is minimized.
- ▶ The number of division operations is kept as low as possible.
- ▶ If one day the finance minister decides to increase the Value Added Tax from 20% to 22%, the programmer needs to change just one line of code!

### 5.3 How Many Types of Variables and Constants Exist?

Many different types of variables and constants exist in most computer languages. The reason for this diversity is the different types of data each

variable or constant can hold. Most of the time, variables and constants hold the following types of data.

- ▶ **Integers:** An *integer* value is a positive or negative number without any fractional part, such as 5, 100, 135, -25, and -5123.
- ▶ **Reals:** A *real* value is a positive or negative number that includes a fractional part, such as 5.1, 7.23, 5.0, 3.14, and -23.78976. Real values are also known as *floats*.
- ▶ **Booleans**<sup>[6]</sup>: A *Boolean* variable (or constant) can hold only one of two values: true or false.
- ▶ **Characters:** A *character* is an *alphanumeric* value (a letter, a symbol, or a number), and it is usually enclosed in single or double quotes, such as "a", "c", or "@". In computer science, a sequence of characters is known as a *string*!!! Probably the word "string" makes you visualize something wearable, but unfortunately it's not. Please keep your dirty precious mind focused on computer science! Examples of strings are "Hello Zeus", "I am 25 years old", or "Peter Loves Jane For Ever".



In C#, strings must be enclosed in double quotes.

## 5.4 Rules for Naming Variables and Constants in C#

Certain rules must be followed when you choose a name for your variable or constant.

- ▶ The name of a variable or constant can contain only Latin characters (English uppercase or lowercase characters), numbers, and the underscore character ( \_ ). Examples of variable names are `firstName`, `last_name1`, and `age`.
- ▶ Variable and constant names are case sensitive, which means there is a distinct difference between uppercase and lowercase characters. For example, `myVAR`, `myvar`, `MYVAR`, and `MyVar` are actually four different names.
- ▶ No space characters are allowed. If a variable or constant is described by more than one word, you can use the underscore character ( \_ ) between the words. For example, the variable name `student age` is wrong. Instead, you might use `student_age`, or even `studentAge`.
- ▶ A valid variable or constant name can start with a letter, or an

underscore. Numbers are allowed, but they cannot be used at the beginning of the name. For example the variable name `1student_name` is not properly written. Instead, you might use something like `student_name1` or `student1_name`.

- A variable or constant name is usually chosen in a way that describes the meaning and the role of the data it contains. For example, a variable that holds a temperature value might be named `temperature`, `temp`, or even `t`.

 *Regarding constants, even though lowercase letters are permitted, it is advisable to use only uppercase letters. This helps you to visually distinguish constants from variables. Examples of constant names are `VAT` and `COMPUTER_NAME`.*

## 5.5 What Does the Phrase “Declare a Variable” Mean?

*Declaration* is the process of reserving a portion in main memory (RAM) for storing the contents of a variable. In many high-level computer languages (including C#), the programmer must write a specific statement to reserve that portion in the RAM before the variable can be used. In most cases, they even need to specify the variable type so that the compiler or the interpreter knows exactly how much space to reserve.

Here are some examples showing how to declare a variable in different high-level computer languages.

Declaration Statement	High-level Computer Language
<code>Dim sum As Integer</code>	Visual Basic
<code>int sum;</code>	C#, C++, Java, and many more
<code>sum: Integer;</code>	Pascal, Delphi
<code>var sum;</code>	Javascript

## 5.6 How to Declare Variables in C#

C# is a strongly typed programming language. This means that each variable must have a specific data type associated with it. For example, a variable can hold an integer, a real, or a character. In C# some of the primitive data types

are: `bool`, `byte`, `short`, `int`, `long`, `float`, `double`, `decimal`, and `char`. Which one to use depends on the given problem! To be more specific:

- ▶ type `bool` can hold only two possible values: that is, `true` or `false`.
- ▶ type `byte` can hold an unsigned integer between 0 and 255.
- ▶ type `sbyte` can hold a signed integer between -128 and +127.
- ▶ type `ushort` can hold an unsigned integer between 0 and +65535.
- ▶ type `short` can hold a signed integer between -32768 and +32767
- ▶ type `uint` can hold an unsigned integer between 0 and  $+2^{32} - 1$ .
- ▶ type `int` can hold a signed integer between  $-2^{31}$  and  $+2^{31} - 1$ .
- ▶ type `ulong` can hold an unsigned integer between 0 and  $+2^{64} - 1$ .
- ▶ type `long` can hold a signed integer between  $-2^{63}$  and  $+2^{63} - 1$
- ▶ type `float` can hold a signed real of single precision.
- ▶ type `double` can hold a signed real of double precision.
- ▶ type `decimal` can hold a signed real of high precision (with 28–29 significant digits).
- ▶ type `char` can hold a single character.

 In many computer languages, there is one more variable type called “string”, which can hold a sequence of characters. These sequences of characters, or strings are usually enclosed in double or single quotes, such as “Hello Zeus”, “I am 25 years old”, and so on. C# also supports strings, but keep in mind that a string in C# is not a primitive data type. Without going into detail, a string in C# is declared the same way as you declare a primitive data type but internally C# stores and handles them in a quite different way.

To declare a variable, the general form of the C# statement is

```
type name [ = value];
```

where

- ▶ `type` can be `bool`, `byte`, `short`, `int`, `string` and so on.
- ▶ `name` is a valid variable name.
- ▶ `value` can be any valid initial value.

Below are some examples of how to declare variables in C#.

```
int number1;
bool found;
string first_name;
string student_name;
```

In C# you can declare and directly assign an initial value to a variable. The next code fragment

```
int num = 5;
string name = "Hera";
char favorite_character = 'w';
```

is equivalent to

```
int num;
string name;
char favorite_character;

num = 5;
name = "Hera";
favorite_character = 'w';
```

 In C#, you can represent the action of assigning a value to a variable by using the equals (=) sign. This is equivalent to the left arrow in flowcharts.

 Note that in C# you assign a value to a variable of type string using double quotes (" "), but you assign a value to a variable of type char using single quotes (' ').

Last but not least, you can declare many variables of the same type on one line by separating them with commas.

```
int a, b;
double x, y, z;
long w = 3, u = 2;
```

## 5.7 How to Declare Constants in C#

You can declare constants in C# using the keyword const.

```
const type name = value;
```

The following examples show how to declare constants in C#.

```
const double VAT = 0.22;
const int NUMBER_OF_PLAYERS = 25;
const string COMPUTER_NAME = "pc01";
const string FAVORITE_SONG = "We are the world";
const char FAVORITE_CHARACTER = 'w';
```

-  Note that in C# you declare a constant of type string using double quotes (" "), but you declare a constant of type char using single quotes (' ').
-  Once a constant is defined, its value cannot be changed while the program is running.
-  C# requires that all statements be terminated with a semicolon ( ; ).
-  Even though the name of a constant can contain lowercase letters, it is advisable to use only uppercase letters. This helps you to visually distinguish constants from variables.

## 5.8 Review Questions: True/False

Choose **true** or **false** for each of the following statements.

1. A variable is a location in the computer's secondary storage device.
2. For a value assignment operator in a flowchart, you can use either a left or a right arrow.
3. The content of a variable can change while the program executes.
4. In general, the content of a constant can change while the program executes.
5. The value 10.0 is an integer.
6. A Boolean variable can hold only one of two values.
7. The value "10.0" enclosed in double quotes is a real value.
8. In computer science, a string is something that you can wear!
9. The name of a variable can contain numbers.
10. A variable can change its name while the program executes.
11. The name of a variable cannot be a number.
12. The name of a constant must always be a descriptive one.
13. The name student\_name is not a valid variable name.
14. The name STUDENT\_NAME is a valid constant name.
15. In C#, the name of a constant can contain uppercase and lowercase letters.
16. In C#, you need to declare a variable before it can be used.
17. In a C# program, you must always use at least one constant.

## **5.9 Review Questions: Multiple Choice**

Select the correct answer for each of the following statements.

1. A variable is a place in
  - a. a hard disk.
  - b. a DVD disc.
  - c. a USB flash drive.
  - d. all of the above
  - e. none of the above
2. A variable can hold
  - a. one value at a time.
  - b. many values at a time.
  - c. all of the above
  - d. none of the above
3. In general, using constants in a program
  - a. helps programmers to completely avoid typographical errors.
  - b. helps programmers to avoid using division and multiplication.
  - c. all of the above
  - d. none of the above
4. Which of the following is an integer?
  - a. 5.0
  - b. -5
  - c. “5”
  - d. none of the above is an integer.
5. A Boolean variable can hold the value
  - a. one.
  - b. “true”.
  - c. true.
  - d. none of the above
6. In C#, a character can be

- a. enclosed in single quotes.
  - b. enclosed in double quotes.
  - c. both of the above
7. Which of the following is **not** a valid C# variable?
- a. city\_name
  - b. cityName
  - c. cityname
  - d. city-name

## 5.10 Review Exercises

Complete the following exercises.

1. Match each element from the first column with one element from the second column.

Value	Data Type
1. “true”	a. Boolean
2. 123	b. Real
3. false	c. String
4. 10.0	d. Integer

2. Match each element from the first column with one element from the second column.

Value	Data Type
1. The name of a person	a. Boolean
2. The age of a person	b. Real
3. The result of the division 5.0/2.0	c. Integer
4. Is it black or is it white?	d. String

3. Complete the following table

Value	Data Type	Declaration and Initialization

The name of my friend	String	name = "Mark"
My address		address = "254 Lookout Rd. Wilson, NY 27893"
The average daily temperature		
A telephone number		phone_number = "1-891-764-2410"
My Social Security Number (SSN)		
The speed of a car		
The number of children in a family		

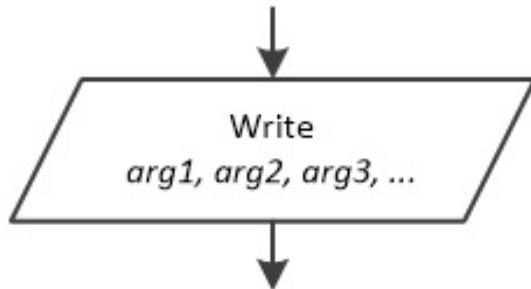
# **Chapter 6**

## **Handling Input and Output**

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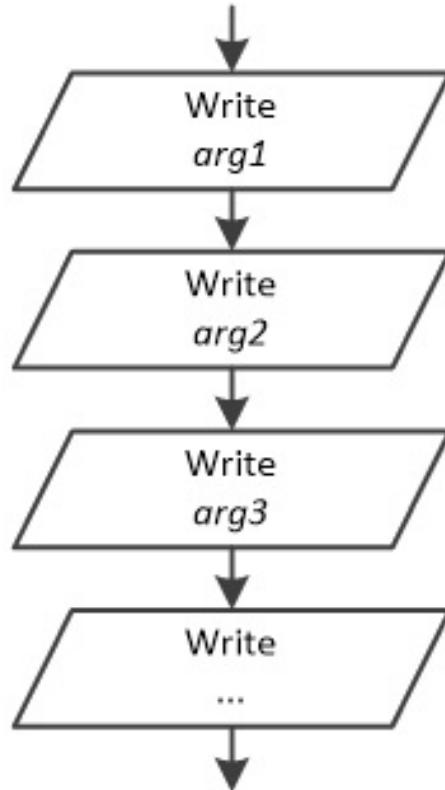
### **6.1 Which Statement Outputs Messages and Results on a User's Screen?**

A flowchart uses the oblique parallelogram and the reserved word “Write” to display a message or the final results to the user's screen.



where *arg1*, *arg2*, and *arg3* can be variables, expressions, constant values, or even strings enclosed in double quotes.

The oblique parallelogram that you have just seen is equivalent to



In C#, you can achieve the same result by using the `Console.WriteLine` statement. Its general form is

```
Console.WriteLine(arg1 + arg2 + arg3 + ... );
```

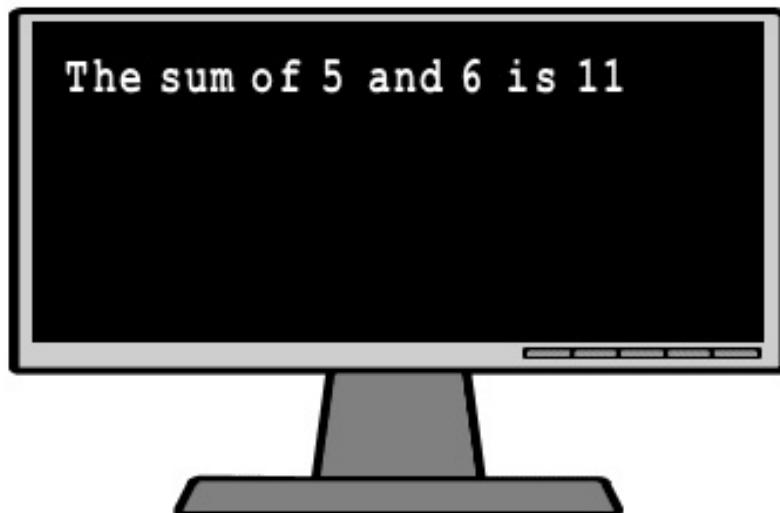
or the equivalent sequence of statements

```
Console.WriteLine(arg1);
Console.WriteLine(arg2);
Console.WriteLine(arg3);
...
```

The following two statements:

```
a = 5 + 6;
Console.WriteLine("The sum of 5 and 6 is " + a);
```

display the message shown in **Figure 6–1**.



**Figure 6–1** A string and an integer displayed on the screen

 In C#, if you want to display a string on the screen, the string must be enclosed in double quotes.

 Note the space inserted at the end of the first string in C#, just after the word “is”. If you remove it, the number 11 will get too close to the last word and the output on the screen will be

```
The sum of 5 and 6 is11
```

You can also calculate the result of a mathematical expression directly in a `Console.WriteLine` statement. The following statement:

```
Console.WriteLine("The sum of 5 and 6 is " + (5 + 6));
```

displays exactly the same message as in **Figure 6–1**.

 Note that C# requires that all statements be terminated with a semicolon.

## 6.2 How to Output Special Characters

Look carefully at the following example:

```
Console.WriteLine("Hello");
Console.WriteLine("Hallo");
Console.WriteLine("Salut");
```

Although you may believe that these three messages are displayed one under the other, the actual output result is shown in **Figure 6–2**.



**Figure 6–2** The output result displays on one line

In order to output a “line break” you must put the special sequence of characters `\n` after every sentence.

```
Console.WriteLine("Hello\n");
Console.WriteLine("Hallo\n");
Console.WriteLine("Salut\n");
```

or use the C# statement `Console.WriteLine` as follows

```
Console.WriteLine("Hello");
Console.WriteLine("Hallo");
Console.WriteLine("Salut");
```

 Note that it is `WriteLine`, not `Write`. The `Console.WriteLine()` statement adds a “line break” at the end of the output.

The output result now appears in **Figure 6–3**.



**Figure 6–3** The output result now displays line breaks

Keep in mind that the same result can also be accomplished with one single statement.

```
Console.WriteLine("Hello\nHallo\nSalut\n");
```

Another interesting sequence of characters is the \t which can be used to output a “tab stop”. The tab character (\t) is useful for aligning output.

```
Console.WriteLine("John\tGeorge");
Console.WriteLine("Sofia\tMary");
```

The output result now appears in **Figure 6–4**.



**Figure 6–4** The output result now displays tabs

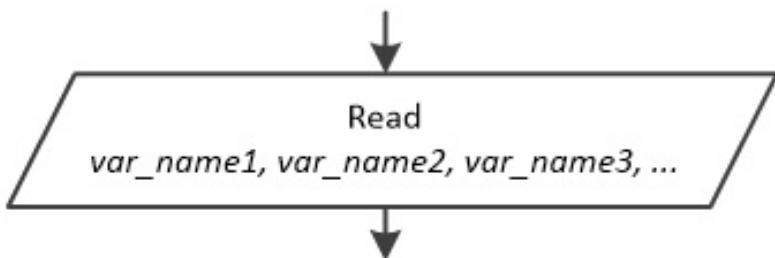
Of course, the same result can be accomplished with one single statement.

```
Console.WriteLine("John\tGeorge\nSofia\tMary");
```

### 6.3 Which Statement Lets the User Enter Data?

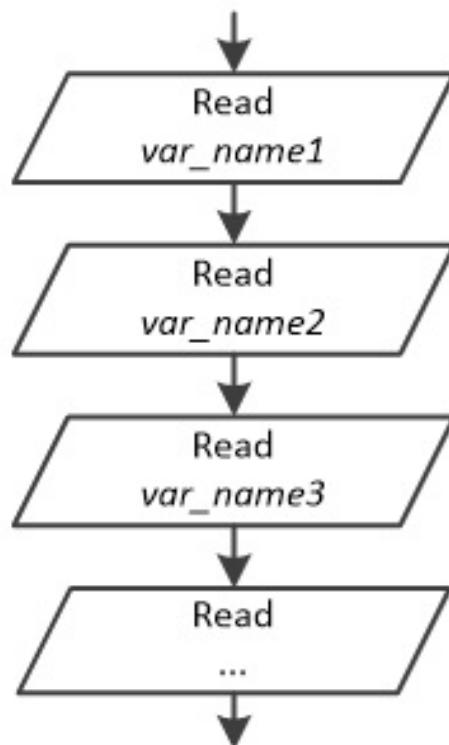
Do you recall the three main stages involved in creating an algorithm or a computer program? The first stage was the “data input” stage, in which the computer lets the user enter data such as numbers, their name, their address, or their year of birth.

A flowchart uses the oblique parallelogram and the reserved word “Read” to let a user enter his or her data.



where *var\_name1*, *var\_name2*, and *var\_name3* must be variables only.

The oblique parallelogram that you have just seen is equivalent to



 When a Read statement is executed, the flow of execution is interrupted until the user has entered all the data. When data entry is complete, the flow of execution continues to the next statement. Usually data are entered from a keyboard.

In C#, data input can be accomplished using some of the following C# statements.

```
string var_name_str;
```

```

byte var_name_byte;
short var_name_short;
int var_name_int;
long var_name_long;
double var_name dbl;

//Read a string from the keyboard
var_name_str = Console.ReadLine();

//Read a very short integer from the keyboard
var_name_byte = Byte.Parse(Console.ReadLine());

//Read a short integer from the keyboard
var_name_short = Int16.Parse(Console.ReadLine());

//Read an integer from the keyboard
var_name_int = Int32.Parse(Console.ReadLine());

//Read a long integer from the keyboard
var_name_long = Int64.Parse(Console.ReadLine());

//Read a real from the keyboard
var_name dbl = Double.Parse(Console.ReadLine());

```

where

- ▶ *var\_name\_str* can be any variable of type **string**.
- ▶ *var\_name\_byte* can be any variable of type **byte**.
- ▶ *var\_name\_short* can be any variable of type **short**.
- ▶ *var\_name\_int* can be any variable of type **int**.
- ▶ *var\_name\_long* can be any variable of type **long**.
- ▶ *var\_name dbl* can be any variable of type **double**.

The following code fragment lets the user enter his or her name and then displays it with the word “Hello” in front of it.

```

string name;

name = Console.ReadLine();
Console.WriteLine("Hello " + name);

```

In the previous code fragment, when the **Console.ReadLine()** statement executes, the flow of execution stops, waiting for the user to enter his or her name. The **Console.WriteLine("Hello " + name)** statement is not yet executed!

As long as the user doesn't enter anything, the computer just waits, as shown in **Figure 6–5**.



**Figure 6–5** When a `Console.ReadLine()` statement executes, the computer waits for data input.

When the user finally enters his or her name and hits the “Enter ↵” key, the flow of execution then continues to the next `Console.WriteLine()` statement as shown in **Figure 6–6**.



**Figure 6–6** The flow of execution continues when the user hits the “Enter ↵” key.

However, it could be even better if, before each data input, a “prompt” message is displayed. This makes the program more user-friendly. For example, look at the following code fragment.

```
string name;  
  
Console.WriteLine("What is your name? ");  
name = Console.ReadLine();  
Console.WriteLine("Hello " + name);
```

In the preceding code fragment, before the `Console.ReadLine()` statement

executes, the message “What is your name?” (without the double quotes) is displayed, as shown in **Figure 6–7**.



**Figure 6–7** When a “prompt” message is displayed before the `Console.ReadLine()` statement. The following code fragment prompts the user to enter his or her name and age.

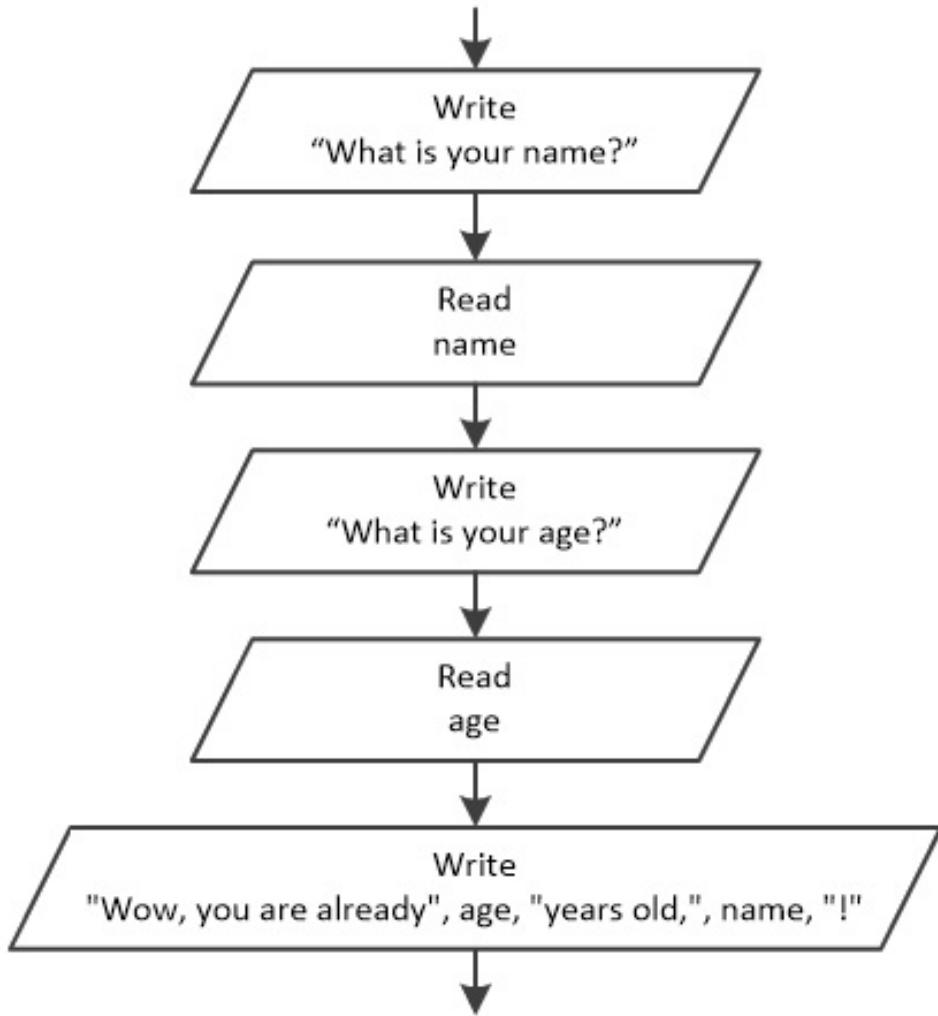
```
string name;
byte age;

Console.WriteLine("What is your name? ");
name = Console.ReadLine();

Console.WriteLine("What is your age? ");
age = Byte.Parse(Console.ReadLine());

Console.WriteLine("Wow, you are already " + age + " years old, " + name + "!");
```

The corresponding flowchart fragment looks like this.



To read a float (a double), that is, a number that contains a fractional part, you need to use a slightly different statement. The following code fragment prompts the user to enter the name and the price of a product.

```

string product_name;
double product_price;

Console.WriteLine("Enter product name: ");
product_name = Console.ReadLine();

Console.WriteLine("Enter product price: ");
product_price = Double.Parse(Console.ReadLine());
  
```

In this book there is a slight difference between the words “prompts” and “lets”. When an exercise says “Write a C# program that **prompts** the user to enter...” this means that you *must* include a prompt message. However, when the exercise says “Write a C# program that **lets** the user enter...” this

means that you are not actually required to include a prompt message; that is, it is not wrong to include one but you don't have to! The following example lets the user enter his or her name and age (but does not prompt him or her to).

```
name = Console.ReadLine();
age = Byte.Parse(Console.ReadLine());
```

What happens here (when the program is executed) is that the computer displays a text cursor without any prompt message and waits for the user to enter two values – one for name and one for age. The user, though, must be a prophet and guess what to enter! Does he have to enter his name first and then his age, or is it the opposite? So, obviously a prompt message is pretty much required, because it makes your program more user-friendly.

## 6.4 Review Questions: True/False

Choose **true** or **false** for each of the following statements.

1. In C#, the word `Console` is a reserved word.
2. The `Console.WriteLine()` statement can be used to display a message or the content of a variable.
3. When the `Console.ReadLine()` statement is executed, the flow of execution is interrupted until the user has entered a value.
4. One single `Console.ReadLine()` statement can be used to enter multiple data values.
5. Before data input, a prompt message must always be displayed.

## 6.5 Review Questions: Multiple Choice

Select the correct answer for each of the following statements.

1. The statement `Console.WriteLine("Hello")` displays
  - a. the word `Hello` (without the double quotes).
  - b. the word `"Hello"` (including the double quotes).
  - c. the content of the variable `Hello`.
  - d. none of the above
2. The statement `Console.WriteLine(Hello)` displays
  - a. the word `Hello` (without the double quotes).

- b. the word "Hello" (including the double quotes).
  - c. the content of the variable Hello.
  - d. none of the above
3. The statement `Console.WriteLine("Hello\nHermes")` displays
- a. the message Hello Hermes.
  - b. the word Hello in one line and the word Hermes in the next one.
  - c. the message HelloHermes.
  - d. the message Hello\nHermes.
  - e. none of the above
4. The statement `data1_data2 = Console.ReadLine()`
- a. lets the user enter a value and assigns it to variable data1. Variable data2 remains empty.
  - b. lets the user enter a value and assigns it to variable data1\_data2.
  - c. lets the user enter two values and assigns them to variables data1 and data2.
  - d. none of the above

# Chapter 7

## Operators

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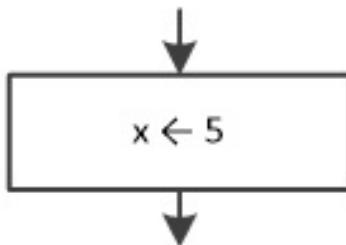
### 7.1 The Value Assignment Operator

The most commonly used operator in C# is the value assignment operator (`=`). For example, the C# statement

```
x = 5
```

assigns a value of 5 to variable `x`.

As you read in [Chapter 5](#), this is equivalent to the left arrow used in flowcharts.



Probably the left arrow used in a flowchart is more convenient and clearer than the (`=`) sign because it shows in a more graphical way that the value or the result of an expression on the right is assigned to a variable on the left.

Be careful! The (`=`) sign is not equivalent to the one used in mathematics. In mathematics, the expression  $x = 5$  is read as “ $x$  is equal to 5”. However, in C# the expression `x = 5` is read as “assign the value 5 to `x`” or “set `x` equal to 5”. They look the same but they act differently!

For example, in mathematics, the following two lines are equivalent. The first one can be read as “ $x$  is equal to the sum of  $y$  and  $z$ ” and the second one as “the sum of  $y$  and  $z$  is equal to  $x$ ”.

```
x = y + z  
y + z = x
```

On the other hand, in C#, these two statements are definitely **not** equivalent. The first statement seems quite correct. It can be read as “Set `x` equal to the sum of `y` and `z`” or “Assign the sum of `y` and `z` to `x`”. But what about the second one? Think! Is it possible to assign the value of `x` to `y + z`? The answer is obviously a big “NO!”

In C#, the variable on the left side of the (`=`) sign represents a region in

main memory (RAM) where a value can be stored.

▀ On the left side of the ( = ) sign only one single variable must exist, whereas on the right side there can be a number, a variable, a string, or even a complex mathematical expression.

In **Table 7-1** you can find some examples of value assignments.

Examples	Description
a = 9;	Assign a value of 9 to variable a.
b = c;	Assign the content of variable c to variable b.
d = "Hello Zeus";	Assign the string <i>Hello Zeus</i> to variable d.
d = a + b;	Calculate the sum of the contents of variables a and b and assign the result to variable d.
b = a + 1;	Calculate the sum of the content of variable a and 1 and assign the result to variable b. Please note that the content of variable a is not altered.
a = a + 1;	Calculate the sum of the content of variable a and 1 and assign the result back to variable a. In other words, increase variable a by one.

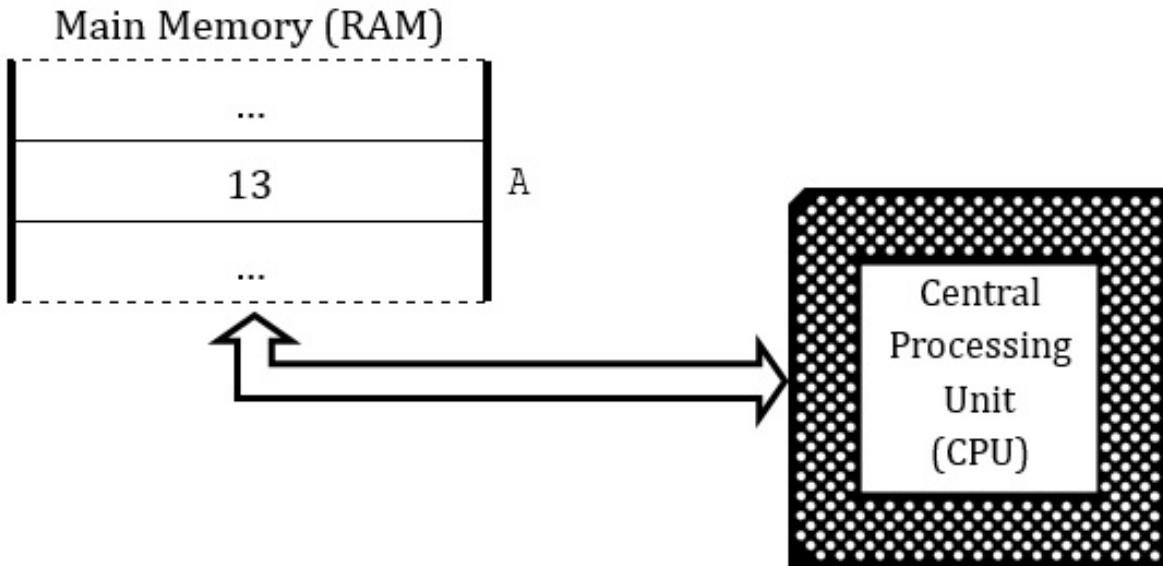
**Table 7-1** Examples of Value Assignments

Confused about the last one? Are you thinking about your math teacher right now? What would he/she say if you had written  $a = a + 1$  on the blackboard? Can you personally think of a number that is equal to the number itself plus one? Are you nuts? This means that 5 is equal to 6 and 10 is equal to 11!

Obviously, things are different in computer science. The statement  $a = a + 1$  is absolutely acceptable! It instructs the CPU to retrieve the value of variable a from main memory (RAM), to add 1 to that value, and to assign the result back to variable a. The old value of variable a is replaced by the new one.

Still don't get it? Let's take a look at how the CPU and main memory (RAM) cooperate with each other in order to execute the statement  $A \leftarrow A + 1$  (this is the same as the statement  $a = a + 1$  in C#).

Let's say that there is a region in memory, named `A` and it contains the number 13.



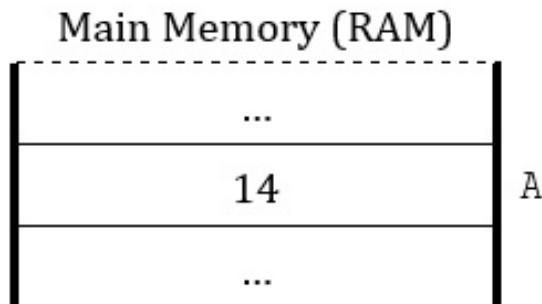
When a program instructs the CPU to execute the statement

$$A \leftarrow A + 1$$

the following procedure is executed:

- ▶ the number 13 is transferred from the RAM's region named `A` to the CPU;
- ▶ the CPU calculates the sum of 13 and 1; and
- ▶ the result, 14, is transferred from the CPU to the RAM's region named `A` replacing the existing number, 13.

After execution, the RAM looks like this.



Now that you understand everything, let's see something more. In C#, you can assign a single value to multiple variables with one single statement. The following statement:

```
| a = b = c = 4;
```

assigns the value of 4 to all three variables a, b, and c.

## 7.2 Arithmetic Operators

Just like every high-level programming language, C# supports almost all types of *arithmetic operators*.

Arithmetic Operator	Description
+	Addition
-	Subtraction
*	Multiplication
/	Division
%	Remainder after integer division (Modulus)

The first two operators are straightforward and need no further explanation.

If you need to multiply two numbers or the content of two variables you have to use the asterisk ( \* ) symbol. For example, if you want to multiply 2 times y, you must write `2 * y`. Likewise, to perform a division, you must use the slash ( / ) symbol. For example, if you want to divide 10 by 2, you must write `10 / 2`.

 In mathematics it is legal to skip the multiplication operator and write  $3x$ , meaning “3 times  $x$ ”. In C#, however, you must always use an asterisk anywhere a multiplication operation exists. This is one of the most common mistakes novice programmers make when they write mathematical expressions in C#.

The modulus operator ( % ) returns the remainder of an integer division, which means that the statement

```
| c = 13 % 3;
```

assigns a value of 1 to variable c.

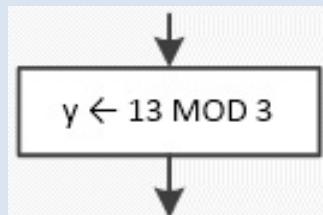
The modulus operator ( % ) can be used with floating-point numbers as well, but the result is a real (float). For example, the operation

```
| d = 14.4 % 3;
```

assigns a value of 2.4 (and not 2, as you may mistakenly expect) to variable

d.

 Keep in mind that flowcharts are a loose method used to represent an algorithm. Although the use of the modulus ( % ) operator is allowed in flowcharts, this book uses the commonly accepted MOD operator instead! For example, the C# statement `y = 13 % 3` is represented in a flowchart as



In mathematics, as you may already know, you are allowed to use parentheses (round brackets) as well as braces (curly brackets) and square brackets.

$$y = \frac{5}{2} \left\{ 3 + 2 \left[ 4 + 7 \left( 7 - \frac{4}{3} \right) \right] \right\}$$

However, in C# there is no such thing as braces and brackets. Parentheses are all you have; therefore, the same expression must be written using parentheses instead of braces or brackets.

```
| y = 5 / 2 * (3 + 2 * (4 + 7 * (7 - 4 / 3)));
```

### 7.3 What is the Precedence of Arithmetic Operators?

Arithmetic operators follow the same precedence rules as in mathematics, and these are: multiplication and division are performed first, addition and subtraction are performed afterwards.

Higher Precedence	Arithmetic Operators
	<code>*, /, %</code>
Lower precedence	<code>+, -</code>

When multiplication and division exist in the same expression, and since both are of the same precedence, they are performed left to right (the same way as you read), which means that the expression

```
| y = 6 / 3 * 2;
```

is equivalent to  $y = \frac{6}{3} \cdot 2$ , and assigns a value of 4 to variable y, (division is performed before multiplication).

If you want, however, the multiplication to be performed before the division, you can use parentheses to change the precedence. This means that

```
y = 6 / (3 * 2);
```

is equivalent to  $y = \frac{6}{3 \cdot 2}$ , and assigns a value of 1 to variable y

(multiplication is performed before division).

 C# programs can be written using your computer's text editor application, but keep in mind that it is not possible to write fractions in the form of  $\frac{6}{3}$  or  $\frac{4x+5}{6}$ . Forget it! There is no equation editor in a text editor!

All fractions must be written on one single line. For example,  $\frac{6}{3}$  must be

written as  $6 / 3$ , and  $\frac{4x+5}{6}$  must be written as  $(4 * x + 5) / 6$ .

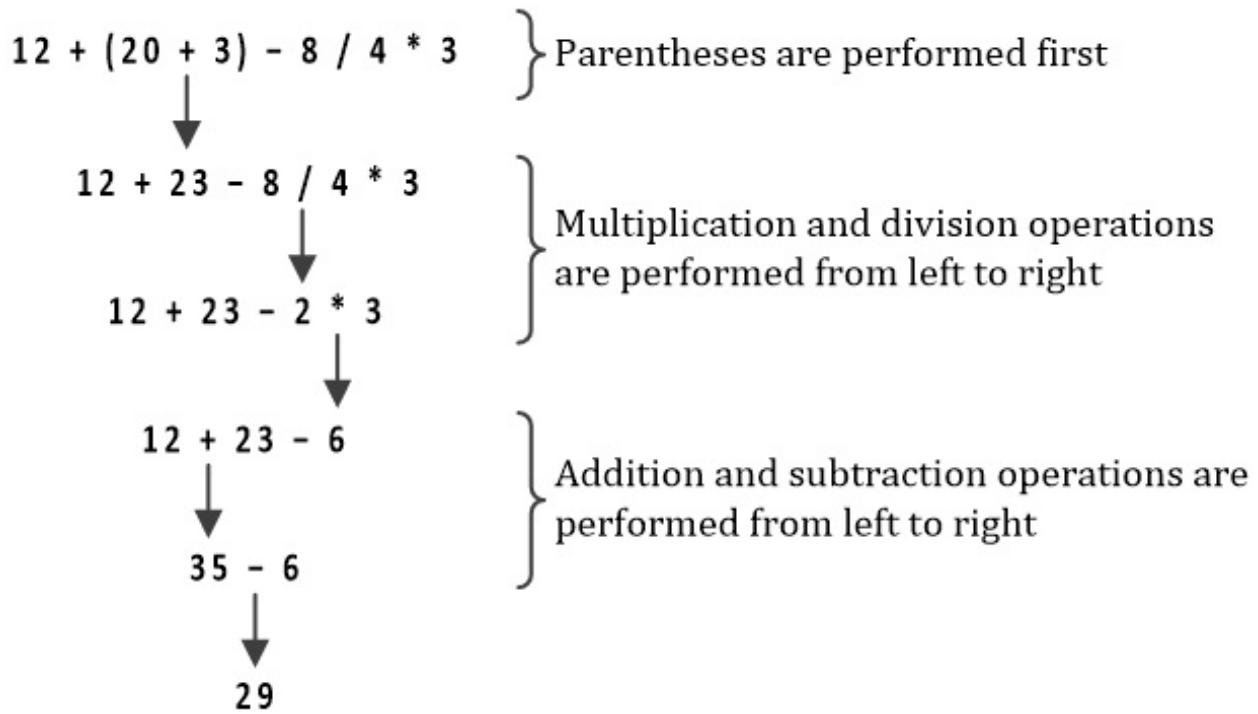
The order of operations can be summarized as follows:

1. Any operations enclosed in parentheses are performed first.
2. Next, any multiplication and division operations are performed from left to right.
3. In the end, any addition and subtraction operations are performed from left to right.

So, in statement  $y = 12 + (20 + 3) - 8 / 4 * 3$  the operations are performed as follows:

1. 20 is added to 3, yielding a result of 23.
2. 8 is divided by 4, yielding a result of 2. This result is then multiplied by 3, yielding a result of 6.
3. 12 is added to 23, yielding a result of 35. Then, 6 is subtracted from 35, yielding a final result of 29.

Next is the same sequence of operations presented in a more graphical way.



## 7.4 Compound Assignment Operators

C# offers a special set of operators known as *compound assignment operators*, which can help you write code faster.

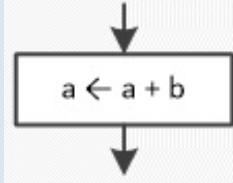
Operator	Description	Example	Equivalent to
<code>+=</code>	Addition assignment	<code>a += b;</code>	<code>a = a + b;</code>
<code>-=</code>	Subtraction assignment	<code>a -= b;</code>	<code>a = a - b;</code>
<code>*=</code>	Multiplication assignment	<code>a *= b;</code>	<code>a = a * b;</code>
<code>/=</code>	Division assignment	<code>a /= b;</code>	<code>a = a / b;</code>
<code>%=</code>	Modulus assignment	<code>a %= b;</code>	<code>a = a % b;</code>

Looking at the “Equivalent to” column, it becomes clear that same result can be achieved by just using the classic assignment (`=`) operator. So the question that arises here is *why do these operators exist?*

The answer is simple: It's a matter of convenience. Once you start using them, your life finds a different meaning!

 Keep in mind that flowcharts are a loose method to represent an algorithm. Although the use of compound assignment operators is allowed in

*flowcharts, this book uses only the commonly accepted operators shown in the “Equivalent to” column. For example, the C# statement `a += b` is represented in a flowchart as*



### **Exercise 7.4-1 Which C# Statements are Syntactically Correct?**

*Which of the following C# assignment statements are syntactically correct?*

- i. `a = -10;`
- ii. `10 = b;`
- iii. `a_b = a_b + 1;`
- iv. `a = "COWS";`
- v. `a = COWS;`
- vi. `a + b = 40;`
- vii. `a = 3 b;`
- viii. `a = "true";`
- ix. `a = true;`
- x. `a //= 2;`
- xi. `a += 1;`
- xii. `a *= 2;`

### **Solution**

- i. **Correct.** It assigns the integer value `-10` to variable `a`.
- ii. **Wrong.** On the left side of the value assignment operator, only variables can exist.
- iii. **Correct.** It increases variable `a_b` by one.
- iv. **Correct.** It assigns the string (the text) `cows` to variable `a`.
- v. **Correct.** It assigns the content of variable `cows` to variable `a`.
- vi. **Wrong.** On the left side of the value assignment operator, only variables (not expressions) can exist.
- vii. **Wrong.** It should have been written as `a = 3 * b`.

- viii. **Correct.** It assigns the string true to variable a.
- ix. **Correct.** It assigns the value true to variable a.
- x. **Correct.** This is equivalent to `a = a // 2`.
- xi. **Correct.** This is equivalent to `a = a + 1`.
- xii. **Wrong.** It should have been be written as `a *= 2` (which is equivalent to `a = a * 2`).

### ***Exercise 7.4-2 Finding Variable Types***

---

*What is the type of each of the following variables?*

- i. `a = 15;`
- ii. `width = "10 meters";`
- iii. `b = "15";`
- iv. `temp = 13.5;`
- v. `b = true;`
- vi. `b = "true";`

### ***Solution***

---

- i. The value 15 belongs to the set of integers, thus the variable a is an integer.
- ii. The “10 meters” is text, thus the width variable is a string.
- iii. The “15” is text string, thus the b variable is a string.
- iv. The value 13.5 belongs to the set of real numbers, thus the variable temp is real.
- v. The value true is Boolean, thus the variable b is a Boolean.
- vi. The value true is a text, thus the variable b is a string.

## **7.5 Incrementing/Decrementing Operators**

Adding 1 to a number, or subtracting 1 from a number, are both so common in computer programs that C# incorporates a special set of operators to do this. C# supports two types of incrementing and decrementing operators:

- ▶ pre-incrementing/decrementing operators
- ▶ post-incrementing/decrementing operators

Pre-incrementing/decrementing operators are placed before the variable name. Post-incrementing/decrementing operators are placed after the

variable name. These four types of operators are shown here.

Operator	Description	Example	Equivalent to
Pre-incrementing	Increment a variable by one	<code>++a;</code>	<code>a = a + 1;</code>
Pre-decrementing	Decrement a variable by one	<code>--a;</code>	<code>a = a - 1;</code>
Post-incrementing	Increment a variable by one	<code>a++;</code>	<code>a = a + 1;</code>
Post-decrementing	Decrement a variable by one	<code>a--;</code>	<code>a = a - 1;</code>

Once again, looking at the “*Equivalent to*” column, it becomes clear that you can achieve the same result by just using the classic assignment operator (`=`). However, it is much more sophisticated and productive to use these new operators. In the beginning you may hate them, but as the years pass you are definitely going to love them!

Let's see an example with a pre-incrementing operator,

```
a = 5;  
++a;    //This is equivalent to a = a + 1  
b = a;  
  
Console.WriteLine(a);  
Console.WriteLine(b);
```

and another one with a post-incrementing operator.

```
a = 5;  
a++;    //This is equivalent to a = a + 1  
b = a;  
  
Console.WriteLine(a);  
Console.WriteLine(b);
```

 *The double slashes ( // ) after the Console.WriteLine() statements indicate that the text that follows is a comment; thus, it is never executed.*

In both examples a value of 6 is assigned to variable `b`! So, where is the catch? Are these two examples equivalent? The answer is “yes”, but only in these two examples. In other cases the answer will likely be “no”. There is a small difference between them.

Let's spot that difference! The rule is that a pre-increment/decrement operator performs the increment/decrement operation first and then delivers

the new value. A post-increment/decrement operator delivers the old value first and then performs the increment/decrement operation. Look carefully at the next two examples.

```
a = 5;  
b = ++a;  
Console.WriteLine(a); //It displays: 6  
Console.WriteLine(b); //It displays: 6
```

and

```
a = 5;  
b = a++;  
Console.WriteLine(a); //It displays: 6  
Console.WriteLine(b); //It displays: 5
```

In the first example, variable a is incremented by one and then its new value is assigned to variable b. In the end, both variables contain a value of 6.

In the second example, the value 5 of variable a is assigned to variable b, and then variable a is incremented by one. In the end, variable a contains a value of 6 but variable b contains a value of 5!

## 7.6 String Operators

Joining two separate strings into a single one is called *concatenation*. There are two operators that you can use to concatenate (join) strings as shown in the table that follows.

Operator	Description	Example	Equivalent to
+	Concatenation	a = "Hi" + "there";	
+=	Concatenation assignment	a += "Hello";	a = a + "Hello";

The following code fragment displays “What's up, dude?”

```
string a, b, c;  
  
a = "What's ";  
b = "up, ";  
c = a + b;  
c += "dude?";  
  
Console.WriteLine(c);
```

## ***Exercise 7.6-1 Concatenating Names***

---

*Write a C# program that prompts the user to enter his or her first and last name (assigned to two different variables) and then joins them together in a single string (concatenation).*

### **Solution**

---

The C# program is shown here.

```
static void Main(string[] args) {
    string first_name, last_name, full_name;

    Console.WriteLine("Enter first name: ");
    first_name = Console.ReadLine();

    Console.WriteLine("Enter last name: ");
    last_name = Console.ReadLine();

    full_name = first_name + " " + last_name;
    Console.WriteLine(full_name);
}
```

 *Note the extra space character added between the first and last name.*

## **7.7 Review Questions: True/False**

Choose **true** or **false** for each of the following statements.

1. The statement `x = 5` can be read as “*Variable x is equal to 5*”.
2. The value assignment operator assigns the result of an expression to a variable.
3. A string can be assigned to a variable only by using the `Console.ReadLine()` statement.
4. The statement `5 = y` assigns value 5 to variable y.
5. On the right side of a value assignment operator an arithmetic operator must always exist.
6. On the right side of a value assignment operator only variables can exist.
7. You cannot use the same variable on both sides of a value assignment operator.
8. The statement `a = a + 1` decrements variable a by one.

9. The statement `a = a + (-1)` decrements variable `a` by one.
10. In C#, the word `MOD` is a reserved word.
11. The statement `x = 0 % 5` assigns a value of 5 to variable `x`.
12. The operation `5 % 0` is not possible.
13. Addition and subtraction have the higher precedence among the arithmetic operators.
14. When division and multiplication operators co-exist in an expression, multiplication operations are performed before division.
15. The expression `8 / 4 * 2` is equal to 1.
16. The expression `4 + 6 / 6 + 4` is equal to 9.
17. The expression `a + b + c / 3` calculates the average value of three numbers.
18. The statement `a += 1` is equivalent to `a = a + 1`
19. The statement `a = "true"` assigns a Boolean value to variable `a`.
20. The statement `a = 2·a` doubles the content of variable `a`.
21. The statements `a += 2` and `a = a - (-2)` are not equivalent.
22. The statement `a -= a + 1` always assigns a value of `-1` to variable `a`.
23. The statement `a = "George" + "Malkovich"` assigns value `GeorgeMalkovich` to variable `a`.
24. The following C# program satisfies the property of definiteness.

```
int a, b;
double x;

a = Int32.Parse(Console.ReadLine());
b = Int32.Parse(Console.ReadLine());
x = a / (b - 7);
Console.WriteLine(x);
```

## 7.8 Review Questions: Multiple Choice

Select the correct answer for each of the following statements.

1. Which of the following C# statements assigns a value of 10.0 to variable `a`?
  - a. `10.0 = a;`

- b. `a ← 10.0;`
  - c. `a = 100.0 / 10.0;`
  - d. none of the above
2. The statement `a = b` can be read as
- a. assign the content of variable `a` to variable `b`.
  - b. variable `b` is equal to variable `a`.
  - c. assign the content of variable `b` to variable `a`.
  - d. none of the above
3. The expression `0 % 10 + 2` is equal to
- a. 7.
  - b. 2.
  - c. 12.
  - d. none of the above
4. Which of the following C# statements is syntactically correct?
- a. `a = 4 * 2y - 8 / (4 * q);`
  - b. `a = 4 * 2 * y - 8 / 4 * q);`
  - c. `a = 4 * 2 * y - 8 / (4 */ q);`
  - d. none of the above
5. Which of the following C# statements is syntactically correct?
- a. `a * 5 = a;`
  - b. `a = a * 5;`
  - c. `a =* 5;`
6. Which of the following C# statements assigns value George Malkovich to variable `a`?
- a. `a = "George" + " " + "Malkovich";`
  - b. `a = "George" + "Malkovich";`
  - c. `a = "George " + "Malkovich";`
  - d. all of the above
7. The following code fragment

```
| x = 2;  
| x++;
```

does **not** satisfy the property of

- a. finiteness.
- b. definiteness.
- c. effectiveness.
- d. none of the above

8. The following code fragment

```
int a;  
double x;  
a = Int32.Parse(Console.ReadLine());  
x = 1 / a;
```

does **not** satisfy the property of

- a. finiteness.
- b. input.
- c. definiteness.
- d. none of the above

## 7.9 Review Exercises

Complete the following exercises.

1. Which of the following C# assignment statements are syntactically correct?
  - i. `a ← a + 1;`
  - ii. `a += b;`
  - iii. `a b = a b + 1;`
  - iv. `a = a + 1;`
  - v. `a = hello;`
  - vi. `a = 40";`
  - vii. `a = b . 5;`
  - viii. `a += "true";`
  - ix. `fdadstwsdgfgw = 1;`
  - x. `a = a * 5;`
2. What is the type of each of the following variables?
  - i. `a = "false";`
  - ii. `w = false;`  
`b = "15 meters";`

- iii. `weight = "40";`
- v. `b = 13.0;`
- vi. `b = 13;`

3. Match each element from the first column with one element from the second column.

Operation	Result
i. <code>1 / 2.0</code>	a. 100
ii. <code>1.0 / 2 * 2</code>	b. 0.25
iii. <code>0 % 10 * 10</code>	c. 0
iv. <code>10 % 2 + 7</code>	d. 0.5
	e. 7
	f. 1.0

4. What displays on the screen after executing each of the following code fragments?
- i. 

```
a = 5;
b = a * a + 1;
Console.WriteLine(b++);
```
  - ii. 

```
a = 9;
b = a / 3 * a;
Console.WriteLine(b + 1);
```
5. What displays on the screen after executing each of the following code fragments?
- i. 

```
a = 5;
a += a - 5;
Console.WriteLine(a);
```
  - ii. 

```
a = 5;
a = a + 1;
Console.WriteLine(a);
```
6. What is the result of each of the following operations?
- i. `21 % 5`
  - ii. `10 % 2`
  - iii. `11 % 2`
  - iv. `10 % 6 % 3`

v.  $0 \% 3$   
vi.  $100 / 10 \% 3$

7. What displays on screen after executing each of the following code fragments?

i. 

```
a = 5;
b = 2;
c = a % (b + 1);
d = (b + 1) % (a + b);
Console.WriteLine(c + " * " + d);
```

ii. 

```
a = 0.4;
b = 8;
a += 0.1;
c = a * b % b;
Console.WriteLine(c)
```

8. Calculate the result of the expression  $a \% b$  for the following cases.

- i.  $a = 20, b = 3$
- ii.  $a = 15, b = 3$
- iii.  $a = 22, b = 3$
- iv.  $a = 0, b = 3$
- v.  $a = 3, b = 1$
- vi.  $a = 2, b = 2$

9. Calculate the result of the expression

$$b * (a \% b) + a / b$$

for each of the following cases.

- i.  $a = 10, b = 5$
- ii.  $a = 10, b = 4$

10. What displays on the screen after executing the following code fragment?

```
a = "My name is";
a += " ";
a = a + "George Malkovich";
Console.WriteLine(a)
```

11. Fill in the gaps in each of the following code fragments so that they display a value of 5.

i. 

```
a = 2;
```

```
a = a - ..... ;
Console.WriteLine(a);
```

ii.

```
a = 4;
b = a * 0.5;
b += a;
a = b - ..... ;
Console.WriteLine(a);
```

12. What displays on the screen after executing the following code fragment?

```
city = "California";
California = city;
Console.WriteLine(city + " " + California);
```

# Chapter 8

## Trace Tables

---

### 8.1 What is a Trace Table?

A *trace table* is a technique used to test algorithms or computer programs for logic errors that occur while the algorithm or program executes.

The trace table simulates the flow of execution. Statements are executed step by step, and the values of variables change as an assignment statement is executed.

Trace tables are typically used by novice programmers to help them visualize how a particular algorithm or program works. Trace tables can also help advanced programmers detect logic errors.

A typical trace table is shown here.

Step	Statement	Notes	variable1	variable2	variable3
1					
2					
...					

Let's see a trace table in action! For the following C# program, a trace table is created to determine the values of the variables in each step.

```
static void Main(string[] args) {
    int x, y, z;

    x = 10;
    y = 15;
    z = x * y;
    z++;
    Console.WriteLine(z);
}
```

The trace table for this program is shown below. Notes are optional, but they help the reader to better understand what is really happening.

Step	Statement	Notes	x	y	z
1	x = 10	The value 10 is assigned to variable x.	10	?	?

2	<code>y = 15</code>	The value 15 is assigned to variable y.	10	15	?
3	<code>z = x * y</code>	The result of the product <code>x * y</code> is assigned to z.	10	15	<b>150</b>
4	<code>z++</code>	Variable z is incremented by one.	10	15	<b>151</b>
5	<code>.WriteLine(z)</code>	It displays: 151			

### Exercise 8.1-1 Creating a Trace Table

What result is displayed when the following program is executed?

```
static void Main(string[] args) {
    string Ugly, Beautiful, Handsome;

    Ugly = "Beautiful";
    Beautiful = "Ugly";
    Handsome = Ugly;

    Console.WriteLine("Beautiful");
    Console.WriteLine(Ugly);
    Console.WriteLine(Handsome);
}
```

### Solution

Let's create a trace table to find the output result.

Step	Statement	Notes	Ugly	Beautiful	Handsome
1	<code>Ugly = "Beautiful"</code>	The string “Beautiful” is assigned to the variable Ugly.	<b>Beautiful</b>	?	?
2	<code>Beautiful = "Ugly"</code>	The string “Ugly” is assigned to the variable Beautiful.	Beautiful	<b>Ugly</b>	?
		The value			

3	Handsome = Ugly	of variable Ugly is assigned to the variable Handsome.	Beautiful	Ugly	Beautiful
4	.WriteLine("Beautiful")	It displays: Beautiful			
5	.WriteLine(Ugly)	It displays: Beautiful			
6	.WriteLine(Handsome)	It displays: Beautiful			

### ***Exercise 8.1-2 Swapping Values of Variables***

---

*Write a C# program that lets the user enter two values, in variables a and b. At the end of the program, the two variables must swap their values. For example, if variables a and b contain the values 5 and 7 respectively, after swapping their values, variable a must contain the value 7 and variable b must contain the value 5!*

### ***Solution***

---

The following code fragment, even though it may seem correct, is erroneous and doesn't really swap the values of variables a and b!

```
int a, b;

a = Int32.Parse(Console.ReadLine());
b = Int32.Parse(Console.ReadLine());

a = b;
b = a;

Console.WriteLine(a + " " + b);
```

Let's see why! Suppose the user enters two values, 5 and 7. The trace table is shown here.

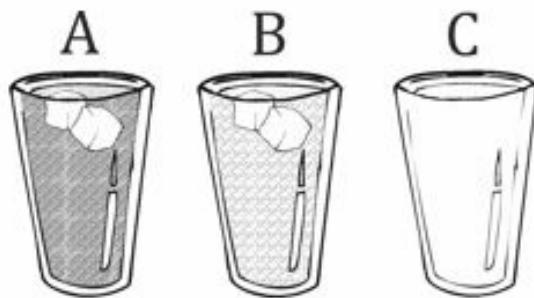
Step	Statement	Notes	a	b
1	a = Int32.Parse(...)	User enters the value 5	5	?
2	b = Int32.Parse(...)	User enters the value 7	5	7

3	<code>a = b</code>	The value of variable b is assigned to variable a. Value 5 is lost!	7	7
4	<code>b = a</code>	The value of variable a is assigned to variable b	7	7
5	<code>.WriteLine(a + " " + b)</code>	It displays: 7 7		

Oops! Where is the value 5?

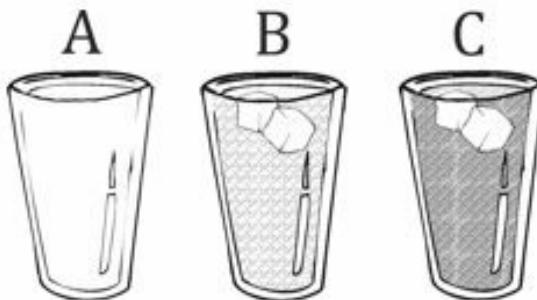
The solution wasn't so obvious after all! So, how do you really swap values anyway?

Consider two glasses: a glass of orange juice (called glass A), and a glass of lemon juice (called glass B). If you want to swap their content, all you must do is find and use one extra empty glass (called glass C).

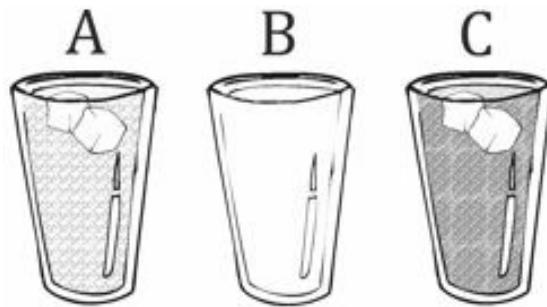


The steps that must be followed are:

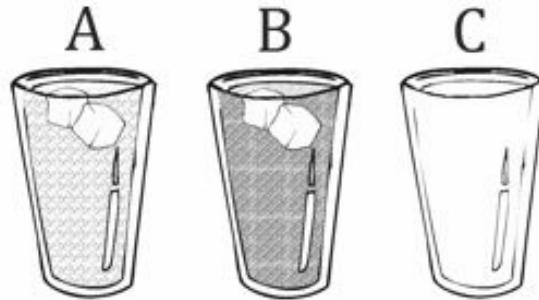
1. Empty the contents of glass A (orange juice) into glass C.



2. Empty the contents of glass B (lemon juice) into glass A.



3. Empty the contents of glass C (orange juice) into glass B.



Swapping completed successfully!

You can follow the same steps to swap the contents of two variables in C#.

```
static void Main(string[] args) {
    int a, b, c;

    a = Int32.Parse(Console.ReadLine());
    b = Int32.Parse(Console.ReadLine());

    c = a;      //Empty the contents of glass A (orange juice) into glass C
    a = b;      //Empty the contents of glass B (lemon juice) into glass A
    b = c;      //Empty the contents of glass C (orange juice) into glass B

    Console.WriteLine(a + " " + b);
}
```

The text after double slashes ( // ) is considered a comment and is never executed.

### Exercise 8.1-3 Swapping Values of Variables – An Alternative Approach

Write a C# program that lets the user enter two integer values, in variables *a* and *b*. In the end, the two variables must swap their values.

#### Solution

Since the variables contain only numeric values, you can use the following

C# program (as an alternative approach).

```
static void Main(string[] args) {
    int a, b;

    a = Int32.Parse(Console.ReadLine());
    b = Int32.Parse(Console.ReadLine());

    a = a + b;
    b = a - b;
    a = a - b;

    Console.WriteLine(a + " " + b);
}
```

 The disadvantage of this method is that it cannot swap the contents of alphanumeric variables (strings).

### Exercise 8.1-4 Creating a Trace Table

Create a trace table to determine the values of the variables in each step of the C# program for three different executions.

The input values for the three executions are: (i) 0.3, (ii) 4.5, and (iii) 10.

```
static void Main(string[] args) {
    double a, b, c;

    b = Double.Parse(Console.ReadLine());
    c = 3;
    c = c * b;
    a = 10 * c % 10;
    Console.WriteLine(a);
}
```

### Solution

- i. For the input value of 0.3, the trace table looks like this.

Step	Statement	Notes	a	b	c
1	b = Double.Parse(...)	User enters value 0.3	?	<b>0.3</b>	?
2	c = 3		?	0.3	<b>3.0</b>
3	c = c * b		?	0.3	<b>0.9</b>
4	a = 10 * c % 10		<b>9.0</b>	0.3	0.9

<b>5</b>	<code>.WriteLine(a)</code>	It displays: 9
----------	----------------------------	----------------

- ii. For the input value of 4.5, the trace table looks like this.

Step	Statement	Notes	a	b	c
<b>1</b>	<code>b = Double.Parse(...)</code>	User enters value 4.5	?	<b>4.5</b>	?
<b>2</b>	<code>c = 3</code>		?	4.5	<b>3.0</b>
<b>3</b>	<code>c = c * b</code>		?	4.5	<b>13.5</b>
<b>4</b>	<code>a = 10 * c % 10</code>		<b>5.0</b>	4.5	13.5
<b>5</b>	<code>.WriteLine(a)</code>	It displays: 5			

- iii. For the input value of 10, the trace table looks like this.

Step	Statement	Notes	a	b	c
<b>1</b>	<code>b = Double.Parse(...)</code>	User enters value 10	?	<b>10.0</b>	?
<b>2</b>	<code>c = 3</code>		?	10.0	<b>3.0</b>
<b>3</b>	<code>c = c * b</code>		?	10.0	<b>30.0</b>
<b>4</b>	<code>a = 10 * c % 10</code>		<b>0.0</b>	10.0	30.0
<b>5</b>	<code>.WriteLine(a)</code>	It displays: 0			

### ***Exercise 8.1-5 Creating a Trace Table***

---

*Create a trace table to determine the values of the variables in each step when a value of 3 is entered.*

```
static void Main(string[] args) {
    double a, b, c, d;

    a = Double.Parse(Console.ReadLine());
    b = a + 10;
    a = b * (a - 3);
    c = 3 * b / 6;
    d = c * c;
    d--;
    Console.WriteLine(d);
}
```

## **Solution**

---

For the input value of 3, the trace table looks like this.

Step	Statement	Notes	a	b	c	d
1	a = Double.Parse(...)	User enters value 3	3.0	?	?	?
2	b = a + 10		3.0	13.0	?	?
3	a = b * (a - 3)		0.0	13.0	?	?
4	c = 3 * b / 6		0.0	13.0	6.5	?
5	d = c * c		0.0	13.0	6.5	42.25
6	d--		0.0	13.0	6.5	41.25
7	.WriteLine(d)	It displays: 41.25				

## **8.2 Review Questions: True/False**

Choose **true** or **false** for each of the following statements.

1. A trace table is a technique for testing a computer.
2. Trace tables help a programmer find errors in a computer program.
3. You cannot execute a computer program without first creating its corresponding trace table.
4. In order to swap the values of two integer variables, you always need an extra variable.

## **8.3 Review Exercises**

Complete the following exercises.

1. Create a trace table to determine the values of the variables in each step of the C# program for three different executions.

The input values for the three executions are: (i) 3, (ii) 4, and (iii) 1.

```
static void Main(string[] args) {
    int a, b, c, d;
    a = Int32.Parse(Console.ReadLine());
    a = (a + 1) * (a + 1) + 6 / 3 * 2 + 20;
    b = a % 13;
    c = b % 7;
```

```
    d = a * b * c;
    Console.WriteLine(a + ", " + b + ", " + c + ", " + d);
}
```

2. Create a trace table to determine the values of the variables in each step of the C# program for two different executions.

The input values for the two executions are: (i) 8, 4; and (ii) 4, 4

```
static void Main(string[] args) {
    double a, b, c, d, e;
    a = Double.Parse(Console.ReadLine());
    b = Double.Parse(Console.ReadLine());
    c = a + b;
    d = 1 + a / b * c + 2;
    e = c + d;
    c += d + e;
    e--;
    d -= c + d % c;
    Console.WriteLine(c + ", " + d + ", " + e);
}
```

# Chapter 9

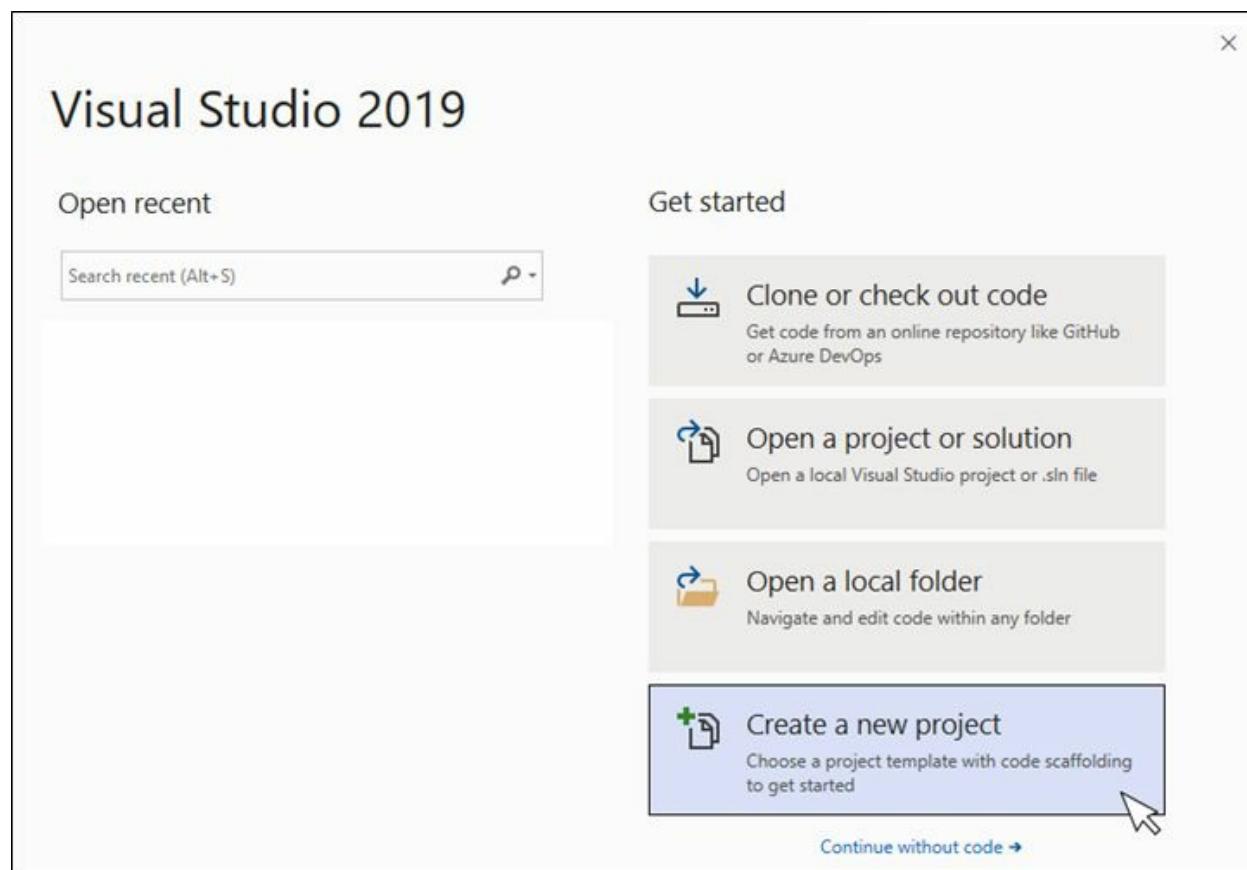
## Using Visual Studio Community

### 9.1 Writing and Executing a C# Program in Visual Studio Community

So far you have learned some really good basics about C# programs. Now it's time to learn how to enter programs into the computer, execute them, see how they perform, and see how they display the results.

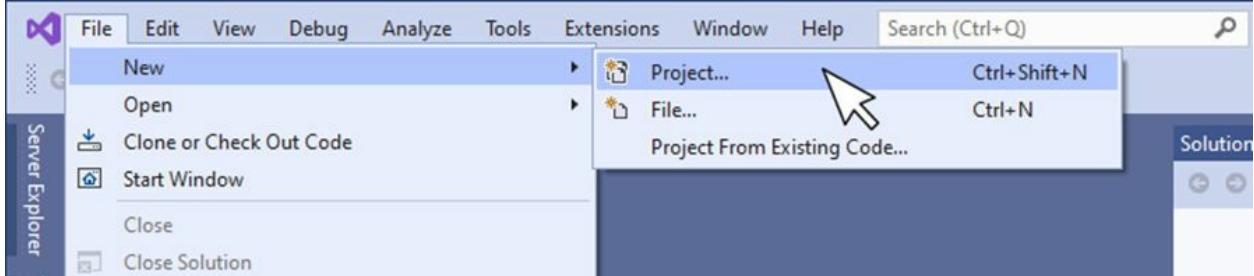
Before you start though, keep in mind that this paragraph is about Visual Studio Community for Windows. If you wish to learn how to use Visual Studio Code (not Community), skip this paragraph and go directly to the next one ([paragraph 9.2](#)).

The first thing you must do is create a new project. Visual Studio Community provides a wizard to help you do that. Start Visual Studio and from the window that opens (see **Figure 9–1**), click on the “Create a new project” button.



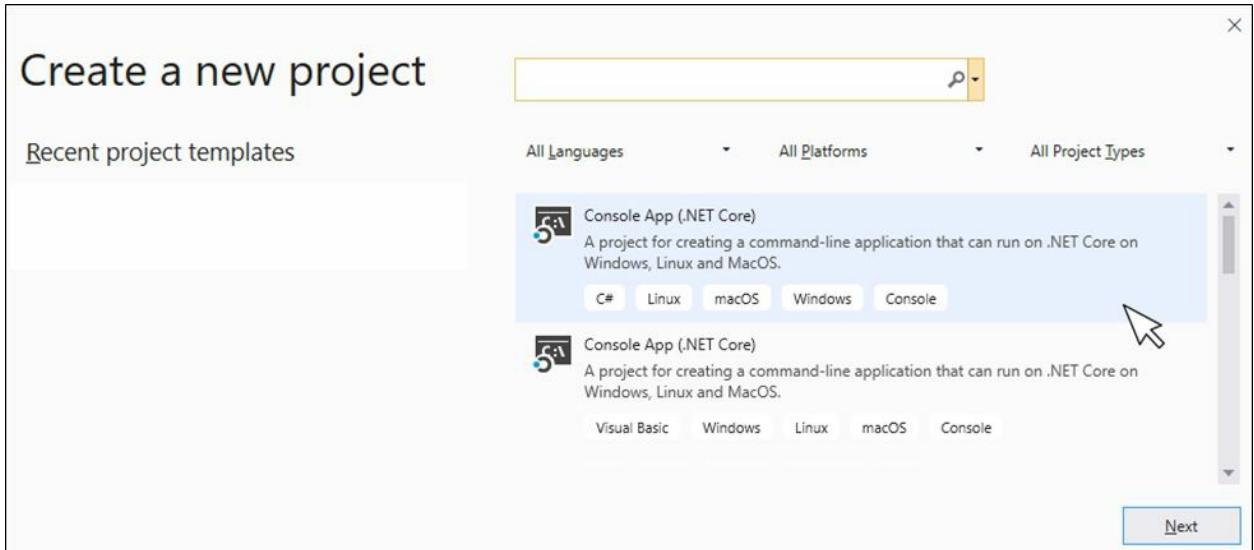
**Figure 9–1** Starting a new project from Visual Studio's “Get started” window

Alternatively, if you click on “Continue without code” from Visual Studio's main menu, you can select “File → New → Project” as shown in **Figure 9–2**.



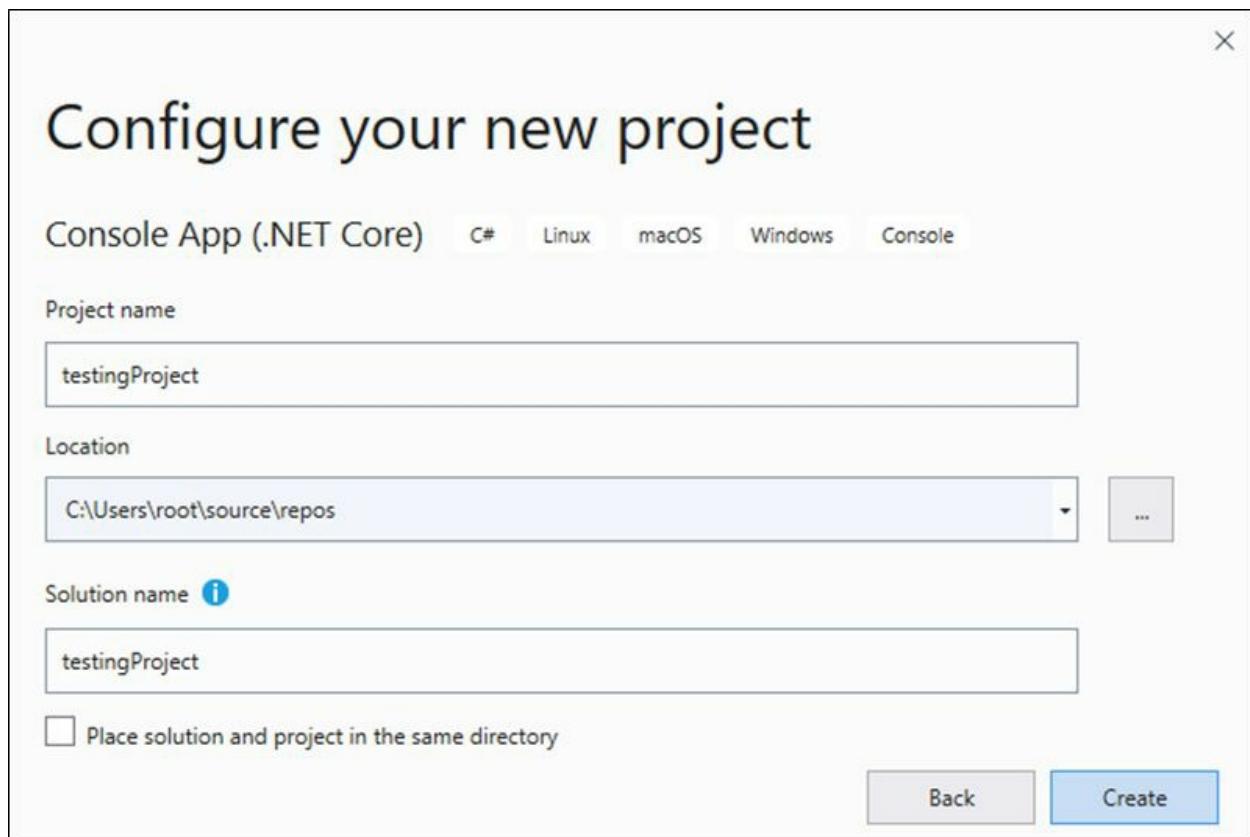
**Figure 9–2** Starting a new project from Visual Studio's main menu

The “Create a new project” dialog box appears. In the right pane, select “Console App (.NET Core)” as shown in **Figure 9–3**, and click on the “Next” button.



**Figure 9–3** Selecting the C# Console App

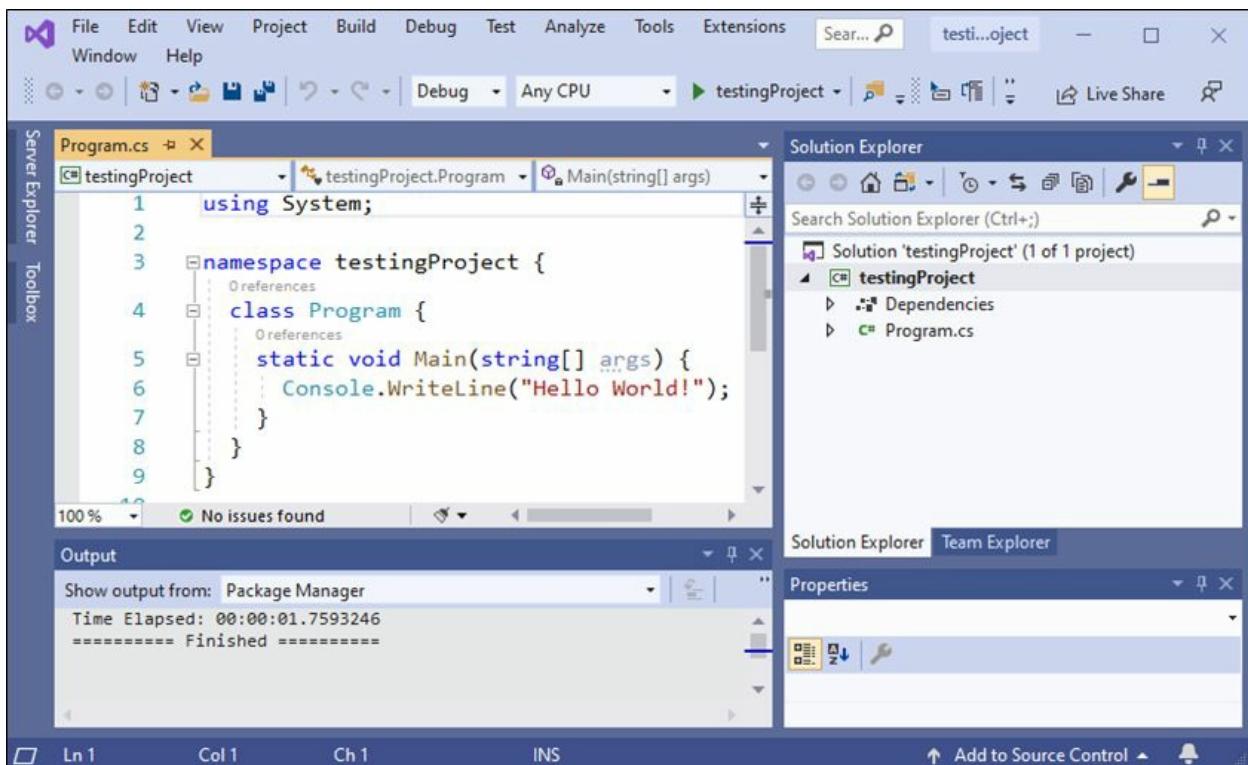
In the “Configure your new project” window that opens (see **Figure 9–4**), in the “Project name” field, you need to enter the name of your project. Type “testingProject” and click on the “Create” button.



**Figure 9–4** Configuring your new project

The project is created and opened in your Visual Studio environment. You should see the following components (see **Figure 9–5**):

- ▶ the “Solution Explorer” window, which contains a tree view of the components of the projects, including source files, libraries that your code may depend on, and so on
- ▶ the “Source Editor” window with the file called “Program.cs” open. In this file you can write your C# code. Of course, one single project can contain many such files
- ▶ the “Output” window in which Visual Studio displays messages useful for the programmer
- ▶ other windows, such as the “Properties” window, which are not necessary for this book's purposes



**Figure 9–5** Viewing the “Solution Explorer”, “Source Editor”, and “Output” windows in Visual Studio Community

You have just seen how to create a new C# console project. Let's now write the following (terrifying, and quite horrifying!) C# program and try to execute it.

```

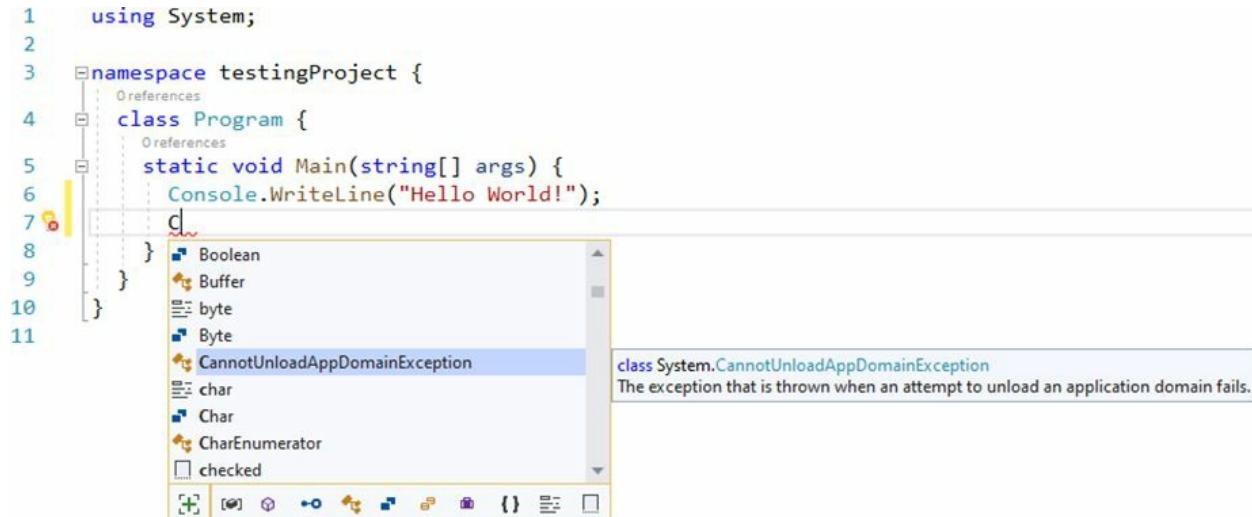
using System;

namespace testingProject {
    class Program {
        static void Main(string[] args) {
            Console.WriteLine("Hello World!");
            Console.WriteLine("Hallo Welt!");
            Console.WriteLine("Bonjour le Monde!");
        }
    }
}

```

As you may have noticed, the first statement, which displays the English message “Hello World!” has been already entered for you automatically. Place your text cursor at the end of that line and hit the “Enter ↵” key. Let's try to type the second statement, the one that displays the German message “Hallo Welt!”. Type only the first character, “C”, from the `Console` statement by hitting the “C” key on your keyboard. A popup window

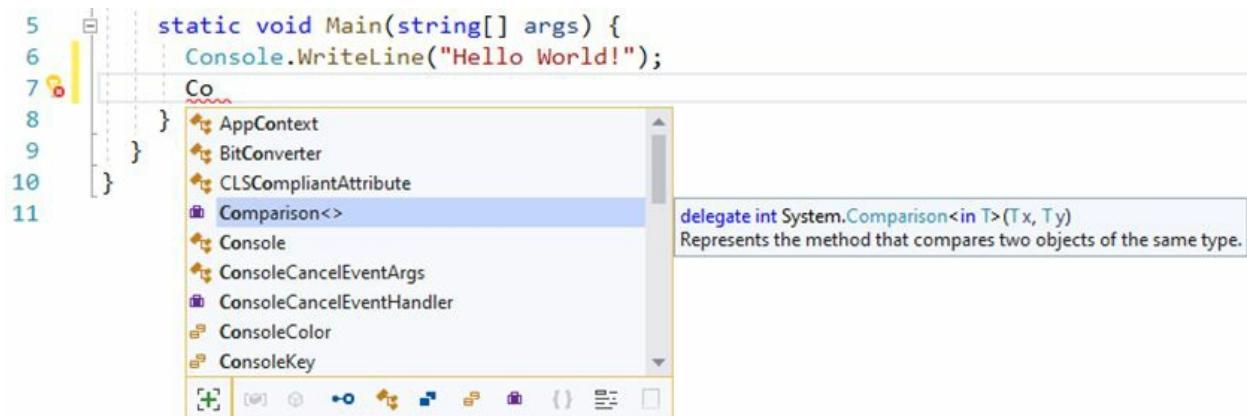
appears, as shown in **Figure 9–6**. This window contains all available C# statements, and other items that begin with the character “C”.



**Figure 9–6** The popup screen in the Source Editor window

You can highlight a selection by using the up and down arrow keys on your keyboard.

Type the second character, “o”, from the `Console` statement. Now the options have become fewer, as shown in **Figure 9–7**.



**Figure 9–7** The popup screen in the Source Editor window

Select the option `Console` using the down arrow key from your keyboard and hit the period “.” key. The statement is automatically entered into your program, as shown in **Figure 9–8**.

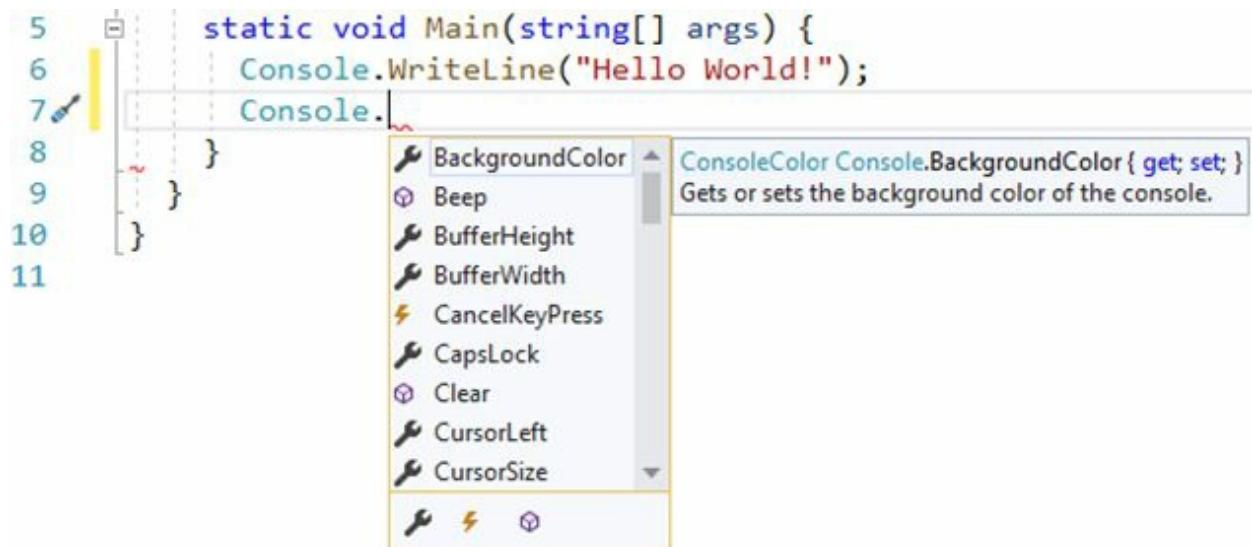


Figure 9–8 The popup screen in the Source Editor window

Complete the statement by writing `Console.WriteLine("Hallo Welt!");`. Then, continue typing the rest of the C# program (as shown in **Figure 9–9**). Your Visual Studio environment should look like this.

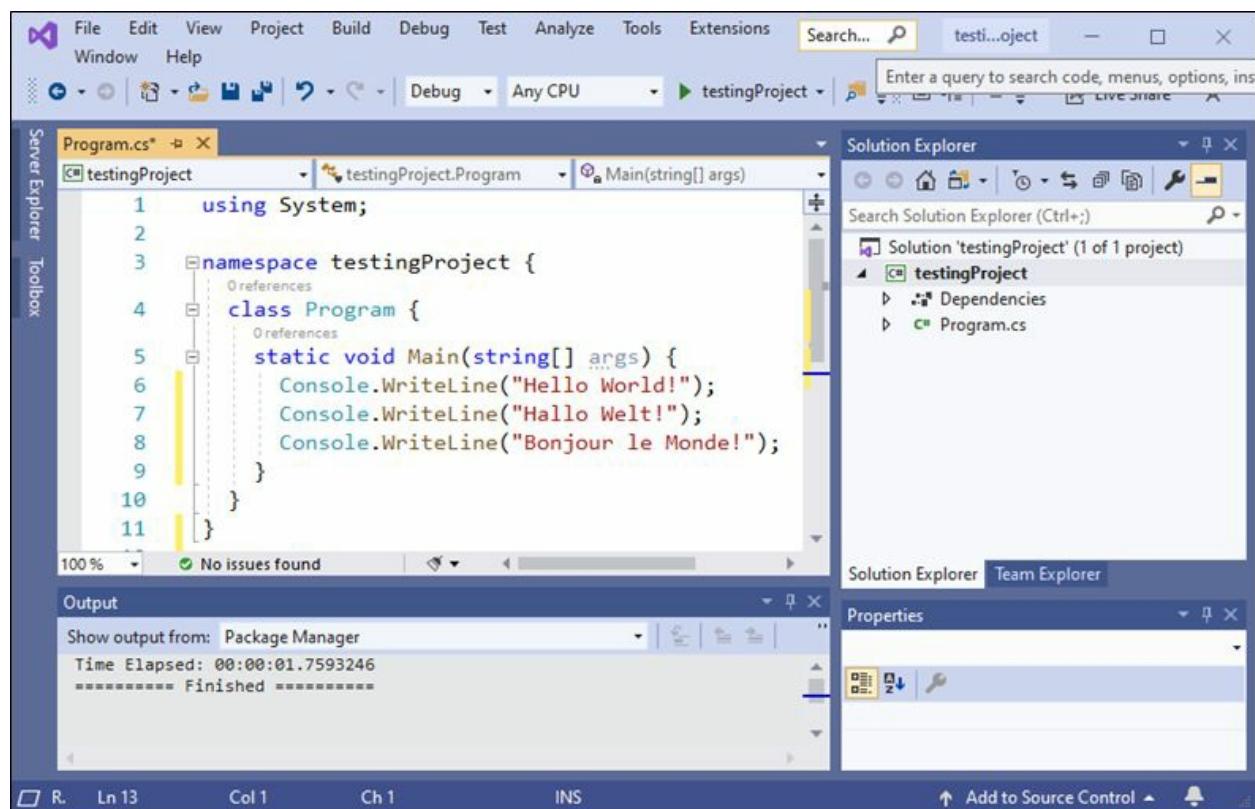
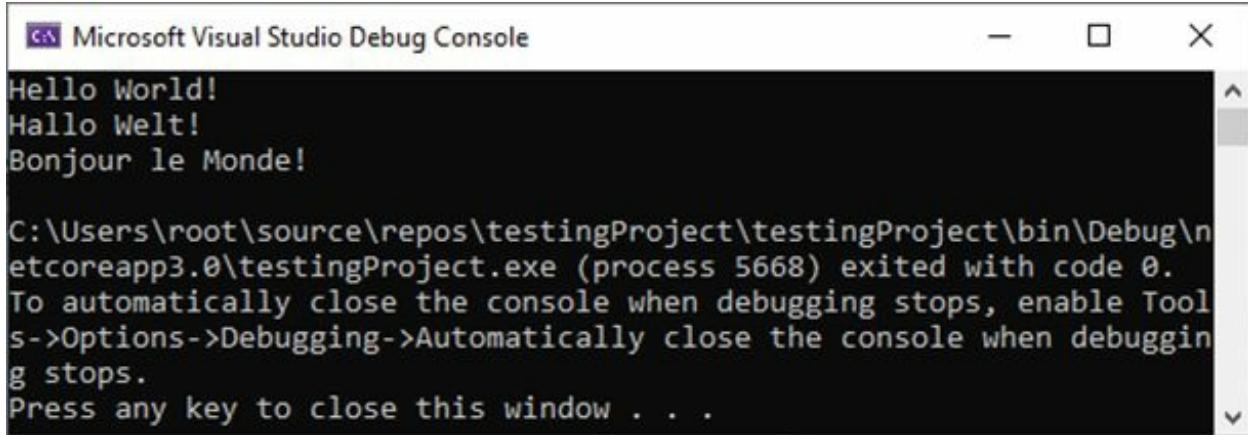


Figure 9–9 Entering a C# program in the “Program.cs” file

Now, let's try to execute the program! From the toolbar, click on the “Start Debugging” ➤ toolbar icon. Alternatively, from the main menu, you can

select “Debug → Start Debugging” or even hit the F5 key. The C# program executes and the output is displayed in the “Debug Console” window, as shown in **Figure 9–10**.



The screenshot shows the Microsoft Visual Studio Debug Console window. The title bar reads "Microsoft Visual Studio Debug Console". The console output displays three lines of text: "Hello World!", "Hallo Welt!", and "Bonjour le Monde!". Below this, it shows the command prompt path: "C:\Users\root\source/repos\testingProject\testingProject\bin\Debug\netcoreapp3.0\testingProject.exe (process 5668) exited with code 0.". A note follows: "To automatically close the console when debugging stops, enable Tools->Options->Debugging->Automatically close the console when debugging stops.". At the bottom, there is a message: "Press any key to close this window . . .".

**Figure 9–10** Viewing the results of the executed program in the “Debug Console” window

Congratulations! You have just written and executed your first C# program! Press any key to close the window.

Now let's write another C# program, one that prompts the user to enter his or her name. Type the following C# statements into Visual Studio and hit F5 to execute the project.

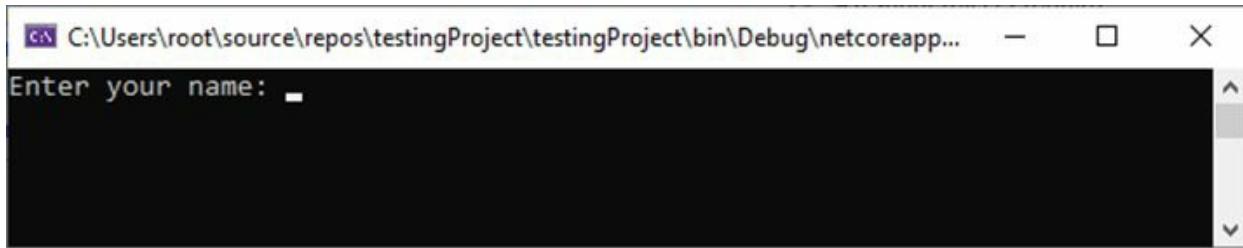
```
using System;

namespace testingProject {
    class Program {
        static void Main(string[] args) {
            string name;

            Console.WriteLine("Enter your name: ");
            name = Console.ReadLine();
            Console.WriteLine("Hello " + name);
        }
    }
}
```

 You can execute a program by clicking on the “Start Debugging”  button, or by selecting “Debug → Start Debugging” from the main menu, or even by hitting the F5 key.

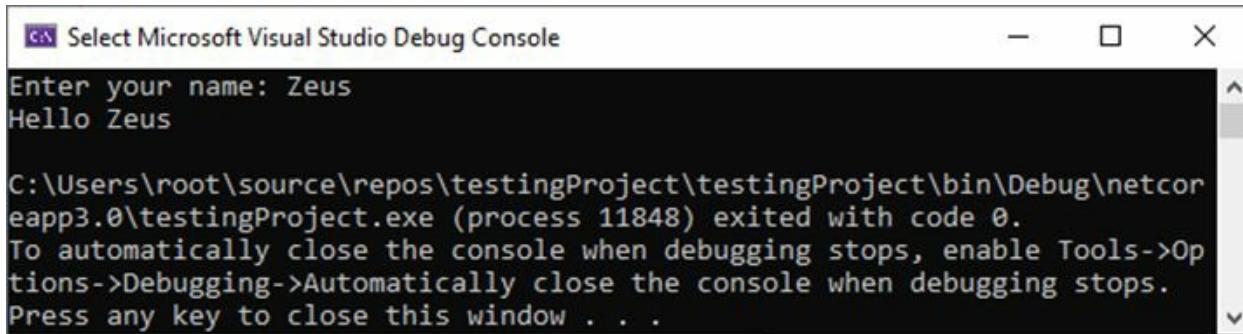
Once you execute the program, the message “Enter your name:” is displayed in the “Debug Console” window. The program waits for you to enter your name, as shown in **Figure 9–11**.



```
C:\Users\root\source\repos\testingProject\testingProject\bin\Debug\netcoreapp... - X
Enter your name:
```

**Figure 9–11** Viewing a prompt in the “Debug Console” window

Type your name and hit the “Enter ↵” key. Once you do that, your computer continues executing the rest of the statements. When execution finishes, the final output is as shown in **Figure 9–12**.



```
Select Microsoft Visual Studio Debug Console - X
Enter your name: Zeus
Hello Zeus

C:\Users\root\source\repos\testingProject\testingProject\bin\Debug\netcor
eapp3.0\testingProject.exe (process 11848) exited with code 0.
To automatically close the console when debugging stops, enable Tools->Op
tions->Debugging->Automatically close the console when debugging stops.
Press any key to close this window . . .
```

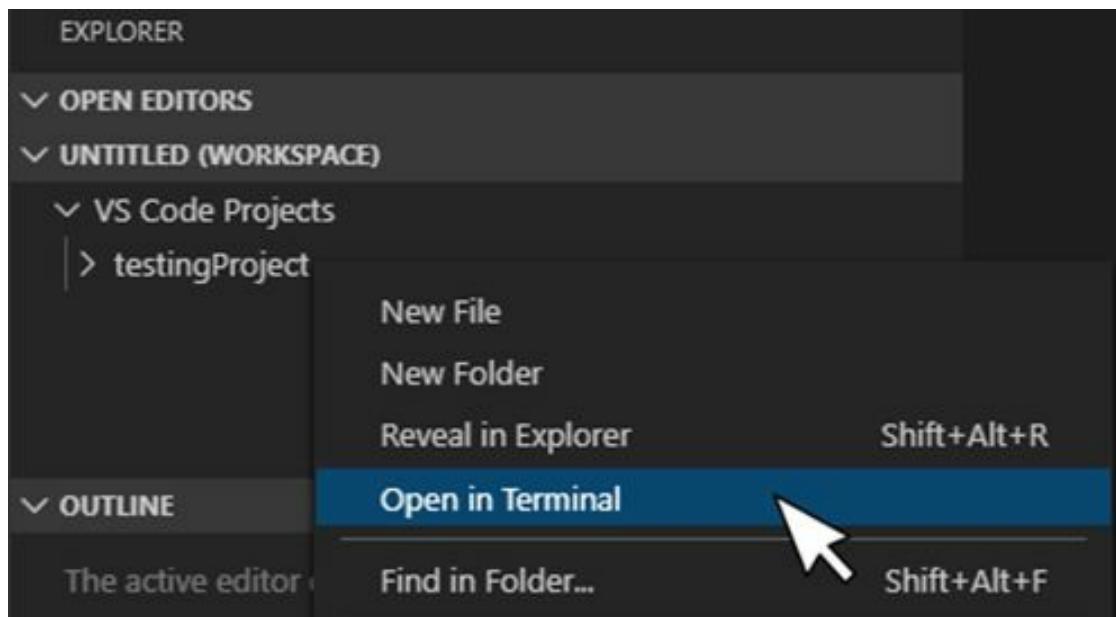
**Figure 9–12** Responding to the prompt in the “Debug Console” window

Press any key to close the window.

## 9.2 Writing and Executing a C# Program in Visual Studio Code

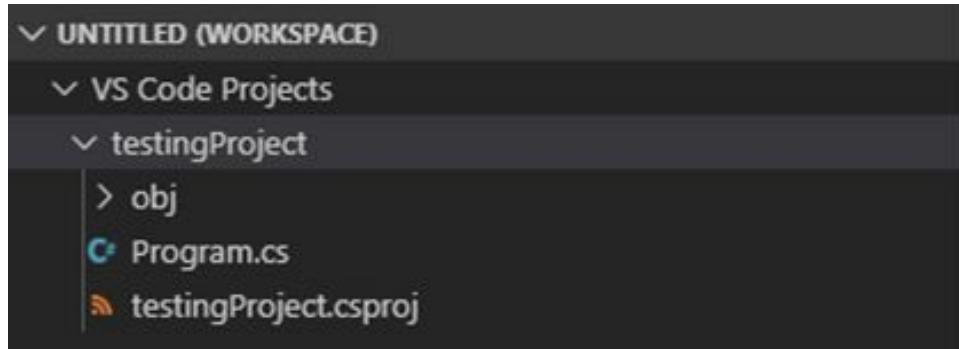
This paragraph is about Visual Studio Code. If you prefer using Visual Studio Community (not Visual Studio Code), skip this paragraph.

The first thing you must do is create a new project. In [paragraph 3.3](#), you added a folder to the workspace. It is probably named “VS Code Projects”. In the Side Bar on the left side of the screen, right click on that folder, select the “New Folder” option, and create a folder named “testingProject”. Then, right click on the “testingProject” folder and select the “Open in Terminal” option, as shown in **Figure 9–13**.



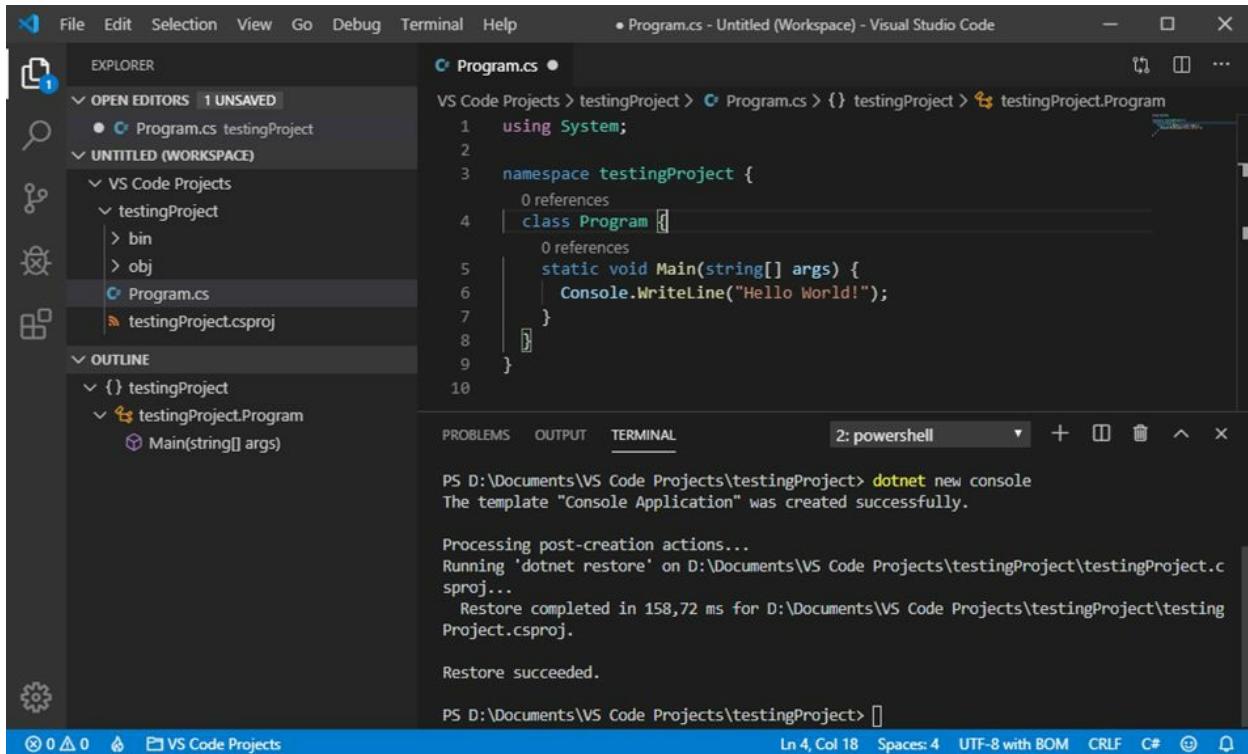
**Figure 9–13** Opening the “testingProject” folder in the “Terminal” window

In the “Terminal” window that opens, type the statement “dotnet new console” and hit the “Enter ↴” key. A new console project is created, as shown in **Figure 9–14**.



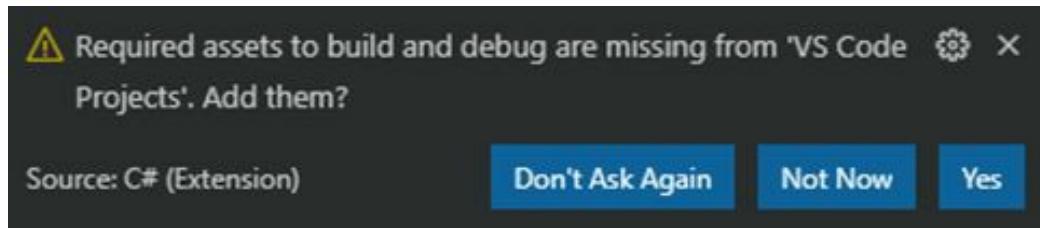
**Figure 9–14** Creating a new console project under the “testingProject” folder

Select the “Program.cs” file. Your Visual Studio Code environment should look like the one in **Figure 9–15**.



**Figure 9–15** Viewing the “Explorer”, “Source Editor”, and “Terminal” windows in Visual Studio Code

When the notification “Required assets to build and debug are missing from VS Code Projects” appears (see **Figure 9–16**) in the bottom right corner of Visual Studio Code, make sure that you click on the “Yes” button.



**Figure 9–16** A notification that prompts you to add assets required to build and debug your projects

You have just seen how to create a new C# console project. Let's now write the following (terrifying, and quite horrifying!) C# program and try to execute it.

```

using System;

namespace testingProject {
    class Program {
        static void Main(string[] args) {
            Console.WriteLine("Hello World!");
            Console.WriteLine("Hallo Welt!");
            Console.WriteLine("Bonjour le Monde!");
        }
    }
}

```

```
    }  
}
```

As you may have noticed, the first statement, which displays the English message “Hello World!” has been already entered for you automatically. Place your text cursor at the end of that line and hit the “Enter ↵” key. Let's try to type the second statement, the one that displays the German message “Hallo Welt!”. Type only the first character, “C”, from the `Console` statement by hitting the “C” key on your keyboard. A popup window appears, as shown in **Figure 9–17**. This window contains all available C# statements, and other items that begin with the character “C”.

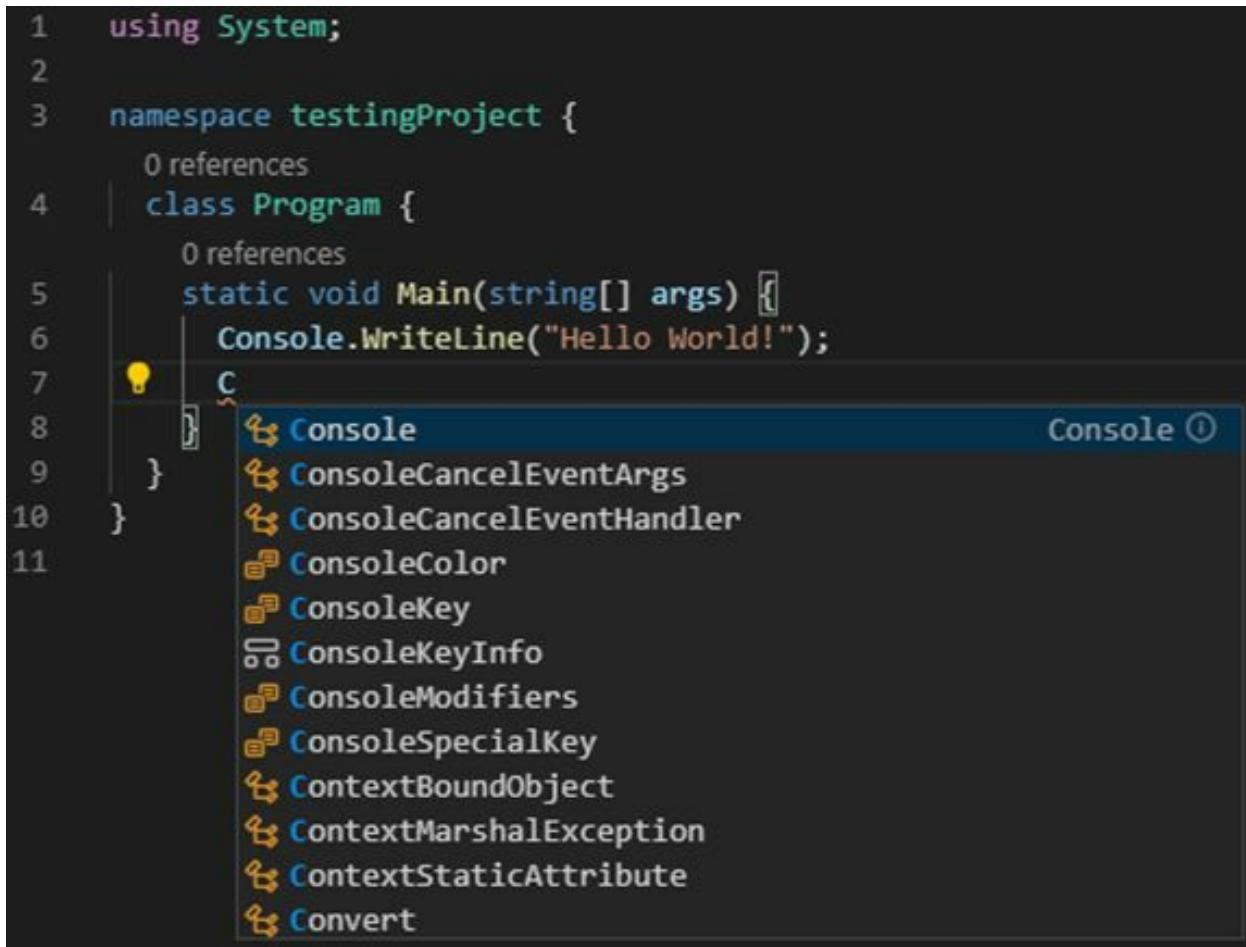


Figure 9–17 The popup screen in the Source Editor window

You can highlight a selection by using the up and down arrow keys on your keyboard.

Type the second character, “o”, from the `Console` statement. Now the options have become fewer, as shown in **Figure 9–18**.

A screenshot of the Visual Studio Code source editor. The cursor is at the end of the line 'Console.WriteLine("Hello World!");'. A dropdown menu shows suggestions starting with 'Console'. The suggestion 'Console' is highlighted in blue. Other suggestions include 'ConsoleCancelEventArgs', 'ConsoleCancelEventHandler', 'ConsoleColor', 'ConsoleKey', 'ConsoleKeyInfo', 'ConsoleModifiers', 'ConsoleSpecialKey', 'ContextBoundObject', 'ContextMarshalException', 'ContextStaticAttribute', and 'Convert'. The status bar at the bottom right says 'Console ①'.

```
5     static void Main(string[] args) {  
6         Console.WriteLine("Hello World!");  
7     }  
8     }  
9 }  
10 }  
11 }
```

Figure 9–18 The popup screen in the Source Editor window

Select the option `Console` using the down arrow key from your keyboard (if necessary) and hit the period “.” key. The statement is automatically entered into your program, as shown in **Figure 9–19**.

A screenshot of the Visual Studio Code source editor. The cursor is at the end of the line 'Console.'. A dropdown menu shows suggestions starting with 'ReadLine'. The suggestion 'ReadLine' is highlighted in blue. Other suggestions include 'ReferenceEquals', 'ResetColor', 'SetBufferSize', 'SetCursorPosition', 'SetError', 'SetIn', 'SetOut', 'SetWindowPosition', 'SetWindowSize', 'Title', and 'TreatControlCAsInput'. The status bar at the bottom right says 'string ReadLine() ①'.

```
5     static void Main(string[] args) {  
6         Console.WriteLine("Hello World!");  
7         Console.  
8     }  
9 }  
10 }  
11 }
```

Figure 9–19 The popup screen in the Source Editor window

Complete the statement by writing `Console.WriteLine("Hello Welt!");`. Then, continue typing the rest of the C# program (as shown in **Figure 9–20**). Save the changes that you have just made. Your Visual Studio Code environment should look like this.

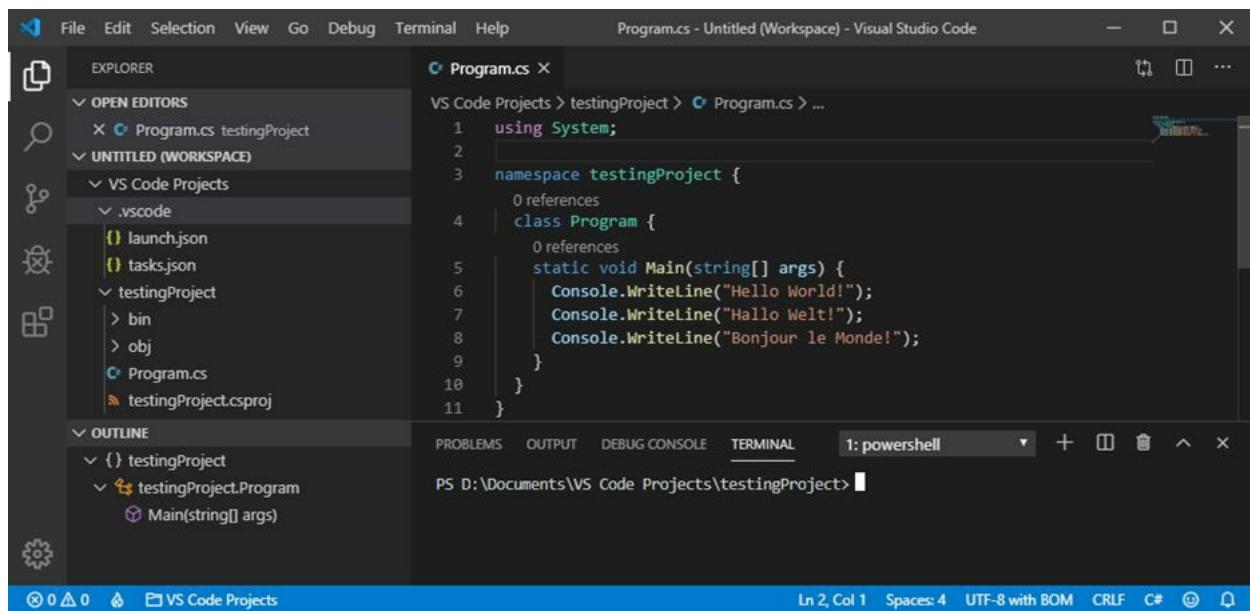


Figure 9–20 Entering a C# program in the “Program.cs” file

Now let's try to execute the program! In the “Terminal” window, make sure that the current folder (directory) is the “testingProject” folder. Type the statement “dotnet run” and hit the “Enter ↴” key. The C# program executes and the output is displayed in the “Terminal” window, as shown in **Figure 9–21**.

A screenshot of the 'TERMINAL' window in Visual Studio Code. The tab bar above it shows 'PROBLEMS', 'OUTPUT', and 'TERMINAL'. The terminal window displays the command 'dotnet run' being typed and its output: 'Hello World!', 'Hallo Welt!', and 'Bonjour le Monde!'. The status bar at the bottom shows 'Ln 2, Col 1 Spaces: 4 UTF-8 with BOM CRLF C#'.

```
PS D:\Documents\VS Code Projects\testingProject> dotnet run
Hello World!
Hallo Welt!
Bonjour le Monde!
PS D:\Documents\VS Code Projects\testingProject>
```

Figure 9–21 Viewing the results of the executed program in the "Terminal" window

Congratulations! You have just written and executed your first C# program!

*You must always save your changes before executing a program. To do so, from Visual Studio's main menu you can select “File → Save” or hit the “CTRL + S” key combination!*

Now let's write another C# program, one that prompts the user to enter his or her name. Type the following C# statements into Visual Studio Code and save the changes.

```
using System;
```

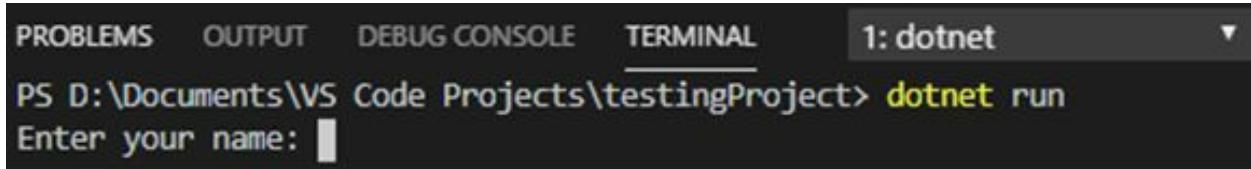
```

namespace testingProject {
    class Program {
        static void Main(string[] args) {
            string name;

            Console.WriteLine("Enter your name: ");
            name = Console.ReadLine();
            Console.WriteLine("Hello " + name);
        }
    }
}

```

Execute the program by typing the statement “dotnet run” in the “Terminal” window. Once you execute it, the message “Enter your name:” is displayed in the “Terminal” window. The program waits for you to enter your name, as shown in **Figure 9–22**.

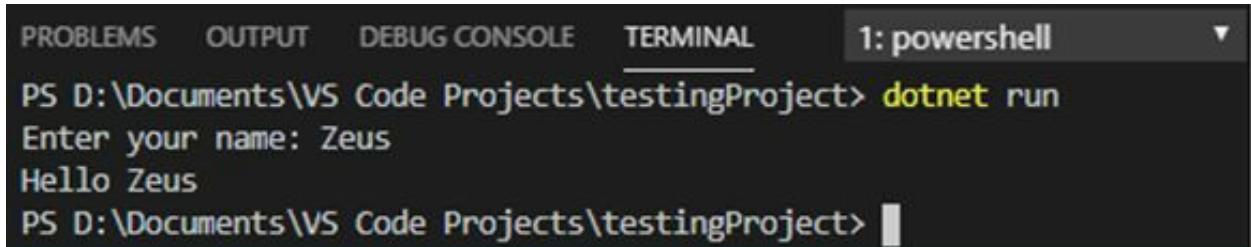


The screenshot shows a terminal window with the following interface elements:

- Top bar: PROBLEMS, OUTPUT, DEBUG CONSOLE, TERMINAL, 1: dotnet
- Content area: PS D:\Documents\VS Code Projects\testingProject> **dotnet run**
- Input field: Enter your name: [cursor]

**Figure 9–22** Viewing a prompt in the “Terminal” window

Type your name and hit the “Enter ↵” key. Once you do this, your computer continues executing the rest of the statements. When execution finishes, the final output appears, as shown in **Figure 9–23**.



The screenshot shows a terminal window with the following interface elements:

- Top bar: PROBLEMS, OUTPUT, DEBUG CONSOLE, TERMINAL, 1: powershell
- Content area: PS D:\Documents\VS Code Projects\testingProject> **dotnet run**
- Input field: Enter your name: Zeus
- Output area: Hello Zeus
- Bottom bar: PS D:\Documents\VS Code Projects\testingProject> [cursor]

**Figure 9–23** Responding to the prompt in the “Terminal” window

### 9.3 What “Debugging” Means

Debugging is the process of finding and reducing the number of defects (bugs) in a computer program, in order to make it perform as expected.

There is a myth about the origin of the term "debugging." In 1940, while Grace Hopper<sup>[2]</sup> was working on a Mark II Computer at Harvard University, her associates discovered a bug (a moth) stuck in a relay (an electrically operated switch). This bug was blocking the proper operation of the Mark II

computer. So, while her associates were trying to remove the bug, Grace Hopper remarked that they were "debugging" the system!

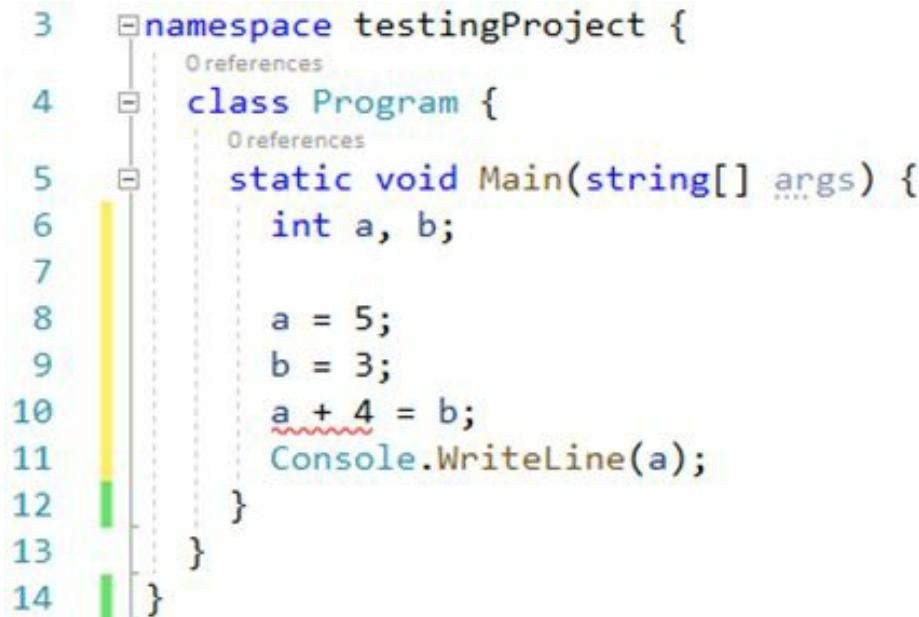
## 9.4 Debugging C# Programs with Visual Studio Community

As you already know, when someone writes code in a high-level language there are two types of errors that he or she might make—syntax errors and logic errors. Visual Studio provides all the necessary tools to help you debug your programs and find the errors.

This paragraph though, is about Visual Studio Community for Windows. If you wish to learn how to use Visual Studio Code (not Visual Studio Community) to debug your programs, skip this paragraph and go directly to the next one ([paragraph 9.5](#)).

### Debugging syntax errors

Fortunately, Visual Studio Community detects syntax errors while you are typing (or when you are trying to run the project) and underlines them with a wavy red line as shown in **Figure 9–24**.



```
3  namespace testingProject {
4      class Program {
5          static void Main(string[] args) {
6              int a, b;
7
8              a = 5;
9              b = 3;
10             a + 4 = b; // Wavy red line under '+'
11             Console.WriteLine(a);
12         }
13     }
14 }
```

**Figure 9–24** In the Visual Studio, syntax errors are underlined with a wavy red line

All you have to do is correct the corresponding error and the red line will disappear at once. However, if you are not certain about what is wrong with your code, you can just place your mouse cursor on the erroneous line. Visual Studio will try to help you by showing a popup window with a brief explanation of the error, as shown in **Figure 9–25**.

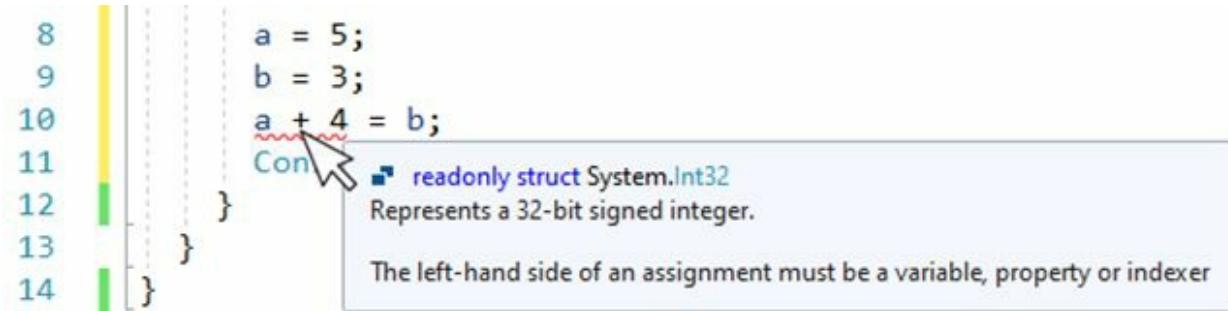


Figure 9–25 The Visual Studio shows an explanation of a syntax error

## Debugging logic errors by executing programs step by step

Compared to syntax errors, logic errors are more difficult to find. Since the Visual Studio cannot spot and underline logic errors, you are all alone! Let's look at the following C# program, for example. It prompts the user to enter two numbers and calculates and displays their sum. However, it contains a logic error!

```
static void Main(string[] args) {
    double S, a, b, s = 0;

    S = 0;
    Console.WriteLine("Initial value of variable S: " + S);

    Console.Write("Enter 1st value: ");
    a = Double.Parse(Console.ReadLine());
    Console.Write("Enter 2nd value: ");
    b = Double.Parse(Console.ReadLine());

    S = a + b;
    Console.WriteLine("Final value of variable S: " + S);

    Console.WriteLine("The sum is: " + s);
}
```

If you type this program into Visual Studio, you will notice that there is not even one wavy red line indicating any error. If you run the program, however, and enter two values, 5 and 3, you can see for yourself that even though the sum of 5 and 3 is 8, Visual Studio insists that it is 0, as shown in **Figure 9–26**.

The screenshot shows the Microsoft Visual Studio Debug Console window. It displays the following text:  
Initial value of variable S: 0  
Enter 1st value: 5  
Enter 2nd value: 3  
Final value of variable S: 8  
The sum is: 0  
  
C:\Users\root\source\repos\testingProject\testingProject\bin\Debug\netcoreapp3.0\testingProject.exe (process 13564) exited with code 0.  
To automatically close the console when debugging stops, enable Tools->Options->Debugging->Automatically close the console when debugging stops.  
Press any key to close this window . . .

Figure 9–26 Viewing the result of a logic error in the “Debug Console” window

What the heck is going on? Of course for an expert programmer, correcting this error would be a piece of cake. But for you, a novice one, even though you are trying hard you find nothing wrong. So, where is the error?

Sometimes human eyes get so tired that they cannot see the obvious. So, let's try to use some magic! Let's try to execute the program step by step using the debugger. This gives you the opportunity to observe the flow of execution and take a closer look at the current values of variables in each step.

Start the debugger by selecting “Debug → Step Over” from the main menu or by hitting the F10 key. By doing this, you enable the debugger and more icons are displayed on the toolbar.



The program counter (the yellow arrow ➔ icon in the gray margin) stops at the first line of the program, as shown in **Figure 9–27**.

The screenshot shows the Visual Studio code editor with the following C# code:

```
3  namespace testingProject {  
4      class Program {  
5          static void Main(string[] args) {  
6              double S, a, b, s = 0;  
7  
8              S = 0;
```

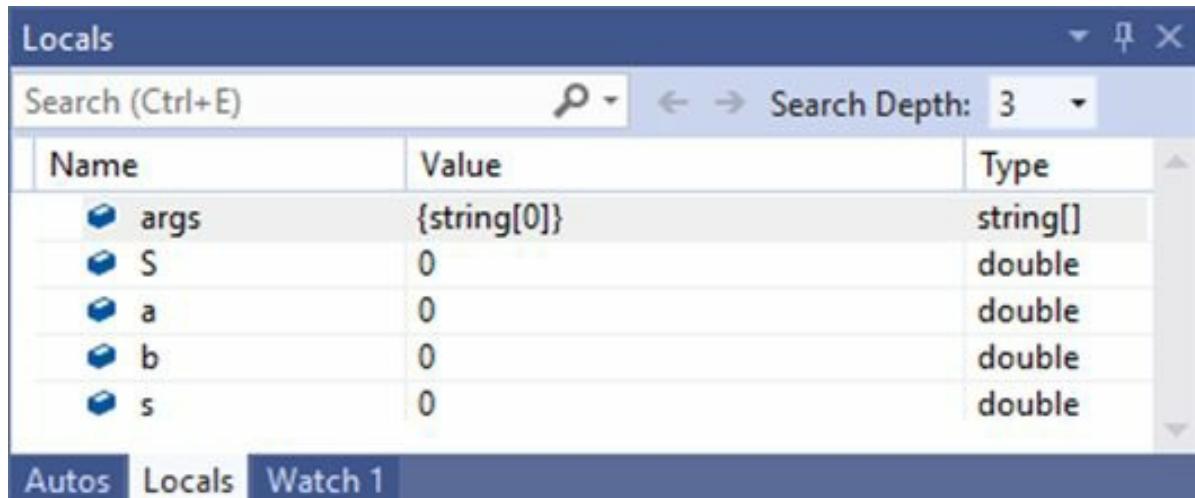
A yellow arrow icon is positioned next to the line number 5, indicating it is the current line of execution. A green vertical bar is positioned next to the line number 8, indicating the cursor is currently on that line.

Figure 9–27 Using the debugger in the Visual Studio

 The program counter shows you, at any time, which statement is the next to be executed.

Click on the “Step Over”  icon on the toolbar or hit the F10 key three more times. This action moves and places the program counter on the `s = 0` statement. In this step, the statement `s = 0` is not yet executed. Hit the F10 key again. Now the statement `s = 0` is executed and the program counter moves to the subsequent C# statement, which is the next to be executed.

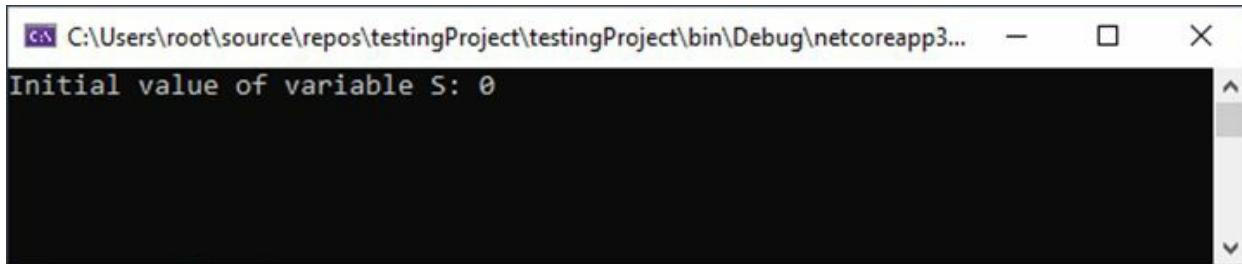
In the “Locals” window, you can see all the variables declared in main memory (RAM) and the value they contain during each step of execution, as shown in **Figure 9–28**.



Name	Value	Type
args	{string[0]}	string[]
S	0	double
a	0	double
b	0	double
s	0	double

**Figure 9–28** All declared variables are displayed in the “Locals” window of the debugger

Click on the “Step Over”  toolbar icon again. The next statement is executed. You can go back to the “Debug Console” window and see the output result (see **Figure 9–29**).



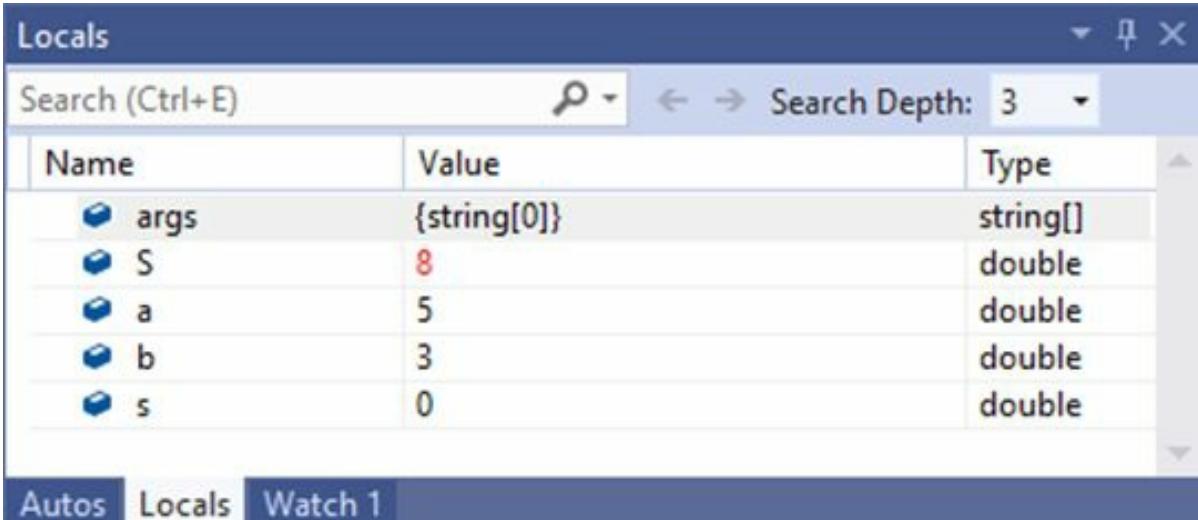
```
C:\Users\root\source\repos\testingProject\testingProject\bin\Debug\netcoreapp3...
Initial value of variable S: 0
```

**Figure 9–29** Viewing a prompt in the “Debug Console” window

Click on the “Step Over”  toolbar icon twice. The next two C# statements are executed and the program waits for you to enter a value. In the “Debug Console” window, type the value 5 and hit the “Enter ↴” key.

The program counter moves to the next C# statement. Click on the “Step Over”  toolbar icon twice. This action executes the next two C# statements. In “Debug Console” window, type the value 3 and hit the “Enter ↴” key.

The program counter moves to the next C# statement. Click on the “Step Over”  toolbar icon once again. The statement `s = a + b` is executed. What you expected here was the sum of 5 and 3, which is 8, to be assigned to variable `s`. Instead of this, the value 8 is assigned to the variable `s` (with a capital S), as shown in **Figure 9–30**.



The screenshot shows the Locals window in the Visual Studio debugger. The window title is "Locals". At the top, there is a search bar labeled "Search (Ctrl+E)" and a dropdown for "Search Depth" set to 3. Below the search bar is a table with three columns: "Name", "Value", and "Type". The table contains the following data:

Name	Value	Type
args	{string[0]}	string[]
S	8	double
a	5	double
b	3	double
s	0	double

At the bottom of the window, there are tabs for "Autos", "Locals" (which is selected), and "Watch 1".

**Figure 9–30** Viewing the current values of the variables in the “Locals” window

Now it becomes more obvious to you! You mistakenly declared two variables in the main memory (RAM), the variable `s` and the variable `S` with a capital S. So, when the flow of execution goes to the last statement, `Console.WriteLine("The sum is: " + s)`, the value 0 instead of the value 8 is displayed.

Congratulations! You have just found the error! Click on the “Stop Debugging”  toolbar icon to cancel execution, then correct the error by changing variable `S` to `s` and you are ready! You just performed your first debugging! Re-execute the program and you will now see that it calculates and displays the sum correctly.

### Debugging logic errors by adding breakpoints

Debugging step by step has a big disadvantage. You have to click on the “Step Over”  toolbar icon again and again until you reach the position where the error might be. Can you imagine yourself doing this in a large

program?

For large programs, there is another approach. If you suspect that the error is somewhere at the end of the program, there is no need to debug all of it right from the beginning. You can add a marker (called a “breakpoint”) where you think that the error might be, then execute the program; when the flow of execution reaches that breakpoint, the flow of execution will pause automatically. You can then take a closer look at the current values of the variables at the position where the program paused.

 When the program pauses, you have two options for resuming the execution: you can add a second breakpoint somewhere below in the program, click on the “Continue”  toolbar icon, and allow the program to continue execution until that new breakpoint; or, you can just use the “Step Over”  toolbar icon and execute the program step by step thereafter.

The next C# program prompts the user to enter two values and calculates their average value. However, the program contains a logic error. When the user enters the values 10 and 12, the value 16, instead of 11, is displayed.

```
static void Main(string[] args) {
    double a, b, average;

    Console.WriteLine("Enter 1st value: ");
    a = Double.Parse(Console.ReadLine());
    Console.WriteLine("Enter 2nd value: ");
    b = Double.Parse(Console.ReadLine());
    average = a + b / 2;
    Console.WriteLine("The average value is: " + average);
}
```

You suspect that the problem is somewhere at the end of the program. However, you do not want to debug the entire program, but just the portion in which the error might be. So, let's try to add a breakpoint at the `average = a + b / 2` statement (see **Figure 9–31**). There are two ways to do this: you can click in the left gray margin on the corresponding line, or you can place the cursor at the line of interest and hit the F9 key.

The screenshot shows a code editor with a C# program. A red circular breakpoint icon is placed in the margin next to the line number 12. The line 12, which contains the assignment statement 'average = a + b / 2;', has a purple vertical bar highlighting it, indicating it is the current line of execution. The code is as follows:

```
3  namespace testingProject {
4      class Program {
5          static void Main(string[] args) {
6              double a, b, average;
7
8              Console.WriteLine("Enter 1st value: ");
9              a = Double.Parse(Console.ReadLine());
10             Console.WriteLine("Enter 2nd value: ");
11             b = Double.Parse(Console.ReadLine());
12             average = a + b / 2;
13             Console.WriteLine("The average value is: " + average);
14         }
15     }
16 }
```

**Figure 9–31** Adding a breakpoint to a program

You know that a breakpoint has been set when the red circle appears in the gray margin and the corresponding line has purple background highlighting it.

Hit F5 to start the program. Enter the values 10 and 12 when requested in the “Debug Console” window. You will notice that just after you enter the second number and hit the “Enter ↵” key, the flow of execution pauses at the breakpoint. (You will see that the purple breakpoint highlighting is replaced by the yellow highlighting of the program counter).

You can run a project by selecting “Debug → Start Debugging” from the main menu or by hitting the F5 key.

Now you can take a closer look at the current values of the variables. Variables a and b contain the values 10 and 12, respectively, as they should, so there is nothing wrong with the data input, as shown in **Figure 9–32**.

Locals		
Search (Ctrl+E) <input type="button" value="🔍"/> ⏪ ⏩ Search Depth: 3 ⏪ ⏩		
Name	Value	Type
args	{string[0]}	string[]
a	10	double
b	12	double
average	0	double

Autos   Locals   Watch 1

Figure 9–32 Viewing the current values of the variables in the “Locals” window

Click on the “Step Over”  toolbar icon once. The statement `average = a + b / 2` executes, and the main memory (RAM) now contains the following values (see **Figure 9–33**).

Locals		
Search (Ctrl+E) <input type="button" value="🔍"/> ⏪ ⏩ Search Depth: 3 ⏪ ⏩		
Name	Value	Type
args	{string[0]}	string[]
a	10	double
b	12	double
average	16	double

Autos   Locals   Watch 1

Figure 9–33 Viewing the current values of the variables in the “Locals” window

There it is! You just found the statement that erroneously assigns a value of 16, instead of 11, to the variable `average`! And now comes the difficult part —you must consider why this happens!

After two days of thinking, it becomes obvious! You had just forgotten to enclose `a + b` inside parentheses; thus, only the variable `b` was divided by 2. Click on the “Stop Debugging”  toolbar icon, remove all breakpoints, correct the error by enclosing `a + b` inside parentheses, and you are ready! Re-execute the program, and you will now see that it calculates and displays the average value correctly.

 You can remove a breakpoint the same way you added it: click in the left gray margin on the corresponding line number, or place the cursor at the

*line that contains a breakpoint and hit the F9 key.*

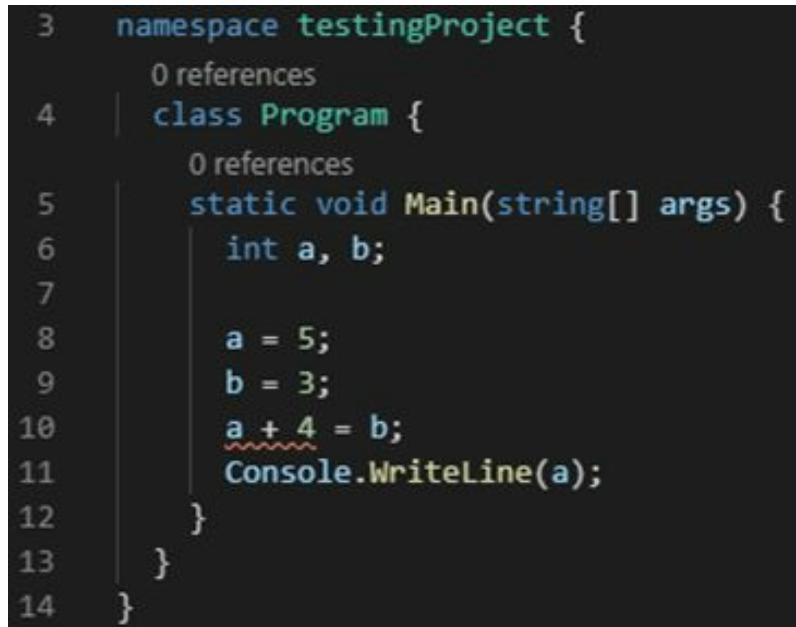
## 9.5 Debugging C# Programs with Visual Studio Code

As you already know, when someone writes code in a high-level language there are two types of errors that he or she might make—syntax errors and logic errors. Visual Studio provides all the necessary tools to help you debug your programs and find the errors.

Keep in mind that this paragraph is about Visual Studio Code. If you prefer using Visual Studio Community (not Visual Studio Code) to debug your program, skip this paragraph.

### Debugging syntax errors

Fortunately, Visual Studio Code detects syntax errors while you are typing (or when you are trying to run the project) and underlines them with a wavy red line, as shown in **Figure 9–34**.



A screenshot of a C# code editor in Visual Studio Code. The code is as follows:

```
3  namespace testingProject {
4      0 references
5      class Program {
6          0 references
7          static void Main(string[] args) {
8              int a, b;
9
10             a = 5;
11             b = 3;
12             a + 4 = b; // Wavy red underline under the assignment operator
13             Console.WriteLine(a);
14         }
15     }
16 }
```

The assignment operator in the line "a + 4 = b;" is underlined with a wavy red line, indicating a syntax error.

**Figure 9–34** In the Visual Studio, syntax errors are underlined with a wavy red line

All you have to do is correct the corresponding error and the red line will disappear at once. However, if you are not certain about what is wrong with your code, you can just place your mouse cursor on the erroneous line. Visual Studio will try to help you by showing a popup window with a brief explanation of the error, as shown in **Figure 9–35**.

The screenshot shows a portion of a C# program in Visual Studio. The code is as follows:

```
4 class Program {  
5     0 references  
6     st int int.operator +(int left, int right)  
7     The left-hand side of an assignment must be a variable,  
8     property or indexer [testingProject] csharp(CS0131)  
9     Peek Problem No quick fixes available  
10    a + 4 = b;  
11    Console.WriteLine(a);  
12 }  
13 }  
14 }
```

A tooltip is displayed over the assignment operator (=) in line 10, indicating a syntax error: "The left-hand side of an assignment must be a variable, property or indexer". The mouse cursor is hovering over the error message.

Figure 9–35 The Visual Studio shows an explanation of a syntax error

## Debugging logic errors by executing programs step by step

Compared to syntax errors, logic errors are more difficult to find. Since the Visual Studio cannot spot and underline logic errors, you are all alone! Let's look at the following C# program, for example. It prompts the user to enter two numbers and calculates and displays their sum. However, it contains a logic error!

```
static void Main(string[] args) {  
    double s, a, b, s = 0;  
  
    s = 0;  
    Console.WriteLine("Initial value of variable S: " + s);  
  
    Console.Write("Enter 1st value: ");  
    a = Double.Parse(Console.ReadLine());  
    Console.Write("Enter 2nd value: ");  
    b = Double.Parse(Console.ReadLine());  
  
    s = a + b;  
    Console.WriteLine("Final value of variable S: " + s);  
  
    Console.WriteLine("The sum is: " + s);  
}
```

If you type this program into Visual Studio, you will notice that there is not even one wavy red line indicating an error. If you run the program, however, and enter two values, 5 and 3, you can see for yourself that even though the sum of 5 and 3 is 8, Visual Studio insists that it is 0, as shown in **Figure 9–36**.

```
PROBLEMS OUTPUT TERMINAL 1: powershell
PS D:\Documents\VS Code Projects\testingProject> dotnet run
Initial value of variable S: 0
Enter 1st value: 5
Enter 2nd value: 3
Final value of variable S: 8
The sum is: 0
PS D:\Documents\VS Code Projects\testingProject>
```

Figure 9–36 Viewing the result of a logic error in the “Terminal” window

What the heck is going on? Of course, for an expert programmer, correcting this error would be a piece of cake. But for you, a novice one, even though you are trying hard you find nothing wrong. So, where is the error?

Sometimes human eyes get so tired that they cannot see the obvious. So, let's try to use some magic! Let's try to execute the program step by step using the debugger. This gives you the opportunity to observe the flow of execution and take a closer look at the current values of variables in each step.

 In order to use the debugger of Visual Studio Code, you will probably need to modify the “launch.json” file. In the Side Bar, click on the “launch.json” file to open the file in the “Code Editor” window. Spot the “Console” parameter and change its value from “internalConsole” to “integratedTerminal”. Save and close the file. You do not have to perform this process for every project you create. This process needs to be performed only once, unless you alter the workspace folder.

Start the debugger by selecting “Debug → Start Debugging” from the main menu or by hitting the F5 key. By doing this, you enable the debugger and more icons are displayed on the toolbar.



The program counter (the yellow arrow  icon in the left margin) stops at the first line of the program, as shown in **Figure 9–37**.

```
5     static void Main(string[] args) {
D 6         double S, a, b, s = 0;
7
8         S = 0;
9         Console.WriteLine("Initial value of variable S: " + S);
10
```

Figure 9–37 Using the debugger in the Visual Studio

 *The program counter shows you, at any time, which statement is the next to be executed.*

Click on the “Step Over”  icon on the toolbar or hit the F10 key once. This action moves and places the program counter on the `S = 0` statement. In this step, the statement `S = 0` is not yet executed. Hit the F10 key again. Now the statement `S = 0` is executed, and the program counter moves to the subsequent C# statement, which is the next to be executed.

In the Side Bar on the left, you can watch all the variables declared in main memory (RAM) and the value they contain during each step of execution, as shown in **Figure 9–38**.

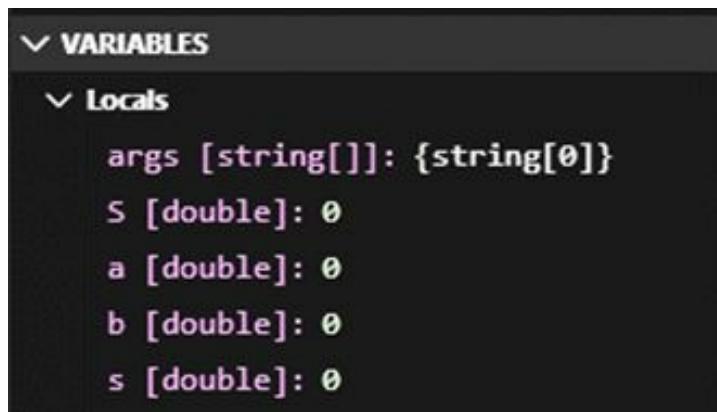


Figure 9–38 All declared variables are displayed in the “Locals” window of the debugger

Click on the “Step Over”  toolbar icon again. The next statement is executed. In the “Terminal” window, you can see the output result (see **Figure 9–39**).

The screenshot shows the VS Code interface with the "TERMINAL" tab selected. The title bar indicates "2: testingProject.dll". The terminal window displays the following text:

```
Windows PowerShell
Copyright (C) Microsoft Corporation. All rights reserved.

Try the new cross-platform PowerShell https://aka.ms/pscore6

PS D:\Documents\VS Code Projects> & 'c:\Users\root\.vscode\extensions\ms-vscode.csharp-1.21.6\.\debugger\vsdbg.exe' '--interpreter=vscode' '--connection=26e15aade02b4dcfb239448cfaa1fc1a
Initial value of variable S: 0
```

Figure 9–39 Viewing a prompt in the “Terminal” window

Click on the “Step Over” toolbar icon twice. The next two C# statements are executed and the program waits for you to enter a value. In the “Terminal” window, type the value 5, and hit the “Enter ↵” key.

The program counter moves to the next C# statement. Click on the “Step Over” toolbar icon twice. This action executes the next two C# statements. In “Terminal” window, type the value 3, and hit the “Enter ↵” key.

The program counter moves to the next C# statement. Click on the “Step Over” toolbar icon once again. The statement `s = a + b` is executed. What you expected here was the sum of 5 and 3, which is 8, to be assigned to variable `s`. Instead of this, the value 8 is assigned to the variable `S` (with a capital S), as shown in **Figure 9–40**.

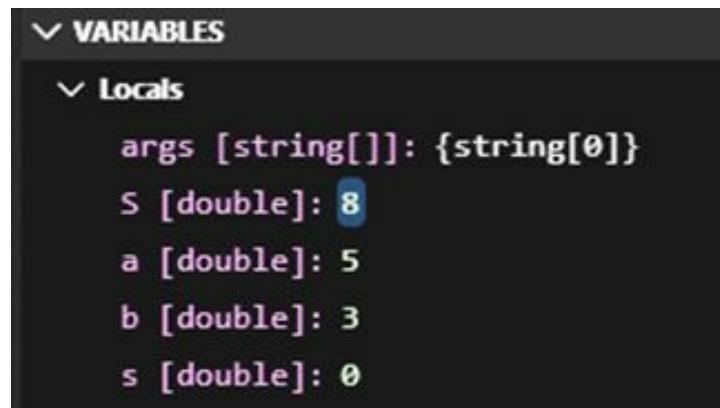


Figure 9–40 Viewing the current values of the variables in the “Locals” window

Now it becomes more obvious to you! You mistakenly declared two variables in the main memory (RAM), the variable `s` and the variable `S` with a capital S. So, when the flow of execution goes to the last statement, `Console.WriteLine("The sum is: " + s)`, the value 0 instead of the value 8 is displayed.

Congratulations! You have just found the error! Click on the “Stop Debugging”  toolbar icon to cancel execution, then correct the error by changing variable `s` to `s`, and you are ready! You just performed your first debugging! Re-execute the program and you will now see that it calculates and displays the sum correctly.

## Debugging logic errors by adding breakpoints

Debugging step by step has a big disadvantage. You have to click on the “Step Over”  toolbar icon again and again until you reach the position where the error might be. Can you imagine yourself doing this in a large program?

For large programs there is another approach. If you suspect that the error is somewhere at the end of the program, there is no need to debug all of it right from the beginning. You can add a marker (called a “breakpoint”) where you think that the error might be, then execute the program; when flow of execution reaches that breakpoint, the flow of execution will pause automatically. You can then take a closer look at the current values of the variables at the position where the program was paused.

 When the program pauses, you have two options for resuming the execution: you can add a second breakpoint somewhere below in the program, click on the “Continue”  toolbar icon, and allow the program to continue execution until that new breakpoint; or, you can just use the “Step Over”  toolbar icon and execute the program step by step thereafter.

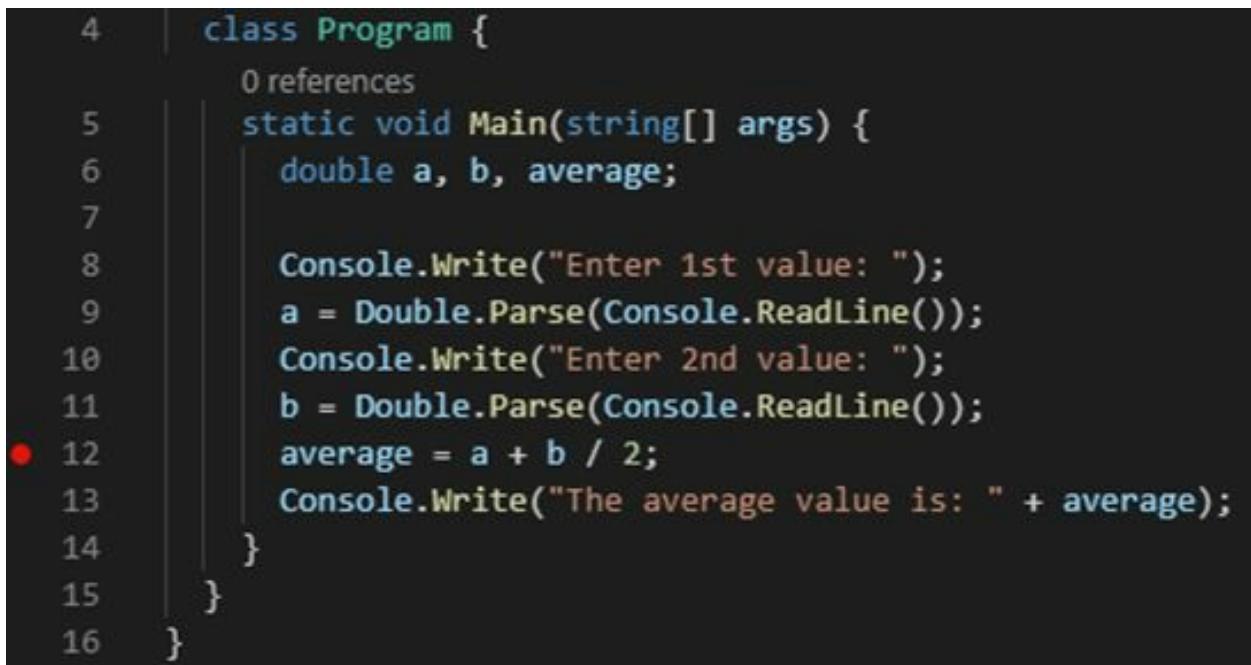
The next C# program prompts the user to enter two values and calculates their average value. However, the program contains a logic error. When the user enters the values 10 and 12, the value 16, instead of 11, is displayed.

```
static void Main(string[] args) {
    double a, b, average;

    Console.WriteLine("Enter 1st value: ");
    a = Double.Parse(Console.ReadLine());
    Console.WriteLine("Enter 2nd value: ");
    b = Double.Parse(Console.ReadLine());
    average = a + b / 2;
    Console.WriteLine("The average value is: " + average);
}
```

You suspect that the problem is somewhere at the end of the program.

However, you do not want to debug the entire program, but just the portion in which the error might be. So, let's try to add a breakpoint at the `average = a + b / 2` statement (see **Figure 9–41**). There are two ways to do this: you can click in the left margin on the corresponding line, or you can place the cursor at the line of interest and hit the F9 key.



```
4  class Program {
5      0 references
6      static void Main(string[] args) {
7          double a, b, average;
8
9          Console.WriteLine("Enter 1st value: ");
10         a = Double.Parse(Console.ReadLine());
11         Console.WriteLine("Enter 2nd value: ");
12         b = Double.Parse(Console.ReadLine());
13         average = a + b / 2;
14         Console.WriteLine("The average value is: " + average);
15     }
16 }
```

A screenshot of a code editor showing a C# program. Line 12, which contains the assignment `average = a + b / 2;`, has a red circular breakpoint icon in the left margin. The background of line 12 is purple, indicating it is highlighted as a breakpoint. The code editor shows lines 4 through 16.

**Figure 9–41** Adding a breakpoint to a program

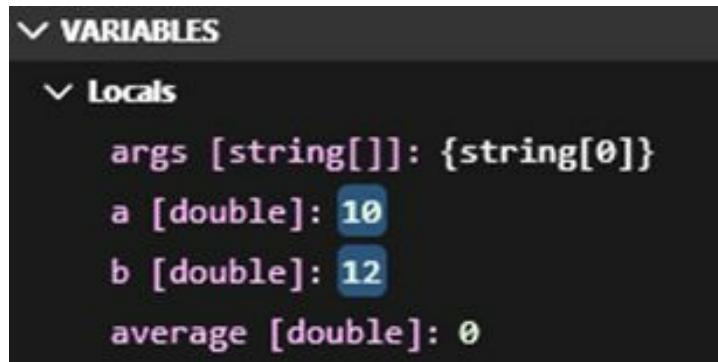
 You know that a breakpoint has been set when the red circle  appears in the gray margin and the corresponding line has purple background highlighting it.

Start the debugger by selecting “Debug → Start Debugging” from the main menu or by hitting the F5 key. Then, click on the “Continue”  toolbar icon. Enter the values 10 and 12 when requested in the “Terminal” window. You will notice that just after you enter the second number and hit the “Enter ↴” key, the flow of execution pauses at the breakpoint (the corresponding line has yellow background highlighting it).

 You can run a project by selecting “Debug → Start Debugging” from the main menu or by hitting the F5 key.

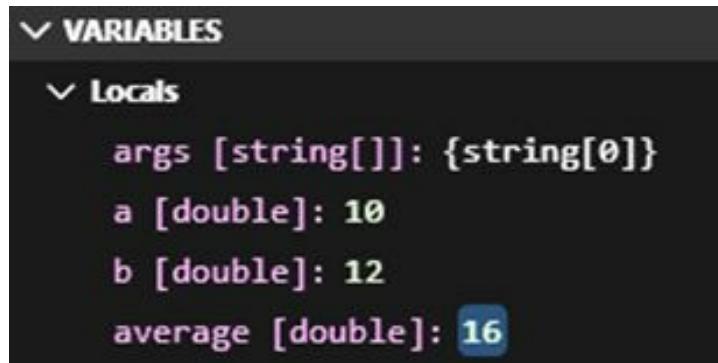
Now you can take a closer look at the current values of the variables. Variables `a` and `b` contain the values 10 and 12, respectively, as they should,

so there is nothing wrong with the data input, as shown in **Figure 9–42**.



**Figure 9–42** Viewing the current values of the variables in the “Locals” window

Click on the “Step Over” toolbar icon once. The statement `average = a + b / 2` executes, and the main memory (RAM) now contains the following values (see **Figure 9–43**).



**Figure 9–43** Viewing the current values of the variables in the “Locals” window

There it is! You just found the statement that erroneously assigns a value of 16, instead of 11, to the variable `average`! And now comes the difficult part—you must consider why this happens!

After two days of thinking, it becomes obvious! You had just forgotten to enclose `a + b` inside parentheses; thus, only the variable `b` was divided by 2. Click on the “Stop Debugging” toolbar icon, remove all breakpoints, correct the error by enclosing `a + b` inside parentheses and you are ready! Re-execute the program and you will now see that it calculates and displays the average value correctly.

You can remove a breakpoint the same way you added it: click in the left gray margin on the corresponding line number, or place the cursor at the line that contains a breakpoint and hit the F9 key.

## 9.6 Review Exercises

Complete the following exercises.

1. Type the following C# program into Visual Studio and execute it step by step. Determine why it doesn't calculate correctly the sum of 1 + 3 + 5.

```
static void Main(string[] args) {
    int SS, S1, S3, S5, S;

    SS = 0;
    S1 = 1;
    S3 = 3;
    S5 = 5;

    S = S1 + S3 + SS;

    Console.WriteLine(S);
}
```

2. Create a trace table to determine the values of the variables in each step of the C# program for two different executions. Then, type the program in the Visual Studio, execute it step by step, and confirm the results.

The input values for the two executions are: (i) 5, 5; and (ii) 4, 2.

```
static void Main(string[] args) {
    int a, b, c, d, e;

    a = Int32.Parse(Console.ReadLine());
    b = Int32.Parse(Console.ReadLine());

    c = a + b;
    d = 5 + a / b * c + 2;
    e = c - d;
    c += d + c;
    e--;
    d += e + c % b;

    Console.WriteLine(c + ", " + d + ", " + e);
}
```

3. Create a trace table to determine the values of the variables in each step of the C# program for three different executions. Then, type the program in the Visual Studio, execute it step by step, and confirm the results.

The input values for the three executions are: (i) 5, (ii) 4, and (iii) 15.

```
static void Main(string[] args) {
    int a, b, c;

    b = Int32.Parse(Console.ReadLine());

    c = 5;
    c = c * b;
    a = 3 * c % 10;

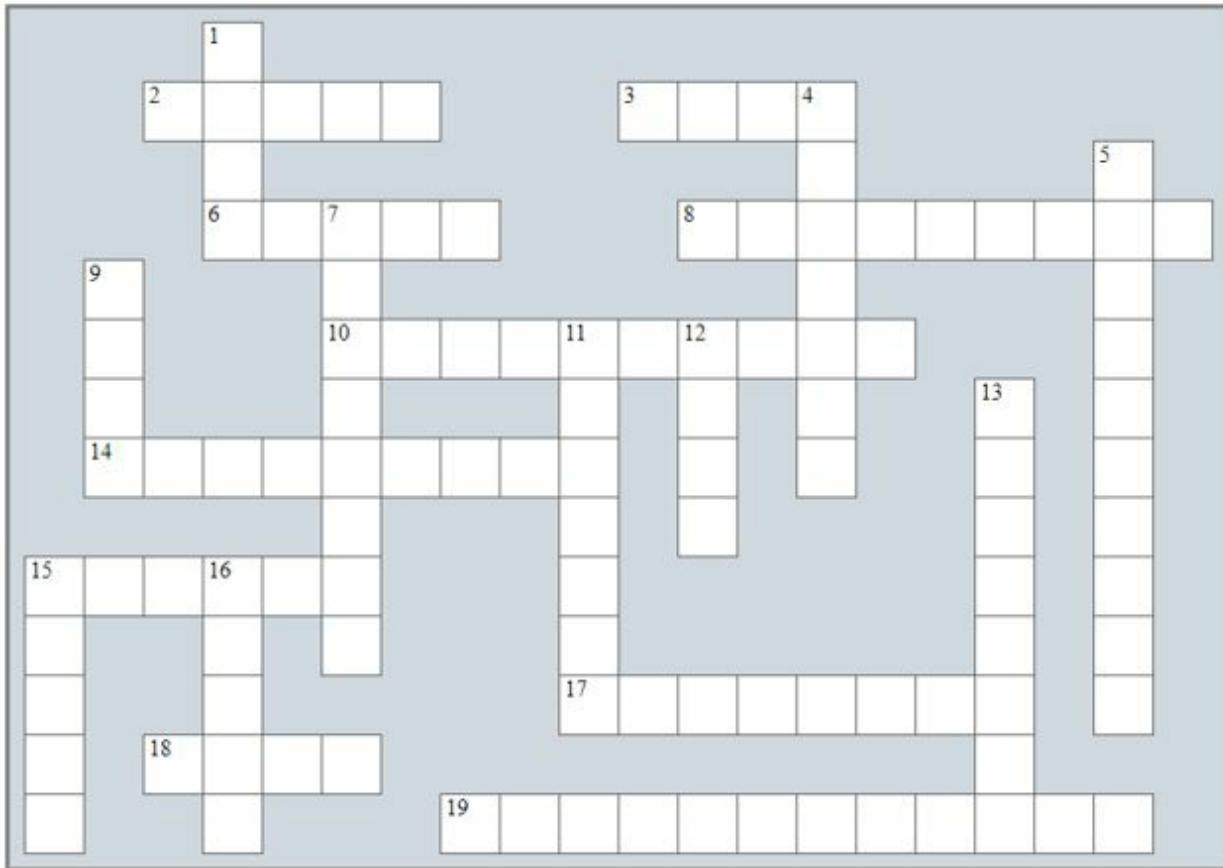
    Console.WriteLine(a);
}
```

# **Review in “Getting Started with C#**

---

## **Review Crossword Puzzles**

1. Solve the following crossword puzzle.



### **Across**

---

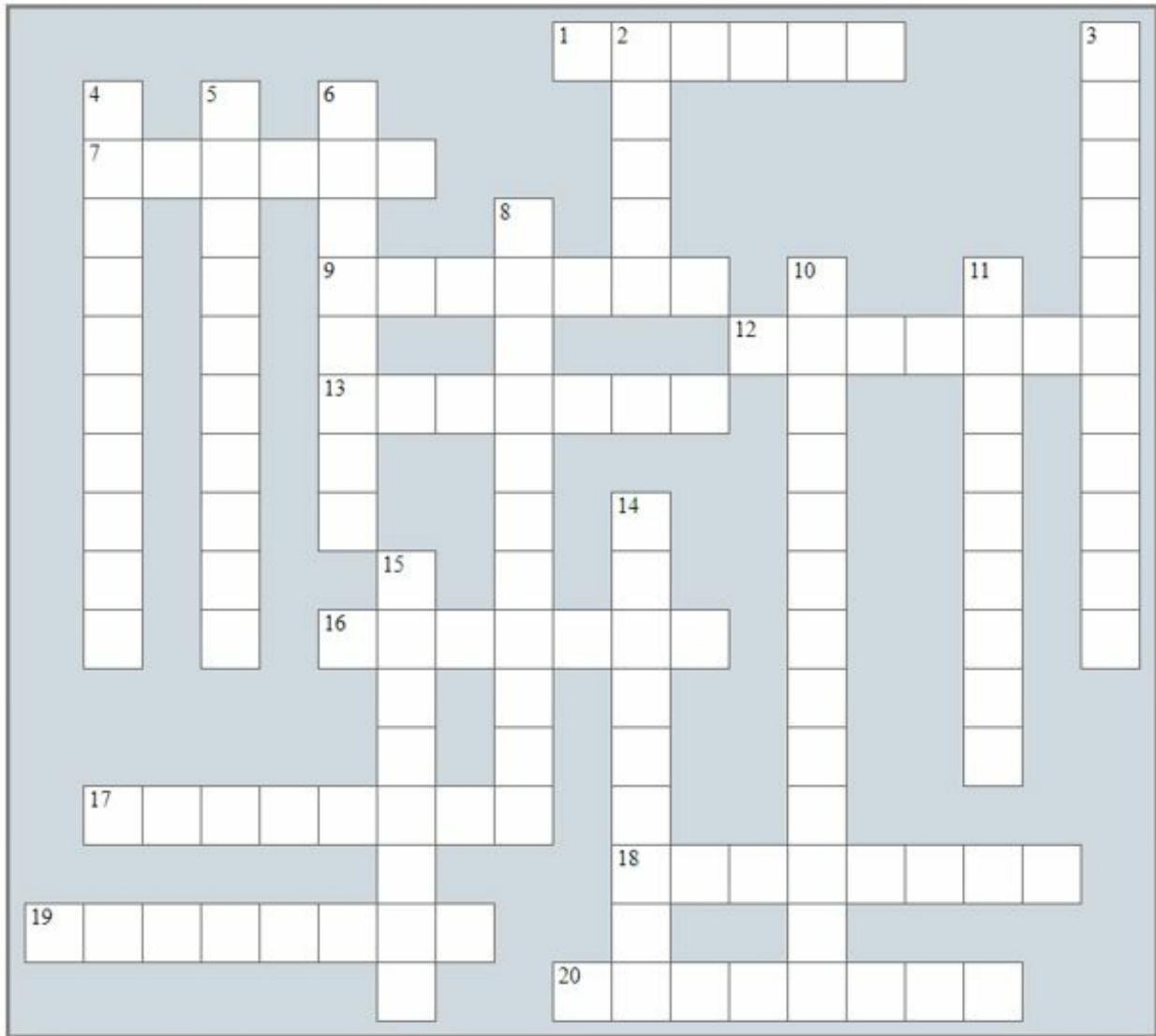
2. These errors are hard to detect.
3. A control structure.
6. It shows the flow of execution in a flowchart.
8. A graphical method of presenting an algorithm.
10. \_\_\_\_\_ programming is a software development method that uses modularization and structured design.
14. Strictly defined finite sequence of well-defined statements that provides the solution to a problem.
15. The term \_\_\_\_\_ means that the algorithm must reach an end point and cannot run forever.

17. This flowchart symbol has one entrance and two exits.
18. Logic errors and runtime errors are commonly referred to as \_\_\_\_\_.
19. It must be possible to perform each step of the algorithm correctly and in a finite amount of time. This is one of the properties an algorithm must satisfy, and it is known as \_\_\_\_\_.

### **Down**

---

1. The principle that best defines user-friendly designs.
  4. This represents a mathematical (formula) calculation in a flowchart.
  5. Data \_\_\_\_\_ is one of the three main stages involved in creating an algorithm.
  7. A word that has a strictly predefined meaning in a computer language.
  9. A programming language.
  11. Statement.
  12. He or she uses a program.
  13. A control structure.
  15. Real.
  16. One of the properties an algorithm must satisfy.
2. Solve the following crossword puzzle.



### **Across**

---

1. An alphanumeric value.
7. A misspelled keyword is a \_\_\_\_\_ error.
9. A positive or negative number without any fractional part.
12. Extra information that can be included in a program to make it easier to read and understand.
13. It can hold only one of two values.
16. An error that occurs during the execution of a program.
17. This control structure is also known as a selection control structure.

18. This is a CPU-time consuming arithmetic operation.
19. A value that cannot change while the program is running.
20. A user-\_\_\_\_\_ program is one that is easy for a novice user.

## **Down**

---

2. A \_\_\_\_\_ table is a technique used to test algorithms or computer programs for logic errors that occur while the algorithm or program executes.
3. Any arithmetic operations enclosed in \_\_\_\_\_ are performed first.
4. The left arrow in flowcharts is called the value \_\_\_\_\_ operator.
5. The only symbol character permitted in a variable name.
6. It represents a location in the computer's main memory (RAM) where a program can store a value.
8. The process of reserving a portion in main memory (RAM) for storing the contents of a variable.
10. Joining two separate strings into a single one.
11. The process of finding and reducing the number of logic errors in a computer program.
14. The modulus operator returns the \_\_\_\_\_ of an integer division.
15. The operator ( / ) returns the \_\_\_\_\_ of a division.

## **Review Questions**

Answer the following questions.

1. What is an algorithm?
2. Give the algorithm for making a cup of coffee.
3. What are the five properties of algorithms?
4. Can an algorithm execute forever?
5. What is a computer program?
6. What are the three parties involved in an algorithm?
7. What are the three stages that make up a computer program?

8. Can a computer program be made up of two stages?
9. What is a flowchart?
10. What are the basic symbols that flowcharts use?
11. What is meant by the term “reserved words”?
12. What is structured programming?
13. What are the three fundamental control structures of structured programming?
14. Give an example of each control structure using flowcharts.
15. Can a programmer write C# programs in a text editor?
16. What is a syntax error? Give one example.
17. What is a logic error? Give one example.
18. What is a runtime error? Give one example.
19. What type of error is caused by a misspelled keyword?
20. Why should a programmer add comments in his or her code?
21. Why should a programmer write user-friendly programs?
22. What does the acronym POLA stand for?
23. What is a variable?
24. How many variables can exist on the left side of the left arrow in flowcharts?
25. In which part of a computer are the values of the variables stored?
26. What is a constant?
27. How can constants be used to help programmers?
28. Why should a programmer avoid division and multiplication operations whenever possible?
29. What are the four fundamental types of variables in C#?
30. What does the phrase “declare a variable” mean?
31. How do you declare a variable in C#? Give an example.
32. How do you declare a constant in C#? Give an example.
33. What symbol is used in flowcharts to display a message?
34. What special sequence of characters is used in C# to output a “line

break”?

35. Which symbol is used in flowcharts to let the user enter data?
36. Which symbol is used in C# as a value assignment operator, and how is it represented in a flowchart?
37. Which arithmetic operators does C# support?
38. What is a modulus operator?
39. Summarize the rules for the precedence of arithmetic operators.
40. What compound assignment operators does C# support?
41. What incrementing/decrementing operators does C# support?
42. What string operators does C# support?
43. What is a trace table?
44. What are the benefits of using a trace table?
45. Describe the steps involved in swapping the contents (either numeric or alphanumeric) of two variables.
46. Two methods for swapping the values of two variables have been proposed in this book. Which one is better, and why?
47. What does the term “debugging” mean?
48. Describe the way in which Visual Studio IDE helps you find syntax errors.
49. Describe the ways in which Visual Studio IDE helps you find logic errors.

# **Section 3**

## **Sequence Control Structures**

---

# Chapter 10

## Introduction to Sequence Control Structures

---

### 10.1 What is the Sequence Control Structure?

Sequence control structure refers to the line-by-line execution by which statements are executed sequentially, in the same order in which they appear in the program, without skipping any of them. They might, for example, carry out a series of read or write operations, arithmetic operations, or assignments to variables.

The following program shows an example of C# statements that are executed sequentially.

#### project\_10\_1

```
static void Main(string[] args) {
    double num, result;

    //Prompt the user to enter value for num
    Console.WriteLine("Enter a number: ");
    num = Double.Parse(Console.ReadLine());

    //Calculate the square of num
    result = num * num;

    //Display the result on user's screen
    Console.WriteLine("The square of " + num + " is " + result);
}
```

 The sequence control structure is the simplest of the three fundamental control structures that you learned about in [paragraph 4.11](#). The other two structures are “decision structure” and “loop structure”. All problems in computer programming can be solved using only these three structures!

 In C#, you can add comments using double slashes ( // ). Comments are for human readers. Compilers and interpreters ignore them.

#### Exercise 10.1-1 Calculating the Area of a Rectangle

---

Write a C# program that prompts the user to enter the length of the base and the height of a rectangle, and then calculates and displays its area.

#### Solution

---

You probably know from school that you can calculate the area of a rectangle using the following formula:

$$\text{Area} = \text{Base} \times \text{Height}$$

In [paragraph 4.6](#), you learned about the three main stages involved in creating an algorithm: data input, data processing, and results output.

In this exercise, these three main stages are as follows:

- **Data input** - the user must enter values for *Base* and *Height*
- **Data processing** - the program must calculate the area of the rectangle
- **Results output** – the program must display the area of the rectangle calculated in previous stage

The solution to this problem is shown here.

### project\_10\_1\_1

```
static void Main(string[] args) {
    double area, b, h;

    //Data input - Prompt the user to enter values for base and height
    Console.WriteLine("Enter the length of Base: ");
    b = Double.Parse(Console.ReadLine());
    Console.WriteLine("Enter the length of Height: ");
    h = Double.Parse(Console.ReadLine());

    //Data processing - Calculate the area of the rectangle
    area = b * h;

    //Results output - Display the result on user's screen
    Console.WriteLine("The area of the rectangle is " + area);
}
```

## Exercise 10.1-2 Calculating the Area of a Circle

Write a C# program that calculates and displays the area of a circle.

### Solution

You can calculate the area of a circle using the following formula:

$$\text{Area} = \pi \cdot \text{Radius}^2$$

The value of  $\pi$  is a known quantity, which is 3.14159. Therefore, the only value the user must enter is the value for *Radius*.

In this exercise, the three main stages that you learned in [paragraph 4.6](#) are

as follows:

- ▶ **Data input** - the user must enter a value for *Radius*
- ▶ **Data processing** - the program must calculate the area of the circle
- ▶ **Results output** – the program must display the area of the circle calculated in previous stage.

The solution to this problem is shown here.

### project\_10\_1\_2a

```
static void Main(string[] args) {  
    double area, radius;  
  
    //Data input - Prompt the user to enter a value for radius  
    Console.WriteLine("Enter the length of Radius: ");  
    radius = Double.Parse(Console.ReadLine());  
  
    //Data processing - Calculate the area of the circle  
    area = 3.14159 * radius * radius;  
  
    //Results output - Display the result on user's screen  
    Console.WriteLine("The area of the circle is " + area);  
}
```

A much better approach would be with to use a constant, PI.

### project\_10\_1\_2b

```
const double PI = 3.14159;  
  
static void Main(string[] args) {  
    double area, radius;  
  
    //Data input - Prompt the user to enter a value for radius  
    Console.WriteLine("Enter the length of Radius: ");  
    radius = Double.Parse(Console.ReadLine());  
  
    //Data processing - Calculate the area of the circle  
    area = PI * radius * radius;  
  
    //Results output - Display the result on user's screen  
    Console.WriteLine("The area of the circle is " + area);  
}
```



Note that the constant PI is declared outside of the method main.

### **Exercise 10.1-3 Calculating Fuel Economy**

---

*In the United States, a car's fuel economy is measured in miles per gallon, or MPG. A car's MPG can be calculated using the following formula:*

$$MPG = \frac{\text{miles driven}}{\text{gallons of gas used}}$$

*Write a C# program that prompts the user to enter the total number of miles he or she has driven and the gallons of gas used. Then the program must calculate and display the car's MPG.*

#### **Solution**

---

This is quite a simple case. The user enters the total number of miles he or she has driven and the gallons of gas used, and then the program must calculate and display the car's MPG.

#### **project\_10\_1\_3**

```
static void Main(string[] args) {
    double gallons, miles_driven, mpg;

    Console.WriteLine("Enter miles driven: ");
    miles_driven = Double.Parse(Console.ReadLine());
    Console.WriteLine("Enter gallons of gas used: ");
    gallons = Double.Parse(Console.ReadLine());

    mpg = miles_driven / gallons;

    Console.WriteLine("Your car's MPG is: " + mpg);
}
```

### **Exercise 10.1-4 Where is the Car? Calculating Distance Traveled**

---

*A car starts from rest and moves with a constant acceleration along a straight horizontal road for a given time. Write a C# program that prompts the user to enter the acceleration and the time the car traveled, and then calculates and displays the distance traveled. The required formula is*

$$S = u_o + \frac{1}{2}at^2$$

*where*

- **S** is the distance the car traveled, in meters (m)

- $u_0$  is the initial velocity (speed) of the car, in meters per second (m/sec)
- $t$  is the time the car traveled, in seconds (sec)
- $a$  is the acceleration, in meters per second<sup>2</sup> (m/sec<sup>2</sup>)

### **Solution**

---

Since the car starts from rest, the initial velocity (speed)  $u_0$  is zero. Thus, the formula becomes

$$S = \frac{1}{2}at^2$$

and the C# program is

#### □ project\_10\_1\_4

```
static void Main(string[] args) {
    double S, a, t;

    Console.WriteLine("Enter acceleration: ");
    a = Double.Parse(Console.ReadLine());
    Console.WriteLine("Enter time traveled: ");
    t = Double.Parse(Console.ReadLine());

    S = 0.5 * a * t * t;

    Console.WriteLine("Your car traveled " + S + " meters");
}
```

### **Exercise 10.1-5 Kelvin to Fahrenheit**

---

Write a C# program that converts a temperature value from degrees Fahrenheit<sup>[8]</sup> to its degrees Kelvin<sup>[9]</sup> equivalent. The required formula is

$$1.8 \times Kelvin = Fahrenheit + 459.67$$

### **Solution**

---

The formula given cannot be used in your program as is. In a computer language such as C#, it is **not** permitted to write

```
1.8 * kelvin = fahrenheit + 459.67;
```

▀ In the position on the left side of the (=) sign, only a variable must exist. This variable is actually a region in RAM where a value can be stored.

The program converts degrees Fahrenheit to degrees Kelvin. The value for degrees Fahrenheit is a known value and it is given by the user, whereas the value for degrees Kelvin is what the C# program must calculate. So, you need to solve for Kelvin. After a bit of work, the formula becomes

$$Kelvin = \frac{Fahrenheit + 459.67}{1.8}$$

and the C# program is shown here.

### project\_10\_1\_5

```
static void Main(string[] args) {
    double fahrenheit, kelvin;

    Console.WriteLine("Enter a temperature in Fahrenheit: ");
    fahrenheit = Double.Parse(Console.ReadLine());

    kelvin = (fahrenheit + 459.67) / 1.8;

    Console.WriteLine("The temperature in Kelvin is " + kelvin);
}
```

### Exercise 10.1-6 Calculating Sales Tax

An employee needs a program to enter the before-tax price of a product and calculate its final price. Assume a value added tax (VAT) of 19%.

### **Solution**

The sales tax can be easily calculated. You must multiply the before-tax price of the product by the sales tax rate. Be careful—the sales tax is not the final price, but only the tax amount.

The after-tax price can be calculated by adding the initial before-tax price and the sales tax that you calculated beforehand.

In this program you can use a constant named VAT for the sales tax rate.

### project\_10\_1\_6

```
const double VAT = 0.19;

static void Main(string[] args) {
    double price_after_tax, price_before_tax, sales_tax;

    Console.WriteLine("Enter the before-tax price: ");
    price_before_tax = Double.Parse(Console.ReadLine());
```

```
    sales_tax = price_before_tax * VAT;
    price_after_tax = price_before_tax + sales_tax;

    Console.WriteLine("The after-tax price is: " + price_after_tax);
}
```

 Note that the constant VAT is declared outside of the method main.

### ***Exercise 10.1-7 Calculating a Sales Discount***

*Write a C# program that prompts the user to enter the price of an item and the discount offered as a percentage (on a scale of 0 to 100). The program must then calculate and display the new price.*

#### ***Solution***

The discount amount can be easily calculated. You must multiply the before-discount price of the product by the discount value and then divide it by 100. The division is necessary since the user enters a value for the discount on a scale of 0 to 100. Be careful—the result is not the final price but only the discount amount.

The final after-discount price can be calculated by subtracting the discount amount that you calculated beforehand from the initial before-discount price.

#### **project\_10\_1\_7**

```
static void Main(string[] args) {
    int discount;
    double discount_amount, price_after_discount, price_before_discount;

    Console.Write("Enter the price of a product: ");
    price_before_discount = Double.Parse(Console.ReadLine());

    Console.Write("Enter the discount offered (0 - 100): ");
    discount = Int32.Parse(Console.ReadLine());

    discount_amount = price_before_discount * discount / 100;
    price_after_discount = price_before_discount - discount_amount;

    Console.WriteLine("The price after discount is: " + price_after_discount);
}
```

### ***Exercise 10.1-8 Calculating the Sales Tax Rate and Discount***

*Write a C# program that prompts the user to enter the before-tax price of an item and the discount offered as a percentage (on a scale of 0 to 100). The program must then calculate and display the new price. Assume a sales tax rate of 19%.*

## Solution

---

This exercise is just a combination of the previous two exercises!

### project\_10\_1\_8

```
const double VAT = 0.19;

static void Main(string[] args) {
    int discount;
    double discount_amount, price_after_discount, price_after_tax;
    double price_before_discount, sales_tax;

    Console.WriteLine("Enter the price of a product: ");
    price_before_discount = Double.Parse(Console.ReadLine());

    Console.WriteLine("Enter the discount offered (0 - 100): ");
    discount = Int32.Parse(Console.ReadLine());

    discount_amount = price_before_discount * discount / 100;
    price_after_discount = price_before_discount - discount_amount;

    sales_tax = price_after_discount * VAT;
    price_after_tax = price_after_discount + sales_tax;

    Console.WriteLine("The discounted after-tax price is: " + price_after_tax);
}
```

## 10.2 Review Exercises

Complete the following exercises.

1. Write a C# program that prompts the user to enter values for base and height, and then calculates and displays the area of a triangle. The required formula is

$$Area = \frac{1}{2} Base \times Height$$

2. Write a C# program that prompts the user to enter two angles of a triangle, and then calculates and displays the third angle.

Hint: The sum of the measures of the interior angles of any triangle is 180 degrees

3. Write a C# program that lets a student enter his or her grades from four tests, and then calculates and displays the average grade.
4. Write a C# program that prompts the user to enter a value for radius, and then calculates and displays the perimeter of a circle. The required formula is

$$\text{Perimeter} = 2\pi R$$

5. Write a C# program that prompts the user to enter a value for diameter in meters, and then calculates and displays the volume of a sphere. The required formula is

$$V = \frac{4}{3}\pi R^3$$

where  $R$  is the radius of the sphere.

6. Regarding the previous exercise, which of the following results output statements are correct? Which one would you choose to display the volume of the sphere on the user's screen, and why?
  - a. `Console.WriteLine(V);`
  - b. `Console.WriteLine(V cubic meters);`
  - c. `Console.WriteLine(V + cubic meters);`
  - d. `Console.WriteLine("The volume of the sphere is: " V);`
  - e. `Console.WriteLine("The volume of the sphere is: " + V);`
  - f. `Console.WriteLine("The volume of the sphere is: " + V + cubic meters);`
  - g. `Console.WriteLine("The volume of the sphere is: " + V + "cubic meters");`
7. Write a C# program that prompts the user to enter a value for diameter, and then calculates and displays the radius, the perimeter, and the area of a circle. For the same diameter, it must also display the volume of a sphere.
8. Write a C# program that prompts the user to enter the charge for a meal in a restaurant, and then calculates and displays the amount of a 10% tip, 7% sales tax, and the total of all three amounts.
9. A car starts from rest and moves with a constant acceleration along a

straight horizontal road for a given time in seconds. Write a C# program that prompts the user to enter the acceleration (in m/sec<sup>2</sup>) and the time traveled (in sec) and then calculates the distance traveled. The required formula is

$$S = u_o + \frac{1}{2}at^2$$

10. Write a C# program that prompts the user to enter a temperature in degrees Fahrenheit, and then converts it into its degrees Celsius<sup>[10]</sup> equivalent. The required formula is

$$\frac{C}{5} = \frac{F - 32}{9}$$

11. The Body Mass Index (BMI) is often used to determine whether a person is overweight or underweight for his or her height. The formula used to calculate the BMI is

$$BMI = \frac{weight \cdot 703}{height^2}$$

Write a C# program that prompts the user to enter his or her weight (in pounds) and height (in inches), and then calculates and displays the user's BMI.

12. Write a C# program that prompts the user to enter the subtotal and gratuity rate (on a scale of 0 to 100) and then calculates the tip and total. For example if the user enters 30 and 10, the C# program must display “Tip is \$3.00 and Total is \$33.00”.
13. An employee needs a program to enter the before-tax price of three products and then calculate the final after-tax price of each product, as well as their average value. Assume a value added tax (VAT) of 20%.
14. An employee needs a program to enter the after-tax price of a product, and then calculate its before-tax price. Assume a value added tax (VAT) of 20%.
15. Write a C# program that prompts the user to enter the initial price of an item and the discount offered as a percentage (on a scale of 0 to 100), and then calculates and displays the final price and the amount of money saved.

16. Write a C# program that prompts the user to enter the electric meter reading in kilowatt-hours (kWh) at the beginning and end of a month. The program must calculate and display the amount of kWh consumed and the amount of money that must be paid given a cost of each kWh of \$0.06 and a value added tax (VAT) of 20%.
17. Write a C# program that prompts the user to enter two numbers, which correspond to current month and current day of the month, and then calculates the number of days until the end of the year. Assume that each month has 30 days.

# Chapter 11

## Manipulating Numbers

---

### 11.1 Introduction

Just like every high-level programming language, C# provides many ready-to-use *subprograms* (called methods) that you can use whenever and wherever you wish.

 A “*subprogram*” is simply a group of statements packaged as a single unit. Each subprogram has a descriptive name and performs a specific task.

To better understand C#'s methods, let's take Heron's<sup>[11]</sup> iterative formula that calculates the square root of a positive number.

$$x_{n+1} = \frac{\left(x_n + \frac{y}{x_n}\right)}{2}$$

where

- ▶  $y$  is the number for which you want to find the square root
- ▶  $x_n$  is the  $n$ -th iteration value of the square root of  $y$

Hey, don't get disappointed! No one at the present time calculates the square root of a number this way. Fortunately, C# includes a method for that purpose! This method, which is actually a small subprogram, has been given the name `Math.Sqrt` and the only thing you have to do is call it by its name and it will do the job for you. Method `Math.Sqrt` probably uses Heron's iterative formula, or perhaps a formula of another ancient or modern mathematician. The truth is that you don't really care! What really matters is that `Math.Sqrt` gives you the right result! An example is shown here.

```
x = Double.Parse(Console.ReadLine());  
y = Math.Sqrt(x);  
Console.WriteLine(y);
```

Even though C# supports many mathematical subprograms (methods), this chapter covers only those absolutely necessary for this book's purpose. However, if you need even more information you can visit

<https://docs.microsoft.com/en-us/dotnet/api/system.math>

---

 Mathematical methods are used whenever you need to calculate a square root, the sine, the cosine, an absolute value, and so on.

## 11.2 Useful Mathematical Methods (Subprograms), and More

### Absolute value

**Math.Abs(number)**

This method returns the absolute value of *number*.

#### Example

##### project\_11\_2a

```
static void Main(string[] args) {
    int a, b;

    a = -5;
    b = Math.Abs(a);
    Console.WriteLine(Math.Abs(a));      //It displays: 5
    Console.WriteLine(b);                //It displays: 5
    Console.WriteLine(Math.Abs(-5.2));   //It displays: 5.2
    Console.WriteLine(Math.Abs(5.2));    //It displays: 5.2
}
```

### Pi

**Math.PI**

This contains the value of  $\pi$ .

 Note that **Math.PI** is a constant, not a method. This is why no parentheses are used.

#### Example

##### project\_11\_2b

```
static void Main(string[] args) {
    Console.WriteLine(Math.PI);        //It displays: 3.141592653589793
}
```

### Sine

**Math.Sin(number)**

This method returns the sine of *number*. The value of *number* must be expressed in radians. You can multiply by **Math.PI/180** to convert degrees to radians.

## Example

### project\_11\_2c

```
static void Main(string[] args) {
    double a, b;

    a = Math.Sin(3 * Math.PI / 2);      //Sine of  $3\pi/2$  radians
    b = Math.Sin(270 * Math.PI / 180); //Sine of 270 degrees
    Console.WriteLine(a + " " + b);    //It displays: -1 -1
}
```

## Cosine

Math.Cos(*number*)

This method returns the cosine of *number*. The value of *number* must be expressed in radians. You can multiply by Math.PI/180 to convert degrees to radians.

## Example

### project\_11\_2d

```
static void Main(string[] args) {
    double a, b;

    a = Math.Cos(2 * Math.PI);        //Cosine of  $2\pi$  radians
    b = Math.Cos(360 * Math.PI / 180); //Cosine of 360 degrees
    Console.WriteLine(a + " " + b);    //It displays: 1 1
}
```

## Tangent

Math.Tan(*number*)

This method returns the tangent of *number*. The value of *number* must be expressed in radians. You can multiply by Math.PI/180 to convert degrees to radians.

## Example

### project\_11\_2e

```
static void Main(string[] args) {
    double a;

    a = Math.Tan(10 * Math.PI / 180); //Tangent of 10 degrees
    Console.WriteLine(a);             //It displays: 0.17632698070846498
}
```

## String to integer

```
| Int32.Parse(value)
```

This method converts a string representation of an integer to its numeric equivalent.

### Example

#### project\_11\_2f

```
static void Main(string[] args) {
    string s1 = "5";
    string s2 = "3";
    int k;

    k = Int32.Parse(s1);
    Console.WriteLine(k); //It displays: 5
    Console.WriteLine(Int32.Parse(s2)); //It displays: 3
    Console.WriteLine(s1 + s2); //It displays: 53
    Console.WriteLine(Int32.Parse(s1) + Int32.Parse(s2)); //It displays: 8
}
```

### String to real

```
| Double.Parse(value)
```

This method converts a string representation of a real to its numeric equivalent.

### Example

#### project\_11\_2g

```
static void Main(string[] args) {
    string s1 = "6.5";
    string s2 = "3.4";
    double x;

    x = Double.Parse(s1);
    Console.WriteLine(x); //It displays: 6.5
    Console.WriteLine(Double.Parse(s2)); //It displays: 3.4
    Console.WriteLine(s1 + s2); //It displays: 6.53.4
    Console.WriteLine(Double.Parse(s1) + Double.Parse(s2)); //It displays: 9.9
}
```

### Integer value (Type casting)

```
| (int)number
```

This returns the integer value of *number*.

### Example

## project\_11\_2h

```
static void Main(string[] args) {
    double a = 5.4;

    Console.WriteLine((int)a);           //It displays: 5
    Console.WriteLine((int)34);          //It displays: 34
    Console.WriteLine((int)34.9);         //It displays: 34
    Console.WriteLine((int)-34.999);     //It displays: -34
}
```

 In computer science, type casting is a way of converting a variable of one data type into another. Note that `(int)` is not a method. It is just a way in C# to turn a real into an integer. Also note that if a real contains a fractional part, that part is lost during conversion.

## Real value (Type casting)

`(double)number`

This returns the *number* as real.

### Example

## project\_11\_2i

```
static void Main(string[] args) {
    int a = 5;

    Console.WriteLine(a / 2);           //It displays: 2
    Console.WriteLine((double)a / 2);   //It displays: 2.5
}
```

 In computer science, type casting is a way of converting a variable of one data type into another. Note that `(double)` is not a method. It is just a way in C# to turn an integer into a real.

 In C#, the result of the division of two integers is always an integer. Thus, in the expression `a / 2`, since variable `a` and number 2 are integers, the results is always an integer. As shown in the last `Console.WriteLine()` statement, if you wish a result of type real you need to add the `(double)` casting operator in front of at least one of the operands of the division.

Moreover, the statement

`Console.WriteLine((double)a / 2);`

is equivalent to

```
Console.WriteLine(a / (double)2);
```

and to

```
Console.WriteLine((double)a / (double)2);
```

and of course to

```
Console.WriteLine(a / 2.0);
```

They all output the value of 2.5.

## Power

```
Math.Pow(number, exp)
```

This method returns the result of *number* raised to the power of *exp*.

### Example

#### project\_11\_2j

```
static void Main(string[] args) {
    double a, b, c;

    a = 2;
    b = 3;
    Console.WriteLine(Math.Pow(a, b)); //It displays: 8
    c = Math.Pow(3, 2);
    Console.WriteLine(c);           //It displays: 9
}
```

Method `Math.Pow()` can be used to calculate the square root of a number as well. It is known from mathematics that  $\sqrt[z]{X} = X^{\frac{1}{z}}$ . So, you can write `y = Math.Pow(x, 1 / 2)` to calculate the square root of `x` or you can even write `y = Math.Pow(x, 1 / 3)` to calculate the cube root of `x`, and so on!

## Random

```
Next(minimum_value, maximum_value)
```

This method returns a pseudo-random integer between *minimum\_value* and *maximum\_value* - 1. Method `Next()` is defined in the `Random` class.

### Example

#### project\_11\_2k

```
static void Main(string[] args) {
    Random rnd = new Random();
```

```
Console.WriteLine(rnd.Next(0, 65536)); //It displays a random integer between 0 and 6
Console.WriteLine(rnd.Next(2, 11));    //It displays a random integer between 2 and 1
Console.WriteLine(rnd.Next(-20, 21)); //It displays a random integer between -20 and 21
}
```

✍ Random numbers are widely used in computer games. For example, an “enemy” may show up at a random time or move in random directions. Also, random numbers are used in simulation programs, in statistical programs, in computer security to encrypt data, and so on.

✍ The statement `Random rnd = new Random()` creates the object `rnd` of the class `Random`. You will learn more about classes and objects in [Section 8](#). Just be patient!

## Round

```
Math.Round(number)
```

This method returns the closest integer of *number*.

### Example

#### project\_11\_21

```
static void Main(string[] args) {
    double a = 5.9;

    Console.WriteLine(Math.Round(a));    //It displays: 6
    Console.WriteLine(Math.Round(5.4));  //It displays: 5
}
```

If you need the rounded value of *number* to a specified *precision*, you can use the following formula:

$$\text{Math.Round}(number * \text{Math.Pow}(10, precision)) / \text{Math.Pow}(10, precision)$$

### Example

#### project\_11\_2m

```
static void Main(string[] args) {
    double a, y;

    a = 5.312;
    y = Math.Round(a * Math.Pow(10, 2)) / Math.Pow(10, 2);
    Console.WriteLine(y);           //It displays: 5.31

    a = 5.315;
```

```

y = Math.Round(a * Math.Pow(10, 2)) / Math.Pow(10, 2);
Console.WriteLine(y); //It displays: 5.32

Console.WriteLine(Math.Round(2.3447 * Math.Pow(10, 3)) / Math.Pow(10, 3)); //It displays: 234.47
Console.WriteLine(Math.Round(2.3447 * 1000) / 1000); //It displays: 2.345
}

```

## Square root

`Math.Sqrt(number)`

This method returns the square root of *number*.

### Example

#### project\_11\_2n

```

static void Main(string[] args) {
    Console.WriteLine(Math.Sqrt(9)); //It displays: 3
    Console.WriteLine(Math.Sqrt(2)); //It displays: 1.4142135623730951
}

```

### Exercise 11.2-1 Calculating the Distance Between Two Points

Write a C# program that prompts the user to enter the coordinates (*x*, *y*) of two points and then calculates the straight line distance between them. The required formula is

$$d = \sqrt{(x_1 - x_2)^2 + (y_1 - y_2)^2}$$

### Solution

In this exercise, you need to use the method `Math.Sqrt()`, which returns the square root of a number.

To simplify things, the terms  $(x_1 - x_2)^2$  and  $(y_1 - y_2)^2$  are calculated individually and the results are assigned to two temporary variables. The C# program is shown here.

#### project\_11\_2\_1a

```

static void Main(string[] args) {
    double d, x1, x2, x_temp, y1, y2, y_temp;

    Console.Write("Enter coordinates for point A: ");
    x1 = Double.Parse(Console.ReadLine());
    y1 = Double.Parse(Console.ReadLine());

    Console.Write("Enter coordinates for point B: ");
    x2 = Double.Parse(Console.ReadLine());

```

```

y2 = Double.Parse(Console.ReadLine());

x_temp = Math.Pow(x1 - x2, 2);
y_temp = Math.Pow(y1 - y2, 2);

d = Math.Sqrt(x_temp + y_temp);
Console.WriteLine("Distance between points: " + d);
}

```

Now let's see another approach.

You should realize that it is actually possible to perform an operation within a method call. Doing that, the result of the operation is used as an argument for the method.

The C# program is shown here.

### project\_11\_2\_1b

```

static void Main(string[] args) {
    double d, x1, x2, y1, y2;

    Console.Write("Enter coordinates for point A: ");
    x1 = Double.Parse(Console.ReadLine());
    y1 = Double.Parse(Console.ReadLine());

    Console.Write("Enter coordinates for point B: ");
    x2 = Double.Parse(Console.ReadLine());
    y2 = Double.Parse(Console.ReadLine());

    d = Math.Sqrt(Math.Pow(x1 - x2, 2) + Math.Pow(y1 - y2, 2));

    Console.WriteLine("Distance between points: " + d);
}

```

 Note how the method `Math.Pow()` is nested within the method `Math.Sqrt()`. The result of the inner (nested) method (or methods) is used as an argument for the outer method. This is a writing style that most programmers prefer to follow because it helps to save a lot of code lines. Of course, if you nest too many methods, no one will be able to understand your code. A nesting of up to four levels is quite acceptable.

## **Exercise 11.2-2 How Far Did the Car Travel?**

A car starts from rest and moves with a constant acceleration along a straight horizontal road for a given distance. Write a C# program that

*prompts the user to enter the acceleration and the distance the car traveled and then calculates the time traveled. The required formula is*

$$S = u_0 + \frac{1}{2}at^2$$

*where*

- *S is the distance the car traveled, in meters (m)*
- *u<sub>0</sub> is the initial velocity (speed) of the car, in meters per second (m/sec)*
- *t is the time the car traveled, in seconds (sec)*
- *a is the acceleration, in meters per second<sup>2</sup> (m/sec<sup>2</sup>)*

### ***Solution***

---

Since the car starts from rest, the initial velocity (speed)  $u_0$  is zero. Thus, the formula becomes

$$S = \frac{1}{2}at^2$$

Now, if you solve for time, the final formula becomes

$$t = \sqrt{\frac{2S}{a}}$$

In C#, you can use the `Math.Sqrt()` method, which returns the square root of a number.

#### **project\_11\_2\_2**

```
static void Main(string[] args) {
    double S, a, t;

    Console.WriteLine("Enter acceleration: ");
    a = Double.Parse(Console.ReadLine());
    Console.WriteLine("Enter distance traveled: ");
    S = Double.Parse(Console.ReadLine());

    t = Math.Sqrt(2 * S / a);

    Console.WriteLine("Your car traveled for " + t + " seconds");
}
```

## 11.3 Review Questions: True/False

Choose **true** or **false** for each of the following statements.

1. C# methods are small subprograms that solve small problems.
2. Every programmer must use Heron's iterative formula to calculate the square root of a positive number.
3. The `Math.Abs()` method returns the absolute position of an item.
4. The statement `(int)3.59` returns a result of 3.6.
5. The `Math.PI` constant is equal to 3.14.
6. The statement `Math.Pow(2, 3)` returns a result of 9.
7. The `Next()` method can also return negative random numbers.
8. There is a 50% possibility that the statement `y = rnd.Next(0, 2)` will assign a value of 1 to variable `y`.
9. The statement `Math.Round(3.59)` returns a result of 4.
10. To calculate the sine of 90 degrees, you have to write `y = Math.Sin(Math.PI / 2)`
11. The statement `y = Math.Sqrt(-2)` is valid.
12. The following code fragment satisfies the property of definiteness.

```
double a, b, x;  
a = Double.Parse(Console.ReadLine());  
b = Double.Parse(Console.ReadLine());  
x = a * Math.Sqrt(b);  
Console.WriteLine(x);
```

## 11.4 Review Questions: Multiple Choice

Select the correct answer for each of the following statements.

1. Which of the following calculates the result of the variable `a` raised to the power of 2?
  - a. `y = a * a;`
  - b. `y = Math.Pow(a, 2);`
  - c. `y = a * a / a * a;`
  - d. all of the above
2. What is the value of the variable `y` when the statement `y = Math.Abs(+5.2)` is executed?

- a. -5.2
  - b. -5
  - c. 0.2
  - d. 5.2
  - e. none of the above
3. Which of the following calculates the sine of 180 degrees?
- a. `Math.Sin(180)`
  - b. `Math.Sin(Math.PI)`
  - c. all of the above
  - d. none of the above
4. What is the value of the variable `y` when the statement `y = (int)(5.0 / 2.0)` is executed?
- a. 2.5
  - b. 3
  - c. 2
  - d. 0.5
5. What is the value of the variable `y` when the statement `y = Math.Pow(Math.Sqrt(4), 2)` is executed?
- a. 4
  - b. 2
  - c. 8
  - d. 16
6. What is the value of the variable `y` when the statement `y = Math.Round(5.2) / 2.0` is executed?
- a. 2
  - b. 2.5
  - c. 2.6
  - d. none of the above

## 11.5 Review Exercises

Complete the following exercises.

1. Create a trace table to determine the values of the variables in each step of the C# program for two different executions.

The input values for the two executions are: (i) 9, and (ii) 4.

```
static void Main(string[] args) {
    double a, b, c;

    a = Double.Parse(Console.ReadLine());
    a += 6 / Math.Sqrt(a) * 2 + 20.4;
    b = Math.Round(a) % 4;
    c = b % 3;
    Console.WriteLine(a + ", " + b + ", " + c);
}
```

2. Create a trace table to determine the values of the variables in each step of the C# program for two different executions.

The input values for the two executions are: (i) -2, and (ii) -3

```
static void Main(string[] args) {
    int a, b, c;

    a = Int32.Parse(Console.ReadLine());

    b = Math.Abs(a) % 4 + (int)Math.Pow(a, 4);
    c = b % 5;
    Console.WriteLine(b + ", " + c);
}
```

3. Write a C# that prompts the user to enter an angle  $\theta$  in radians and then calculates and displays the angle in degrees. It is given that  $2\pi = 360^\circ$ .
4. Write a C# program that prompts the user to enter the two right angle sides A and B of a right-angled triangle and then calculates its hypotenuse. It is known from the Pythagorean<sup>[12]</sup> theorem that

$$\text{hypotenuse} = \sqrt{A^2 + B^2}$$

5. Write a C# program that prompts the user to enter the angle  $\theta$  (in degrees) of a right-angled triangle and the length of its adjacent side, and then calculates the length of the opposite side. It is known that

$$\tan(\theta) = \frac{\text{Opposite}}{\text{Adjacent}}$$

# Chapter 12

## Complex Mathematical Expressions

---

### 12.1 Writing Complex Mathematical Expressions

In [paragraph 7.2](#) you learned all about arithmetic operators but little about how to use them and how to write your own complex mathematical expressions. In this chapter, you are going to learn how easy is to convert mathematical expressions to C# statements.

 *Arithmetic operators follow the same precedence rules as in mathematics, which means that multiplication and division are performed first, and addition and subtraction are performed next. Moreover, when multiplication and division co-exist in the same expression, and since both are of the same precedence, these operations are performed left to right.*

#### **Exercise 12.1-1 Representing Mathematical Expressions in C#**

---

Which of the following C# statements correctly represent the following mathematical expression?

$$x = \frac{1}{10 + z} 27$$

- i.  $x = 1 * 27 / 10 + z;$
- ii.  $x = 1 \cdot 27 / (10 + z);$
- iii.  $x = 27 / 10 + z;$
- iv.  $x = 27 / (10 + z);$
- v.  $x = (1 / 10 + z) * 27;$
- vi.  $x = 1 / ((10 + z) * 27);$
- vii.  $x = 1 / (10 + z) * 27;$
- viii.  $x = 1 / (10 + z) / 27;$

#### **Solution**

---

- i. **Wrong.** Since the multiplication and the division are performed before the addition, this is equivalent to  $x = \frac{1 \cdot 27}{10} + z.$
- ii. **Wrong.** An asterisk must have been used for multiplication.

- iii. **Wrong.** Since the division is performed before the addition, this is equivalent to  $x = \frac{27}{10} + z$ .
- iv. **Correct.** This is equivalent to  $x = \frac{27}{10+z}$ .
- v. **Wrong.** Inside parentheses, the division is performed before the addition. This is equivalent to  $x = \left(\frac{1}{10} + z\right) 27$ .
- vi. **Wrong.** Parentheses are executed first and this is equivalent to  $x = \frac{1}{(10+z)27}$ .
- vii. **Correct.** Division is performed before multiplication (left to right). The term  $\frac{1}{10+z}$  is calculated first and then, the result is multiplied by 27.
- viii. **Wrong.** This is equivalent to  $x = \frac{1}{\frac{10+z}{27}}$ .

### ***Exercise 12.1-2 Writing a Mathematical Expression in C#***

---

*Write a C# program that calculates the mathematical expression*

$$y = 10x - \frac{10-z}{4}$$

### ***Solution***

---

First, you must distinguish between the data input and the output result. Obviously, the output result is assigned to  $y$  and the user must enter values for  $x$  and  $z$ . The solution for this exercise is shown here.

#### project\_12\_1\_2

```
static void Main(string[] args) {
    double x, y, z;

    Console.WriteLine("Enter value for x: ");
    x = Double.Parse(Console.ReadLine());
    Console.WriteLine("Enter value for z: ");
    z = Double.Parse(Console.ReadLine());
```

```

    y = 10 * x - (10 - z) / 4;

    Console.WriteLine("The result is: " + y);
}

```

### ***Exercise 12.1-3 Writing a Complex Mathematical Expression in C#***

---

*Write a C# program that calculates the mathematical expression*

$$y = \frac{5 \frac{3x^2 + 5x + 2}{7w - \frac{1}{z}} - z}{4 \frac{3+x}{7}}$$

### ***Solution***

---

Oops! Now the expression is more complex! In fact, it is much more complex! So, let's take a look at a quite different approach. The main idea is to break the complex expression into smaller, simpler expressions and assign each sub-result to temporary variables. In the end, you can build the original expression out of all these temporary variables! This approach is presented next.

#### **project\_12\_1\_3a**

```

static void Main(string[] args) {
    double denominator, nominator, temp1, temp2, temp3, w, x, y, z;

    Console.Write("Enter value for x: ");
    x = Double.Parse(Console.ReadLine());
    Console.Write("Enter value for w: ");
    w = Double.Parse(Console.ReadLine());
    Console.Write("Enter value for z: ");
    z = Double.Parse(Console.ReadLine());

    temp1 = 3 * x * x + 5 * x + 2;
    temp2 = 7 * w - 1 / z;
    temp3 = (3 + x) / 7;
    nominator = 5 * temp1 / temp2 - z;
    denominator = 4 * temp3;

    y = nominator / denominator;

    Console.WriteLine("The result is: " + y);
}

```

You may say, “Okay, but I wasted so many variables and as everybody knows, each variable is a portion of main memory. How can I write the original expression in one single line and waste less memory?”

This job may be a piece of cake for an advanced programmer, but what about you? What about a novice programmer?

The next method will help you write even the most complex mathematical expressions without any syntax or logic errors! The rule is very simple. “After breaking the complex expression into smaller, simpler expressions and assigning each sub-result to temporary variables, start backwards and replace each variable with its assigned expression. Be careful though! When you replace a variable with an expression, you must always enclose the expression in parentheses!”

Confused? Don't be! It's easier in action. Let's try to rewrite the previous C# program. Starting backwards, replace variables nominator and denominator with their assigned expressions. The result is

$$y = (5 * \text{temp1} / \text{temp2} - z) / (4 * \text{temp3})$$


 Note the extra parentheses added.

Now you must replace variables temp1, temp2, and temp3 with their assigned expressions, and the one-line expression is complete!

$$y = (5 * (3 * x^{**} 2 + 5 * x + 2) / (7 * w - 1 / z) - z) / (4 * ((3 + x) / 7))$$


It may look scary at the end but it wasn't that difficult, was it?

The C# program can now be rewritten

### project\_12\_1\_3b

```
static void Main(string[] args) {
    double w, x, y, z;

    Console.Write("Enter value for x: ");
    x = Double.Parse(Console.ReadLine());
```

```

Console.WriteLine("Enter value for w: ");
w = Double.Parse(Console.ReadLine());
Console.WriteLine("Enter value for z: ");
z = Double.Parse(Console.ReadLine());

y = (5 * (3 * x * x + 5 * x + 2) / (7 * w - 1 / z) - z) / (4 * ((3 + x) / 7));

Console.WriteLine("The result is: " + y);
}

```

## 12.2 Review Exercises

Complete the following exercises.

- Match each element from the first table with one **or more** elements from the second table.

Expression
i. $5 / \text{Math.Pow}(x, 2) * y + \text{Math.Pow}(x, 3)$
ii. $5 / (\text{Math.Pow}(x, 3) * y) + \text{Math.Pow}(x, 2)$

Expression
a. $5 * y / \text{Math.Pow}(x, 2) + \text{Math.Pow}(x, 3)$
b. $5 * y / x * x + \text{Math.Pow}(x, 3)$
c. $5 / (x * x * x * y) + x * x$
d. $5 / (x * x * x) * y + x * x$
e. $5 * y / (x * x) + x * x * x$
f. $1 / (x * x * x * y) * 5 + x * x$
g. $y / (x * x) * 5 + \text{Math.Pow}(x, 3)$
h. $1 / (x * x) * 5 * y + x / 1 * x * x$

- Write the following mathematical expressions in C# using one line of code for each.
  -

$$y = \frac{(x+3)^{5w}}{7(x-4)}$$

ii.

$$y = \sqrt[5]{\left(3x^2 - \frac{1}{4}x^3\right)}$$

iii.

$$y = \frac{\sqrt{x^4 - 2x^3 - 7x^2 + x}}{\sqrt[3]{4\left(7x^4 - \frac{3}{4}x^3\right)(7x^2 + x)}}$$

iv.

$$y = \frac{x}{x-3(x-1)} + \left(x\sqrt[5]{x-1}\right) \frac{1}{(x^3-2)(x-1)^3}$$

v.

$$y = \left(\sin\left(\frac{\pi}{3}\right) - \cos\left(\frac{\pi}{2}w\right)\right)^2$$

vi.

$$y = \frac{\left(\sin\left(\frac{\pi}{2}x\right) + \cos\left(\frac{3\pi}{2}w\right)\right)^3}{\left(\tan\left(\frac{2\pi}{3}w\right) - \sin\left(\frac{\pi}{2}x\right)\right)^{\frac{1}{2}}} + 6$$

3. Write a C# program that prompts the user to enter a value for  $x$  and then calculates and displays the result of the following mathematical expression.

$$y = \sqrt{x}(x^3 + x^2)$$

4. Write a C# program that prompts the user to enter a value for  $x$  and then calculates and displays the result of the following mathematical expression.

$$y = \frac{7x}{2x + 4(x^2 + 4)}$$

Suggestion: Try to write the expression in one line of code.

5. Write a C# program that prompts the user to enter a value for  $x$  and  $w$  and then calculates and displays the result of the following

mathematical expression.

$$y = \frac{x^{x+1}}{\left(\tan\left(\frac{2w}{3} + 5\right) - \tan\left(\frac{x}{2} + 1\right)\right)^3}$$

Suggestion: Try to write the expression in one line of code

6. Write a C# program that prompts the user to enter a value for  $x$  and  $w$  and then calculates and displays the result of the following mathematical expression.

$$y = \frac{3+w}{6x-7(x+4)} + (x^{\sqrt[5]{3w+1}}) \frac{5x+4}{(x^3+3)(x-1)^7}$$

Suggestion: Try to write the expression in one line of code.

7. Write a C# program that prompts the user to enter a value for  $x$  and  $w$  and then calculates and displays the result of the following mathematical expression.

$$y = \frac{x^x}{\left(\sin\left(\frac{2w}{3} + 5\right) - x\right)^2} + \frac{(\sin(3x) + w)^{x+1}}{(\sqrt{7w})^{\frac{3}{2}}}$$

Suggestion: Try to write the expression in one line of code

8. Write a C# program that prompts the user to enter the lengths of all three sides A, B, and C, of a triangle and then calculates and displays the area of the triangle. You can use Heron's formula, which has been known for nearly 2,000 years!

$$\text{Area} = \sqrt{S(S-A)(S-B)(S-C)}$$

where  $S$  is the semi-perimeter  $S = \frac{A+B+C}{2}$

# Chapter 13

## Exercises With a Quotient and a Remainder

---

### 13.1 Introduction

What types of problems might require the use of the quotient and the remainder of an integer division? There is no simple answer to that question! However, quotients and remainders can be used to:

- ▶ split a number into individual digits
- ▶ examine if a number is odd or even
- ▶ convert an elapsed time (in seconds) to hours, minutes, and seconds
- ▶ convert an amount of money (in USD) to a number of \$100 notes, \$50 notes, \$20 notes, and such
- ▶ calculate the greatest common divisor
- ▶ determine if a number is a palindrome
- ▶ count the number of digits within a number
- ▶ determine how many times a specific digit occurs within a number

Of course, these are some of the uses and certainly you can find so many others. Next you will see some exercises that make use of the quotient and the remainder of integer division.

#### ***Exercise 13.1-1 Calculating the Quotient and Remainder of Integer Division***

---

*Write a C# program that prompts the user to enter two integers and then calculates the quotient and the remainder of the integer division.*

#### ***Solution***

---

The modulus ( % ) operator performs an integer division and returns the integer remainder. Since C# doesn't actually incorporate an arithmetic operator that calculates the integer quotient, you can use the (int) casting operator to achieve the same result. The solution is presented here.

##### **project\_13\_1\_1**

```
static void Main(string[] args) {  
    int number1, number2, q, r;
```

```

Console.WriteLine("Enter first number: ");
number1 = Int32.Parse(Console.ReadLine());

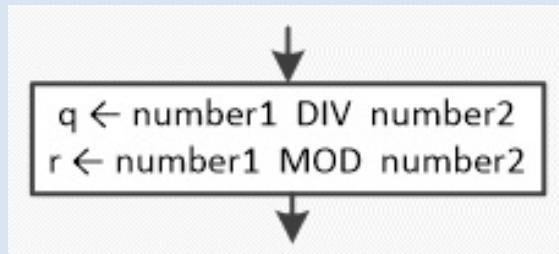
Console.WriteLine("Enter second number: ");
number2 = Int32.Parse(Console.ReadLine());

q = (int)(number1 / number2);
r = number1 % number2;

Console.WriteLine("Integer Quotient: " + q + "\nInteger Remainder: " + r);
}

```

 In flowcharts, in order to calculate the quotient and the remainder of an integer division, you can use the popular DIV and MOD operators. An example is shown here.



 In C#, the result of the division of two integers is always an integer. Thus, in the statement `q = (int)(number1 / number2)`, since variables `number1` and `number2` are integers, the `(int)` casting operator is redundant. However, it is a good practice to keep it there just for improved readability.

### **Exercise 13.1-2 Finding the Sum of Digits**

Write a C# program that prompts the user to enter a four-digit integer and then calculates the sum of its digits.

#### **Solution**

What you should keep in mind here is that statements like this one

```
number = Int32.Parse(Console.ReadLine());
```

assign the given four-digit integer to one single variable, `number`, and not to four individual variables. So, after the user enters the four-digit integer, the program must split the integer into its four digits and assign each digit to a separate variable. Then it can calculate the sum of these four variables and get the required result. There are two approaches available.

#### **First Approach**

Let's try to understand the first approach using an arithmetic example. Take the number 6753, for example.

<b>First digit = 6</b>	The first digit can be isolated if you divide the given number by 1000 using the ( / ) operator and the (int) type casting operator to get the integer quotient $\text{digit1} = (\text{int})(6753 / 1000)$
<b>Remaining digits = 753</b>	The remaining digits can be isolated if you divide the given number by 1000 again, this time using the ( % ) operator to get the integer remainder $r = 6753 \% 1000$
<b>Second digit = 7</b>	The second digit can be isolated if you divide the remaining digits by 100 using the ( / ) operator and the (int) type casting operator to get the integer quotient $\text{digit2} = (\text{int})(753 / 100)$
<b>Remaining digits = 53</b>	The remaining digits are now $r = 753 \% 100$
<b>Third digit = 5</b>	The third digit can be isolated if you divide the remaining digits by 10 using the ( / ) operator and the (int) type casting operator to get the integer quotient $\text{digit3} = (\text{int})(53 / 10)$
<b>Fourth digit = 3</b>	The last remaining digit, which happens to be the fourth digit, is $\text{digit4} = 53 \% 10$

The C# program that solves this algorithm is shown here.

### project\_13\_1\_2a

```
static void Main(string[] args) {
    int digit1, digit2, digit3, digit4, number, r, total;

    Console.WriteLine("Enter a four-digit integer: ");
    number = Int32.Parse(Console.ReadLine());

    digit1 = (int)(number / 1000);
    r = number % 1000;

    digit2 = (int)(r / 100);
    r = r % 100;

    digit3 = (int)(r / 10);
    r = r % 10;

    digit4 = r;
}
```

```

        digit3 = (int)(r / 10);
        digit4 = r % 10;

        total = digit1 + digit2 + digit3 + digit4;
        Console.WriteLine(total);
    }
}

```

The trace table for the program that you have just seen is shown here.

Step	Statement	Notes	number	digit1	digit2	digit3	digit4	r
1	.Write("Enter...")	It displays: Enter a four-digit integer:						
2	number = Int32.Parse(...)	User enters 6753	6753	?	?	?	?	?
3	digit1 = (int)(number / 1000)		6753	6	?	?	?	?
4	r = number % 1000		6753	6	?	?	?	753
5	digit2 = (int)(r / 100)		6753	6	7	?	?	75
6	r = r % 100		6753	6	7	?	?	53
7	digit3 = (int)(r / 10)		6753	6	7	5	?	5
8	digit4 = r % 10		6753	6	7	5	3	5
9	total = digit1 + digit2 + digit3 + digit4		6753	6	7	5	3	5
10	.WriteLine(total)	It displays: 21						

To further help you, there is also a general purpose C# program that can be used to split any given integer. Since the length of your program depends on the number of digits,  $N$ , all you have to do is write  $N-1$  pairs of statements.

```

Console.WriteLine("Enter an N-digit integer: ");
number = Int32.Parse(Console.ReadLine());

digit1 = (int)(number / 10N-1);
r = number % 10N-1;

```

```

digit2 = (int)(r / 10N-2);
r = r % 10N-2;
.

.

.

digit(N-2) = (int)(r / 100);
r = r % 100;

digit(N-1) = (int)(r / 10);
digitN = r % 10;

```

For example, if you want to split a six-digit integer, you need to write five pairs of statements as shown in the program that follows.

### project\_13\_1\_2b

```

static void Main(string[] args) {
    int digit1, digit2, digit3, digit4, digit5, digit6, number, r;

    Console.WriteLine("Enter a six-digit integer: ");
    number = Int32.Parse(Console.ReadLine());

    digit1 = (int)(number / 100000);
    r = number % 100000;

    digit2 = (int)(r / 10000);
    r = r % 10000;

    digit3 = (int)(r / 1000);
    r = r % 1000;

    digit4 = (int)(r / 100);
    r = r % 100;

    digit5 = (int)(r / 10);
    digit6 = r % 10;

    Console.WriteLine(digit1 + " " + digit2 + " " + digit3 + " ");
    Console.WriteLine(digit4 + " " + digit5 + " " + digit6);
}

```

## Second Approach

Once more, let's try to understand the second approach using an arithmetic example. Take the same number, 6753, for example.

**Fourth**

The fourth digit can be isolated if you divide the given number

<b>digit = 3</b>	by 10 using the ( % ) operator to get the integer remainder digit4 = 6753 % 10
<b>Remaining digits = 675</b>	The remaining digits can be isolated if you divide the given number by 10 again using the ( / ) operator and the (int) type casting operator to get the integer quotient r = (int)(6753 / 10)
<b>Third digit = 5</b>	The third digit can be isolated if you divide the remaining digits by 10 using the ( % ) operator to get the integer remainder digit3 = 675 % 10
<b>Remaining digits = 67</b>	The remaining digits are now r = (int)(675 / 10)
<b>Second digit = 7</b>	The second digit can be isolated if you divide the remaining digits by 10 using the ( % ) operator to get the integer remainder digit2 = 67 % 10
<b>First digit = 6</b>	The last remaining digit, which happens to be the first digit, is digit1 = (int)(67 / 10)

The C# program for this algorithm is shown here.

### project\_13\_1\_2c

```
static void Main(string[] args) {
    int digit1, digit2, digit3, digit4, number, r, total;

    Console.WriteLine("Enter a four-digit integer: ");
    number = Int32.Parse(Console.ReadLine());

    digit4 = number % 10;
    r = (int)(number / 10);

    digit3 = r % 10;
    r = (int)(r / 10);

    digit2 = r % 10;
    digit1 = (int)(r / 10);

    total = digit1 + digit2 + digit3 + digit4;
    Console.WriteLine(total);
```

```
| }
```

To further help you, there is also a general purpose C# program that can be used to split any given integer. This program uses the second approach. Once again, since the length of your program depends on the number of the digits, N, all you have to do is write N-1 pairs of statements.

```
Console.WriteLine("Enter a N-digit integer: ");
number = Int32.Parse(Console.ReadLine());

digit(N) = number % 10;
r = (int)(number / 10);

digit(N-1) = r % 10;
r = (int)(r / 10);
.

.

.

digit3 = r % 10;
r = (int)(r / 10);

digit2 = r % 10;
digit1 = (int)(r / 10);
```

For example, if you want to split a five-digit integer, you must use four pairs of statements as shown in the program that follows.

### project\_13\_1\_2d

```
static void Main(string[] args) {
    int digit1, digit2, digit3, digit4, digit5, number, r;

    Console.WriteLine("Enter a five-digit integer: ");
    number = Int32.Parse(Console.ReadLine());

    digit5 = number % 10;
    r = (int)(number / 10);

    digit4 = r % 10;
    r = (int)(r / 10);

    digit3 = r % 10;
    r = (int)(r / 10);

    digit2 = r % 10;
    digit1 = (int)(r / 10);
```

```
    Console.WriteLine(digit1 + " " + digit2 + " " + digit3 + " " + digit4 + " " + digit5)
}
```

### ***Exercise 13.1-3 Displaying an Elapsed Time***

---

*Write a C# program that prompts the user to enter an integer that represents an elapsed time in seconds and then displays it in the format “DD days HH hours MM minutes and SS seconds”. For example if the user enters the number 700005, the message “8 days 2 hours 26 minutes and 45 seconds” must be displayed.*

#### ***Solution***

---

Let's try to analyze the number 700005 using the first approach that you learned in the previous exercise.

As you may already know, there are 60 seconds in a minute, 3600 seconds in an hour ( $60 \times 60$ ), and 86400 seconds in a day ( $3600 \times 24$ ).

<b>Days = 8</b>	The number of days can be isolated if you divide the given integer by 86400 using the ( / ) operator and the (int) type casting operator to get the integer quotient $\text{days} = (\text{int})(700005 / 86400)$
<b>Remaining seconds = 8805</b>	The remaining seconds can be isolated if you divide the given integer by 86400 again, this time using the ( % ) operator to get the integer remainder $r = 700005 \% 86400$
<b>Hours = 2</b>	The number of hours can be isolated if you divide the remaining seconds by 3600 using the ( / ) operator and the (int) type casting operator to get the integer quotient $\text{hours} = (\text{int})(8805 / 3600)$
<b>Remaining seconds = 1605</b>	The remaining seconds are now $r = 8805 \% 3600$
<b>Minutes = 26</b>	The number of minutes can be isolated if you divide the remaining seconds by 60 using the ( / ) operator and the (int) type casting operator to get the integer quotient $\text{minutes} = (\text{int})(1605 / 60)$
<b>Seconds =</b>	The last remainder, which happens to be the number of

45

seconds left, is  
seconds = 1605 % 60

The C# program for this algorithm is as follows.

### project\_13\_1\_3a

```
static void Main(string[] args) {
    int days, hours, minutes, number, r, seconds;

    Console.WriteLine("Enter a period of time in seconds: ");
    number = Int32.Parse(Console.ReadLine());

    days = (int)(number / 86400);      // 60 * 60 * 24 = 86400
    r = number % 86400;

    hours = (int)(r / 3600);          // 60 * 60 = 3600
    r = r % 3600;

    minutes = (int)(r / 60);
    seconds = r % 60;

    Console.WriteLine(days + " days " + hours + " hours ");
    Console.WriteLine(minutes + " minutes and " + seconds + " seconds");
}
```

You can also solve this exercise using the second approach from the previous exercises. All you have to do is first divide by 60, then divide again by 60, and finally divide by 24, as shown here.

### project\_13\_1\_3b

```
static void Main(string[] args) {
    int days, hours, minutes, number, r, seconds;

    Console.WriteLine("Enter a period of time in seconds: ");
    number = Int32.Parse(Console.ReadLine());

    seconds = number % 60;
    r = (int)(number / 60);

    minutes = r % 60;
    r = (int)(r / 60);

    hours = r % 24;
    days = (int)(r / 24);
```

```
    Console.WriteLine(days + " days " + hours + " hours ");
    Console.WriteLine(minutes + " minutes and " + seconds + " seconds");
}
```

### ***Exercise 13.1-4 Reversing a Number***

*Write a C# program that prompts the user to enter a three-digit integer and then reverses it. For example, if the user enters the number 375, the number 573 must be displayed.*

#### **Solution**

To isolate the three digits of the given number, you can use either first or second approach. Afterward, the only difficulty in this exercise is to build the reversed number. Take the number 375, for example. The three digits, after isolation, are

```
digit1 = 3
digit2 = 7
digit3 = 5
```

You can build the reversed number by simply calculating the sum of the products:

$$\text{digit3} \times 100 + \text{digit2} \times 10 + \text{digit1} \times 1$$

For a change, you can split the given number using the second approach. The C# program will look like this.

#### **project\_13\_1\_4**

```
static void Main(string[] args) {
    int digit1, digit2, digit3, number, r, reversed_number;

    Console.WriteLine("Enter a three-digit integer: ");
    number = Int32.Parse(Console.ReadLine());

    digit3 = number % 10;           //This is the rightmost digit
    r = (int)(number / 10);

    digit2 = r % 10;               //This is the digit in the middle
    digit1 = (int)(r / 10);        //This is the leftmost digit

    reversed_number = digit3 * 100 + digit2 * 10 + digit1;
    Console.WriteLine(reversed_number);
}
```

## 13.2 Review Exercises

Complete the following exercises.

1. Write a C# program that prompts the user to enter any integer and then multiplies its last digit by 8 and displays the result.

Hint: It is not necessary to know the exact number of digits. You can isolate the last digit of any integer using a modulus 10 operation.

2. Write a C# program that prompts the user to enter a five-digit integer and then reverses it. For example, if the user enters the number 32675, the number 57623 must be displayed.
3. Write a C# program that prompts the user to enter an integer and then it displays 1 when the number is odd; otherwise, it displays 0. Try not to use any decision control structures since you haven't learned anything about them yet!
4. Write a C# program that prompts the user to enter an integer and then it displays 1 when the number is even; otherwise, it displays 0. Try not to use any decision control structures since you haven't learned anything about them yet!
5. Write a C# program that prompts the user to enter an integer representing an elapsed time in seconds and then displays it in the format “WW week(s) DD day(s) HH hour(s) MM minute(s) and SS second(s)”. For example, if the user enters the number 2000000, the message “3 week(s) 2 day(s) 3 hour(s) 33 minute(s) and 20 second(s)” must be displayed.
6. Inside an ATM bank machine there are notes of \$20, \$10, \$5, and \$1. Write a C# program that prompts the user to enter the amount of money he or she wants to withdraw (using an integer value) and then displays the least number of notes the ATM must give. For example, if the user enters an amount of \$76, the program must display the message “3 note(s) of \$20, 1 note(s) of \$10, 1 note(s) of \$5, and 1 note(s) of \$1”.
7. A robot arrives on the moon in order to perform some experiments. Each of the robot's steps is 25 inches long. Write a C# program that prompts the user to enter the number of steps the robot made and then calculates and displays the distance traveled in miles, feet, yards, and inches. For example, if the distance traveled is 100000 inches, the program must display the message “1 mile(s), 1017 yard(s), 2 foot/feet,

and 4 inch(es)".

It is given that

- 1 mile = 63360 inches
- 1 yard = 36 inches
- 1 foot = 12 inches

# Chapter 14

## Manipulating Strings

---

### 14.1 Introduction

Generally speaking, a string is anything that you can type using the keyboard, including letters, symbols (such as &, \*, and @), and digits. In C#, a string is always enclosed in double quotes.

Each statement in the next example outputs a string.

```
a = "Everything enclosed in double quotes is a string, even the numbers: ";
b = "3, 54, 731";
Console.WriteLine(a + b);
Console.WriteLine("You can even mix letters, symbols and digits like this: ");
Console.WriteLine("The result of 3 + 4 equals to 4");
```

Many times programs deal with data that comes in the form of strings (text). Strings are everywhere—from word processors, to web browsers, to text messaging programs. Many exercises in this book actually make extensive use of strings. Even though C# supports many useful methods for manipulating strings, this chapter covers only those methods that are necessary for this book's purpose. However, if you need even more information you can visit

<https://docs.microsoft.com/en-us/dotnet/api/system.string>

 *C# string methods (subprograms) can be used when there is a need, for example, to isolate a number of characters from a string, to remove spaces that might exist at the beginning of it, or to convert all of its characters to uppercase.*

 *Methods are nothing more than small subprograms that solve small problems.*

### 14.2 The Position of a Character in a String

Let's use the text «Hello World» in the following example. The string consists of 11 characters (including the space character between the two words). The position of each character is shown here.

<i>0</i>	<i>1</i>	<i>2</i>	<i>3</i>	<i>4</i>	<i>5</i>	<i>6</i>	<i>7</i>	<i>8</i>	<i>9</i>	<i>10</i>
H	e	l	l	o		W	o	r	l	d

C# numerates characters assuming that the first one is at position 0, the second one is at position 1, and so on.

 A space is a character just like any other character. Just because nobody can see it, it doesn't mean it doesn't exist!

## 14.3 Useful String Methods (Subprograms), and More

### Trimming

*Trimming* is the process of removing whitespace characters from the beginning or the end of a string.

Some of the whitespace characters that are removed with the trimming process are:

- ▶ an ordinary space
- ▶ a tab
- ▶ a new line (line feed)
- ▶ a carriage return

For example, you can trim any spaces that the user mistakenly entered at the end or at the beginning of a string.

The method that you can use to trim a string is

`subject.Trim()`

This method returns a copy of *subject* in which any whitespace characters are removed from both the beginning and the end of the *subject* string.

### Example

#### project\_14\_3a

```
static void Main(string[] args) {
    string a, b;

    a = "    Hello      ";
    b = a.Trim();

    Console.WriteLine(b + " Poseidon!"); //It displays: Hello Poseidon!
    Console.WriteLine(a + " Poseidon!"); //It displays:    Hello      Poseidon!
```

}

 Note that the content of variable *a* is not altered. If you do need to alter its content, you can use the statement `a = a.Trim();`

## String replacement

`subject.Replace(search, replace)`

This method searches in *subject* and returns a copy of it in which all occurrences of the *search* string are replaced with the *replace* string.

### Example

#### project\_14\_3b

```
static void Main(string[] args) {
    string a, b;

    a = "I am newbie in C++. C++ rocks!";
    b = a.Replace("C++", "C#");

    Console.WriteLine(b);      //It displays: I am newbie in C#. C# rocks
    Console.WriteLine(a);      //It displays: I am newbie in C++. C++ rocks
}
```

 Note that the content of variable *a* is not altered. If you do need to alter its content, you can use the statement `a = a.Replace("C++", "C#");`

## Counting the number of characters

`subject.Length`

This contains the length of *subject* or, in other words, the number of characters *subject* consists of (including space characters, symbols, numbers, and so on).

### Example

#### project\_14\_3c

```
static void Main(string[] args) {
    string a;
    int k;

    a = "Hello Olympians!";

    Console.WriteLine(a.Length);          //It displays: 16
    k = a.Length;
```

```
    Console.WriteLine(k);                                //It displays: 16
    Console.WriteLine("I am newbie in C#".Length);      //It displays: 17
}
```

 Note that Length is an attribute, not a method. Therefore, you must not put parentheses at the end. You will learn more about attributes in [Section 8](#).

## Finding string position

```
subject.IndexOf(search)
```

This method finds the numerical position of the first occurrence of *search* in *subject*.

### Example

#### project\_14\_3d

```
static void Main(string[] args) {
    int i;
    string a;

    a = "I am newbie in C#. C# rocks!";
    i = a.IndexOf("newbie");

    Console.WriteLine(i);                            //It displays: 5
    Console.WriteLine(a.IndexOf("C#"));             //It displays: 15
    Console.WriteLine(a.IndexOf("C++"));            //It displays: -1
}
```

 The first character is at position 0.

## Converting to lowercase

```
subject.ToLower()
```

This method returns a copy of *subject* in which all the letters of the string *subject* are converted to lowercase.

### Example

#### project\_14\_3e

```
static void Main(string[] args) {
    string a, b;

    a = "My NaMe is JohN";
    b = a.ToLower();
```

```
    Console.WriteLine(b);      //It displays: my name is john
    Console.WriteLine(a);      //It displays: My NaMe is John
}
```

 Note that the content of variable *a* is not altered. If you do need to alter its content, you can use the statement `a = a.ToLower();`

## Converting to uppercase

```
subject.ToUpper()
```

This method returns a copy of *subject* in which all the letters of the string *subject* are converted to uppercase.

### Example

#### project\_14\_3f

```
static void Main(string[] args) {
    string a, b;

    a = "My NaMe is JohN";
    b = a.ToUpper();

    Console.WriteLine(b);      //It displays: MY NAME IS JOHN
    Console.WriteLine(a);      //It displays: My NaMe is John
}
```

 Note that the content of variable *a* is not altered. If you do need to alter its content, you can use the statement `a = a.ToUpper();`

## Retrieving an individual character from a string

```
subject[ index ]
```

This notation returns the character located at *subject*'s specified *index*. As already mentioned, the string indexes start from zero. You can use index 0 to access the first character, index 1 to access the second character, and so on. The index of the last character is 1 less than the length of the string.

 The notation `subject[ index ]` is called “substring notation”. The substring notation lets you refer to individual characters within a string.

### Example

#### project\_14\_3g

```
static void Main(string[] args) {
```

```

string a;

a = "Hello World";

Console.WriteLine(a[0]);      //It displays: H (the first letter)
Console.WriteLine(a[6]);      //It displays: W
Console.WriteLine(a[10]);     //It displays: d (the last letter)
}

```

 Note that the space between the words “Hello” and “World” is considered a character as well. So, the letter W exists in position 6 and not in position 5.

If you attempt to use an invalid index such as a negative one or an index greater than the length of the string, C# throws an error message as shown in **Figure 14–1**.



**Figure 14–1** An error message indicating an invalid index

 String indexes must be in a range from 0 to one less than the length of the string.

## Getting part of a string

`subject.Substring(beginIndex [, length] )`

This method returns a portion of `subject`. Specifically, it starts from position `beginIndex` and returns a substring of `length` characters. The argument `length` is optional. If it is omitted, the substring starting from position

*beginIndex* until the end of *subject* is returned.

## Example

### project\_14\_3h

```
static void Main(string[] args) {
    string a;

    a = "Hello Athena";

    Console.WriteLine(a.Substring(6, 3)); //It displays: Ath
    Console.WriteLine(a.Substring(7));    //It displays: thena
}
```

## Comparing strings

*subject.CompareTo(string)*

This method returns the value 0 when *subject* is lexicographically equal to *string*; a value less than 0 if *subject* is lexicographically less than *string*; and a value greater than 0 if *subject* is lexicographically greater than *string*.

The term “lexicographically” means that the letter “A” is considered “less than” the letter “B”, the letter “B” is considered “less than” the letter “C”, and so on. Of course, if two strings contain words in which the first letter is identical, C# moves on and compares their second letters and perhaps their third letters (if necessary). For example, the word “backspace” is considered “less than” the word “backwards” because the fifth letter, “s”, is “less than” the fifth letter, “w”.

## Example

### project\_14\_3i

```
static void Main(string[] args) {
    string a = "backspace";
    string b = "backwards";
    string c = "Backspace";
    string d = "winter";
    string e = "winter";

    Console.WriteLine(a.CompareTo(b));    //It displays: -1
    Console.WriteLine(a.CompareTo(c));    //It displays: -1
    Console.WriteLine(d.CompareTo(a));    //It displays: 1
    Console.WriteLine(d.CompareTo(e));    //It displays: 0
}
```

 Note that the letters “b” and “B” are considered two different letters.

## Converting a number or a character to a string

`subject.ToString()`

This method returns a string version of `subject` or, in other words, it converts a number (real or integer) or character into a string.

### Example

#### project\_14\_3j

```
static void Main(string[] args) {
    string a;
    char b;
    int c, d;

    b = 'W';
    a = b.ToString();      //Assign letter W to string variable a
    Console.WriteLine(a);   //It displays: W

    c = 12;
    d = 34;

    Console.WriteLine(c + d); //It displays: 46
    Console.WriteLine(c.ToString() + d.ToString()); //It displays: 1234
}
```

In C#, however, the same result can be achieved if you just start the sequence with a string, even an empty one, as shown in the example that follows.

#### project\_14\_3k

```
static void Main(string[] args) {
    string a;
    char b;
    int c, d;

    b = 'W';
    a = "" + b;      //Assign letter W to string variable a
    Console.WriteLine(a);   //It displays: W

    c = 12;
    d = 34;

    Console.WriteLine(c + d); //It displays: 46
```

```
    Console.WriteLine("'" + c + d); //It displays: 1234
    Console.WriteLine("Result - " + c + d); //It displays: Result - 1234
}
```

### **Exercise 14.3-1 Displaying a String Backwards**

*Write a C# program that prompts the user to enter any string with four letters and then displays its contents backwards. For example, if the string entered is “Zeus”, the program must display “sueZ”.*

#### **Solution**

Let's say that user's input is assigned to variable s. You can access the fourth letter using s[3], the third letter using s[2], and so on.

The C# program is shown here. The concatenation operant ( + ) is used to reassemble the final reversed string.

#### **project\_14\_3\_1**

```
static void Main(string[] args) {
    string s, s_reversed;

    Console.Write("Enter a word with four letters: ");
    s = Console.ReadLine();

    s_reversed = "" + s[3] + s[2] + s[1] + s[0];

    Console.WriteLine(s_reversed);
}
```

 *In C#, it is sometimes necessary to force the compiler to do concatenation, and not normal addition, by starting the sequence with a string, even an empty one.*

### **Exercise 14.3-2 Switching the Order of Names**

*Write a C# program that prompts the user to enter in one single string both first and last name. In the end, the program must change the order of the two names.*

#### **Solution**

This exercise is not the same as the one that you learned in Exercises [8.1-2](#) and [8.1-3](#), which swapped the numeric values of two variables. In this exercise both the first and last names are entered in one single string, so the

first thing that the program must do is split the string and assign each name to a different variable. If you manage to do so, then you can just rejoin them in a different order.

Let's try to understand this exercise using an example. The string that you must split and the position of its individual character is shown here.

0	1	2	3	4	5	6	7	8
T	o	m		s	m	i	t	h

The character that visually separates the first name from the last name is the space character between them. The problem is that this character is not always at position 3. Someone can have a short first name like “Tom” and someone else can have a longer one like “Robert”. Thus, you need something that actually finds the position of the space character regardless of the content of the string.

Method `IndexOf()` is what you are looking for! If you use it to find the position of the space character in the string “Tom Smith”, it returns the value 3. But if you use it to find the space character in another string, such as “Angelina Brown”, it returns the value 8 instead.

 *The value 3 is not just the position where the space character exists. It also represents the number of characters that the word “Tom” contains! The same applies to the value 8 that is returned for the string “Angelina Brown”. It represents both the position where the space character exists and the number of characters that the word “Angelina” contains!*

The C# program for this algorithm is shown here.

### project\_14\_3\_2

```
static void Main(string[] args) {
    string full_name, name1, name2;
    int space_pos;

    Console.Write("Enter your full name: ");
    full_name = Console.ReadLine();

    //Find the position of space character. This is also the number
    //of characters first name contains
    space_pos = full_name.IndexOf(" ");
```

```

//Get space_pos number of characters starting from position 0
name1 = full_name.Substring(0, space_pos);

//Get the rest of the characters starting from position space_pos + 1
name2 = full_name.Substring(space_pos + 1);

full_name = name2 + " " + name1;

Console.WriteLine(full_name);
}

```

 *The method `subject.Substring(beginIndex [, length]`) returns a portion of `subject`. Specifically, it starts from position `beginIndex` and returns a substring of `length` characters.*

 *Note that this program cannot be applied to a Spanish name such as “*Maria Teresa García Ramírez de Arroyo*”. The reason is obvious!*

### ***Exercise 14.3-3 Creating a Login ID***

*Write a C# program that prompts the user to enter his or her last name and then creates a login ID from the first four letters of the name (in lowercase) and a three-digit random integer.*

#### ***Solution***

To create a random integer you can use the `Next()` method. Since you need a random integer of three digits, the range must be between 100 and 999.

The C# program for this algorithm is shown here.

#### ***project\_14\_3\_3***

```

static void Main(string[] args) {
    int random_int;
    string last_name, login_ID;

    Random rnd = new Random();

    Console.Write("Enter last name: ");
    last_name = Console.ReadLine();

    //Get random integer between 100 and 999
    random_int = rnd.Next(100, 1000);
}

```

```
    login_ID = last_name.Substring(0, 4).ToLower() + random_int;
    Console.WriteLine(login_ID);
}
```

 Note how the method `Substring()` is chained to the method `ToLower()`. The result of the first method is used as a subject for the second method. This is a writing style that most programmers prefer to follow because it helps to save a lot of code lines. Of course you can chain as many methods as you wish, but if you chain too many of them, no one will be able to understand your code.

### **Exercise 14.3-4 Creating a Random Word**

Write a C# program that displays a random word consisting of five letters.

#### **Solution**

To create a random word you need a string that contains all 26 letters of the English alphabet. Then you can use the `Next()` method to choose a random letter between position 0 and 25.

The C# program for this algorithm is shown here.

#### project\_14\_3\_4a

```
static void Main(string[] args) {
    string alphabet, random_word;

    Random rnd = new Random();

    alphabet = "abcdefghijklmnopqrstuvwxyz";

    random_word = "" + alphabet[rnd.Next(0, 26)] +
                  alphabet[rnd.Next(0, 26)] +
                  alphabet[rnd.Next(0, 26)] +
                  alphabet[rnd.Next(0, 26)] +
                  alphabet[rnd.Next(0, 26)];

    Console.WriteLine(random_word);
}
```

 Note that the method `Next(0, 26)` is called five times and each time it may return a different random number.

 In C#, it is sometimes necessary to force the compiler to do

*concatenation, and not normal addition, by starting the sequence with a string, even an empty one.*

You can also use the `Length` property to get the length of string alphabet as shown here.

### project\_14\_3\_4b

```
static void Main(string[] args) {
    string alphabet, random_word;

    Random rnd = new Random();

    alphabet = "abcdefghijklmnopqrstuvwxyz";

    random_word = "" + alphabet[rnd.Next(0, alphabet.Length)] +
                  alphabet[rnd.Next(0, alphabet.Length)] +
                  alphabet[rnd.Next(0, alphabet.Length)] +
                  alphabet[rnd.Next(0, alphabet.Length)] +
                  alphabet[rnd.Next(0, alphabet.Length)];

    Console.WriteLine(random_word);
}
```

### ***Exercise 14.3-5 Finding the Sum of Digits***

*Write a C# program that prompts the user to enter a three-digit integer and then calculates the sum of its digits. Solve this exercise without using arithmetic operators.*

### **Solution**

Now you may wonder why this exercise is placed in this chapter, where the whole discussion is about how to manipulate strings. You may also say that you already know how to split a three-digit integer into its three digits and assign each digit to a separate variable as you did learn a method in [Chapter 13](#) using the division ( / ) and the integer remainder ( % ) operators. So, why is this exercise written here again?

The reason is that C# is a very powerful language and you can use its magic forces to solve this exercise in a totally different way. The main idea is to convert the given integer to type string and assign each digit (each character) into individual variables

### project\_14\_3\_5

```

static void Main(string[] args) {
    int number, total;
    string s_number, digit1, digit2, digit3;

    Console.Write("Enter an three-digit integer: ");
    number = Int32.Parse(Console.ReadLine());

    s_number = "" + number; //Convert number to string

    digit1 = "" + s_number[0]; //Convert character at position 0 to string
    digit2 = "" + s_number[1]; //Convert character at position 1 to string
    digit3 = "" + s_number[2]; //Convert character at position 2 to string

    total = Int32.Parse(digit1) + Int32.Parse(digit2) + Int32.Parse(digit3);

    Console.WriteLine(total);
}

```

## 14.4 Review Questions: True/False

Choose **true** or **false** for each of the following statements.

1. A string is anything that you can type using the keyboard.
2. Strings must be enclosed in parentheses.
3. The phrase “Hi there!” contains 8 characters.
4. In the phrase “Hi there!” the letter “t” is at position 3.
5. The statement `y = a[1]` assigns the second character of the string contained in variable `a` to variable `y`.
6. The following statement  
`y = a[-1];`  
 satisfies the property of definiteness.
7. Trimming is the process of removing whitespace characters from the beginning or the end of a string.
8. The statement `y = ("Hello Aphrodite").Trim()` assigns the value “HelloAphrodite” to variable `y`.
9. The statement `Console.WriteLine(("Hi there!").Replace("Hi", "Hello"))` displays the message “Hello there!”.
10. The statement `index = ("Hi there").IndexOf("the")` assigns the value 4 to the variable `index`.

11. The statement `Console.WriteLine("hi there!").ToUpper()` displays the message “Hi There”.
12. The statement `Console.WriteLine("Hi there!").Substring(0)` displays the message “Hi there!”
13. The statement `Console.WriteLine(a.Substring(0, a.Length))` displays some letters of the variable a.
14. The statement

```
Console.WriteLine(a.Substring(a.Length - 1));
```

is equivalent to the statement

```
Console.WriteLine(a[a.Length - 1]);
```
15. The statement

```
Console.WriteLine(("hello there!").ToUpper().Substring(0, 5))
```

displays the word “HELLO”.
16. If variable a contains a string of 100 characters then the statement

```
Console.WriteLine(a[a.Length - 1]);
```

is equivalent to the statement

```
Console.WriteLine(a[99]);
```

## 14.5 Review Questions: Multiple Choice

Select the correct answer for each of the following statements.

1. Which of the following is **not** a string?
  - a. “Hello there!”
  - b. “13”
  - c. “13.5”
  - d. All of the above are strings.
2. In which position does the space character in the string “Hello Zeus!”, exist?
  - a. 6
  - b. 5
  - c. Space is not a character.
  - d. none of the above
3. The statement

```
Console.WriteLine(a.Substring(a.Length - 1, 1));
```

displays

- a. the last character of variable a.
- b. the second to last character of variable a.
- c. The statement is not valid.

4. The statement

```
a.Trim().Replace("a", "b").Replace("w", "y");
```

is equivalent to the statement

- a. a.Replace("a", "b").Replace("w", "y").Trim()
- b. a.Replace("a", "b").Trim().Replace("w", "y")
- c. a.Trim().Replace("w", "y").Replace("a", "b")
- d. all of the above

5. The statement a.Replace(" ", "")

- a. adds a space between each letter in the variable a.
- b. removes all space characters from the variable a.
- c. empties the variable a.

6. The statement (" Hello ").Replace(" ", "") is equivalent to the statement

- a. (" Hello ").Replace("", " ")
- b. (" Hello ").Trim()
- c. all of the above
- d. none of the above

7. The following code fragment

```
a = "";
Console.WriteLine(a.Length);
```

displays

- a. nothing.
- b. 1.
- c. 0.
- d. The statement is invalid.
- e. none of the above

8. Which value assigns the following code fragment

```
to_be_or_not_to_be = "2b Or Not 2b";
Shakespeare = to_be_or_not_to_be.IndexOf("b")
```

to the variable Shakespeare?

- a. 1
- b. 2
- c. 6
- d. none of the above

9. What does the following code fragment?

```
a = "Hi there";
b = a.Substring(a.IndexOf(" ") + 1);
```

- a. It assigns the word “Hi” to the variable b.
- b. It assigns a space character to the variable b.
- c. It assigns the word “there” to the variable b.
- d. none of the above

## 14.6 Review Exercises

Complete the following exercises.

1. Write a C# program that prompts the user to enter his or her first name, middle name, last name, and his or her preferred title (Mr., Mrs., Ms., Dr., and so on) and displays them formatted in all the following ways.

*Title FirstName MiddleName LastName*

*FirstName MiddleName LastName*

*LastName, FirstName*

*LastName, FirstName MiddleName*

*LastName, FirstName MiddleName, Title*

*FirstName LastName*

For example, assume that the user enters the following:

First name: Aphrodite

Middle name: Maria

Last name: Boura

Title: Ms.

The program must display the user's name formatted in all the following ways:

Ms. Aphrodite Maria Boura

Aphrodite Maria Boura

Boura, Aphrodite

Boura, Aphrodite Maria

Boura, Aphrodite Maria, Ms.

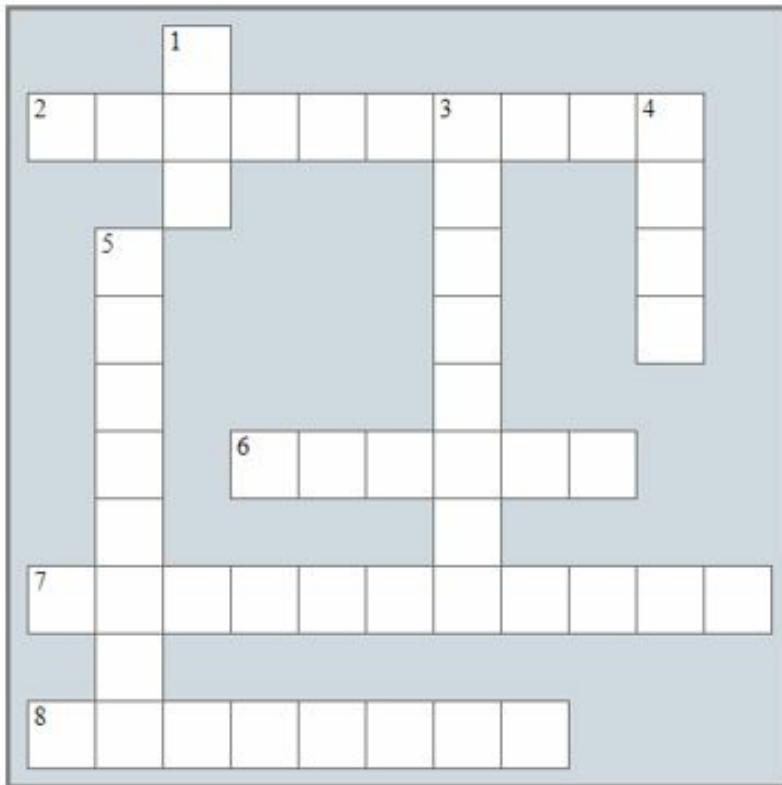
Aphrodite Boura

2. Write a C# program that creates and displays a random word consisting of five letters. The first letter must be a capital letter.
3. Write a C# program that prompts the user to enter his or her name and then creates a secret password consisting of three letters (in lowercase) randomly picked up from his or her name, and a random four-digit number. For example, if the user enters “Vassilis Bouras” a secret password can probably be one of “sar1359” or “vbs7281” or “bor1459”.
4. Write a C# program that prompts the user to enter an integer and then reverses it. For example, if the user enters the number 375, the number 573 must be displayed.

# **Review in “Sequence Control Structures”**

## **Review Crossword Puzzle**

1. Solve the following crossword puzzle.



### **Across**

2. The `Length` attribute contains the number of \_\_\_\_\_ in a string.
6. Anything that you can type using the keyboard.
7. C# provides many ready-to-use \_\_\_\_\_.
8. This control structure refers to the line-by-line execution by which statements are executed sequentially.

### **Down**

1. A whitespace character.
3. The process of removing whitespace characters from the beginning or the end of a string.
4. The `Math.Sin()` method returns the \_\_\_\_\_ of a number.
5. The `Math.Abs()` method returns the \_\_\_\_\_ value of a

number.

## Review Questions

Answer the following questions.

1. What is a sequence control structure?
2. What operations can a sequence control structure perform?
3. Give some examples of how you can use the quotient and the remainder of an integer division.
4. What is a method?
5. What does the term “chain a method” mean?
6. What does the term “nest a method” mean?

# **Section 4**

## **Decision Control Structures**

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# Chapter 15

## Making Questions

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### 15.1 Introduction

All you have learned so far is the sequence control structure, where statements are executed sequentially, in the same order in which they appear in the program. However, in serious C# programming, rarely do you want the statements to be executed sequentially. Many times you want a block of statements to be executed in one situation and an entirely different block of statements to be executed in another situation.

### 15.2 What is a Boolean Expression?

Let's say that variable `x` contains a value of 5. This means that if you ask the question “*is x greater than 2?*” the answer is obviously “Yes”. For a computer, these questions are called *Boolean expressions*. For example, if you write `x > 2`, this is a Boolean expression, and the computer must check whether or not the expression `x > 2` is true or false.

- ☞ A Boolean expression is an expression that results in a Boolean value, that is, either true or false.
- ☞ Boolean expressions are questions and they should be read as “Is something equal to/greater than/less than something else?” and the answer is just a “Yes” or a “No” (true or false).
- ☞ A decision control structure can evaluate a Boolean expression or a set of Boolean expressions and then decide which block of statements to execute.

### 15.3 How to Write Simple Boolean Expressions

A simple Boolean expression is written as

*Operand1      Comparison\_Operator      Operand2*

where

- *Operand1* and *Operand2* can be values, variables or mathematical expressions
- *Comparison\_Operator* can be one of those shown in **Table 15-1**.



Comparison Operator	Description
<code>==</code>	Equal (not assignment)
<code>!=</code>	Not equal
<code>&gt;</code>	Greater than
<code>&lt;</code>	Less than
<code>&gt;=</code>	Greater than or equal to
<code>&lt;=</code>	Less than or equal to

**Table 15-1** Comparison Operators in C#

Here are some examples of Boolean expressions:

- ▶  $x > y$ . This Boolean expression is a question to the computer and can be read as “*is x greater than y?*”
- ▶  $x \leq y$ . This Boolean expression is also a question to the computer and can be read as “*is x less than or equal to y?*”
- ▶  $x \neq 3 * y + 4$ . This can be read as “*is x not equal to the result of the expression  $3 * y + 4$ ?*”
- ▶  $s == "Hello"$ . This can be read as “*is s equal to the word 'Hello'?*” In other words, this question can be read as “*does s contain the word 'Hello'?*”
- ▶  $x == 5$ . This can be read as “*is x equal to 5?*”

 A very common mistake that novice programmers make when writing C# programs is to confuse the value assignment operator with the equal operator. They frequently make the mistake of writing  $x = 5$  when they actually want to say  $x == 5$ .

### **Exercise 15.3-1 Filling in the Table**

Fill in the following table with the words “true” or “false” according to the values of the variables  $a$ ,  $b$ , and  $c$ .

a	b	c	$a == 10$	$b \leq a$	$c > 3 * a - b$
3	-5	7			
10	10	21			

-4	-2	-9		

## Solution

The first two Boolean expressions are straightforward and need no further explanation.

Regarding the Boolean expression  $c > 3 * a - b$ , be very careful with the cases where  $b$  is negative. For example, in the first line,  $a$  is equal to 3 and  $b$  is equal to  $-5$ . The result of the expression  $3 * a - b$  is  $3 * 3 - (-5) = 3 * 3 + 5 = 14$ . Since the content of variable  $c$  (in the first line) is not greater than 14, the result of the Boolean expression  $c > 3 * a - b$  is false.

After a little work , the table becomes

a	b	c	a == 10	b <= a	c > 3 * a - b
3	-5	7	false	true	false
10	10	21	true	true	true
-4	-2	-9	false	false	true

## 15.4 Logical Operators and Complex Boolean Expressions

A more complex Boolean expression can be built of simpler Boolean expressions and can be written as

$BE1 \ Logical\_Operator \ BE2$

where

- $BE1$  and  $BE2$  can be any Boolean expression.
- $Logical\_Operator$  can be one of those shown in **Table 15-2**.

Logical Operator	Description
&&	AND (also known as logical conjunction)
	OR (also known as logical disjunction)
!	NOT (also known as negation or logical complement)

**Table 15-2** Logical Operators in C#

 When you combine simple Boolean expressions with logical operators, the whole Boolean expression is called a “complex Boolean expression”.

*For example, the expression `x == 3 && y > 5` is a complex Boolean expression.*

☞ *In flowcharts, this book uses the commonly accepted AND, OR, and NOT operators!*

## The AND ( `&&` ) operator

When you use the AND ( `&&` ) operator between two Boolean expressions ( $BE1 \ \&\& \ BE2$ ), it means that the result of the whole complex Boolean expression is `true` only when both ( $BE1$  **and**  $BE2$ ) Boolean expressions are `true`.

You can organize this information in something known as a *truth table*. A truth table shows the result of a logical operation between two or more Boolean expressions for all their possible combinations of values. The truth table for the AND ( `&&` ) operator is shown here.

<b><math>BE1</math></b> <b>(Boolean Expression 1)</b>	<b><math>BE2</math></b> <b>(Boolean Expression 2)</b>	<b><math>BE1 \ \&amp;\&amp; \ BE2</math></b>
<b>false</b>	<b>false</b>	<i>false</i>
<b>false</b>	<b>true</b>	<i>false</i>
<b>true</b>	<b>false</b>	<i>false</i>
<b>true</b>	<b>true</b>	<i>true</i>

Are you still confused? You shouldn't be! It is quite simple! Let's see an example. The complex Boolean expression

```
name == "John" && age > 5
```

is `true` only when the variable `name` contains the word “John” (without the double quotes) **and** variable `age` contains a value greater than 5. Both Boolean expressions must be `true`. If at least one of them is `false`, for example, the variable `age` contains a value of 3, then the whole complex Boolean expression is `false`.

## The OR ( `||` ) operator

When you use the OR ( `||` ) operator between two Boolean expressions ( $BE1 \ || \ BE2$ ), it means the result of the whole complex Boolean expression is `true` when either the first ( $BE1$ ) **or** the second ( $BE2$ ) Boolean expression is `true` (at least one).

The truth table for the OR ( `||` ) operator is shown here.

<b>BE1</b> <b>(Boolean Expression 1)</b>	<b>BE2</b> <b>(Boolean Expression 2)</b>	<b>BE1    BE2</b>
<b>false</b>	<b>false</b>	<i>false</i>
<b>false</b>	<b>true</b>	<i>true</i>
<b>true</b>	<b>false</b>	<i>true</i>
<b>true</b>	<b>true</b>	<i>true</i>

Let's see an example. The complex Boolean expression

```
name == "John" || name == "George"
```

is true when the variable `name` contains the word “John” **or** the word “George” (without the double quotes). At least one Boolean expression must be true. If both Boolean expressions are `false`, for example, the variable `name` contains the word “Maria”, then the whole complex Boolean expression is `false`.

### The NOT ( `!` ) operator

When you use the NOT ( `!` ) operator in front of a Boolean expression (*BE*), it means that the whole complex Boolean expression is `true` when the Boolean expression *BE* is `false` and vice versa.

The truth table for the NOT ( `!` ) operator is shown here.

<b>BE</b> <b>(Boolean Expression)</b>	<b>!(BE)</b>
<b>false</b>	<i>true</i>
<b>true</b>	<i>false</i>

For example, the complex Boolean expression

```
!(age > 5)
```

is true when the variable `age` contains a value less than or equal to 5. If, for example, the variable `age` contains a value of 6, then the whole complex Boolean expression is `false`.

 *The logical operator NOT ( `!` ) reverses the result of a Boolean expression. In C#, the Boolean expression must be enclosed in parentheses.*

## 15.5 Assigning the Result of a Boolean Expression to a Variable

Given that a Boolean expression actually returns a value (`true` or `false`), this value can be directly assigned to a variable. For example, the expression

```
a = x > y;
```

assigns a value of `true` or `false` to Boolean variable `a`. It can be read as “*If the content of variable x is greater than the content of variable y, assign the value true to variable a; otherwise, assign the value false*”. This next example displays the value `true` on the screen.

```
static void Main(string[] args) {
    int x, y;
    bool a;

    x = 8;
    y = 5;
    a = x > y;

    Console.WriteLine(a);
}
```

## 15.6 What is the Order of Precedence of Logical Operators?

A more complex Boolean expression may use several logical operators like the expression shown here

$$x > y \text{ || } x == 5 \text{ && } x \leq z \text{ || } !(z == 1)$$

So, a reasonable question is “which logical operation is performed first?”

Logical operators follow the same precedence rules that apply to the majority of programming languages. The order of precedence is: logical complements (`!`) are performed first, logical conjunctions (`&&`) are performed next, and logical disjunctions (`||`) are performed at the end.

Higher Precedence	Logical Operator
	!
	&&

Table 15-3 The Order of Precedence of Logical Operators



You can always use parentheses to change the default precedence.

---

## 15.7 What is the Order of Precedence of Arithmetic, Comparison, and Logical Operators?

In many cases, an expression may contain different type of operators, such as the one shown here.

```
a * b + 2 > 21 || !(c == b / 2) && c > 13
```

In such cases, arithmetic operations are performed first, comparison operations are performed next, and logical operations are performed at the end, as shown in the following table.

Higher Precedence	Arithmetic Operators	* , / , %
	Comparison Operators	+ , -
	Logical Operators	< , <= , > , >= , == , !=
Lower Precedence		!
		&&

**Table 15-4** The Order of Precedence of Arithmetic, Comparison, and Logical Operators

### ***Exercise 15.7-1 Filling in the Truth Table***

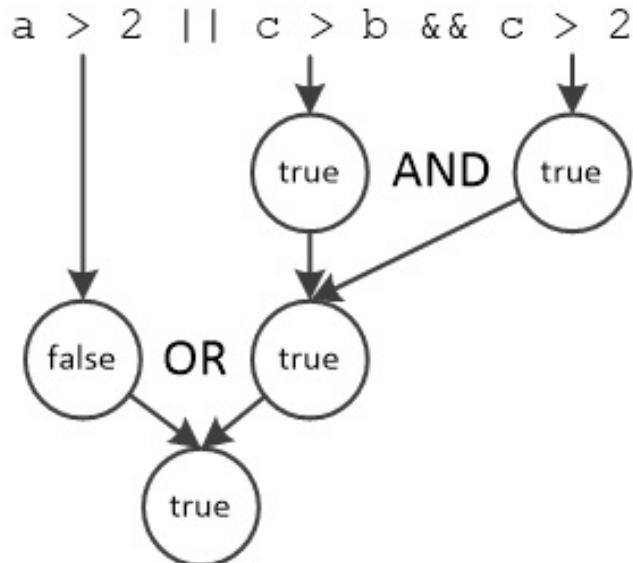
*Fill in the following table with the words “true” or “false” according to the values of the variables a, b and c .*

a	b	c	$a > 2 \parallel c > b \ \&\& \ c > 2$	$!(a > 2 \parallel c > b \ \&\& \ c > 2)$
1	-5	7		
10	10	3		
-4	-2	-9		

### ***Solution***

To calculate the result of complex Boolean expressions you can use the following graphical method.

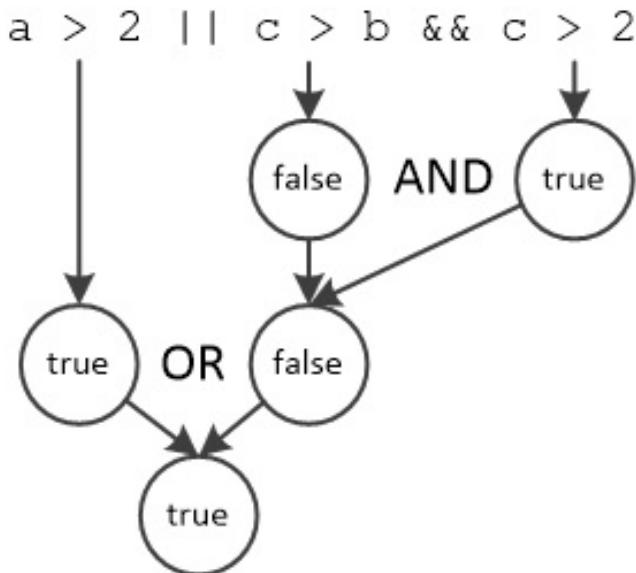
For  $a = 1$ ,  $b = -5$ ,  $c = 7$ ,



the final result is true.

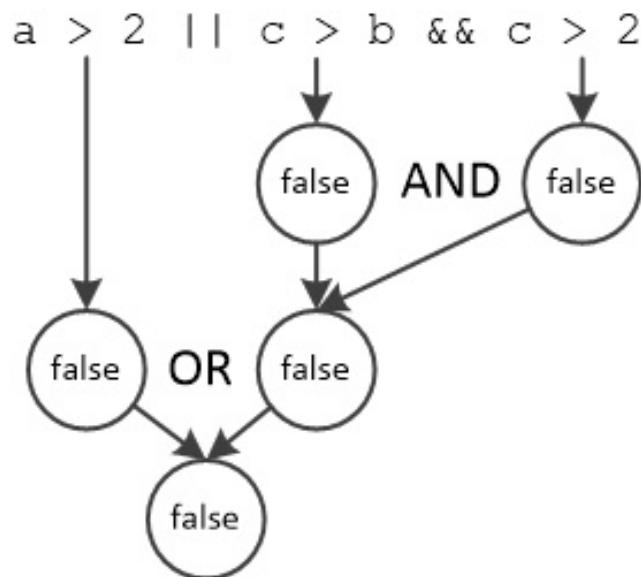
*The AND ( && ) operation has a higher precedence and is performed before the or operation.*

For  $a = 10, b = 10, c = 3$ ,



the final result is true.

For  $a = -4, b = -2, c = -9$ ,



the final result is `false`.

The values in the table's fifth column can be calculated very easily because the Boolean expression in its column heading is almost identical to the one in the fourth column. The only difference is the NOT ( `!` ) operator in front of the expression. So, the values in the fifth column can be calculated by simply negating the results in the fourth column!

The final truth table is shown here.

a	b	c	$a > 2 \parallel c > b \&\& c > 2$	$!(a > 2 \parallel c > b \&\& c > 2)$
1	-5	7	<i>true</i>	<i>false</i>
10	10	3	<i>true</i>	<i>false</i>
-4	-2	-9	<i>false</i>	<i>true</i>

### Exercise 15.7-2 Calculating the Results of Complex Boolean Expressions

Calculate the results of the following complex Boolean expressions when variables  $a$ ,  $b$ ,  $c$ , and  $d$  contain the values 5, 2, 7, and -3 respectively.

i.  $(3 * a + b / 47 - c * b / a > 23) \&\& (b != 2)$

ii.  $(a * b - c / 2 + 21 * c / 3) \parallel (a \geq 5)$

### Solution

Don't be scared! The results can be found very easily. All you need is to recall what applies to AND ( `&&` ) and OR ( `||` ) operators.

- i. The result of an AND ( `&&` ) operator is true when both Boolean expressions are true. If you take a closer look, the result of the Boolean expression on the right (`b != 2`) is false. So, you don't have to waste your time calculating the result of the Boolean expression on the left. The final result is definitely false.
- ii. The result of an OR ( `||` ) operator is true when at least one Boolean expression is true. If you take a closer look, the result of the Boolean expression on the right (`a >= 5`) is actually true. So, don't bother calculating the result of the Boolean expression on the left. The final result is definitely true.

### ***Exercise 15.7-3 Converting English Sentences to Boolean Expressions***

---

*A head teacher asks the students to raise their hands according to their age. He wants to find the students who are*

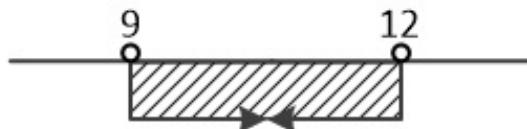
- i. *between the ages of 9 and 12.*
- ii. *under the age of 8 and over the age of 11.*
- iii. *8, 10, and 12 years old.*
- iv. *between the ages of 6 and 8, and between the ages of 10 and 12.*
- v. *neither 10 nor 12 years old.*

### ***Solution***

---

To compose the required Boolean expressions, a variable `age` is used.

- i. The sentence “*between the ages of 9 and 12*” can be graphically represented as shown here.



Be careful though! It is valid to write  $9 \leq \text{age} \leq 12$  in mathematics, but in C# the following is **not** possible

`9 <= age <= 12`

What you can do is to split the expression into two parts, as shown here

`age >= 9 && age <= 12`

 For your confirmation, you can test this Boolean expression for several values inside and outside of the “region of interest” (the range of data that

*(you have specified). For example, the result of the expression is false for the age values 7, 8, 13, and 17. On the contrary, for the age values 9, 10, 11, and 12, the result is true.*

- ii. The sentence “*under the age of 8 and over the age of 11*” can be graphically represented as shown here.



Note the absence of the two circles that you saw in solution (i). This means the values 8 and 11 are **not** included within the two regions of interest.

Be careful with the sentence “Under the age of 8 **and** over the age of 11”. It's a trap! Don't make the mistake of writing

`age < 8 && age > 11`

There is no person on the planet Earth that can be under the age of 8 **and** over the age of 11 concurrently!

The trap is in the word “**and**”. Try to rephrase the sentence and make it “*Children! Please raise your hand if you are under the age of 8 **or** over the age of 11.*” Now it's better and the correct Boolean expression becomes

`age < 8 || age > 11`

For your confirmation, you can test this expression for several values inside and outside of the regions of interest. For example, the result of the expression is false for the age values 8, 9, 10 and 11. On the contrary, for the age values 6, 7, 12, and 15, the result is true.

- iii. Oops! Another trap in the sentence “8, 10, and 12 years old” with the “**and**” word again! Obviously, the next Boolean expression is wrong.

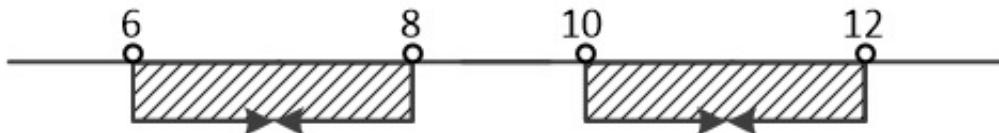
`age == 8 && age == 10 && age == 12`

As before, there isn't any student who is 8 **and** 10 **and** 12 years old concurrently! Once again, the correct Boolean expression must use the OR ( **||** ) operator.

```
age == 8 || age == 10 || age == 12
```

✎ For your confirmation, you can test this expression for several values inside and outside of the regions of interest. For example, the result of the expression is false for the age values 7, 9, 11, and 13. For the age values 8, 10, and 12, the result is true.

- iv. The sentence “between the ages of 6 and 8, and between the ages of 10 and 12” can be graphically represented as shown here.



and the Boolean expression is

```
age >= 6 && age <= 8 || age >= 10 && age <= 12
```

✎ For your confirmation, the result of the expression is false for the age values 5, 9, 13, and 16. For the age values 6, 7, 8, 10, 11, and 12, the result is true.

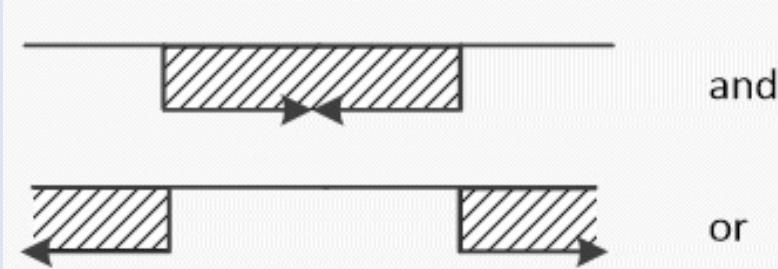
- v. The Boolean expression for the sentence “neither 10 nor 12 years old” can be written as

```
age != 10 && age != 12
```

or as

```
!(age == 10 || age == 12)
```

✎ When the arrows of the region of interest are pointing toward each other, a logical operator AND ( `&&` ) must be used; otherwise, a logical operator OR ( `||` ) must be used.



## 15.8 How to Negate Boolean Expressions

Negation is the process of reversing the meaning of a Boolean expression. There are two approaches used to negate a Boolean expression.

## First Approach

The first approach is the easiest one. Just use a NOT ( ! ) operator in front of the original Boolean expression and your negated Boolean expression is ready! For example, if the original Boolean expression is

$x > 5 \ \&\& \ y == 3$

the negated Boolean expression becomes

$!(x > 5 \ \&\& \ y == 3)$

 Note that the entire expression must be enclosed in parentheses. It would be completely incorrect if you had written the expression as  $!(x > 5) \ \&\& \ y == 3$ . In this case the NOT ( ! ) operator would negate only the first Boolean expression,  $x > 5$ .

## Second Approach

The second approach is a little bit more complex but not difficult to learn. All you must do is negate every operator according to the following table.

Original Operator	Negated Operator
$==$	$!=$
$!=$	$==$
$>$	$\leq$
$<$	$\geq$
$\leq$	$>$
$\geq$	$<$
$\&\&$	$\ $
$\ $	$\&\&$
!	!

 Note that the NOT ( ! ) operator remains intact.

For example, if the original Boolean expression is

`x > 5 && y == 3`

the negated Boolean expression becomes

`x <= 5 || y != 3`

However, there is a small detail that you should be careful with. If both AND ( `&&` ) and OR ( `||` ) operators co-exist in a complex Boolean expression, then the expressions that use the OR ( `||` ) operators in the negated Boolean expression must be enclosed in parentheses, in order to preserve the initial order of precedence. For example, if the original Boolean expression is

`x >= 5 && x <= 10 || y == 3`

the negated Boolean expression must be

`(x < 5 || x > 10) && y != 3`

 *If you forget to enclose the expression `x < 5 || x > 10` in parentheses, since the AND ( `&&` ) operator has a higher precedence than the OR ( `||` ) operator, the expression `x > 10 && y != 3` is evaluated first, which is wrong of course!*

### Exercise 15.8-1 Negating Boolean Expressions

Negate the following Boolean expressions using both approaches.

- i. `b != 4`
- ii. `a * 3 + 2 > 0`
- iii. `!(a == 5 && b >= 7)`
- iv. `a == true`
- v. `b > 7 && !(x > 4)`
- vi. `a == 4 || b != 2`

### Solution

#### **First Approach**

- i. `!(b != 4)`
- ii. `!(a * 3 + 2 > 0)`
- iii. `!(!(a == 5 && b >= 7)),` or the equivalent `a == 5 && b >= 7`

 *Two negations result in an affirmative. That is, two NOT ( `!` ) operators in a row negate each other.*

- iv. `!(a == true)`
- v. `!(b > 7 && !(x > 4))`
- vi. `!(a == 4 || b != 2)'`

## Second Approach

- i. `b == 4`
- ii. `a * 3 + 2 <= 0`

 Note that arithmetic operators are **not** “negated”. Don't you ever dare replace the plus ( + ) with a minus ( - ) operator!

- iii. `!(a != 5 || b < 7)`

 Note that the NOT ( ! ) operator remains intact.

- iv. `a != true`
- v. `b <= 7 || !(x <= 4)`
- vi. `a != 4 && b == 2`

## 15.9 Review Questions: True/False

Choose **true** or **false** for each of the following statements.

1. A Boolean expression is an expression that always results in one of two values.
2. A Boolean expression includes at least one logical operator.
3. In C#, the expression `x = 5` tests if the variable `x` is equal to 5.
4. In C#, the statement  
`a = b == c;`  
is not a valid C# statement.
5. The Boolean expression `b < 5` tests if the variable `b` is 5 or less.
6. The AND ( `&&` ) operator is also known as a logical disjunction operator.
7. The OR ( `||` ) operator is also known as a logical complement operator.
8. The result of a logical conjunction of two Boolean expressions equals the result of the logical disjunction of them, given that both Boolean expressions are **true**.

9. The result of a logical disjunction of two Boolean expressions is definitely true, given that the Boolean expressions have different values.
10. The expression `c == 3 && d > 7` is considered a complex Boolean expression.
11. The result of the logical operator OR (`||`) is true when both operands (Boolean expressions) are true.
12. The result of the Boolean expression `!(x == 5)` is true when the variable `x` contains any value except 5.
13. The NOT (`!`) operator has the highest precedence among logical operators.
14. The OR (`||`) operator has the lowest precedence among logical operators.
15. In the Boolean expression `x > y || x == 5 && x <= z`, the AND (`&&`) operation is performed before the OR (`||`) operation.
16. In the Boolean expression `a * b + c > 21 || c == b / 2`, the program first tests if `c` is greater than 21.
17. When a teacher wants to find the students who are under the age of 8 and over the age of 11, the corresponding Boolean expression is `age < 8 && age > 11`.
18. The Boolean expression `x < 0 && x > 100` is, for any value of `x`, always false.
19. The Boolean expression `x > 0 || x < 100` is, for any value of `x`, always true.
20. The Boolean expression `x > 5` is equivalent to `!(x < 5)`.
21. The Boolean expression `!(x > 5 && y == 5)` is not equivalent to `!(x > 5) && y == 5`.
22. In William Shakespeare<sup>[13]</sup>'s *Hamlet* (Act 3, Scene 1), the main character says “To be, or not to be: that is the question:....” If you write this down as a Boolean expression `to_be || !to_be`, the result of this “Shakesboolean” expression is true for the following code fragment.

```
to_be = 1 > 0;
that_is_the_question = to_be || !to_be;
```

23. The Boolean expression `!(!(x > 5))` is equivalent to `x > 5`.

## 15.10 Review Questions: Multiple Choice

Select the correct answer for each of the following statements.

1. Which of the following is **not** a comparison operator?
  - a. `>=`
  - b. `=`
  - c. `<`
  - d. All of the above are comparison operators.
2. Which of the following is not a C# logical operator?
  - a. `&`
  - b. `||`
  - c. All of the above are logical operators.
  - d. None of the above is a logical operator.
3. If variable `x` contains a value of 5, what value does the statement `y = x % 2 == 1` assign to variable `y`?
  - a. `true`
  - b. `false`
  - c. none of the above
4. If variable `x` contains a value of 5, what value does the statement `y = x % 2 == 0 || (int)(x / 2) == 2` assign to variable `y`?
  - a. `true`
  - b. `false`
  - c. none of the above
5. The temperature in a laboratory room must be between 50 and 80 degrees Fahrenheit. Which of the following Boolean expressions tests for this condition?
  - a. `t >= 50 || t <= 80`
  - b. `50 < t < 80`
  - c. `t >= 50 && t <= 80`
  - d. `t > 50 || t < 80`
  - e. none of the above

6. Which of the following is equivalent to the Boolean expression `t == 3 || t > 30`?
- `t == 3 && !(t <= 30)`
  - `t == 3 && !(t < 30)`
  - `!(t != 3) || !(t < 30)`
  - `!(t != 3 && t <= 30)`
  - none of the above

## 15.11 Review Exercises

Complete the following exercises.

1. Match each element from the first column with one or more elements from the second column.

Operator	Sign
i. Logical operator	a. %
ii. Arithmetic operator	b. +=
iii. Comparison operator	c. &&
iv. Assignment operator (in general)	d. ==
	e.
	f. >=
	g. !
	h. =
	i. *=
	j. /

2. Fill in the following table with the words “true” or “false” according to the values of variables `a`, `b`, and `c`.

a	b	c	<code>a != 1</code>	<code>b &gt; a</code>	<code>c / 2 &gt; 2 * a</code>
3	-5	8			
1	10	20			

-4	-2	-9			
----	----	----	--	--	--

3. Fill in the following table with the words “true” or “false” according to the values of the Boolean expressions BE1 and BE2.

Boolean Expression1 (BE1)	Boolean Expression2 (BE2)	BE1    BE2	BE1 && BE2	!(BE2)
false	false			
false	true			
true	false			
true	true			

4. Fill in the following table with the words “true” or “false” according to the values of variables a, b, and c.

a	b	c	a > 3    c > b && c > 1	a > 3 && c > b    c > 1
4	-6	2		
-3	2	-4		
2	5	5		

5. For  $x = 4$ ,  $y = -2$  and  $flag = true$ , fill in the following table with the corresponding values.

Expression	Value
<code>Math.Pow(x + y, 3)</code>	
<code>(x + y) / (Math.Pow(x, 2) - 14)</code>	
<code>(x - 1) == y + 5</code>	
<code>x &gt; 2 &amp;&amp; y == 1</code>	
<code>x == 1    y == -2 &amp;&amp; !(flag == false)</code>	
<code>!(x &gt;= 3) &amp;&amp; (x % 2 &gt; 1)</code>	

6. Calculate the result of each the following complex Boolean expressions when variables a, b, c, and d contain the values 6, -3, 4, and 7 respectively.

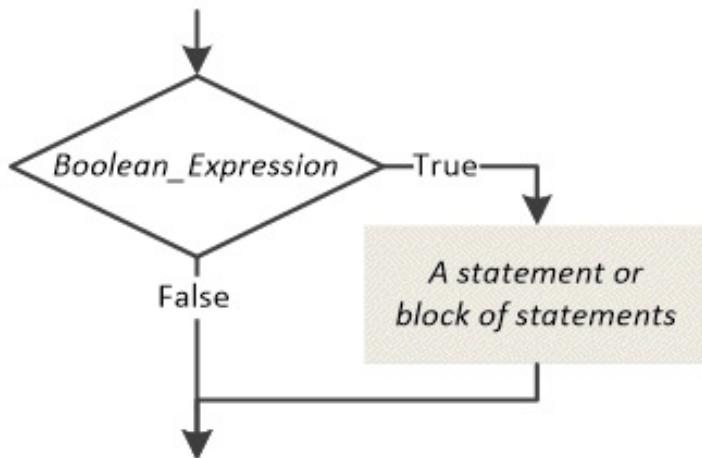
- i.  $(3 * a + b / 5 - c * b / a > 4) \&\& (b != -3)$
  - ii.  $(a * b - c / 2 + 21 * c / 3 != 8) || (a >= 5)$
7. A head teacher asks the students to raise their hands according to their age. He wants to find the students who are:
- i. under the age of 12, but not those who are 8 years old.
  - ii. between the ages of 6 and 9, and also those who are 11 years old.
  - iii. over the age of 7, but not those who are 10 or 12 years old.
  - iv. 6, 9, and 11 years old.
  - v. between the ages of 6 and 12, but not those who are 8 years old.
  - vi. neither 7 nor 10 years old.
- To compose the required Boolean expressions, use a variable age.
8. Negate the following Boolean expressions without using the NOT ( ! ) operator.
- i.  $x == 4 \&\& y != 3$
  - ii.  $x + 4 <= 0$
  - iii.  $!(x > 5) || y == 4$
  - iv.  $x != \text{false}$
  - v.  $!(x >= 4 || z > 4)$
  - vi.  $x != 2 \&\& x >= -5$
9. As you already know, two negations result in an affirmative. Write the equivalent of the following Boolean expressions by negating them twice (applying both methods).
- i.  $x >= 4 \&\& y != 10$
  - ii.  $x - 2 >= 9$
  - iii.  $!(x >= 2) || y != 4$
  - iv.  $x != \text{false} || y == 3$
  - v.  $!(x >= 2 \&\& y >= 2)$
  - vi.  $x != -2 \&\& x <= 2$

# Chapter 16

## The Single-Alternative Decision Structure

### 16.1 The Single-Alternative Decision Structure

This is the simplest decision control structure. It includes a statement or block of statements on the “true” path only.



If *Boolean\_Expression* evaluates to true, the statement, or block of statements, of the structure is executed; otherwise, the statements are skipped.

The general form of the C# statement is

```
if (Boolean_Expression) {  
    A statement or block of statements  
}
```

Note that the statement or block of statements is indented by 2 spaces.

In the next example, the message “You are underage!” displays only when the user enters a value less than 18. Nothing is displayed when the user enters a value that is greater than or equal to 18.

#### project\_16\_1a

```
static void Main(string[] args) {  
    int age;  
  
    Console.WriteLine("Enter your age: ");  
    age = Int32.Parse(Console.ReadLine());
```

```
    if (age < 18) {
        Console.WriteLine("You are underage!");
    }
}
```

 Note that the `Console.WriteLine()` statement is indented by 2 spaces.

In the next example, the message “You are underage!” and the message “You have to wait for a few more years” are displayed only when the user enters a value less than 18. Same as previously, no messages are displayed when the user enters a value that is greater than or equal to 18.

### project\_16\_1b

```
static void Main(string[] args) {
    int age;

    Console.Write("Enter your age: ");
    age = Int32.Parse(Console.ReadLine());

    if (age < 18) {
        Console.WriteLine("You are underage!");
        Console.WriteLine("You have to wait for a few more years.");
    }
}
```

 All statements that appear inside an `if` statement should be indented to the right by the same number of spaces. In the previous example, both `Console.WriteLine()` statements are indented by 2 spaces.

 To save paper, this book uses 2 spaces per indentation level. C#'s official website, however, recommends the use of 4 spaces per indentation level.

 In order to indent the text cursor, instead of typing space characters, you can hit the “Tab ↗” key once!

 In order to indent an existing statement or a block of statements, select it and hit the “Tab ↗” key!

 In order to unindent a statement or a block of statements, select it and hit the “Shift ↑ + Tab ↘” key combination!

In the next example, the message “You are the King of the Gods!” is displayed only when the user enters the name “Zeus”. The message “You

live on Mount Olympus”, however, is always displayed, no matter what name the user enters.

### project\_16\_1c

```
static void Main(string[] args) {
    string name;

    Console.WriteLine("Enter the name of an Olympian: ");
    name = Console.ReadLine();

    if (name == "Zeus") {
        Console.WriteLine("You are the King of the Gods!");
    }

    Console.WriteLine("You live on Mount Olympus.");
}
```

 Note that the last `Console.WriteLine()` statement does **not** belong to the block of statements of the single-alternative decision structure.

 A very common mistake that novice programmers make when writing C# programs is to confuse the value assignment operator with the “equal” operator. They frequently make the mistake of writing  
`if (name = "Zeus")` when they actually want to say `if (name == "Zeus")`.

When only one single statement is enclosed in the `if` statement, you can omit the braces `{ }`. Thus, the `if` statement becomes

```
if (Boolean_Expression)
    One_Single_Statement;
```

or you can even write the statement on one single line, like this:

```
if (Boolean_Expression) One_Single_Statement;
```

The braces are required only when more than one statement is enclosed in the `if` statement. Without the braces, C# cannot tell whether a statement is part of the `if` statement or part of the statements that follow the `if` statement. Many programmers prefer to always use braces even if the `if` statement includes only one single statement. In both of the following examples the `Console.WriteLine(y)` statement is **not** part of the `if` statement.

```
if (x == y)
    x++;
    System.out.println(y);
```

```
if (x == y) {  
    x++;  
}  
System.out.println(y);
```

### ***Exercise 16.1-1 Trace Tables and Single-Alternative Decision Structures***

---

*Design the corresponding flowchart and create a trace table to determine the values of the variables in each step of the next C# program for two different executions.*

*The input values for the two executions are (i) 10, and (ii) 51.*

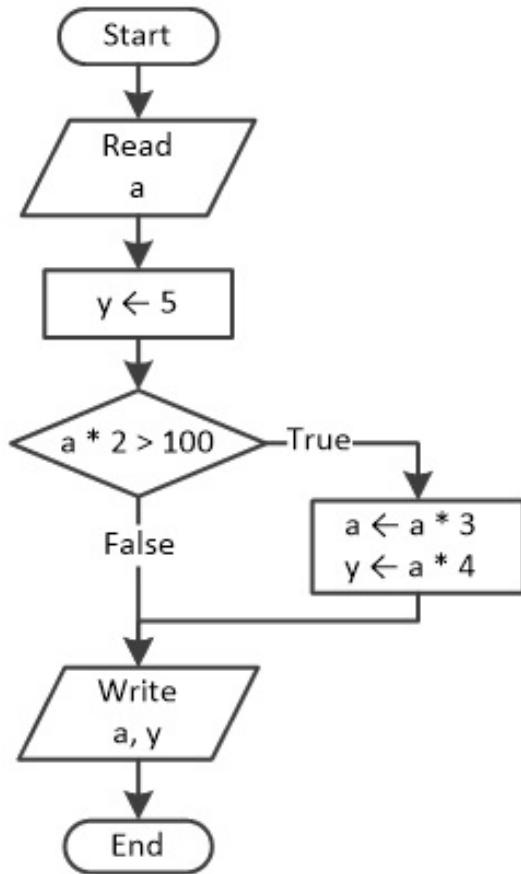
#### **project\_16\_1\_1**

```
static void Main(string[] args) {  
    int a, y;  
  
    a = Int32.Parse(Console.ReadLine());  
  
    y = 5;  
    if (a * 2 > 100) {  
        a = a * 3;  
        y = a * 4;  
    }  
    Console.WriteLine(a + " " + y);  
}
```

### ***Solution***

---

The flowchart is shown here.



The trace tables for each input are shown here.

- For the input value of 10, the trace table looks like this.

Step	Statement	Notes	a	y
1	<code>a = Int32.Parse(...)</code>	User enters the value 10	10	?
2	<code>y = 5</code>		10	5
3	<code>if (a * 2 &gt; 100)</code>	This evaluates to false		
4	<code>.WriteLine(a + " " + y)</code>	It displays: 10 5		

- For the input value of 51, the trace table looks like this.

Step	Statement	Notes	a	y
1	<code>a = Int32.Parse(...)</code>	User enters the value 51	51	?
2	<code>y = 5</code>		51	5
3	<code>if (a * 2 &gt; 100)</code>	This evaluates to true		

4	<code>a = a * 3</code>		153	5
5	<code>y = a * 4</code>		153	612
6	<code>.WriteLine(a + " " + y)</code>	It displays: 153 612		

### ***Exercise 16.1-2 The Absolute Value of a Number***

---

*Design a flowchart and write the corresponding C# program that lets the user enter a number and then displays its absolute value.*

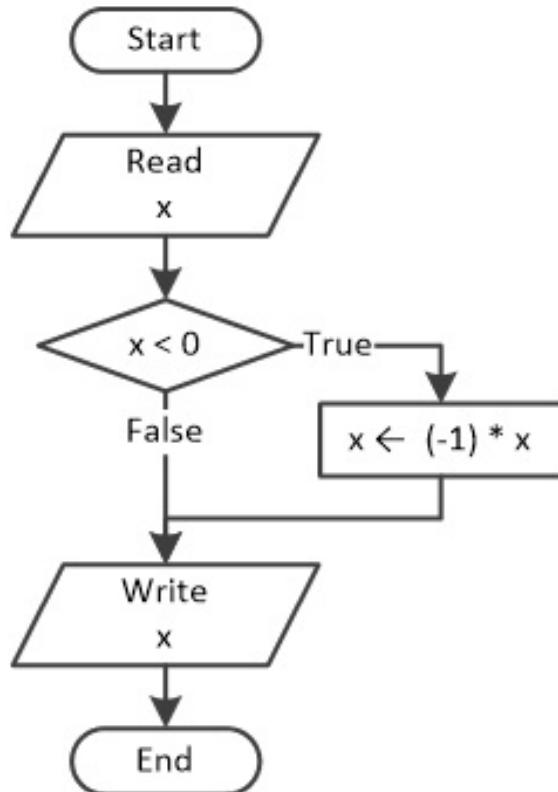
#### **Solution**

---

Actually, there are two approaches. The first approach uses a single-alternative decision structure, whereas the second one uses the built-in `Math.Abs()` method.

#### **First Approach – Using a single-alternative decision structure**

The approach is simple. If the user enters a negative value, for example  $-5$ , this value is changed and displayed as  $+5$ . A positive number or zero, however, must remain as is. The solution is shown in the flowchart that follows.



The corresponding C# program is as follows.

### project\_16\_1\_2a

```
static void Main(string[] args) {
    double x;

    x = Double.Parse(Console.ReadLine());

    if (x < 0) {
        x = (-1) * x;
    }
    Console.WriteLine(x);
}
```

### Second Approach – Using the `Math.Abs()` method

In this case, you need just a few lines of code without any decision control structure!

### project\_16\_1\_2b

```
static void Main(string[] args) {
    double x;

    x = Double.Parse(Console.ReadLine());
    Console.WriteLine(Math.Abs(x));
}
```

## 16.2 Review Questions: True/False

Choose **true** or **false** for each of the following statements.

1. The single-alternative decision structure is used when a sequence of statements must be executed.
2. You use a single-alternative decision structure to allow other programmers to more easily understand your program.
3. It is possible that none of the statements enclosed in a single-alternative decision structure will be executed.
4. In a flowchart, the Decision symbol represents the beginning and the end of an algorithm.
5. The following code

```
const int if = 5;
static void Main(string[] args) {
    int x;
```

```
    x = if + 5;
    Console.WriteLine(x);
}
```

is syntactically correct.

6. The single-alternative decision structure uses the reserved keyword `else`.
7. The following code fragment satisfies the property of definiteness.

```
if (b != 3) {
    x = a / (b - 3);
}
```

8. The following C# program satisfies the property of definiteness.

```
static void Main(string[] args) {
    double a, b, x;

    a = Double.Parse(Console.ReadLine());
    b = Double.Parse(Console.ReadLine());

    if (b != 3) {
        x = a / (b - 3);
    }
    Console.WriteLine(x);
}
```

### 16.3 Review Questions: Multiple Choice

Select the correct answer for each of the following statements.

1. The single-alternative decision structure is used when
  - a. statements are executed one after another.
  - b. a decision must be made before executing some statements.
  - c. none of the above
  - d. all of the above
2. The single-alternative decision structure includes a statement or block of statements on
  - a. the false path only.
  - b. both paths.
  - c. the true path only.
3. In the following code fragment,

```
| if (x == 3)
|   x = 5;
|   y++;
```

the statement `y++` is executed

- a. only when variable `x` contains a value of 3.
  - b. only when variable `x` contains a value of 5.
  - c. only when variable `x` contains a value other than 3.
  - d. either way.
4. In the following code fragment,

```
| if (x % 2 == 0) y++;
```

the statement `y++` is executed when

- a. variable `x` is exactly divisible by 2.
- b. variable `x` contains an even number.
- c. variable `x` does not contain an odd number.
- d. all of the above
- e. none of the above

5. In the following code fragment,

```
| x = 3 * y;
| if (x > y) y++;
```

the statement `y++` is

- a. always executed.
- b. never executed.
- c. executed either way.
- d. executed only when variable `y` contains positive values.
- e. none of the above

## 16.4 Review Exercises

Complete the following exercises.

1. Identify the syntax errors in the following C# program:

```
| static void Main(string[] args) {
|   double x, y
|
|   x = Double.Parse(Console.ReadLine());
```

```

y ← -5;
if (x * y / 2 > 20)
    y *= 2
    x += 4 * x2;
}

Console.WriteLine(x y);
}

```

2. Create a trace table to determine the values of the variables in each step of the following C# program for two different executions. Then, design the corresponding flowchart.

The input values for the two executions are (i) 10, and (ii) -10.

```

static void Main(string[] args) {
    double x, y;

    x = Double.Parse(Console.ReadLine());

    y = -5;
    if (x * y / 2 > 20) {
        y--;
        x -= 4;
    }
    if (x > 0) {
        y += 30;
        x = Math.Pow(x, 2);
    }

    Console.WriteLine(x + ", " + y);
}

```

3. Create a trace table to determine the values of the variables in each step of the following C# program for two different executions. Then, design the corresponding flowchart.

The input values for the two executions are (i) -11, and (ii) 11.

```

static void Main(string[] args) {
    int x, y;

    x = Int32.Parse(Console.ReadLine());

    y = 8;
    if (Math.Abs(x) > 10) {
        y += x;
    }
}

```

```

        x--;
    }
    if (Math.Abs(x) > 10) {
        y *= 3;
    }

    Console.WriteLine(x + ", " + y);
}

```

4. Create a trace table to determine the values of the variables in each step of the following C# program for two different executions. Then, design the corresponding flowchart.

The input values for the two executions are (i) 1, 2, 3; and (ii) 4, 2, 1.

```

static void Main(string[] args) {
    int x, y, z;

    x = Int32.Parse(Console.ReadLine());
    y = Int32.Parse(Console.ReadLine());
    z = Int32.Parse(Console.ReadLine());

    if (x + y > z)
        x = y + z;
    if (x > y + z)
        y = x + z;
    if (x > y - z)
        z = x - z % 2;

    Console.WriteLine(x + ", " + y + ", " + z);
}

```

5. Write a C# program that prompts the user to enter a number, and then displays the message “Positive” when the given number is positive.
6. Write a C# program that prompts the user to enter two numbers, and then displays the message “Positive” when both given numbers are positives.
7. Write a C# program that prompts the user to enter his or her age and then displays the message “*You can drive a car in Kansas (USA)*” when the given age is greater than 14.
8. Write a C# program that prompts the user to enter a string, and then displays the message “Uppercase” when the given string contains only uppercase characters.

Hint: Use the `ToUpper()` method.

9. Write a C# program that prompts the user to enter a string, and then displays the message “Many characters” when the given string contains more than 20 characters.

Hint: Use the `Length` property.

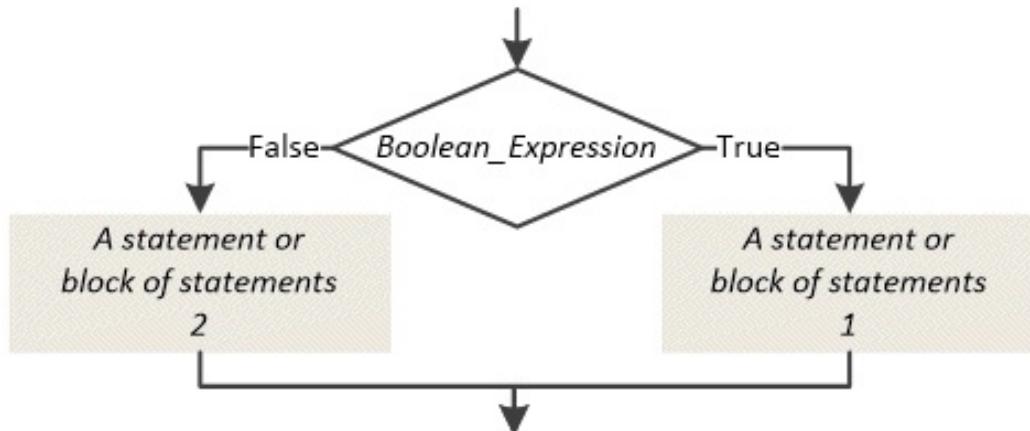
10. Write a C# program that prompts the user to enter four numbers and, if one of them is negative, it displays the message “Among the given numbers, there is a negative one!”
11. Write a C# program that prompts the user to enter two numbers. If the first number given is greater than the second one, the program must swap their values. In the end, the program must display the numbers, always in ascending order.
12. Write a C# program that prompts the user to enter three temperature values measured at three different points in New York, and then displays the message “Heat Wave” if the average value is greater than 60 degrees Fahrenheit.

# Chapter 17

## The Dual-Alternative Decision Structure

### 17.1 The Dual-Alternative Decision Structure

In contrast to the single-alternative decision structure, this type of decision control structure includes a statement or block of statements on both paths.



If *Boolean\_Expression* evaluates to true, the statement or block of statements 1 is executed; otherwise, the statement or block of statements 2 is executed.

The general form of the C# statement is

```
if (Boolean_Expression) {  
    A statement or block of statements 1  
}  
else {  
    A statement or block of statements 2  
}
```

In the next example, the message “You are an adult” is displayed when the user enters a value greater than or equal to 18. The message “You are underage!” is displayed otherwise.

#### project\_17\_1

```
static void Main(string[] args) {  
    int age;  
  
    Console.WriteLine("Enter your age: ");  
    age = Int32.Parse(Console.ReadLine());
```

```

if (age >= 18) {
    Console.WriteLine("You are an adult!");
}
else {
    Console.WriteLine("You are underage!");
}

```

Once again, single statements can be written without being enclosed inside braces { }, and the if-else statement becomes

```

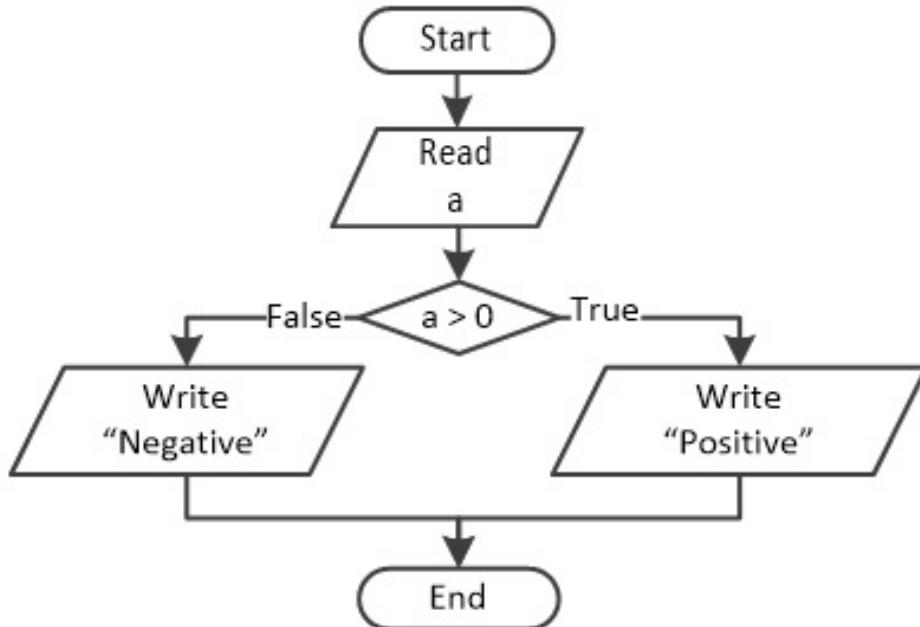
if (Boolean_Expression)
    One_Single_Statement_1;
else
    One_Single_Statement_2;

```

### Exercise 17.1-1 Finding the Output Message

For the following flowchart, determine the output message for three different executions.

The input values for the three executions are (i) 3, (ii) -3, and (iii) 0.



### Solution

- When the user enters the value 3, the Boolean expression evaluates to true. The flow of execution follows the right path and the message “Positive” is displayed.

- ii. When the user enters the value `-3`, the Boolean expression evaluates to `false`. The flow of execution follows the left path and the message “Negative” is displayed.
- iii. Can you predict what happens when the user enters the value `0`? If you believe that none of the messages will be displayed, you are wrong! The dual-alternative decision structure must always follow a path, either the right or the left! It cannot skip the execution of both of its blocks of statements. At least one statement or block of statements must be executed. So, in this case, when the user enters the value `0`, the Boolean expression evaluates to `false`, the flow of execution follows the left path, and the message “Negative” is displayed!

 Obviously, something is not quite right with this flowchart! As you already know, zero is not a negative value! And it is not a positive value either. Later in this book (in [Exercise 20.1-2](#)), you will learn how to display three messages, depending on whether the given value is greater than, less than, or equal to zero.

 A Decision symbol has one entrance and two exit paths! You cannot have a third exit!

### Exercise 17.1-2 Trace Tables and Dual-Alternative Decision Structures

Create a trace table to determine the values of the variables in each step of the next C# program for two different executions.

The input values for the two executions are (i) 5, and (ii) 10.

#### project\_17\_1\_2

```
static void Main(string[] args) {
    double a, z, w, y;

    a = Double.Parse(Console.ReadLine());

    z = a * 10;
    w = (z - 4) * (a - 3) / 7 + 36;

    if (z >= w && a < z) {
        y = 2 * a;
    }
    else {
        y = 4 * a;
    }
}
```

```

    }

    Console.WriteLine(y);
}

```

## **Solution**

---

- i. For the input value of 5, the trace table looks like this.

Step	Statement	Notes	a	z	w	y
1	a = Double.Parse(...)	User enters the value 5	5.0	?	?	?
2	z = a * 10		5.0	50.0	?	?
3	w = (z - 4) * (a - 3) / 7 + 36		5.0	50.0	49.142	?
4	if (z >= w && a < z)	This evaluates to true				
5	y = 2 * a		5.0	50.0	49.142	10.0
6	.WriteLine(y)	It displays: 10				

- ii. For the input value of 10, the trace table looks like this.

Step	Statement	Notes	a	z	w	y
1	a = Double.Parse(...)	User enters the value 10	10.0	?	?	?
2	z = a * 10		10.0	100.0	?	?
3	w = (z - 4) * (a - 3) / 7 + 36		10.0	100.0	132.0	?
4	if (z >= w && a < z)	This evaluates to false				
5	y = 4 * a		10.0	100.0	132.0	40.0
6	.WriteLine(y)	It displays: 40				

## **Exercise 17.1-3 Who is the Greatest?**

---

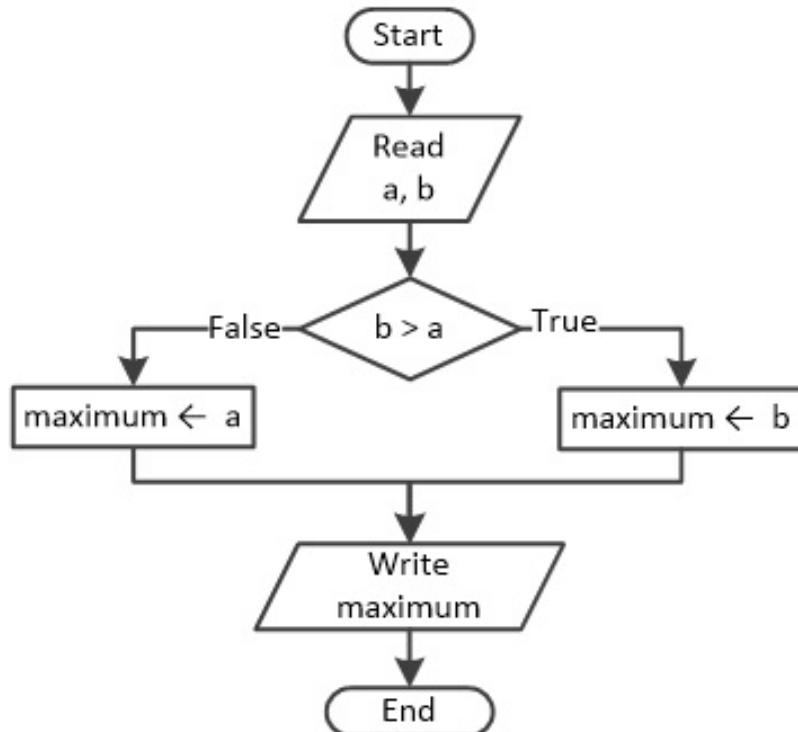
*Design a flowchart and write the corresponding C# program that lets the user enter two numbers A and B and then determines and displays the greater of the two numbers.*

## Solution

This exercise can be solved using either the single- or dual-alternative decision structure. So, let's use them both!

### First Approach – Using a dual-alternative decision structure

This approach tests if the value of number B is greater than that of number A. If so, number B is the greatest; otherwise, number A is the greatest.



and the C# program is as follows.

#### project\_17\_1\_3a

```
static void Main(string[] args) {
    double a, b, maximum;

    a = Double.Parse(Console.ReadLine());
    b = Double.Parse(Console.ReadLine());

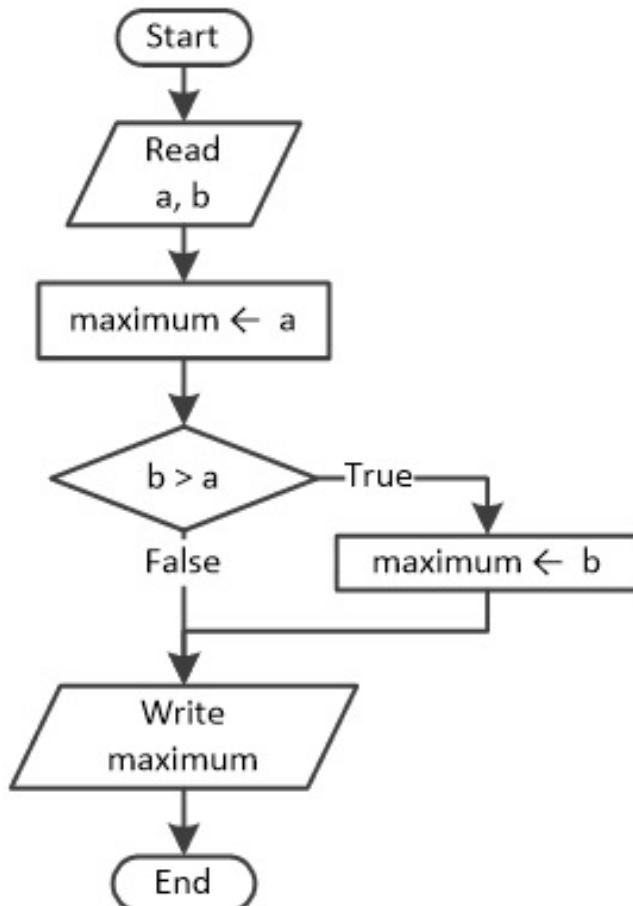
    if (b > a) {
        maximum = b;
    }
    else {
        maximum = a;
    }
```

```
    Console.WriteLine("Greatest value: " + maximum);
}
```

 Note that this exercise is trying to determine the greatest value and not which variable this value is actually assigned to (to variable A or to variable B).

## Second Approach – Using a single-alternative decision structure

This approach initially assumes that number A is probably the greatest value (this is why it assigns the value of variable a to variable maximum). However, if it turns out that number B is actually greater than number A, then the greatest value is updated, that is, variable maximum is assigned a new value, the value of variable b. Thus, whatever happens, in the end, variable maximum always contains the greatest value!



The C# program is shown here.

### project\_17\_1\_3b

```
static void Main(string[] args) {
```

```

double a, b, maximum;

a = Double.Parse(Console.ReadLine());
b = Double.Parse(Console.ReadLine());

maximum = a;
if (b > a) {
    maximum = b;
}

Console.WriteLine("Greatest value: " + maximum);
}

```

### ***Exercise 17.1-4 Finding Odd and Even Numbers***

---

*Design a flowchart and write the corresponding C# program that prompts the user to enter a positive integer, and then displays a message indicating whether this number is even; it must display “Odd” otherwise.*

#### ***Solution***

---

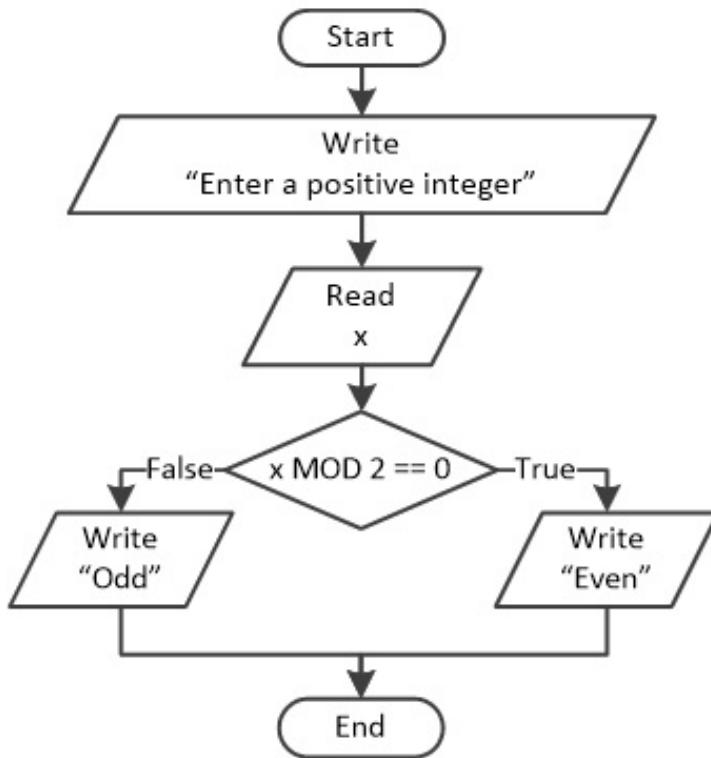
Next you can find various odd and even numbers:

- ▶ Odd numbers: 1, 3, 5, 7, 9, 11, ...
- ▶ Even numbers: 0, 2, 4, 6, 8, 10, 12, ....

 *Note that zero is considered an even number.*

In this exercise, you need to find a way to determine whether a number is odd or even. You need to find a common attribute between all even numbers, or between all odd numbers. And actually there is one! All even numbers are exactly divisible by 2. So, when the result of the operation  $x \bmod 2$  equals 0,  $x$  is even; otherwise,  $x$  is odd.

The flowchart is shown here.



and the C# program is as follows.

### project\_17\_1\_4

```

static void Main(string[] args) {
    int x;

    Console.Write("Enter a positive integer: ");
    x = Int32.Parse(Console.ReadLine());

    if (x % 2 == 0) {
        Console.WriteLine("Even");
    }
    else {
        Console.WriteLine("Odd");
    }
}
  
```

### Exercise 17.1-5 Weekly Wages

Gross pay depends on the pay rate and the total number of hours worked per week. However, if someone works more than 40 hours, he or she gets paid time-and-a-half for all hours worked over 40. Design a flowchart and write the corresponding C# program that lets the user enter a pay rate and

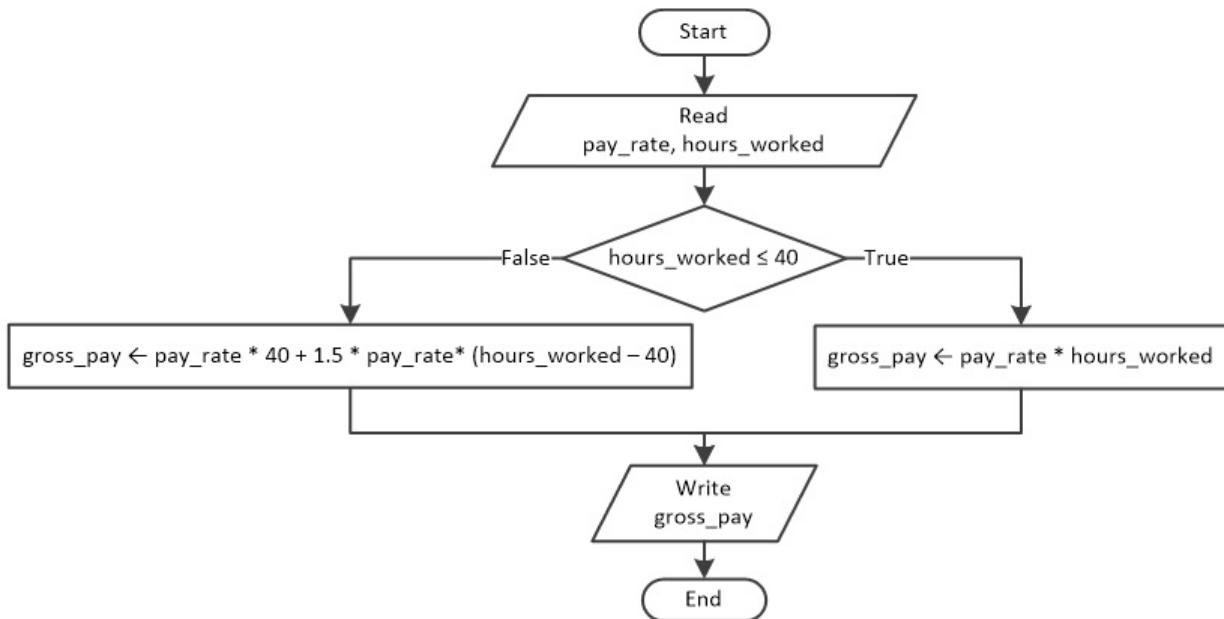
the hours worked and then calculates and displays the gross pay.

## Solution

This exercise can be solved using the dual-alternative decision structure. When the hours worked are over 40, the gross pay is calculated as follows:

$$\text{gross pay} = (\text{pay rate}) \times 40 + 1.5 \times (\text{pay rate}) \times (\text{all hours worked over 40})$$

The flowchart that solves this problem is shown here.



and the C# program is shown here.

### project\_17\_1\_5

```
static void Main(string[] args) {
    int hours_worked;
    double pay_rate, gross_pay;

    pay_rate = Double.Parse(Console.ReadLine());
    hours_worked = Int32.Parse(Console.ReadLine());

    if (hours_worked <= 40) {
        gross_pay = pay_rate * hours_worked;
    }
    else {
        gross_pay = pay_rate * 40 + 1.5 * pay_rate * (hours_worked - 40);
    }

    Console.WriteLine("Gross Pay: " + gross_pay);
```

| }

## 17.2 Review Questions: True/False

Choose **true** or **false** for each of the following statements.

1. It is possible that none of the statements enclosed in a dual-alternative decision structure will be executed.
2. The dual-alternative decision structure must include at least two statements.
3. The dual-alternative decision structure uses the reserved keyword **else**.
4. The statement

| **int else = 5;**

is syntactically correct.

5. In a dual-alternative decision structure, the evaluated Boolean expression can return more than two values.
6. The following code fragment satisfies the property of effectiveness.

```
| int x, y, z;

| x = Int32.Parse(Console.ReadLine());
| y = Int32.Parse(Console.ReadLine());
| z = Int32.Parse(Console.ReadLine());

| if (x > y && x > z) {
|   Console.WriteLine("Value " + x + " is the greatest one");
| }
| else {
|   Console.WriteLine("Value " + y + " is the greatest one");
| }
```

## 17.3 Review Questions: Multiple Choice

Select the correct answer for each of the following statements.

1. The dual-alternative decision structure includes a statement or block of statements on
  - a. the false path only.
  - b. both paths.
  - c. the true path only.
2. In the following code fragment,

```
if (x % 2 == 0) {  
    x = 0;  
}  
else {  
    y++;  
}
```

the statement `y++` is executed when

- a. variable `x` is exactly divisible by 2.
- b. variable `x` contains an even number.
- c. variable `x` contains an odd number.
- d. none of the above

3. In the following code fragment,

```
if (x == 3)  
    x = 5;  
else  
    x = 7;  
y++;
```

the statement `y++` is executed

- a. when variable `x` contains a value of 3.
- b. when variable `x` contains a value other than 3.
- c. both of the above

## 17.4 Review Exercises

Complete the following exercises.

1. Create a trace table to determine the values of the variables in each step of the next C# program for two different executions. Then, design the corresponding flowchart.

The input values for the two executions are (i) 3, and (ii) 0.5.

```
static void Main(string[] args) {  
    double a, z, y;  
  
    a = Double.Parse(Console.ReadLine());  
    z = a * 3 - 2;  
    if (z >= 1) {  
        y = 6 * a;  
    }  
    else {
```

```

        z++;
        y = 6 * a + z;
    }
    Console.WriteLine(z + ", " + y);
}

```

2. Create a trace table to determine the values of the variables in each step of the next C# program. Then, design the corresponding flowchart.

```

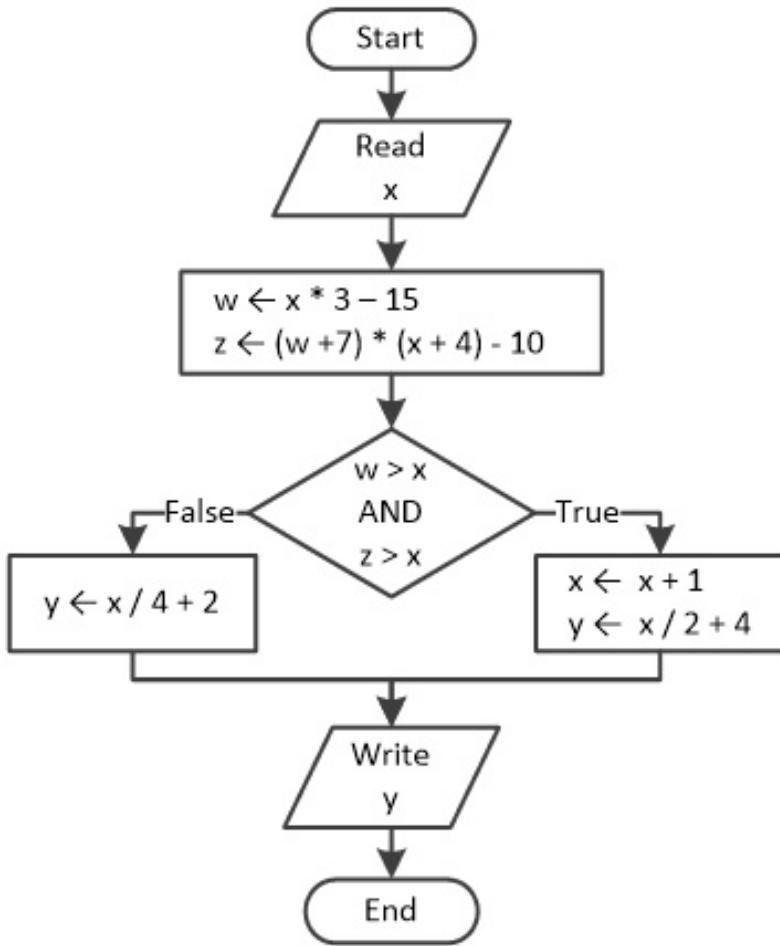
static void Main(string[] args) {
    double x, y, z;

    x = 3;
    y = Math.Pow(x, 3) + 9;
    z = 2 * x + y - 4;
    if (x > y) {
        y = z % x;
        z = Math.Sqrt(x);
    }
    else {
        x = z % y;
        z = Math.Sqrt(y);
    }
    Console.WriteLine(x + ", " + y + ", " + z);
}

```

3. Write the C# program that corresponds to the following flowchart and then create a trace table to determine the values of the variables in each step for two different executions.

The input values for the two executions are (i) 10, and (ii) 2.



4. Two football teams play against each other in the UEFA Champions League. Write a C# program that prompts the user to enter the names of the two teams and the goals that each team scored, and then displays the name of the winner. Assume that the user enters valid values and there is no tie (draw).
5. Write a C# program that lets the user enter an integer, and then displays a message indicating whether the given number is a multiple of 6; it must display “NN is not a multiple of 6” otherwise (where NN is the given number). Assume that the user enters a non-negative<sup>[14]</sup> value.
6. Write a C# program that lets the user enter an integer, and then displays one of two possible messages. One message indicates if the given number is a multiple of 6 or a multiple of 7; the other message indicates if the given number is neither a multiple of 6 nor a multiple of 7. Assume that the user enters a non-negative value.
7. Write a C# program that lets the user enter an integer, and then displays

a message indicating whether the given number is a multiple of 4; it must display “NN is not a multiple of 4” otherwise (where NN is the given number). Moreover, the C# program must display the structure of the given integer, including the given integer, the quotient, and any remainder. For example, if the given integer is 14, the message “ $14 = 3 \times 4 + 2$ ” must be displayed. Assume that the user enters a non-negative value.

8. Write a C# program that lets the user enter an integer, and then displays a message indicating whether the given integer is a four-digit integer; it must display “NN is not a four-digit integer” otherwise (where NN is the given number). Assume that the user enters a non-negative value.

Hint: Four-digit integers are between 1000 and 9999.

9. Design a flowchart and write the corresponding C# program that lets the user enter two values, and then determines and displays the smaller of the two values. Assume that the user enters two different values.
10. Write a C# program that lets the user enter three numbers, and then displays a message indicating whether the given numbers can be lengths of the three sides of a triangle; it must display “Given numbers cannot be lengths of the three sides of a triangle” otherwise. Assume that the user enters valid values.

Hint: In any triangle, the length of each side is less than the sum of the lengths of the other two sides.

11. Write a C# program that lets the user enter three numbers, and then displays a message indicating whether the given numbers can be lengths of the three sides of a right triangle (or right-angled triangle); it must display “Given numbers cannot be lengths of the three sides of a right triangle” otherwise. Assume that the user enters valid values.

Hint 1: Use the Pythagorean theorem.

Hint 2: You can use lengths of 3, 4 and 5 (which can be lengths of the three sides of a right triangle) to test your program.

12. Athletes in the long jump at the Olympic Games in Athens in 2004 participated in three different qualifying jumps. An athlete, in order to qualify, has to achieve an average jump distance of at least 8 meters. Write a C# program that prompts the user to enter the three performances, and then displays the message “Qualified” when the

average value is greater than or equal to 8 meters; it displays “Disqualified” otherwise. Assume that the user enters valid values.

13. Gross pay depends on the pay rate and the total number of hours worked per week. However, if someone works more than 40 hours, he or she gets paid double for all hours worked over 40. Design a flowchart and write the corresponding C# program that lets the user enter the pay rate and hours worked and then calculates and displays net pay. Net pay is the amount of pay that is actually paid to the employee after any deductions. Deductions include taxes, health insurance, retirement plans, on so on. Assume a total deduction of 30% and that the user enters valid values.
14. Regular servicing will keep your vehicle more reliable, reducing the chance of breakdowns, inconvenience and unnecessary expenses. In general, there are two types of service you need to perform:
  - a. a minor service every 6000 miles
  - b. a major service every 12000 milesWrite a C# program that prompts the user to enter the miles traveled, and then calculates and displays how many miles are left until the next service, as well as the type of the next service. Assume that the user enters a valid value.
15. Two cars start from rest and move with a constant acceleration along a straight horizontal road for a given time. Write a C# program that prompts the user to enter the time the two cars traveled (same for both cars) and the acceleration for each one of them, and then calculates and displays the distance between them as well as a message “Car A is first” or “Car B is first” depending on which car is leading the race. The required formula is

$$S = u_o + \frac{1}{2}at^2$$

Assume that the acceleration values entered are different from each other. Also assume that the user enters valid values.

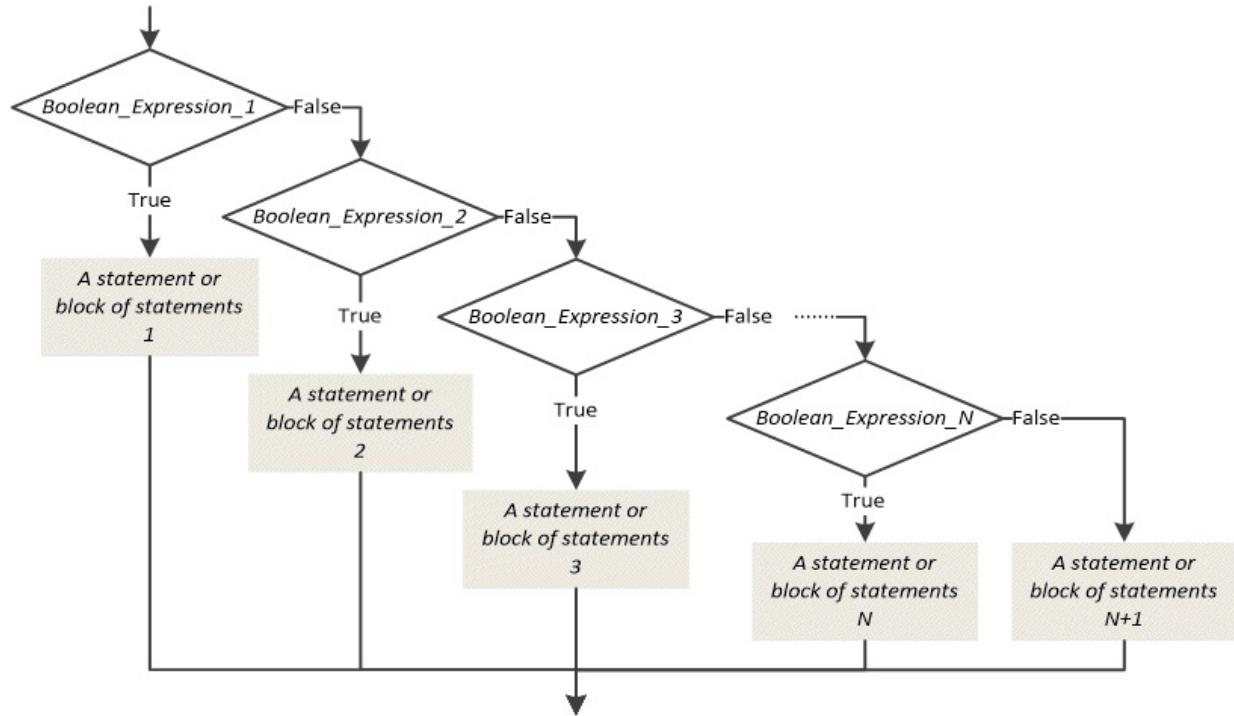
# Chapter 18

## The Multiple-Alternative Decision Structure

---

### 18.1 The Multiple-Alternative Decision Structure

The multiple-alternative decision structure is used to expand the number of alternatives, as shown in the following flowchart fragment.



When a multiple-alternative decision structure is executed, *Boolean Expression\_1* is evaluated. If *Boolean Expression\_1* evaluates to true, the corresponding statement or block of statements that immediately follows it is executed; then the rest of the structure is skipped, continuing to any remaining statements that may exist **after** the multiple-alternative decision structure. However, if *Boolean Expression\_1* evaluates to false, the flow of execution evaluates *Boolean Expression\_2*. If it evaluates to true, the corresponding statement or block of statements that immediately follows it is executed and the rest of the structure is skipped. This process continues until one Boolean expression evaluates to true or until no more Boolean expressions are left.

The last statement or block of statements *N+1* is executed when none of the previous Boolean expressions has evaluated to true. Moreover, this last

statement or block of statements  $N + 1$  is optional and can be omitted. It depends on the algorithm you are trying to solve.

The general form of the C# statement is

```
if (Boolean_Expression_1) {  
    A statement or block of statements 1  
}  
else if (Boolean_Expression_2) {  
    A statement or block of statements 2  
}  
else if (Boolean_Expression_3) {  
    A statement or block of statements 3  
}  
.  
. .  
  
else if (Boolean_Expression_N) {  
    A statement or block of statements N  
}  
else {  
    A statement or block of statements N+1  
}
```

A simple example is shown here.

### project\_18\_1

```
static void Main(string[] args) {  
    string name;  
  
    Console.WriteLine("What is your name? ");  
    name = Console.ReadLine();  
  
    if (name == "John") {  
        Console.WriteLine("You are my cousin!");  
    }  
    else if (name == "Aphrodite") {  
        Console.WriteLine("You are my sister!");  
    }  
    else if (name == "Loukia") {  
        Console.WriteLine("You are my mom!");  
    }  
}
```

```

    }
    else {
        Console.WriteLine("Sorry, I don't know you.");
    }
}

```

### Exercise 18.1-1 Trace Tables and Multiple-Alternative Decision Structures

Create a trace table to determine the values of the variables in each step for three different executions of the next C# program.

The input values for the three executions are (i) 5, 8; (ii) -13, 0; and (iii) 1, -1.

#### project\_18\_1\_1

```

static void Main(string[] args) {
    int a, b;

    a = Int32.Parse(Console.ReadLine());
    b = Int32.Parse(Console.ReadLine());

    if (a > 3)
        Console.WriteLine("Message #1");
    else if (a > 4 && b <= 10) {
        Console.WriteLine("Message #2");
        Console.WriteLine("Message #3");
    }
    else if (a * 2 == -26) {
        Console.WriteLine("Message #4");
        Console.WriteLine("Message #5");
        b++;
    }
    else if (b == 1)
        Console.WriteLine("Message #6");
    else {
        Console.WriteLine("Message #7");
        Console.WriteLine("Message #8");
    }

    Console.WriteLine("The end!");
}

```



Note that you can use braces {} only when necessary.

### Solution

- i. For the input values of 5 and 8, the trace table looks like this.

Step	Statement	Notes	a	b
1	<code>a = Int32.Parse(...)</code>	User enters the value 5	5	?
2	<code>b = Int32.Parse(...)</code>	User enters the value 8	5	8
3	<code>if (a &gt; 3)</code>	This evaluates to true		
4	<code>.WriteLine("Message #1")</code>	It displays: Message #1		
5	<code>.WriteLine("The end!")</code>	It displays: The end!		

 Note that even though the second Boolean expression (`a > 4 && b <= 10`) could also have evaluated to true, it was never checked.

- ii. For the input values of -13 and 0, the trace table looks like this.

Step	Statement	Notes	a	b
1	<code>a = Int32.Parse(...)</code>	User enters the value -13	-13	?
2	<code>b = Int32.Parse(...)</code>	User enters the value 0	-13	0
3	<code>if (a &gt; 3)</code>	This evaluates to false		
4	<code>else if (a &gt; 4 &amp;&amp; b &lt;= 10)</code>	This evaluates to false		
5	<code>else if (a * 2 == -26)</code>	This evaluates to true		
6	<code>.WriteLine("Message #4")</code>	It displays: Message #4		
7	<code>.WriteLine("Message #5")</code>	It displays: Message #5		
8	<code>b++</code>		-13	1
9	<code>.WriteLine("The end!")</code>	It displays: The end!		

 Note that after step 8 the fourth Boolean expression (`b == 1`) could also have evaluated to true, but it was never checked.

- iii. For the input values of 1 and -1, the trace table looks like this.

Step	Statement	Notes	a	b

1	<code>a = Int32.Parse(...)</code>	User enters the value 1	1	?	
2	<code>b = Int32.Parse(...)</code>	User enters the value -1	1	-1	
3	<code>if (a &gt; 3)</code>	This evaluates to false			
4	<code>else if (a &gt; 4 &amp;&amp; b &lt;= 10)</code>	This evaluates to false			
5	<code>else if (a * 2 == -26)</code>	This evaluates to false			
6	<code>else if (b == 1)</code>	This evaluates to false			
7	<code>.WriteLine("Message #7")</code>	It displays: Message #7			
8	<code>.WriteLine("Message #8")</code>	It displays: Message #8			
9	<code>.WriteLine("The end!")</code>	It displays: The end!			

### ***Exercise 18.1-2 Counting the Digits***

---

*Write a C# program that prompts the user to enter an integer between 0 and 999 and then counts its total number of digits. In the end, a message “You entered a N-digit number” must be displayed, where N is the total number of digits. Assume that the user enters a valid integer between 0 and 999.*

### ***Solution***

---

You may be trying to figure out how to solve this exercise using DIV operations. You are probably thinking of dividing the given integer by 10 and checking whether the integer quotient is 0. If it is, this means that the given integer is a one-digit integer. And you can divide it by 100, or by 1000 to check for two-digit and three-digit integers correspondingly. Your thinking is partly true!

The following multiple-alternative decision structure depicts your thoughts.

```
if ((int)(x / 10) == 0)
    digits = 1;
else if ((int)(x / 100) == 0)
    digits = 2;
else if ((int)(x / 1000) == 0)
    digits = 3;
```

If the given integer (in variable x) has one digit, the first Boolean expression evaluates to true and the rest of the Boolean expressions are never checked! If the given integer has two digits, the first Boolean expression evaluates to

false, the second one evaluates to true, and the last one is never checked! And finally, if the given integer has three digits, the first two Boolean expressions evaluate to false and the last one evaluates to true!

So, you may now wonder where the problem is.

What if the wording of the exercise was “*Write a C# program that prompts the user to enter an integer and displays a message when the given integer has two digits*”. Probably you would do something such as the following:

```
Console.WriteLine("Enter an integer: ");
x = Int32.Parse(Console.ReadLine());

if ((int)(x / 100) == 0)
    Console.WriteLine("A 2-digit integer entered");
```

The Boolean expression `((int)(x / 100) == 0)` works perfectly well for all given integers that have two digits or more. If the given integer has two digits, it evaluates to true and if the given integer has three digits or more, it evaluates to false. “*Problem solved!*” you may say. But is it really? What about a one-digit integer? Does this Boolean expression evaluate to false? Unfortunately not!

The solution is much easier than you would probably believe! What is the smallest two-digit integer that you can think of? It is 10, right? And what is the greatest one that you can think of? It is 99, right? So, the proper solution is as follows.

```
Console.WriteLine("Enter an integer: ");
x = Int32.Parse(Console.ReadLine());

if (x >= 10 && x <= 99)
    Console.WriteLine("A 2-digit integer entered");
```

And the complete solution to the exercise is as follows!

### project\_18\_1\_2a

```
static void Main(string[] args) {
    int x, digits;

    Console.WriteLine("Enter an integer (0 - 999): ");
    x = Int32.Parse(Console.ReadLine());

    if (x >= 0 && x <= 9) {
        digits = 1;
    }
```

```

    else if (x >= 10 && x <= 99) {
        digits = 2;
    }
    else {
        digits = 3;
    }

    Console.WriteLine("You entered a " + digits + "-digit number");
}

```

Since the wording of this exercise assumes that the user enters a valid integer between 0 and 999, the program should not include checking the validity of data input. However, if you wish to make your program even better and display an error message to the user when he or she enters a value that is not between 0 and 999, you can do something like this:

### project\_18\_1\_2b

```

static void Main(string[] args) {
    int x;

    Console.Write("Enter an integer (0 - 999): ");
    x = Int32.Parse(Console.ReadLine());

    if (x >= 0 && x <= 9) {
        Console.WriteLine("A 1-digit integer entered");
    }
    else if (x >= 10 && x <= 99) {
        Console.WriteLine("A 2-digit integer entered ");
    }
    else if (x >= 100 && x <= 999) {
        Console.WriteLine("A 3-digit integer entered ");
    }
    else {
        Console.WriteLine("Wrong integer");
    }
}

```

## 18.2 Review Questions: True/False

Choose **true** or **false** for each of the following statements.

1. The multiple-alternative decision structure is used to expand the number of alternatives.
2. The multiple-alternative decision structure can have at most three

alternatives.

3. In a multiple-alternative decision structure, once a Boolean expression evaluates to true, the next Boolean expression is also evaluated.
4. In a multiple-alternative decision structure, the last statement or block of statements N+1 (appearing below the else C# keyword) is always executed.
5. In a multiple-alternative decision structure, the last statement or block of statements N+1 (appearing below the else C# keyword) is executed when at least one of the previous Boolean expressions has evaluated to true.
6. In a multiple-alternative decision structure, the last statement or block of statements N+1, and by extension the else C# keyword, can be omitted.
7. In the following code fragment, the statement y++ is executed only when variable a contains a value other than 1, 2, or 3.

```
if (a == 1)
    x += 5;
else if (a == 2)
    x -= 2;
else if (a == 3)
    x -= 9;
else
    x += 3;
y++;
```

8. In the code fragment of the previous exercise, the statement x += 3 is executed only when variable a contains a value other than 1, 2, or 3.

### 18.3 Review Exercises

Complete the following exercises.

1. Create a trace table to determine the values of the variables in each step for four different executions of the next C# program.

The input values for the four executions are (i) 5, (ii) 150, (iii) 250, and (iv) -1.

```
static void Main(string[] args) {
    int q, b;

    q = Int32.Parse(Console.ReadLine());
```

```

    if (q > 0 && q <= 50) {
        b = 1;
    }
    else if (q > 50 && q <= 100) {
        b = 2;
    }
    else if (q > 100 && q <= 200) {
        b = 3;
    }
    else {
        b = 4;
    }
    Console.WriteLine(b);
}

```

2. Create a trace table to determine the values of the variables in each step for three different executions of the next C# program.

The input values for the three executions are (i) 5, (ii) 150, and (iii) -1.

```

static void Main(string[] args) {
    double amount, discount, payment;

    amount = Double.Parse(Console.ReadLine());
    discount = 0;

    if (amount < 20) {
        discount = 0;
    }
    else if (amount >= 20 && amount < 60) {
        discount = 5;
    }
    else if (amount >= 60 && amount < 100) {
        discount = 10;
    }
    else if (amount >= 100) {
        discount = 15;
    }
    payment = amount - amount * discount / 100;

    Console.WriteLine(discount + ", " + payment);
}

```

3. Write the following C# program using correct indentation.

```

static void Main(string[] args) {
double a, y;

```

```
a = Double.Parse(Console.ReadLine());  
  
if (a < 1) {  
    y = 5 + a;  
    Console.WriteLine(y);  
}  
else if (a < 5) {  
    y = 23 / a;  
    Console.WriteLine(y);  
}  
else if (a < 10) {  
    y = 5 * a;  
    Console.WriteLine(y);  
}  
else {  
    Console.WriteLine("Error!");  
}  
}
```

4. Two football teams play against each other in the UEFA Champions League. Write a C# program that prompts the user to enter the names of the two teams and the goals each team scored and then displays the name of the winner or the message “It's a tie!” when both teams score equal number of goals. Assume that the user enters valid values.
5. Design a flowchart and write the corresponding C# program that lets the user enter an integer between –9999 and 9999, and then counts its total number of digits. In the end, a message “You entered a N-digit number” is displayed, where N is the total number of digits. Assume that the user enters a valid integer between –9999 and 9999.
6. Rewrite the C# program of the previous exercise to validate the data input. An error message must be displayed when the user enters an invalid value.
7. Write a C# program that displays the following menu:
  1. Convert USD to Euro (EUR)
  2. Convert USD to British Pound Sterling (GBP)
  3. Convert USD to Japanese Yen (JPY)
  4. Convert USD to Canadian Dollar (CAD)

It then prompts the user to enter a choice (of 1, 2, 3, or 4) and an

amount in US dollars and calculates and displays the required value. Assume that the user enters valid values. It is given that

- \$1 = 0.87 EUR (€)
  - \$1 = 0.78 GBP (£)
  - \$1 = ¥ 108.55 JPY
  - \$1 = 1.33 CAD (\$)
8. Write a C# program that prompts the user to enter the number of a month between 1 and 12, and then displays the corresponding season. Assume that the user enters a valid value. It is given that
    - Winter includes months 12, 1, and 2
    - Spring includes months 3, 4, and 5
    - Summer includes months 6, 7, and 8
    - Fall (Autumn) includes months 9, 10, and 11
  9. Rewrite the C# program of the previous exercise to validate the data input. An error message must be displayed when the user enters an invalid value.
  10. Write a C# program that prompts the user to enter a number between 1.0 and 4.9, and then displays the number as English text. For example, for the number 2.3, it must display “Two point three”. Assume that the user enters a valid value. Try not to check each real number individually (1.0, 1.1, 1.2, ... 4.9). Find a more clever way!
  11. The most popular and commonly used grading system in the United States uses discrete evaluation in the form of letter grades. Design a flowchart and write the corresponding C# program that prompts the user to enter a letter between A and F, and then displays the corresponding percentage according to the following table.

Grade	Percentage
A	90 - 100
B	80 - 89
C	70 - 79
D	60 - 69

E / F 0 - 59

Assume that the user enters a valid value.

# Chapter 19

## The Case Decision Structure

---

### 19.1 The Case Decision Structure

The *case decision structure* is a simplified version of the multiple-alternative decision structure. It helps you write code faster and increases readability, especially for algorithms that require complex combinations of decision structures. The case decision structure is used to expand the number of alternatives in the same way as the multiple-alternative decision structure does.

The general form of the C# statement is

```
switch (a variable or an expression to evaluate) {
    case value-1:
        A statement or block of statements 1
        break;
    case value-2:
        A statement or block of statements 2
        break;
    case value-3:
        A statement or block of statements 3
        break;
    .
    .
    .
    case value-N:
        A statement or block of statements N
        break;
    default:
        A statement or block of statements N+1
        break;
}
```

 The last statement or last block of statements  $N + 1$  is optional and can be omitted (you need to omit the keyword `default` and the corresponding `break` statement as well).

 Note that in C# the switch statement works only with certain data types such as bool, sbyte, byte, short, ushort, int, uint, long, ulong, char, or string.

 You cannot always use a case decision structure instead of a multiple-alternative decision structure. In a case decision structure the evaluated variable or expression is written once, which means that this same variable or expression is evaluated in all cases. In a multiple-alternative decision structure, however, the evaluated variable or expression can be different in each case.

An example that uses the case decision structure is shown here.

### project\_19\_1

```
static void Main(string[] args) {
    string name;

    Console.WriteLine("What is your name? ");
    name = Console.ReadLine();

    switch (name) {
        case "John":
            Console.WriteLine("You are my cousin!");
            break;
        case "Aphrodite":
            Console.WriteLine("You are my sister!");
            break;
        case "Loukia":
            Console.WriteLine("You are my mom!");
            break;
        default:
            Console.WriteLine("Sorry, I don't know you.");
            break;
    }
}
```

#### Exercise 19.1-1 The Days of the Week

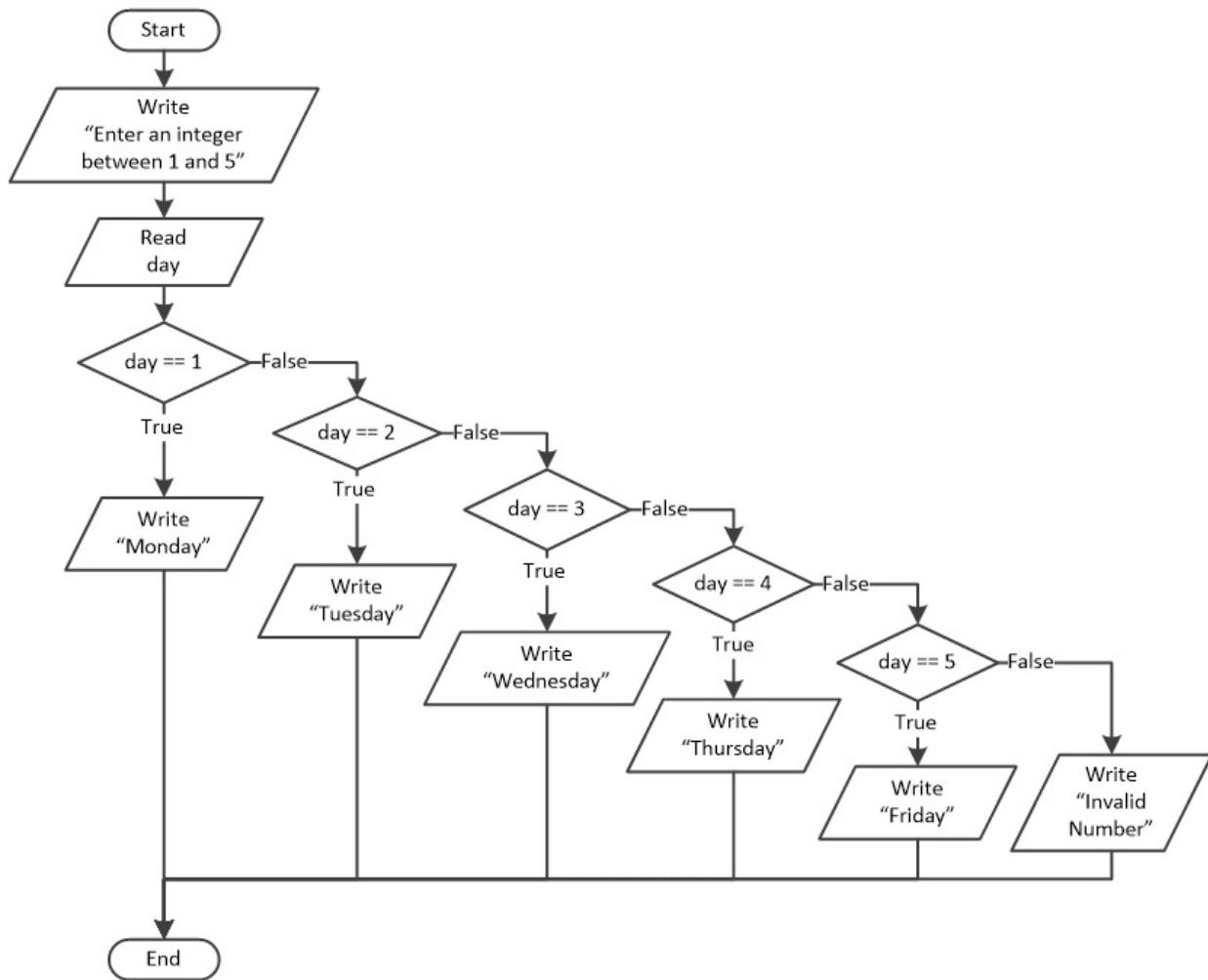
Write a C# program that prompts the user to enter an integer between 1 and 5, and then displays the corresponding work day (Monday, Tuesday, Wednesday, Thursday, or Friday). If the value entered is invalid, an error message must be displayed.

#### Solution

This C# program can be written using either a multiple-alternative decision structure or a case decision structure. Let's try them both!

## First Approach – Using a multiple-alternative decision structure

The flowchart is as follows.



and the corresponding C# program is shown here.

### project\_19\_1\_1a

```
static void Main(string[] args) {
    int day;

    Console.WriteLine("Enter an integer between 1 and 5: ");
    day = Int32.Parse(Console.ReadLine());

    if (day == 1) {
        Console.WriteLine("Monday");
    }
}
```

```

    else if (day == 2) {
        Console.WriteLine("Tuesday");
    }
    else if (day == 3) {
        Console.WriteLine("Wednesday");
    }
    else if (day == 4) {
        Console.WriteLine("Thursday");
    }
    else if (day == 5) {
        Console.WriteLine("Friday");
    }
    else {
        Console.WriteLine("Invalid Number");
    }
}

```

## Second Approach – Using a case decision structure

### project\_19\_1\_1b

```

static void Main(string[] args) {
    int day;

    Console.Write("Enter an integer between 1 and 5: ");
    day = Int32.Parse(Console.ReadLine());

    switch (day) {
        case 1:
            Console.WriteLine("Monday");
            break;
        case 2:
            Console.WriteLine("Tuesday");
            break;
        case 3:
            Console.WriteLine("Wednesday");
            break;
        case 4:
            Console.WriteLine("Thursday");
            break;
        case 5:
            Console.WriteLine("Friday");
            break;
        default:
            Console.WriteLine("Invalid Number");
            break;
    }
}

```

| }

## 19.2 Review Questions: True/False

Choose **true** or **false** for each of the following statements.

1. The case decision structure is used to expand the number of alternatives.
2. The case decision structure can always be used instead of a multiple-alternative decision structure.
3. The case decision structure can have as many alternatives as the programmer wishes.
4. In a case decision structure, the last statement or block of statements N + 1 (appearing below the `default` C# keyword) is always executed.
5. In a case decision structure, the last statement or block of statements N + 1 (appearing below the `default` C# keyword) is executed when none of the previous cases has evaluated to `true`.
6. The last statement or block of statements N + 1, as well as the `default` keyword and the corresponding `break` statement, cannot be omitted.
7. In the following C# program,

```
switch (a) {  
    case 1: x = x + 5; break;  
    case 2: x = x - 2; break;  
    case 3: x = x - 9; break;  
    default: x = x + 3; y++; break;  
}
```

the statement `y++` is executed only when variable `a` contains a value other than 1, 2, or 3.

## 19.3 Review Exercises

Complete the following exercises.

1. Create a trace table to determine the values of the variables in each step of the next C# program for three different executions.

The input values for the three executions are (i) 1, (ii) 3, and (iii) 250.

```
static void Main(string[] args) {  
    int a, x, y;  
  
    a = Int32.Parse(Console.ReadLine());
```

```

x = 0;
y = 0;
switch (a) {
    case 1: x = x + 5; y = y + 5; break;
    case 2: x = x - 2; y--; break;
    case 3: x = x - 9; y = y + 3; break;
    default: x = x + 3; y++; break;
}
Console.WriteLine(x + ", " + y);
}

```

2. Create a trace table to determine the values of the variables in each step of the next C# program for three different executions.

The input values for the three executions are (i) 10, 2, 5; (ii) 5, 2, 3; and (iii) 4, 6, 2.

```

static void Main(string[] args) {
    int a, x;
    double y;

    a = Int32.Parse(Console.ReadLine());
    x = Int32.Parse(Console.ReadLine());
    y = Double.Parse(Console.ReadLine());

    switch (a) {
        case 10:
            x = x % 2;
            y = Math.Pow(y, 2);
            break;
        case 3:
            x = x * 2;
            y--;
            break;
        case 5:
            x = x + 4;
            y += 7;
            break;
        default:
            x -= 3;
            y++;
            break;
    }
    Console.WriteLine(x + ", " + y);
}

```

3. Write a C# program that prompts the user to enter the name of a month, and then displays the corresponding number (1 for January, 2 for February, and so on). If the value entered is invalid, an error message must be displayed.
  4. Write a C# program that displays the following menu:
    1. Convert Miles to Yards
    2. Convert Miles to Feet
    3. Convert Miles to Inches
- It then prompts the user to enter a choice (of 1, 2, or 3) and a distance in miles. Then, it calculates and displays the required value. Assume that the user enters a valid value for the distance. However, if the choice entered is invalid, an error message must be displayed. It is given that
- 1 mile = 1760 yards
  - 1 mile = 5280 feet
  - 1 mile = 63360 inches
5. Roman numerals are shown in the following table.

Number	Roman Numeral
1	I
2	II
3	III
4	IV
5	V
6	VI
7	VII
8	VIII
9	IX
10	X

Write a C# program that prompts the user to enter a Roman numeral

between I and X, and then displays the corresponding number. However, if the choice entered is invalid, an error message must be displayed.

6. An online CD shop awards points to its customers based on the total number of audio CDs purchased each month. The points are awarded as follows:
  - If the customer purchases 1 CD, he or she is awarded 3 points.
  - If the customer purchases 2 CDs, he or she is awarded 10 points.
  - If the customer purchases 3 CDs, he or she is awarded 20 points.
  - If the customer purchases 4 CDs or more, he or she is awarded 45 points.

Write a C# program that prompts the user to enter the total number of CDs that he or she has purchased in a month, and then displays the number of points awarded. Assume that the user enters a valid value.

7. Write a C# program that prompts the user to enter his or her name, and then displays "Good morning NN" or "Good evening NN" or "Good night NN", where NN is the name of the user. The message to be displayed must be chosen randomly.
8. Write a C# program that lets the user enter a word such as "zero", "one" or "two", and then converts it into the corresponding digit, such as 0, 1, or 2. This must be done for the numbers 0 to 9. Display "I don't know this number!" when the user enters an unknown.
9. The Beaufort<sup>[15]</sup> scale is an empirical measure that relates wind speed to observed conditions on land or at sea. Write a C# program that prompts the user to enter the Beaufort number, and then displays the corresponding description from the following table. However, if the number entered is invalid, an error message must be displayed.

Beaufort Number	Description
0	Calm
1	Light air
2	Light breeze
3	Gentle breeze

4	Moderate breeze
5	Fresh breeze
6	Strong breeze
7	Moderate gale
8	Gale
9	Strong gale
10	Storm
11	Violent storm
12	Hurricane force

# Chapter 20

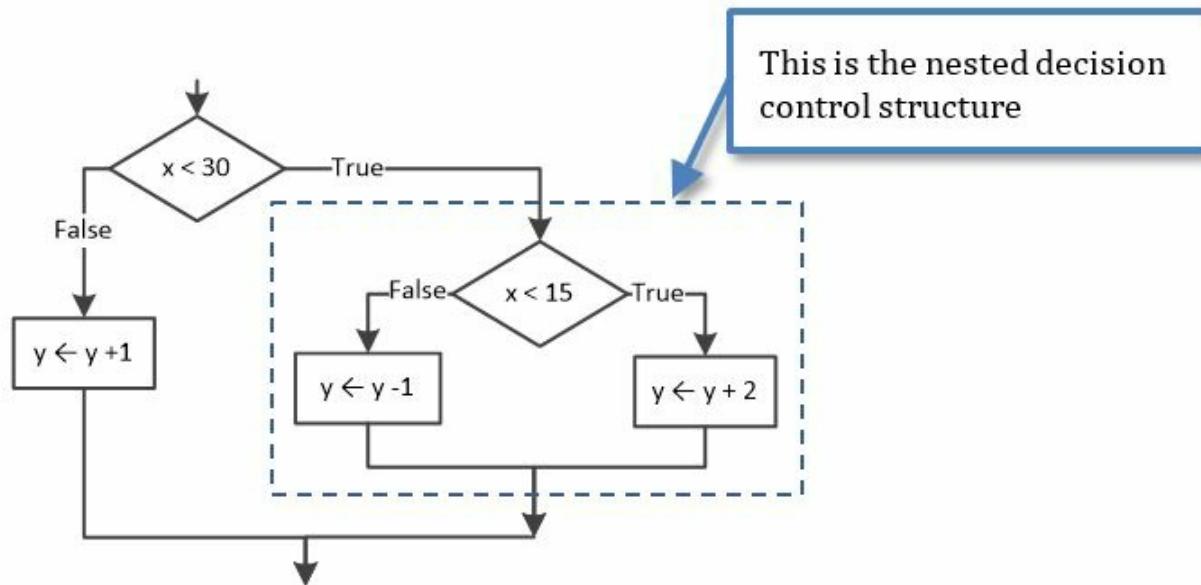
## Nested Decision Control Structures

---

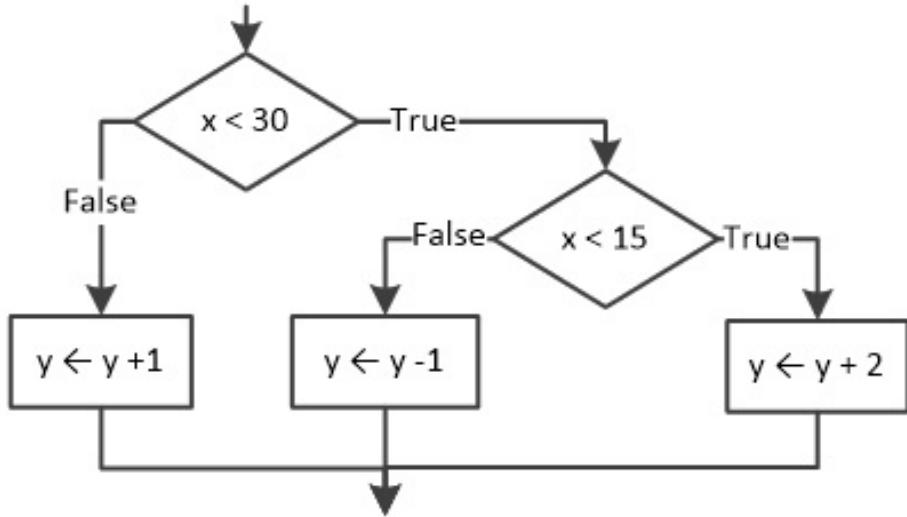
### 20.1 What are Nested Decision Control Structures?

*Nested decision control structures* are decision control structures that are “nested” (enclosed) within another decision control structure. This means that one decision control structure can nest (enclose) another decision control structure (which then becomes the “nested” decision control structure). In turn, that nested decision control structure can enclose another decision structure, and so on.

An example of a nested decision control structure is shown here.



This can be rearranged to become



and the C# code is shown here.

```

if (x < 30) {
    if (x < 15) { [More...]
        y = y + 2;
    }
    else {
        y--;
    }
}
else {
    y++;
}

```

There are no practical limitations to how deep this nesting can go. As long as the syntax rules are not violated, you can nest as many decision control structures as you wish. For practical reasons however, as you move to three or four levels of nesting, the entire structure becomes very complex and difficult to understand.

*Complex code may lead to invalid results! Try to keep your code as simple as possible by breaking large nested decision control structures into multiple smaller ones, or by using other types of decision control structures.*

Obviously, you can nest **any** decision control structure inside **any other** decision control structure as long as you keep them syntactically and logically correct. In the next example, a multiple-alternative decision structure is nested within a dual-alternative decision structure.

## project\_20\_1

```
static void Main(string[] args) {
    int x;

    Console.WriteLine("Enter a choice: ");
    x = Int32.Parse(Console.ReadLine());

    if (x < 1 || x > 4) {
        Console.WriteLine("Invalid choice");
    }
    else {
        Console.WriteLine("Valid choice");

        switch (x) {
            case 1:
                Console.WriteLine("1st choice selected");
                break;
            case 2:
                Console.WriteLine("2nd choice selected");
                break;
            case 3:
                Console.WriteLine("3rd choice selected");
                break;
            case 4:
                Console.WriteLine("4th choice selected");
                break;
        }
    }
}
```

[More...]

 Note that keyword default is missing from the switch statement.

### Exercise 20.1-1 Trace Tables and Nested Decision Control Structures

Create a trace table to determine the values of the variables in each step of the next C# program for three different executions.

The input values for the three executions are (i) 13, (ii) 18, and (iii) 30.

## project\_20\_1\_1

```
static void Main(string[] args) {
    int x, y;

    x = Int32.Parse(Console.ReadLine());
```

```

y = 10;

if (x < 30) {
    if (x < 15) {
        y = y + 2;
    }
    else {
        y--;
    }
}
else {
    y++;
}

Console.WriteLine(y);
}

```

## **Solution**

---

- i. For the input value of 13, the trace table looks like this.

Step	Statement	Notes	x	y
1	x = Int32.Parse(...)	User enters the value 13	13	?
2	y = 10		13	10
3	if (x < 30)	This evaluates to true		
4	if (x < 15)	This evaluates to true		
5	y = y + 2		13	12
6	.WriteLine(y)	It displays: 12		

- ii. For the input value of 18, the trace table looks like this.

Step	Statement	Notes	x	y
1	x = Int32.Parse(...)	User enters the value 18	18	?
2	y = 10		18	10
3	if (x < 30)	This evaluates to true		
4	if (x < 15)	This evaluates to false		
5	y--		18	9

6	.WriteLine(y)	It displays: 9
---	---------------	----------------

iii. For the input value of 30, the trace table looks like this.

Step	Statement	Notes	x	y
1	<code>x = Int32.Parse(...)</code>	User enters the value 30	30	?
2	<code>y = 10</code>		30	10
3	<code>if (x &lt; 30)</code>	This evaluates to false		
4	<code>y++</code>		30	11
5	.WriteLine(y)	It displays: 11		

### ***Exercise 20.1-2 Positive, Negative or Zero?***

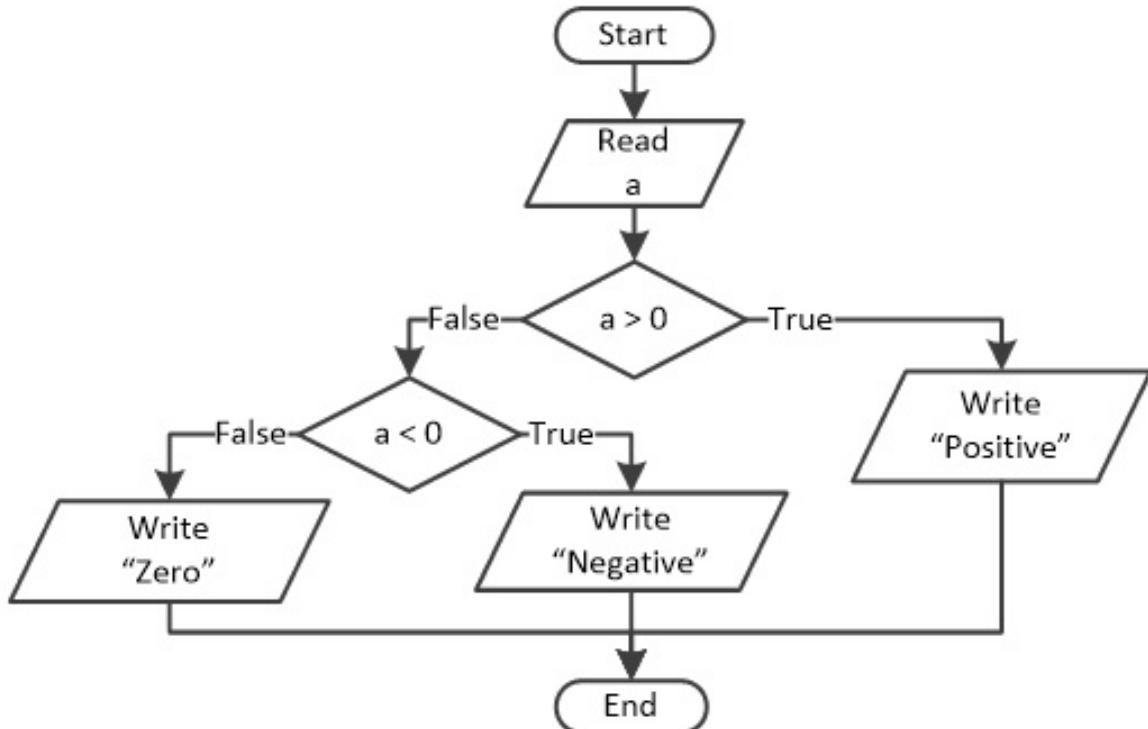
---

*Design a flowchart and write the corresponding C# program that lets the user enter a number from the keyboard and then displays the messages “Positive”, “Negative”, or “Zero” depending on whether the given value is greater than, less than, or equal to zero.*

### ***Solution***

---

The flowchart is shown here.



This C# program can be written using either a nested decision control structure or a multiple-alternative decision structure. Let's try them both!

### First approach – Using a nested decision control structure

#### project\_20\_1\_2a

```

static void Main(string[] args) {
    double a;

    a = Double.Parse(Console.ReadLine());

    if (a > 0) {
        Console.WriteLine("Positive");
    }
    else {
        if (a < 0) {
            Console.WriteLine("Negative");
        }
        else {
            Console.WriteLine("Zero");
        }
    }
}

```

### Second approach – Using a multiple-alternative decision structure

## project\_20\_1\_2b

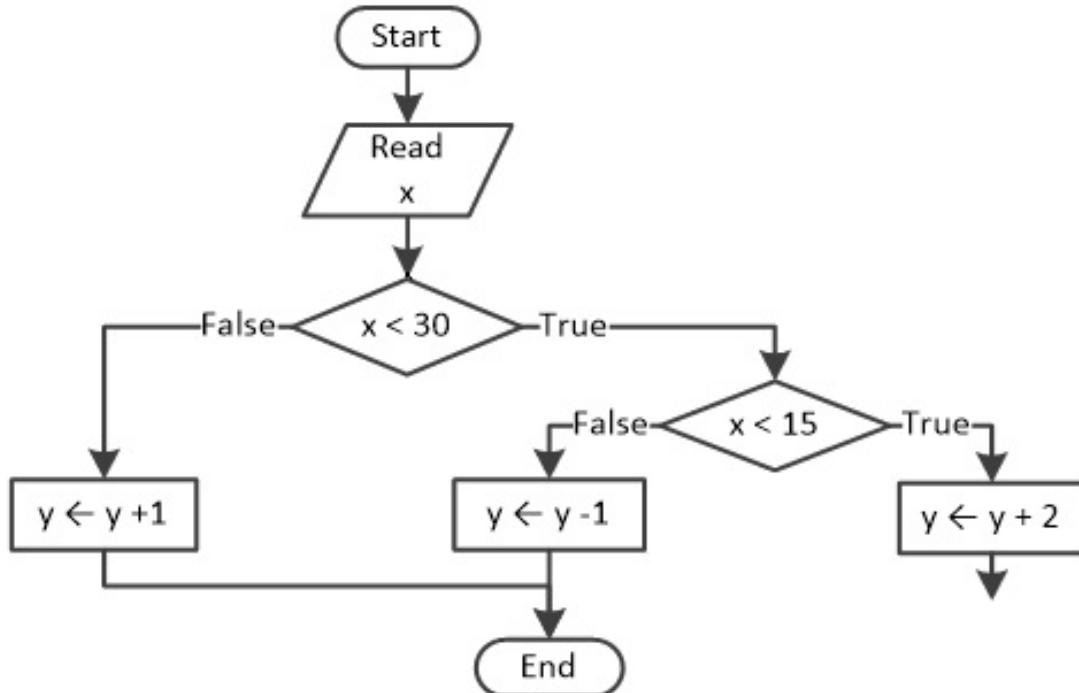
```
static void Main(string[] args) {
    double a;

    a = Double.Parse(Console.ReadLine());

    if (a > 0) {
        Console.WriteLine("Positive");
    }
    else if (a < 0) {
        Console.WriteLine("Negative");
    }
    else {
        Console.WriteLine("Zero");
    }
}
```

## 20.2 A Mistake That You Will Probably Make!

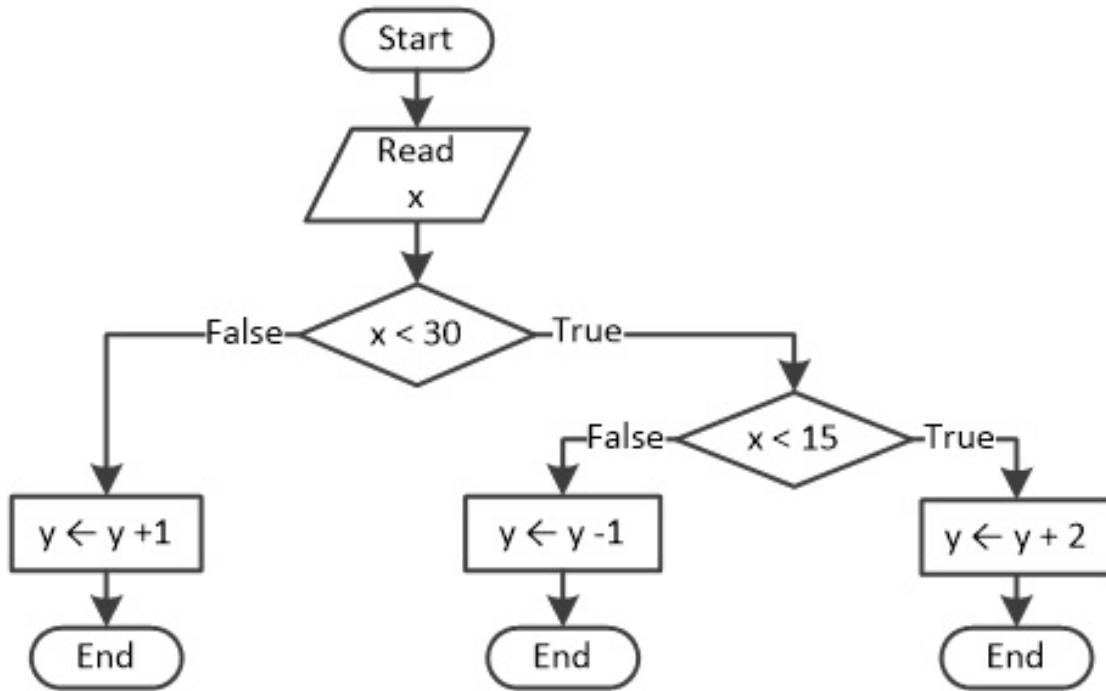
In flowcharts, a very common mistake that novice programmers make is to leave some paths unconnected, as shown in the flowchart that follows.



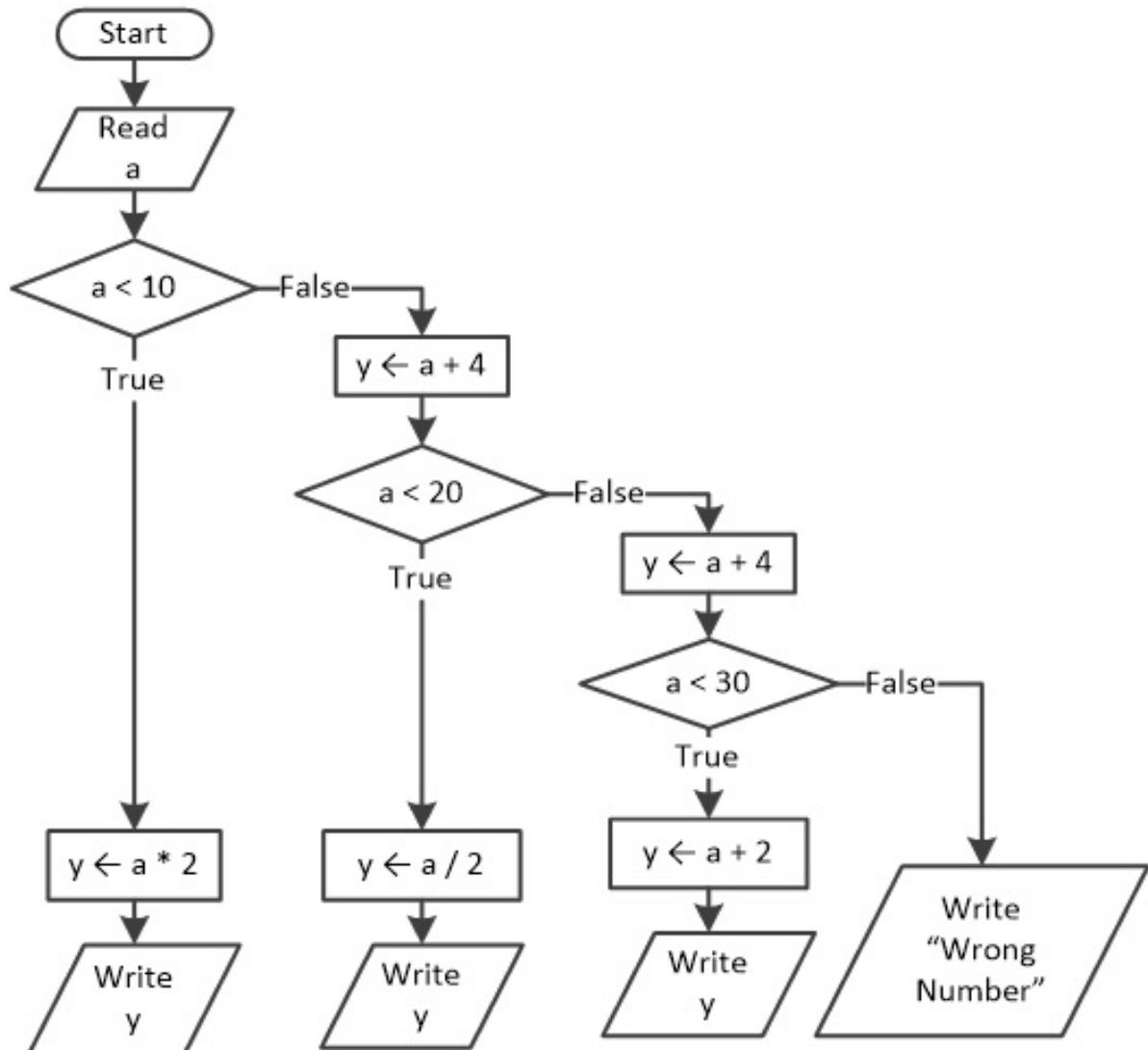
Please keep in mind that every path tries to reach the end of the algorithm, thus you cannot leave any of them unconnected.

On the other hand, try to avoid flowcharts that use many End symbols, as

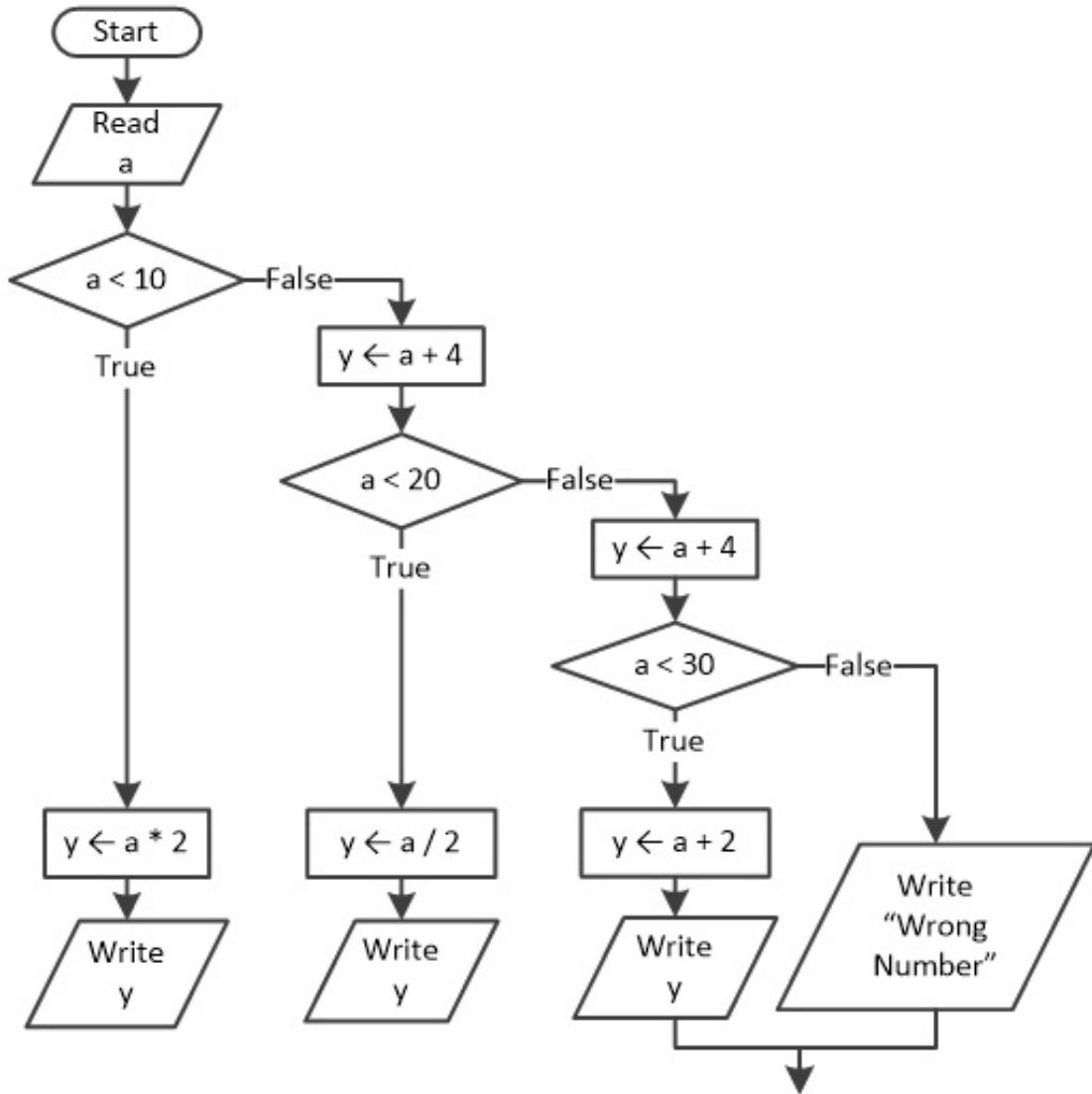
shown below, since these algorithms are difficult to read and understand.



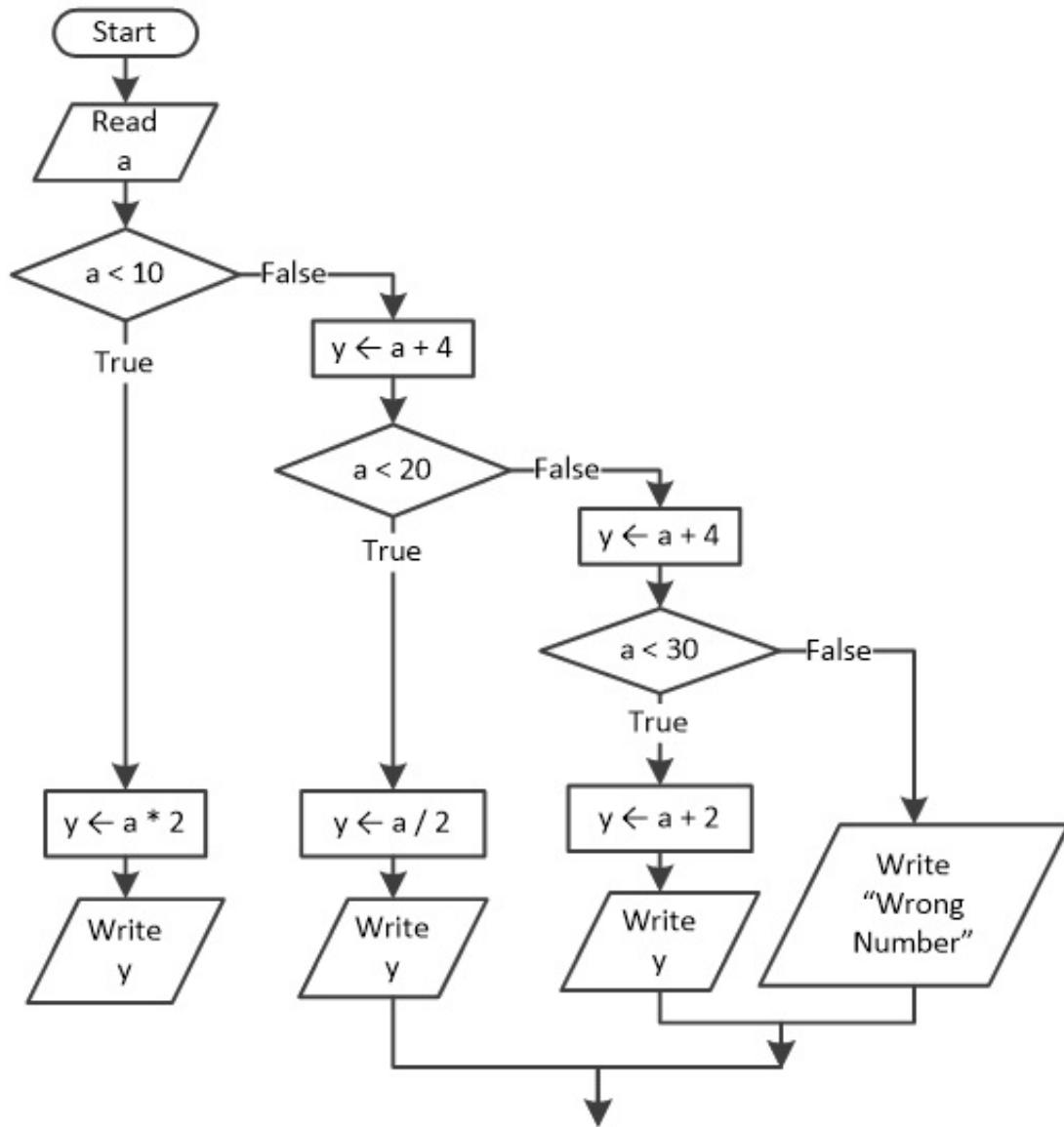
Let's say that you are in the middle of designing a flowchart (see the flowchart that follows), and you want to start closing all of its decision control structures.



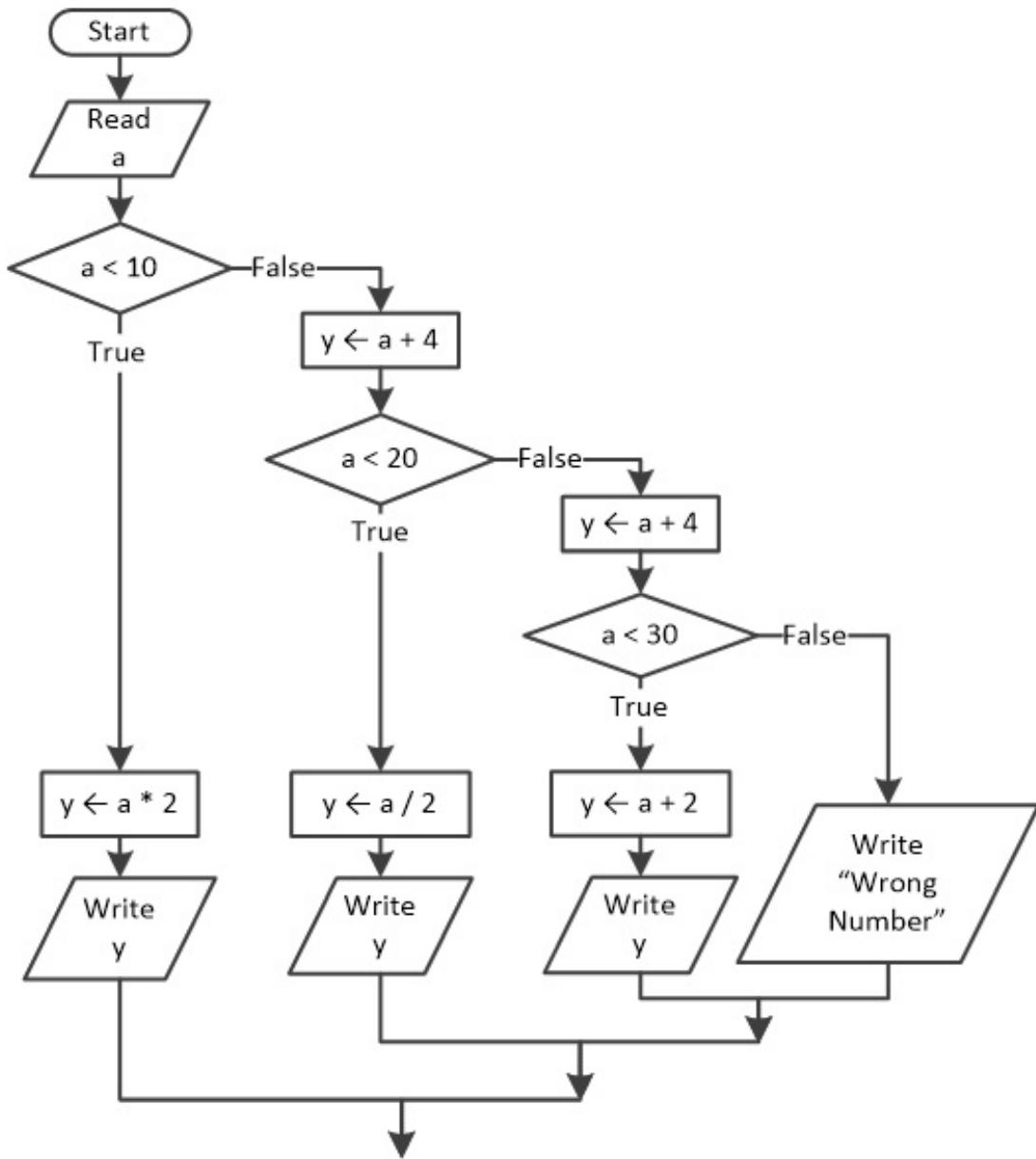
Just remember that the decision control structure that opens last must be the first one to close! In this example, the last decision control structure is the one that evaluates the expression  $a < 30$ . This is the first one that you need to close, as shown here.



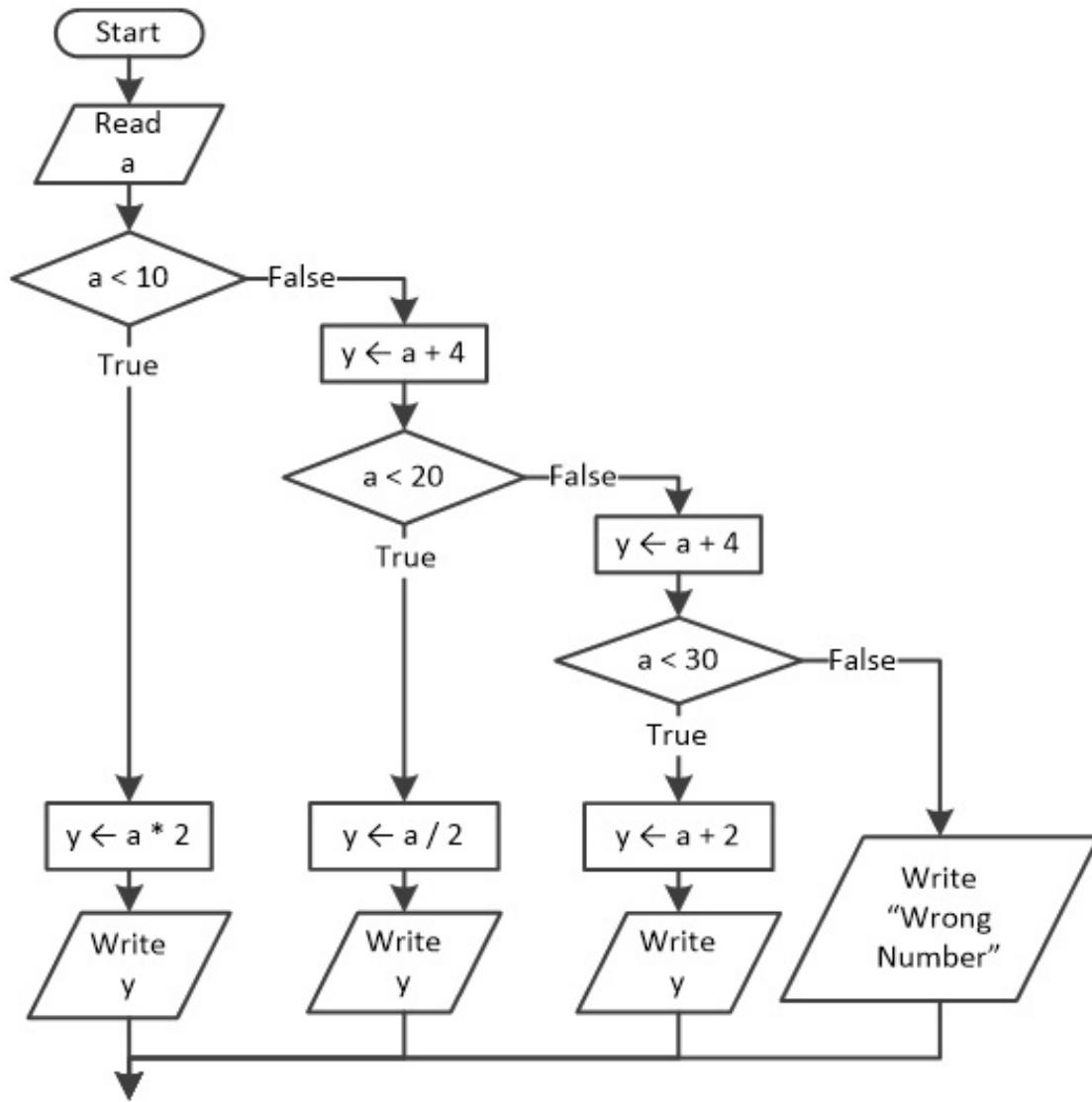
Next, you need to close the second to last decision control structure as shown here.



And finally, you need to close the third to last decision control structure as shown here.



The last flowchart can be rearranged to become like the one shown here.



## 20.3 Review Questions: True/False

Choose **true** or **false** for each of the following statements.

1. Nesting of decision control structures describes a situation in which one or more than one path of a decision control structure enclose other decision control structures.
2. Nesting level can go as deep as the programmer wishes.
3. When a problem can be solved using either a case decision structure or nested decision control structures, the second option is better because the program becomes more readable.
4. It is possible to nest a multiple-alternative decision structure within a case decision structure, but not the opposite.

- When designing flowcharts with nested decision control structures, the decision control structure that opens first must be the last one to close.

## 20.4 Review Exercises

Complete the following exercises.

- Create a trace table to determine the values of the variables in each step of the next C# program for four different executions.

The input values for the four executions are (i) 20, 1; (ii) 20, 3; (iii) 12, 8; and (iv) 50, 0.

```
static void Main(string[] args) {
    int x, y;

    x = Int32.Parse(Console.ReadLine());
    y = Int32.Parse(Console.ReadLine());

    if (x < 30) {
        switch (y) {
            case 1:
                x = x % 3;
                y = 5;
                break;
            case 2:
                x = x * 2;
                y = 2;
                break;
            case 3:
                x = x + 5;
                y += 3;
                break;
            default:
                x -= 2;
                y++;
                break;
        }
    }
    else {
        y++;
    }

    Console.WriteLine(x + ", " + y);
}
```

- Create a trace table to determine the values of the variables in each step

of the next C# program for four different executions.

The input values for the four executions are (i) 60, 25; (ii) 50, 8; (iii) 20, 15; and (iv) 10, 30.

```
static void Main(string[] args) {
    int x, y;

    x = Int32.Parse(Console.ReadLine());
    y = Int32.Parse(Console.ReadLine());

    if ((x + y) / 2 <= 20) {
        if (y < 10) {
            x = x % 3;
            y += 2;
        }
        else if (y < 20) {
            x = x * 5;
            y += 2;
        }
        else {
            x = x - 2;
            y += 3;
        }
    }
    else {
        if (y < 15) {
            x = x % 4;
            y = 2;
        }
        else if (y < 23) {
            x = x % 2;
            y -= 2;
        }
        else {
            x = 2 * x + 5;
            y += 1;
        }
    }

    Console.WriteLine(x + ", " + y);
}
```

3. Write the following C# program using correct indentation.

```
static void Main(string[] args) {
    int a;
```

```
a = Int32.Parse(Console.ReadLine());  
  
if (a > 1000)  
    Console.WriteLine("Big Positive");  
else {  
    if (a > 0)  
        Console.WriteLine("Positive");  
    else {  
        if (a < -1000)  
            Console.WriteLine("Big Negative");  
        else {  
            if (a < 0)  
                Console.WriteLine("Negative");  
            else  
                Console.WriteLine("Zero");  
        }  
    }  
}  
}
```

4. Write a C# program that prompts the user to enter the lengths of three sides of a triangle, and then determines whether or not the given numbers can be lengths of the three sides of a triangle. If the lengths are not valid, a corresponding message must be displayed; otherwise the program must further determine whether the triangle is
  - a. equilateral  
Hint: In an equilateral triangle, all sides are equal.
  - b. right (or right-angled)  
Hint: Use the Pythagorean Theorem.
  - c. not special  
Hint: In any triangle, the length of each side is less than the sum of the lengths of the other two sides.
5. Inside an automated teller machine (ATM) there are notes of \$10, \$5, and \$1. Write a C# program to emulate the way this ATM works. At the beginning, the machine prompts the user to enter the four-digit PIN and then checks for PIN validity (assume “1234” as the valid PIN). If given PIN is correct, the program must prompt the user to enter the amount of money (an integer value) that he or she wants to withdraw and finally it displays the least number of notes the ATM must dispense. For

example, if the user enters an amount of \$36, the program must display “3 note(s) of \$10, 1 note(s) of \$5, and 1 note(s) of \$1”. Moreover, if the user enters a wrong PIN, the machine will allow him or her two retries. If the user enters an incorrect PIN all three times, the message “PIN locked” must be displayed and the program must end. Assume that the user enters a valid value for the amount.

6. Write a C# program that prompts the user to enter two values, one for temperature and one for wind speed. If the temperature is above 75 degrees Fahrenheit, the day is considered hot, otherwise it is cold. If the wind speed is above 12 miles per hour, the day is considered windy, otherwise it is not windy. The program must display one single message, depending on values given. For example, if a user enters 60 for temperature and 10 for wind speed, the program must display “The day is cold and not windy”. Assume that the user enters valid values.

# Chapter 21

## More about Flowcharts with Decision Control Structures

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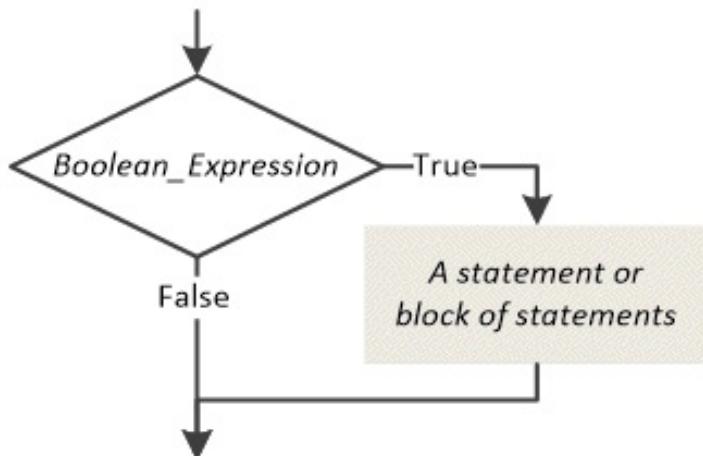
### 21.1 Introduction

By working through the previous chapters, you've become familiar with all the decision control structures. Since flowcharts are an ideal way to learn “Algorithmic Thinking” and to help you better understand specific control structures, this chapter is dedicated to teaching you how to convert a C# program to a flowchart, or a flowchart to a C# program.

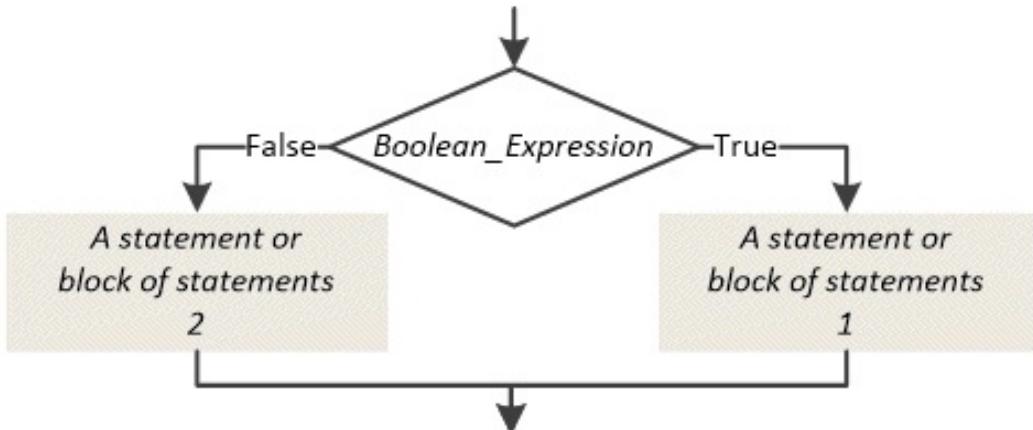
### 21.2 Converting C# Programs to Flowcharts

To convert a C# program to its corresponding flowchart, you need to recall all the decision control structures and their corresponding flowchart fragments. They are all summarized here.

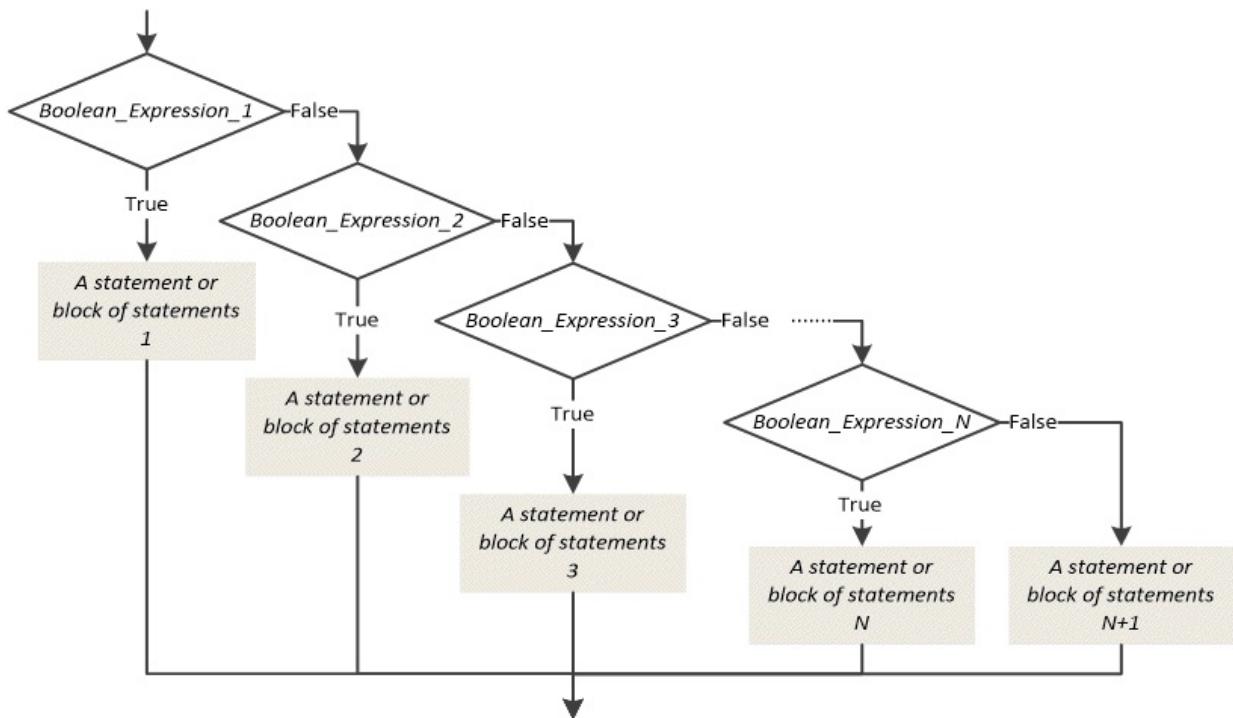
#### The single-alternative decision structure



#### The dual-alternative decision structure



### The multiple-alternative decision structure



You can use this same flowchart to represent C# code that uses a case decision structure as well!

### Exercise 21.2-1 Designing the Flowchart

Design the flowchart that corresponds to the following C# program.

```

static void Main(string[] args) {
    double x, z, w, y, a;

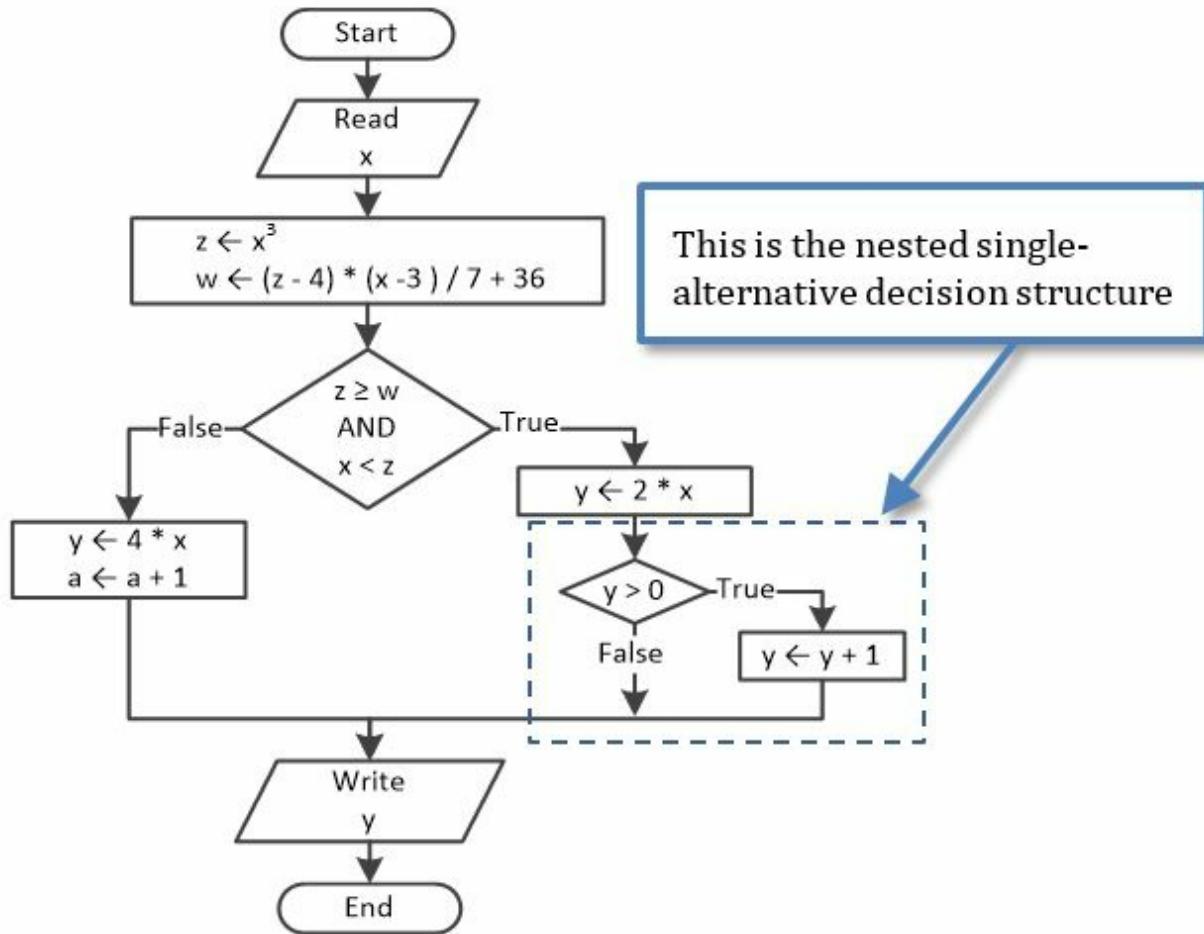
    x = Double.Parse(Console.ReadLine());
  
```

```
z = Math.Pow(x, 3);
w = (z - 4) * (x - 3) / 7 + 36;
if (z >= w && x < z) {
    y = 2 * x;
    if (y > 0) { //This is a nested single-
        y += 1           //alternative decision structure
    }
}
else {
    y = 4 * x;
    a++;
}
Console.WriteLine(y);
}
```

## Solution

---

In this C# program there is a single-alternative decision structure nested within a dual-alternative decision structure. Its corresponding flowchart is as follows.



- ❑ A flowchart is a very loose method of representing an algorithm. Thus, it is quite permissible to write  $x^3$  or even to use the C# method `Math.Pow()`. Do whatever you wish; everything is permitted, on condition that anyone familiar with flowcharts can clearly understand what you are trying to say!
- ❑ In flowcharts, this book uses the commonly accepted AND, OR, and NOT operators!

### Exercise 21.2-2 Designing the Flowchart

Design the flowchart that corresponds to the following code fragment given in general form.

```
if (Boolean_Expression_A) {
```

A statement or block of statements A1

```
if (Boolean_Expression_B) {
```

A statement or block of statements B1

```
}

A statement or block of statements A2

}

else {

    A statement or block of statements A3

    if (Boolean_Expression_C) {

        A statement or block of statements C1

    }

    else {

        A statement or block of statements C2

    }
}
```

## Solution

---

For better observation, the initial code fragment is presented again with all the nested decision control structures enclosed in rectangles.

```
if (Boolean_Expression_A) {

    A statement or block of statements A1

    if (Boolean_Expression_B) { [More...]

        A statement or block of statements B1

    }

    A statement or block of statements A2

}

else {

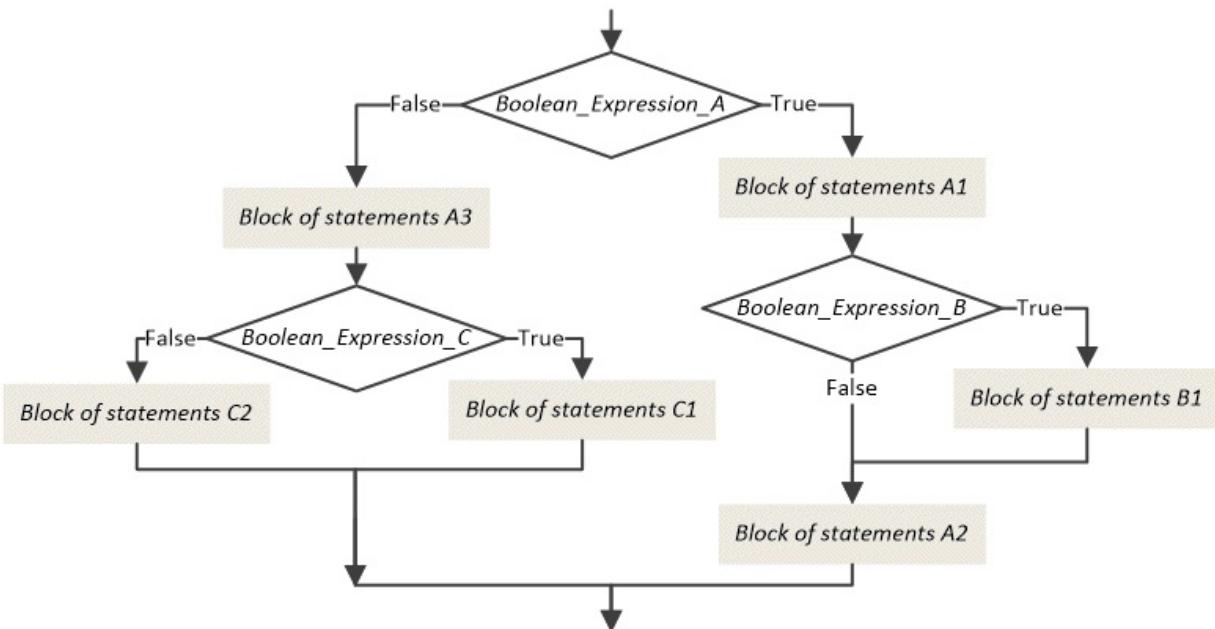
    A statement or block of statements A3
}
```

```

if (Boolean_Expression_C) { [More...]
    A statement or block of statements C1
}
else {
    A statement or block of statements C2
}
}

```

and the flowchart fragment in general form is as follows.



### Exercise 21.2-3 Designing the Flowchart

Design the flowchart that corresponds to the following C# program.

```

static void Main(string[] args) {
    double a, y, b;

    a = Double.Parse(Console.ReadLine());

    if (a < 0)
        y = a * 2;
    else if (a < 10)
        y = a / 2;
    else if (a < 100)
        y = a + 2;
    else {

```

```

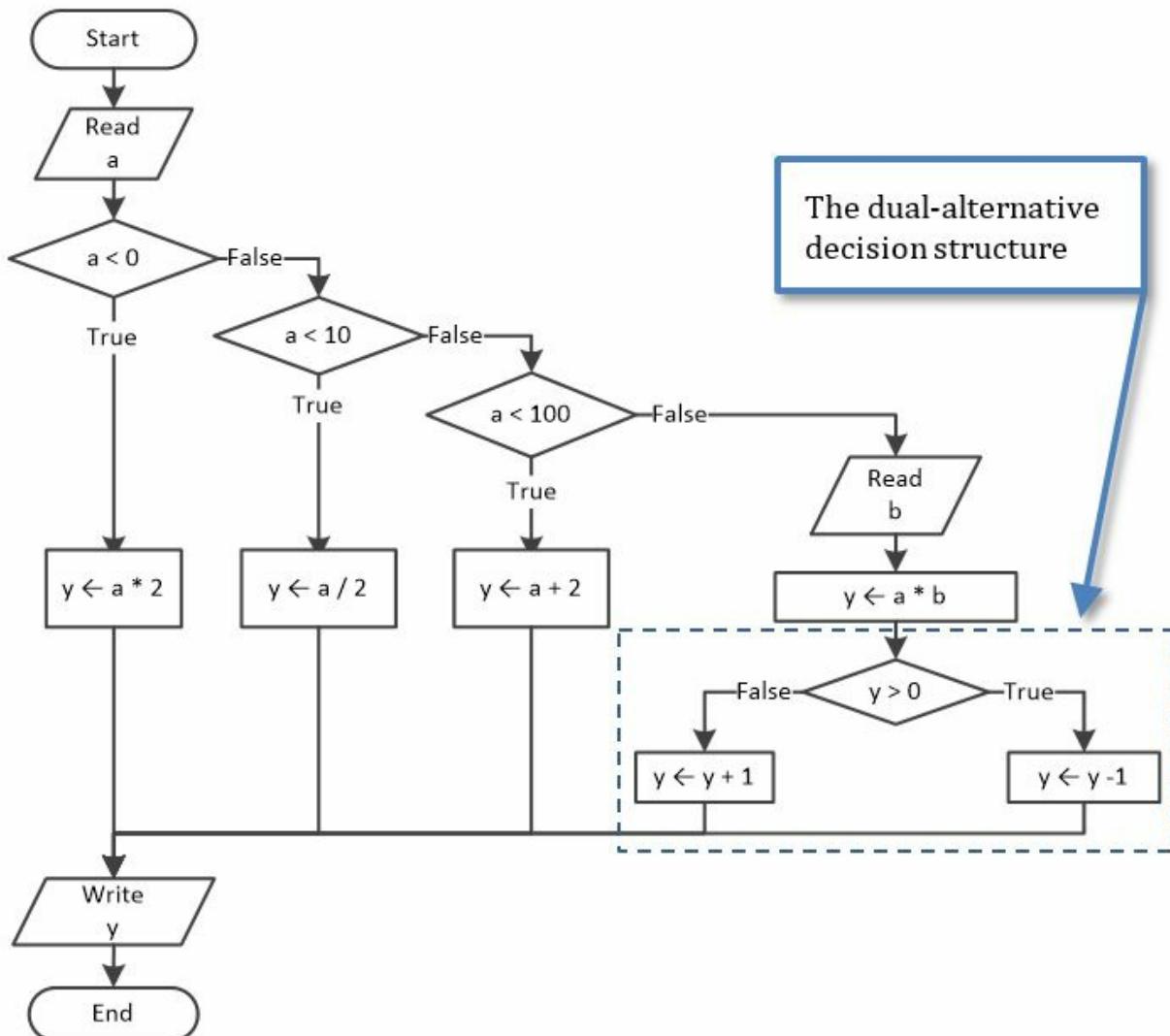
    b = Int32.Parse(Console.ReadLine());
    y = a * b;
    if (y > 0) //This is a nested dual-alternative decision structure
        y--;
    else
        y++;
}
Console.WriteLine(y);
}

```

## Solution

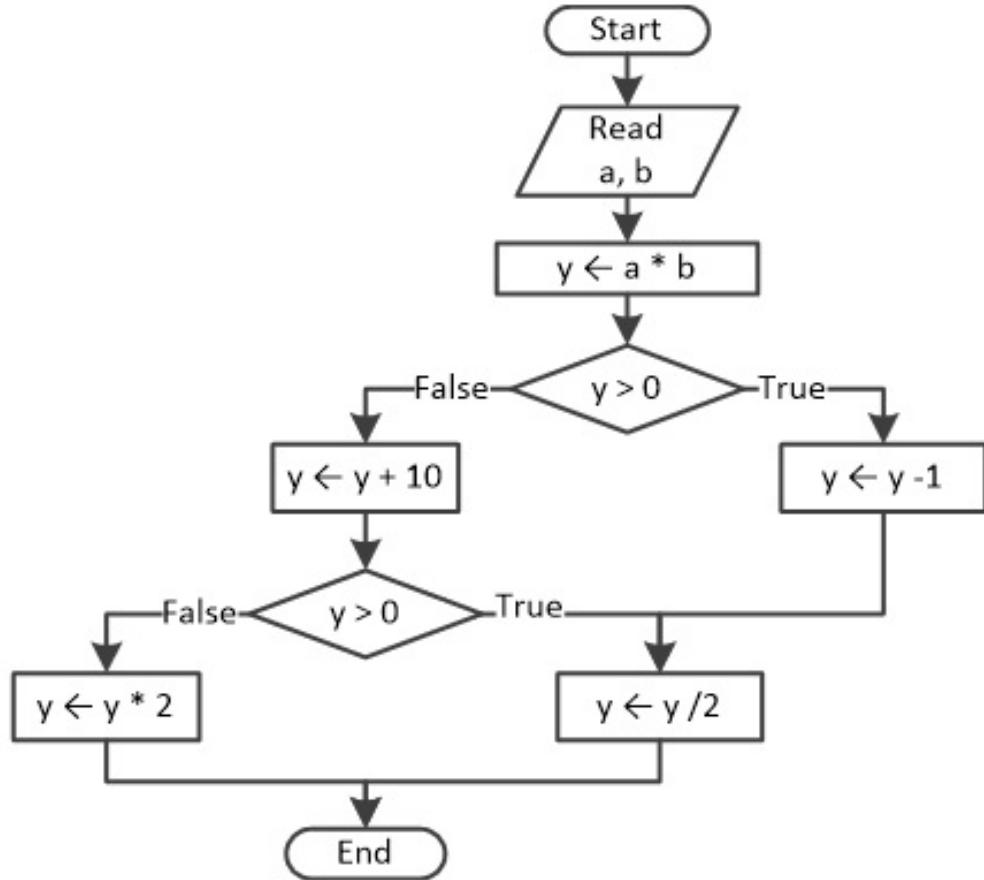
In this C# program, a dual-alternative decision structure is nested within a multiple-alternative decision structure.

The flowchart is as follows.



## 21.3 Converting Flowcharts to C# Programs

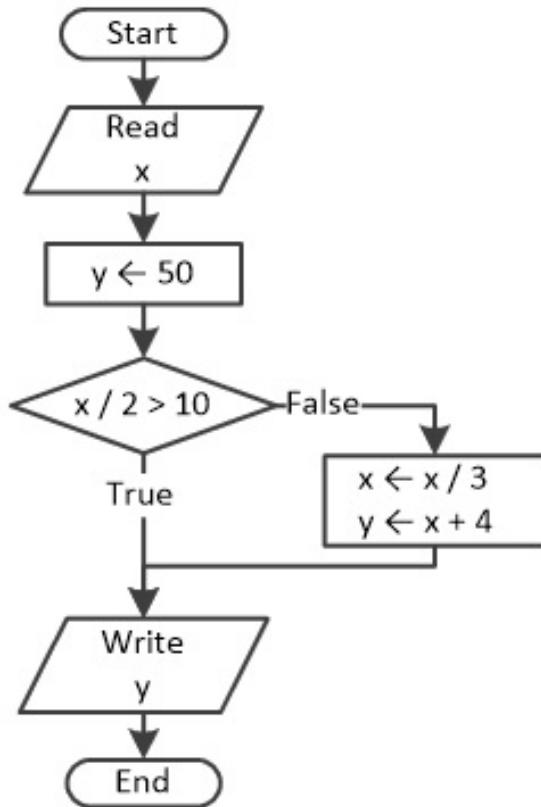
This conversion is not always an easy one. There are cases in which the flowchart designers follow no particular rules, so the initial flowchart may need some modifications before it can become a C# program. An example of one such case is as follows.



As you can see, the decision control structures included in this flowchart fragment match none of the structures that you have already learned, such as the single-alternative, the dual-alternative, and the multiple-alternative. Thus, you have only one choice and this is to modify the flowchart by adding extra statements or removing existing ones until known decision control structures start to appear. Following are some exercises in which the initial flowchart does need modification.

### Exercise 21.3-1 Writing the C# Program

*Write the C# program that corresponds to the following flowchart.*

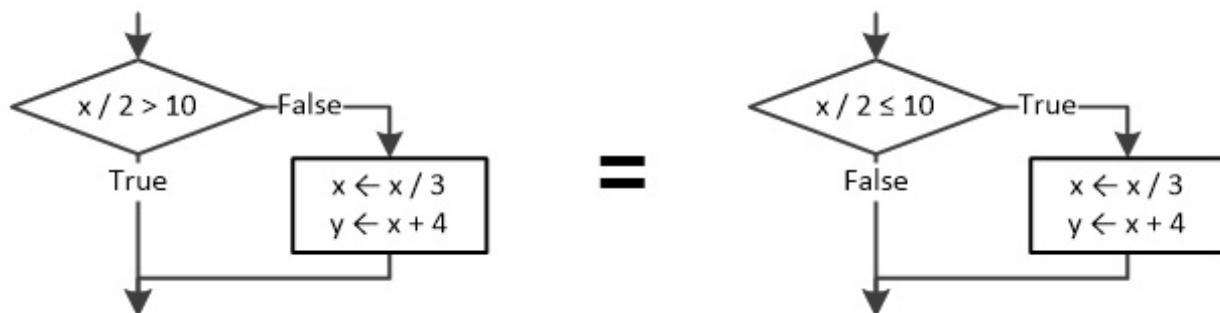


### **Solution**

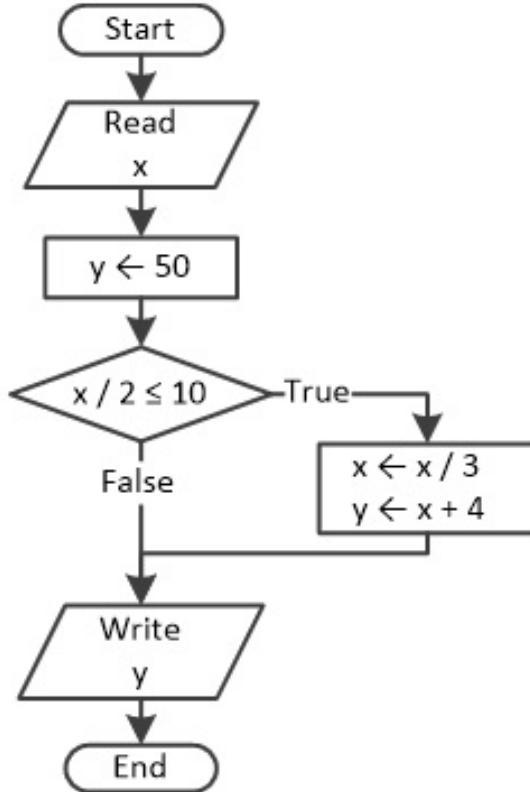
---

This is quite easy. The only obstacle you must overcome is that the true and false paths are not quite in the right positions. You need to use the true path, and not the false path, to actually include the statements in the single-alternative decision structure.

It is possible to switch the two paths, but you also need to negate the corresponding Boolean expression. The following two flowchart fragments are equivalent.



Thus, the flowchart can be modified and look like this.



and the corresponding C# program is shown here.

```

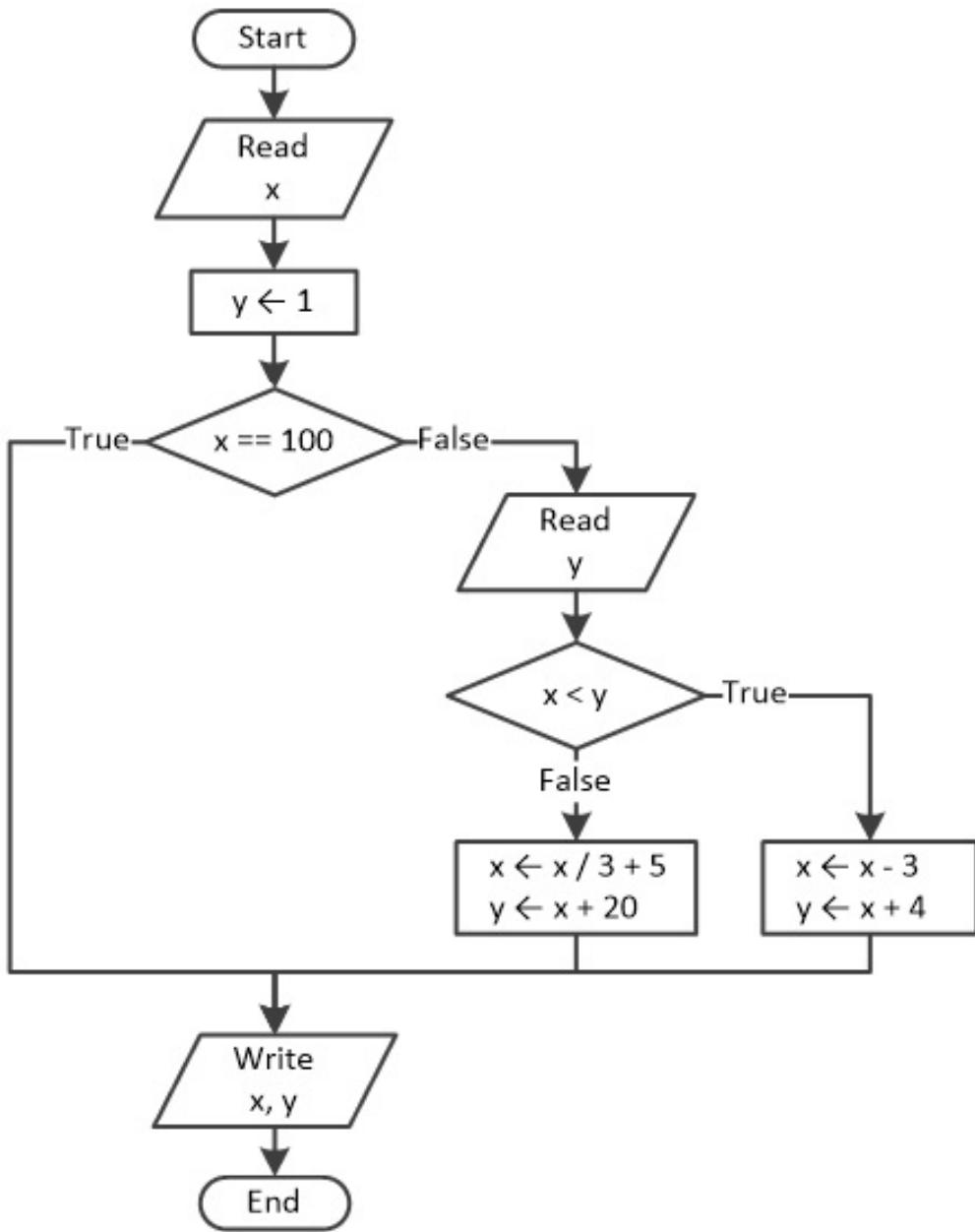
static void Main(string[] args) {
    double x, y;

    x = Double.Parse(Console.ReadLine());

    y = 50;
    if (x / 2 <= 10) {
        x = x / 3;
        y = x + 4;
    }
    Console.WriteLine(y);
}
    
```

### Exercise 21.3-2 Writing the C# Program

*Write the C# program that corresponds to the following flowchart.*



## Solution

In this exercise there is a dual-alternative decision structure nested within a single-alternative one. You just need to negate the Boolean expression  $x == 100$  and switch the true/false paths. The C# program is shown here.

```

static void Main(string[] args) {
    double x, y;

    x = Double.Parse(Console.ReadLine());
    y = 1;

```

```

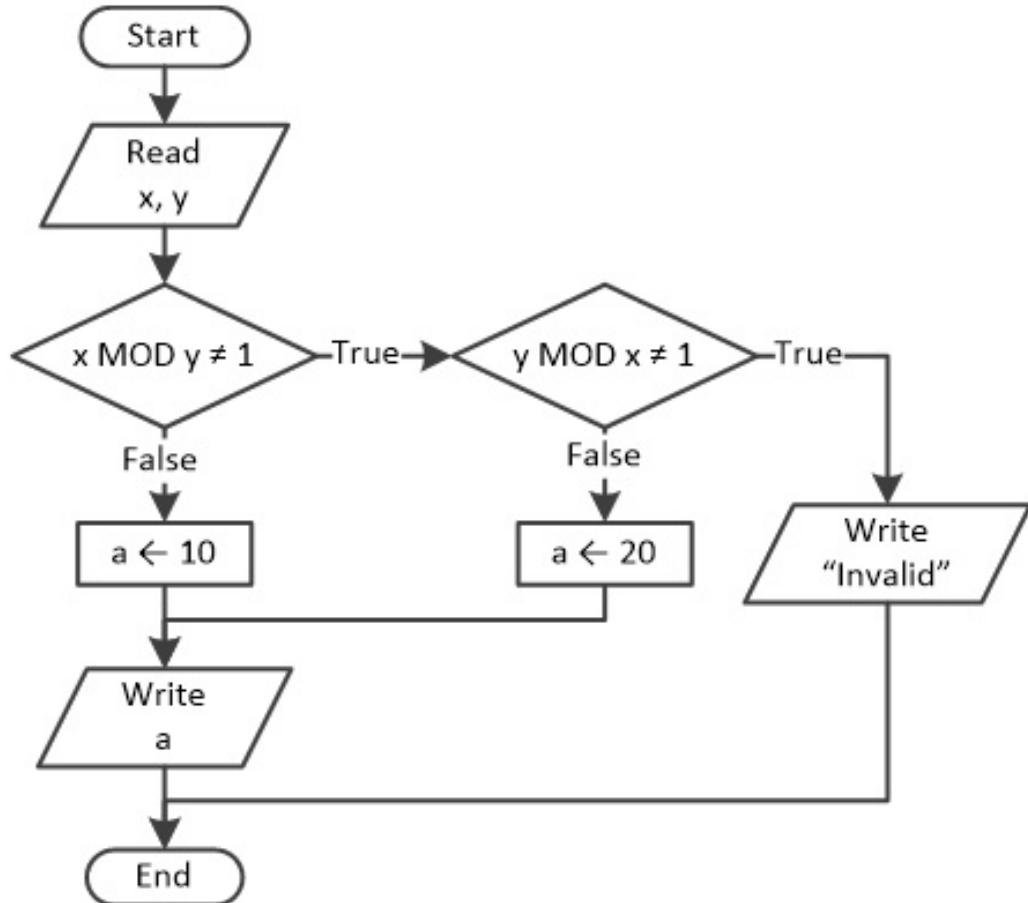
if (x != 100) { //This is a single-alternative decision structure
    y = Double.Parse(Console.ReadLine());
    if (x < y) { //This is a nested dual-alternative decision structure
        x = x - 3;
        y = x + 4;
    }
    else {
        x = x / 3 + 5;
        y = x + 20;
    }
}

Console.WriteLine(x + " " + y);
}

```

### Exercise 21.3-3 Writing the C# Program

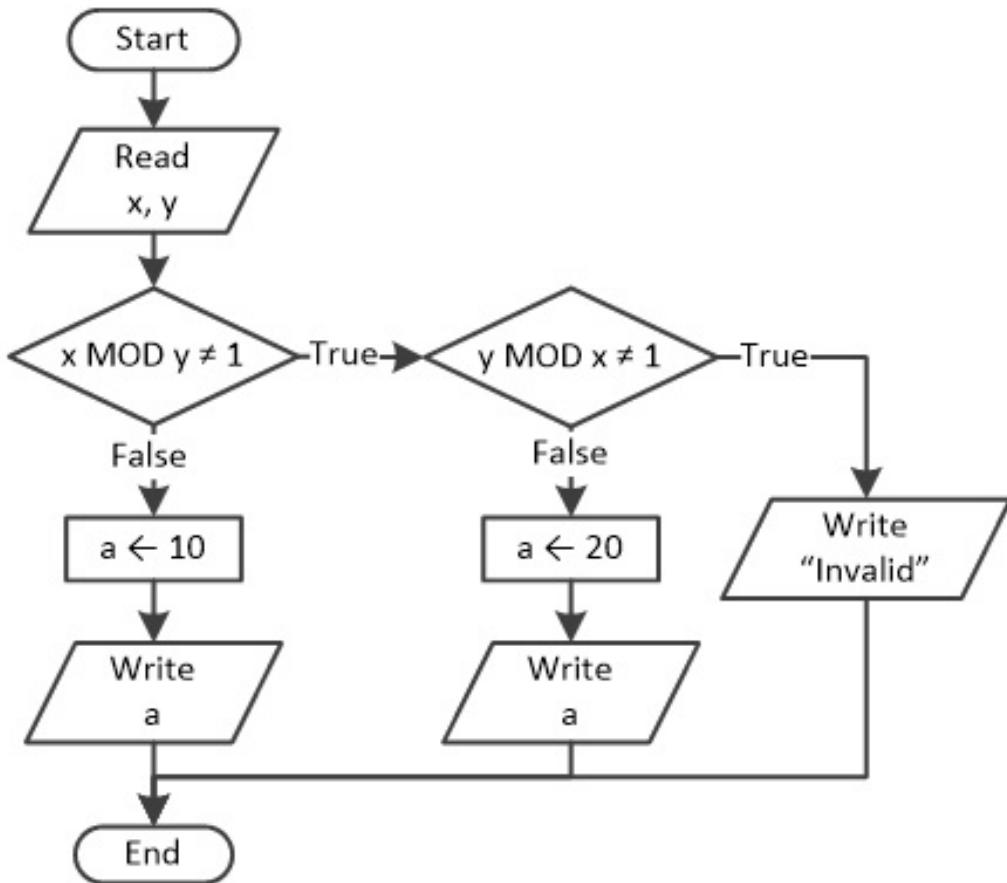
Write the C# program that corresponds to the following flowchart.



### Solution

In this flowchart, the decision control structures match none of the decision control structures that you have already learned, such as the single-alternative, the dual-alternative, and the multiple-alternative. Thus, you must modify the flowchart by adding extra statements or removing existing ones until known decision control structures start to appear!

The obstacle you must overcome in this exercise is the decision control structure that evaluates the  $y \bmod x \neq 1$  Boolean expression. Note that when flow of execution follows the false path, it executes the statement  $a \leftarrow 20$  and then the statement `write a` before it reaches the end of the algorithm. Thus, if you simply add a new statement, `write a`, inside its false path you can keep the flow of execution intact. The following flowchart is equivalent to the initial one.



Now, the flowchart includes known decision control structures; that is, a dual-alternative decision structure nested within another dual-alternative one.

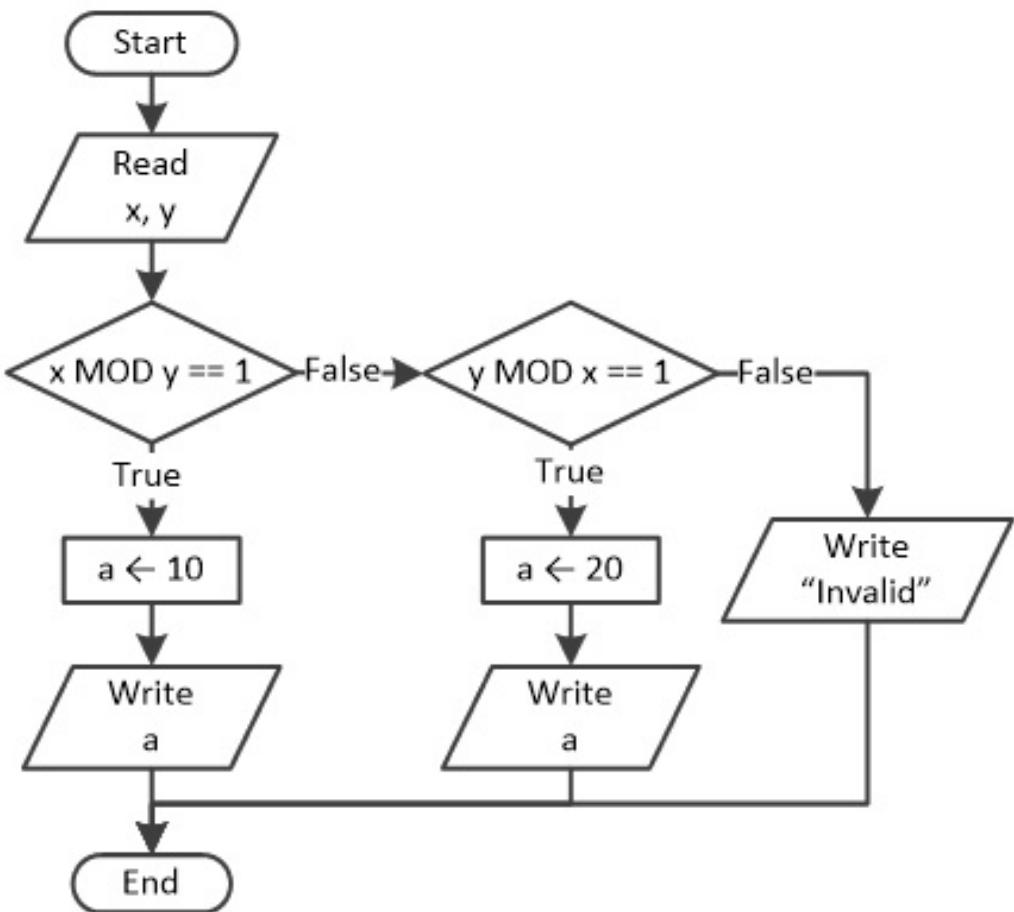
The corresponding C# program is as follows.

```
static void Main(string[] args) {
    int x, y, a;

    x = Int32.Parse(Console.ReadLine());
    y = Int32.Parse(Console.ReadLine());

    if (x % y != 1) {
        if (y % x != 1) {
            Console.WriteLine("Invalid");
        }
        else {
            a = 20;
            Console.WriteLine(a);
        }
    }
    else {
        a = 10;
        Console.WriteLine(a);
    }
}
```

However, there is something better that you can do! If you negate all Boolean expressions and also switch their true/false paths, you can have a multiple-alternative decision structure, which is more convenient in C# than nested decision control structures. The modified flowchart is shown here.



and the corresponding C# program is as follows.

```

static void Main(string[] args) {
    int x, y, a;

    x = Int32.Parse(Console.ReadLine());
    y = Int32.Parse(Console.ReadLine());

    if (x % y == 1) {
        a = 10;
        Console.WriteLine(a);
    }
    else if (y % x == 1) {
        a = 20;
        Console.WriteLine(a);
    }
    else {
        Console.WriteLine("Invalid");
    }
}

```

## 21.4 Review Exercises

Complete the following exercises.

1. Design the flowchart that corresponds to the following C# program.

```
static void Main(string[] args) {
    int a;

    a = Int32.Parse(Console.ReadLine());

    if (a % 10 == 0) {
        a++;
        Console.WriteLine("Message #1");
    }
    if (a % 3 == 1) {
        a += 5;
        Console.WriteLine("Message #2");
    }
    if (a % 3 == 2) {
        a += 10;
        Console.WriteLine("Message #3");
    }

    Console.WriteLine(a);
}
```

2. Design the flowchart that corresponds to the following C# program.

```
static void Main(string[] args) {
    int a;

    a = Int32.Parse(Console.ReadLine());

    if (a % 10 == 0) {
        a++;
        Console.WriteLine("Message #1");
    }

    if (a % 3 == 1) {
        a += 5;
        Console.WriteLine("Message #2");
    }
    else {
        a += 7;
    }
    Console.WriteLine(a);
```

| }

3. Design the flowchart that corresponds to the following C# program.

```
static void Main(string[] args) {
    double a, y, b;

    a = Double.Parse(Console.ReadLine());

    if (a < 0) {
        y = a * 2;
        if (y > 0)
            y += 2;
        else if (y == 0)
            y *= 6;
        else
            y /= 7;
    }
    else if (a < 22)
        y = a / 3;
    else if (a < 32)
        y = a - 7;
    else {
        b = Double.Parse(Console.ReadLine());
        y = a - b;
    }
    Console.WriteLine(y);
}
```

4. Design the flowchart that corresponds to the following code fragment given in general form.

```
if (Boolean_Expression_A) {
    if (Boolean_Expression_B) {
        A statement or block of statements B1
    }
    else {
        A statement or block of statements B2
    }
    A statement or block of statements A1
}
else {
    A statement or block of statements A2
}
```

```

if (Boolean_Expression_C) {
    A statement or block of statements C1
}
else if (Boolean_Expression_D) {
    A statement or block of statements D1
}
else {
    A statement or block of statements E1
}
A statement or block of statements A3
}

```

5. Design the flowchart that corresponds to the following C# program.

```

static void Main(string[] args) {
    int a;
    double y, b;

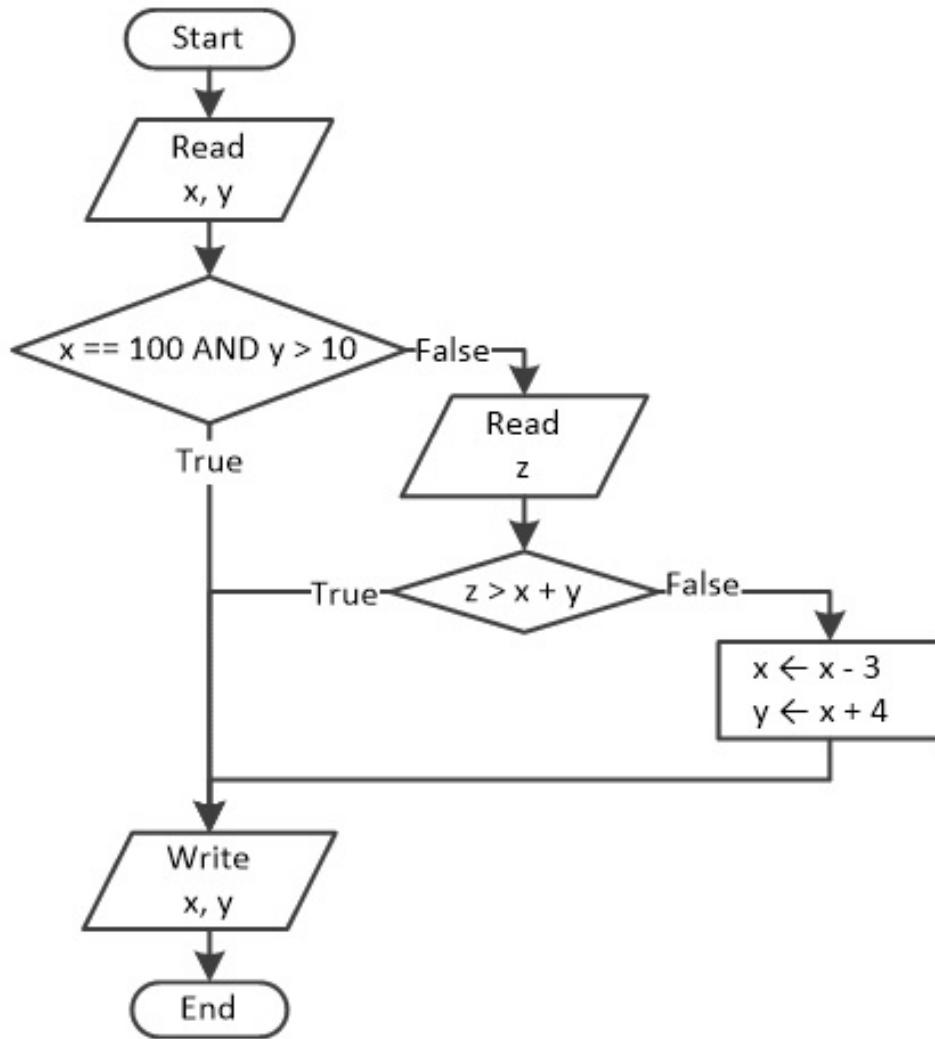
    a = Int32.Parse(Console.ReadLine());
    y = 0;

    switch (a) {
        case 1:
            y = a * 2;
            break;
        case 2:
            y = a - 3;
            break;
        case 3:
            y = a + 3;
            if (y % 2 == 1)
                y += 2;
            else if (y == 0)
                y *= 6;
            else
                y /= 7;
            break;
        case 4:
            b = Double.Parse(Console.ReadLine());
            y = a + b + 2;
            break;
    }
}

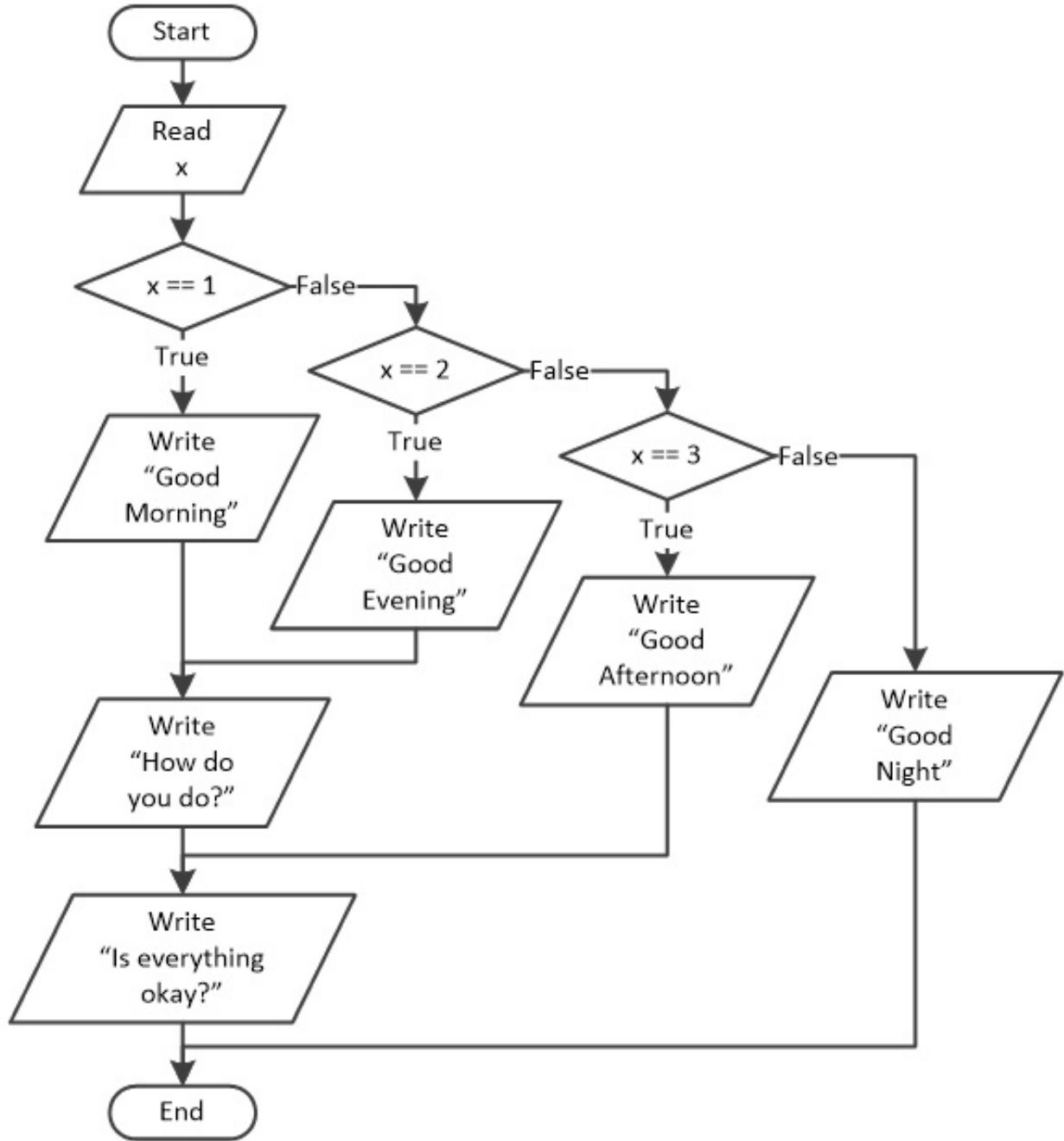
```

```
    Console.WriteLine(y);
}
```

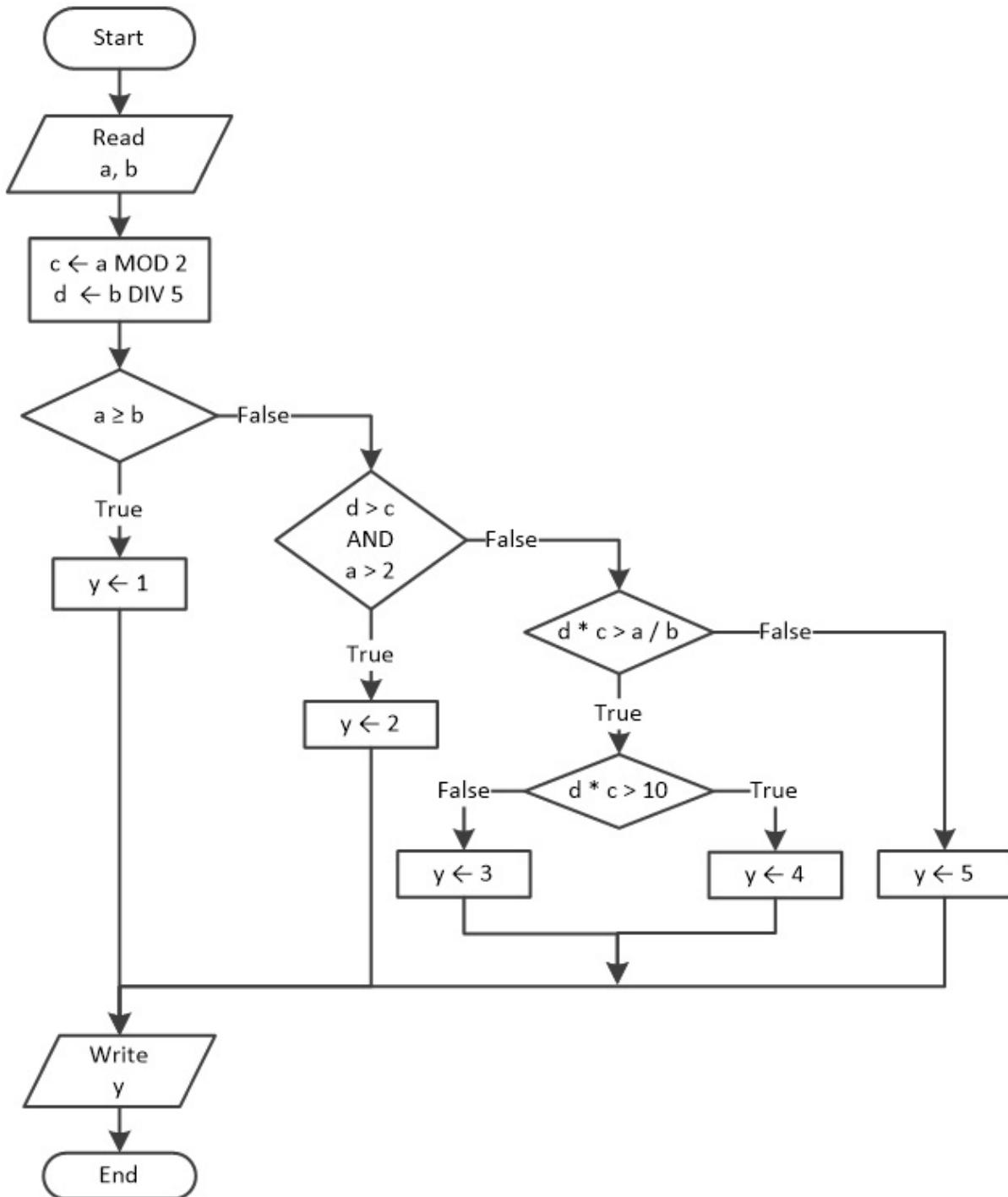
6. Write the C# program that corresponds to the following flowchart.



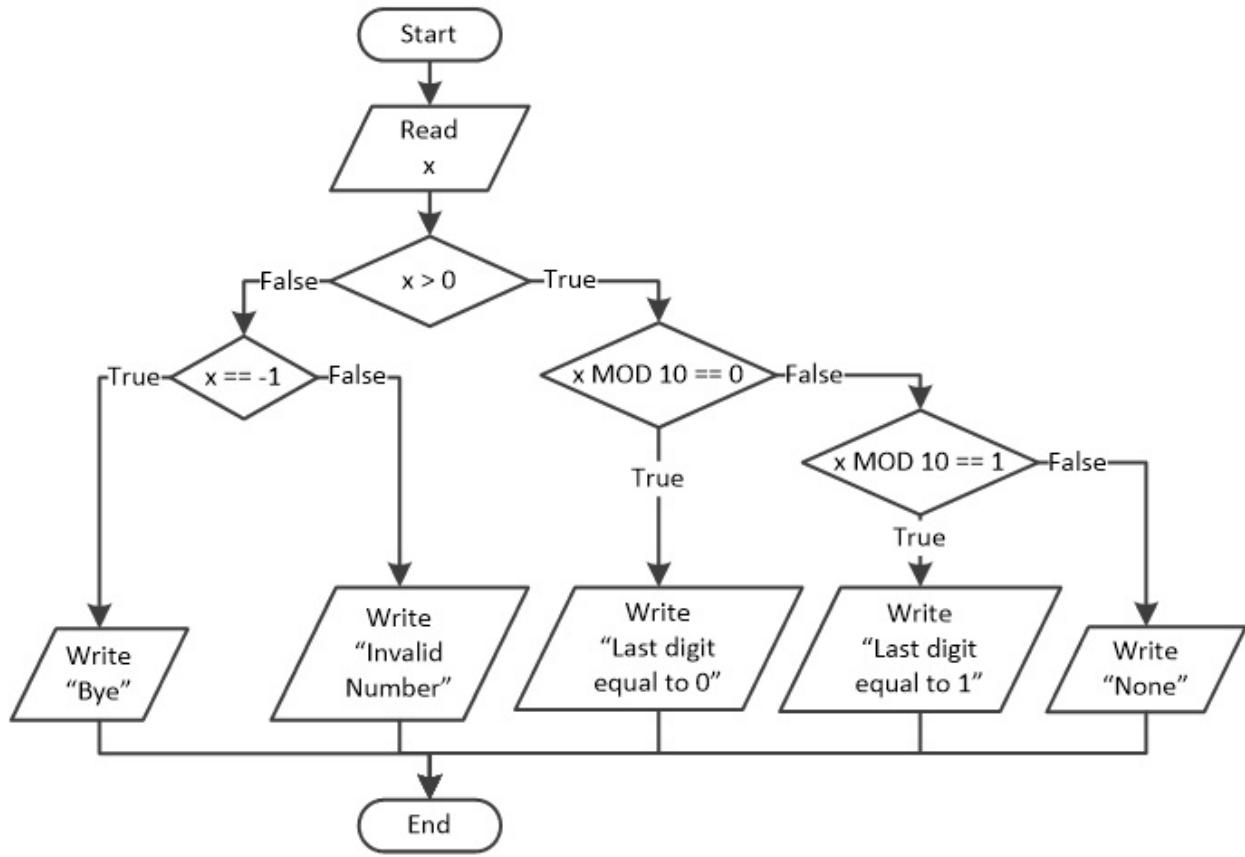
7. Write the C# program that corresponds to the following flowchart.



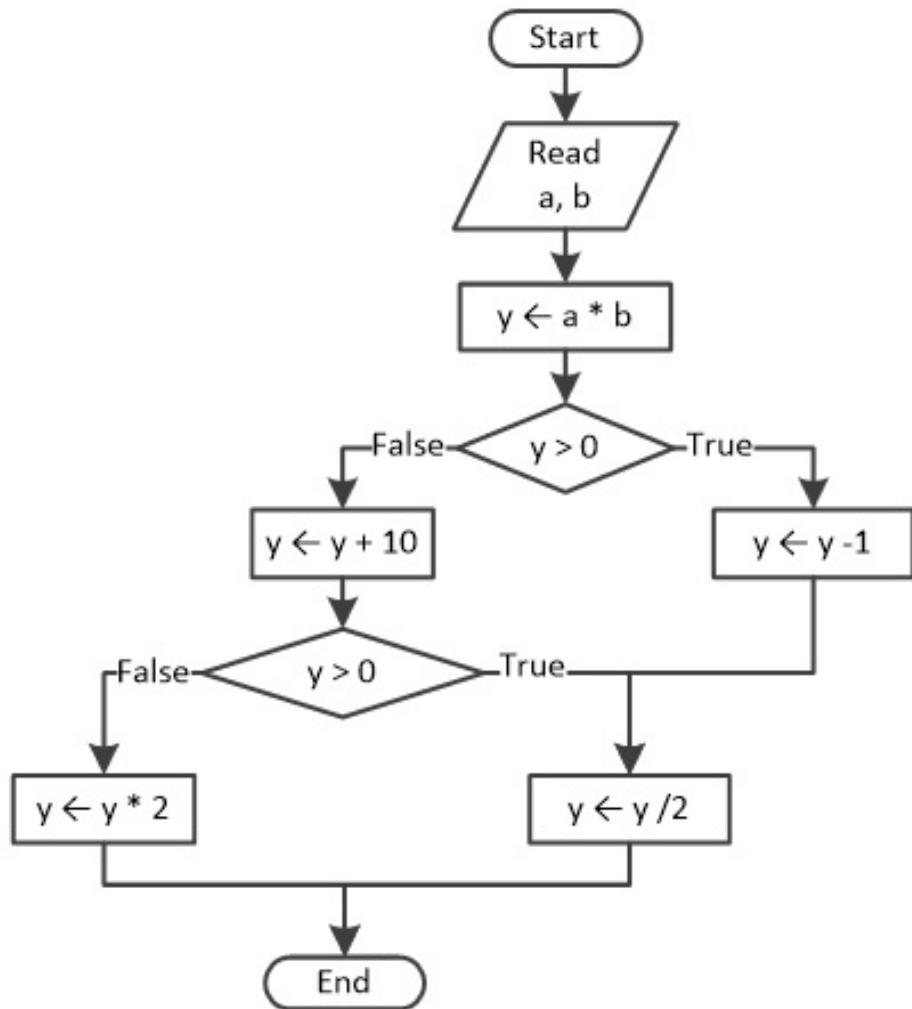
8. Write the C# program that corresponds to the following flowchart.



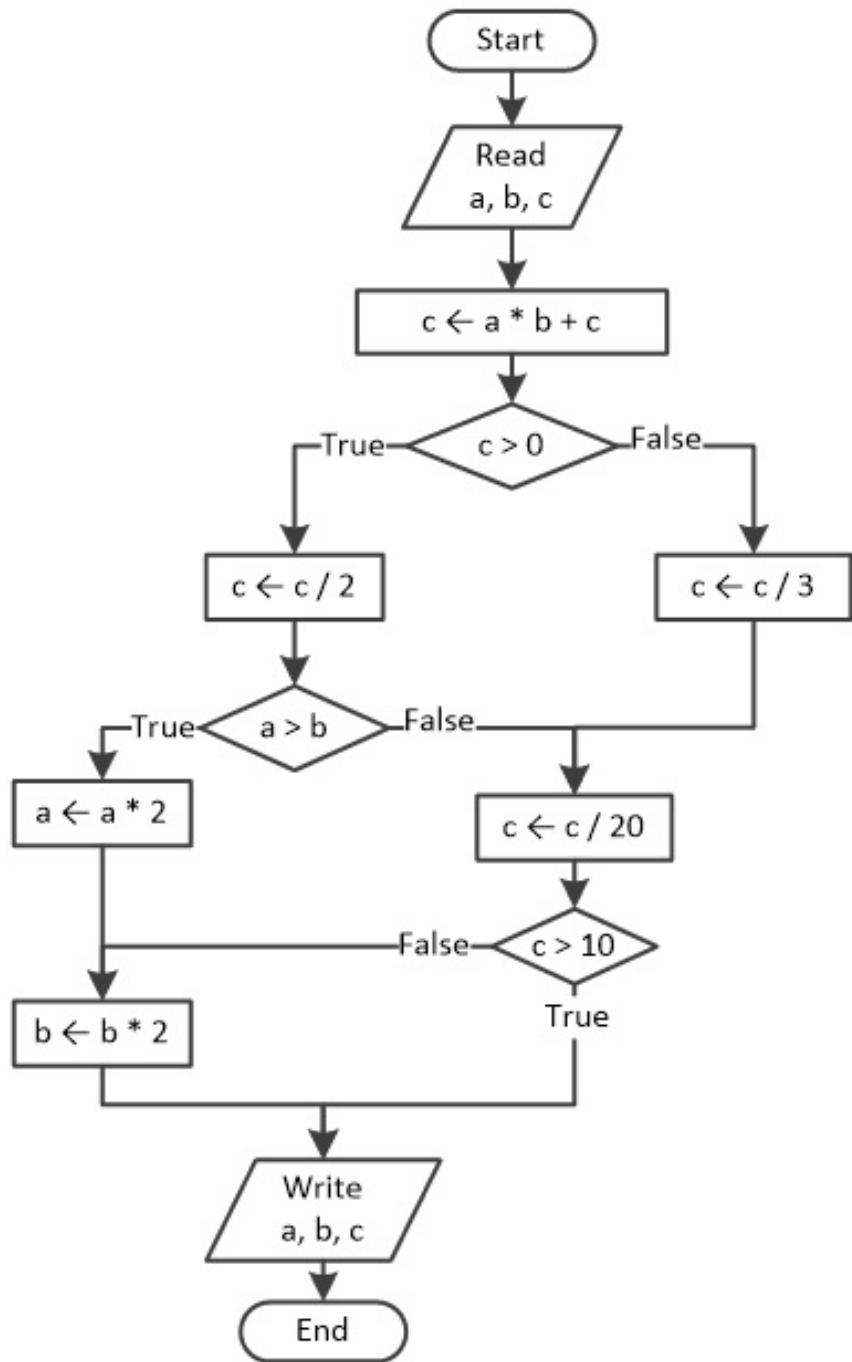
9. Write the C# program that corresponds to the following flowchart.



10. Write the C# program that corresponds to the following flowchart.



11. Write the C# program that corresponds to the following flowchart.



# Chapter 22

## Tips and Tricks with Decision Control Structures

### 22.1 Introduction

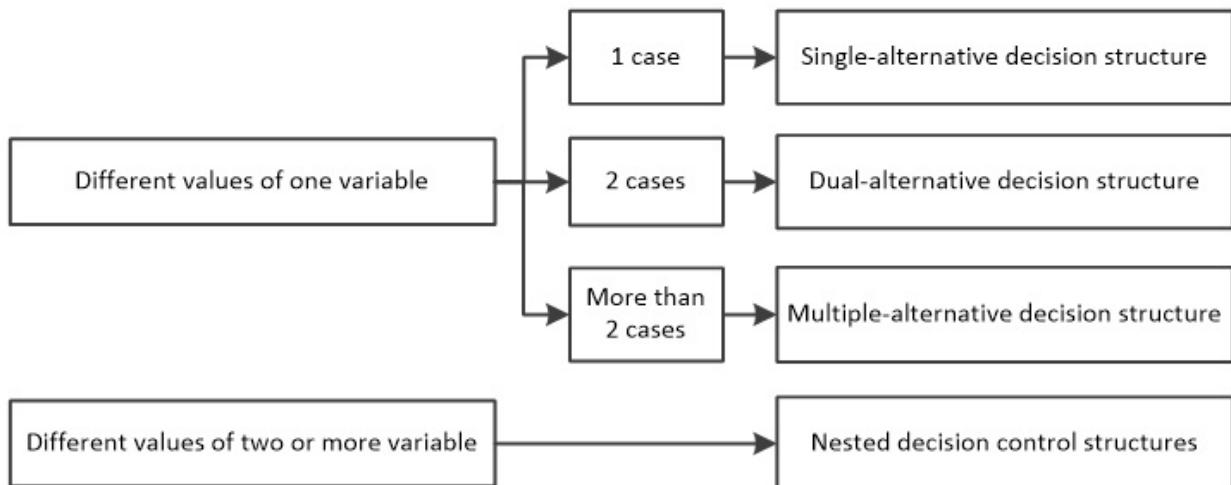
This chapter is dedicated to teaching you some useful tips and tricks that can help you write “better” code. You should always keep them in mind when you design your own algorithms, or even your own C# programs.

These tips and tricks can help you increase your code's readability and help make the code shorter or even faster. Of course there is no single perfect methodology because on one occasion the use of a specific tip or trick may help, but on another occasion the same tip or trick may have exactly the opposite result. Most of the time, code optimization is a matter of programming experience.

 *Smaller algorithms are not always the best solution to a given problem. In order to solve a specific problem, you might write a very short algorithm that unfortunately proves to consume a lot of CPU time. On the other hand, you may solve the same problem with another algorithm which, even though it seems longer, calculates the result much faster.*

### 22.2 Choosing a Decision Control Structure

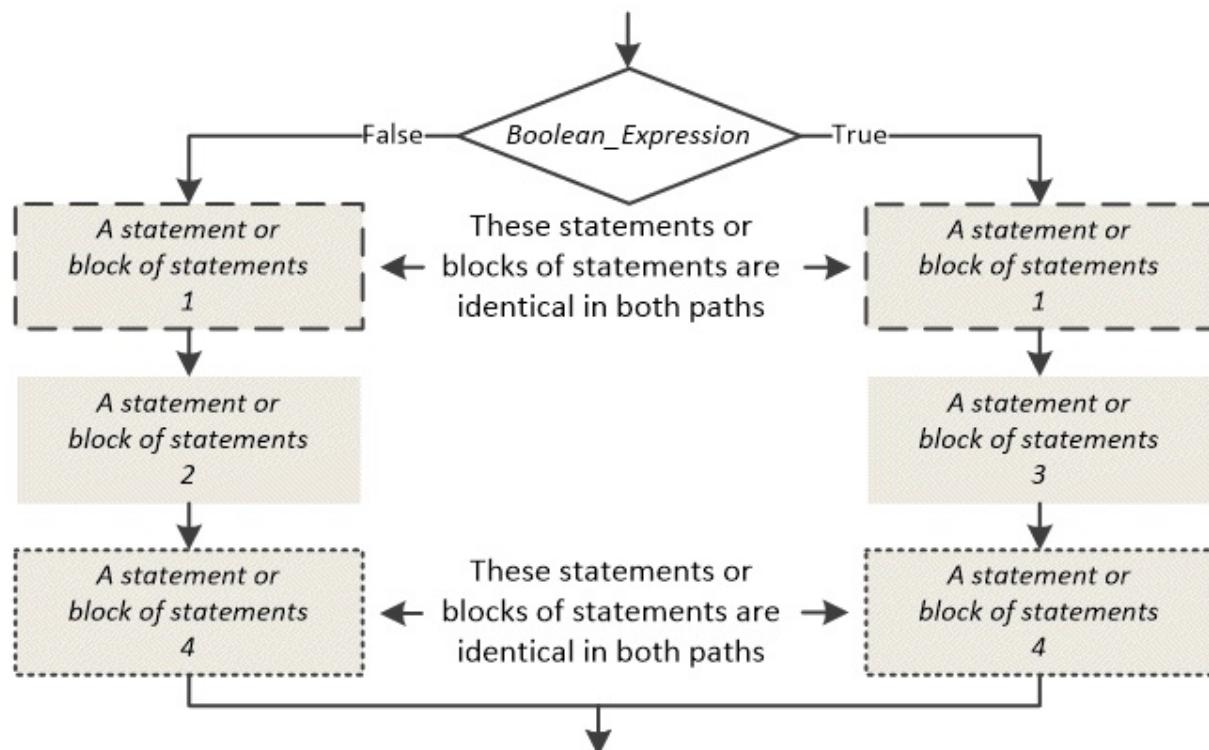
The following diagram can help you decide which decision control structure is a better choice for a given problem depending on the number of variables checked.



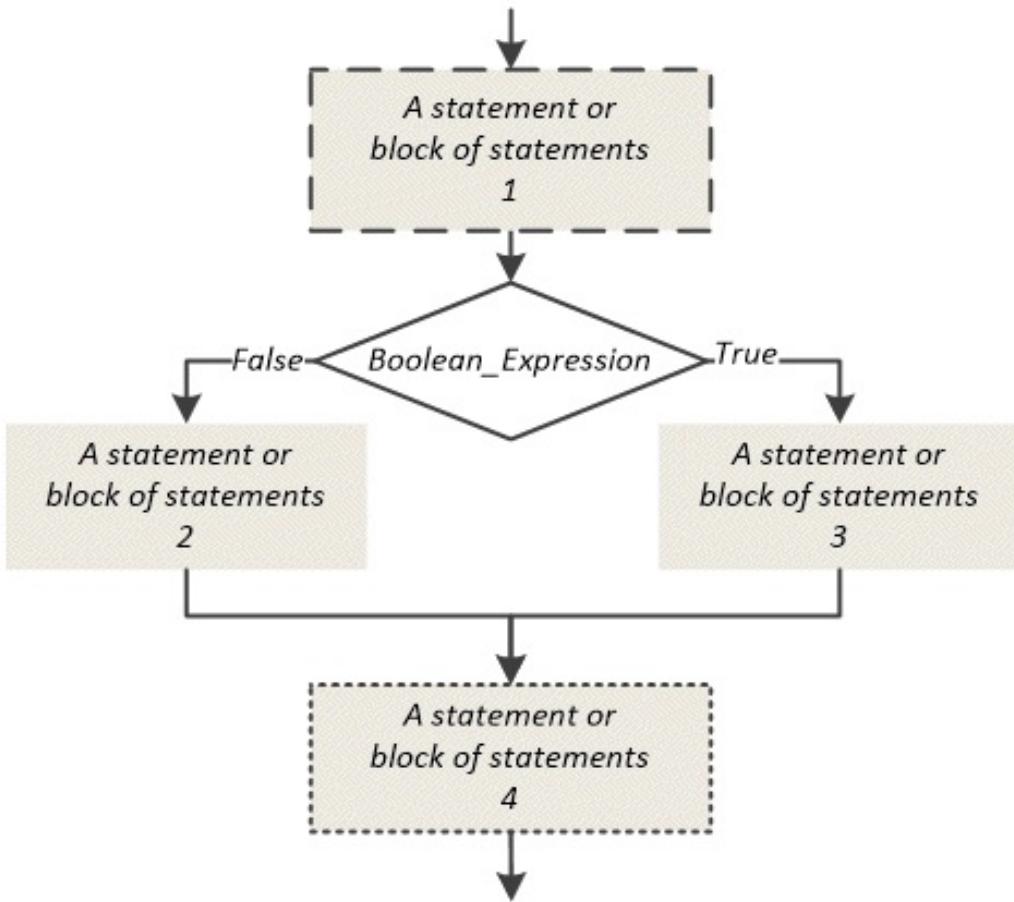
 This diagram recommends the best option, not the only option. For example, when there are more than two cases for one variable, it is not wrong to use a nested decision control structure instead. The proposed multiple-alternative decision structure and the proposed case decision structure, though, are better since they are more convenient.

## 22.3 Streamlining the Decision Control Structure

Look carefully at the following flowchart fragment given in general form.



As you can see, two identical statements or blocks of statements exist at the beginning and two other identical statements or blocks of statements exist at the end of both paths of the dual-alternative decision structure. This means that, regardless of the result of *Boolean\_Expression*, these statements are executed either way. Thus, you can simply move them outside and (respectively) right before and right after the dual-alternative decision structure, as shown in this equivalent structure.



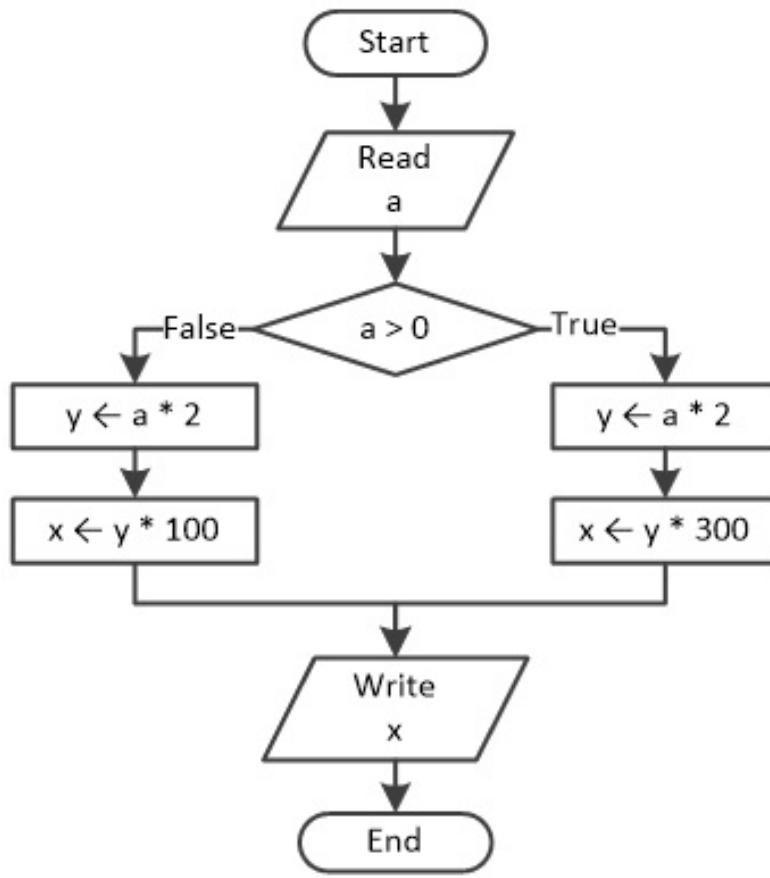
The same tip can be applied to any decision control structure, as long as an identical statement or block of statements exists in all paths. Of course, there are also cases where this tip cannot be applied.

Are you still confused? Next, you will find some exercises that can help you to understand better.

### ***Exercise 22.3-1 “Shrinking” the Algorithm***

---

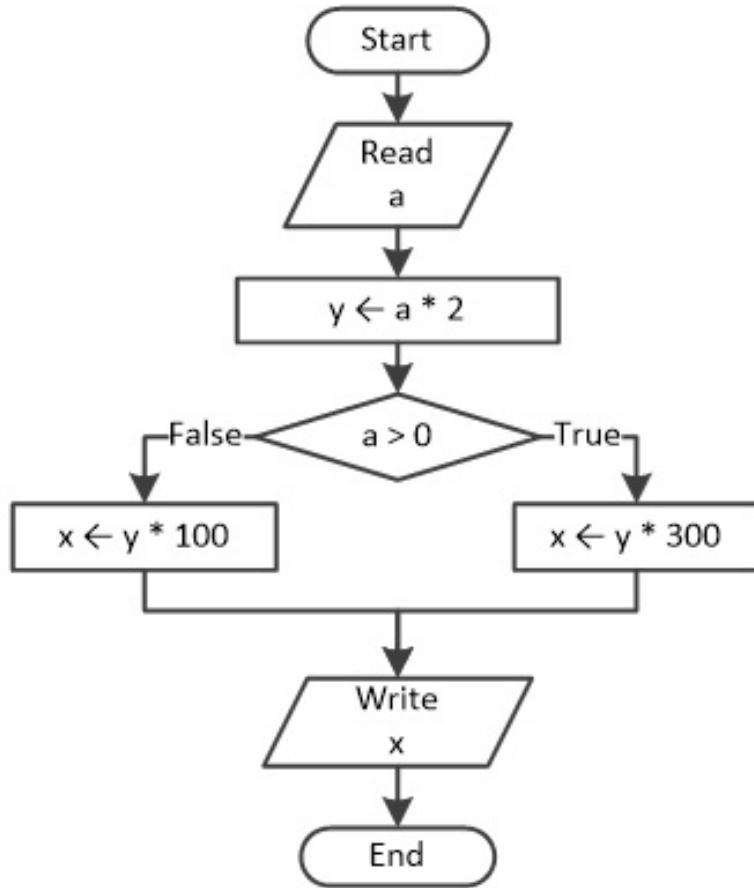
*Redesign the following flowchart using fewer statements.*



### **Solution**

---

As you can see, the statement  $y \leftarrow a * 2$  exists in both paths of the dual-alternative decision structure. This means that, regardless of the result of the Boolean expression, this statement is executed either way. Therefore, you can simply move the statement outside and right before the dual-alternative decision structure, as follows.



### Exercise 22.3-2 “Shrinking” the C# Program

Rewrite the following C# program using fewer statements.

```

static void Main(string[] args) {
    int a, y;

    a = Int32.Parse(Console.ReadLine());

    if (a > 0) {
        y = a * 4;
        Console.WriteLine(y);
    }
    else {
        y = a * 3;
        Console.WriteLine(y);
    }
}
  
```

### Solution

As you can see, the statement `Console.WriteLine(y)` exists in both paths of

the dual-alternative decision structure. This means that, regardless of the result of the Boolean expression, this statement is executed either way. Therefore, you can simply move the statement outside and right after the dual-alternative decision structure, as shown here.

```
static void Main(string[] args) {
    int a, y;

    a = Int32.Parse(Console.ReadLine());

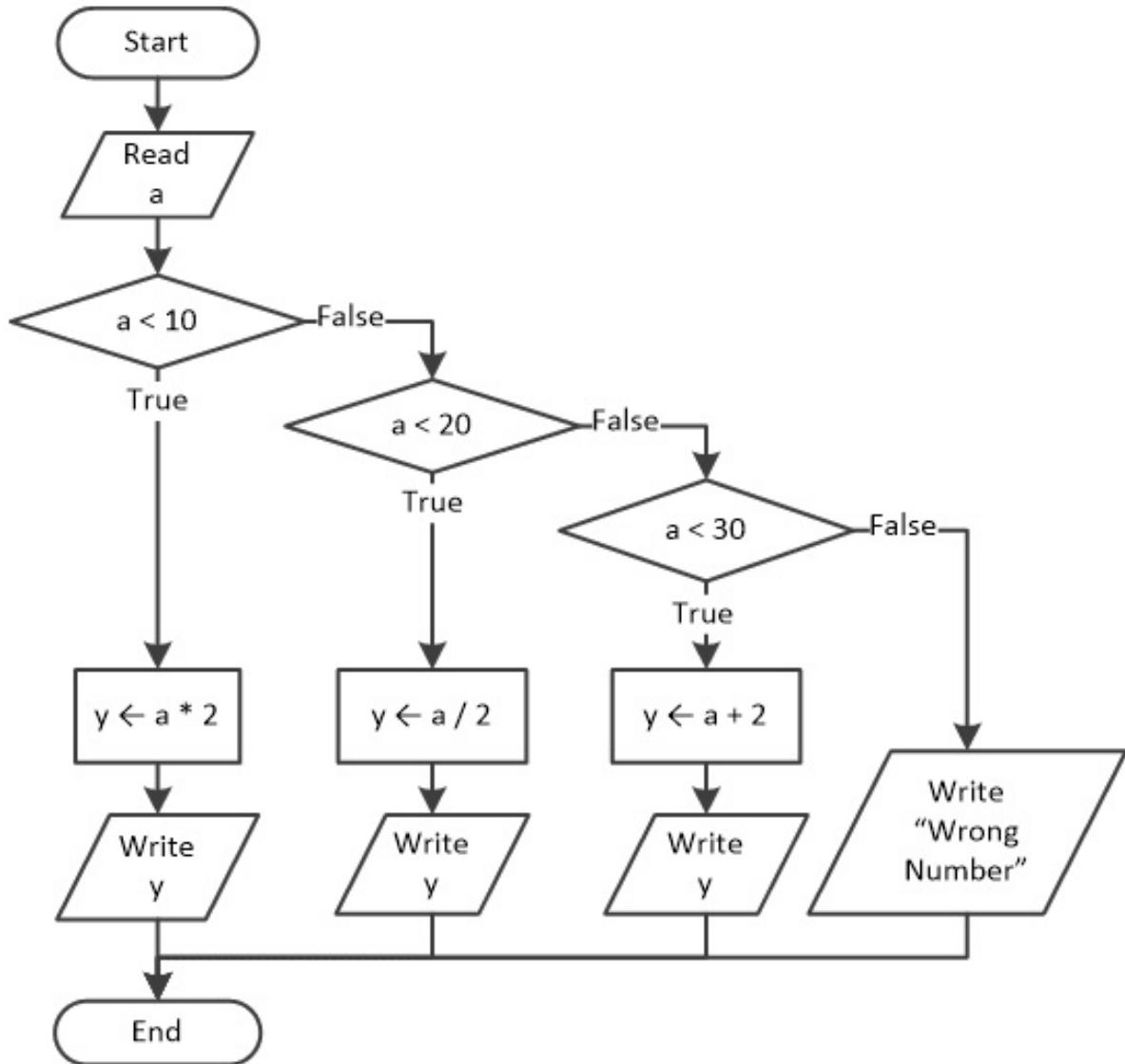
    if (a > 0) {
        y = a * 4;
    }
    else {
        y = a * 3;
    }

    Console.WriteLine(y);
}
```

### ***Exercise 22.3-3 “Shrinking” the Algorithm***

---

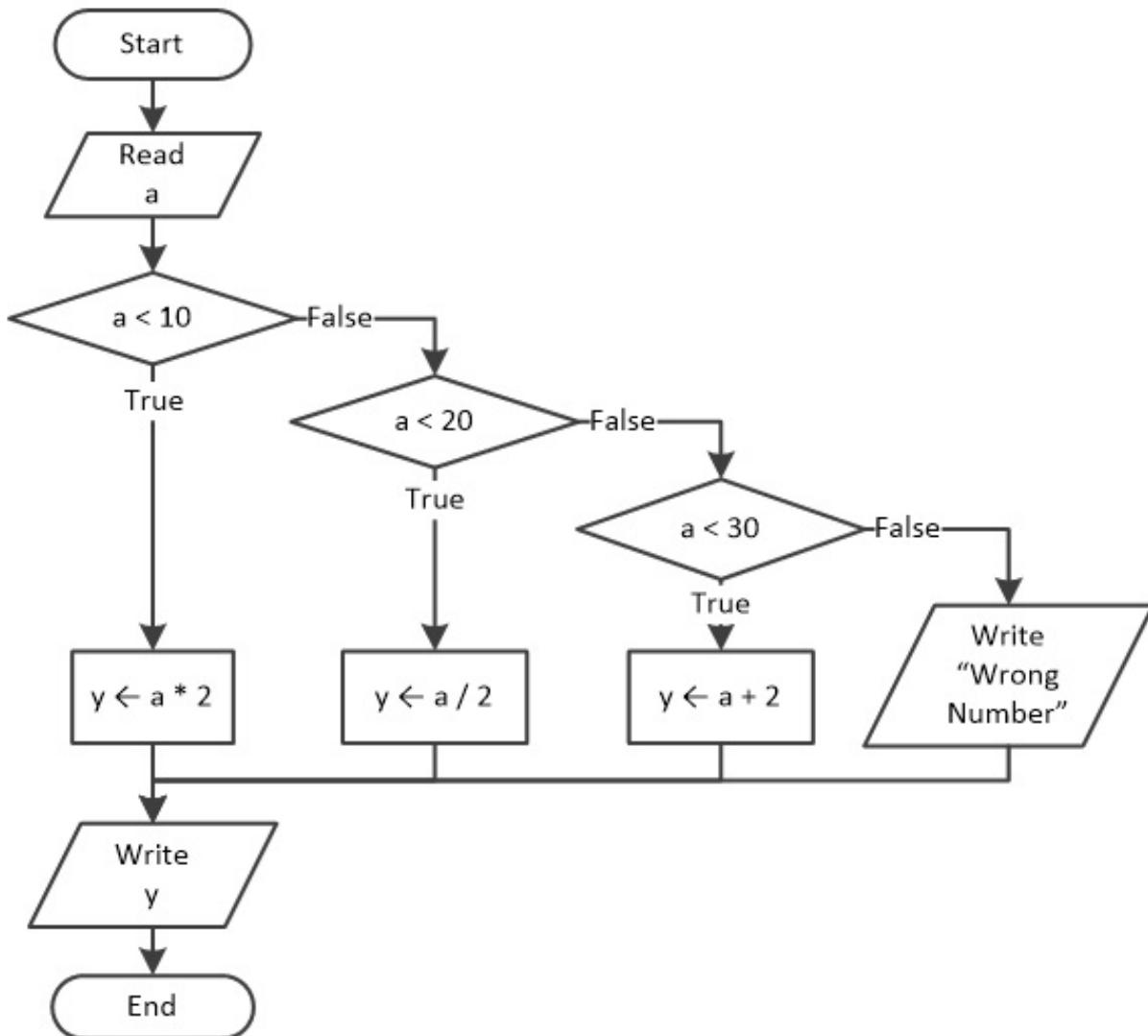
*Redesign the following flowchart using fewer statements and then write the corresponding C# program.*



## **Solution**

---

In this case, nothing special can be done. If you try to move the `write y` statement outside of the multiple-alternative decision structure, the resulting flowchart that follows is definitely **not** equivalent to the initial one.



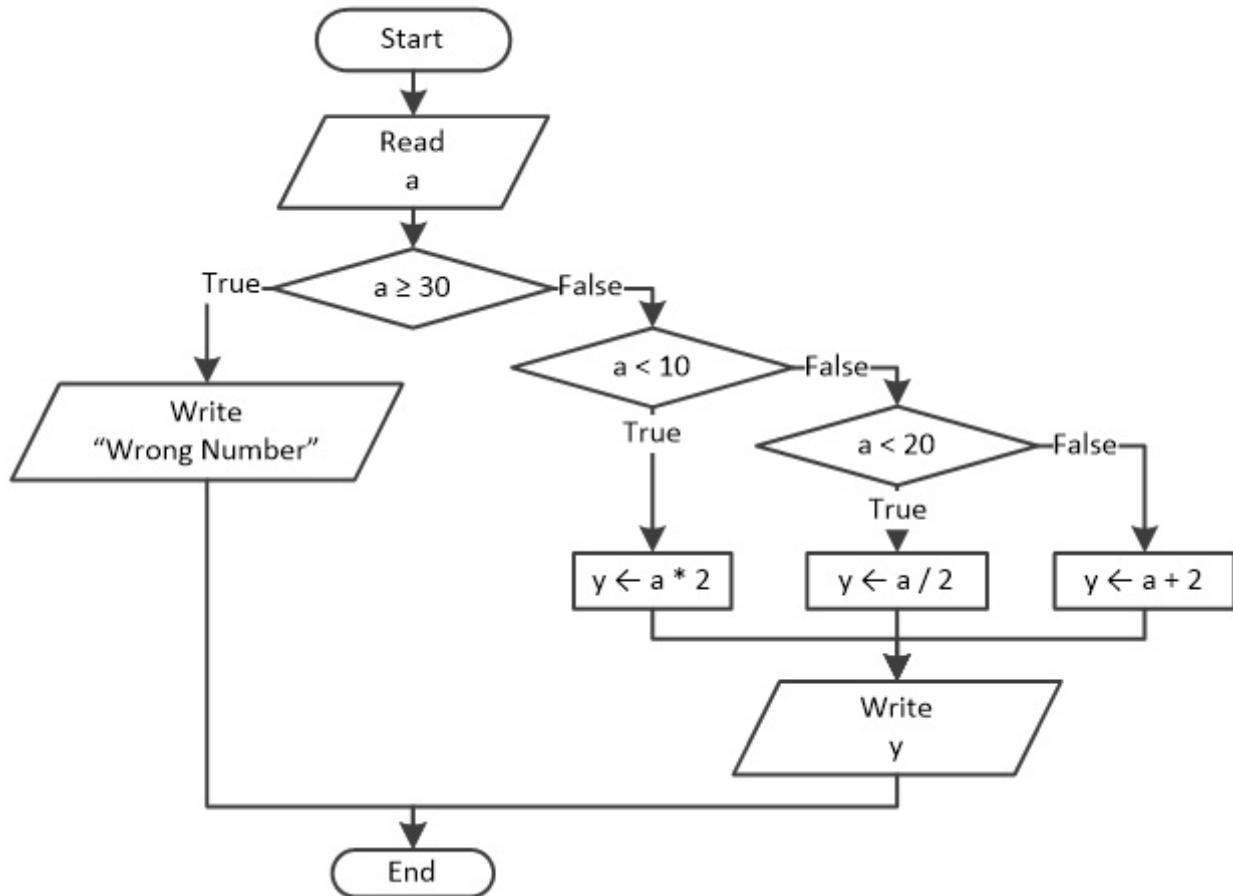
This is because of the last path on the right side which, in the initial flowchart, didn't include the `write y` statement.

Examine both flowcharts to see whether they produce the same result. For example, suppose a user enters a wrong number. In both flowcharts, the flow of execution goes to the `Write "Wrong Number"` statement. After that, the initial flowchart executes no other statements but on the contrary, the second flowchart executes an extra `Write y` statement.

 You cannot move a statement or block of statements outside of a decision control structure if it does not exist in all paths.

You may now wonder whether there is any other way to move the `write y` statement outside of the multiple-alternative decision structure. The answer

is “yes”, but you need to slightly rearrange the flowchart. You need to completely remove the last path on the right and use a brand new decision control structure in the beginning to check whether or not the given number is wrong. One possible solution is shown here.



and the C# program is

```

static void Main(string[] args) {
    double a, y;

    a = Double.Parse(Console.ReadLine());

    if (a >= 30) {
        Console.WriteLine("Wrong Number");
    }
    else {
        if (a < 10) {
            y = a * 2;
        }
        else if (a < 20) {
            y = a / 2;
        }
        else {
            y = a + 2;
        }
    }
}
  
```

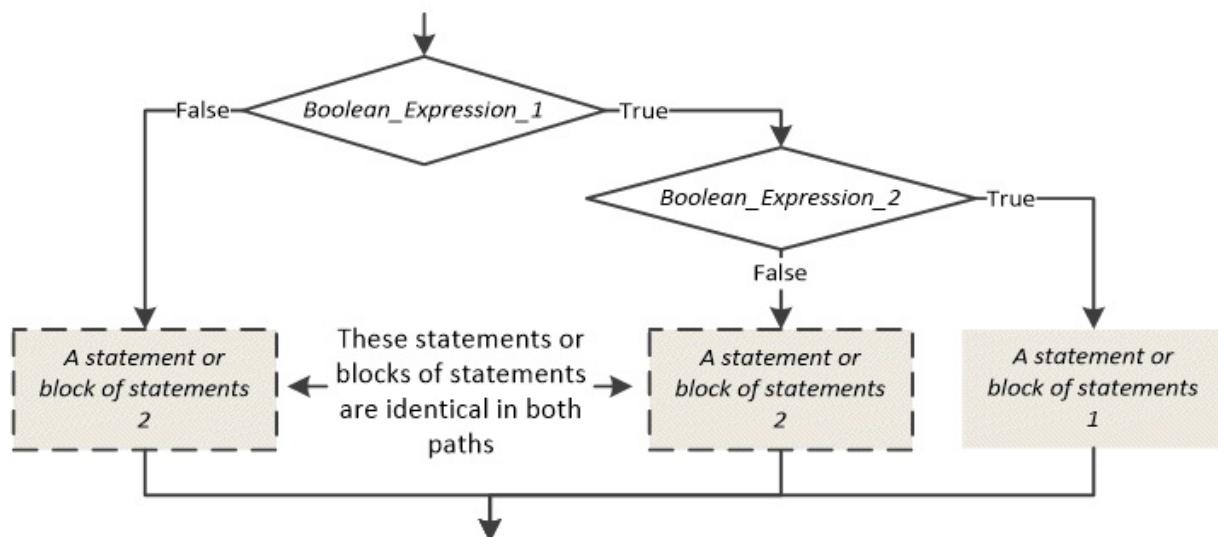
```

    }
    else {
        y = a + 2;
    }
    Console.WriteLine(y);
}
}

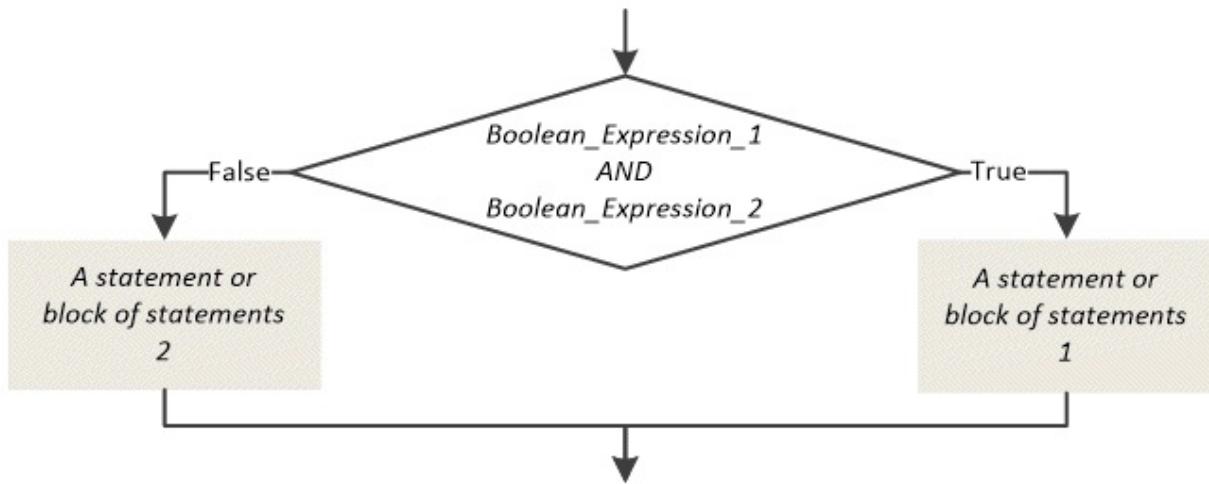
```

## 22.4 Logical Operators – to Use, or not to Use: That is the Question!

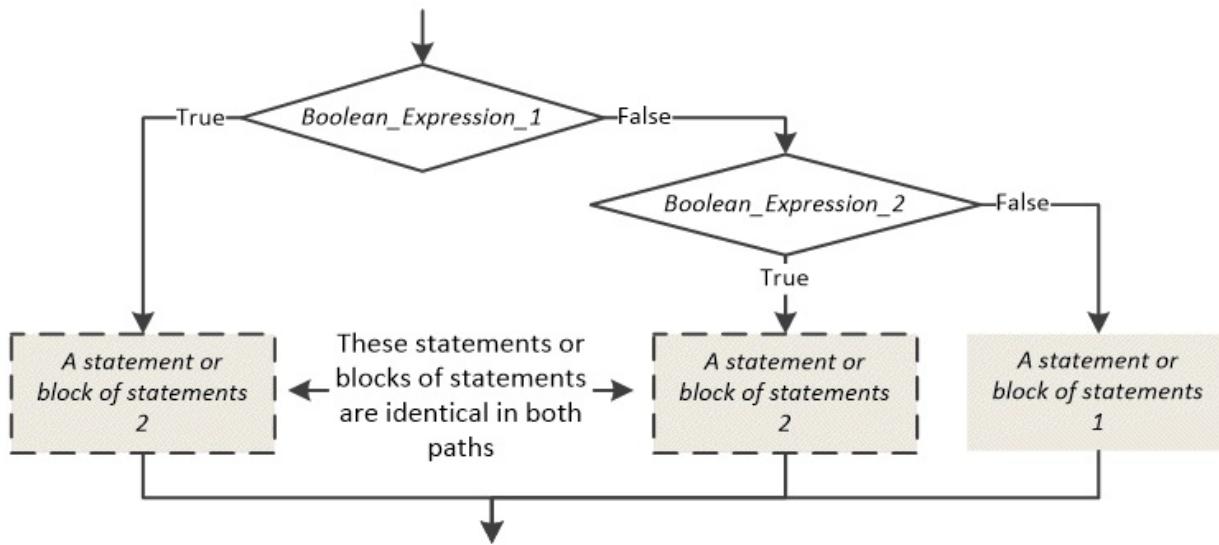
There are some cases in which you can use a logical operator instead of nested decision control structures, and this can lead to increased readability. Take a look at the following flowchart fragment given in general form.



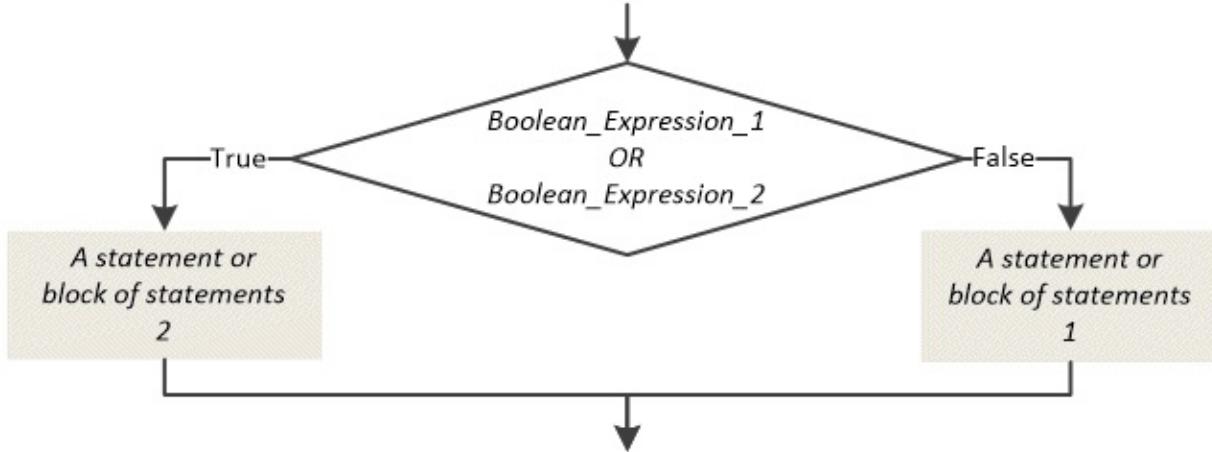
As you can see, the statement or block of statements *1* is executed only when **both** Boolean expressions evaluate to **true**. The statement or block of statements *2* is executed in all other cases. Therefore, this flowchart fragment can be redesigned using the **AND** logical operator.



Now, let's take a look at another flowchart fragment given in general form.



In this flowchart fragment, the statement or block of statements 2 is executed when **either** *Boolean\_Expression\_1* evaluates to true **or** *Boolean\_Expression\_2* evaluates to true. Therefore, you can redesign this flowchart fragment using the OR logical operator as shown here.



Obviously, these methodologies can be adapted to be used on nested decision control structures as well.

### Exercise 22.4-1 Rewriting the Code

Rewrite the following C# program using logical operators.

```

static void Main(string[] args) {
    string today, name;

    today = Console.ReadLine();
    name = Console.ReadLine();

    if (today == "February 16") {
        if (name == "Loukia") {
            Console.WriteLine("Happy Birthday!!!");
        }
        else {
            Console.WriteLine("No match!");
        }
    }
    else {
        Console.WriteLine("No match!");
    }
}

```

### Solution

The `Console.WriteLine("Happy Birthday!!!")` statement is executed only when **both** Boolean expressions evaluate to true. The statement `Console.WriteLine("No match!")` is executed in all other cases. Therefore, you can rewrite the C# program using the AND ( `&&` ) logical operator.

```
static void Main(string[] args) {
    string today, name;

    today = Console.ReadLine();
    name = Console.ReadLine();

    if (today == "February 16" && name == "Loukia") {
        Console.WriteLine("Happy Birthday!!!");
    }
    else {
        Console.WriteLine("No match!");
    }
}
```

### Exercise 22.4-2 Rewriting the Code

Rewrite the following C# program using logical operators.

```
static void Main(string[] args) {
    int a, b, y;

    a = Int32.Parse(Console.ReadLine());
    b = Int32.Parse(Console.ReadLine());

    y = 0;
    if (a > 10) {
        y++;
    }
    else if (b > 20) {
        y++;
    }
    else {
        y--;
    }
    Console.WriteLine(y);
}
```

### Solution

The `y++` statement is executed when **either** variable `a` is greater than 10 **or** variable `b` is greater than 20. Therefore, you can rewrite the C# program using the OR ( `||` ) logical operator.

```
static void Main(string[] args) {
    int a, b, y;

    a = Int32.Parse(Console.ReadLine());
```

```

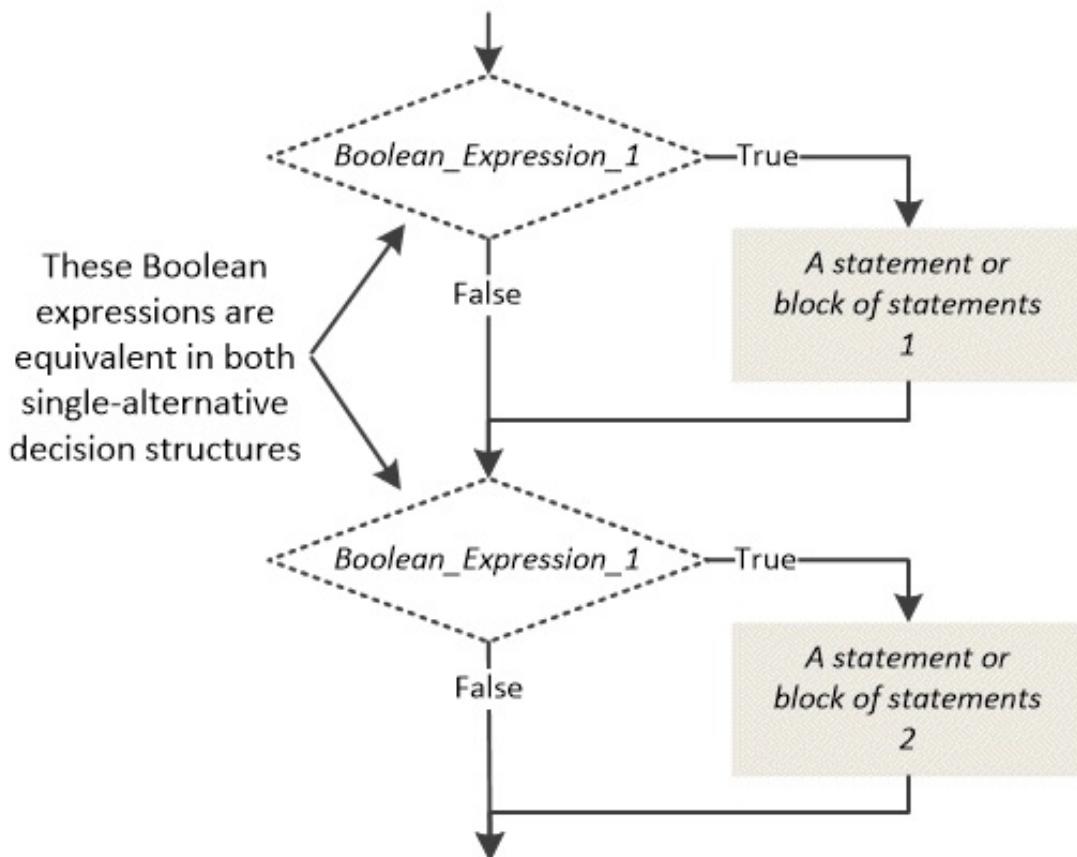
b = Int32.Parse(Console.ReadLine());

y = 0;
if (a > 10 || b > 20) {
    y++;
}
else {
    y--;
}
Console.WriteLine(y);
}

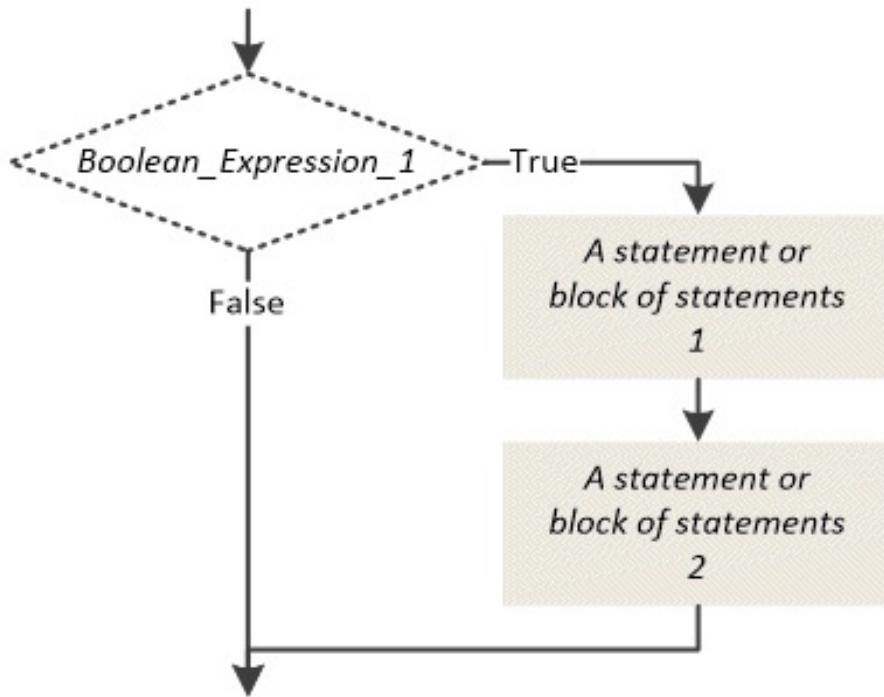
```

## 22.5 Merging Two or More Single-Alternative Decision Structures

Many times, an algorithm contains two or more single-alternative decision structures in a row which actually evaluate the same Boolean expression. An example is shown here.



When a situation like this occurs, you can just merge all single-alternative decision structures to a single one, as follows.



 The single-alternative decision structures need to be adjacent to each other. If any statement exists between them, you can't merge them unless you are able to move this statement to somewhere else in your code.

### Exercise 22.5-1 Merging the Decision Control Structures

In the following C# program, merge the single-alternative decision structures.

```

static void Main(string[] args) {
    int a;

    a = Int32.Parse(Console.ReadLine());

    if (a > 0) {
        Console.WriteLine("Hello");
    }

    if (a > 0) {
        Console.WriteLine("Hermes");
    }
}
  
```

### Solution

The first and second decision control structures are evaluating exactly the same Boolean expressions, so they can simply be merged into a single one.

The C# program becomes

```
static void Main(string[] args) {
    int a;

    a = Int32.Parse(Console.ReadLine());

    if (a > 0) {
        Console.WriteLine("Hello");
        Console.WriteLine("Hermes");
    }
}
```

### Exercise 22.5-2 Merging the Decision Control Structures

In the following C# program, merge as many single-alternative decision structures as possible.

```
static void Main(string[] args) {
    int a, y, b;

    a = Int32.Parse(Console.ReadLine());

    y = 0;

    if (a > 0) {
        y += a + 1;
    }
}
```

b = Int32.Parse(Console.ReadLine());

[More...]

```
if (!(a <= 0)) {
    Console.WriteLine("Hello Hera");
}
```

a++;

[More...]

```
if (a > 0) {
    Console.WriteLine("Hallo Welt");
}
```

Console.WriteLine(y);

}

## Solution

---

If you take a closer look at the C# program, it becomes clear that the first and second decision control structures are actually evaluating exactly the same Boolean expression. Negation of  $a > 0$  results in  $a \leq 0$ , and a second negation of  $a \leq 0$  (using the NOT ( ! ) operator this time) results in  $!(a \leq 0)$ . Thus,  $a > 0$  is in fact equivalent to  $!(a \leq 0)$ .

 *Two negations result in an affirmative.*

However, between the first and second decision control structures there is the statement `b = Int32.Parse(Console.ReadLine())`, which prevents you from merging them into a single one. Fortunately, this statement can be moved to the beginning of the program since it doesn't really affect the rest flow of execution.

On the other hand, between the second and third decision control structures there is the statement `a++`, which also prevents you from merging; unfortunately, this statement cannot be moved anywhere else because it does affect the rest of the flow of execution (the second and third decision control structures are dependent upon this statement). Thus, the third decision control structure cannot be merged with the first and second ones!

The final C# program looks like this.

```
static void Main(string[] args) {
    int a, b, y;

    a = Int32.Parse(Console.ReadLine());
    b = Int32.Parse(Console.ReadLine());

    y = 0;

    if (a > 0) {
        y += a + 1;
        Console.WriteLine("Hello Hera");
    }

    a++;

    if (a > 0) {
        Console.WriteLine("Hallo Welt");
    }
}
```

```
    Console.WriteLine(y);
}
```

## 22.6 Replacing Two Single-Alternative Decision Structures with a Dual-Alternative One

Take a look at the next example.

```
if (x > 40) {
    //Do something
}

if (x <= 40) {
    //Do something else
}
```

The first decision control structure evaluates variable *x* to test if it is bigger than 40, and right after that, a second decision control structure evaluates the same variable again to test if it is less than or equal to 40!

This is a very common “mistake” that novice programmers make. They use two single-alternative decision structures even though one dual-alternative decision structure can accomplish the same thing.

The previous example can be rewritten using only one dual-alternative decision structure, as shown here.

```
if (x > 40) {
    //Do something
}
else {
    //Do something else
}
```

Even though both examples are absolutely correct and work perfectly well, the second alternative is better. The CPU needs to evaluate only one Boolean expression, which results in faster execution time.

 *The two single-alternative decision structures must be adjacent to each other. If any statement exists between them, you can't “merge” them (that is, replace them with a dual-alternative decision structure) unless you are able to move this statement to somewhere else in your code.*

### Exercise 22.6-1 “Merging” the Decision Control Structures

*In the following code fragment, “merge” as many single-alternative*

*decision structures as possible.*

```
int a, y, b;

a = Int32.Parse(Console.ReadLine());

y = 0;

if (a > 0) {
    y += a;
}

b = Int32.Parse(Console.ReadLine());

if (!(a > 0)) {
    Console.WriteLine("Hello Zeus");
}

if (y > 0) {
    Console.WriteLine(y + 5);
}

y++;

if (y <= 0) {
    Console.WriteLine(y + 12);
}
```

## Solution

---

The first decision control structure evaluates variable a to test if it is greater than zero, and just right after that the second decision control structure evaluates variable a again to test if it is not greater than zero. Even though there is the statement `b = Int32.Parse(Console.ReadLine())` between them, this statement can be moved somewhere else because it doesn't really affect the rest of the flow of execution. Therefore, the first and second decision control structures can be merged!

On the other hand, between the third and fourth decision control structures there is the statement `y++` which also prevents you from merging.

Unfortunately, this statement cannot be moved anywhere else because it does affect the rest of the flow of execution (the third and fourth decision control structures are dependent upon this statement). Therefore, the third and fourth decision control structures cannot be merged!

The final code fragment becomes

```
int a, b, y;

a = Int32.Parse(Console.ReadLine());
b = Int32.Parse(Console.ReadLine());

y = 0;

if (a > 0) {
    y += a;
}
else {
    Console.WriteLine("Hello Zeus");
}

if (y > 0) {
    Console.WriteLine(y + 5);
}

y++;

if (y <= 0) {
    Console.WriteLine(y + 12);
}
```

## 22.7 Put the Boolean Expressions Most Likely to be True First

Both the multiple-alternative and the case decision structure often need to check several Boolean expressions before deciding which statement or block of statements to execute. In the next decision control structure,

```
if (Boolean_Expression_1) {
    A statement or block of statements 1
}
else if (Boolean_Expression_2) {
    A statement or block of statements 2
}
else if (Boolean_Expression_3) {
    A statement or block of statements 3
}
```

the program first tests if *Boolean\_Expression\_1* is true. If not, it tests if

*Boolean\_Expression\_2* is true, and if not, it tests *Boolean\_Expression\_3*. However, what if *Boolean\_Expression\_1* is false most of the time and *Boolean\_Expression\_3* is true most of the time? This means that time is wasted testing *Boolean\_Expression\_1*, which is usually false, before testing *Boolean\_Expression\_3*, which is usually true.

To make your programs more efficient, you can put the Boolean expressions that are most likely to be true at the beginning, and the Boolean expressions that are most likely to be false at the end, as follows.

```
if (Boolean_Expression_3) {  
    A statement or block of statements 3  
}  
}  
else if (Boolean_Expression_2) {  
    A statement or block of statements 2  
}  
}  
else if (Boolean_Expression_1) {  
    A statement or block of statements 1  
}
```

 Although this change may seem nonessential, every little bit of time that you save can add up to make your programs run faster and more efficiently.

### ***Exercise 22.7-1 Rearranging the Boolean Expressions***

According to an ultra-high top secret report, America's favorite pets are dogs, with cats at second place, guinea pigs next, and parrots coming in last. In the following code fragment, rearrange the Boolean expressions to make the program run faster and more efficiently for most of the cases.

```
string kind;  
  
Console.WriteLine("What is your favorite pet? ");  
kind = Console.ReadLine();  
  
switch (kind) {  
    case "Parrots":  
        Console.WriteLine("It screeches!");  
        break;  
    case "Guinea pig":  
        Console.WriteLine("It squeaks");  
        break;
```

```
    case "Dog":  
        Console.WriteLine("It barks");  
        break;  
    case "Cat":  
        Console.WriteLine("It meows");  
        break;  
}
```

## Solution

---

For this top secret report, you can rearrange the code fragment to make it run a little bit faster for most of the cases.

```
string kind;  
  
Console.Write("What is your favorite pet? ");  
kind = Console.ReadLine();  
  
switch (kind) {  
    case "Dog":  
        Console.WriteLine("It barks");  
        break;  
    case "Cat":  
        Console.WriteLine("It meows");  
        break;  
    case "Guinea pig":  
        Console.WriteLine("It squeaks");  
        break;  
    case "Parrots":  
        Console.WriteLine("It screeches!");  
        break;  
}
```

## 22.8 Why is Code Indentation so Important?

As you've been reading through this book, you may wonder why space characters appear in front of the C# statements and why these statements are not written at the leftmost edge of the paragraph, as in the following example.

```
static void Main(string[] args) {  
    int x, y;  
  
    Console.Write("Enter a number: ");  
    x = Int32.Parse(Console.ReadLine());  
    Console.Write("Enter a second number: ");
```

```
y = Int32.Parse(Console.ReadLine());
if (x > 5) {
    Console.WriteLine("Variable x is greater than 5");
}
else {
    x = x + y;
    Console.WriteLine("Hello Zeus!");
    if (x == 3) {
        Console.WriteLine("Variable x equals to 3");
    }
    else {
        x = x - y;
        Console.WriteLine("Hello Olympians!");
        if (x + y == 24) {
            Console.WriteLine("The sum of x + y equals to 24");
        }
        else {
            Console.WriteLine("Nothing of the above");
        }
    }
}
```

The answer is obvious! A code without indentation is difficult to read and understand. Anyone who reads a code written this way gets confused about the `if` – `else` pairing (that is, to which `if` an `else` belongs). Moreover, if a long C# program is written this way, it is almost impossible to find, for example, the location of a forgotten closing brace  `}`.

Code indentation can be defined as a way to organize your source code. Indentation formats the code using spaces or tabs in order to improve readability. Well indented code is very helpful, even if it takes some extra effort, because in the long run it saves you a lot of time when you revisit your code. Unfortunately, it is sometimes overlooked and the trouble occurs at a later time. Following a particular programming style helps you to avoid syntax and logic errors. It also helps programmers to more easily study and understand code written by others.

 *Code indentation is similar to the way authors visually arrange the text of a book. Instead of writing long series of sentences, they break the text into chapters and paragraphs. This action doesn't change the meaning of the text but it makes it easier to read.*

All statements that appear inside a set of braces { } should always be indented. For example, by indenting the statements inside a dual-alternative decision structure, you visually set them apart. As a result, anyone can tell at a glance which statements are executed when the Boolean expression evaluates to true, and which are executed when the Boolean expression evaluates to false.

 *Only humans have difficulty reading and understanding a program without indentation. A computer can execute any C# code, written with or without indentation, as long as it contains no syntax errors.*

## 22.9 Review Questions: True/False

Choose **true** or **false** for each of the following statements.

1. Smaller algorithms are always the best solution to a given problem.
2. You can move a statement outside, and right before, a dual-alternative decision structure as long as it exists at the beginning of both paths of the decision structure.
3. You can always use a logical operator instead of nested decision control structures to increase readability.
4. Two single-alternative decision structures can be merged into one single-alternative decision only when they are in a row and when they evaluate the same Boolean expression.
5. Conversion from a dual-alternative decision structure to two single-alternative decision structures is always possible.
6. Two single-alternative decision structures can be replaced by one dual-alternative decision only when they are in a row and only when they evaluate the same Boolean expression.
7. C# programs that include decision control structures and written without code indentation cannot be executed by a computer.

## 22.10 Review Questions: Multiple Choice

Select the correct answer for each of the following statements.

1. The following two programs

```
static void Main(string[] args) {
    int a;
```

```
a = Int32.Parse(Console.ReadLine());
if (a > 40) {
    Console.WriteLine(a * 2);
    a++;
}
else {
    Console.WriteLine(a * 2);
    a += 5;
}
}
```

```
static void Main(string[] args) {
    int a;

    a = Int32.Parse(Console.ReadLine());
    Console.WriteLine(a * 2);
    if (a > 40) {
        a++;
    }
    else {
        a += 5;
    }
}
```

- a. produce the same result.
- b. do not produce the same result.
- c. none of the above

2. The following two programs

```
static void Main(string[] args) {
    int a;

    a = Int32.Parse(Console.ReadLine());
    if (a > 40) {
        Console.WriteLine(a * 2);
    }
    if (a > 40) {
        Console.WriteLine(a * 3);
    }
}
```

```
static void Main(string[] args) {
```

```

int a;

a = Int32.Parse(Console.ReadLine());
if (a > 40) {
    Console.WriteLine(a * 2);
    Console.WriteLine(a * 3);
}
}

```

- a. produce the same results, but the first program is faster.
- b. produce the same results, but the second program is faster.
- c. do not produce the same results.
- d. none of the above
3. The following two programs

```

static void Main(string[] args) {
    int a;

    a = Int32.Parse(Console.ReadLine());
    if (a > 40) {
        Console.WriteLine(a * 2);
    }
    else {
        Console.WriteLine(a * 3);
    }
}

```

```

static void Main(string[] args) {
    int a;

    a = Int32.Parse(Console.ReadLine());
    if (a > 40) {
        Console.WriteLine(a * 2);
    }
    if (a <= 40) {
        Console.WriteLine(a * 3);
    }
}

```

- a. produce the same result(s), but the first program is faster.
- b. produce the same result(s), but the second program is faster.
- c. do not produce the same result(s).

- d. none of the above
4. The following program

```
static void Main(string[] args) {  
    int x;  
    x = Int32.Parse(Console.ReadLine());  
    if (x < 0) {  
        x = (-1) * x;  
        Console.WriteLine(x);  
    }  
}
```

cannot be executed by a computer because

- a. it does not use code indentation.
- b. it includes logic errors.
- c. none of the above

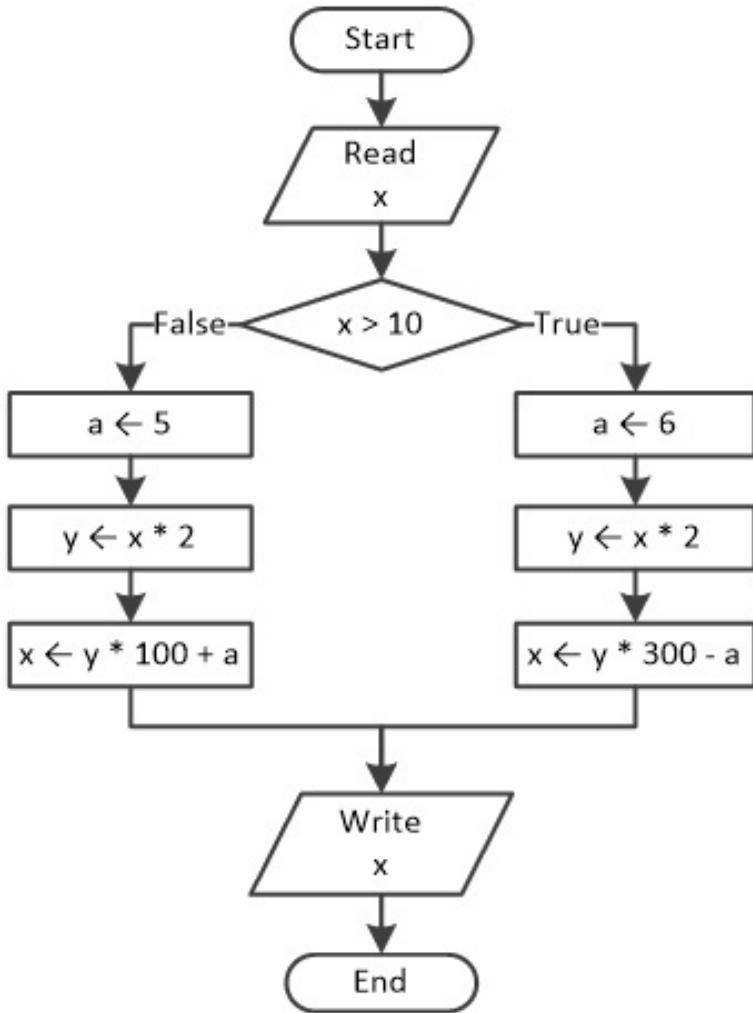
## 22.11 Review Exercises

Complete the following exercises.

1. Rewrite the following C# program using fewer statements.

```
static void Main(string[] args) {  
    int a, x, y;  
  
    y = Int32.Parse(Console.ReadLine());  
  
    if (y > 0) {  
        x = Int32.Parse(Console.ReadLine());  
        a = x * 4 * y;  
        Console.WriteLine(y);  
        a++;  
    }  
    else {  
        x = Int32.Parse(Console.ReadLine());  
        a = x * 2 * y + 7;  
        Console.WriteLine(y);  
        a--;  
    }  
    Console.WriteLine(a);  
}
```

2. Redesign the following flowchart using fewer statements.



3. Rewrite the following C# program using fewer statements.

```

static void Main(string[] args) {
    double a, y;

    a = Double.Parse(Console.ReadLine());

    if (a < 1) {
        y = 5 + a;
        Console.WriteLine(y);
    }
    else if (a < 5) {
        y = 23 / a;
        Console.WriteLine(y);
    }
    else if (a < 10) {
        y = 5 * a;
        Console.WriteLine(y);
    }
}

```

```

    }
    else {
        Console.WriteLine("Error!");
    }
}

```

4. Rewrite the following C# program using logical operators.

```

static void Main(string[] args) {
    int day, month;
    string name;

    day = Int32.Parse(Console.ReadLine());
    month = Int32.Parse(Console.ReadLine());
    name = Console.ReadLine();

    if (day == 16) {
        if (month == 2) {
            if (name == "Loukia") {
                Console.WriteLine("Happy Birthday!!!");
            }
            else {
                Console.WriteLine("No match!");
            }
        }
        else {
            Console.WriteLine("No match!");
        }
    }
    else {
        Console.WriteLine("No match!");
    }
}

```

5. A teacher asks her students to rewrite the following C# program without using logical operators.

```

static void Main(string[] args) {
    double a, b, c, d;

    a = Double.Parse(Console.ReadLine());
    b = Double.Parse(Console.ReadLine());
    c = Double.Parse(Console.ReadLine());

    if (a > 10 && c < 2000) {
        d = (a + b + c) / 12;
        Console.WriteLine("The result is: " + d);
    }
}

```

```

    }
    else {
        Console.WriteLine("Error!");
    }
}

```

One student wrote the following C# program:

```

static void Main(string[] args) {
    double a, b, c, d;

    a = Double.Parse(Console.ReadLine());
    b = Double.Parse(Console.ReadLine());
    c = Double.Parse(Console.ReadLine());

    if (a > 10) {
        if (c < 2000) {
            d = (a + b + c) / 12;
            Console.WriteLine("The result is: " + d);
        }
        else {
            Console.WriteLine("Error!");
        }
    }
}

```

Determine if the program operates the same way for all possible paths as the one given by his teacher. If not, try to modify it and make it work the same way.

- Rewrite the following C# program using only single-alternative decision structures.

```

static void Main(string[] args) {
    double a, b, c, d;

    a = Double.Parse(Console.ReadLine());
    b = Double.Parse(Console.ReadLine());
    c = Double.Parse(Console.ReadLine());

    if (a > 10) {
        if (b < 2000) {
            if (c != 10) {
                d = (a + b + c) / 12;
                Console.WriteLine("The result is: " + d);
            }
        }
    }
}

```

```
    }
    else {
        Console.WriteLine("Error!");
    }
}
```

7. In the following C# program, replace the two single-alternative decision structures by one dual-alternative decision structure.

```
static void Main(string[] args) {
    int a, b, y;

    a = Int32.Parse(Console.ReadLine());

    y = 3;
    if (a > 0) {
        y = y * a;
    }
    b = Int32.Parse(Console.ReadLine());
    if (!(a <= 0)) {
        Console.WriteLine("Hello Zeus");
    }

    Console.WriteLine(y + " " + b);
}
```

8. Rewrite the following C# program, using only one dual-alternative decision structure.

```
static void Main(string[] args) {
    double a, b, y;

    a = Double.Parse(Console.ReadLine());

    y = 0;
    if (a > 0) {
        y = y + 7;
    }
    b = Double.Parse(Console.ReadLine());
    if (!(a > 0)) {
        Console.WriteLine("Hello Zeus");
    }
    if (a <= 0) {
        Console.WriteLine(Math.Abs(a));
    }
    Console.WriteLine(y);
}
```

9. According to research from 2013, the most popular operating system on tablet computers was iOS, with Android being in second place and Microsoft Windows in last place. In the following C# program, rearrange the Boolean expressions to make the program run more efficiently for most of the cases.

```
static void Main(string[] args) {
    string os;

    Console.WriteLine("What is your tablet's OS? ");
    os = Console.ReadLine();

    if (os == "Windows") {
        Console.WriteLine("Microsoft");
    }
    else if (os == "iOS") {
        Console.WriteLine("Apple");
    }
    else if (os == "Android") {
        Console.WriteLine("Google");
    }
}
```

# Chapter 23

## More Exercises with Decision Control Structures

---

### 23.1 Simple Exercises with Decision Control Structures

#### Exercise 23.1-1 Both Odds or Both Evens?

*Write a C# program that prompts the user to enter two integers and then displays a message indicating whether both numbers are odd or both are even; otherwise the message “Nothing special” must be displayed.*

#### Solution

The C# program is shown here.

```
project_23_1_1
```

```
static void Main(string[] args) {
    int n1, n2;

    Console.WriteLine("Enter an integer: ");
    n1 = Int32.Parse(Console.ReadLine());
    Console.WriteLine("Enter a second integer: ");
    n2 = Int32.Parse(Console.ReadLine());

    if (n1 % 2 == 0 && n2 % 2 == 0) {
        Console.WriteLine("Both numbers are evens");
    }
    else if (n1 % 2 != 0 && n2 % 2 != 0) {
        Console.WriteLine("Both numbers are odds");
    }
    else {
        Console.WriteLine("Nothing special!");
    }
}
```

#### Exercise 23.1-2 Is it an Integer?

*Write a C# program that prompts the user to enter a number and then displays a message indicating whether the data type of this number is integer or real.*

#### Solution

It is well known that a number is considered an integer when it contains no

fractional part. In C#, you can use the `(int)` casting operator to get the integer portion of any real number. If the number given is equal to its integer portion, then the number is considered an integer.

For example, if the user enters the number 7, this number and its integer portion, `(int)(7)`, are equal.

On the other hand, if the user enters the number 7.3, this number and its integer portion, `(int)(7.3)`, are not equal.

The C# program is as follows.

### project\_23\_1\_2

```
static void Main(string[] args) {
    double x;

    Console.WriteLine("Enter a number: ");
    x = Double.Parse(Console.ReadLine());

    if (x == (int)x) {
        Console.WriteLine(x + " is integer");
    }
    else {
        Console.WriteLine(x + " is real");
    }
}
```

 Note that the method `Double.Parse()` is used in the data input stage. This is necessary in order to allow the user to enter either an integer or a float.

### **Exercise 23.1-3 Validating Data Input and Finding Odd and Even Numbers**

Design a flowchart and write the corresponding C# program that prompts the user to enter a non-negative integer, and then displays a message indicating whether this number is even; it must display “Odd” otherwise. Moreover, if the user enters a negative value or a float, an error message must be displayed.

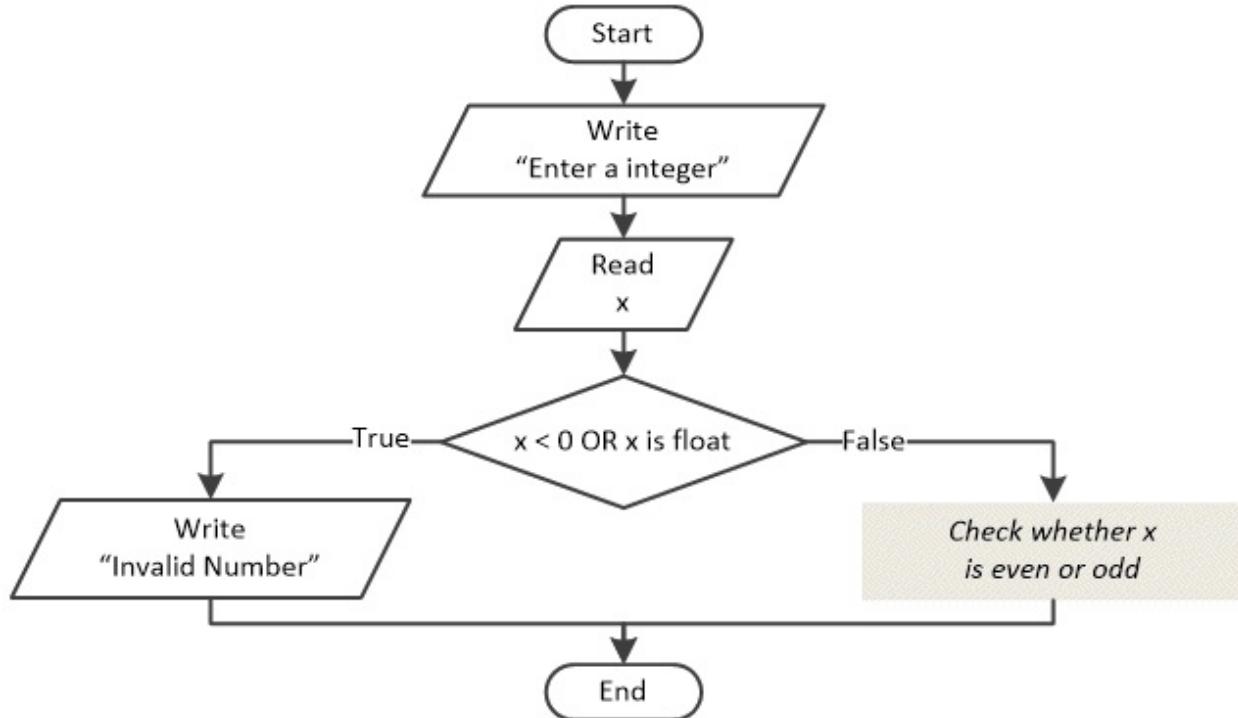
(This exercise gives you some practice in working with data validation).

### **Solution**

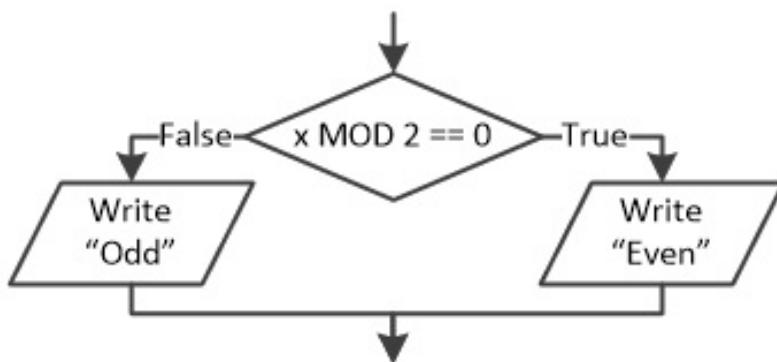
Data validation is the process of restricting data input, forcing the user to

enter only valid values.

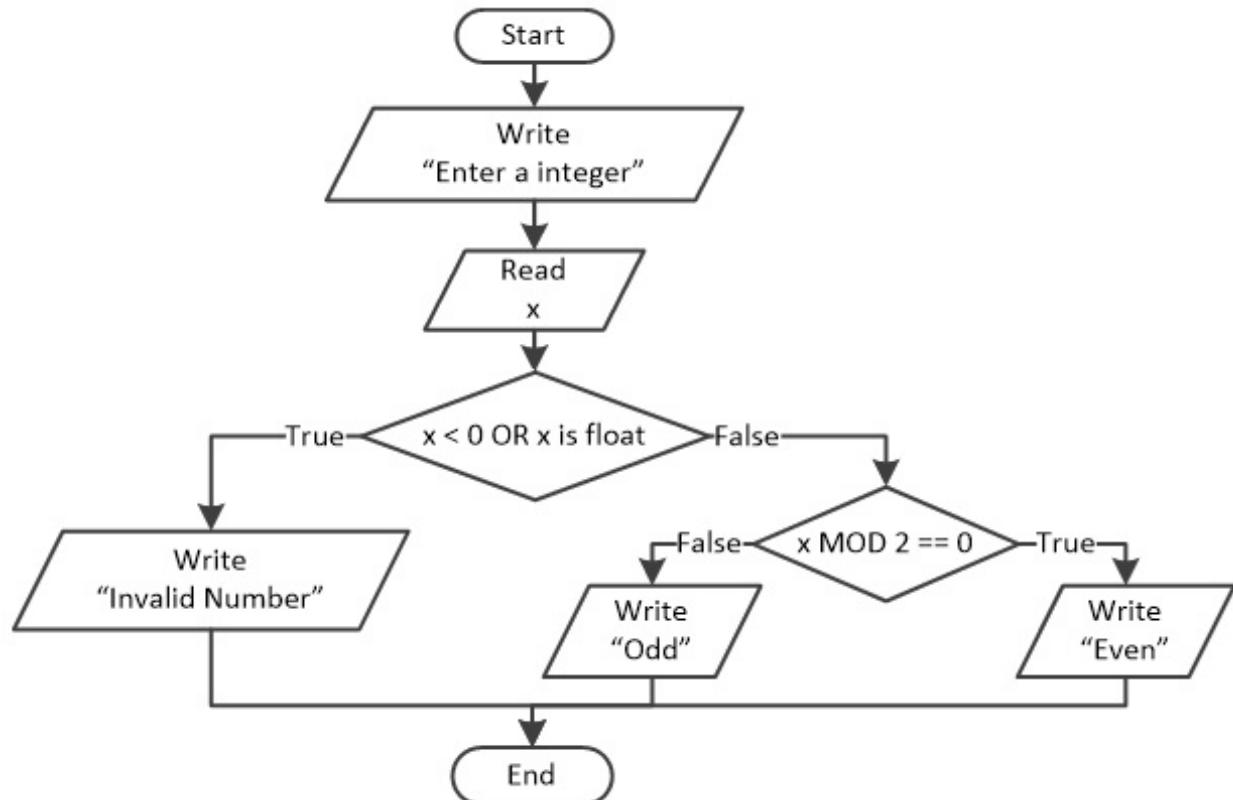
In this exercise, you need to prompt the user to enter a non-negative integer and display an error message when he or she enters either a negative value or a float. The flowchart that solves this exercise given in general form is as follows.



The following decision control structure is taken from [Exercise 17.1-4](#). It tests whether variable  $x$  is even or odd.



After combining both flowcharts, the final flowchart looks like this.



The C# program is shown here.

### project\_23\_1\_3

```

static void Main(string[] args) {
    double x;

    Console.WriteLine("Enter an integer: ");
    x = Double.Parse(Console.ReadLine());

    if (x < 0 || x != (int)x) {
        Console.WriteLine("Invalid Number");
    }
    else {
        if (x % 2 == 0) {
            Console.WriteLine("Even");
        }
        else {
            Console.WriteLine("Odd");
        }
    }
}

```

### Exercise 23.1-4 Converting Gallons to Liters, and Vice Versa

*Write a C# program that displays the following menu:*

1. Convert gallons to liters
2. Convert liters to gallons

*The program prompts the user to enter a choice (1 or 2) and a quantity. Then, it calculates and displays the required value. It is given that*

$$1 \text{ gallon} = 3.785 \text{ liters}$$

### **Solution**

---

The C# program is shown here.

#### project\_23\_1\_4

```
const double COEFFICIENT = 3.785;

static void Main(string[] args) {
    int choice;
    double quantity, result;

    Console.WriteLine("1: Gallons to liters");
    Console.WriteLine("2: Liters to gallons");
    Console.Write("Enter choice: ");
    choice = Int32.Parse(Console.ReadLine());

    Console.Write("Enter quantity: ");
    quantity = Double.Parse(Console.ReadLine());

    if (choice == 1) {
        result = quantity * COEFFICIENT;
        Console.WriteLine(quantity + " gallons = " + result + " liters");
    }
    else {
        result = quantity / COEFFICIENT;
        Console.WriteLine(quantity + " liters = " + result + " gallons");
    }
}
```

### **Exercise 23.1-5 Converting Gallons to Liters, and Vice Versa (with Data Validation)**

---

*Rewrite the C# program of the previous exercise to validate the data input. Individual error messages must be displayed when the user enters a choice other than 1 or 2, or a negative gas quantity.*

## Solution

---

The following C# program, given in general form, solves this exercise. It prompts the user to enter a choice. If the choice is invalid, it displays an error message; otherwise, it prompts the user to enter a quantity. However, if the quantity entered is invalid too, it displays another error message; otherwise it proceeds to data conversion, depending on the user's choice.

### >Main Code

```
const double COEFFICIENT = 3.785;

static void Main(string[] args) {
    int choice;
    double quantity, result;

    Console.WriteLine("1: Gallons to liters");
    Console.WriteLine("2: Liters to gallons");
    Console.Write("Enter choice: ");
    choice = Int32.Parse(Console.ReadLine());

    if (choice != 1 && choice != 2) {
        Console.WriteLine("Wrong choice!");
    }
    else {
        Console.Write("Enter quantity: ");
        quantity = Double.Parse(Console.ReadLine());
        if (quantity < 0) {
            Console.WriteLine("Invalid quantity!");
        }
        else {

            Code Fragment 1: Convert gallons to liters  
or liters to gallons depending on user's  
choice.

        }
    }
}
```

**Code Fragment 1** shown below is taken from the previous exercise ([Exercise 23.1-4](#)). It converts gallons to liters, or liters to gallons, depending on the user's choice.

### Code Fragment 1

```
if (choice == 1) {
```

```

        result = quantity * COEFFICIENT;
        Console.WriteLine(quantity + " gallons = " + result + " liters");
    }
else {
    result = quantity / COEFFICIENT;
    Console.WriteLine(quantity + " liters = " + result + " gallons");
}

```

After embedding **Code Fragment 1** in **Main Code**, the final C# program becomes

### project\_23\_1\_5

```

const double COEFFICIENT = 3.785;

static void Main(string[] args) {
    int choice;
    double quantity, result;

    Console.WriteLine("1: Gallons to liters");
    Console.WriteLine("2: Liters to gallons");
    Console.Write("Enter choice: ");
    choice = Int32.Parse(Console.ReadLine());

    if (choice != 1 && choice != 2) {
        Console.WriteLine("Wrong choice!");
    }
    else {
        Console.Write("Enter quantity: ");
        quantity = Double.Parse(Console.ReadLine());
        if (quantity < 0) {
            Console.WriteLine("Invalid quantity!");
        }
        else {
            if (choice == 1) {
                result = quantity * COEFFICIENT;
                Console.WriteLine(quantity + " gallons = " + result + " liters");
            }
            else {
                result = quantity / COEFFICIENT;
                Console.WriteLine(quantity + " liters = " + result + " gallons");
            }
        }
    }
}

```

### Exercise 23.1-6 Where is the Tollkeeper?

*In a toll gate, there is an automatic system that recognizes whether the passing vehicle is a motorcycle, a car, or a truck. Write a C# program that lets the user enter the type of the vehicle (M for motorcycle, C for car, and T for truck) and then displays the corresponding amount of money the driver must pay according to the following table.*

Vehicle Type	Amount to Pay
Motorcycle	\$1
Car	\$2
Track	\$4

*The program must function properly even when characters are given in lowercase. For example, the program must function properly either for “M” or “m”. However, if the user enters a character other than M, C, or T, an error message must be displayed.*

(Some more practice with data validation!)

### **Solution**

---

The solution to this problem is quite simple. The only catch is that the user may enter the uppercase letters M, C, or T, or even the lowercase letters m, c, or t. The program needs to accept both. To handle this, you can convert the user's input to uppercase using the `ToUpper()` method. Then you need to test only for the M, C, or T characters in uppercase.

The C# program is shown here.

#### project\_23\_1\_6

```
static void Main(string[] args) {
    string v;

    v = Console.ReadLine().ToUpper();

    if (v == "M") {          //You need to test only for capital M
        Console.WriteLine("You need to pay $1");
    }
    else if (v == "C") {    //You need to test only for capital C
        Console.WriteLine("You need to pay $2");
    }
    else if (v == "T") {    //You need to test only for capital T
        Console.WriteLine("You need to pay $4");
```

```

    }
    else {
        Console.WriteLine("Invalid vehicle");
    }
}

```



*Note how C# converts the user's input to uppercase.*

### Exercise 23.1-7 The Most Scientific Calculator Ever!

Write a C# program that prompts the user to enter a number, the type of operation (+, -, \*, /), and a second number. The program must execute the required operation and display the result.

#### Solution

The only thing that you need to take care of in this exercise is the possibility the user could enter zero for the divisor (the second number). As you know from mathematics, division by zero is not possible.

The following C# program uses the multiple-alternative decision structure to check the type of operation.

#### project\_23\_1\_7

```

static void Main(string[] args) {
    double a, b;
    string op;

    Console.WriteLine("Enter 1st number: ");
    a = Double.Parse(Console.ReadLine());
    Console.WriteLine("Enter type of operation: ");
    op = Console.ReadLine(); //Variable op is of type string
    Console.WriteLine("Enter 2nd number: ");
    b = Double.Parse(Console.ReadLine());

    switch (op) {
        case "+":
            Console.WriteLine(a + b);
            break;
        case "-":
            Console.WriteLine(a - b);
            break;
        case "*":
            Console.WriteLine(a * b);
            break;
    }
}

```

```

        case "/":
            if (b == 0) {
                Console.WriteLine("Error: Division by zero");
            }
            else {
                Console.WriteLine(a / b);
            }
            break;
    }
}

```

## 23.2 Decision Control Structures in Solving Mathematical Problems

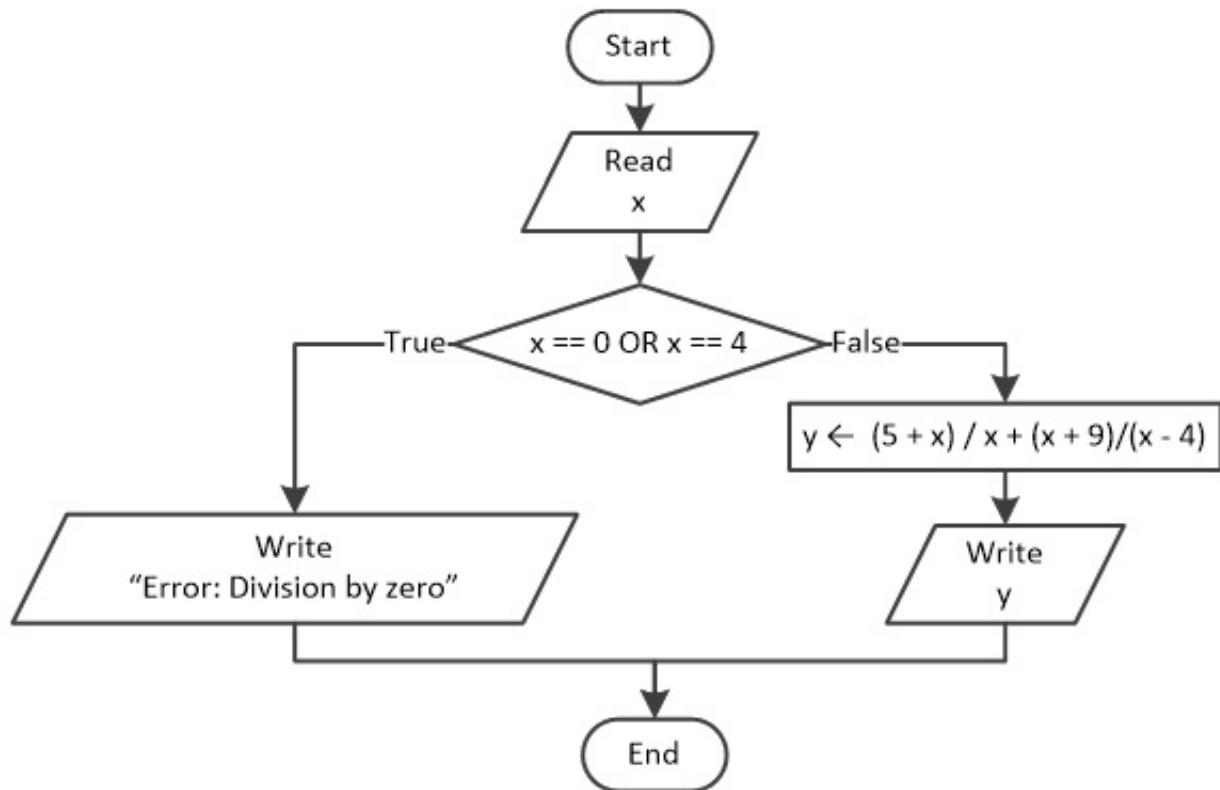
### Exercise 23.2-1 Finding the Value of y

*Design a flowchart and write the corresponding C# program that finds and displays the value of y (if possible) in the following formula.*

$$y = \frac{5+x}{x} + \frac{x+9}{x-4}$$

### Solution

In this exercise the user must not be allowed to enter values 0 or 4 because they make the denominator equal to zero. Therefore, the program needs to take these restrictions into consideration. The flowchart is shown here.



and the C# program is shown here.

### project\_23\_2\_1

```

static void Main(string[] args) {
    double x, y;

    x = Double.Parse(Console.ReadLine());

    if (x == 0 || x == 4) {
        Console.WriteLine("Error: Division by zero!");
    }
    else {
        y = (5 + x) / x + (x + 9) / (x - 4);
        Console.WriteLine(y);
    }
}
  
```

### Exercise 23.2-2 Finding the Values of y

Design a flowchart and write the corresponding C# program that finds and displays the values of y (if possible) in the following formula.

$$y = \begin{cases} \frac{7+x}{x-3} + \frac{3-x}{x}, & x \geq 0 \\ \frac{40x}{x-5} + 3, & x < 0 \end{cases}$$

### **Solution**

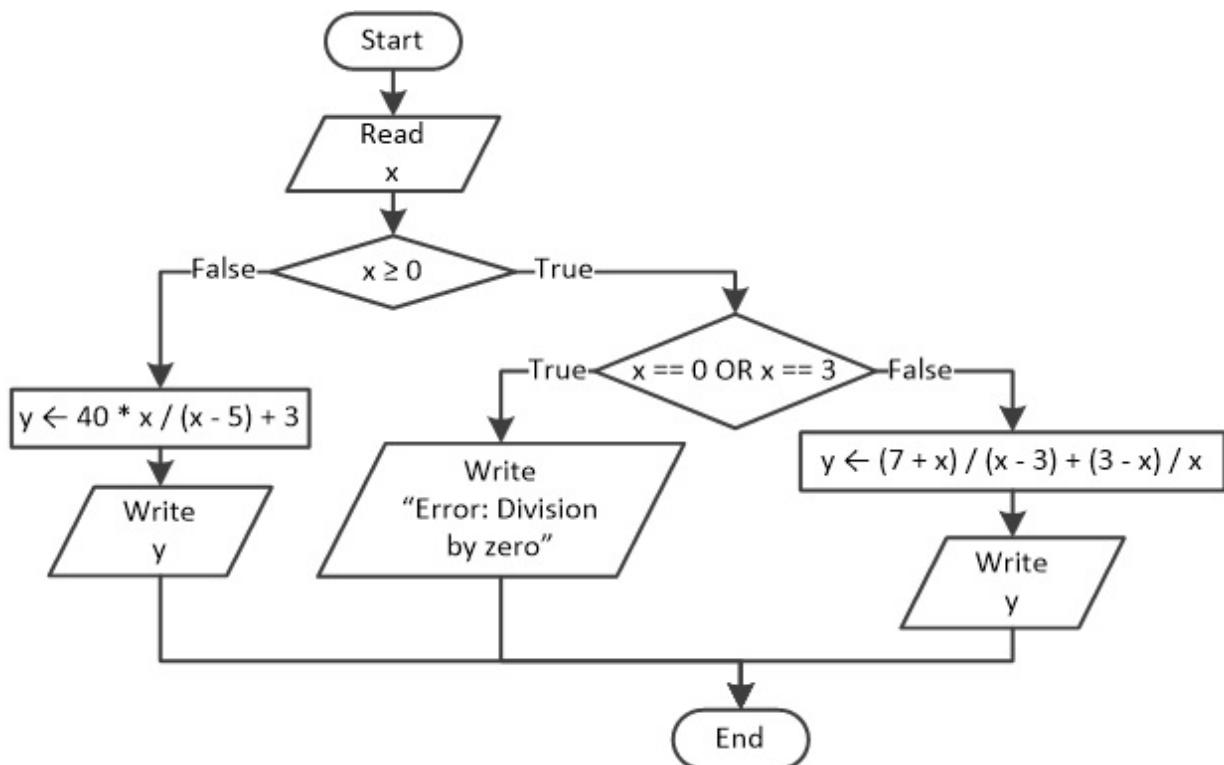
---

The formula has two different results.

- ▶ When  $x$  is greater than or equal to zero, the value of  $y$  in  $\frac{7+x}{x-3} + \frac{3-x}{x}$  can be found following the method shown in the previous exercise.
- ▶ However, for an  $x$  less than zero, a small detail can save you some lines of C# code. If you look carefully, you can see that there are no restrictions on the fraction  $\frac{40x}{x-5}$  because  $x$  can never be +5. Why?

Because in the given formula  $x$  is less than zero!

The flowchart is shown here.



The C# program is shown here.

## project\_23\_2\_2

```
static void Main(string[] args) {
    double x, y;

    x = Double.Parse(Console.ReadLine());

    if (x >= 0) {
        if (x == 0 || x == 3) {
            Console.WriteLine("Error: Division by zero!");
        }
        else {
            y = (7 + x) / (x - 3) + (3 - x) / x;
            Console.WriteLine(y);
        }
    }
    else {
        y = 40 * x / (x - 5) + 3;
        Console.WriteLine(y);
    }
}
```

### Exercise 23.2-3 Solving the Linear Equation $ax + b = 0$

Design a flowchart and write the corresponding C# program that finds and displays the root of the linear equation

$$ax + b = 0$$

### **Solution**

In the equation  $ax + b = 0$ , the coefficients  $a$  and  $b$  are known real numbers and  $x$  represents an unknown quantity to be found. Because  $x$  appears to the first power, this equation is called a *linear equation* or an *equation of the first degree*.

The *root of the equation* is the value of  $x$ , for which this equation is satisfied; that is, the left side of the equality  $ax + b$  equals zero.

In this exercise, the user must enter values for coefficients  $a$  and  $b$ , and the program must find the value of  $x$  for which  $ax + b$  equals zero.

The equation  $ax + b = 0$ , when solved for  $x$ , becomes  $x = -b / a$ .

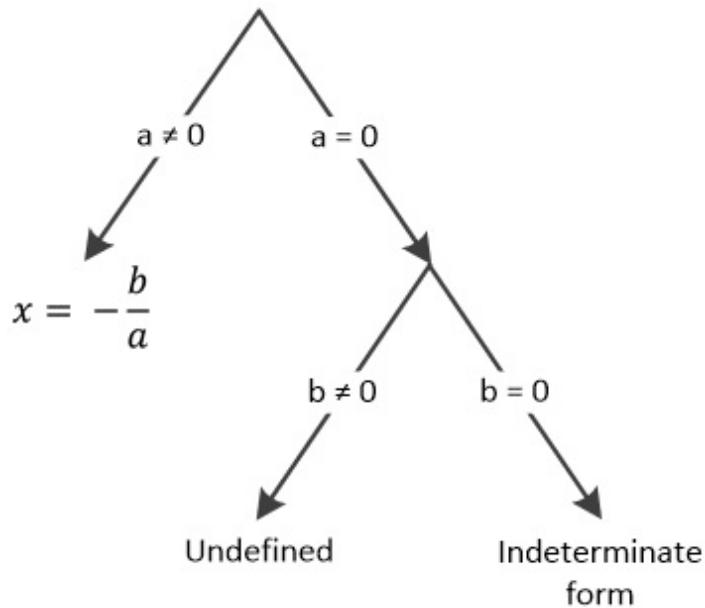
Depending on the user's entered data, three possible situations can arise:

- i. The user might enter the value 0 for coefficient  $a$  and a non-zero value for coefficient  $b$ . In this situation, the result of  $x = -b / a$  is undefined.

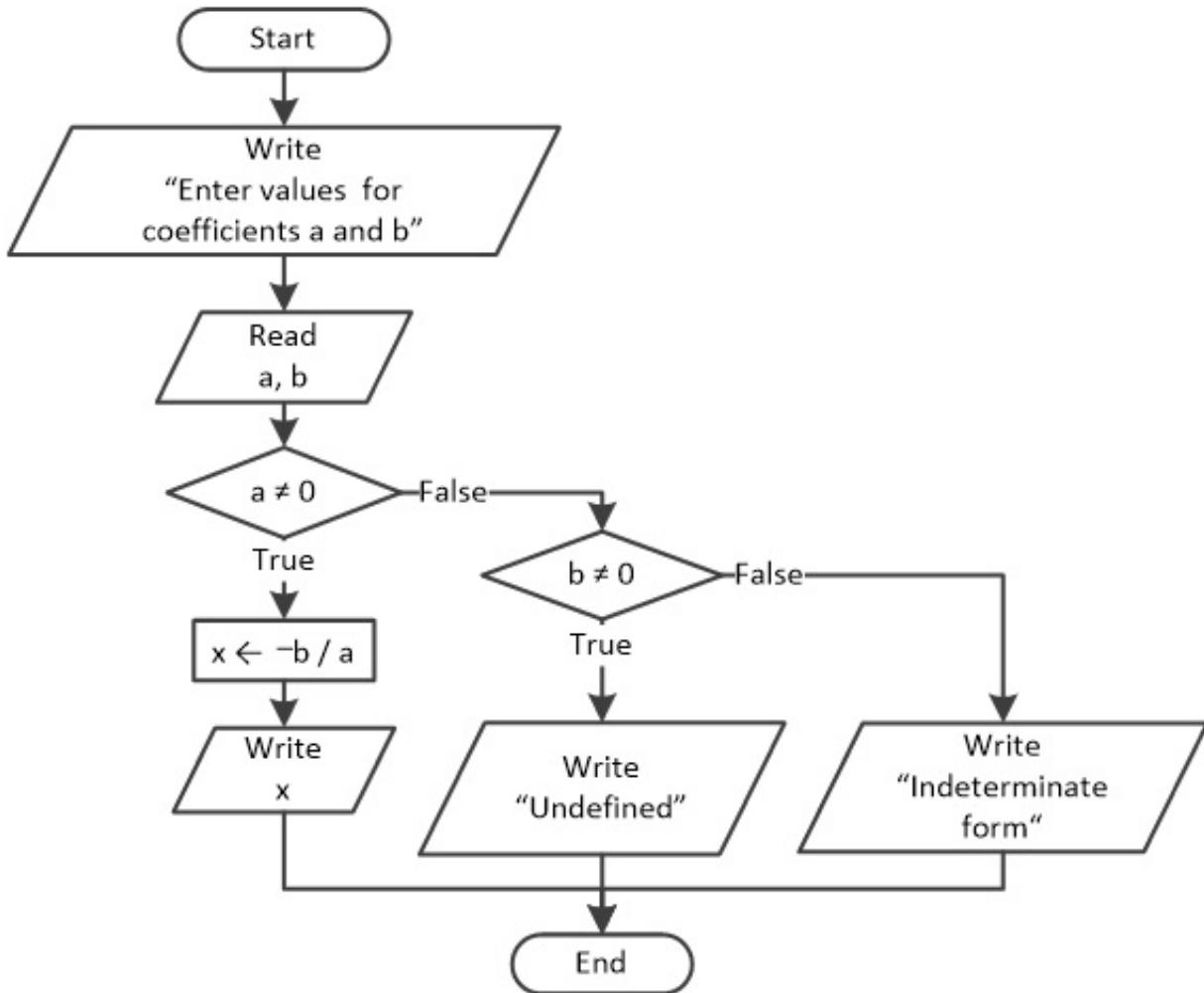
The division by zero, as you already know from mathematics, cannot be performed.

- ii. The user might enter the value 0 for both coefficients  $a$  and  $b$ . In this situation, the result of  $x = -b / a$  has no defined value, and it is called an indeterminate form.
- iii. The user might enter any other pair of values.

Therefore, these three situations result in three paths, respectively.



These three paths are represented in the flowchart that follows with the use of a multiple-alternative decision structure.



The C# program is shown here.

### project\_23\_2\_3

```

static void Main(string[] args) {
    double a, b, x;

    Console.WriteLine("Enter values for coefficients a and b: ");
    a = Double.Parse(Console.ReadLine());
    b = Double.Parse(Console.ReadLine());

    if (a != 0) {
        x = -b / a;
        Console.WriteLine(x);
    }
    else if (b != 0) {
        Console.WriteLine("Undefined");
    }
}

```

```

    else {
        Console.WriteLine("Indeterminate form");
    }
}

```

### Exercise 23.2-4 Solving the Quadratic Equation $ax^2 + bx + c = 0$

Design a flowchart and write the corresponding C# program that finds and displays the roots of the quadratic equation

$$ax^2 + bx + c = 0$$

#### **Solution**

In the equation  $ax^2 + bx + c = 0$ , the coefficients  $a$ ,  $b$ , and  $c$  are known real numbers and  $x$  represents an unknown quantity to be found. Because  $x$  appears to the second power, this equation is called a *quadratic equation* or an *equation of the second degree*.

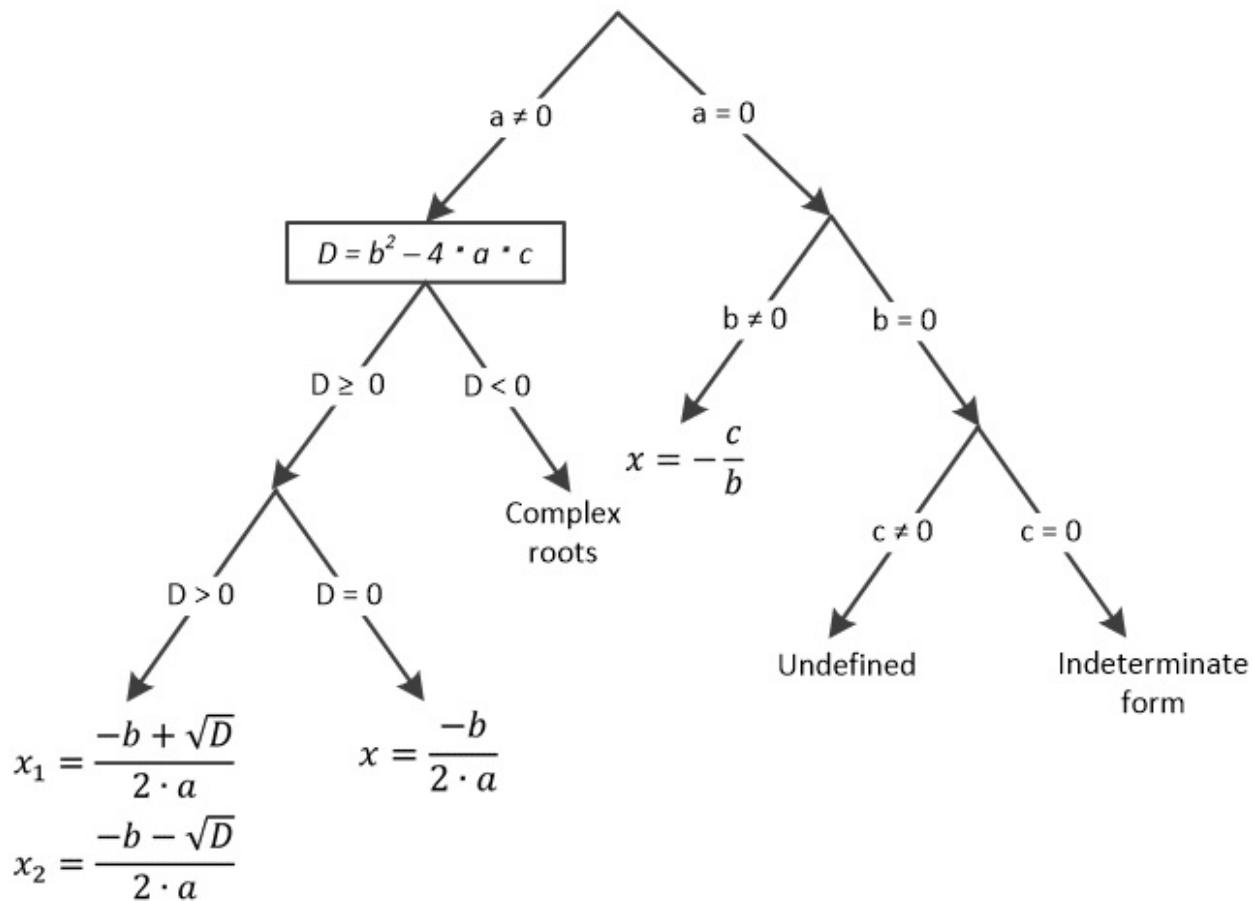
The *roots of the equation* are the values of  $x$ , for which this equation is satisfied; that is, the left side of the equality  $ax^2 + bx + c$  equals zero.

In this exercise, the user must enter values for coefficients  $a$ ,  $b$ , and  $c$ , and the program must find the value(s) of  $x$  for which  $ax^2 + bx + c$  equals zero.

This problem can be divided into two individual subproblems depending on the value of coefficient  $a$ .

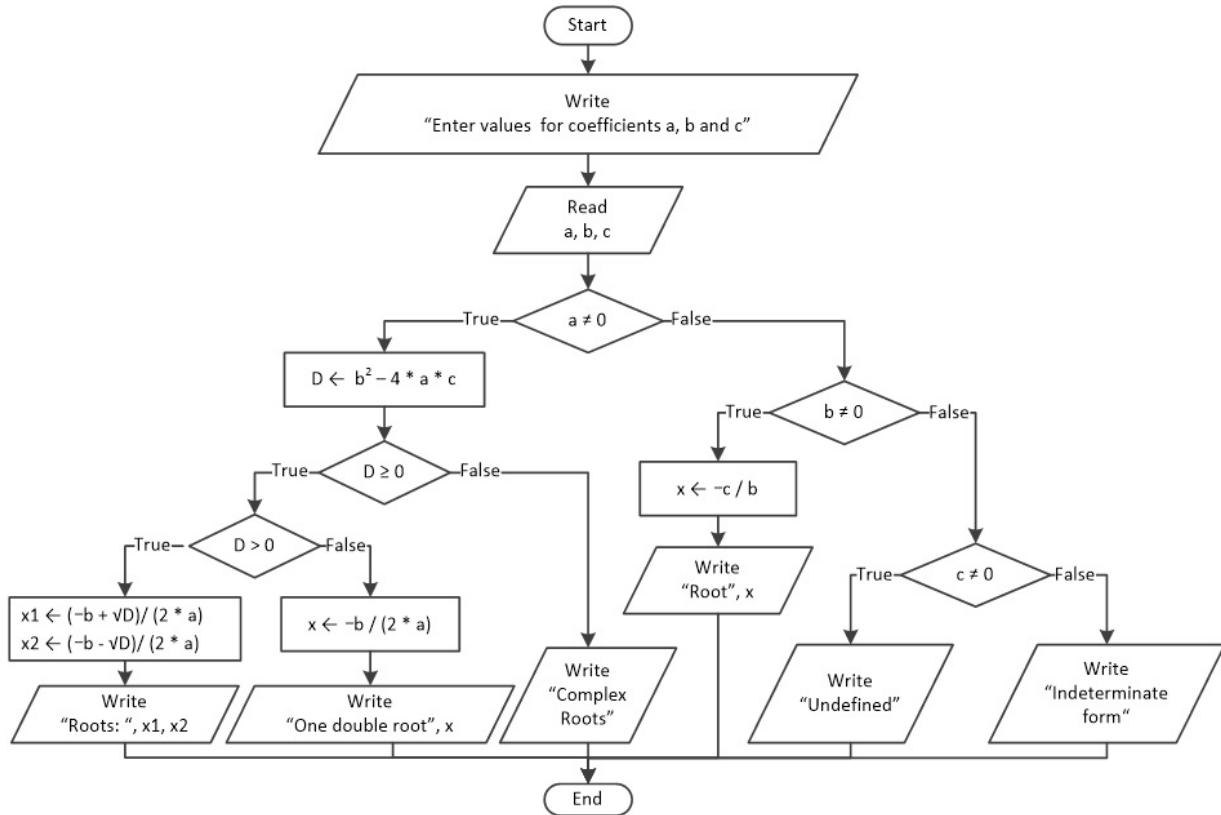
- i. If coefficient  $a$  is not equal to zero, the roots of the equation can be found using the discriminant  $D$ . Please note that this solution finds no complex roots when  $D < 0$ ; this is beyond the scope of this book.
- ii. If coefficient  $a$  is equal to zero, the equation becomes a linear equation,  $bx + c = 0$ , for which the solution was given in the previous exercise.

All necessary paths are shown here.



The path on the right ( $a = 0$ ) is the solution to the linear equation  $bx + c = 0$ , which was shown in the previous exercise ([Exercise 23.2-3](#)).

Using this diagram you can design the following flowchart.



The C# program is shown here.

### project\_23\_2\_4

```

static void Main(string[] args) {
    double a, b, c, D, x1, x2, x;

    Console.WriteLine("Enter values for coefficients a, b and c: ");
    a = Double.Parse(Console.ReadLine());
    b = Double.Parse(Console.ReadLine());
    c = Double.Parse(Console.ReadLine());

    if (a != 0) {
        D = b * b - 4 * a * c;
        if (D >= 0) {
            if (D > 0) {
                x1 = (-b + Math.Sqrt(D)) / (2 * a);
                x2 = (-b - Math.Sqrt(D)) / (2 * a);
                Console.WriteLine("Roots: " + x1 + ", " + x2);
            }
            else {
                x = -b / (2 * a);
                Console.WriteLine("One double root: " + x);
            }
        }
    }
}

```

```

    }
    else {
        Console.WriteLine("Complex Roots");
    }
}
else {
    if (b != 0) {
        x = -c / b;
        Console.WriteLine("Root: " + x);
    }
    else if (c != 0) {
        Console.WriteLine("Undefined");
    }
    else {
        Console.WriteLine("Indeterminate form");
    }
}
}
}

```

### 23.3 Finding Minimum and Maximum Values with Decision Control Structures

Suppose there are some men and you want to find the lightest one. Let's say that each one of them comes by and tells you his weight. What you must do is, memorize the weight of the first person that has come by and for each new person, you have to compare his weight with the one that you keep memorized. If he is heavier, you ignore his weight. However, if he is lighter, you need to forget the previous weight and memorize the new one. The same procedure continues until all the people have come by.

Let's ask four men to come by at a random order. Assume that their weights, in order of appearance, are 165, 170, 160, and 180 pounds.

Procedure	Value of Variable minimum in Your Mind!
The first person comes by. He weighs 165 pounds. Keep his weight in your mind (imagine a variable in your mind named <code>minimum</code> ).	<code>minimum = 165</code>

The second person comes by. He weighs 170 pounds. He does not weigh less than the weight you are keeping in variable `minimum`, so you must ignore his weight. Variable `minimum` in your mind still contains the value 165.

`minimum = 165`

The third person comes by. He weighs 160 pounds, which is less than the weight you are keeping in variable `minimum`, so you must forget the previous value and keep the value 160 in variable `minimum`.

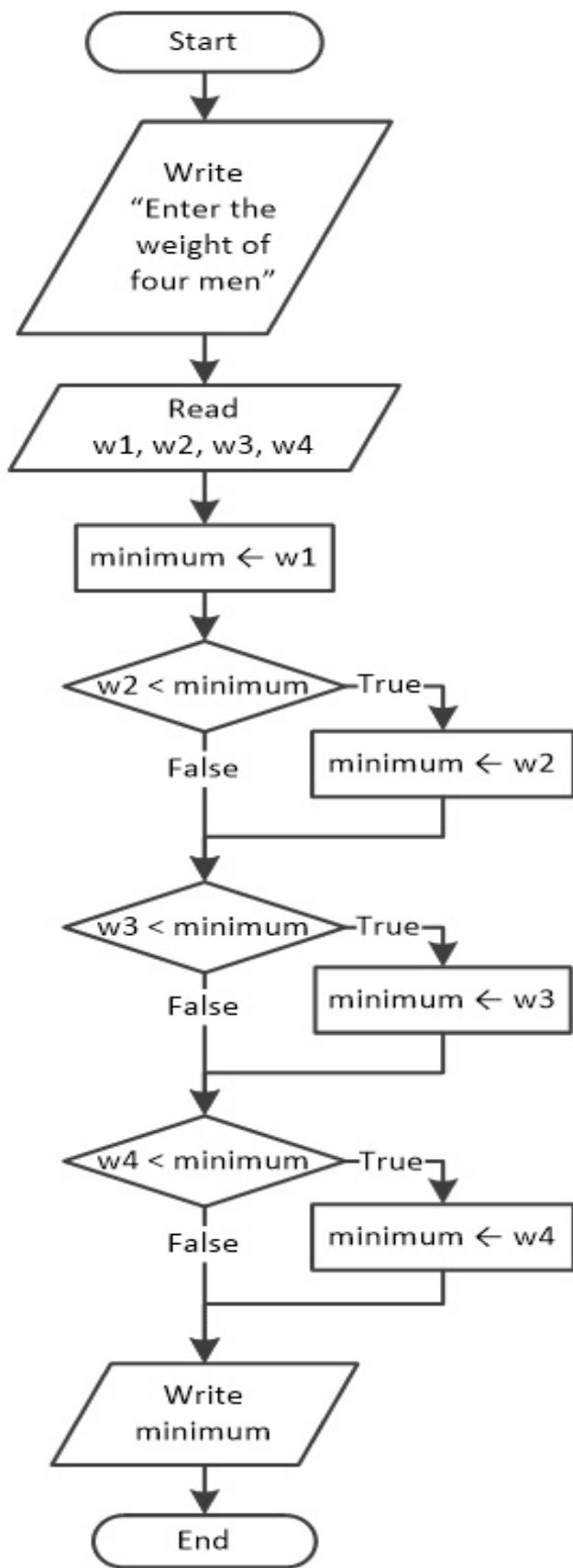
`minimum = 160`

The fourth person comes by. He weighs 180 pounds. He does not weigh less than the weight you are keeping in variable `minimum`, so you must ignore his weight. Variable `minimum` still contains the value 160.

`minimum = 160`

When the procedure finishes, the variable `minimum` in your mind contains the weight of the lightest man!

Following are the flowchart and the corresponding C# program that prompts the user to enter the weight of four people and then finds and displays the lightest weight.



## project\_23\_3

```
static void Main(string[] args) {
    int w1, w2, w3, w4, minimum;

    Console.WriteLine("Enter the weight ");
    Console.WriteLine("of four men:");

    w1 = Int32.Parse(Console.ReadLine());
    w2 = Int32.Parse(Console.ReadLine());
    w3 = Int32.Parse(Console.ReadLine());
    w4 = Int32.Parse(Console.ReadLine());

    //Memorize the weight of the first person
    minimum = w1;

    //If second one is lighter, forget
    //everything and memorize this weight
    if (w2 < minimum) {
        minimum = w2;
    }

    //If third one is lighter, forget
    //everything and memorize this weight
    if (w3 < minimum) {
        minimum = w3;
    }

    //If fourth one is lighter, forget
    //everything and memorize this weight
    if (w4 < minimum) {
        minimum = w4;
    }

    Console.WriteLine(minimum);
}
```

 You can find the maximum instead of the minimum value by simply replacing the “less than” with a “greater than” operator in all Boolean expressions.

### Exercise 23.3-1 Finding the Name of the Heaviest Person

*Write a C# program that prompts the user to enter the weights and the names of three people and then displays the name and the weight of the heaviest person.*

## **Solution**

---

In this exercise, along with the maximum weight, you need to store in another variable the name of the person who actually has that weight. The C# program is shown here.

### project\_23\_3\_1

```
static void Main(string[] args) {
    int w1, w2, w3, maximum;
    string n1, n2, n3, m_name;

    Console.WriteLine("Enter the weight of the 1st person: ");
    w1 = Int32.Parse(Console.ReadLine());

    Console.WriteLine("Enter the name of the 1st person: ");
    n1 = Console.ReadLine();

    Console.WriteLine("Enter the weight of the 2nd person: ");
    w2 = Int32.Parse(Console.ReadLine());

    Console.WriteLine("Enter the name of the 2nd person: ");
    n2 = Console.ReadLine();

    Console.WriteLine("Enter the weight of the 3rd person: ");
    w3 = Int32.Parse(Console.ReadLine());

    Console.WriteLine("Enter the name of the 3rd person: ");
    n3 = Console.ReadLine();

    maximum = w1;           //Memorize the weight of the first person.
    m_name = n1;           //Memorize his or her name

    if (w2 > maximum) { //If second one is heavier,
        maximum = w2;     //memorize his or her weight
        m_name = n2;       //and his or her name.
    }

    if (w3 > maximum) { //If third one is heavier,
        maximum = w3;     //memorize his or her weight
        m_name = n3;       //and his or her name.
    }
}
```

```

    }

    Console.WriteLine("The heaviest person is " + m_name);
    Console.WriteLine("His or her weight is " + maximum);
}

```

 In case the two heaviest people happen to have the same weight, the name of the first one in order is found and displayed.

## 23.4 Exercises with Series of Consecutive Ranges of Values

As you have already seen, in many problems the value of a variable or the result of an expression can define which statement or block of statements must be executed. In the exercises that follow, you will learn how to test if a value or the result of an expression belongs within a specific range of values (from a series of consecutive ranges of values).

Suppose that you want to display a message indicating the types of clothes a woman might wear at different temperatures.

Outdoor Temperature (in degrees Fahrenheit)	Types of Clothes a Woman Might Wear
Temperature < 45	Sweater, coat, jeans, shirt, shoes
45 ≤ Temperature < 65	Sweater, jeans, jacket, shoes
65 ≤ Temperature < 75	Capris, shorts, t-shirt, tank top, flip flops, athletic shoes
75 ≤ Temperature	Shorts, t-shirt, tank top, skort, skirt, flip flops

At first glance you might be tempted to use single-alternative decision structures. It is not wrong actually but if you take a closer look, it becomes clear that each condition is interdependent, which means that when one of these evaluates to `true`, none of the others should be evaluated. You need to select just one alternative from a set of possibilities.

To solve this type of exercise, you can use a multiple-alternative decision structure or nested decision control structures. However, the former is the

best choice. It is more convenient and increases readability, as you can see in the code fragment that follows.

```
if (temperature < 45)
    Console.WriteLine("Sweater, coat, jeans, shirt, shoes");
else if (temperature >= 45 && temperature < 65)
    Console.WriteLine("Sweater, jeans, jacket, shoes");
else if (temperature >= 65 && temperature < 75)
    Console.WriteLine("Capris, shorts, t-shirt, tank top, flip flops, athletic shoes");
else if (temperature >= 75)
    Console.WriteLine("Shorts, t-shirt, tank top, skort, skirt, flip flops");
```

A closer examination, however, reveals that all the underlined Boolean expressions are not actually required. For example, if the first Boolean expression (`temperature < 45`) evaluates to `false`, the flow of execution continues to evaluate the second Boolean expression. In this step, however, variable `temperature` is definitely greater than or equal to 45 because of the first Boolean expression, which has already evaluated to `false`. Therefore, the Boolean expression `temperature >= 45`, when evaluated, is always true and thus can be omitted. The same logic applies to all cases; you can omit all the underlined Boolean expressions. The final code fragment is shown here, with all unnecessary evaluations removed.

```
if (temperature < 45)
    Console.WriteLine("Sweater, coat, jeans, shirt, shoes");
else if (temperature < 65)
    Console.WriteLine("Sweater, jeans, jacket, shoes");
else if (temperature < 75)
    Console.WriteLine("Capris, shorts, t-shirt, tank top, flip flops, athletic shoes");
else
    Console.WriteLine("Shorts, t-shirt, tank top, skort, skirt, flip flops");
```

### ***Exercise 23.4-1 Calculating the Discount***

---

*A customer receives a discount based on the total amount of his or her order. If the total amount ordered is less than \$30, no discount is given. If the total amount is equal to or greater than \$30 and less than \$70, a discount of 5% is given. If the total amount is equal to or greater than \$70 and less than \$150, a discount of 10% is given. If the total amount is \$150 or more, the customer receives a discount of 20%. Write a C# program that prompts the user to enter the total amount of his or her order and then calculates and displays the discount given as a percentage (for example, 0%, 5%, and so on), the discount amount in dollars, and the final after-*

*discount amount. Assume that the user enters a non-negative value for the amount.*

### **Solution**

---

The following table summarizes the various discounts that are offered.

Range	Discount
amount < \$30	0%
\$30 ≤ amount < \$70	5%
\$70 ≤ amount < \$150	10%
\$150 ≤ amount	20%

The C# program is as follows.

#### project\_23\_4\_1a

```
static void Main(string[] args) {
    double amount, discount_amount, final_amount, discount = 0;

    Console.WriteLine("Enter total amount: ");
    amount = Double.Parse(Console.ReadLine());

    if (amount < 30) {
        discount = 0;
    }
    else if (amount >= 30 && amount < 70) {
        discount = 5;
    }
    else if (amount >= 70 && amount < 150) {
        discount = 10;
    }
    else if (amount >= 150) {
        discount = 20;
    }

    discount_amount = amount * discount / 100;
    final_amount = amount - discount_amount;

    Console.WriteLine("You got a discount of " + discount + "%");
    Console.WriteLine("You saved $" + discount_amount);
    Console.WriteLine("You must pay $" + final_amount);
}
```

As previously, all the underlined Boolean expressions are not actually required. The final C# program is shown here, with all unnecessary evaluations removed.

```
project_23_4_1b
```

```
static void Main(string[] args) {
    double amount, discount_amount, final_amount, discount;

    Console.WriteLine("Enter total amount: ");
    amount = Double.Parse(Console.ReadLine());

    if (amount < 30) {
        discount = 0;
    }
    else if (amount < 70) {
        discount = 5;
    }
    else if (amount < 150) {
        discount = 10;
    }
    else {
        discount = 20;
    }

    discount_amount = amount * discount / 100;
    final_amount = amount - discount_amount;

    Console.WriteLine("You got a discount of " + discount + "%");
    Console.WriteLine("You saved $" + discount_amount);
    Console.WriteLine("You must pay $" + final_amount);
}
```

### Exercise 23.4-2 Validating Data Input and Calculating the Discount

Rewrite the C# program of the previous exercise to validate the data input. An error message must be displayed when the user enters a negative value.

#### Solution

The C# program that solves this exercise, given in general form, is as follows.

#### Main Code

```
Console.WriteLine("Enter total amount: ");
amount = Double.Parse(Console.ReadLine());
```

```

if (amount < 0) {
    Console.WriteLine("Entered value is negative");
}
else {

    Code Fragment 1: Calculate and display the
    discount given, the discount amount and
    the final after-discount amount.

}

```

**Code Fragment 1** that follows is taken from the previous exercise ([Exercise 23.4-1](#)). It calculates and displays the discount given as a percentage (for example, 0%, 5%, and so on), the discount amount in dollars, and the final after-discount amount.

### Code Fragment 1

```

if (amount < 30) {
    discount = 0;
}
else if (amount < 70) {
    discount = 5;
}
else if (amount < 150) {
    discount = 10;
}
else {
    discount = 20;
}

discount_amount = amount * discount / 100;
final_amount = amount - discount_amount;

Console.WriteLine("You got a discount of " + discount + "%");
Console.WriteLine("You saved $" + discount_amount);
Console.WriteLine("You must pay $" + final_amount);

```

After embedding **Code Fragment 1** in **Main Code**, the final C# program becomes

### project\_23\_4\_2

```

static void Main(string[] args) {
    double amount, discount_amount, final_amount, discount;

    Console.Write("Enter total amount: ");

```

```

amount = Double.Parse(Console.ReadLine());

if (amount < 0) {
    Console.WriteLine("Entered value is negative");
}
else {
    if (amount < 30) {
        discount = 0;
    }
    else if (amount < 70) {
        discount = 5;
    }
    else if (amount < 150) {
        discount = 10;
    }
    else {
        discount = 20;
    }

    discount_amount = amount * discount / 100;
    final_amount = amount - discount_amount;

    Console.WriteLine("You got a discount of " + discount + "%");
    Console.WriteLine("You saved $" + discount_amount);
    Console.WriteLine("You must pay $" + final_amount);
}
}

```

### ***Exercise 23.4-3 Sending a Parcel***

---

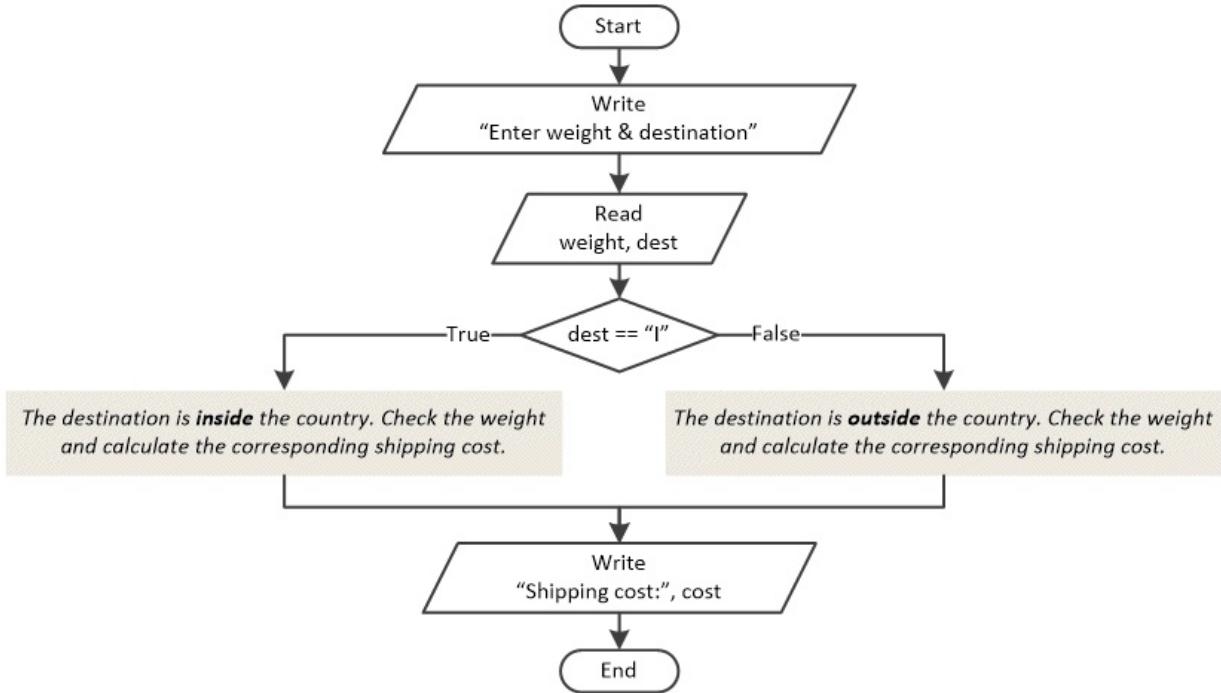
*In a post office, the shipping cost for sending a medium parcel depends on its weight and whether its destination is inside or outside the country. Shipping costs are calculated according to the following table.*

Parcel's Weight (in lb)	Destination Inside the Country (in USD per lb)	Destination Outside the Country (in USD)
weight $\leq$ 1	\$0.010	\$10
$1 < \text{weight} \leq 2$	\$0.013	\$20
$2 < \text{weight} \leq 4$	\$0.015	\$50
$4 < \text{weight}$	\$0.020	\$60

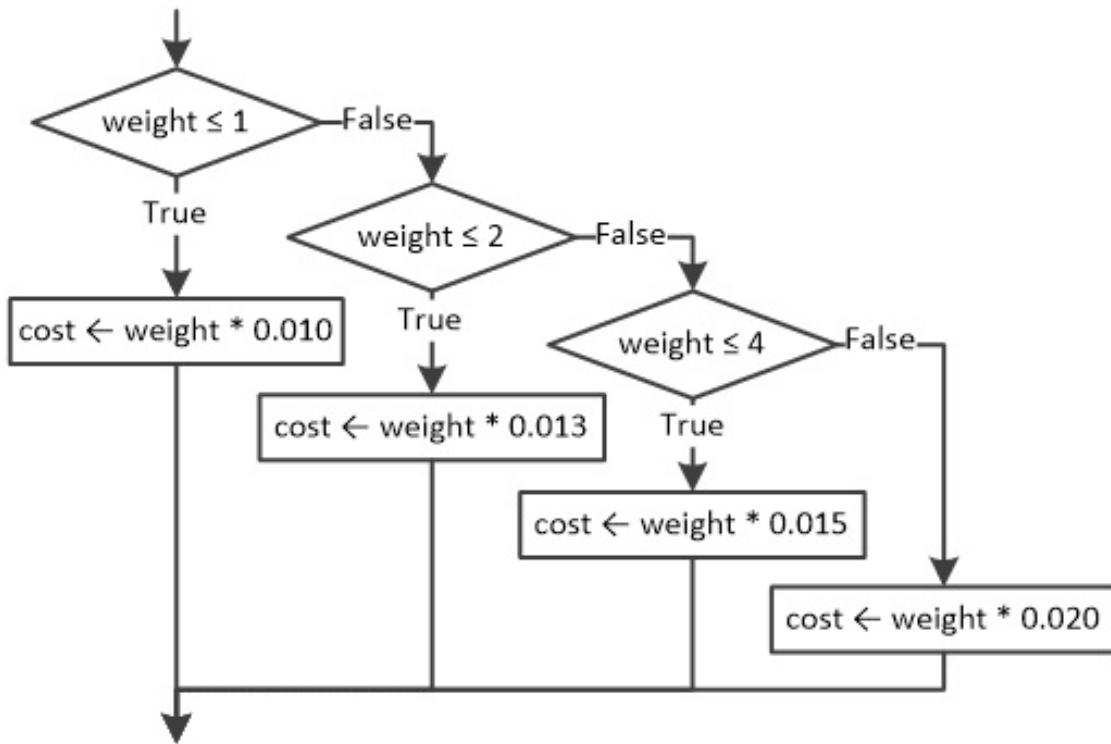
*Design a flowchart and write the corresponding C# program that prompts the user to enter the weight of a parcel and its destination (I: inside the country, O: outside the country) and then calculates and displays the shipping cost.*

## Solution

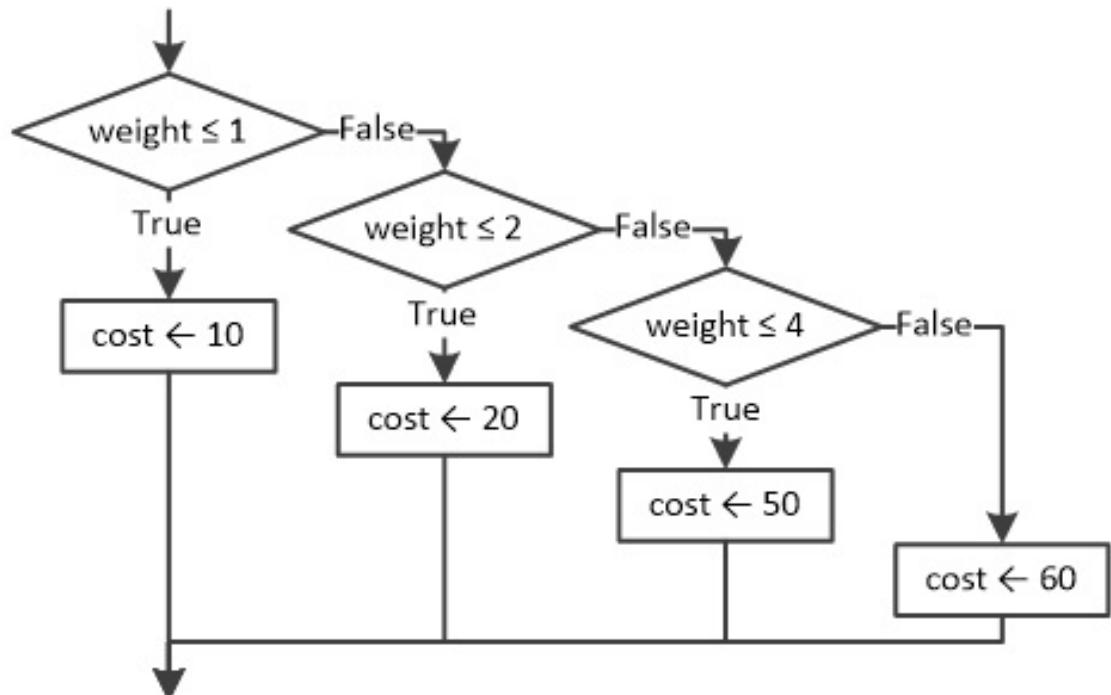
The following flowchart, given in general form, solves this exercise.



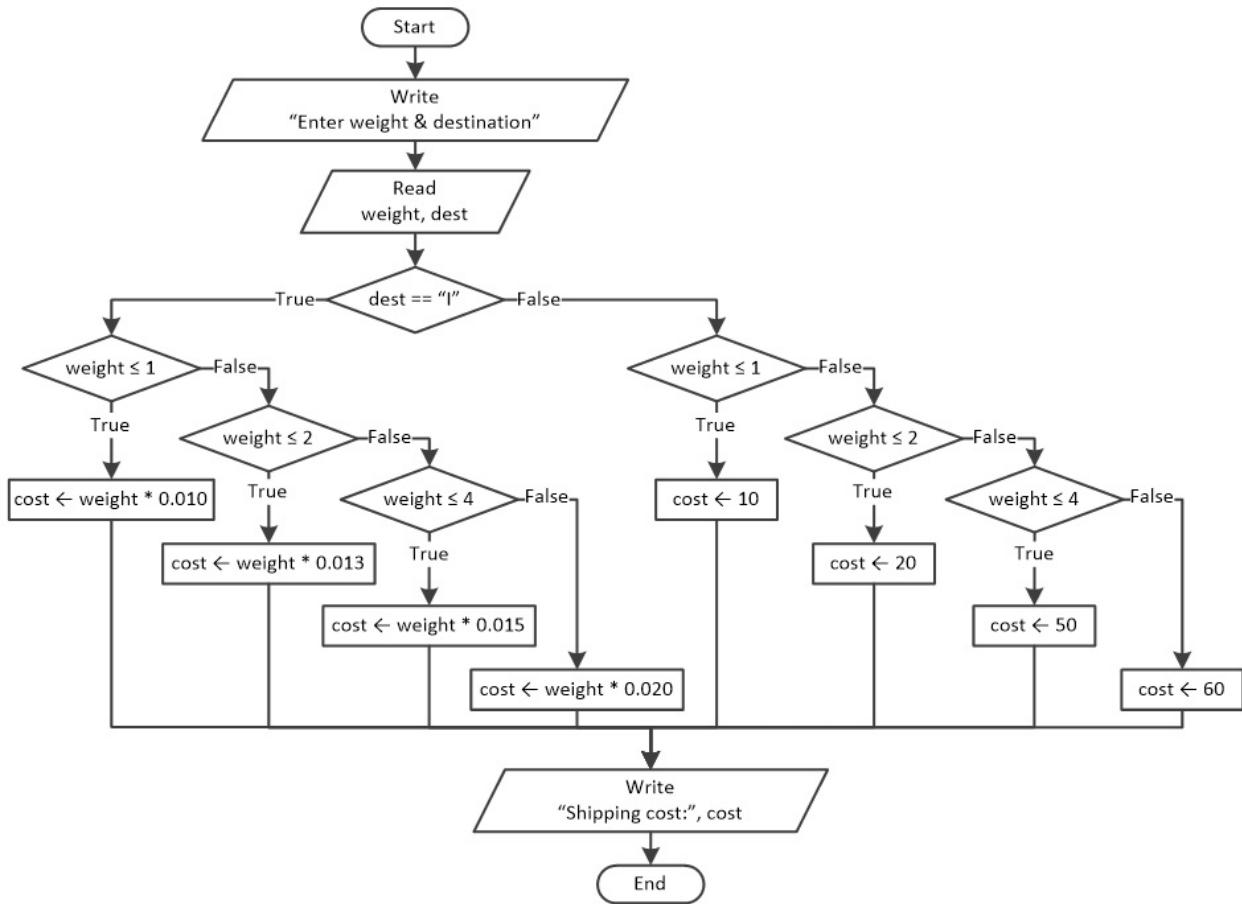
Now you need a multiple-alternative decision structure to calculate the shipping cost for parcels sent **inside** the country, as shown here.



And you need another multiple-alternative decision structure to calculate the shipping cost for parcels sent **outside** the country, as shown here.



After combining all three flowcharts, the final flowchart becomes



The corresponding C# program is shown here.

### project\_23\_4\_3

```

static void Main(string[] args) {
    double weight, cost;
    string dest;

    Console.WriteLine("Enter weight & destination: ");
    weight = Double.Parse(Console.ReadLine());
    dest = Console.ReadLine();

    if (dest.ToUpper() == "I") {
        if (weight <= 1) {
            cost = weight * 0.010;
        }
        else if (weight <= 2) {
            cost = weight * 0.013;
        }
        else if (weight <= 4) {
            cost = weight * 0.015;
        }
    }
    else {
        if (weight <= 1) {
            cost = 10;
        }
        else if (weight <= 2) {
            cost = 20;
        }
        else {
            cost = 50;
        }
    }
    Console.WriteLine("Shipping cost:", cost);
}

```

```

    }
    else {
        cost = weight * 0.020;
    }
}
else {
    if (weight <= 1) {
        cost = 10;
    }
    else if (weight <= 2) {
        cost = 20;
    }
    else if (weight <= 4) {
        cost = 50;
    }
    else {
        cost = 60;
    }
}

Console.WriteLine("Shipping cost: " + cost);
}

```

 A user may enter the letter I (for destination) in lowercase or uppercase. The method `ToUpper()` ensures that the program executes properly for both cases.

### ***Exercise 23.4-4 Finding the Values of y***

*Design a flowchart and write the corresponding C# program that finds and displays the values of y (if possible) in the following formula*

$$y = \begin{cases} \frac{x}{x-3} + \frac{8+x}{x+1}, & -5 < x \leq 0 \\ \frac{40x}{x-8}, & 0 < x \leq 6 \\ \frac{3x}{x-9}, & 6 < x \leq 20 \\ |x|, & \text{for all other values of } x \end{cases}$$

### ***Solution***

In this exercise, there are two restrictions on the fractions:

- In fraction  $\frac{8+x}{x+1}$ , the value of  $x$  cannot be  $-1$ .
- In fraction  $\frac{3x}{x-9}$ , the value of  $x$  cannot be  $+9$ .

For all other fractions, it's impossible for the denominators to be set to zero because of the range in which  $x$  belongs.

The C# program is shown here.

### project\_23\_4\_4a

```
static void Main(string[] args) {
    double x, y;

    Console.WriteLine("Enter a value for x: ");
    x = Double.Parse(Console.ReadLine());

    if (x > -5 && x <= 0) {
        if (x != -1) { [More...]
            y = x / (x - 3) + (8 + x) / (x + 1);
            Console.WriteLine(y);
        }
        else {
            Console.WriteLine("Invalid value");
        }
    }
    else if (x > 0 && x <= 6) {
        y = 40 * x / (x - 8); [More...]
        Console.WriteLine(y);
    }
    else if (x > 6 && x <= 20) {
        if (x != 9) { [More...]
            y = 3 * x / (x - 9);
            Console.WriteLine(y);
        }
        else {
            Console.WriteLine("Invalid value");
        }
    }
    else {
```

```
y = Math.Abs(x);      [More...]  
Console.WriteLine(y);  
}  
}
```

If you are wondering whether you can remove all `Console.WriteLine(y)` statements and write them as a single statement at the end of the program, the answer is “no”. Since there are paths that do not include the `Console.WriteLine(y)` statement, you must write this statement, again and again, in every path required.

One thing you should learn in computer programming, however, is that you must never give up! By modifying your code a little, checking for invalid values in the beginning, gives you the opportunity to remove the statement `Console.WriteLine(y)` outside of all paths and move it at the end of them. The modified C# program is shown here.

### project\_23\_4\_4b

```
static void Main(string[] args) {  
    double x, y;  
  
    Console.Write("Enter a value for x: ");  
    x = Double.Parse(Console.ReadLine());  
  
    if (x == -1 || x == 9) {  
        Console.WriteLine("Invalid value");  
    }  
    else {  
        if (x > -5 && x <= 0) {  
            y = x / (x - 3) + (8 + x) / (x + 1);  
        }  
        else if (x > 0 && x <= 6) {  
            y = 40 * x / (x - 8);  
        }  
        else if (x > 6 && x <= 20) {  
            y = 3 * x / (x - 9);  
        }  
        else {  
            y = Math.Abs(x);  
        }  
  
        Console.WriteLine(y);  
    }  
}
```

Now, if you are speculating about whether the underlined Boolean expressions are redundant, the answer is “no” again. Why? Suppose you do remove them and the user enters a value of  $-20$  for  $x$ . The flow of execution then reaches the Boolean expression  $x \leq 0$ , which evaluates to true. Then the fraction  $\frac{x}{x-3} + \frac{8+x}{x+1}$ , instead of the absolute value of  $x$ , is calculated.

Yet still there is hope! Next, you can find a proposed solution in which unnecessary Boolean expressions are actually removed. The trick here is that the case of the absolute value of  $x$  is examined first.

### project\_23\_4\_4c

```
static void Main(string[] args) {
    double x, y;

    Console.WriteLine("Enter a value for x: ");
    x = Double.Parse(Console.ReadLine());

    if (x == -1 || x == 9) {
        Console.WriteLine("Invalid value");
    }
    else {
        if (x <= -5 || x > 20) {
            y = Math.Abs(x);
        }
        else if (x <= 0) {
            y = x / (x - 3) + (8 + x) / (x + 1);
        }
        else if (x <= 6) {
            y = 40 * x / (x - 8);
        }
        else {
            y = 3 * x / (x - 9);
        }

        Console.WriteLine(y);
    }
}
```

 It is obvious that one problem can have many solutions. It is up to you to find the optimal one!

## Exercise 23.4-5 Progressive Rates and Electricity Consumption

*The LAV Electricity Company charges subscribers for their electricity consumption according to the following table (monthly rates for domestic accounts). Assume that all extra charges such as transmission service charges and distribution charges are all included.*

Kilowatt-hours (kWh)	USD per kWh
kWh ≤ 500	\$0.10
501 ≤ kWh ≤ 2000	\$0.25
2001 ≤ kWh ≤ 4500	\$0.40
4501 ≤ kWh	\$0.60

*Write a C# program that prompts the user to enter the total number of kWh consumed and then calculates and displays the total amount to pay.*

*Please note that the rates are progressive.*

### **Solution**

---

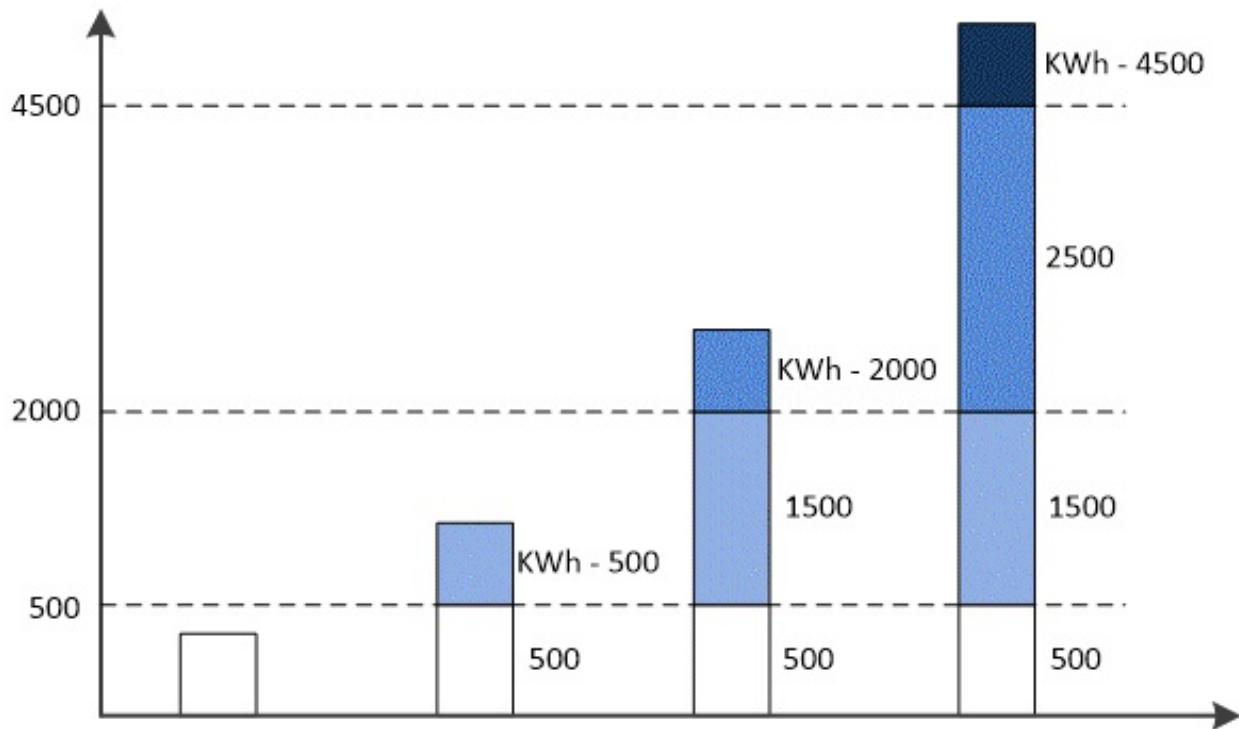
The term *progressive rates* means that when a customer consumes, for example, 2200 kWh, not all of the kilowatt-hours are charged at \$0.40. The first 500 kWh are charged at \$0.10, the next 1500 kWh are charged at \$0.25 and only the last 200 kWh are charged at \$0.40. Thus, the customer must pay

$$500 \times \$0.10 + 1500 \times \$0.25 + 200 \times \$0.40 = \$505$$

The same logic can be used to calculate the total amount to pay when the customer consumes, for example, 4800 kWh. The first 500 kWh are charged at \$0.10, the next 1500 kWh are charged at \$0.25, the next 2500 kWh are charged at \$0.40, and only the last 300 kWh are charged at \$0.60. Thus, the customer must pay

$$500 \times \$0.10 + 1500 \times \$0.25 + 2500 \times \$0.40 + 300 \times \$0.60 = \$1605$$

The following diagram can help you fully understand how to calculate the total amount to pay when the rates are progressive.



The C# program is shown here.

### project\_23\_4\_5

```

static void Main(string[] args) {
    int kwh;
    double t;

    Console.WriteLine("Enter number of Kilowatt-hours consumed: ");
    kwh = Int32.Parse(Console.ReadLine());

    if (kwh <= 500) {
        t = kwh * 0.10;
    }
    else if (kwh <= 2000) {
        t = 500 * 0.10 + (kwh - 500) * 0.25;
    }
    else if (kwh <= 4500) {
        t = 500 * 0.10 + 1500 * 0.25 + (kwh - 2000) * 0.40;
    }
    else {
        t = 500 * 0.10 + 1500 * 0.25 + 2500 * 0.4 + (kwh - 4500) * 0.60;
    }
    Console.WriteLine("Total amount to pay: " + t);
}

```

## ***Exercise 23.4-6 Progressive Rates and Text Messaging Services***

---

*The LAV Cell Phone Company charges customers a basic rate of \$8 per month to send text messages. Additional rates are charged based on the total number of text messages sent, as shown in the following table.*

Number of Text Messages Sent	Additional Rates (in USD per text message)
Up to 50	Free of charge
51 - 150	\$0.05
151 and above	\$0.10

*Federal, state, and local taxes add a total of 10% to each bill.*

*Write a C# program that prompts the user to enter the number of text messages sent and then calculates and displays the total amount to pay.*

*Please note that the rates are progressive.*

### **Solution**

---

The C# program is presented here.

#### project\_23\_4\_6

```
static void Main(string[] args) {
    int count;
    double extra, total_without_taxes, taxes, total;

    Console.WriteLine("Enter number of text messages sent: ");
    count = Int32.Parse(Console.ReadLine());

    if (count <= 50) {
        extra = 0;
    }
    else if (count <= 150) {
        extra = (count - 50) * 0.05;
    }
    else {
        extra = 100 * 0.05 + (count - 150) * 0.10;
    }

    total_without_taxes = 8 + extra;           //Add basic rate of $8
    taxes = total_without_taxes * 10 / 100; //Calculate the total taxes
    total = total_without_taxes + taxes;      //Calculate the total amount to pay
```

```
        Console.WriteLine("Total amount to pay: " + total);
    }
```

## 23.5 Exercises of a General Nature with Decision Control Structures

### Exercise 23.5-1 Finding a Leap Year

*Write a C# program that prompts the user to enter a year and then displays a message indicating whether it is a leap year; otherwise the message “Not a leap year” must be displayed. Moreover, if the user enters a year less than 1582, an error message must be displayed.*

(Note that this involves data validation!)

### Solution

According to the Gregorian calendar, which was first introduced in 1582, a year is a leap year when at least one of the following conditions is met:

**1<sup>st</sup> Condition:** The year is exactly divisible by 4, and not by 100.

**2<sup>nd</sup> Condition:** The year is exactly divisible by 400.

In the following table, some years are not leap years because neither of the two conditions evaluates to true.

Year	Conditions	Leap Year
1600	2 <sup>nd</sup> Condition is true. It is exactly divisible by 400	Yes
1900	Both conditions are false.	No
1918	Both conditions are false.	No
2000	2 <sup>nd</sup> Condition is true. It is exactly divisible by 400	Yes
2002	Both conditions are false.	No
2004	1 <sup>st</sup> Condition is true. It is exactly divisible by 4, and not by 100	Yes
2020	1 <sup>st</sup> Condition is true. It is exactly divisible by 4, and not by 100	Yes

The C# program is shown here.

### project\_23\_5\_1

```
static void Main(string[] args) {
    int y;

    Console.WriteLine("Enter a year: ");
    y = Int32.Parse(Console.ReadLine());

    if (y < 1582) {
        Console.WriteLine("Error! The year cannot be less than 1582");
    }
    else {
        if (y % 4 == 0 && y % 100 != 0 || y % 400 == 0) {
            Console.WriteLine("Leap year!");
        }
        else {
            Console.WriteLine("Not a leap year");
        }
    }
}
```

 *The AND ( && ) operator has a higher precedence than the OR ( || ) operator.*

### Exercise 23.5-2 Displaying the Days of the Month

Write a C# program that prompts the user to enter a year and a month and then displays how many days are in that month. The program needs to take into consideration the leap years. In case of a leap year, February has 29 instead of 28 days. Moreover, if the user enters a year less than 1582, an error message must be displayed.

### Solution

The following C# program, given in general form, solves this exercise.

### Main Code

```
static void Main(string[] args) {
    int m, y;

    Console.WriteLine("Enter a year: ");
    y = Int32.Parse(Console.ReadLine());
```

```

if (y < 1582) {
    Console.WriteLine("Error! The year cannot be less than 1582");
}
else {
    Console.Write("Enter a month (1 - 12): ");
    m = Int32.Parse(Console.ReadLine());
    if (m == 2) {

        Code Fragment 1: Check whether the year
        (in variable y) is a leap year and display
        how many days are in February.

    }
    else if (m == 4 || m == 6 || m == 9 || m == 11) {
        Console.WriteLine("This month has 30 days");
    }
    else {
        Console.WriteLine("This month has 31 days");
    }
}
}

```

**Code Fragment 1**, shown here, checks whether the year (in variable y) is a leap year and displays how many days are in February.

### Code Fragment 1

```

if (y % 4 == 0 && y % 100 != 0 || y % 400 == 0) {
    Console.WriteLine("This month has 29 days");
}
else {
    Console.WriteLine("This month has 28 days");
}

```

After embedding **Code Fragment 1** in **Main Code**, the final C# program becomes

### project\_23\_5\_2a

```

static void Main(string[] args) {
    int m, y;

    Console.Write("Enter a year: ");
    y = Int32.Parse(Console.ReadLine());

    if (y < 1582) {
        Console.WriteLine("Error! The year cannot be less than 1582");
    }
    else {
        if (y % 4 == 0 && y % 100 != 0 || y % 400 == 0) {
            Console.WriteLine("This month has 29 days");
        }
        else {
            Console.WriteLine("This month has 28 days");
        }
    }
}

```

```

Console.WriteLine("Enter a month (1 - 12): ");
m = Int32.Parse(Console.ReadLine());
if (m == 2) {
    if (y % 4 == 0 && y % 100 != 0 || y % 400 == 0) {
        Console.WriteLine("This month has 29 days");
    }
    else {
        Console.WriteLine("This month has 28 days");
    }
}
else if (m == 4 || m == 6 || m == 9 || m == 11) {
    Console.WriteLine("This month has 30 days");
}
else {
    Console.WriteLine("This month has 31 days");
}
}
}
}

```

Below, the same problem is solved again, using, however, the case decision structure.

### project\_23\_5\_2b

```

static void Main(string[] args) {
    int m, y;

    Console.WriteLine("Enter year: ");
    y = Int32.Parse(Console.ReadLine());

    if (y < 1582) {
        Console.WriteLine("Error! The year cannot be less than 1582");
    }
    else {
        Console.WriteLine("Enter a month (1 - 12): ");
        m = Int32.Parse(Console.ReadLine());
        switch (m) {
            case 2:
                if (y % 4 == 0 && y % 100 != 0 || y % 400 == 0) {
                    Console.WriteLine("This month has 29 days");
                }
                else {
                    Console.WriteLine("This month has 28 days");
                }
                break;
            case 4:

```

```

        case 6:
        case 9:
        case 11:
            Console.WriteLine("This month has 30 days");
            break;
        default:
            Console.WriteLine("This month has 31 days");
            break;
    }
}

```

 Note the way cases 4, 6, and 9 are written. Since there isn't any break statement in any of those cases, they all reach case 11.

### Exercise 23.5-3 Is the Number a Palindrome?

A *palindrome* is a number that remains the same after reversing its digits. For example, the number 13631 is a palindrome. Write a C# program that lets the user enter a five-digit integer and tests whether or not this number is a palindrome. Moreover, individual error messages must be displayed when the user enters a float, or any integer with either less than or more than five digits.

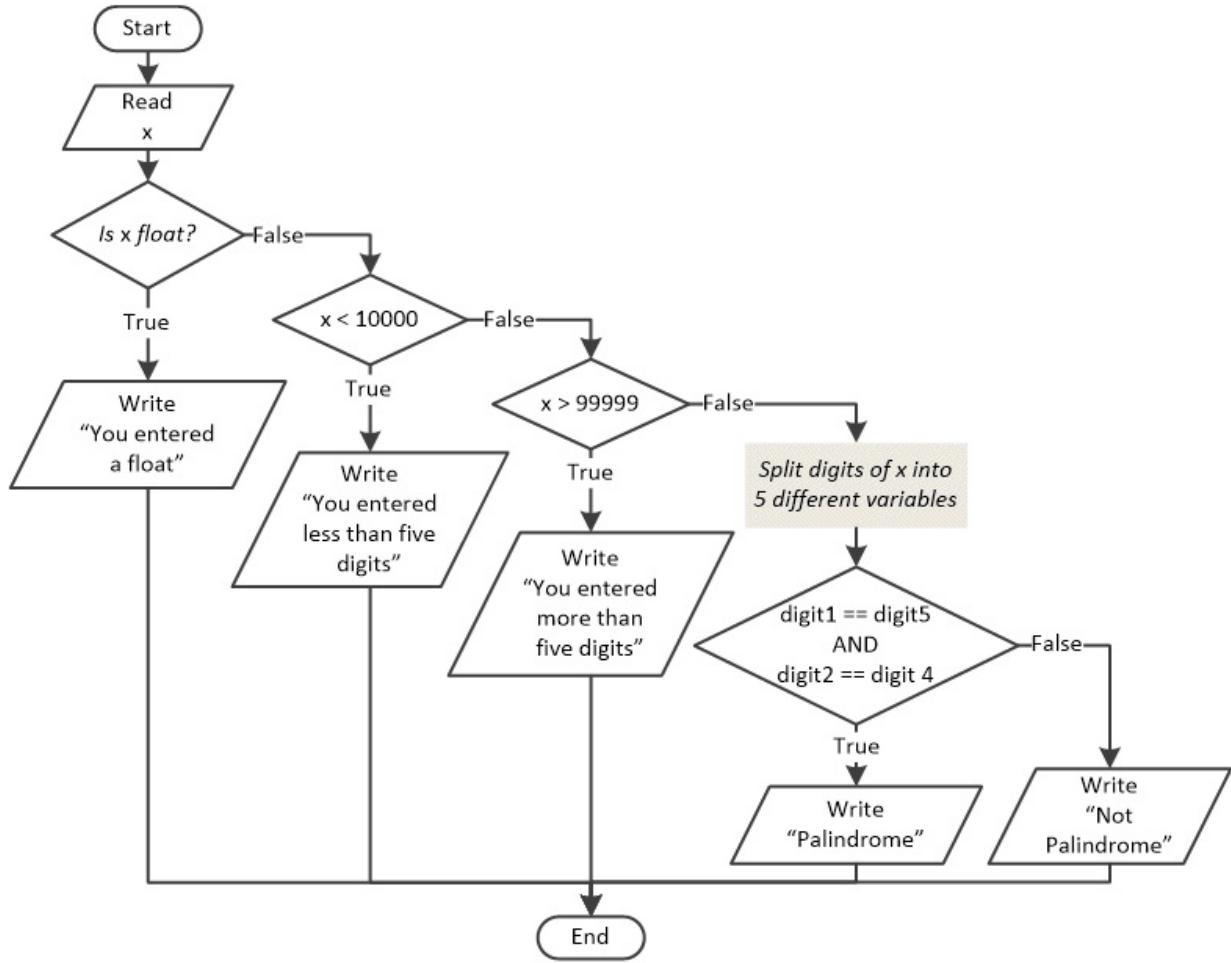
(Note that this involves data validation!)

### Solution

To test if the user enters a palindrome number, you need to split its digits into five different variables as you learned in [Chapter 13](#). Then, you can check whether the 1<sup>st</sup> digit is equal to the 5<sup>th</sup> digit and the 2<sup>nd</sup> digit is equal to the 4<sup>th</sup> digit. If this evaluates to true, the number is a palindrome.

To validate data input, you need to check whether the user has entered a five-digit number. Keep in mind that all five-digit numbers are in the range of 10000 to 99999. Therefore, you can just restrict the data input to within this range.

In order to display many different error messages, the best practice is to use a multiple-alternative decision structure which first checks data input validity for all cases, and then tries to solve the required problem. For example, if you need to check for various errors, you can do something like the following.



The final C# program is shown here.

### project\_23\_5\_3

```

static void Main(string[] args) {
    int digit1, r, digit2, digit3, digit4, digit5;
    double x;

    x = Double.Parse(Console.ReadLine());

    if (x != (int)x) {
        Console.WriteLine("You entered a float");
    }
    else if (x < 10000) {
        Console.WriteLine("You entered less than five digits");
    }
    else if (x > 99999) {
        Console.WriteLine("You entered more than five digits");
    }
    else {

```

```
//Split the digits of x into 5 different variables
digit1 = (int)(x / 10000);
r = (int)x % 10000;
digit2 = (int)(r / 1000);
r = r % 1000;
digit3 = (int)(r / 100);
r = r % 100;
digit4 = (int)(r / 10);
digit5 = r % 10;

if (digit1 == digit5 && digit2 == digit4) {
    Console.WriteLine("Palindrome");
}
else {
    Console.WriteLine("Not Palindrome");
}
}
```

### **Exercise 23.5-4 Checking for Proper Capitalization and Punctuation**

*Write a C# program that prompts the user to enter a sentence and then checks it for proper capitalization and punctuation. The program must determine if the string begins with an uppercase letter and ends with a punctuation mark (check only for periods, question marks, and exclamation marks).*

### **Solution**

In this exercise you need to isolate the first and the last character of the string. As you already know, you can access any individual character of a string using substring notation. You can use index 0 to access the first character, index 1 to access the second character, and so on.

Thus, you can isolate the first character of a string using the following C# statement.

```
first_char = sentence[0];
```

On the other hand, the index of the last character is 1 less than the length of the string. But, how long is that string?

You can get the length of any string using the `Length` property. The following code fragment isolates the last character of a string.

```
length = sentence.Length;  
last_char = sentence[length - 1];
```

or you can even write it with one single statement.

```
last_char = sentence[sentence.Length - 1];
```

The C# program is shown here.

```
project_23_5_4
```

```
static void Main(string[] args) {
    string sentence, first_char, last_char;
    bool sentence_is_okay;

    Console.WriteLine("Enter a sentence: ");
    sentence = Console.ReadLine();

    //Get first character and convert it from char to string
    first_char = "" + sentence[0];
    //Get last character and convert it from char to string
    last_char = "" + sentence[sentence.Length - 1];

    sentence_is_okay = true;

    if (first_char != first_char.ToUpper()) {
        sentence_is_okay = false;
    }
    else if (last_char != "." && last_char != "?" && last_char != "!") {
        sentence_is_okay = false;
    }

    if (sentence_is_okay) {
        Console.WriteLine("Sentence is okay!");
    }
}
```

In the beginning, the program assumes that the sentence is okay (`sentence_is_okay = true`). Then, it checks for proper capitalization and proper punctuation and if it finds something wrong, it assigns the value `false` to the variable `sentence_is_okay`.

## 23.6 Review Exercises

Complete the following exercises.

1. Write a C# program that prompts the user to enter a numeric value and then calculates and displays its square root. Moreover, an error message must be displayed when the user enters a negative value.
2. Design a flowchart that lets the user enter an integer and, if its last digit

is equal to 5, a message “Last digit equal to 5” is displayed; otherwise, a message “Nothing special” is displayed. Moreover, if the user enters a negative value, an error message must be displayed.

Hint: You can isolate the last digit of any integer using a modulus 10 operation.

3. Design a flowchart and write the corresponding C# program that lets the user enter two integers and then displays a message indicating whether at least one integer is odd; otherwise, a message “Nothing special” is displayed. Moreover, if the user enters negative values, an error message must be displayed.
4. Design a flowchart and write the corresponding C# program that prompts the user to enter an integer, and then displays a message indicating whether this number is even; it must display “Odd” otherwise. Moreover, individual error messages must be displayed when the user enters a negative value or a float.
5. Design a flowchart and write the corresponding C# program that prompts the user to enter an integer and then displays a message indicating whether this number is exactly divisible by 3 and by 4; otherwise the message “NN is not what you are looking for!” must be displayed (where NN is the given number). For example, 12 is exactly divisible by 3 and by 4. Moreover, an error message must be displayed when the user enters a negative value or a float.
6. Design a flowchart and write the corresponding C# program that lets the user enter two integers and then displays a message indicating whether they are both divisible exactly by 3 and by 4; otherwise the message “X and Y are not what you are looking for!” must be displayed (where X and Y are the given numbers). Moreover, individual error messages must be displayed when the user enters any negative values or any floats.
7. Write a C# program that displays the following menu:
  1. Convert Kelvin to Fahrenheit
  2. Convert Fahrenheit to Kelvin
  3. Convert Fahrenheit to Celsius
  4. Convert Celsius to Fahrenheit

It then prompts the user to enter a choice (of 1 to 4) and a temperature value. It then calculates and displays the required value. Moreover, individual error messages must be displayed when the user enters a choice other than 1, 2, 3, or 4, or a temperature value lower than absolute zero<sup>[16]</sup>.

It is given that

$$1.8 \times \text{Kelvin} = \text{Fahrenheit} + 459.67$$

and

$$\frac{\text{Celsius}}{5} = \frac{\text{Fahrenheit} - 32}{9}$$

8. Write a C# program that prompts the user to enter an integer, the type of operation (+, -, \*, /, DIV, MOD, POWER), and a second integer. The program must execute the required operation and display the result.
9. Rewrite the C# program of the previous exercise to validate the data input. If the user enters an input other than +, -, \*, /, DIV, MOD, POWER, an error message must be displayed.
10. Design a flowchart and write the corresponding C# program that finds and displays the value of  $y$  (if possible) in the following formula.

$$y = \frac{5x + 3}{x - 5} + \frac{3x^2 + 2x + 2}{x + 1}$$

11. Design a flowchart and write the corresponding C# program that finds and displays the values of  $y$  (if possible) in the following formula.

$$y = \begin{cases} \frac{x^2}{x+1} + \frac{3-\sqrt{x}}{x+2}, & x \geq 10 \\ \frac{40x}{x-9} + 3x, & x < 10 \end{cases}$$

12. Write a C# program that finds and displays the values of  $y$  (if possible) in the following formula.

$$y = \begin{cases} \frac{x}{\sqrt{x+30}} + \frac{(8+x)^2}{x+1}, & -15 < x \leq -10 \\ \frac{|40x|}{x-8}, & -10 < x \leq 0 \\ \frac{3x}{\sqrt{x-9}}, & 0 < x \leq 25 \\ \frac{x}{x-1}, & \text{for all other values of } x \end{cases}$$

13. Write a C# program that prompts the user to enter the names and the ages of three people and then displays the names of the youngest person and the oldest person.
14. Write a C# program that prompts the user to enter the ages of three people and then finds and displays the age in the middle.
15. Write a C# program that prompts the user to enter the names and the ages of three people and then displays the name of the youngest person or the oldest person, depending on which one is closer to the third age in the middle.
16. A positive integer is called an Armstrong number when the sum of the cubes of its digits is equal to the number itself. The number 371 is such a number, since  $3^3 + 7^3 + 1^3 = 371$ . Write a C# program that lets the user enter a three-digit integer and then displays a message indicating whether or not the given number is an Armstrong one. Moreover, individual error messages must be displayed when the user enters a float or any number other than a three-digit one.
17. Write a C# program that prompts the user to enter a day (1 – 31), a month (1 – 12), and a year and then finds and displays how many days are left until the end of that month. The program must take into consideration the leap years. In the case of a leap year, February has 29 instead of 28 days.
18. Write a C# program that lets the user enter a word of six letters and then displays a message indicating whether or not every second letter is capitalized. The word “AtHeNa” is such a word, but it can be also given as “aThEnA”.
19. An online book store sells e-books for \$10 each. Quantity discounts are

given according to the following table.

Quantity	Discount
3 - 5	10%
6 - 9	15%
10 - 13	20%
14 - 19	27%
20 or more	30%

Write a C# program that prompts the user to enter the total number of e-books purchased and then displays the amount of discount (if any), and the total amount of the purchase after the discount. Assume that the user enters valid values.

20. In a supermarket, the discount that a customer receives based on the before-tax amount of their order is presented in the following table.

Range	Discount
amount < \$50	0%
\$50 ≤ amount < \$100	1%
\$100 ≤ amount < \$200	2%
\$250 ≤ amount	3%

Write a C# program that prompts the user to enter the before-tax amount of his or her order and then calculates and displays the discount amount that customers receive (if any). A VAT (Value Added Tax) of 19% must be added in the end. Moreover, an error message must be displayed when the user enters a negative value.

21. The Body Mass Index (BMI) is often used to determine whether an adult person is overweight or underweight for his or her height. The formula used to calculate the BMI of an adult person is

$$BMI = \frac{weight \cdot 703}{height^2}$$

Write a C# program that prompts the user to enter his or her age, weight

(in pounds) and height (in inches) and then displays a description according to the following table.

Body Mass Index	Description
BMI < 15	Very severely underweight
15.0 ≤ BMI < 16.0	Severely underweight
16.0 ≤ BMI < 18.5	Underweight
18.5 ≤ BMI < 25	Normal
25.0 ≤ BMI < 30.0	Overweight
30.0 ≤ BMI < 35.0	Severely overweight
35.0 ≤ BMI	Very severely overweight

The message “Invalid age” must be displayed when the user enters an age less than 18.

22. The LAV Water Company charges for subscribers' water consumption according to the following table (monthly rates for domestic accounts).

Water Consumption (cubic feet)	USD per cubic foot
consumption ≤ 10	\$3
11 ≤ consumption ≤ 20	\$5
21 ≤ consumption ≤ 35	\$7
36 ≤ consumption	\$9

Write a C# program that prompts the user to enter the total amount of water consumed (in cubic feet) and then calculates and displays the total amount to pay. Please note that the rates are progressive. Federal, state, and local taxes add a total of 10% to each bill. Moreover, an error message must be displayed when the user enters a negative value.

23. Write a C# program that prompts the user to enter his or her taxable income and the number of his or her children and then calculates the total tax to pay according to the following table. However, total tax is reduced by 2% when the user has at least one child. Please note that the

rates are progressive.

Taxable Income (USD)	Tax Rate
income $\leq$ 8000	10%
$8000 < \text{income} \leq 30000$	15%
$30000 < \text{income} \leq 70000$	25%
$70000 < \text{income}$	30%

24. The Beaufort scale is an empirical measure that relates wind speed to observed conditions on land or at sea. Write a C# program that prompts the user to enter the wind speed and then displays the corresponding Beaufort number and description according to the following table. An additional message “It's Fishing Day!!!” must be displayed when wind speed is 3 Beaufort or less. Moreover, an error message must be displayed when the user enters a negative value.

Wind Speed (miles per hour)	Beaufort Number	Description
wind speed $< 1$	0	Calm
$1 \leq \text{wind speed} < 4$	1	Light air
$4 \leq \text{wind speed} < 8$	2	Light breeze
$8 \leq \text{wind speed} < 13$	3	Gentle breeze
$13 \leq \text{wind speed} < 18$	4	Moderate breeze
$18 \leq \text{wind speed} < 25$	5	Fresh breeze
$25 \leq \text{wind speed} < 31$	6	Strong breeze
$31 \leq \text{wind speed} < 39$	7	Moderate gale
$39 \leq \text{wind speed} < 47$	8	Gale
$47 \leq \text{wind speed} < 55$	9	Strong gale
$55 \leq \text{wind speed} < 64$	10	Storm
$64 \leq \text{wind speed} < 74$	11	Violent storm

$74 \leq$  wind speed

12

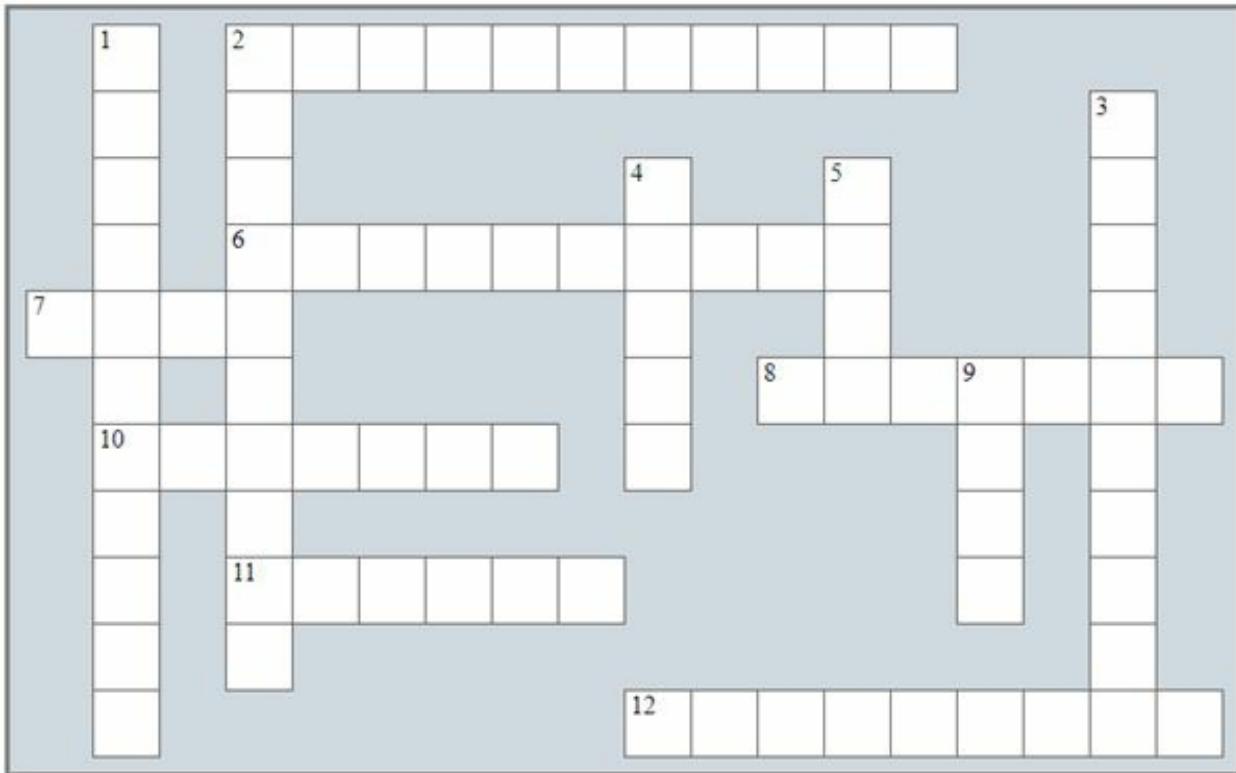
Hurricane force

# **Review in “Decision Control Structures”**

---

## **Review Crossword Puzzle**

1. Solve the following crossword puzzle.



### **Across**

---

2. The AND ( && ) operator is also known as a logical \_\_\_\_\_.
6. This number remains the same after reversing its digits.
7. The \_\_\_\_\_-alternative decision structure includes a statement or block of statements on both paths.
8. This is an expression that results in a value that is either true or false.
10. This Boolean expression can be built of simpler Boolean expressions.
11. This control structure is a structure that is enclosed within another structure.
12. A positive integer where the sum of the cubes of its digits is equal to the number itself.

## **Down**

---

1. The OR ( || ) operator is also known as a logical \_\_\_\_\_.
2. The NOT ( ! ) operator is also known as a logical \_\_\_\_\_.
3. The ( > ) is a \_\_\_\_\_ operator.
4. This table shows the result of a logical operation between two or more Boolean expressions for all their possible combinations of values.
5. This number is considered an even number.
9. This year is exactly divisible by 4 and not by 100, or it is exactly divisible by 400.

## **Review Questions**

Answer the following questions.

1. What is a Boolean expression?
2. Which comparison operators does C# support?
3. Which logical operator performs a logical conjunction?
4. Which logical operator performs a logical disjunction?
5. When does the logical operator AND ( && ) return a result of true?
6. When does the logical operator OR ( || ) return a result of true?
7. State the order of precedence of logical operators.
8. State the order of precedence of arithmetic, comparison, membership, and logical operators.
9. What is code indentation?
10. Design the flowchart and write the corresponding C# statement (in general form) of a single-alternative decision structure. Describe how this decision structure operates.
11. Design the flowchart and write the corresponding C# statement (in general form) of a dual-alternative decision structure. Describe how this decision structure operates.
12. Design the flowchart and write the corresponding C# statement (in general form) of a multiple-alternative decision structure. Describe how this decision structure operates.

13. Write the C# statement (in general form) of a case decision structure.  
Describe how this decision structure operates.
14. What does the term “nesting a decision structure” mean?
15. How deep can the nesting of decision control structures go? Is there any practical limit?
16. Create a diagram that shows all possible paths for solving a linear equation.
17. Create a diagram that shows all possible paths for solving a quadratic equation.
18. When is a year considered a leap year?
19. What is a palindrome number?

# **Section 5**

## **Loop Control Structures**

---

# Chapter 24

## Introduction to Loop Control Structures

---

### 24.1 What is a Loop Control Structure?

A loop control structure is a control structure that allows the execution of a statement or block of statements multiple times until a specified condition is met.

### 24.2 From Sequence Control to Loop Control Structures

The next example lets the user enter four numbers and it then calculates and displays their sum. As you can see, there is no loop control structure yet, just your familiar sequence control structure.

```
static void Main(string[] args) {
    double x, y, z, w, total;

    x = Double.Parse(Console.ReadLine());
    y = Double.Parse(Console.ReadLine());
    z = Double.Parse(Console.ReadLine());
    w = Double.Parse(Console.ReadLine());

    total = x + y + z + w;

    Console.WriteLine(total);
}
```

This program is quite short. However, think of an analogous program that lets the user enter 1000 numbers instead of four! Can you imagine writing the statement `Double.Parse(Console.ReadLine())` 1000 times? Wouldn't it be much easier if you could write this statement only once but "tell" the computer to execute it 1000 times? Of course it would be! But for this you need a loop control structure!

Let's try to solve a riddle first! Without using a loop structure yet, try to rewrite the previous program, but using only two variables, `x` and `total`. Yes, you heard that right! This program must calculate and display the sum of four given numbers, but it must do it with only two variables! Can you find a way?

Hmmm... it's obvious what you are thinking right now: "*The only thing that I can do with two variables is to read one single value in variable x and then*

*assign that value to total*". Your thinking is quite correct, and it is presented here.

```
x = Double.Parse(Console.ReadLine());  
total = x;
```

which can equivalently be written as

```
total = 0;  
  
x = Double.Parse(Console.ReadLine());  
total = total + x;
```

And now what? Now, there are three things that you can actually do, and these are: think, think, and of course, think!

The first number has been stored in variable `total`, so variable `x` is now free for further use! Thus, you can reuse variable `x` to read a second value which will also be accumulated in variable `total`, as follows.

```
total = 0;  
  
x = Double.Parse(Console.ReadLine());  
total = total + x;  
  
x = Double.Parse(Console.ReadLine());  
total = total + x;
```

 Statement `total = total + x` accumulates the value of `x` to `total`, which means that it adds the value of `x` to `total` along with any previous value in `total`. For example, if variable `total` contains the value 5 and variable `x` contains the value 3, the statement `total = total + x` assigns the value 8 to variable `total`.

Since the second number has been accumulated in variable `total`, variable `x` can be re-used! This process can go on again and again until all four numbers are read and accumulated in variable `total`. The final C# program is as follows. Please note that this program does not use any loop control structure yet!

```
total = 0;  
  
x = Double.Parse(Console.ReadLine());  
total = total + x;  
  
x = Double.Parse(Console.ReadLine());
```

```
total = total + x;

x = Double.Parse(Console.ReadLine());
total = total + x;

x = Double.Parse(Console.ReadLine());
total = total + x;

Console.WriteLine(total);
```

 *This program and the initial one are considered equivalent. The main difference between them, however, is that this one has four identical pairs of statements.*

Of course, you can use this example to read and find the sum of more than four numbers. However, you can't write that pair of statements over and over again because soon you will realize how painful this is. Also, if you forget to write at least one pair of statements, it will eventually lead to incorrect results.

What you really need here is to keep only **one** pair of those statements but use a loop control structure that executes it four times (or even 1000 times, if you wish). You can use something like the following code fragment.

```
total = 0;

execute_these_statements_4_times {
    x = Double.Parse(Console.ReadLine());
    total = total + x;
}

Console.WriteLine(total);
```

Obviously there isn't any *execute\_these\_statements\_4\_times* statement in C#. This is for demonstration purposes only but soon enough you will learn everything about all the loop control structures that C# supports!

## 24.3 Review Questions: True/False

Choose **true** or **false** for each of the following statements.

1. A loop control structure is a structure that allows the execution of a statement or block of statements multiple times until a specified condition is met.

2. It is possible to use a sequence control structure that prompts the user to enter 1000 numbers and then calculates their sum.
3. The following code fragment

```
total = 10;  
a = 0;  
total = total + a;
```

accumulates the value 10 in variable total.

4. The following C# program

```
static void Main(string[] args) {  
    int a, total;  
    a = 5;  
    total = total + a;  
    Console.WriteLine(total);  
}
```

satisfies the property of definiteness.

5. The following two code fragments are considered equivalent.

```
a = 5;  
total = a;
```

and

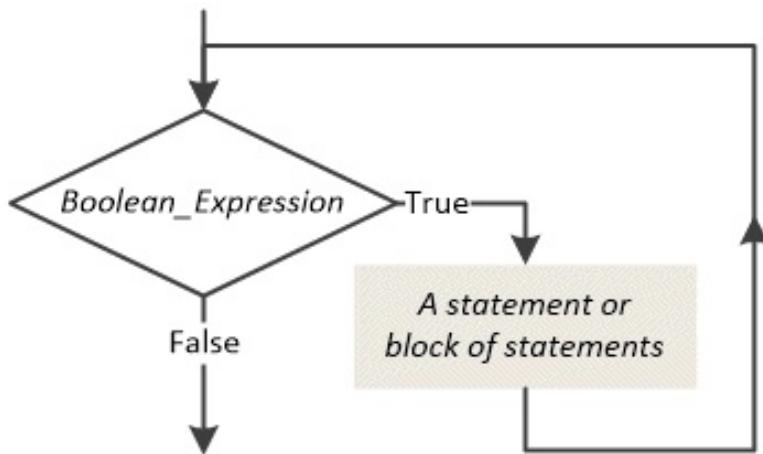
```
total = 0;  
a = 5;  
total = total + a;
```

# Chapter 25

## Pre-Test, Mid-Test and Post-Test Loop Structures

### 25.1 The Pre-Test Loop Structure

The pre-test loop structure is shown in the following flowchart.



The Decision symbol (the diamond, or rhombus) is used both in decision control structures and in loop control structures. However, in loop control structures, one of the diamond's exits always has an upward direction.

Let's see what happens when the flow of execution reaches a pre-test loop structure. If *Boolean\_Expression* evaluates to true, the statement or block of statements of the structure is executed and the flow of execution goes back to check *Boolean\_Expression* once more. If *Boolean\_Expression* evaluates to true again, the process repeats. The iterations stop when *Boolean\_Expression*, at some point, evaluates to false and the flow of execution exits the loop.

- A “pre-test loop structure” is named this way because first the Boolean expression is evaluated, and afterwards the statement or block of statements of the structure is executed.
- Because the Boolean expression is evaluated before entering the loop, a pre-test loop may perform from zero to many iterations.
- Each time the statement or block of statements of a loop control structure is executed, the term used in computer science is “the loop is iterating” or

*“the loop performs an iteration”.*

The general form of the C# statement is

```
while (Boolean_Expression) {  
    A statement or block of statements  
}
```

The following example displays the numbers 1 to 10.

### project\_25\_1

```
static void Main(string[] args) {  
    int i = 1;  
    while (i <= 10) {  
        Console.WriteLine(i);  
        i++;  
    }  
}
```

 Just as in decision control structures, the statements inside a loop control structure should be indented.

When only one single statement needs to be part of the while statement, you are allowed to omit the braces { }. Thus, the while statement becomes

```
while (Boolean_Expression)  
    One_Single_Statement;
```

 Many programmers prefer to always use braces, even when the while statement encloses just one statement.

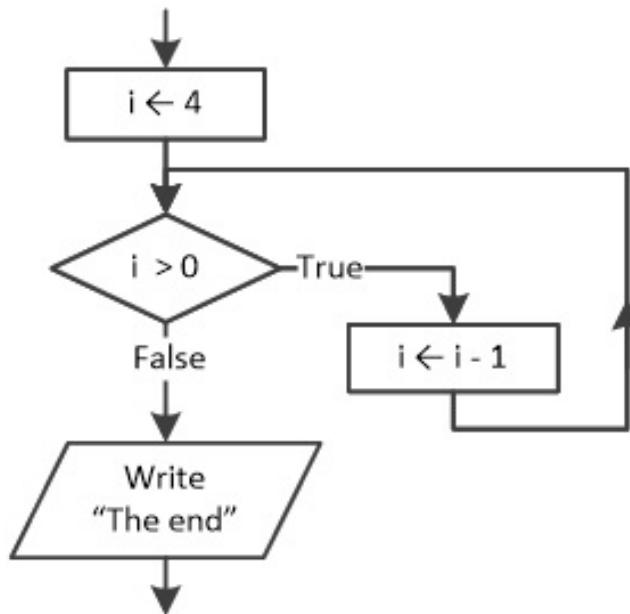
### Exercise 25.1-1 Designing the Flowchart and Counting the Total Number of Iterations

Design the corresponding flowchart for the following code fragment. How many iterations does this C# code perform?

```
int i = 4;  
while (i > 0) {  
    i--;  
}  
  
Console.WriteLine("The end");
```

### Solution

The corresponding flowchart fragment is as follows.



Next, a trace table can help you observe the flow of execution.

Step	Statement	Notes	i
1	$i = 4$		4
2	while ( $i > 0$ )	This evaluates to true	
3	$i--$		3
4	while ( $i > 0$ )	This evaluates to true	
5	$i--$		2
6	while ( $i > 0$ )	This evaluates to true	
7	$i--$		1
8	while ( $i > 0$ )	This evaluates to true	
9	$i--$		0
10	while ( $i > 0$ )	This evaluates to false	
11	.WriteLine("The end")	It displays: The end	

As you can see from the trace table, the total number of iterations is four.

Now, let's draw some conclusions!

- If you want to find the total number of iterations, you need to count the number of times the statement or block of statements of the structure is executed and not the number of times the Boolean expression is evaluated.
- In a pre-test loop structure, when the statement or block of statements of the structure is executed N times, the Boolean expression is evaluated N+1 times.

### ***Exercise 25.1-2 Counting the Total Number of Iterations***

---

*How many iterations does this code fragment perform?*

```
int i = 4;
while (i >= 0) {
    i--;
}
Console.WriteLine("The end");
```

### ***Solution***

---

This exercise is almost identical to the previous one. The only difference is that the Boolean expression here remains true, even for  $i = 0$ . Therefore, it performs an additional iteration, that is, five iterations.

### ***Exercise 25.1-3 Designing the Flowchart and Counting the Total Number of Iterations***

---

*How many iterations does this code fragment perform?*

```
int i = 1;
while (i != 6) {
    i += 2;
}
Console.WriteLine("The end");
```

### ***Solution***

---

Let's create a trace table to observe the flow of execution.

Step	Statement	Notes	i	
1	$i = 1$		1	
2	$while (i != 6)$	This evaluates to true		1 <sup>st</sup> iteration

3	<code>i += 2</code>		3	
4	<code>while (i != 6)</code>	This evaluates to true		2 <sup>nd</sup> iteration
5	<code>i += 2</code>		5	
6	<code>while (i != 6)</code>	This evaluates to true		3 <sup>rd</sup> iteration
7	<code>i += 2</code>		7	
8	<code>while (i != 6)</code>	This evaluates to true		
9	...	...		... ...

As you can see from the trace table, since the value 6 is never assigned to variable `i`, this program will iterate for an infinite number of times! Obviously, this program does not satisfy the property of finiteness.

### ***Exercise 25.1-4 Counting the Total Number of Iterations***

---

*How many iterations does this code fragment perform?*

```
int i = -10;
while (i > 0) {
    i--;
}

Console.WriteLine("The end");
```

### ***Solution***

---

Initially, the value `-10` is assigned to variable `i`. The Boolean expression directly evaluates to `false` and the flow of execution goes right to the `Console.WriteLine("The end")` statement. Thus, this program performs zero iterations.

### ***Exercise 25.1-5 Finding the Sum of Four Numbers***

---

*Using a pre-test loop structure, write a C# program that lets the user enter four numbers and then calculates and displays their sum.*

### ***Solution***

---

Do you remember the example in [paragraph 24.2](#) for calculating the sum of four numbers? At the end, after a little work, the proposed code fragment became

```
total = 0;
```

```
execute_these_statements_4_times {
    x = Double.Parse(Console.ReadLine());
    total = total + x;
}

Console.WriteLine(total);
```

Now, you need a way to “present” the statement `execute_these_statements_4_times` with real C# statements. The `while` statement is actually able to do this, but you need one extra variable to count the total number of iterations. Then, when the desired number of iterations has been performed, the flow of execution must exit the loop.

Following is a general purpose code fragment that iterates for the number of times specified by `total_number_of_iterations`,

```
i = 1;
while ( i <= total_number_of_iterations ) {

    A statement or block of statements

    i++;
}
```

where `total_number_of_iterations` can be a constant value or even a variable or an expression.

 *The name of the variable `i` is not binding. You can use any variable name you wish such as counter, count, k, and more.*

After combining this code fragment with the previous one, the final program becomes

### project\_25\_1\_5

```
static void Main(string[] args) {
    double total, x;
    int i;

    total = 0;

    i = 1;
    while (i <= 4) {
        x = Double.Parse(Console.ReadLine());      [More...]
        total = total + x;
    }
}
```

```
i++;  
}  
  
Console.WriteLine(total);  
}
```

### **Exercise 25.1-6 Finding the Sum of Odd Numbers**

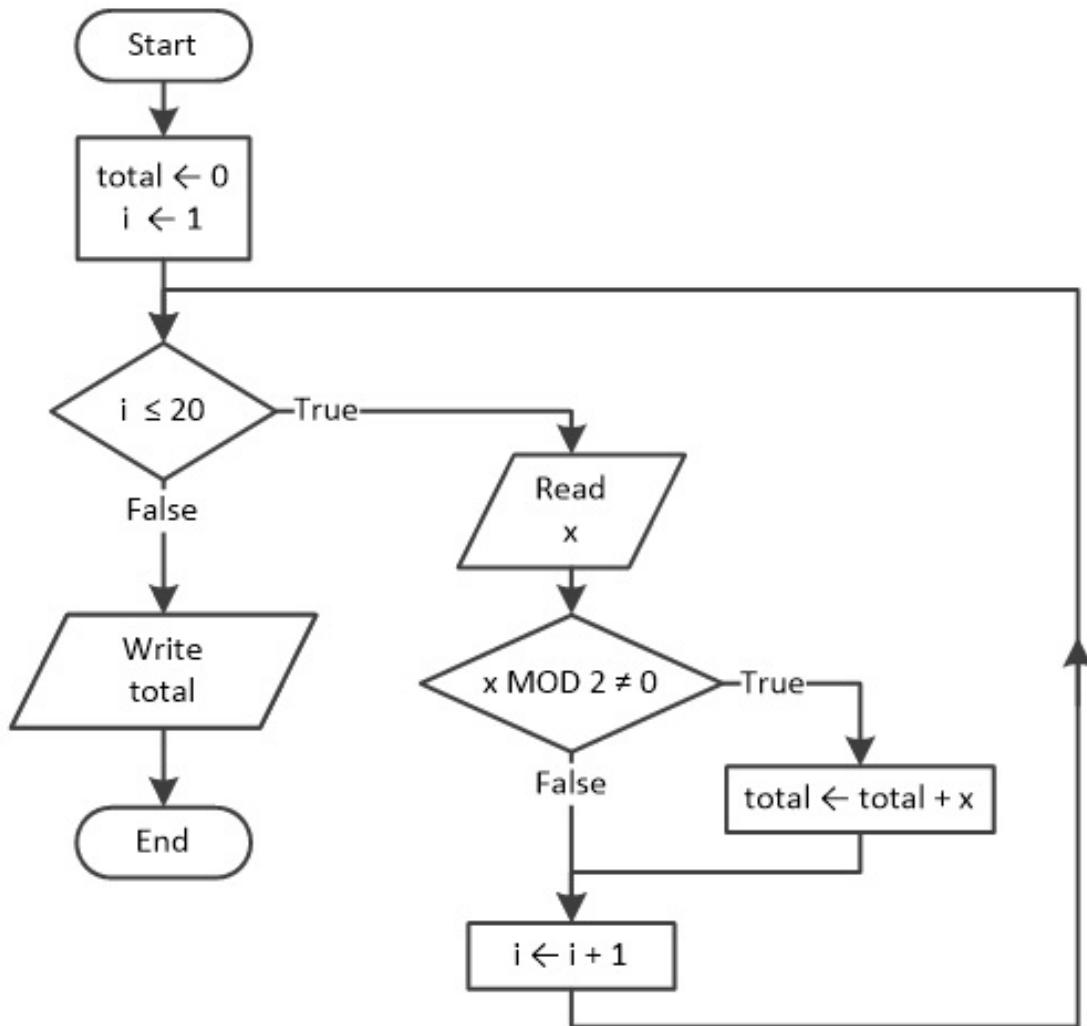
---

*Design a flowchart and write the corresponding C# program that lets the user enter 20 integers, and then calculates and displays the sum of the odd numbers.*

### **Solution**

---

This is quite easy. What the program must do inside the loop is check whether or not a given number is odd and, if it is, that number must accumulate to variable total; even numbers must be ignored. The flowchart is as follows. It includes a single-alternative decision structure nested within a pre-test loop structure.



The corresponding C# program is as follows.

### project\_25\_1\_6

```

static void Main(string[] args) {
    int total, i, x;

    total = 0;

    i = 1;
    while (i <= 20) {
        x = Int32.Parse(Console.ReadLine());
        if (x % 2 != 0) {
            total += x;      //This is equivalent to total = total + x
        }
        i++;
    }
}

```

```
    Console.WriteLine(total);
}
```

 You can nest **any** decision control structure inside **any** loop control structure as long as you keep them syntactically and logically correct.

### **Exercise 25.1-7 Finding the Sum of N Numbers**

Write a C# program that lets the user enter  $N$  numbers and then calculates and displays their sum. The value of  $N$  must be given by the user at the beginning of the program.

#### **Solution**

In this exercise, the total number of iterations depends on a value that the user must enter. Following is a general purpose code fragment that iterates for  $N$  times, where  $N$  is given by the user.

```
n = Int32.Parse(Console.ReadLine());  
  
i = 1;  
while (i <= n) {  
    A statement or block of statements  
    i++;  
}
```

According to what you have learned so far, the final program becomes

#### project\_25\_1\_7

```
static void Main(string[] args) {  
    int n, i;  
    double x, total;  
  
    total = 0;  
  
    n = Int32.Parse(Console.ReadLine());  
  
    i = 1;  
    while (i <= n) {  
        x = Double.Parse(Console.ReadLine());  
        total += x;  
        i++;  
    }  
  
    Console.WriteLine(total);
```

```
| }
```

### **Exercise 25.1-8 Finding the Sum of an Unknown Quantity of Numbers**

*Write a C# program that lets the user enter integer values repeatedly until the value  $-1$  is entered. When data input is completed, the sum of the numbers entered must be displayed. (The value of  $-1$  must not be included in the final sum). Next, create a trace table to check if your program operates properly using  $10, 20, 5$ , and  $-1$  as input values.*

#### **Solution**

In this exercise, the total number of iterations is unknown. If you were to use decision control structures, your program would look something like the code fragment that follows.

```
total = 0;

x = Int32.Parse(Console.ReadLine());
if (x != -1) { //Check variable x
    total += x; //and execute this statement
    x = Int32.Parse(Console.ReadLine()); //and this one
}
if (x != -1) { //Check variable x
    total += x; //and execute this statement
    x = Int32.Parse(Console.ReadLine()); //and this one
    if (x != -1) { //Check variable x
        total += x; //and execute this statement
        x = Int32.Parse(Console.ReadLine()); //and this one
        ...
        ...
    }
}
Console.WriteLine(total);
```

[More...]

Now let's rewrite this program using a loop control structure instead. The final program is presented next. If you try to follow the flow of execution, you will find that it operates equivalently to the previous one.

#### **project\_25\_1\_8**

```
static void Main(string[] args) {
    double total, x;
    total = 0;
```

```

x = Int32.Parse(Console.ReadLine());
while (x != -1) { //Check variable x
    total += x;      //and execute this statement
    x = Int32.Parse(Console.ReadLine()); //and this one
}

Console.WriteLine(total);
}

```

Now let's create a trace table to determine if this program operates properly using 10, 20, 5, and  $-1$  as input values.

Step	Statement	Notes	x	total
1	total = 0		?	0
2	x = Int32.Parse(...)		10	0
3	while (x != -1)	This evaluates to true		
4	total += x		10	10
5	x = Int32.Parse(...)		20	10
6	while (x != -1)	This evaluates to true		
7	total += x		20	30
8	x = Int32.Parse(...)		5	30
9	while (x != -1)	This evaluates to true		
10	total += x		5	35
11	x = Int32.Parse(...)		-1	35
12	while (x != -1)	This evaluates to false		
13	.WriteLine(total)	It displays: 35		

As you can see, in the end, variable `total` contains the value 35, which is, indeed, the sum of the values  $10 + 20 + 5$ . Moreover, the final given value of  $-1$  does not participate in the final sum.

 When the number of iterations is known before the loop starts iterating the loop is often called “definite loop”. In this exercise, however, the

*number of iterations is not known before the loop starts iterating, and it depends on a certain condition. This type of loop is often called “indefinite loop”.*

### ***Exercise 25.1-9 Finding the Product of 20 Numbers***

*Write a C# program that lets the user enter 20 numbers and then calculates and displays their product.*

#### **Solution**

If you were to use a sequence control structure, it would be something like the next code fragment.

```
p = 1;

x = Double.Parse(Console.ReadLine());      [More...]
p = p * x;

x = Double.Parse(Console.ReadLine());
p = p * x;

x = Double.Parse(Console.ReadLine());
p = p * x;

...
...
x = Double.Parse(Console.ReadLine());
p = p * x;
```

 Note that variable `p` is initialized to 1 instead of 0. This is necessary for the statement `p = p * x` to operate properly; the final product would be zero otherwise.

Using knowledge from the previous exercises, the final program becomes

#### **project\_25\_1\_9**

```
static void Main(string[] args) {
    double p, x;
    int i;

    p = 1;

    i = 1;
```

```

while (i <= 20) {
    x = Double.Parse(Console.ReadLine());
    p = p * x;

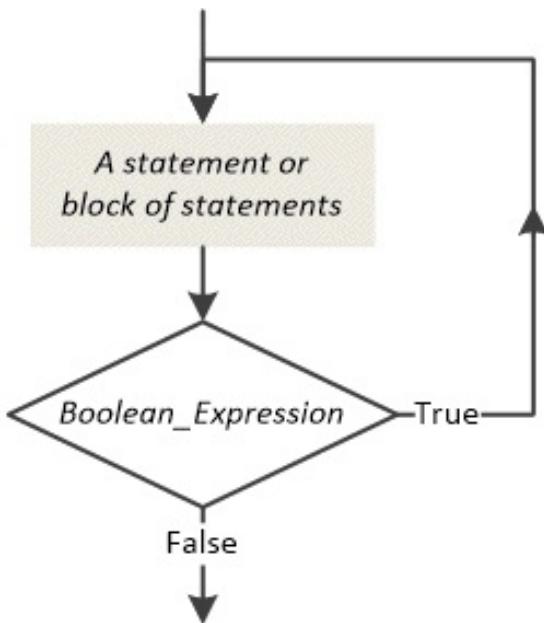
    i++;
}

Console.WriteLine(p);
}

```

## 25.2 The Post-Test Loop Structure

The post-test loop structure is shown in the following flowchart.



 In loop control structures, one of the diamond's exits always has an upward direction.

Let's see what happens when the flow of execution reaches a post-test loop structure. The statement or block of statements of the structure is directly executed and if *Boolean\_Expression* evaluates to true, the flow of execution goes back to the point just above the statement or block of statements of the structure. The statement or block of statements is executed once more and if *Boolean\_Expression* evaluates to true again, the process repeats. The iterations stop when *Boolean\_Expression*, at some point, evaluates to false and the flow of execution exits the loop.

 The post-test loop differs from the pre-test loop in that first the statement or block of statements of the structure is executed and afterwards the Boolean expression is evaluated. Consequently, the post-test loop performs at least one iteration!

 Each time the statement or block of statements of a loop control structure is executed, the term used in computer science is “the loop is iterating” or “the loop performs an iteration”.

The general form of the C# statement is

```
do {  
    A statement or block of statements  
} while (Boolean_Expression);
```

The following example displays the numbers 1 to 10.

### project\_25\_2

```
static void Main(string[] args) {  
    int i;  
  
    i = 1;  
    do {  
        Console.WriteLine(i);  
        i++;  
    } while (i <= 10);  
}
```

 Note the presence of a semicolon ( ; ) character at the end of the do-while statement.

When only one single statement needs to be part of the do-while statement, you are allowed to omit the braces { }. Thus the do-while statement becomes

```
do  
    One_Single_Statement;  
while (Boolean_Expression);
```

 Many programmers prefer to always use braces even when the do-while statement encloses just one statement.

## **Exercise 25.2-1 Designing the Flowchart and Counting the Total Number**

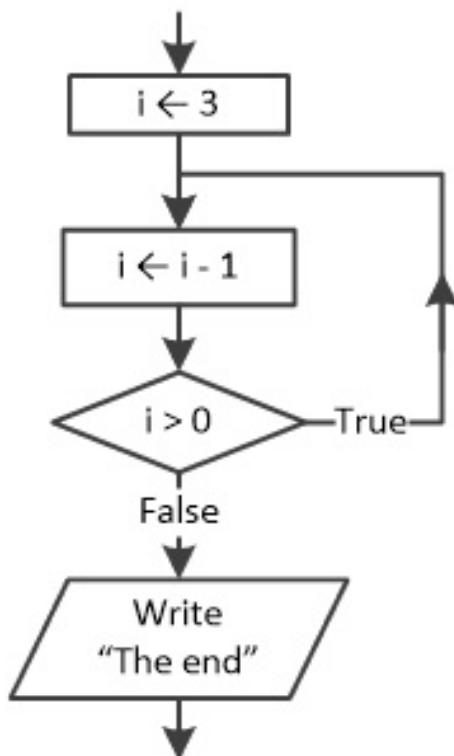
## of Iterations

Design the corresponding flowchart for the following code fragment. How many iterations does this C# code perform?

```
int i;  
  
i = 3;  
do {  
    i--;  
} while (i > 0);  
  
Console.WriteLine("The end");
```

## Solution

The corresponding flowchart fragment is as follows.



Now, let's create a trace table to observe the flow of execution.

Step	Statement	Notes	i	
1	$i = 3$		3	
2	$i--$		2	1 <sup>st</sup> iteration
3	<code>while (i &gt; 0)</code>	This evaluates to true		

4	i--		1	
5	while (i > 0)	This evaluates to true		2 <sup>nd</sup> iteration
6	i--		0	
7	while (i > 0)	This evaluates to false		3 <sup>rd</sup> iteration
8	.WriteLine("The end")	It displays: The end		

As you can see from the trace table, the total number of iterations is three.

Now, let's draw some conclusions!

- If you have to find the total number of iterations, you can count the number of times the statement or block of statements of the structure is executed but also the number of times the Boolean expression is evaluated, since both numbers are equal.
- In a post-test loop structure, when the statement or block of statements of the structure is executed N times, the Boolean expression is evaluated N times as well.

### ***Exercise 25.2-2 Counting the Total Number of Iterations***

---

*How many iterations does this code fragment perform?*

```
int i = 3;
do {
    i--;
} while (i >= 0);

Console.WriteLine("The end");
```

### ***Solution***

---

This exercise is almost identical to the previous one. The only difference is that the Boolean expression  $i \geq 0$  here remains true even for  $i = 0$ . Therefore, it performs an additional iteration, that is, four iteration.

### ***Exercise 25.2-3 Designing the Flowchart and Counting the Total Number of Iterations***

---

*Design the corresponding flowchart for the following code fragment. How many iterations does this code perform? What happens if you switch the post-test loop with a pre-test loop structure?*

```
int i = -1;
```

```

do {
    i--;
    Console.WriteLine("Hello there!");
} while (i > 0);

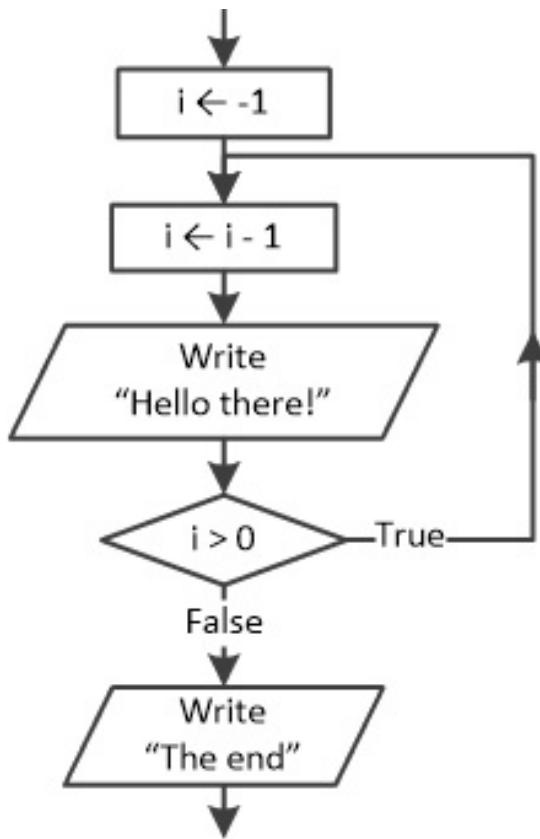
Console.WriteLine("The end");

```

## Solution

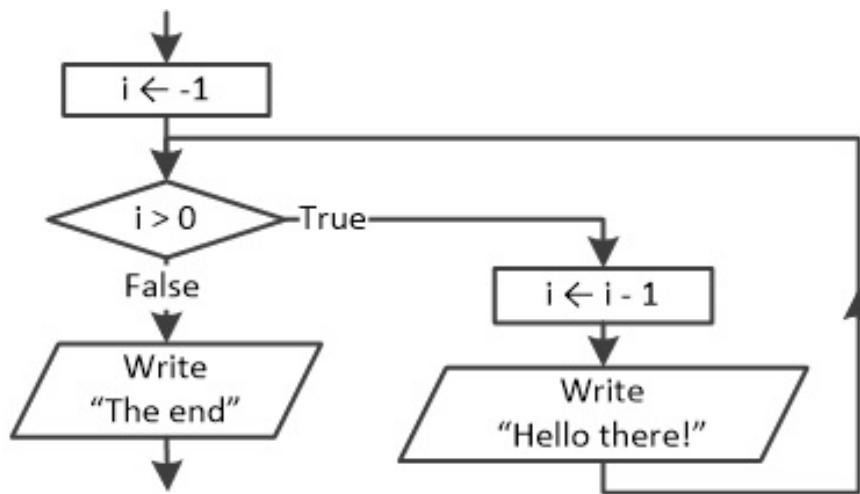
---

The corresponding flowchart fragment is as follows.



Initially the value  $-1$  is assigned to variable  $i$ . Inside the loop, variable  $i$  is decremented by one (value  $-2$  is assigned) and the message "Hello there!" is displayed. The Boolean expression  $i > 0$  evaluates to false and the flow of execution goes right to the write ("The end") statement. Thus, this algorithm and the corresponding C# code fragment perform one iteration!

Now, in the flowchart that follows, let's see what happens if you switch the post-test loop with a pre-test loop structure .



The value  $-1$  is assigned to variable  $i$ . The Boolean expression  $i > 0$  evaluates to false and the flow of execution goes directly to the `Write ("The end")` statement. Thus, this algorithm performs zero iterations!

A pre-test loop structure may perform zero iterations in contrast to the post-test loop structure which performs **at least** one iteration!

### Exercise 25.2-4 Counting the Total Number of Iterations

How many iterations does this code fragment perform?

```

int i = 1;
do {
    i = i + 2;
} while (i != 4);

Console.WriteLine("The end");
  
```

### Solution

Let's create a trace table to observe the flow of execution.

Step	Statement	Notes	i	
1	$i = 1$		1	
2	$i = i + 2$		3	
3	<code>while (i != 4)</code>	This evaluates to true		1 <sup>st</sup> iteration
4	$i = i + 2$		5	
5	<code>while (i != 4)</code>	This evaluates to true		2 <sup>nd</sup> iteration

6	<code>i = i + 2</code>	7	
7	<code>while (i != 4)</code>	This evaluates to true	3 <sup>rd</sup> iteration
8	...	...	...
9	...	...	...

As you can see from the trace table, since the value 4 is never assigned to variable `i`, this program will iterate for an infinite number of times!  
Obviously, this program does not satisfy the property of finiteness.

### ***Exercise 25.2-5 Finding the Product of N Numbers***

*Write a C# program that lets the user enter N numbers and then calculates and displays their product. The value of N must be given by the user at the beginning of the program. What happens if you switch the post-test loop structure with a pre-test loop structure? Do both programs operate exactly the same way for all possible input values of N?*

### **Solution**

Both programs below let the user enter N numbers and then calculate and display their product. The left one, however, uses a pre-test while the right one uses a post-test loop structure. If you try to execute them and enter any value greater than zero for N, both programs operate exactly the same way!

#### **project\_25\_2\_5a**

```
static void Main(string[] args){
    int n, i;
    double p, x;

    n = Int32.Parse(Console.ReadLine());

    p = 1;
    i = 1;
    while (i <= n) {
        x = Double.Parse(Console.ReadLine());
        p = p * x;

        i++;
    }
    Console.WriteLine(p);
}
```

## project\_25\_2\_5b

```
static void Main(string[] args){  
    int n, i;  
    double p, x;  
  
    n = Int32.Parse(Console.ReadLine());  
  
    p = 1;  
    i = 1;  
    do {  
        x = Double.Parse(Console.ReadLine());  
        p = p * x;  
  
        i++;  
    } while (i <= n);  
    Console.WriteLine(p);  
}
```

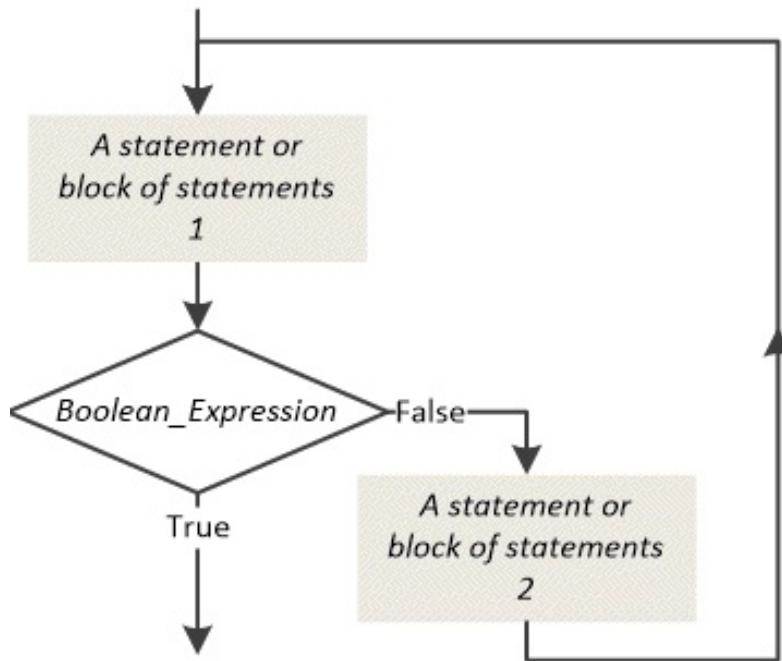
The two C# programs, however, operate in different ways when the user enters a non-positive<sup>[17]</sup> value for N. For example, if the value 0 is entered, the left program performs **zero** iterations whereas the right program performs **one** iteration!

☞ A pre-test loop structure may perform zero iterations in contrast to the post-test loop structure, which performs **at least** one iteration!

☞ Obviously, the left program (the one that uses a pre-test loop structure) is the best choice to solve this exercise. Suppose the user executes the program but then decides not to enter any values. He or she can then enter value zero for N and the program won't ask for any other values!

### 25.3 The Mid-Test Loop Structure

The mid-test loop structure is shown in the following flowchart.



Let's see what happens when the flow of execution reaches a mid-test loop structure. The statement or block of statements 1 of the structure is directly executed and if *Boolean\_Expression* evaluates to false, the statement or block of statements 2 is executed and the flow of execution goes back to the point just above the statement or block of statements 1 of the structure. The statement or block of statements 1 is executed once more and if *Boolean\_Expression* evaluates to false again, the process repeats. The iterations stop when *Boolean\_Expression*, at some point, evaluates to true and the flow of execution exits the loop.

Although this loop control structure is directly supported in some computer languages such as Ada, unfortunately this is not true for C#. However, you can still write mid-test loops using the `while` statement along with an `if` and a `break` statement. The main idea is to create an endless loop and break out of it when the Boolean expression that exists between the two statements (or block of statements) of the structure evaluates to true. The idea is shown in the code fragment given in general form that follows.

```

while (true) {
    A statement or block of statements 1
    if (Boolean_Expression) break;
    A statement or block of statements 2
}

```

| }

 You can break out of a loop before it actually completes all of its iterations by using the `break` statement.

The following example displays the numbers 1 to 10.

### project\_25\_3

```
static void Main(string[] args) {
    int i = 1;
    while (true) {
        Console.WriteLine(i);
        if (i >= 10) break;
        i++;
    }
}
```

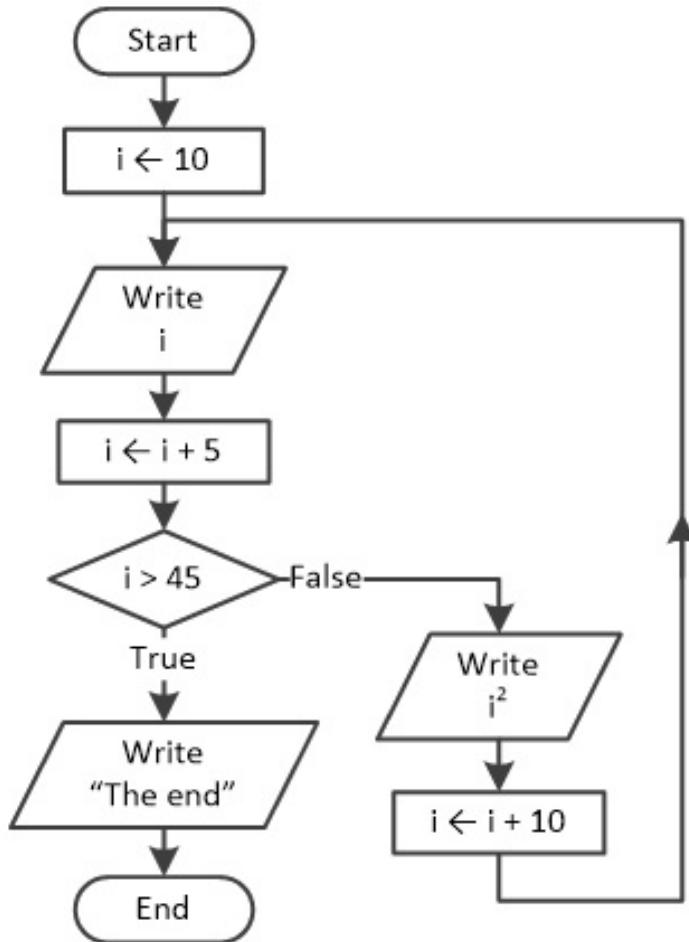
#### **Exercise 25.3-1 Designing the Flowchart and Counting the Total Number of Iterations**

Design the corresponding flowchart for the following code fragment and create a trace table to determine the values of variable `i` in each step.

```
int i = 10;
while (true) {
    Console.WriteLine(i);
    i += 5;
    if (i > 45) break;
    Console.WriteLine(i * i);
    i += 10;
}
Console.WriteLine("The end");
```

#### **Solution**

The corresponding flowchart fragment is as follows.



Now, let's create a trace table to observe the flow of execution.

Step	Statement	Notes	i
1	<code>i = 10</code>		<b>10</b>
2	<code>.WriteLine(i)</code>	It displays: 10	
3	<code>i += 5</code>		<b>15</b>
4	<code>if (i &gt; 45)</code>	This evaluates to false	
5	<code>.WriteLine(i * i)</code>	It displays: 225	
6	<code>i += 10</code>		<b>25</b>
7	<code>.WriteLine(i)</code>	It displays: 25	
8	<code>i += 5</code>		<b>30</b>
9	<code>if (i &gt; 45)</code>	This evaluates to false	

<b>10</b>	<code>.WriteLine(i * i)</code>	It displays: 900	
<b>11</b>	<code>i += 10</code>		<b>40</b>
<b>12</b>	<code>.WriteLine(i)</code>	It displays: 40	
<b>13</b>	<code>i += 5</code>	<b>45</b>	
<b>14</b>	<code>if (i &gt; 45)</code>	This evaluates to false	
<b>15</b>	<code>.WriteLine(i * i)</code>	It displays: 2025	
<b>16</b>	<code>i += 10</code>		<b>55</b>
<b>17</b>	<code>.WriteLine(i)</code>	It displays: 55	
<b>18</b>	<code>i += 5</code>		<b>60</b>
<b>19</b>	<code>if (i &gt; 45)</code>	This evaluates to true	
<b>20</b>	<code>.WriteLine("The end")</code>	It displays: The end	

## 25.4 Review Questions: True/False

Choose **true** or **false** for each of the following statements.

1. A pre-test loop may perform zero iterations.
2. In flowcharts, both exits of the diamond symbol in a pre-test loop structure, have an upwards direction.
3. The statement or block of statements of a pre-test loop structure is executed at least one time.
4. A pre-test loop stops iterating when its Boolean expression evaluates to true
5. In a pre-test loop structure, when the statement or block of statements of the structure is executed N times, the Boolean expression is evaluated N – 1 times.
6. A post-test loop may perform zero iterations.
7. A post-test loop stops iterating when its Boolean expression evaluates to true.
8. In a post-test loop structure, when the statement or block of statements of the structure is executed N times, its Boolean expression is evaluated

N times as well.

9. You cannot nest a decision control structure inside a post-test loop structure.
10. In the mid-test loop structure, the statement or block of statements 1 is executed the same number of times as the statement or block of statements 2.
11. In the following code fragment

```
int i = 1;
while (i <= 10)
    Console.WriteLine("Hello");
    i++;
```

the word “Hello” is displayed 10 times

12. The following C# program

```
static void Main(string[] args) {
    int i;

    i = 1;
    while (i != 10) {
        Console.WriteLine("Hello");
        i += 2;
    }
}
```

does **not** satisfy the property of finiteness

13. In the following code fragment

```
int i = 1;
do {
    Console.WriteLine("Hello");
} while (i >= 10);
```

the word “Hello” is displayed an infinite number of times.

14. The following C# program

```
static void Main(string[] args) {
    int i;

    do {
        Console.WriteLine("Hello");
        i++;
    } while (i <= 10);
}
```

satisfies the property of definiteness.

15. The following code fragment

```
int b;
double a;

b = Int32.Parse(Console.ReadLine());
do {
    a = 1 / (b - 1);
    b++;
} while (b <= 10);
```

does **not** satisfy the property of definiteness.

16. In the following code fragment

```
int i = 1;
while (true) {
    Console.WriteLine("Zeus");
    if (i > 10) break;
    i++;
}
```

the word “Zeus” is displayed 10 times.

## 25.5 Review Questions: Multiple Choice

Select the correct answer for each of the following statements.

1. In flowcharts, the diamond symbol is being used
  - a. in decision control structures.
  - b. in loop control structures.
  - c. all of the above
2. A post-test loop structure
  - a. performs one iteration more than the pre-test loop structure does.
  - b. performs the same number of iterations as the pre-test loop structure does.
  - c. none of the above
3. In a post-test loop structure, the statement or block of statements of the structure
  - a. are executed before the loop's Boolean expression is evaluated.
  - b. are executed after the loop's Boolean expression is evaluated.

- c. none of the above
- 4. In the following code fragment

```
int i = 1;
while (i < 10) {
    Console.WriteLine("Hello Hermes");
    i++;
}
```

- the message “Hello Hermes” is displayed
- a. 10 times.
  - b. 9 times.
  - c. 1 time.
  - d. 0 times.
  - e. none of the above

- 5. In the following code fragment

```
int i = 1;
while (i < 10)
    Console.WriteLine("Hi!");
    Console.WriteLine("Hello Ares");
    i++;
```

- the message “Hello Ares” is displayed
- a. 10 times.
  - b. 11 time.
  - c. 1 times.
  - d. none of the above

- 6. In the following code fragment

```
int i = 1;
while (i < 10)
    i++;
    Console.WriteLine("Hi!");
    Console.WriteLine("Hello Aphrodite");
```

- the message “Hello Aphrodite” is displayed
- a. 10 times.
  - b. 1 time.
  - c. 0 times.

- d. none of the above
7. In the following code fragment

```
int i = 1;
while (i >= 10) {
    Console.WriteLine("Hi!");
    Console.WriteLine("Hello Apollo");
    i++;
}
```

- the message “Hello Apollo” is displayed
- a. 10 times.
  - b. 1 time.
  - c. 0 times.
  - d. none of the above
8. The following code fragment

```
int i, n;
double s;
n = Int32.Parse(Console.ReadLine());
s = 0;
i = 1;
while (i < n) {
    a = Double.Parse(Console.ReadLine());
    s = s + a;
    i++;
}
Console.WriteLine(s);
```

- calculates and displays the sum of
- a. as many numbers as the value of variable *n* denotes.
  - b. as many numbers as the result of the expression *n - 1* denotes.
  - c. as many numbers as the value of variable *i* denotes.
  - d. none of the above
9. In the following code fragment

```
int i = 1;
do {
    Console.WriteLine("Hello Poseidon");
    i++;
} while (i > 5);
```

- the message “Hello Poseidon” is displayed

- a. 5 times.
  - b. 1 time.
  - c. 0 times.
  - d. none of the above
10. In the following code fragment

```
int i = 1;
do {
    Console.WriteLine("Hello Athena");
    i += 5;
} while (i != 50);
```

- the message “Hello Athena” is displayed
- a. at least one time.
  - b. at least 10 times.
  - c. an infinite number of times.
  - d. all of the above
11. In the following code fragment

```
int i = 0;
do {
    Console.WriteLine("Hello Apollo");
} while (i > 10);
```

- the message “Hello Apollo” is displayed
- a. at least one time.
  - b. an infinite number of times.
  - c. none of the above
12. In the following code fragment

```
int i = 10;
while (true) {
    i--;
    if (i > 0) break;
    Console.WriteLine("Hello Aphrodite");
}
```

- the message “Hello Aphrodite” is displayed
- a. at least one time.
  - b. an infinite number of times.

- c. ten times
- d. none of the above

## 25.6 Review Exercises

Complete the following exercises.

1. Identify the error(s) in the following C# program. It must display the numbers 3, 2, 1 and the message “The end”.

```
static void Main(string[] args) {
    int i;

    i = 3;
    do
        Console.WriteLine(i);
        i--;
    } while (i >= 0)
    Console.WriteLine(The end);
}
```

2. Create a trace table to determine the values of the variables in each step of the next code fragment. How many iterations does this C# program perform?

```
int i, x;

i = 3;
x = 0;
while (i >= 0) {
    i--;
    x += i;
}

Console.WriteLine(x);
```

3. Design the corresponding flowchart and create a trace table to determine the values of the variables in each step of the next C# program. How many iterations does this C# program perform?

```
static void Main(string[] args) {
    int i;

    i = -5;
    while (i < 10) {
        i--;
    }
}
```

```
        Console.WriteLine(i);
    }
```

4. Create a trace table to determine the values of the variables in each step of the next code fragment. How many iterations does this C# program perform?

```
int a, b, c, d;

a = 2;
while (a <= 10) {
    b = a + 1;
    c = b * 2;
    d = c - b + 1;
    switch (d) {
        case 4:
            Console.WriteLine(b + ", " + c);
            break;
        case 5:
            Console.WriteLine(c);
            break;
        case 8:
            Console.WriteLine(a + ", " + b);
            break;
        default:
            Console.WriteLine(a + ", " + b + ", " + d);
            break;
    }
    a += 4;
}
```

5. Create a trace table to determine the values of the variables in each step of the next code fragment. How many iterations does this C# code perform?

```
int a, b, c, d, x;

a = 1;
b = 1;
c = 0;
d = 0;
while (b < 2) {
    x = a + b;
    if (x % 2 != 0)
        c = c + 1;
    else
```

```
    d = d + 1;
    a = b;
    b = c;
    c = d;
}
```

6. Fill in the gaps in the following code fragments so that all loops perform exactly four iterations.

- i. 

```
int a = 3;
while (a > ..... ) {
    a--;
}
```
- ii. 

```
int a = 5;
while (a < ..... ) {
    a++;
}
```
- iii. 

```
double a = 9;
while (a != 10 ) {
    a = a + ..... ;
}
```
- iv. 

```
int a = 1;
while (a != ..... ) {
    a -= 2;
}
```
- v. 

```
int a = 2;
while (a < ..... ) {
    a = 2 * a;
}
```
- vi. 

```
double a = 1;
while (a < ..... ) {
    a = a + 0.1;
}
```

7. Create a trace table to determine the values of the variables in each step of the next code fragment. How many iterations does this code perform?

```
int y, x;

y = 5;
x = 38;
do {
    y *= 2;
    x++;
}
```

```
    Console.WriteLine(y);
} while (y < x);
```

8. Create a trace table to determine the values of the variables in each step of the next code fragment. How many iterations does this code perform?

```
int x;

x = 1;
do {
    if (x % 2 == 0) {
        x++;
    }
    else {
        x += 3;
    }
    Console.WriteLine(x);
} while (x < 12);
```

9. Create a trace table to determine the values of the variables in each step of the next code fragment. How many iterations does this code perform?

```
double x, y;

y = 2;
x = 0;
do {
    y = Math.Pow(y, 2);
    if (x < 256) {
        x = x + y;
    }
    Console.WriteLine(x + ", " + y);
} while (y < 65535);
```

10. Create a trace table to determine the values of the variables in each step of the next code fragment. How many iterations does this code perform?

```
int a, b, c, d, x;

a = 2;
b = 4;
c = 0;
d = 0;
do {
```

```

x = a + b;
if (x % 2 != 0) {
    c = c + 5;
}
else if (d % 2 == 0) {
    d = d + 5;
}
else {
    c = c + 3;
}
a = b;
b = d;
} while (c < 11);

```

11. Fill in the gaps in the following code fragments so that all loops perform exactly six iterations.

i. `int a = 5;  
do {  
 a--;  
} while (a > .....);`

ii. `int a = 12;  
do {  
 a++;  
} while (a < .....);`

iii. `int a = 20;  
do {  
 a = a + .....;  
} while (a != 23);`

iv. `int a = 100;  
do {  
 a -= 20;  
} while (a != .....);`

v. `int a = 2;  
do {  
 a = 2 * a;  
} while (a != .....);`

vi. `double a = 10;  
do {  
 a = a + 0.25;  
} while (a <= .....);`

12. Fill in the gaps in the following code fragments so that all display the value 10 at the end.

```

i.   int x = 0;
     int y = 0;
     do {
         x++;
         y += 2;
     } while (x <= ..... );
     Console.WriteLine(y);

ii.  int x = 1;
      double y = 20;
      do {
          x--;
          y -= 2.5;
      } while (x >= ..... );
      Console.WriteLine(y);

iii. int x = 3;
       double y = 2.5;
       do {
           x--;
           y *= 2;
       } while (x >= ..... );
       Console.WriteLine(y);

iv.   int x = 30;
        int y = 101532;
        do {
            x -= ....;
            y = (int)(y / 10);
        } while (x >= 0);
        Console.WriteLine(y);

```

13. Using a pre-test loop structure, write a C# program that lets the user enter N numbers and then calculates and displays their sum and their average. The value of N must be given by the user at the beginning of the program.
14. Using a pre-test loop structure, write a C# program that lets the user enter N integers and then calculates and displays the product of those that are even. The value of N must be given by the user at the beginning of the program.
15. Using a pre-test loop structure, write a C# program that lets the user enter 100 integers and then calculates and displays the sum of those with a last digit of 0. For example, the values 10, 2130, and 500 are such numbers.

Hint: You can isolate the last digit of any integer using a modulus 10 operation.

16. Using a pre-test loop structure, write a C# program that lets the user enter 20 integers and then calculates and displays the sum of those that consist of three digits.

Hint: All three-digit integers are between 100 and 999.

17. Using a pre-test loop structure, write a C# program that lets the user enter numeric values repeatedly until the value 0 is entered. When data input is completed, the product of the numbers entered must be displayed. (The last 0 entered must not be included in the final product). Next, create a trace table to check if your program operates properly using 3, 2, 9, and 0 as input values.

18. The population of a town is now at 30000 and is expanding at a rate of 3% per year. Using a pre-test loop structure, write a C# program to determine how many years it will take for the population to exceed 100000.

19. Using a post-test loop structure, design a flowchart and write the corresponding C# program that lets the user enter 50 integers and then calculates and displays the sum of those that are odd and the sum of those that are even.

20. Using a post-test loop structure, write a C# program that lets the user enter N integers and then calculates and displays the product of those that are negative. The value of N must be given by the user at the beginning of the program, and the final product must always be displayed as a positive value. Assume that the user enters a value greater than 0 for N.

21. Using a post-test loop structure, write a C# program that prompts the user to enter five integers and then calculates and displays the product of all three-digit integers with a first digit of 5. For example, the values 512, 555, and 593 are all such numbers

Hint: All three-digit integers with a first digit of 5 are between 500 and 599.

22. The population of a beehive is now at 50000, but due to environmental reasons it is contracting at a rate of 10% per year. Using a post-test loop structure, write a C# program to determine how many years it will take

for the population to be less than 20000.

# Chapter 26

## The for statement

---

### 26.1 The for statement

In [Chapter 25](#), as you certainly noticed, the `while` statement was used to create both definite and indefinite loops. In other words, it was used to iterate for a known number of times but also for an unknown number of times. Since definite loops are so frequently used in computer programming, almost every computer language, including C#, incorporates a special statement that is much more readable and convenient than the `while` statement—and this is the `for` statement.

The general form of the `for` statement, is

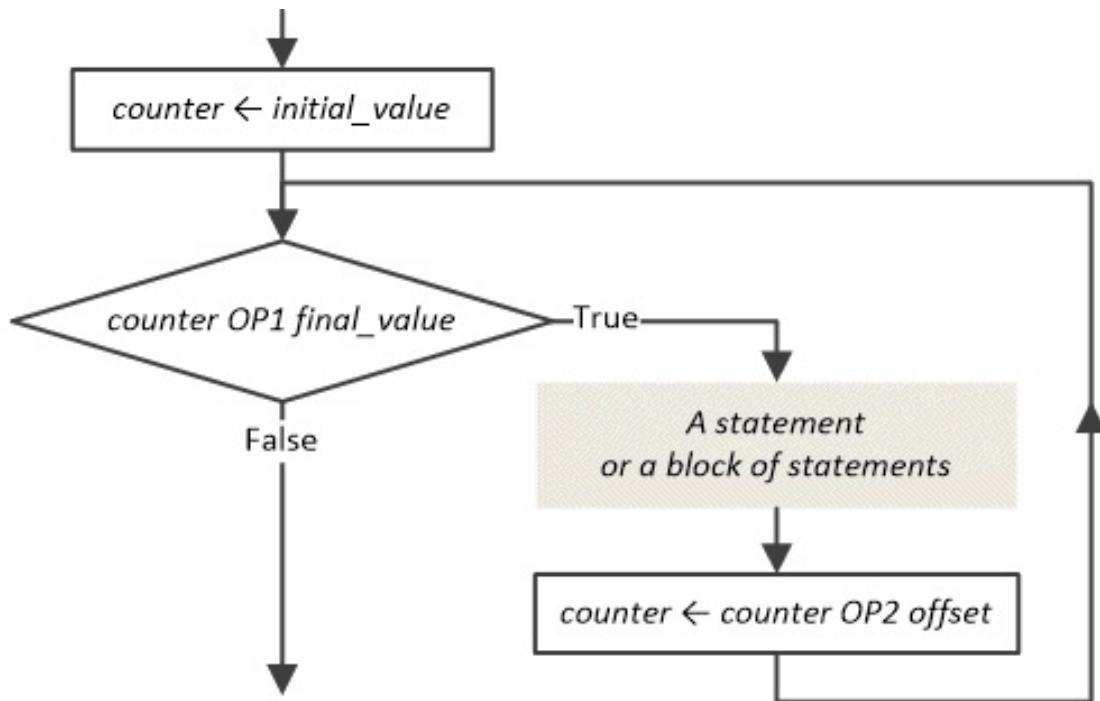
```
for (counter = initial_value; counter OP1 final_value; counter = counter OP2 offset){  
    A statement or block of statements  
}
```

where

- ▶ `counter` must always be a variable
- ▶ `initial_value`, `final_value` and `offset` can be a constant value or even a variable or an expression. In case of a variable or an expression, however, the content or the result correspondingly must be invariable inside the loop. Negative values are also permitted.
- ▶ `OP1` should be `<=` when `counter` increments and `>=` when `counter` decrements
- ▶ `OP2` should be `+` when `counter` increments and `-` when `counter` decrements

 Even though the `for` statement in C# can be written in so many different ways, this book deals only with its basic form.

The flowchart of the C#'s `for` statement is shown here.



Let's see what happens when the flow of execution reaches a for-loop. An initial value is assigned to variable *counter* and if the Boolean expression evaluates to true, the statement or block of statements of the structure is executed. The variable *counter* is incremented (or decremented) by *offset* and the flow of execution goes back to the point just above the diamond symbol. If the Boolean expression evaluates to true again, the process repeats. When the Boolean expression evaluates to false, the flow of execution exits the loop.

A for-loop is actually a pre-test loop structure.

The following example displays the numbers 1, 2, 3, 4, and 5. Variable *counter* (here *i*) increments from 1 to 6, allowing the loop to perform 5 iterations.

### project\_26\_1a

```

static void Main(string[] args) {
    int i;

    for (i = 1; i <= 5; i = i + 1) {
        Console.WriteLine(i);
    }
}

```

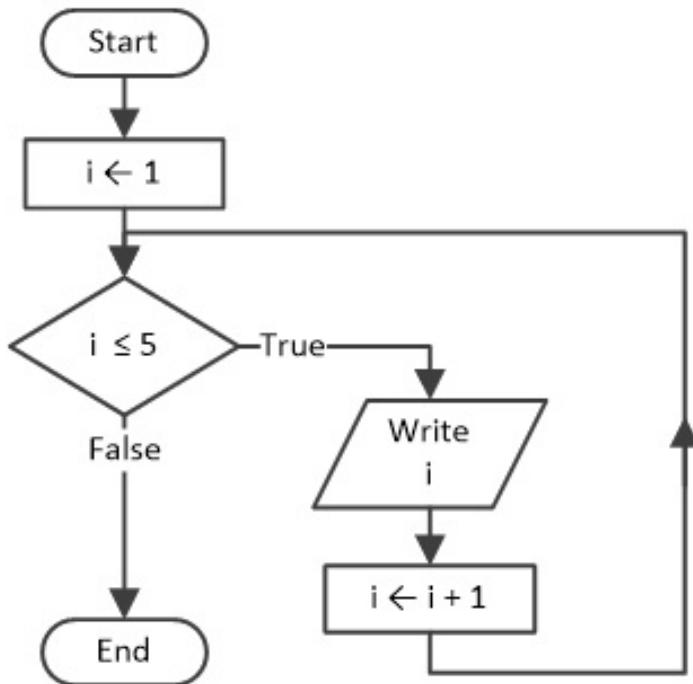
Of course, when variable *counter* increments (or decrements) by 1, it is more convenient to use incrementing (or decrementing) operators. The previous example can also be written as

```
project_26_1b
```

```
static void Main(string[] args) {
    int i;

    for (i = 1; i <= 5; i++) {
        Console.WriteLine(i);
    }
}
```

The flowchart for the program that you have just seen is shown here.



When the flow of execution reaches the for-loop, the initial value 1 is assigned to variable *i*, the Boolean expression *i* ≤ 5 evaluates to true, and the statement write *i* is executed. The variable *i* increments by one and the flow of execution goes back to the point just above the diamond symbol. The Boolean expression evaluates to true again and the process repeats. When, after 5 iterations, the value of variable *i* becomes 6, the Boolean expression evaluates to false and the flow of execution exits the loop.

Note that the flow of execution exits the loop when the value of counter actually exceeds final\_value. In this example, when the flow of execution

*does finally exit the loop, counter `i` does not contain the final value 5 but the next one in order, which is the value 6.*

⚠ *Don't ever dare alter the value of counter inside the loop! The same applies to `initial_value`, `final_value`, and `offset` (in case they are variables and not constant values). This makes your code unreadable and could lead to incorrect results. If you insist, though, please use a `while` or a `do-while` statement instead.*

The following example displays even numbers from 10 to 2.

#### project\_26\_1c

```
static void Main(string[] args) {
    int i;

    for (i = 10; i >= 2; i = i - 2) {
        Console.WriteLine(i);
    }
}
```

⚠ *Note that the comparison operator should be `<=` when counter increments and `>=` when counter decrements.*

Of course, when variable `counter` increments or decrements by a value other than 1, it is more convenient to use compound assignment operators. The previous example can also be written as

#### project\_26\_1d

```
static void Main(string[] args) {
    int i;

    for (i = 10; i >= 2; i -= 2) {
        Console.WriteLine(i);
    }
}
```

The following example displays the letters “H”, “e”, “l”, “l”, and “o” (all without the double quotes).

#### project\_26\_1e

```
static void Main(string[] args) {
    int i;
    string message = "Hello";
```

```
    for (i = 0; i <= message.Length - 1; i++) {
        Console.WriteLine(message[i]);
    }
}
```

- ▀ The `Length` property contains the number of characters variable `message` consists of (see [paragraph 14.3](#)).
- ▀ The `message[i]` notation returns the character located at variable's `message` specified position (see [paragraph 14.3](#)).

### ***Exercise 26.1-1 Creating the Trace Table***

---

*Design the corresponding flowchart and create a trace table to determine the values of the variables in each step of the next code fragment when the input value 1 is entered.*

```
int a, i;

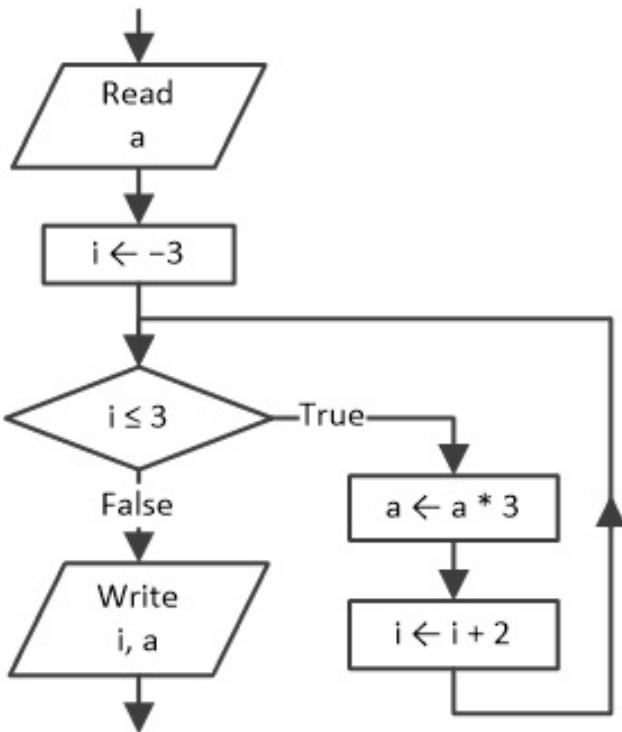
a = Int32.Parse(Console.ReadLine());

for (i = -3; i <= 3; i += 2) {
    a = a * 3;
}
Console.WriteLine(i + " " + a);
```

### ***Solution***

---

The corresponding flowchart fragment is as follows.



You should keep in mind that a for-loop is actually a pre-test loop structure!

If you rewrite the code fragment using the while statement the result is as follows.

```

int a, i;

a = Int32.Parse(Console.ReadLine());

i = -3;
while (i <= 3) {
    a = a * 3;
    i += 2;
}

Console.WriteLine(i + " " + a);
  
```

Now, in order to create a trace table for a for statement you have two choices: you can use either the corresponding flowchart or the equivalent program written with the while statement.

Step	Statement	Notes	a	i
1	a = Int32.Parse(...)		1	?

2	i = -3		1	-3	
3	i <= 3	This evaluates to true			
4	a = a * 3		3	-3	1 <sup>st</sup> iteration
5	i += 2		3	-1	
6	i <= 3	This evaluates to true			
7	a = a * 3		9	-1	2 <sup>nd</sup> iteration
8	i += 2		9	1	
9	i <= 3	This evaluates to true			
10	a = a * 3		27	1	3 <sup>rd</sup> iteration
11	i += 2		27	3	
12	i <= 3	This evaluates to true			
13	a = a * 3		81	3	4 <sup>th</sup> iteration
14	i += 2		81	5	
15	i <= 3	This evaluates to false			
16	.WriteLine (i + " " + a)	It displays: 5 81			

 Note that the flow of execution exits the loop when the value of counter i exceeds final\_value. In this example, when the flow of execution does finally exit the loop, counter i does not contain the final value 3 but the next one in order, which is the value 5.

### Exercise 26.1-2 Creating the Trace Table

Create a trace table to determine the values of the variables in each step of the next code fragment when the input value 4 is entered.

```
int a, i;

a = Int32.Parse(Console.ReadLine());

for (i = 6; i >= a; i--) {
    Console.WriteLine(i);
```

```
| }
```

## Solution

---

Once again the program can be rewritten using the `while` statement.

```
int a, i;

a = Int32.Parse(Console.ReadLine());

i = 6;
while (i >= a) {
    Console.WriteLine(i);
    i--;
}
```

Following is the trace table used to determine the values of the variables in each step.

Step	Statement	Notes	a	i
1	<code>a = Int32.Parse(...)</code>		4	?
2	<code>i = 6</code>		4	6
3	<code>i &gt;= a</code>	This evaluates to true		
4	<code>.WriteLine(i)</code>	It displays: 6		
5	<code>i--</code>		4	5
6	<code>i &gt;= a</code>	This evaluates to true		
7	<code>.WriteLine(i)</code>	It displays: 5		
8	<code>i--</code>		4	4
9	<code>i &gt;= a</code>	This evaluates to true		
10	<code>.WriteLine(i)</code>	It displays: 4		
11	<code>i--</code>		4	3
12	<code>i &gt;= a</code>	This evaluates to false		

### Exercise 26.1-3 Counting the Total Number of Iterations

Count the total number of iterations performed by the following code

fragment for two different executions.

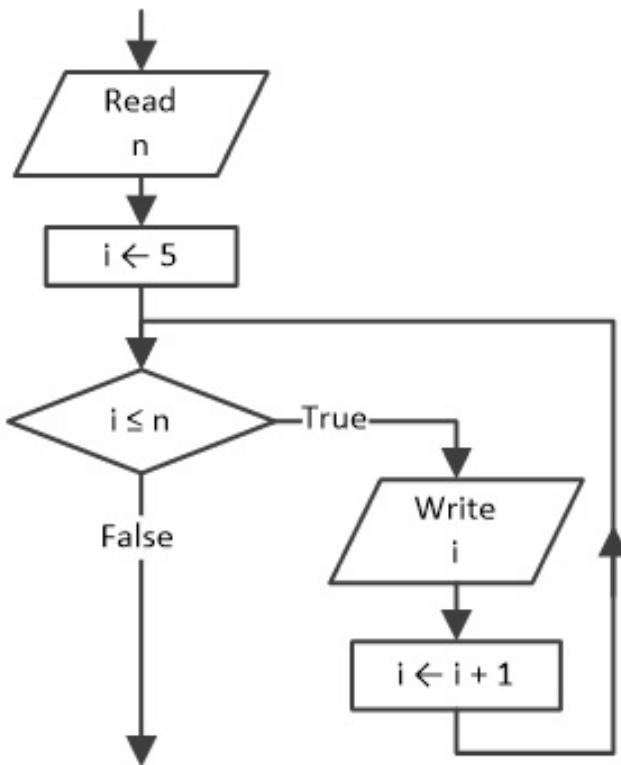
The input values for the two executions are: (i) 6, and (ii) 5.

```
n = Int32.Parse(Console.ReadLine());  
for (i = 5; i <= n; i++) {  
    Console.WriteLine(i);  
}
```

## Solution

---

In order to better understand what really goes on, instead of creating a trace table, you can just design its corresponding flowchart fragment.



From this flowchart fragment you can see that

- i. for the input value 5, the Boolean expression evaluates to true and the flow of execution enters the loop. Variable *i* increases to 6, the Boolean expression evaluates to false, and the flow of execution exits the loop. Thus, the loop performs one iteration.
- ii. for the input value 6 the loop obviously performs two iterations.

## ***Exercise 26.1-4 Finding the Sum of Four Numbers***

---

*Write a C# program that prompts the user to enter four numbers and then calculates and displays their sum.*

## Solution

In [Exercise 25.1-5](#), the solution proposed with a while statement was the following:

```
static void Main(string[] args) {
    double total, x;
    int i;

    total = 0;
    i = 1;
    while (i <= 4) {
        x = Double.Parse(Console.ReadLine());
        total = total + x;
        i++;
    }

    Console.WriteLine(total);
}
```

It's now very easy to rewrite it using a for statement and have it display a prompt message before every data input.

### project\_26\_1\_4

```
static void Main(string[] args) {
    int i;
    double total, x;

    total = 0;
    for (i = 1; i <= 4; i++) {
        Console.Write("Enter a number: ");
        x = Double.Parse(Console.ReadLine());
        total += x;
    }
    Console.WriteLine(total);
}
```

 Note the absence of the `i++` statement inside the loop control structure. In a for statement, counter (variable `i`) automatically increases, either way, at the end of each loop iteration.

## Exercise 26.1-5 Finding the Square Roots from 0 to N

Write a C# program that prompts the user to enter an integer and then calculates and displays the square root of all integers from 0 to that given

*integer.*

## **Solution**

---

It's a piece of cake! The C# program is as follows.

### project\_26\_1\_5

```
static void Main(string[] args) {
    int num, i;

    Console.WriteLine("Enter an integer: ");
    num = Int32.Parse(Console.ReadLine());

    for (i = 0; i <= num; i++) {
        Console.WriteLine(Math.Sqrt(i));
    }
}
```

## ***Exercise 26.1-6 Finding the Sum of $1 + 2 + 3 + \dots + 100$***

---

*Write a C# program that calculates and displays the following sum:*

$$S = 1 + 2 + 3 + \dots + 100$$

## **Solution**

---

If you were to use a sequence control structure to solve this exercise, it would be something like the next code fragment.

```
s = 0;
i = 1;

s = s + i;
i = i + 1;

s = s + i;
i = i + 1;

...
...
s = s + i;
i = i + 1;
```

Let's use a trace table to better understand it.

Step	Statement	Notes	i	s
1	$s = 0$	0	?	0

<b>2</b>	<code>i = 1</code>		<b>1</b>	0
<b>3</b>	<code>s = s + i</code>	$0 + 1 = \mathbf{1}$	1	<b>1</b>
<b>4</b>	<code>i = i + 1</code>		<b>2</b>	1
<b>5</b>	<code>s = s + i</code>	$0 + 1 + 2 = \mathbf{3}$	2	<b>3</b>
<b>6</b>	<code>i = i + 1</code>		<b>3</b>	3
<b>7</b>	<code>s = s + i</code>	$0 + 1 + 2 + 3 = \mathbf{6}$	3	<b>6</b>
<b>8</b>	<code>i = i + 1</code>		<b>4</b>	6
...	...		...	...
...	...		...	...
<b>199</b>	<code>s = s + i</code>		99	<b>4950</b>
<b>200</b>	<code>i = i + 1</code>		<b>100</b>	4950
<b>201</b>	<code>s = s + i</code>	$0 + 1 + 2 + 3 + \dots + 99 + 100 = \mathbf{5050}$	100	<b>5050</b>
<b>202</b>	<code>i = i + 1</code>		<b>101</b>	5050

Now that everything has been cleared up, you can do the same using instead a for-loop that increments variable `i` by 1.

### project\_26\_1\_6

```
static void Main(string[] args) {
    int s, i;

    s = 0;
    for (i = 1; i <= 100; i++) {
        s = s + i;
    }
    Console.WriteLine(s);
}
```

### Exercise 26.1-7 Finding the Product of $2 \times 4 \times 6 \times 8 \times 10$

Write a C# program that calculates and displays the following product:

$$P = 2 \times 4 \times 6 \times 8 \times 10$$

### Solution

As in the previous exercise, let's study this exercise using the following sequence control structure.

```
p = 1;
i = 2;

p = p * i;
i = i + 2;

p = p * i;
i = i + 2;

p = p * i;
i = i + 2;

p = p * i;
i = i + 2;
```

The corresponding trace table is shown here.

Step	Statement	Notes	i	p
1	$p = 1$	1	?	<b>1</b>
2	$i = 2$		2	1
3	$p = p * i$	$1 \times 2 = 2$	2	<b>2</b>
4	$i = i + 2$		<b>4</b>	2
5	$p = p * i$	$2 \times 4 = 8$	4	<b>8</b>
6	$i = i + 2$		<b>6</b>	8
7	$p = p * i$	$2 \times 4 \times 6 = 48$	6	<b>48</b>
8	$i = i + 2$		<b>8</b>	48
9	$p = p * i$	$2 \times 4 \times 6 \times 8 = 384$	8	<b>384</b>
10	$i = i + 2$		<b>10</b>	384
11	$p = p * i$	$2 \times 4 \times 6 \times 8 \times 10 = 3840$	8	<b>3840</b>
12	$i = i + 2$		<b>12</b>	3840

Now that everything has been cleared up, you can do the same thing, this time using a for-loop that increments variable *i* by 2.

### project\_26\_1\_7

```
static void Main(string[] args) {
    int p, i;

    p = 1;
    for (i = 2; i <= 10; i += 2) {
        p = p * i;
    }
    Console.WriteLine(p);
}
```

### ***Exercise 26.1-8 Finding the Sum of $2^2 + 4^2 + 6^2 + \dots (2N)^2$***

---

*Write a C# program that lets the user enter an integer N and then calculates and displays the following sum:*

$$S = 2^2 + 4^2 + 6^2 + \dots (2N)^2$$

### **Solution**

---

In this exercise, variable *i* must increment by 2. In each iteration though, its value must be raised to the second power before it is accumulated in variable *s*. The final C# program is as follows.

### project\_26\_1\_8

```
static void Main(string[] args) {
    int N, i;
    double s;

    N = Int32.Parse(Console.ReadLine());
    s = 0;
    for (i = 2; i <= 2 * N; i += 2) {
        s = s + Math.Pow(i, 2);
    }

    Console.WriteLine(s);
}
```

### ***Exercise 26.1-9 Finding the Sum of $3^3 + 6^6 + 9^9 + \dots (3N)^{3N}$***

---

*Write a C# program that lets the user enter an integer N and then calculates and displays the following sum:*

$$S = 3^3 + 6^6 + 9^9 + \dots + (3N)^{3N}$$

## Solution

---

This is pretty much the same as the previous exercise. The only difference is that variable *i* must be raised to the *i<sup>th</sup>* power before it is accumulated in variable *s*. Using the for-loop, the final C# program is as follows.

### project\_26\_1\_9

```
static void Main(string[] args) {
    int N, i;
    double s;

    N = Int32.Parse(Console.ReadLine());
    s = 0;
    for (i = 3; i <= 3 * N; i += 3) {
        s = s + Math.Pow(i, i);
    }
    Console.WriteLine(s);
}
```

## Exercise 26.1-10 Finding the Average Value of Positive Numbers

---

Write a C# program that lets the user enter 100 numbers and then calculates and displays the average value of the positive numbers. Add all necessary checks to make the program satisfy the property of definiteness.

## Solution

---

Since you know the total number of iterations, you can use a for-loop. Inside the loop, however, a decision control structure must check whether or not the given number is positive; if so, it must accumulate the given number in variable *s*. The variable *count* counts the number of positive numbers given. When the flow of execution exits the loop, the average value can then be calculated. The C# program is as follows.

### project\_26\_1\_10

```
static void Main(string[] args) {
    int count, i;
    double s, x;

    s = 0;
    count = 0;
    for (i = 1; i <= 100; i++) {
```

```

        x = Double.Parse(Console.ReadLine());
        if (x > 0) {
            s = s + x;
            count++;
        }
    }

    if (count != 0) {
        Console.WriteLine(s / count);
    }
    else {
        Console.WriteLine("No numbers entered!");
    }
}

```

 *The if (count != 0) statement is necessary, because there is a possibility that the user may enter negative values only. By including this check, the program prevents any division-by-zero errors and thereby satisfies the property of definiteness.*

### **Exercise 26.1-11 Counting the Vowels**

*Write a C# program that prompts the user to enter a message and then counts and displays the number of vowels the message contains.*

#### **Solution**

The C# program that follows counts the vowels in an English message. The for-loop iterates for all the characters that the message contains. The single-alternative decision structure checks one character at each iteration and if it is a vowel, variable count is increased by one.

#### **project\_26\_1\_11**

```

static void Main(string[] args) {
    string message;
    char character;
    string vowels = "AEIOU";
    int i, count;

    Console.Write("Enter an English message: ");
    message = Console.ReadLine().ToUpper();

    count = 0;
    for (i = 0; i <= message.Length - 1; i++) {

```

```

        character = message[i];

        if (vowels.IndexOf(character) != -1) { //If character is found in vowels
            count++;
        }
    }
    Console.WriteLine("Vowels: " + count);
}

```

- ▀ The Length property contains the number of characters variable message consists of (see [paragraph 14.3](#)).
- ▀ The message[i] notation returns the character located at variable's message specified position (see [paragraph 14.3](#)).
- ▀ The IndexOf() method returns the value of -1 if character is not found in variable vowels (see [paragraph 14.3](#)).

## 26.2 Rules that Apply to For-Loops

There are certain rules you must always follow when writing programs with for-loops, since they can save you from undesirable side effects.

- **Rule 1:** The *counter* variable can appear in a statement inside the loop but its value must never be altered. The same applies to *initial\_value*, *final\_value*, and *offset* in case they are variables and not constant values.
- **Rule 2:** The *offset* must never be zero. If it is set to zero, the loop performs an infinite number of iterations!
- **Rule 3:** If *initial\_value* is smaller than *final\_value* and the *offset* is negative, the loop performs zero iterations. Breaking this rule on purpose, however, can be useful in certain situations.
- **Rule 4:** If *initial\_value* is greater than *final\_value* and the *offset* is positive, the loop performs zero iterations. Breaking this rule on purpose, however, can be useful in certain situations.

### **Exercise 26.2-1 Counting the Total Number of Iterations**

How many iterations does the following code fragment perform?

```

for (i = 5; i <= 10; i++) {
    Console.WriteLine(i);
    i--;
}

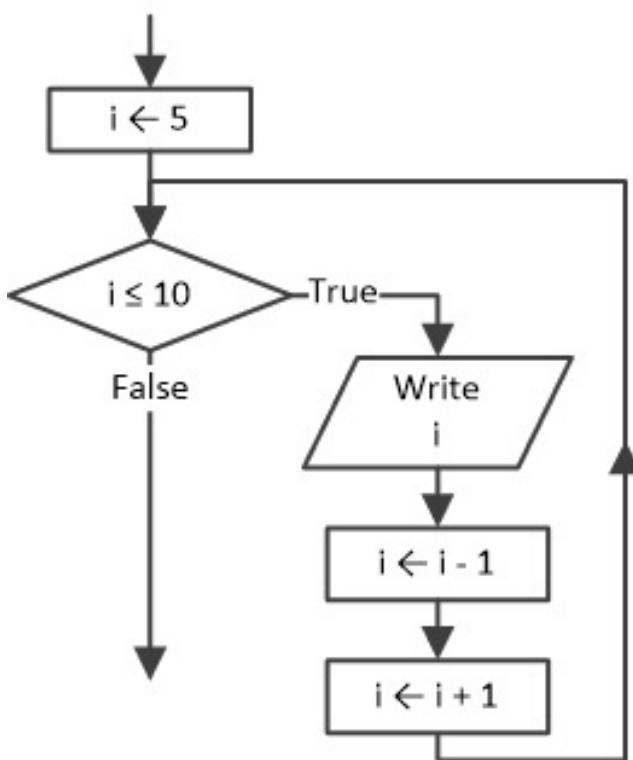
```

| }

## Solution

This program breaks the first rule of for-loops, which states, *The counter variable can appear in a statement inside the loop but its value must never be altered.*

The corresponding flowchart fragment that follows can help you better understand what really goes on.



As you can see, since the initial value 5 of variable  $i$  is less than 10, the flow of execution enters the loop. Inside the loop, however, the statement  $i \leftarrow i - 1$  eliminates the statement  $i \leftarrow i + 1$  and this results in a non-incrementing variable  $i$ , which can never reach *final\_value* 10. Thus, the loop performs an infinite number of iterations.

You must never alter the value of counter variable inside the loop. The same applies to *initial\_value*, *final\_value*, and *offset* (in case they are variables and not constant values).

### Exercise 26.2-2 Counting the Total Number of Iterations

How many iterations does the following code fragment perform?

```

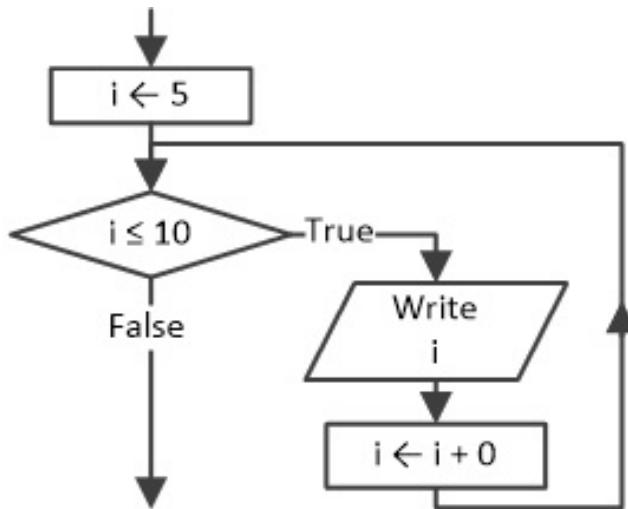
for (i = 5; i <= 10; i += 0) {
    Console.WriteLine(i);
}

```

## Solution

This program breaks the second rule of for-loops, which states, *the offset must never be zero*.

The corresponding flowchart fragment that follows can help you better understand what really goes on.



As you can see, since the initial value 5 of variable *i* is less than 10, the flow of execution enters the loop. However, the statement *i*  $\leftarrow$  *i* + 0 never increments variable *i* and this results in a non-incrementing variable *i*, which can never reach *final\_value* 10. Thus, the loop performs an infinite number of iterations.

*The offset must never be zero.*

## Exercise 26.2-3 Counting the Total Number of Iterations

How many iterations does the following code fragment perform?

```

for (i = 5; i >= 10; i--) {
    Console.WriteLine(i);
}

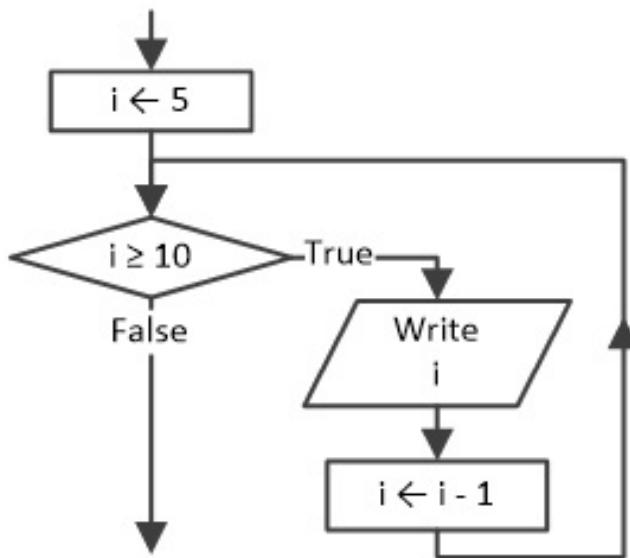
```

## Solution

This program breaks the third rule of for-loops, which states, *if initial\_value is smaller than final\_value and the offset is negative, the*

loop performs zero iterations.

The corresponding flowchart fragment that follows can help you better understand what really goes on.



When the flow of execution reaches the loop control structure, the value 5 is assigned to variable *i*. However, the Boolean expression evaluates to false and the flow of execution never enters the loop! Thus, the loop performs zero iterations.

A *for-loop* is actually a *pre-test loop structure*. Because of this, it may perform from zero to many iterations.

Breaking the third rule of *for-loops* on purpose can be useful in certain situations.

#### **Exercise 26.2-4 Counting the Total Number of Iterations**

How many iterations does the following code fragment perform?

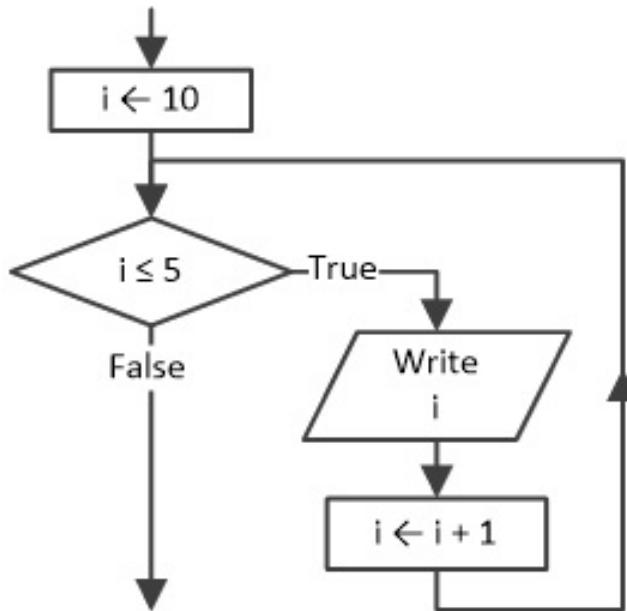
```
for (i = 10; i <= 5; i++) {  
    Console.WriteLine(i);  
}
```

#### **Solution**

This program breaks the fourth rule of *for-loops*, which states, *if initial\_value is greater than final\_value and the offset is positive, the loop performs zero iterations*.

The corresponding flowchart fragment that follows can help you better

understand what really goes on.



When the flow of execution reaches the loop control structure, the value 10 is assigned to variable *i*. However, the Boolean expression evaluates to false and the flow of execution never enters the loop! Thus, the loop performs zero iterations.

*Breaking the fourth rule of for-loops on purpose can be useful in certain situations.*

### Exercise 26.2-5 Finding the Sum of N Numbers

*Write a C# program that prompts the user to enter *N* numbers and then calculates and displays their sum. The value of *N* must be given by the user at the beginning of the program.*

#### Solution

The solution is presented here.

#### project\_26\_2\_5

```
static void Main(string[] args) {
    int n, i;
    double a, total;

    Console.Write("Enter quantity of numbers to enter: ");
    n = Int32.Parse(Console.ReadLine());
```

```

total = 0;
for (i = 1; i <= n; i++) {
    Console.WriteLine("Enter number No " + i + ": ");
    a = Double.Parse(Console.ReadLine());
    total += a; //This is equivalent to total = total + a
}

Console.WriteLine("Sum: " + total);
}

```

 Even though it breaks the fourth rule of for-loops, in this particular exercise this situation is very useful. If the user enters a non-positive value for variable *n*, the for statement performs zero iterations.

## 26.3 Review Questions: True/False

Choose **true** or **false** for each of the following statements.

1. In a for statement, the value of *counter* increments or decrements automatically at the end of each loop.
2. A definite loop can be used when the number of iterations is known.
3. In a definite loop, the statement or block of statements of the loop is executed at least one time.
4. In a for-loop, the *initial\_value* cannot be greater than the *final\_value*.
5. When flow of execution exits a for-loop, the value of *counter* is equal to *final\_value*.
6. In a for-loop, the value of *initial\_value*, *final\_value* and *offset* can be either an integer or a float.
7. In a for-loop, when *offset* is set to zero the loop performs infinite number of iterations.
8. In a for-loop, the *counter* variable can appear in a statement inside the loop but its value must never be altered.
9. In a for-loop, the *offset* can be zero for certain situations.
10. In the following code fragment

```

for (i = 0; i <= 10; i++) {
    Console.WriteLine("Hello");
}

```

the word “Hello” is displayed 10 times.

11. The following code fragment

```
b = Int32.Parse(Console.ReadLine());  
for (i = 0; i <= 8; i += b) {  
    Console.WriteLine("Hello");  
}
```

satisfies the property of finiteness.

12. The following code fragment

```
int b, i;  
double a;  
  
b = Int32.Parse(Console.ReadLine());  
for (i = 0; i <= 10; i++) {  
    a = Math.Sqrt(b) + i;  
    b *= 2;  
}
```

satisfies the property of definiteness.

## 26.4 Review Questions: Multiple Choice

Select the correct answer for each of the following statements.

1. A definite loop that uses the `for` statement
  - a. executes one iteration more than the equivalent post-test loop structure (that uses the `while` statement).
  - b. executes one iteration less than the equivalent post-test loop structure (that uses the `while` statement).
  - c. none of the above
2. A for-loop can be used in a problem in which
  - a. the user enters numbers repeatedly until the value  $-1$  is entered.
  - b. the user enters numbers repeatedly until the value entered is greater than *final\_value*.
  - c. all of the above
  - d. none of the above
3. In a for-loop *initial\_value*, *final\_value*, and *offset* can be
  - a. a constant value.

- b. a variable.
  - c. an expression.
  - d. all of the above
4. In a for-loop, when *initial\_value*, *final\_value*, and *offset* are variables, their values
- a. cannot change inside the loop.
  - b. must not change inside the loop.
  - c. none of the above
5. In a for-loop, when *counter* increments, the *offset* is
- a. greater than zero.
  - b. equal to zero.
  - c. less than zero.
  - d. none of the above
6. In a for-loop, the initial value of *counter*
- a. must be 0.
  - b. can be 0.
  - c. cannot be a negative one.
  - d. none of the above
7. In a for-loop, variable *counter* increments or decrements automatically
- a. at the end of each iteration.
  - b. at the beginning of each iteration.
  - c. It does not increment automatically.
  - d. none of the above
8. In the following code fragment

```
i = 1;  
for (i = 5; i <= 5; i++) {  
    Console.WriteLine("Hello Hera");  
}
```

the message “Hello Hera” is displayed

- a. 5 times.
- b. 1 time.

- c. 0 times.
  - d. none of the above
9. In the following code fragment

```
for (i = 5; i <= 4; i++) {  
    i = 1;  
    Console.WriteLine("Hello Artemis");  
}
```

- the message “Hello Artemis” is displayed
- a. 1 time.
  - b. an infinite number of times.
  - c. 0 times.
  - d. none of the above
10. In the following code fragment

```
for (i = 5; i <= 5; i++) {  
    i = 1;  
    Console.WriteLine("Hello Ares");  
}
```

- the message “Hello Ares” is displayed
- a. 1 time.
  - b. an infinite number of times.
  - c. 0 times.
  - d. none of the above
11. In the following code fragment

```
for (i = 2; i <= 8; i++) {  
    if (i % 2 == 0) {  
        Console.WriteLine("Hello Demeter");  
    }  
}
```

- the message “Hello Demeter” is displayed
- a. 8 times.
  - b. 7 times.
  - c. 5 times.
  - d. none of the above

12. In the following code fragment

```
double i;  
for (i = 4; i <= 5; i += 0.1) {  
    Console.WriteLine("Hello Dionysus");  
}
```

the message “Hello Dionysus” is displayed

- a. 1 time.
- b. 2 times.
- c. 10 times.
- d. 11 times.

13. In the following code fragment

```
k = 0;  
for (i = 1; i <= 5; i += 2) {  
    k = k + i;  
}  
Console.WriteLine(i);
```

the value displayed is

- a. 3.
- b. 6.
- c. 9.
- d. none of the above

14. In the following code fragment

```
k = 0;  
for (i = 100; i >= -100; i -= 5) {  
    k = k + i;  
}  
Console.WriteLine(i);
```

the value displayed is

- a. -95.
- b. -105.
- c. -100.
- d. none of the above

## 26.5 Review Exercises

Complete the following exercises.

1. Create a trace table to determine the values of the variables in each step of the next code fragment. How many iterations does this code perform?

```
int a, b, j;

a = 0;
b = 0;
for (j = 0; j <= 8; j += 2) {
    if (j < 5) {
        b++;
    }
    else {
        a += j - 1;
    }
}
Console.WriteLine(a + ", " + b);
```

2. Create a trace table to determine the values of the variables in each step of the next code fragment for two different executions.

The input values for the two executions are: (i) 10, and (ii) 21.

```
int a, b, j;

a = Int32.Parse(Console.ReadLine());
b = a;
for (j = a - 5; j <= a; j += 2) {
    if (j % 2 != 0) {
        b = a + j + 5;
    }
    else {
        b = a - j;
    }
}
Console.WriteLine(b);
```

3. Create a trace table to determine the values of the variables in each step of the next code fragment for the input value 12.

```
int a, j, x, y;

a = Int32.Parse(Console.ReadLine());
for (j = 2; j <= a - 1; j += 3) {
    x = j * 3 + 3;
    y = j * 2 + 10;
```

```

    if (y - x > 0 || x > 30) {
        y *= 2;
    }
    x += 4;
    Console.WriteLine(x + ", " + y);
}

```

4. Fill in the gaps in the following code fragments so that all loops perform exactly five iterations.

- i. 

```

int a;
for (a = 5; a <= ..... ; a++) {
    b++;
}
```
- ii. 

```

double a;
for (a = 0; a <= ..... ; a += 0.5) {
    b++;
}
```
- iii. 

```

int a;
for (a = ..... ; a >= -15; a -= 2) {
    b++;
}
```
- iv. 

```

int a;
for (a = -11 ; a >= -15; a = a ..... ) {
    b++;
}
```

5. Without using a trace table, can you find out what the next code fragment displays?

```

string word = "Zeus";
string s = "";
int i;

for (i = word.Length - 1; i >= 0; i--) {
    s = s + word[i];
}
Console.WriteLine(s);

```

6. Design a flowchart and write the corresponding C# program that prompts the user to enter 20 numbers and then calculates and displays their product and their average value.
7. Write a C# program that calculates and displays the sine of all numbers from 0 to  $360^\circ$ , using a step of  $0.5^\circ$ . It is given that  $2\pi = 360^\circ$ .
8. Write a C# program that prompts the user to enter a number in degrees

and then calculates and displays the cosine of all numbers from 0 to that given number, using a step of 1. It is given that  $2\pi = 360^\circ$ .

9. Write a C# program that calculates and displays the sum of the following:

$$S = 1 + 3 + 5 + \dots + 99$$

10. Write a C# program that lets the user enter an integer  $N$  and then calculates and displays the product of the following:

$$P = 2^1 \times 4^3 \times 6^5 \times \dots \times 2N^{(N-1)}$$

11. Write a C# program that calculates and displays the sum of the following:

$$S = 1 + 2 + 4 + 7 + 11 + 16 + 22 + 29 + 37 + \dots + 191$$

12. Design a flowchart and write the corresponding C# program that lets a teacher enter the total number of students as well as their grades and then calculates and displays the average value of those who got an “A”, that is 90 to 100. Add all necessary checks to make the program satisfy the property of definiteness.

13. Design a flowchart and write the corresponding C# program that prompts the user to enter 30 four-digit integers and then calculates and displays the sum of those with a first digit of 5 and a last digit of 3. For example, values 5003, 5923, and 5553 are all such integers.

14. Design a flowchart and write the corresponding C# program that prompts the user to enter  $N$  integers and then displays the total number of those that are even. The value of  $N$  must be given by the user at the beginning of the program. Moreover, if all integers given are odd, the message “You entered no even integers” must be displayed.

15. Design a flowchart and write the corresponding C# program that prompts the user to enter 50 integers and then calculates and displays the average value of those that are odd and the average value of those that are even.

16. Design a flowchart and write the corresponding C# program that prompts the user to enter two integers into variables `start` and `finish` and then displays all integers from `start` to `finish`. However, at the beginning the program must check if variable `start` is bigger than variable `finish`. If this happens, the program must swap their values so

that they are always in the proper order.

17. Design a flowchart and write the corresponding C# program that prompts the user to enter two integers into variables `start` and `finish` and then displays all integers from `start` to `finish` that are multiples of five. However, at the beginning the program must check if variable `start` is bigger than variable `finish`. If this happens, the program must swap their values so that they are always in the proper order.
18. Write a C# program that prompts the user to enter a real and an integer and then displays the result of the first number raised to the power of the second number, without using the `Math.Pow()` method.
19. Write a C# program that prompts the user to enter a message and then displays the number of words it contains. For example, if the string entered is “My name is Bill Bouras”, the program must display “The message entered contains 5 words”. Assume that the words are separated by a single space character.

Hint: Use the `Length` property to get the number of characters that the given message contains.

20. Write a C# program that prompts the user to enter a message and then displays the average number of letters in each word. For example, if the message entered is “My name is Aphrodite Boura”, the program must display “The average number of letters in each word is 4.4”. Space characters must not be counted.
21. Write a C# program that prompts the user to enter a message and then counts and displays the number of consonants the message contains.
22. Write a C# program that prompts the user to enter a message and then counts and displays the number of vowels, the number of consonants, and the number of arithmetic characters the message contains.

# Chapter 27

## Nested Loop Control Structures

---

### 27.1 What is a Nested Loop?

A *nested loop* is a loop within another loop or, in other words, an inner loop within an outer one.

The outer loop controls the number of **complete** iterations of the inner loop. This means that the first iteration of the outer loop triggers the inner loop to start iterating until completion. Then the second iteration of the outer loop triggers the inner loop to start iterating until completion again. This process repeats until the outer loop has performed all of its iterations.

Take the following C# program, for example.

 project\_27\_1

```
static void Main(string[] args) {
    int i, j;

    for (i = 1; i <= 2; i++) {
        for (j = 1; j <= 3; j++) {
            Console.WriteLine(i + " " + j);
        }
    }
}
```

The outer loop, the one that is controlled by variable *i*, controls the number of complete iterations that the inner loop performs. That is, when variable *i* contains the value 1, the inner loop performs three iterations (for *j* = 1, *j* = 2, and *j* = 3). The inner loop finishes but the outer loop needs to perform one more iteration

(for *i* = 2). Therefore, the inner loop starts over and performs three new iterations again (for *j* = 1, *j* = 2 and *j* = 3).

The previous example is similar to the following one.

```
int i, j;

i = 1;                                //Outer loop assigns value 1 to variable i
for (j = 1; j <= 3; j++) {           //and inner loop performs three iterations
    Console.WriteLine(i + " " + j);
}

i = 2;                                //Outer loop assigns value 2 to variable i
```

```
for (j = 1; j <= 3; j++) {           //and inner loop starts over and
    Console.WriteLine(i + " " + j);   //performs three new iterations
}
```

The output result is as follows.



- ☞ As long as the syntax rules are not violated, you can nest as many loop control structures as you wish. For practical reasons however, as you move to four or five levels of nesting, the entire loop structure becomes very complex and difficult to understand. However, experience shows that the maximum levels of nesting that you will do in your entire life as a programmer is probably three or four.
- ☞ The inner and outer loops do not need to be the same type. For example, a for statement may nest (enclose) a while statement, or vice versa.

### **Exercise 27.1-1 Say “Hello Zeus”. Counting the Total Number of Iterations.**

Find the number of times message “Hello Zeus” is displayed.

#### **project\_27\_1\_1**

```
static void Main(string[] args) {
    int i, j;
    for (i = 0; i <= 2; i++) {
        for (j = 0; j <= 3; j++) {
            Console.WriteLine("Hello Zeus");
        }
    }
}
```

| }

## Solution

The values of variables *i* and *j* (in order of appearance) are as follows:

- For *i* = 0, the inner loop performs 4 iterations (for *j* = 0, *j* = 1, *j* = 2, and *j* = 3) and the message “Hello Zeus” is displayed 4 times.
- For *i* = 1, the inner loop performs 4 iterations (for *j* = 0, *j* = 1, *j* = 2, and *j* = 3) and the message “Hello Zeus” is displayed 4 times.
- For *i* = 2, the inner loop performs 4 iterations (for *j* = 0, *j* = 1, *j* = 2, and *j* = 3) and the message “Hello Zeus” is displayed 4 times.

Therefore, the message “Hello Zeus” is displayed a total of  $3 \times 4 = 12$  times.

□ *The outer loop controls the number of complete iterations of the inner one!*

## Exercise 27.1-2 Creating the Trace Table

For the next code fragment, determine the value that variable *a* contains at the end.

```
int a, i, j;  
a = 1;  
i = 5;  
while (i < 7) {  
    for (j = 1; j <= 3; j += 2) {  
        a = a * j + i;  
    }  
    i++;  
}  
Console.WriteLine(a);
```

## Solution

The trace table is shown here.

Step	Statement	Notes	a	i	j
1	<code>a = 1</code>		1	?	?
2	<code>i = 5</code>		1	5	?
3	<code>i &lt; 7</code>	This evaluates to true			

<b>4</b>	<code>j = 1</code>		<b>1</b>	<b>5</b>	<b>1</b>
<b>5</b>	<code>j &lt;= 3</code>	This evaluates to true			
<b>6</b>	<code>a = a * j + i</code>		<b>6</b>	<b>5</b>	<b>1</b>
<b>7</b>	<code>j = j + 2</code>		<b>6</b>	<b>5</b>	<b>3</b>
<b>8</b>	<code>j &lt;= 3</code>	This evaluates to true			
<b>9</b>	<code>a = a * j + i</code>		<b>23</b>	<b>5</b>	<b>3</b>
<b>10</b>	<code>j = j + 2</code>		<b>23</b>	<b>5</b>	<b>5</b>
<b>11</b>	<code>j &lt;= 3</code>	This evaluates to false			
<b>12</b>	<code>i = i + 1</code>		<b>23</b>	<b>6</b>	<b>5</b>
<b>13</b>	<code>i &lt; 7</code>	This evaluates to true			
<b>14</b>	<code>j = 1</code>		<b>23</b>	<b>6</b>	<b>1</b>
<b>15</b>	<code>j &lt;= 3</code>	This evaluates to true			
<b>16</b>	<code>a = a * j + i</code>		<b>29</b>	<b>6</b>	<b>1</b>
<b>17</b>	<code>j = j + 2</code>		<b>29</b>	<b>6</b>	<b>3</b>
<b>18</b>	<code>j &lt;= 3</code>	This evaluates to true			
<b>19</b>	<code>a = a * j + i</code>		<b>93</b>	<b>6</b>	<b>3</b>
<b>20</b>	<code>j = j + 2</code>		<b>93</b>	<b>6</b>	<b>5</b>
<b>21</b>	<code>j &lt;= 3</code>	This evaluates to false			
<b>22</b>	<code>i = i + 1</code>		<b>93</b>	<b>7</b>	<b>5</b>
<b>23</b>	<code>i &lt; 7</code>	This evaluates to false			
<b>24</b>	<code>.WriteLine(a)</code>	It displays: 93			

At the end of the program, variable a contains the value 93.

## 27.2 Rules that Apply to Nested Loops

Beyond the four rules that apply to for-loops, there are two extra rules that you must always follow when writing programs with nested loops, since

they can save you from undesirable side effects.

- **Rule 1:** The inner loop must begin and end entirely within the outer loop, which means that the loops must not overlap.
- **Rule 2:** An outer loop and the inner (nested) loop must not use the same *counter* variable.

### ***Exercise 27.2-1 Breaking the First Rule***

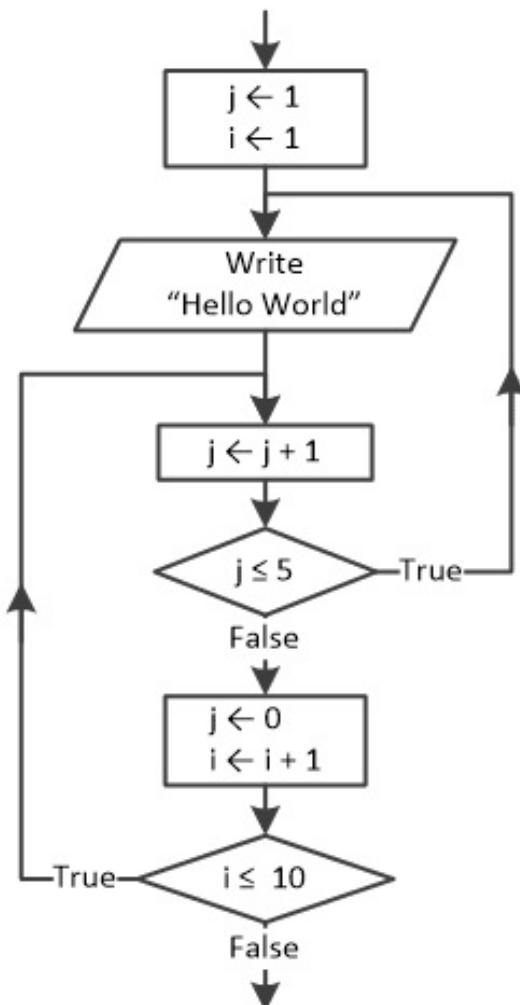
---

*Design a flowchart fragment that breaks the first rule of nested loops, which states, “The inner loop must begin and end entirely within the outer loop”.*

### ***Solution***

---

The following flowchart fragment breaks the first rule of nested loops.



If you try to follow the flow of execution, you can see how smoothly it performs  $5 \times 10 = 50$  iterations. No one can tell that this flowchart is wrong;

on the contrary, it is absolutely correct. The problem, however, is that this flowchart is completely unreadable. No one can tell, at first glance, what this flowchart really does. Moreover, this structure matches none of the already known loop control structures that you have been taught, so it cannot become a C# program as is. Try to avoid this kind of nested loop!

### ***Exercise 27.2-2 Counting the Total Number of Iterations***

---

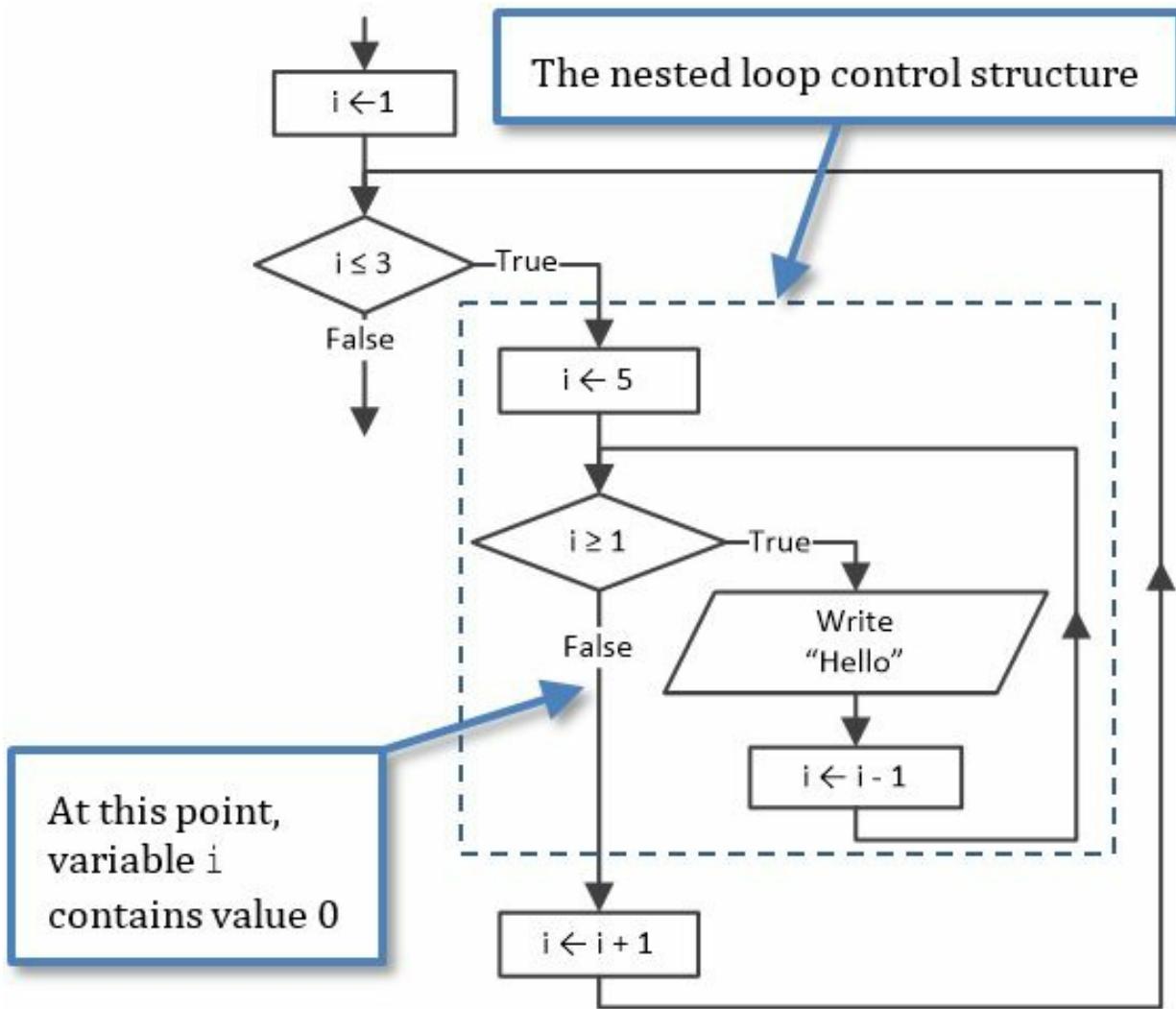
*Find the number of times message “Hello” is displayed.*

```
for (i = 1; i <= 3; i++) {  
    for (i = 5; i >= 1; i--) {  
        Console.WriteLine("Hello");  
    }  
}
```

### ***Solution***

---

At first glance, one would think that the word “Hello” is displayed  $3 \times 5 = 15$  times. However, a closer second look reveals that things are not always as they seem. This program breaks the second rule of nested loops, which states, “*An outer loop and the inner (nested) loop must not use the same counter variable*”. Let's design the corresponding flowchart.



If you try to follow the flow of execution in this flowchart fragment, you can see that when the inner loop completes all of its five iterations, variable *i* contains the value 0. Then, variable *i* increments by 1 and the outer loop repeats again. This process can continue forever since variable *i* can never exceed the value 3 that the Boolean expression of the outer loop requires. Therefore, the message “Hello” is displayed an infinite number of times.

## 27.3 Review Questions: True/False

Choose **true** or **false** for each of the following statements.

1. A nested loop is an inner loop within an outer one.
2. It is possible to nest a mid-test loop structure within a pre-test loop structure.
3. The maximum number of levels of nesting in a loop control structure is

four.

4. When two loop control structures are nested one within the other, the loop that starts last must complete first.
5. When two loop control structures are nested one within the other, they must not use the same variable.
6. In the following code fragment

```
for (i = 1; i <= 3; i++) {  
    for (j = 1; j <= 3; j++) {  
        Console.WriteLine("Hello");  
    }  
}
```

the word “Hello” is displayed six times.

7. In the following code fragment

```
for (i = 0; i <= 1; i++) {  
    for (j = 1; j <= 3; j++) {  
        for (k = 1; k <= 4; k += 2) {  
            Console.WriteLine("Hello");  
        }  
    }  
}
```

the word “Hello” is displayed 12 times.

8. In the following code fragment

```
for (i = 1; i <= 3; i++) {  
    for (i = 3; i >= 1; i--) {  
        Console.WriteLine("Hello");  
    }  
}
```

the word “Hello” is displayed an infinite number of times.

9. In the following code fragment

```
for (i = 0; i <= 2; i++) {  
    j = 1;  
    do {  
        Console.WriteLine("Hello");  
        j++;  
    } while (j < 4);  
}
```

the word “Hello” is displayed nine times.

10. In the following code fragment

```

int s, a;

s = 0;
while (!false) {
    while (!false) {
        a = Int32.Parse(Console.ReadLine());
        if (a >= -1) break;
    }
    if (a == -1) break;
    s += a;
}
Console.WriteLine(s);

```

there is at least one mid-test loop structure.

## 27.4 Review Questions: Multiple Choice

Select the correct answer for each of the following statements.

1. In the following code fragment

```

for (i = 1; i <= 2; i++) {
    for (j = 1; j <= 2; j++) {
        Console.WriteLine("Hello");
    }
}

```

the values of variables *i* and *j* (in order of appearance) are

- a. *j* = 1, *i* = 1, *j* = 1, *i* = 2, *j* = 2, *i* = 1, *j* = 2, *i* = 2
- b. *i* = 1, *j* = 1, *i* = 1, *j* = 2, *i* = 2, *j* = 1, *i* = 2, *j* = 2
- c. *i* = 1, *j* = 1, *i* = 2, *j* = 2
- d. *j* = 1, *i* = 1, *j* = 2, *i* = 2

2. In the following code fragment

```

x = 2;
while (x > -2) {
    do {
        x--;
        Console.WriteLine("Hello Hestia");
    } while (x < -2);
}

```

the message “Hello Hestia” is displayed

- a. 4 times.
- b. an infinite number of times.

- c. 0 times.
  - d. none of the above
3. In the following code fragment

```
x = 1;
while (x != 500) {
    for (i = x; i <= 3; i++) {
        Console.WriteLine("Hello Artemis");
    }
    x++;
}
```

- the message “Hello Artemis” is displayed
- a. an infinite number of times.
  - b. 1500 times.
  - c. 6 times.
  - d. none of the above
4. The following code fragment

```
for (i = 1; i <= 3; i++) {
    for (j = 1; j <= i; j++) {
        Console.Write(i * j + ", ");
    }
}
Console.WriteLine("The End!");
```

- displays
- a. 1, 2, 4, 3, 6, 9, The End!
  - b. 1, 2, 3, 4, 6, 9, The End!
  - c. 1, 2, The End!, 4, 3, The End!, 6, 9, The End!
  - d. none of the above
5. The following code fragment

```
for (i = 1; i <= 10 ; i++) {
    for (i = 10; i >= 1 ; i--) {
        Console.WriteLine("Hello Dionysus");
    }
}
```

- does **not** satisfy the property of
- a. definiteness.

- b. finiteness.
- c. effectiveness.
- d. none of the above

## 27.5 Review Exercises

Complete the following exercises.

1. Fill in the gaps in the following code fragments so that all code fragments display the message “Hello Hephaestus” exactly 100 times.

```

i.   int a, b;
    for (a = 7; a <= ..... ; a++) {
        for (b = 1; b <= 25 ; b++) {
            Console.WriteLine("Hello Hephaestus");
        }
    }
ii.  double a, b;
    for (a = 0; a <= ..... ; a += 0.5) {
        for (b = 10; b <= 19 ; b++) {
            Console.WriteLine("Hello Hephaestus");
        }
    }
iii. int a, b;
    for (a = ..... ; a >= -15; a -= 2) {
        for (b = 10; b >= 0.5 ; b -= 0.5) {
            Console.WriteLine("Hello Hephaestus");
        }
    }
iv.   int a, b;
    for (a = -11 ; a >= -15; a -= 1) {
        for (b = 100; b <= ..... ; b += 2) {
            Console.WriteLine("Hello Hephaestus");
        }
    }

```

2. Design the corresponding flowchart and create a trace table to determine the values of the variables in each step of the next code fragment.

```

a = 1;
for (j = 1; j <= 2; j += 0.5) {
    i = 10;
    while (i < 30) {
        a = a + j + i;
    }
}

```

```

        i += 10;
    }
}
Console.WriteLine(a);

```

3. Create a trace table to determine the values of the variables in each step of the next code fragment. How many times is the statement `s = s + i * j` executed?

```

s = 0;
for (i = 1; i <= 4; i++) {
    for (j = 3; j >= i; j--) {
        s = s + i * j;
    }
}
Console.WriteLine(s);

```

4. Create a trace table to determine the values of the variables in each step of the next code fragment for three different executions. How many iterations does this code perform?

The input values for the three executions are: (i) NO, (ii) YES, NO; and (iii) YES, YES, NO.

```

int s, y, i;
string ans;

s = 1;
y = 25;
do {
    for (i = 1; i <= 3; i++) {
        s = s + y;
        y -= 5;
    }
    ans = Console.ReadLine();
} while (ans == "YES");
Console.WriteLine(s);

```

5. Write a C# program that displays an hours and minutes table in the following form.

0 0

0 1

0 2

0 3

...

0 59

1 0

1 1

1 2

1 3

...

23 59

Please note that the output is aligned with tabs.

6. Using nested loop control structures, write a C# program that displays the following output.

5 5 5 5 5

4 4 4 4

3 3 3

2 2

1

7. Using nested loop control structures, write a C# program that displays the following output.

0

0 1

0 1 2

0 1 2 3

0 1 2 3 4

0 1 2 3 4 5

8. Using nested loop control structures, write a C# program that displays the following rectangle.

\* \* \* \* \* \* \* \* \* \*

\* \* \* \* \* \* \* \* \* \*

\* \* \* \* \* \* \* \* \* \*

\* \* \* \* \* \* \* \* \* \*

9. Write a C# program that prompts the user to enter an integer N between 3 and 20 and then displays a square of size N on each side. For

example, if the user enters 4 for N, the program must display the following square.

```
* * * *
* * * *
* * * *
* * * *
```

10. Write a C# program that prompts the user to enter an integer N between 3 and 20 and then displays a hollow square of size N on each side. For example, if the user enters 4 for N, the program must display the following hollow square.

```
* * * *
*       *
*       *
* * * *
```

11. Using nested loop control structures, write a C# program that displays the following triangle.

```

*
*
*
*
*
*
*
*
*
```

# Chapter 28

## Tips and Tricks with Loop Control Structures

### 28.1 Introduction

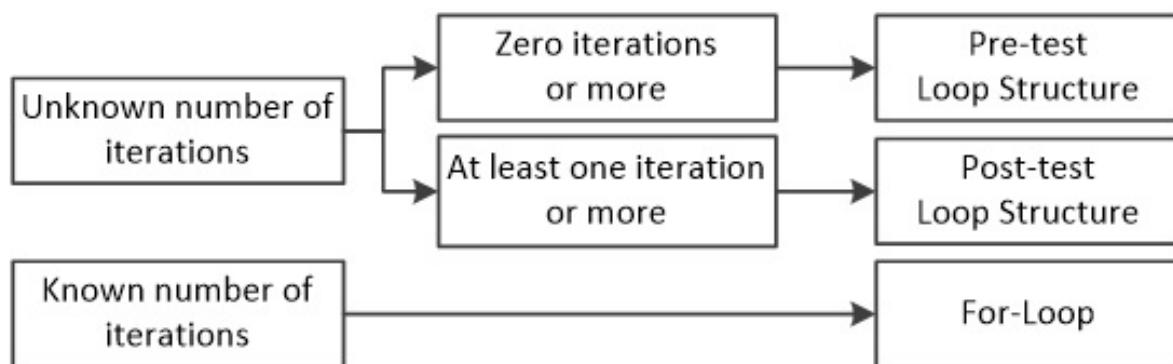
This chapter is dedicated to teaching you some useful tips and tricks that can help you write “better” code. You should always keep them in mind when you design your own algorithms, or even your own C# programs.

These tips and tricks can help you increase your code's readability, help you choose which loop control structure is better to use in each given problem, and help make the code shorter or even faster. Of course there is no single perfect method because on one occasion the use of a specific tip or trick may help, but on another occasion the same tip or trick may have exactly the opposite result. Most of the time, code optimization is a matter of programming experience.

 *Smaller algorithms are not always the best solution to a given problem. In order to solve a specific problem, you might write a short algorithm that unfortunately proves to consume a lot of CPU time. On the other hand, you might solve the same problem with another algorithm that seems longer but calculates the result much faster.*

### 28.2 Choosing a Loop Control Structure

The following diagram can help you choose which loop control structure is better to use in each given problem, depending on the number of iterations.



 *This diagram recommends the best option, not the only option. For example, when the number of iterations is known, it is not wrong to use a*

*pre-test or a post-test loop structure instead. The proposed for-loop, though, is more convenient.*

## 28.3 The “Ultimate” Rule

One question that often preys on programmers' minds when using pre-test or post-test loop structures, is how to determine which statements should be written inside, and which outside, the loop control structure and in which order.

There is one simple yet powerful rule—the “*Ultimate*” rule! Once you follow it, the potential for making a logic error is reduced to zero!

The “Ultimate” rule states:

- ▶ The variable or variables that participate in a loop's Boolean expression must be initialized before entering the loop.
- ▶ The value of the variable or variables that participate in a loop's Boolean expression must be updated (altered) within the loop. And more specifically, the statement that does this update/alteration must be one of the **last** statements of the loop.

For example, if variable *x* is the variable that participates in a loop's Boolean expression, a pre-test loop structure should be in the following form,

```
Initialize x
while ( Boolean_Expression(x) ) {
    A statement or block of statements
    Update/alter x
}
```

and a post-test loop structure should be in the following form,

```
Initialize x
do {
    A statement or block of statements
    Update/alter x
} while ( Boolean_Expression(x) );
```

where

- ▶ *Initialize*  $x$  is any statement that assigns an initial value to variable  $x$ . It can be either an input statement such as `Console.ReadLine()`, or an assignment statement using the value assignment operator (`=`). In a post-test loop structure though, this statement may sometimes be redundant and can be omitted since initialization of  $x$  can occur directly inside the loop.
  - ▶ *Boolean\_Expression( $x$ )* can be any Boolean expression from a simple to a complex one, dependent on variable  $x$ .
  - ▶ *Update/alter*  $x$  is any statement that alters the value of  $x$  such as an input statement, an assignment statement using the value assignment operator (`=`), or even compound assignment operators. This statement must be placed just before the point at which the loop's Boolean expression is evaluated. This is why it must be one of the **last** statements of the loop.

Following are some examples that use the “Ultimate” rule.

## Example 1

```
a = Int32.Parse(Console.ReadLine()); //Initialization of a
while (a > 0) { //A Boolean expression dependent on a
    Console.WriteLine(a);
    a = a - 1; //Update/alteration of a
}
```

## Example 2

```
a = Int32.Parse(Console.ReadLine()); //Initialization of a
b = Int32.Parse(Console.ReadLine()); //Initialization of b
while (a > b) { //A Boolean expression dependent on a and b
    Console.WriteLine(a + " " + b);
    a = Int32.Parse(Console.ReadLine()); //Update/alteration of a
    b = Int32.Parse(Console.ReadLine()); //Update/alteration of b
}
```

### Example 3

```

s = 0;                                //Initialization of s
do {
    y = Int32.Parse(Console.ReadLine());
    s = s + y;                          //Update/alteration of s
} while (s < 1000);                  //A Boolean expression dependent on s

```

## Example 4

```
y = 0; //Initialization of y  
do {
```

```
y = Int32.Parse(Console.ReadLine()); //Update/alteration of y
} while (y < 0); //A Boolean expression dependent on y
```

In this example, though, initialization of variable *y* outside the loop is redundant and can be omitted since initialization is done inside the loop, as shown here.

```
do {
    y = Int32.Parse(Console.ReadLine()); //Initialization and update/alteration of y
} while (y < 0); //A Boolean expression dependent on y
```

## Example 5

```
odd = 0; //Initialization of odd
even = 0; //Initialization of even
while (odd + even < 5) //A Boolean expression dependent on odd and even
    x = Int32.Parse(Console.ReadLine());
    if (x % 2 == 0) {
        even++; //Update/alteration of even
    }
    else {
        odd++; //Update/alteration of odd
    }
}
Console.WriteLine("Odds: " + odd + " Evens: " + even)
```

Now, you will realize why you should always follow the “Ultimate” rule! Let's take a look at the following exercise:

*Write a code fragment that lets the user enter numbers repeatedly until the total number of positives given is three.*

This exercise was given to a class, and a student gave the following code fragment as an answer.

```
int positives_given;
double x;

positives_given = 0;

x = Double.Parse(Console.ReadLine());
while (positives_given != 3) {
    if (x > 0) {
        positives_given += 1;
    }
    x = Double.Parse(Console.ReadLine());
}

Console.WriteLine("Three Positives given!");
```

At first sight the program looks correct. It lets the user enter a number, it enters the loop and checks whether or not the given number is positive, then it lets the user enter a second number, and so on. However, this program contains a logic error—and unfortunately a difficult one. Can you spot it?

If you try to follow the flow of execution, you can confirm for yourself that the program runs smoothly—so smoothly that it makes you wonder if this book is reliable or if you must throw it away!

The problem becomes clear only when you try to enter all three of the expected positive values. The trace table that follows can help you determine where the problem lies. Assume that the user wants to enter the values 5, -10, -2, 4, and 20.

Step	Statement	Notes	positives_given	x
1	positives_given = 0		0	?
2	x = Double.Parse(...)		0	5.0
3	while (positives_given != 3)	This evaluates to true		
4	if (x > 0)	This evaluates to true		
5	positives_given += 1		1	5.0
6	x = Double.Parse(...)		1	-10.0
7	while (positives_given != 3)	This evaluates to true		
8	if (x > 0)	This evaluates to false		
9	x = Double.Parse(...)		1	-2.0
10	while (positives_given != 3)	This evaluates to true		
11	if (x > 0)	This evaluates to false		
12	x = Double.Parse(...)		1	4.0
13	while (positives_given != 3)	This evaluates to true		
14	if (x > 0)	This evaluates to true		
15	positives_given += 1		2	4.0
16	x = Double.Parse(...)		2	20.0

17	<code>while (positives_given != 3)</code>	This evaluates to true		
18	<code>if (x &gt; 0)</code>	This evaluates to true		
19	<code>positives_given += 1</code>		3	20.0
20	<code>x = Double.Parse(...)</code>		3	???

And here is the logic error! At step 20, even though the total number of positives given is three, and you expect that the program will stop, unfortunately it asks the user to enter an additional number!

 *You needed a C# program that lets the user enter three positive numbers, not four!*

This is why you should always go by the book! Let's see how this program should be written.

Since the Boolean expression of the while-loop is dependent on the variable `positives_given`, this is the variable that must be initialized outside of the loop. This variable must also be updated or altered within the loop. The statement that does this update or alteration must be the last statement within the loop, as shown in the code fragment (in general form) that follows.

```
int positives_given;
double x;

positives_given = 0;           //Initialization of positives_given
while (positives_given != 3) { //This is dependent on positives_given
    A statement or block of statements
    if (x > 0) {
        positives_given += 1;   //Update/alteration of positives_given
    }
}
```

Now you can add any necessary statements to complete the program. The only statements that are missing here are the statement that lets the user enter a number (this must be done within the loop), and the statement that displays the last message (this must be done when the loop finishes all of its iterations). So, the final code fragment becomes

```
int positives_given;
double x;
```

```

positives_given = 0;
while (positives_given != 3) {
    x = Double.Parse(Console.ReadLine());
    if (x > 0) {
        positives_given += 1;
    }
}

Console.WriteLine("Three Positives given!");

```

## 28.4 Breaking Out of a Loop

Loops can consume too much CPU time so you have to be very careful when you use them. There are times when you need to break out of, or end, a loop before it completes all of its iterations, usually when a specified condition is met.

Suppose there is a hidden password and you know that it is three characters long and it contains only digits. The following for-loop performs 900 iterations and tries to find that hidden password using a *brute-force attack*.

```

found = false;
for (i = 100; i <= 999; i++) {
    if (i == hidden_password) {
        password = i;
        found = true;
    }
}

if (found == true) {
    Console.WriteLine("Hidden password is: " + password);
}

```

 A *brute-force attack* is the simplest method to gain access to anything that is password protected. An attacker tries combinations of letters, numbers, and symbols with the hope of eventually guessing correctly.

Now, suppose that the hidden password is 123. As you already know, the for-loop iterates a specified number of times, and in this case, it doesn't care whether the hidden password is actually found or not. Even though the password is found in the 24<sup>th</sup> iteration, the loop unfortunately continues to iterate until variable *i* reaches the value of 999, thus wasting CPU time.

Someone may say “So what? 900 iterations is not a big deal!” But it is a big

deal, actually! In large scale data processing everything counts, so you should be very careful when using loop control structures, especially those that iterate too many times. What if the hidden password was ten characters long? This means that the for-loop would have to perform 9,000,000,000 iterations!

There are two approaches that can help you make programs like the previous one run faster. The main idea, in both of them, is to break out of the loop when a specified condition is met; in this case when the hidden password is found.

### First Approach – Using the `break` statement

You can break out of a loop before it actually completes all of its iterations by using the `break` statement.

Look at the following C# program. When the hidden password is found, the flow of execution immediately exits (breaks out of) the for-loop.

```
found = false;
for (i = 100; i <= 999; i++) {
    if (i == hidden_password) {
        password = i;
        found = true;
        break;
    }
}

if (found) {
    Console.WriteLine("Hidden password is: " + password);
}
```

 *The statement `if (found)` is equivalent to the statement `if (found == true)`.*

### Second Approach – Using a flag

The `break` statement doesn't actually exist in all computer languages; and since this book's intent is to teach you “Algorithmic Thinking” (and not just special statements that only C# supports), let's look at an alternate approach.

In the following C# program, when the hidden password is found, the Boolean expression `found == false` forces the flow of execution to exit the loop.

```
found = false;
```

```
i = 100;
while (i <= 999 && found == false) {
    if (i == hidden_password) {
        password = i;
        found = true;
    }
    i++;
}

if (found) {
    Console.WriteLine("Hidden password is: " + password);
}
```

 *Imagine variable found as a flag. Initially, the flag is not “raised” (found = false). The flow of execution enters the loop, and the loop continues iterating as long as the flag is down (while ... found == false). When something (usually a condition) raises the flag (assigns value true to variable found), the flow of execution exits the loop.*

 *The while (i <= 999 && found == false) can alternatively be written as while (i <= 999 && !found).*

## 28.5 Cleaning Out Your Loops

As already stated, loops can consume too much CPU time, so you must be very careful and use them sparingly. Although a large number of iterations is sometimes inevitable, there are always things that you can do to make your loops perform better.

The next code fragment calculates the average value of the numbers 1, 2, 3, 4, 5, ... 10000.

```
s = 0;
i = 1;
do {
    count_of_numbers = 10000;
    s = s + i;
    i++;
} while (i <= count_of_numbers);

average = s / count_of_numbers;
Console.WriteLine(average);
```

What you should always keep in mind when using loops, especially those that perform many iterations, is to avoid putting any statement inside a loop

that serves no purposes in that loop. In the previous example, the statement `count_of_numbers = 10000` is such a statement. Unfortunately, as long as it exists inside the loop, the computer executes it 10000 times for no reason, which of course affects the computer's performance.

To resolve this problem, you can simply move this statement outside the loop, as follows.

```
count_of_numbers = 10000;  
s = 0;  
i = 1;  
do {  
    s = s + i;  
    i++;  
} while (i <= count_of_numbers);  
  
average = s / count_of_numbers;  
Console.WriteLine(average);
```

### ***Exercise 28.5-1 Cleaning Out the Loop***

---

*The following code fragment calculates the average value of numbers 1, 2, 3, 4, ... 10000. Try to move as many statements as possible outside the loop to make the program more efficient.*

```
s = 0;  
for (i = 1; i <= 10000; i++) {  
    s = s + i;  
    average = s / 10000;  
}  
Console.WriteLine(average);
```

### ***Solution***

---

One very common mistake that novice programmers make when calculating average values is to put the statement that divides the total sum by how many numbers there are in the sum (here `average = s / 10000`) inside the loop. Think about it! Imagine that you want to calculate your average grade in school. Your first step would be to calculate the sum of the grades for all of the courses that you're taking. Then, when all your grades have been summed up, you would divide that sum by the number of courses that you're taking.

---

 *Calculating an average is a two-step process.*

Therefore, it is pointless to calculate the average value inside the loop. You can move this statement outside and right after the loop, and leave the loop just to sum up the numbers as follows.

```
s = 0;  
for (i = 1; i <= 10000; i++) {  
    s = s + i;  
}  
average = s / 10000;  
Console.WriteLine(average);
```

### ***Exercise 28.5-2 Cleaning Out the Loop***

---

*The next formula*

$$S = \frac{1}{1^1 + 2^2 + 3^3 + \dots + N^N} + \frac{2}{1^1 + 2^2 + 3^3 + \dots + N^N} + \dots + \frac{N}{1^1 + 2^2 + 3^3 + \dots + N^N}$$

*is solved using the following code fragment, where N is given by the user.*

```
int n, i, j, denom;  
double s;  
  
Console.Write("Enter N: ");  
n = Int32.Parse(Console.ReadLine());  
s = 0;  
for (i = 1; i <= n; i++) {  
    denom = 0;  
    for (j = 1; j <= n; j++) {  
        denom += Math.Pow(j, j);  
    }  
    s += i / (double)denom;  
}  
Console.WriteLine(s);
```

*Try to move as many statements as possible outside the loop to make the code more efficient.*

### ***Solution***

---

As you can see from the formula, the denominator is common for all fractions. Thus, it is pointless to calculate it again and again for every fraction. You can calculate the denominator just once and use the result many times, as follows.

```
int n, i, j, denom;  
double s;
```

```
Console.WriteLine("Enter N: ");
n = Int32.Parse(Console.ReadLine());

denom = 0; [More...]
for (j = 1; j <= n; j++) {
    denom += Math.Pow(j, j);
}

s = 0;
for (i = 1; i <= n; i++) {
    s += i / (double)denom;
}
Console.WriteLine(s);
```

## 28.6 Endless Loops and How to Avoid Them

All while-loops must include a way to stop endless iterations from occurring within them. This means that there must be something inside the loop that eventually makes the flow of execution exit the loop.

The next example contains an endless loop. Unfortunately, the programmer forgot to increase variable *i* inside the loop; therefore, variable *i* can never reach the value 10.

```
i = 1;
while (i != 10) {
    Console.WriteLine("Hello there!");
}
```

 If a loop cannot stop iterating, it is called an *endless loop* or an *infinite loop*.

An endless loop continues to iterate forever and the only way to stop it from iterating is to use magic forces! For example, when an application in a Windows operating system “hangs” (probably because the flow of execution entered an endless loop), the user must use the key combination ALT+CTRL+DEL to force the application to end. In Visual Studio, on the other hand, when you accidentally write and execute an endless loop, you can just click on the “Stop Debugging”  toolbar icon and the C# compiler immediately stops any action.

 In Visual Studio Code, you can use the key combination CTRL+C to force the application to end.

---

So, always remember to include at least one such statement that makes the flow of execution exit the loop. But still, this is not always enough! Take a look at the following code fragment.

```
i = 1;
while (i != 10) {
    Console.WriteLine("Hello there!");
    i += 2;
}
```

Even though this code fragment does contain a statement that increases variable *i* inside the loop (*i* += 2), unfortunately the flow of execution never exits the loop because the value 10 is never assigned to the variable *i*.

One thing that you can do to avoid this type of mistake is to never check the counter variable (here, variable *i*) using == and != comparison operators, especially in cases in which the counter variable increments or decrements by a value other than 1. You can use <, <=, >, and >= comparison operators instead; they guarantee that the flow of execution exits the loop when the counter variable exceeds the termination value. The previous example can be fixed by replacing the != with a <, or even a <= comparison operator.

```
i = 1;
while (i < 10) {
    Console.WriteLine("Hello there!");
    i += 2;
}
```

## 28.7 The “From Inner to Outer” Method

*From inner to outer* is a method proposed by this book to help you learn “Algorithmic Thinking” from the inside out. This method first manipulates and designs the inner (nested) control structures and then, as the algorithm (or the program) is developed, more and more control structures are added, nesting the previous ones. This method can be used in large and complicated control structures as it helps you design error-free flowcharts or even C# programs. This book uses this method wherever and whenever it seems necessary.

Let's try the following example.

*Write a C# program that displays the following multiplication table as it is shown below.*

1x1=1	1x2=2	1x3=3	1x4=4	1x5=5	1x6=6	1x7=7	1x8=8	1x9=9
2x1=2	2x2=4	2x3=6	2x4=8	2x5=10	2x6=12	2x7=14	2x8=16	2x9=18
3x1=3	3x2=6	3x3=9	3x4=12	3x5=15	3x6=18	3x7=21	3x8=24	3x9=27
4x1=4	4x2=8	4x3=12	4x4=16	4x5=20	4x6=24	4x7=28	4x8=32	4x9=36
5x1=5	5x2=10	5x3=15	5x4=20	5x5=25	5x6=30	5x7=35	5x8=40	5x9=45
6x1=6	6x2=12	6x3=18	6x4=24	6x5=30	6x6=36	6x7=42	6x8=48	6x9=54
7x1=7	7x2=14	7x3=21	7x4=28	7x5=35	7x6=42	7x7=49	7x8=56	7x9=63
8x1=8	8x2=16	8x3=24	8x4=32	8x5=40	8x6=48	8x7=56	8x8=64	8x9=72
9x1=9	9x2=18	9x3=27	9x4=36	9x5=45	9x6=54	9x7=63	9x8=72	9x9=81

According to the “from inner to outer” method, you start by writing the inner control structure and then, when everything is tested and operates fine, you can add the outer control structures.

So, let's try to display only the first line of the multiplication table. If you examine this line it reveals that, in each multiplication, the multiplicand is always 1. Imagine a variable *i* that contains the value 1. The loop control structure that displays only the first line of the multiplication table is as follows.

### Code Fragment 1

```
for (j = 1; j <= 9; j++) {
    Console.WriteLine(i + "x" + j + "=" + i * j + "\t");
}
```

If you execute this code fragment, the result is

1x1=1    1x2=2    1x3=3    1x4=4    1x5=5    1x6=6    1x7=7    1x8=8    1x9=9

 *The special sequence of characters \t “displays” a tab character after each iteration. This ensures that everything is aligned properly.*

The inner (nested) loop control structure is ready. What you need now is a way to execute this control structure nine times, but each time variable *i* must contain a different value, from 1 to 9. This code fragment is as follows.

### Code Fragment 2

```
for (i = 1; i <= 9; i++) {

    Code Fragment 1: Display one single line
    of the multiplication table

    Console.WriteLine();
}
```

| }

 The `Console.WriteLine()` statement is used to “display” a line break between lines.

Now, you can combine both code fragments, nesting the first into the second one. The final C# program becomes

### project\_28\_7

```
static void Main(string[] args) {
    int i, j;

    for (i = 1; i <= 9; i++) {
        for (j = 1; j <= 9; j++) {
            Console.Write(i + "x" + j + "=" + i * j + "\t");
        }
        Console.WriteLine();
    }
}
```

## 28.8 Review Questions: True/False

Choose **true** or **false** for each of the following statements.

1. When the number of iterations is unknown, you can use a definite loop.
2. When the number of iterations is known, you cannot use a post-test loop structure.
3. According to the “Ultimate” rule, in a pre-test loop structure, the initialization of the variable that participates in the loop's Boolean expression must be done inside the loop.
4. According to the “Ultimate” rule, in a pre-test loop structure, the statement that updates/alters the value of the variable that participates in the loop's Boolean expression must be the last statement within the loop.
5. According to the “Ultimate” rule, in a post-test loop structure, the initialization of the variable that participates in the loop's Boolean expression can sometimes be done inside the loop.
6. According to the “Ultimate” rule, in a post-test loop structure, the update/alteration of the variable that participates in the loop's Boolean expression must be the first statement within the loop.

7. In C#, you can break out of a loop before it completes all iterations using the `break_loop` statement.
8. A statement that assigns a constant value to a variable is better placed inside a loop control structure.
9. In the following code fragment:

```
for (i = 1; i <= 30; i++) {  
    a = "Hello";  
    Console.WriteLine(a);  
}
```

there is at least one statement that can be moved outside the for-loop.

10. In the following code fragment:

```
s = 0;  
count = 1;  
while (count < 100) {  
    a = Int32.Parse(Console.ReadLine());  
    s += a;  
    average = s / (double)count;  
    count++;  
}  
Console.WriteLine(average);
```

there is at least one statement that can be moved outside the while-loop.

11. In the following code fragment:

```
s = 0;  
y = Int32.Parse(Console.ReadLine());  
while (y != -99) {  
    s = s + y;  
    y = Int32.Parse(Console.ReadLine());  
}
```

there is at least one statement that can be moved outside the while-loop.

12. The following code fragment:

```
i = 1;  
while (i != 100) {  
    Console.WriteLine("Hello there!");  
    i += 5;  
}
```

satisfies the property of finiteness.

13. When the not equal ( `!=` ) comparison operator is used in the Boolean expression of a pre-test loop structure, the loop always iterates

endlessly.

14. The following code fragment:

```
i = 0;  
do {  
    Console.WriteLine("Hello there!");  
    i += 5;  
} while (i < 100);
```

satisfies the property of finiteness.

## 28.9 Review Questions: Multiple Choice

Select the correct answer for each of the following statements.

1. When the number of iterations is unknown, you can use
  - a. the pre-test loop structure.
  - b. the post-test loop structure.
  - c. all of the above
2. When the number of iterations is known, you can use
  - a. the pre-test loop structure.
  - b. the post-test loop structure.
  - c. a for-loop.
  - d. all of the above
3. According to the “Ultimate” rule, in a pre-test loop structure, the initialization of the variable that participates in the loop's Boolean expression must be done
  - a. inside the loop.
  - b. outside the loop.
  - c. all of the above
4. According to the “Ultimate” rule, in a pre-test loop structure, the update/alteration of the variable that participates in the loop's Boolean expression must be done
  - a. inside the loop.
  - b. outside the loop.
  - c. all of the above

- According to the “Ultimate” rule, in a post-test loop structure, the
- 5. update/alteration of the variable that participates in the loop's Boolean expression must be done
    - a. inside the loop.
    - b. outside the loop.
    - c. all of the above
  - 6. In the following code fragment

```
s = 0;
for (i = 1; i <= 100; i++) {
    s = s + i;
    x = 100.0;
    average = s / x;
}
```

- the number of statements that can be moved outside of the for-loop is
- a. 0.
  - b. 1.
  - c. 2.
  - d. 3.
- 7. When this comparison operator is used in the Boolean expression of a post-test loop structure, the loop iterates forever.
    - a. ==
    - b. !=
    - c. it depends

## 28.10 Review Exercises

Complete the following exercises.

- 1. The following program is supposed to prompt the user to enter names repeatedly until the word “STOP” (used as a name) is entered. At the end, the program must display the total number of names entered as well as how many of these names were not “John”.

```
count_names = 0;
count_not_johns = 0;
name = "";
while (name != "STOP") {
    Console.WriteLine("Enter a name: ");
```

```

name = Console.ReadLine();
count_names++;
if (name != "John") {
    count_not_johns++;
}
Console.WriteLine(count_names + " names entered");
Console.WriteLine("Names other than John entered " + count_not_johns + " times");

```

However, the program displays wrong results! Using the “Ultimate” Rule, try to modify the program so that it displays the correct results.

2. Write a C# program that prompts the user to enter some text. The text can be either a single word or a whole sentence. Then, the program must display a message stating whether the given text is one single word or a complete sentence.

Hint: Search for a space character! If a space character is found, it means that the user entered a sentence. The program must stop searching further when it finds at least one space character.

3. Write a C# program that prompts the user to enter a sentence. The program then displays the message “The sentence contains a number” if the sentence contains at least one number. The program must stop searching further when it finds at least one digit.
4. Correct the following code fragment so that it does not iterate endlessly.

```

Console.WriteLine("Printing all integers from 1 to 100");
i = 1;
while (i < 101) {
    Console.WriteLine(i);
}

```

5. Correct the Boolean expression of the following loop control structure so that it does not iterate endlessly.

```

Console.WriteLine("Printing odd integers from 1 to 99");
i = 1;
while (i != 100) {
    Console.WriteLine(i);
    i += 2;
}

```

6. The following code fragment calculates the average value of 100 numbers entered by the user. Try to move as many statements as possible outside the loop to make it more efficient.

```

s = 0;
for (i = 1; i <= 100; i++) {
    number = Double.Parse(Console.ReadLine());
    s = s + number;
    average = s / 100.0;
}
Console.WriteLine(average);

```

7. The following formula

$$S = \frac{1}{1 \cdot 2 \cdot 3 \cdot \dots \cdot 100} + \frac{2}{1 \cdot 2 \cdot 3 \cdot \dots \cdot 100} + \dots + \frac{100}{1 \cdot 2 \cdot 3 \cdot \dots \cdot 100}$$

is solved using the following code fragment

```

int i, j, denom;
double s;

s = 0;
for (i = 1; i <= 100; i++) {
    denom = 1;
    for (j = 1; j <= 100; j++) {
        denom *= j;
    }
    s += i / (double)denom;
}
Console.WriteLine(s);

```

Try to move as many statements as possible outside the loop to make it more efficient.

8. Write a C# program that displays every combination of two integers as well as their resulting product, for pairs of integers between 1 and 4. The output must display as follows.

```

1 x 1 = 1
1 x 2 = 2
1 x 3 = 3
1 x 4 = 4
2 x 1 = 2
2 x 2 = 4
2 x 3 = 6
2 x 4 = 8
...
...

```

4 x 1 = 4

4 x 2 = 8

4 x 3 = 12

4 x 4 = 16

9. Write a C# program that displays the multiplication table for pairs of integers between 1 and 12, as shown next. Please note that the output is aligned with tabs.

	1	2	3	4	5	6	7	8	9	10	11	12
1	1	2	3	4	5	6	7	8	9	10	11	12
2	2	4	6	8	10	12	14	16	18	20	22	24
3	3	6	9	12	15	18	21	24	27	30	33	36
...	...	...	...	...	...	...	...	...	...	...	...	...
11	11	22	33	44	55	66	77	88	99	110	121	132
12	12	24	36	48	60	72	84	96	108	120	132	144

10. Write a C# program that prompts the user to enter an integer and then displays the multiplication table for pairs of integers between 1 and that integer. For example, if the user enters the value 5, the output must be as shown next. Please note that the output is aligned with tabs.

	1	2	3	4	5
1	1	2	3	4	5
2	2	4	6	8	10
3	3	6	9	12	15
4	4	8	12	16	20
5	5	10	15	20	25

# Chapter 29

## Flowcharts with Loop Control Structures

---

### 29.1 Introduction

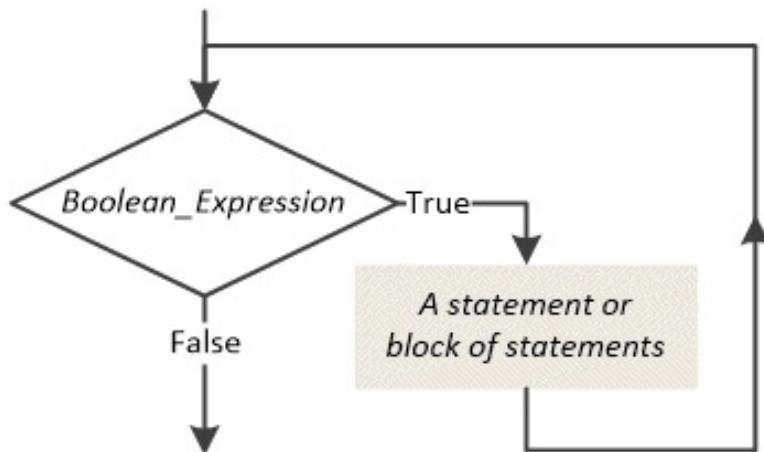
By working through the previous chapters, you've become familiar with all the loop control structures, how to use them, and which to use in every case. You've learned about the “Ultimate” rule, how to break out of a loop, how to convert from one loop control structure to another, and much more. Since flowcharts are an ideal way to learn “Algorithmic Thinking” and to help you better understand specific control structures, this chapter will teach you how to convert a C# program to a flowchart and vice versa, that is, a flowchart to a C# program.

### 29.2 Converting C# Programs to Flowcharts

To convert a C# program to a flowchart, you need to recall all loop control structures and their corresponding flowcharts. Following you will find them all summarized.

#### The Pre-Test Loop Structure

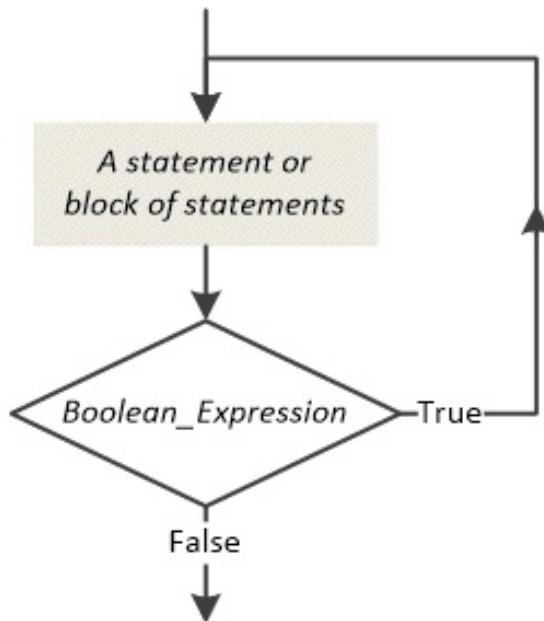
```
while (Boolean_Expression) {  
    A statement or block of statements  
}
```



#### The Post-Test Loop Structure

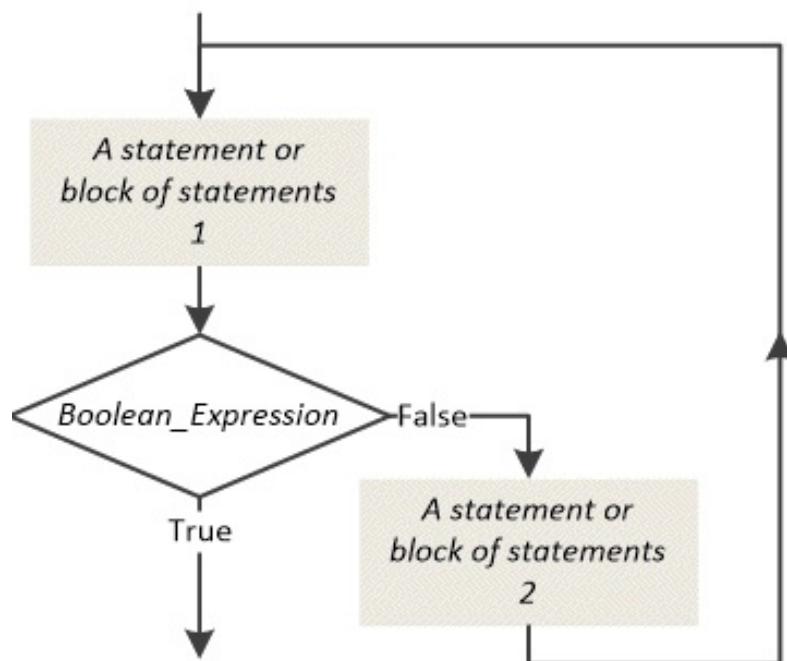
```
do {  
    A statement or block of statements
```

```
| while (Boolean_Expression);
```



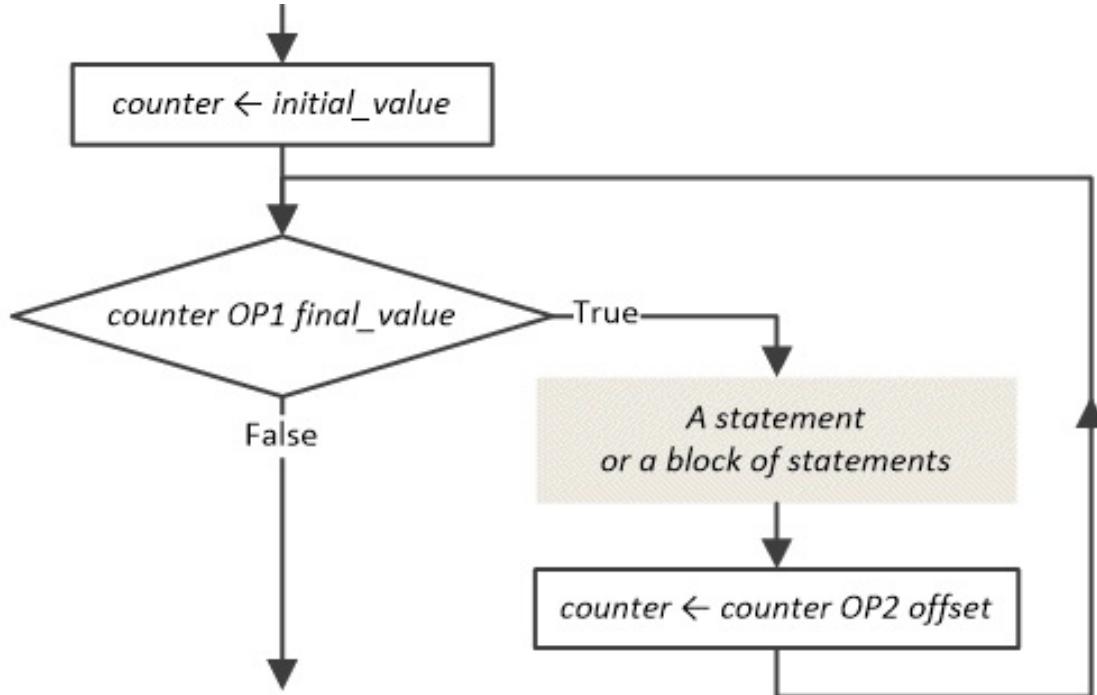
## The Mid-Test Loop Structure

```
while (true) {  
    A statement or block of statements 1  
    if (Boolean_Expression) break;  
    A statement or block of statements 2  
}
```



## The For-Loop

```
for (counter = initial_value;  
     counter OP1 final_value;  
     counter = counter OP2 offset){  
  
    A statement or block of statements  
  
}
```



Next, you will find many exercises that can clarify things that you might still need help understanding.

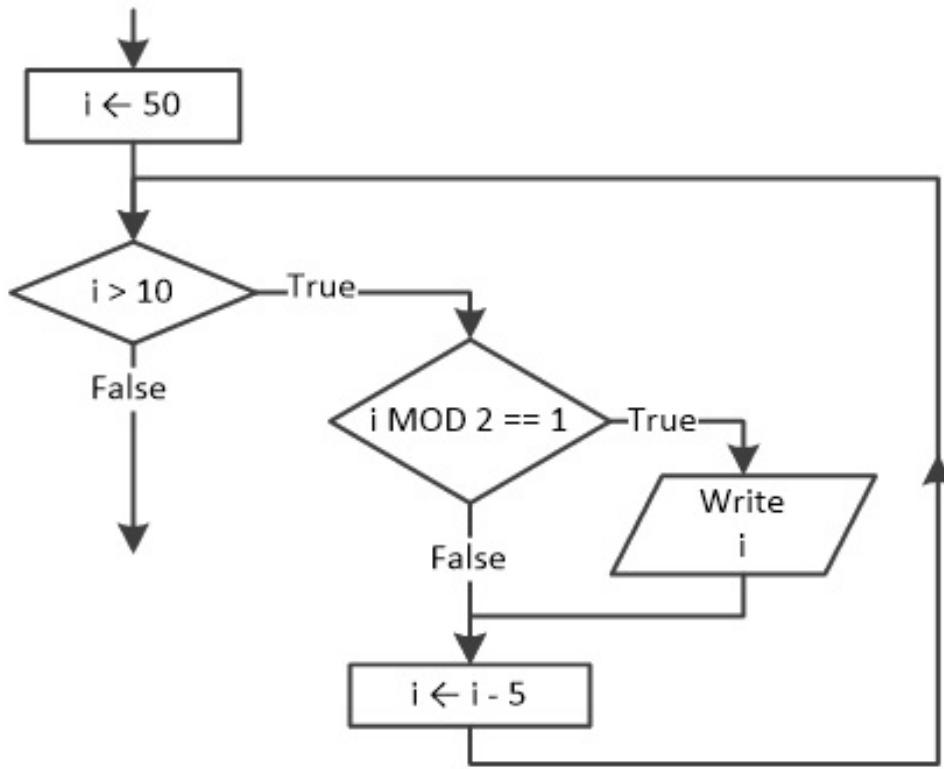
### Exercise 29.2-1 Designing the Flowchart Fragment

*Design the flowchart that corresponds to the following code fragment.*

```
int i = 50;  
while (i > 10) {  
    if (i % 2 == 1) {  
        Console.WriteLine(i);  
    }  
    i -= 5;  
}
```

### Solution

This code fragment contains a pre-test loop structure which nests a single-alternative decision structure. The corresponding flowchart fragment that follows includes what you have been taught so far.



### Exercise 29.2-2 Designing the Flowchart Fragment

Design the flowchart that corresponds to the following code fragment.

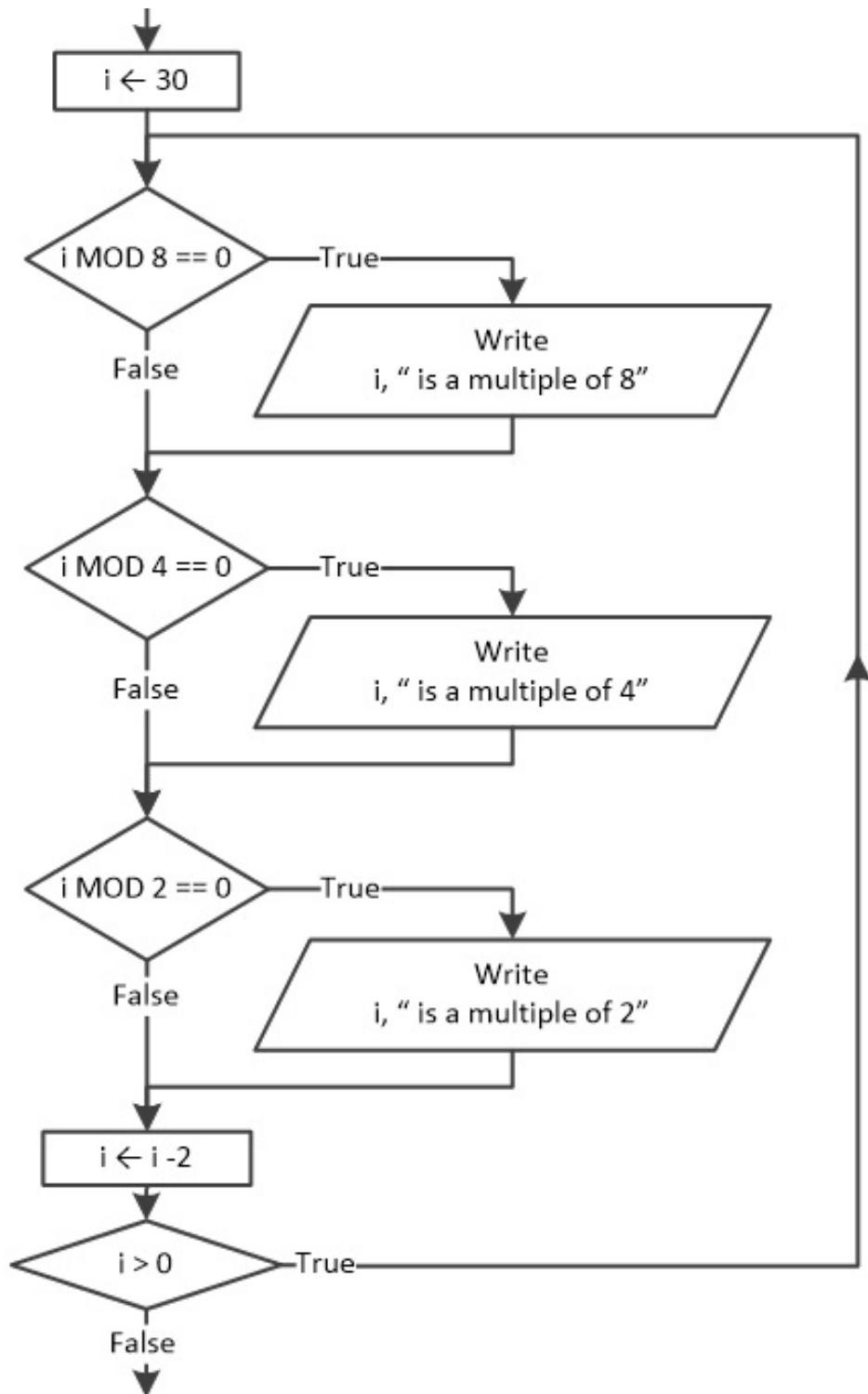
```

int i = 30;
do {
    if (i % 8 == 0) {
        Console.WriteLine(i + " is a multiple of 8");
    }
    if (i % 4 == 0) {
        Console.WriteLine(i + " is a multiple of 4");
    }
    if (i % 2 == 0) {
        Console.WriteLine(i + " is a multiple of 2");
    }
    i -= 2;
} while (i > 0);

```

### Solution

This code fragment contains a post-test loop structure that nests three single-alternative decision structures. The corresponding flowchart fragment is as follows.



### Exercise 29.2-3 Designing the Flowchart

Design the flowchart that corresponds to the following C# program.

```

static void Main(string[] args) {
    int hour;

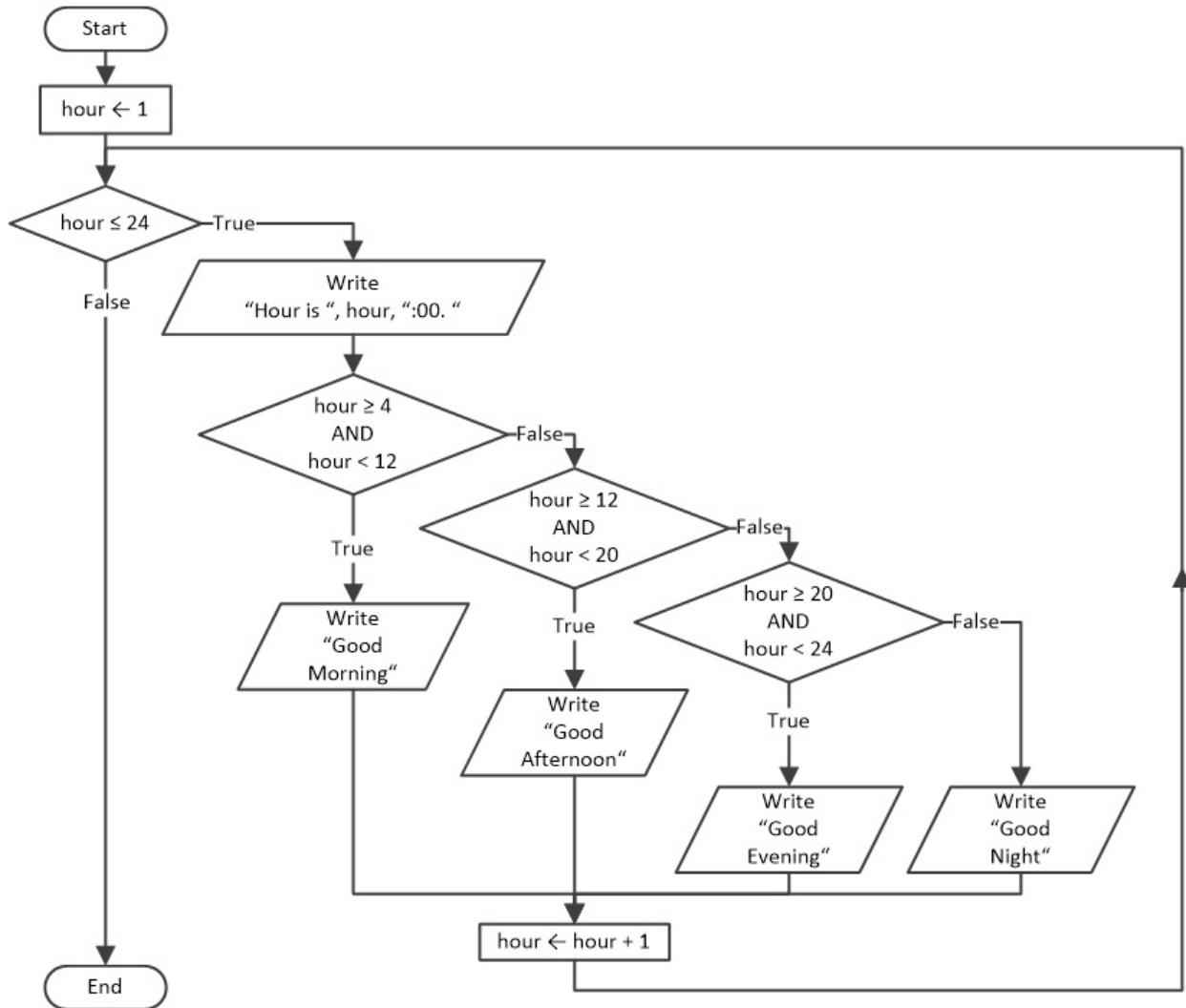
```

```
for (hour = 1; hour <= 24; hour++) {
    Console.WriteLine("Hour is " + hour + ":00. ");
    if (hour >= 4 && hour < 12) {
        Console.WriteLine("Good Morning");
    }
    else if (hour >= 12 && hour < 20) {
        Console.WriteLine("Good Afternoon");
    }
    else if (hour >= 20 && hour < 24) {
        Console.WriteLine("Good Evening");
    }
    else {
        Console.WriteLine("Good Night");
    }
}
```

## Solution

---

This C# program contains a for-loop that nests a multiple-alternative decision structure. The corresponding flowchart is as follows.



### Exercise 29.2-4 Designing the Flowchart Fragment

Design the flowchart that corresponds to the following code fragment.

```

int a, i;
a = Int32.Parse(Console.ReadLine());

switch (a) {
    case 1:
        for (i = 1; i <= 9; i += 2) {
            Console.WriteLine(i);
        }
        break;
    case 2:
        for (i = 9; i >= 1; i -= 2) {
            Console.WriteLine(i);
        }
}
```

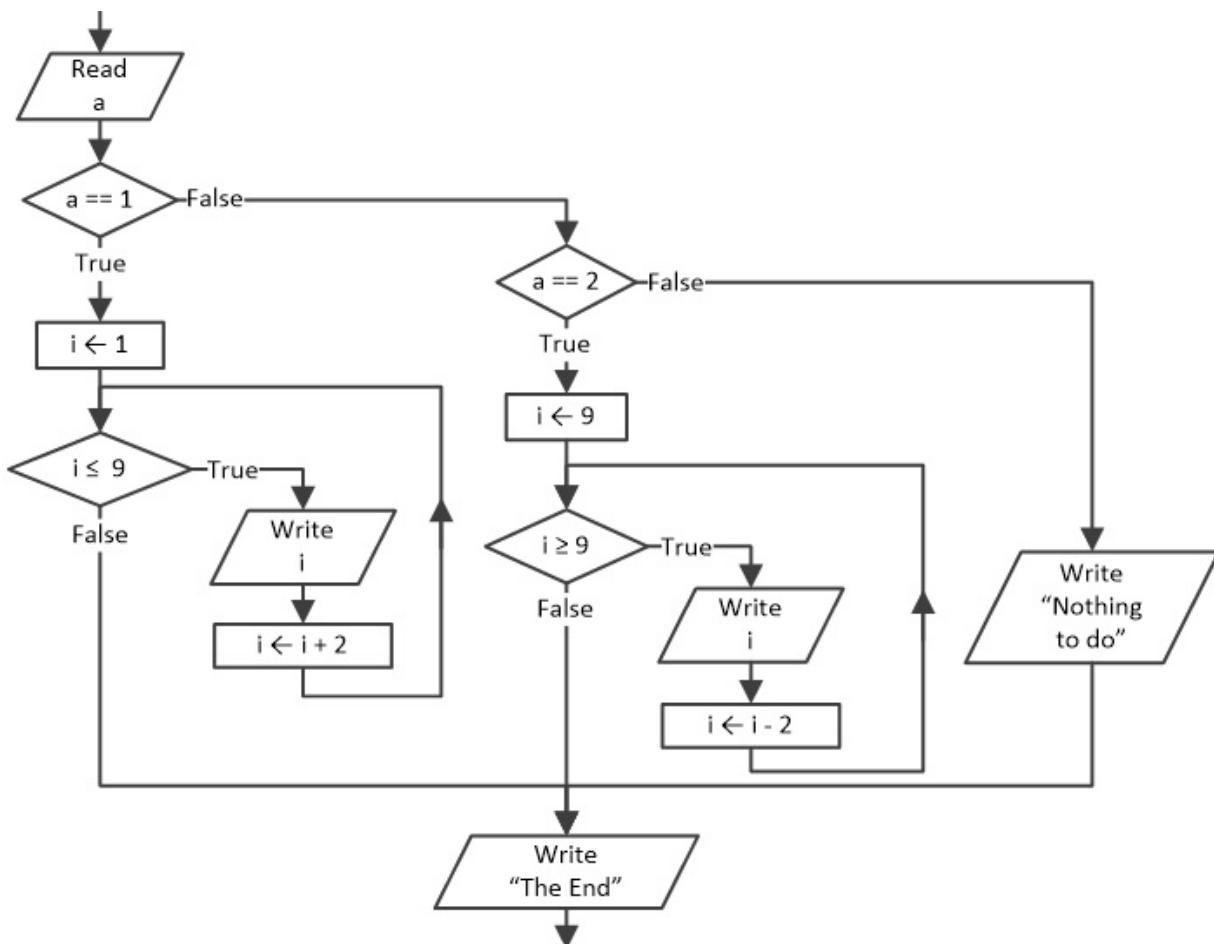
```

        break;
    default:
        Console.WriteLine("Nothing to do!");
        break;
    }
Console.WriteLine("The End!");

```

## Solution

This code fragment contains a case decision structure that nests two for-loops. The corresponding flowchart fragment is as follows.



The multiple-alternative decision structure and the case decision structure can share the same flowchart.

## Exercise 29.2-5 Designing the Flowchart

Design the flowchart that corresponds to the following C# program.

```

static void Main(string[] args) {
    int n, m, total, i, j;

```

```

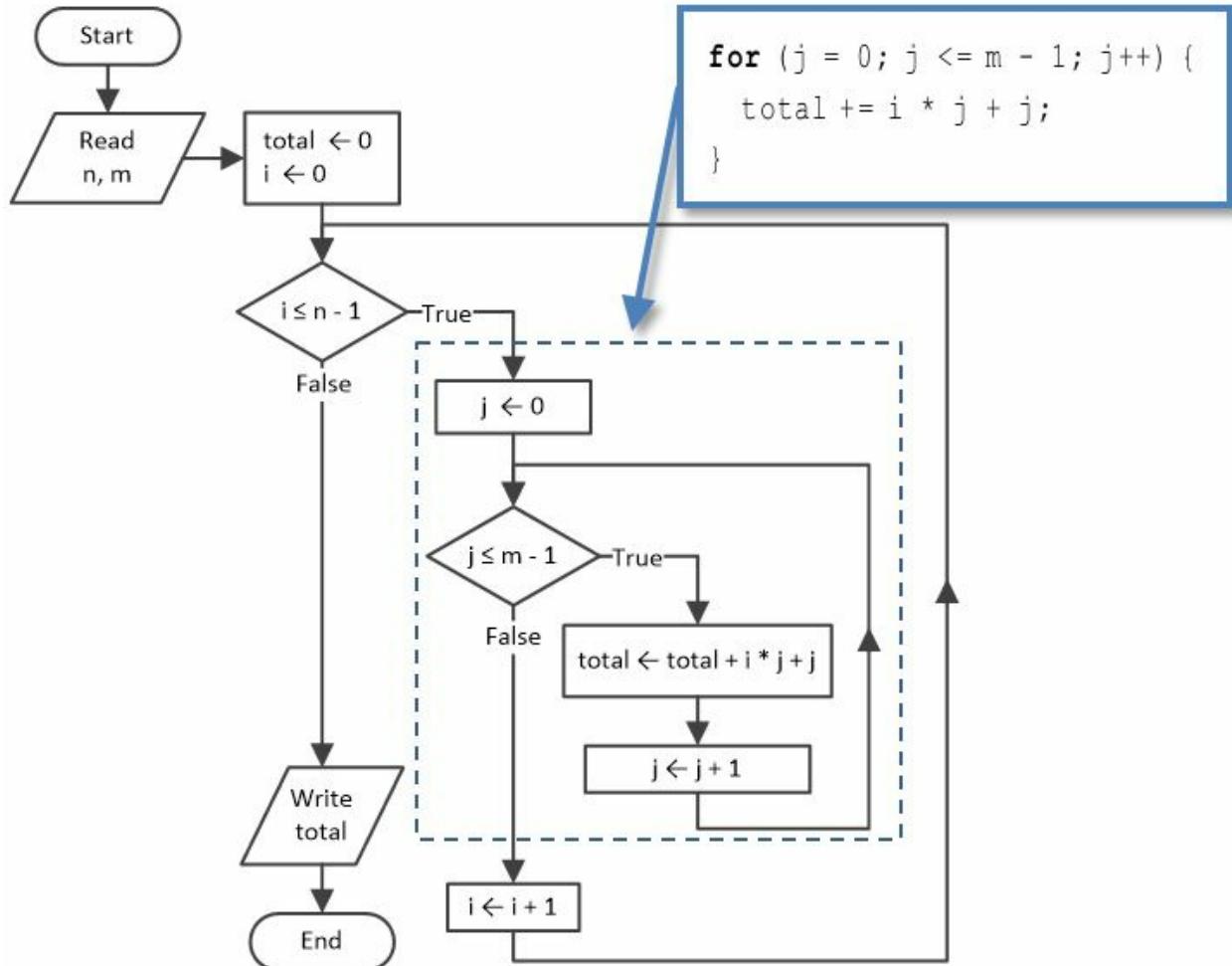
n = Int32.Parse(Console.ReadLine());
m = Int32.Parse(Console.ReadLine());

total = 0;
for (i = 0; i <= n - 1; i++) {
    for (j = 0; j <= m - 1; j++) {
        total += i * j + j;
    }
}
Console.WriteLine(total);
}

```

## Solution

This C# program contains nested loop control structures; a for-loop nested within another for-loop. The corresponding flowchart is as follows.



## Exercise 29.2-6 Designing the Flowchart

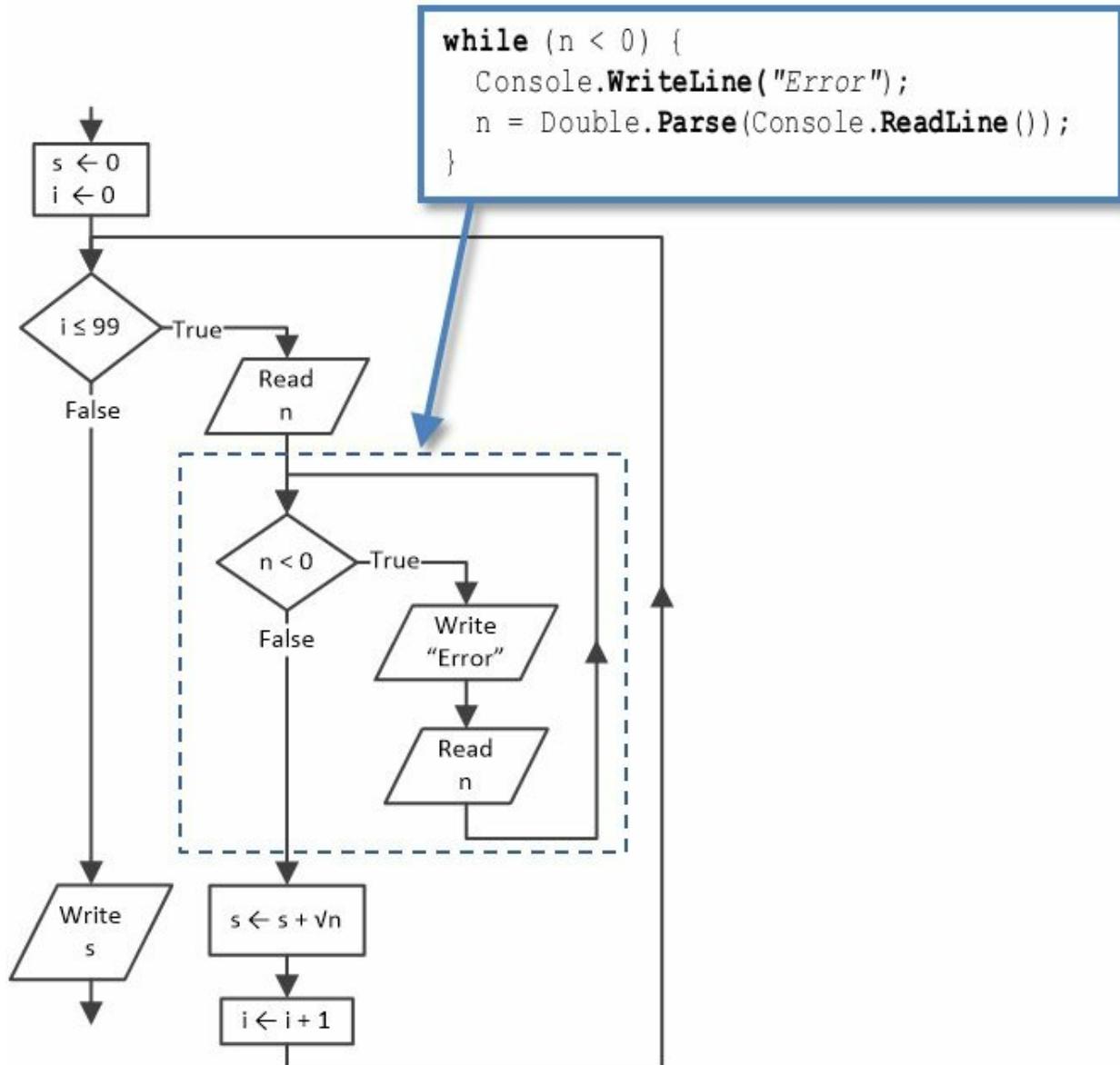
*Design the flowchart that corresponds to the following code fragment.*

```
int i;
double n, s = 0;
for (i = 0; i <= 99; i++) {
    n = Double.Parse(Console.ReadLine());
    while (n < 0) {
        Console.WriteLine("Error");
        n = Double.Parse(Console.ReadLine());
    }
    s += Math.Sqrt(n);
}
Console.WriteLine(s);
```

### **Solution**

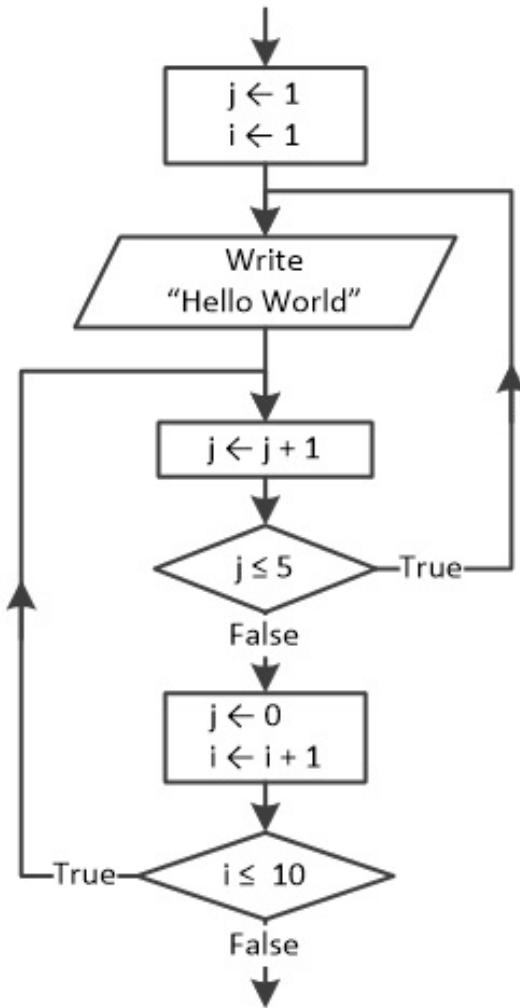
---

This code fragment contains nested loop control structures; a pre-test loop structure nested within a for-loop. The corresponding flowchart fragment is as follows.



### 29.3 Converting Flowcharts to C# Programs

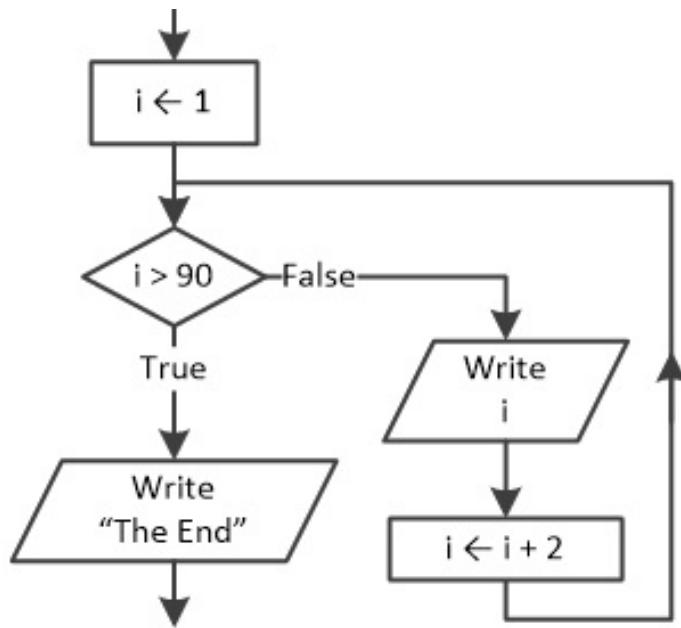
This conversion is not always an easy one. There are cases in which the flowchart designers follow no particular rules, so the initial flowchart may need some modifications before it can become a C# program. The following is an example of one such case.



As you can see, the loop control structures included in this flowchart fragment match none of the structures that you have already learned, such as the pre-test, the post-test, the mid-test, or even the for-loop control structure. Thus, you have only one choice and this is to modify the flowchart by adding extra statements or removing existing ones until known loop control structures start to appear. Following are some exercises in which the initial flowchart does need modification.

### Exercise 29.3-1 Writing the C# Program

Write the C# code that corresponds to the following flowchart fragment.



## **Solution**

---

This is an easy one. The only obstacle you have to overcome is that the true and false paths are not quite in the right position. You need the true and not the false path to actually iterate. As you already know, it is possible to switch the two paths but you need to negate the Boolean expression as well. Thus, the code fragment becomes

```
i = 1;
while (i <= 90) {
    Console.WriteLine(i);
    i = i + 2;
}

Console.WriteLine("The End");
```

or you can even use a for statement

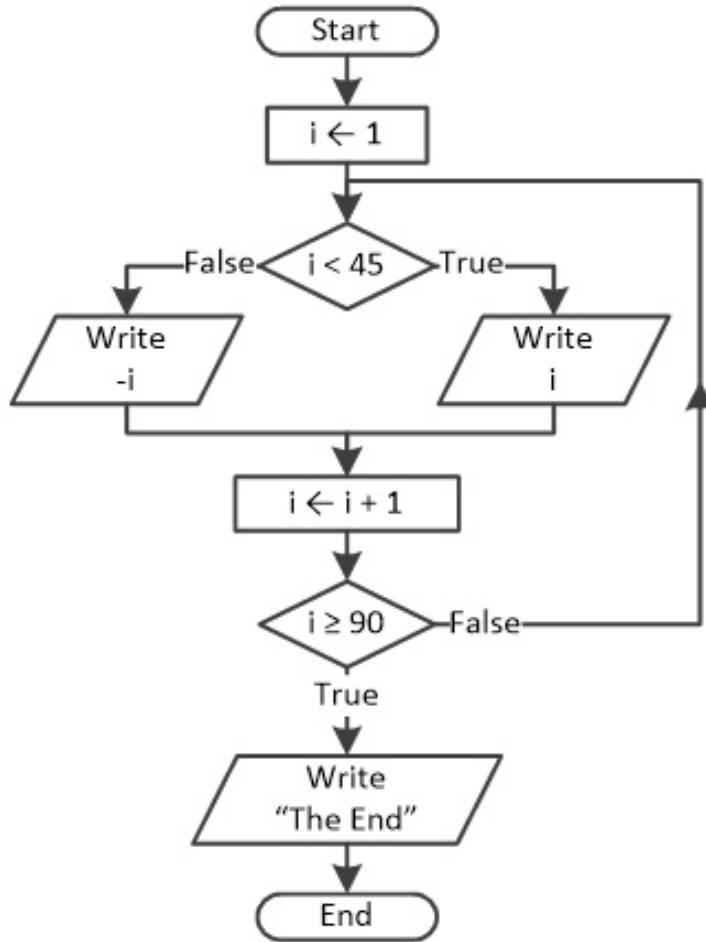
```
for (i = 1; i <= 90; i += 2) {
    Console.WriteLine(i);
}

Console.WriteLine("The End");
```

## **Exercise 29.3-2 Writing the C# Program**

---

*Write the C# program that corresponds to the following flowchart.*



## Solution

This flowchart contains a post-test loop structure that nests a dual-alternative decision structure. The C# program is as follows.

```

static void Main(string[] args) {
    int i;

    i = 1;
    do {
        if (i < 45) { [More...]
            Console.WriteLine(i);
        }
        else {
            Console.WriteLine(-i);
        }
        i++;
    } while (i < 90);

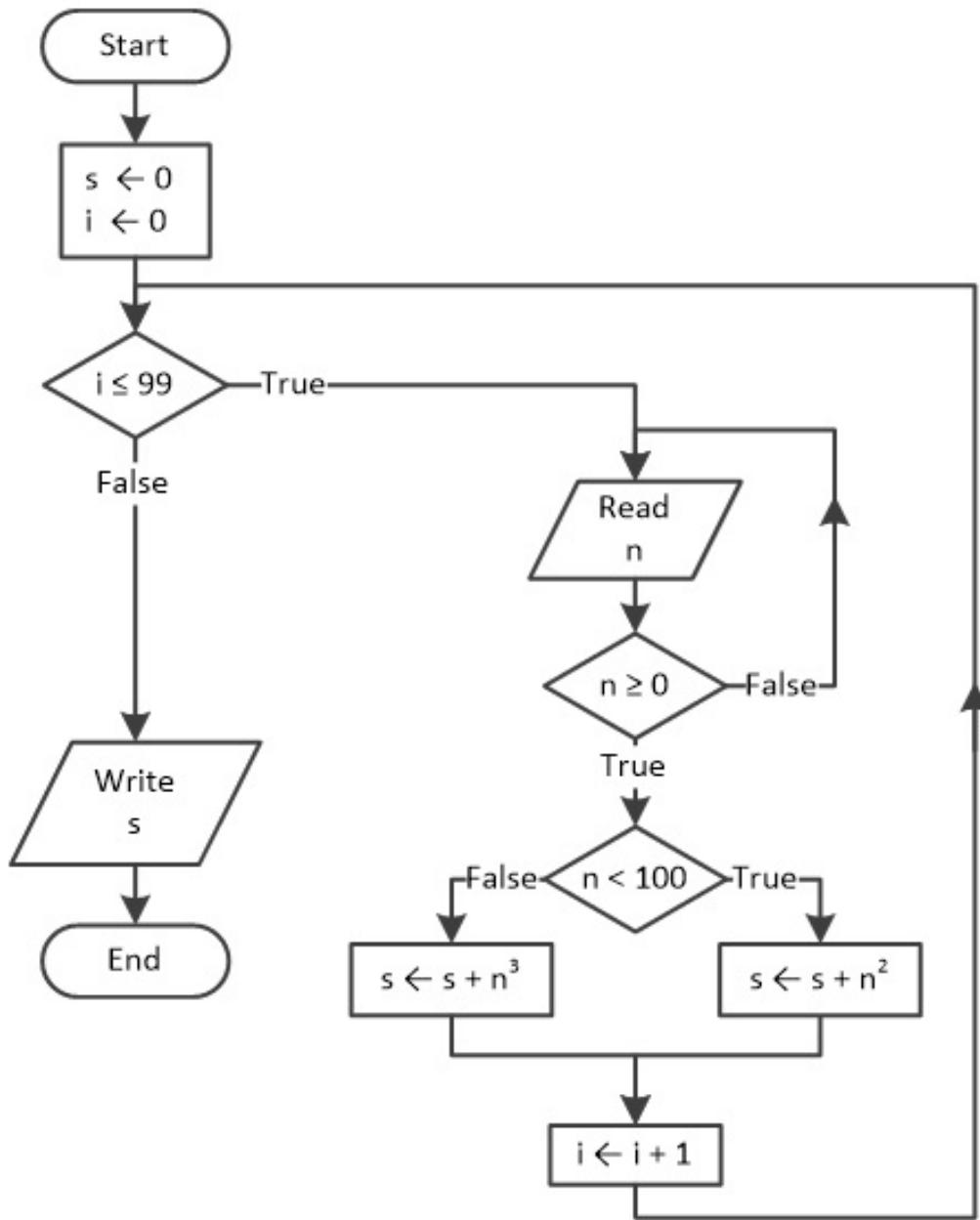
    Console.WriteLine("The End");
}

```

| }

### Exercise 29.3-3 Writing the C# Program

Write the C# program that corresponds to the following flowchart.

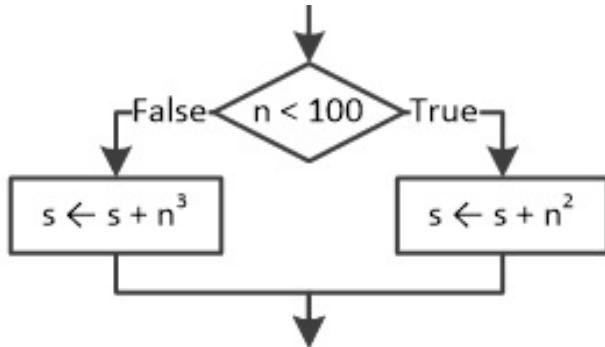


### Solution

Oops! What a mess! So many diamonds here! Be careful though, because one of them is actually a decision control structure! Can you spot it?

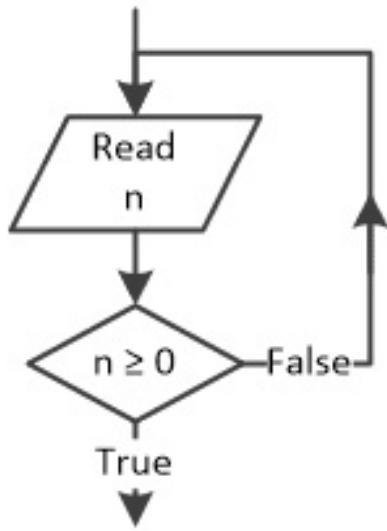
You should be quite familiar with loop control structures so far. As you already know, in loop control structures, one of the diamond's (rhombus's)

exits always has an upward direction. Thus, the following flowchart fragment, extracted from the initial one, is obviously the decision control structure that you are looking for.

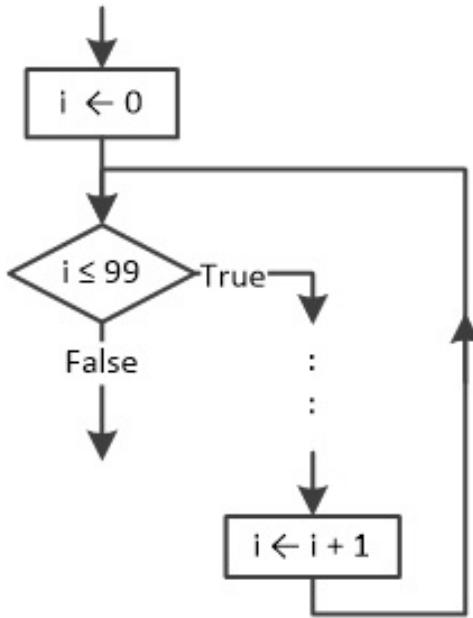


And of course, it's a dual-alternative decision structure!

Now, let's identify the rest of the structures. Right before the dual-alternative decision structure, there is a post-test loop structure. Its flowchart fragment is as follows.



And finally, both the dual-alternative decision structure and the post-test loop structure, mentioned before, are nested within the next flowchart fragment,



which happens to be a pre-test loop structure and can be written in C# using either a `while` or a `for` statement. The corresponding C# program is as follows.

```

static void Main(string[] args) {
    int i;
    double s, n;

    s = 0;
    for (i = 0; i <= 99; i++) {
        do { [More...]
            n = Double.Parse(Console.ReadLine());
        } while (n < 0);
    }

    if (n < 100) [More...]
        s = s + Math.Pow(n, 2);
    else
        s = s + Math.Pow(n, 3);
    }

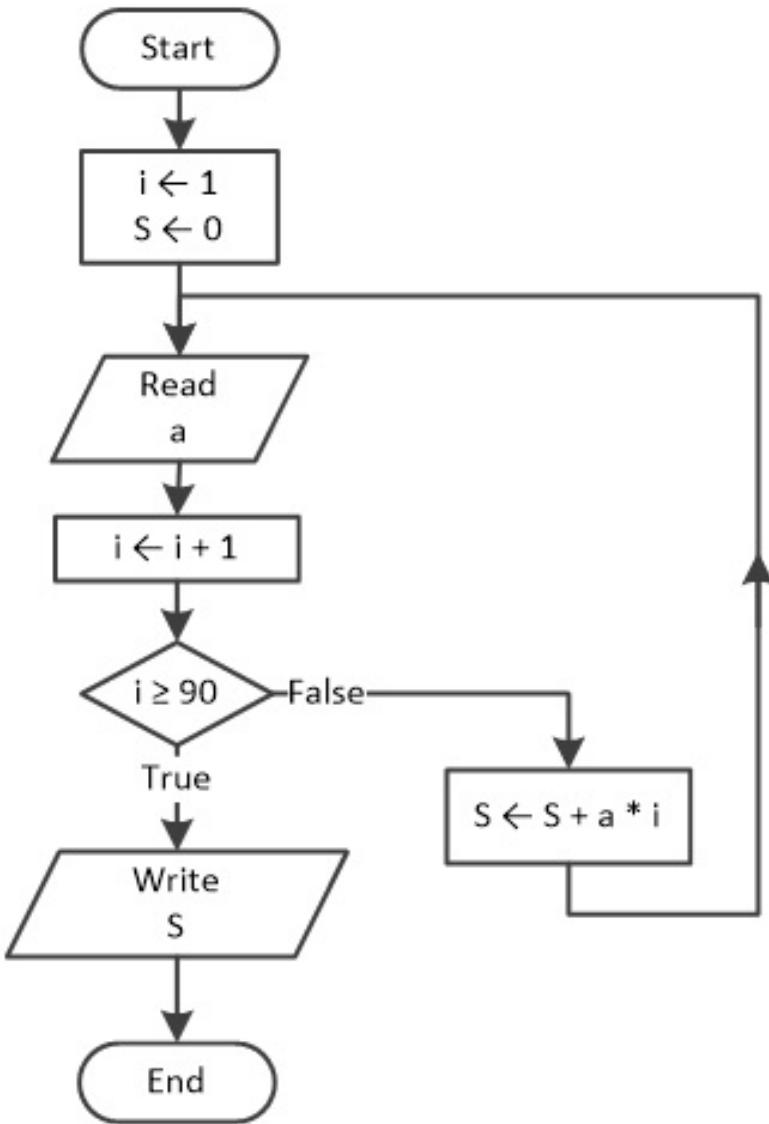
    Console.WriteLine(s);
}

```

Wasn't so difficult after all, was it?

#### ***Exercise 29.3-4 Writing the C# Program***

*Write the C# program that corresponds to the following flowchart.*



## **Solution**

---

This is a mid-test loop structure. Since there is no direct C# statement for this structure, you can use the `break` statement—or you can even convert the flowchart to something more familiar as shown in the next two approaches

### **First Approach – Using the `break` statement**

The main idea is to create an endless loop `while (true) { ... }` and break out of it when the Boolean expression that exists between the two statements or blocks of statements evaluates to true (see [paragraph 25.3](#)).

According to this approach, the initial flowchart can be written in C# as follows.

```
static void Main(string[] args) {
    int i;
    double S, a;

    i = 1;
    S = 0;

    while (true) {
        a = Double.Double(Console.ReadLine());      [More...]
        i++;

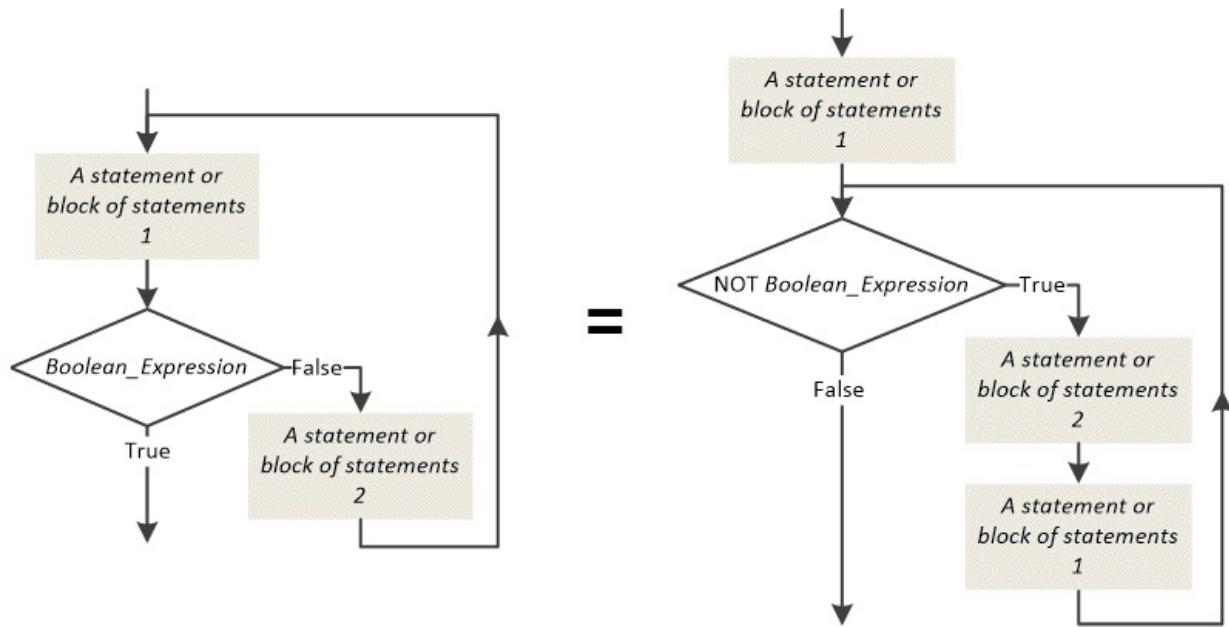
        if (i >= 90) break;

        S = S + a * i;      [More...]
    }
    Console.WriteLine(S);
}
```

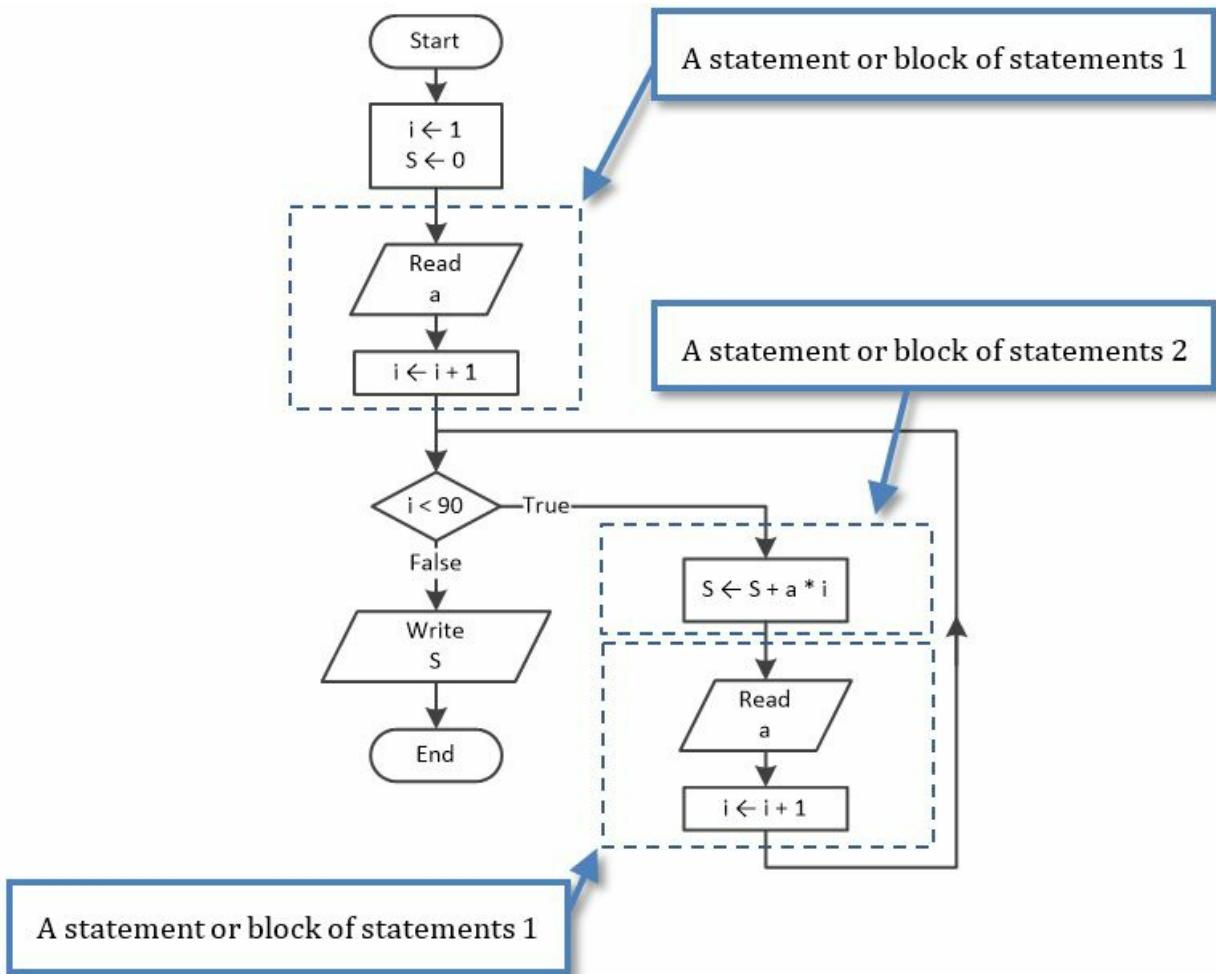
 Keep in mind that even though the break statement can sometimes be useful, it may also lead you to write code that is difficult to read and understand, especially when you make extensive use of it. So, please use it cautiously and sparingly!

## Second Approach – Converting the flowchart

The mid-test loop structure and its equivalent, using a pre-test loop structure, are as follows.



Accordingly, the initial flowchart becomes



Now, it's easy to write the corresponding C# program.

```
static void Main(string[] args) {
    int i;
    double S, a;

    i = 1;
    S = 0;

    a = Double.Parse(Console.ReadLine());      [More...]
    i++;

    while (i < 90) {
        S = S + a * i;      [More...]

        a = Double.Parse(Console.ReadLine());      [More...]
        i++;
    }
    Console.WriteLine(S);
}
```

## 29.4 Review Exercises

Complete the following exercises.

1. Design the flowchart that corresponds to the following C# program.

```
static void Main(string[] args) {
    int i;

    i = 100;
    while (i > 0) {
        Console.WriteLine(i);
        i -= 5;
    }
}
```

2. Design the flowchart that corresponds to the following C# program.

```
static void Main(string[] args) {
    int i;

    i = -100;
    while (i <= 100) {
        Console.WriteLine(i);
        i++;
    }
}
```

| }

3. Design the flowchart that corresponds to the following C# program. .

```
static void Main(string[] args) {
    int i;

    i = Int32.Parse(Console.ReadLine());
    do {
        Console.WriteLine(i);
        i++;
    } while (i <= 100);
}
```

4. Design the flowchart that corresponds to the following C# program.

```
static void Main(string[] args) {
    int a, b, i;

    a = Int32.Parse(Console.ReadLine());
    b = Int32.Parse(Console.ReadLine());
    for (i = a; i <= b; i++) {
        Console.WriteLine(i);
    }
}
```

5. Design the flowchart that corresponds to the following C# program.

```
static void Main(string[] args) {
    int i, x;

    i = 35;
    while (i > -35) {
        if (i % 2 == 0)
            Console.WriteLine(2 * i);
        else
            Console.WriteLine(3 * i);
        i--;
    }
}
```

6. Design the flowchart that corresponds to the following C# program.

```
static void Main(string[] args) {
    int i, x;

    i = -20;
    do {
        x = Int32.Parse(Console.ReadLine());
        if (x == 0)
```

```

        Console.WriteLine("Zero");
    else if (x % 2 == 0)
        Console.WriteLine(2 * i);
    else
        Console.WriteLine(3 * i);
    i++;
} while (i <= 20);
}

```

7. Design the flowchart that corresponds to the following C# program.

```

static void Main(string[] args) {
    int a, i;

    a = Int32.Parse(Console.ReadLine());
    if (a > 0) {
        i = 0;
        while (i <= a) {
            Console.WriteLine(i);
            i += 5;
        }
    }
    else {
        Console.WriteLine("Non-Positive Entered!");
    }
}

```

8. Design the flowchart that corresponds to the following C# program.

```

static void Main(string[] args) {
    int a, i;

    a = Int32.Parse(Console.ReadLine());
    if (a > 0) {
        i = 0;
        while (i <= a) {
            Console.WriteLine(3 * i + i / 2.0);
            i++;
        }
    }
    else {
        i = 10;
        do {
            Console.WriteLine(2 * i - i / 3.0);
            i -= 3;
        } while (i >= a);
    }
}

```

| }

9. Design the flowchart that corresponds to the following C# program.

```
static void Main(string[] args) {
    int a, b, i;

    a = Int32.Parse(Console.ReadLine());
    if (a > 0) {
        for (i = 0; i <= a; i++) {
            Console.WriteLine(3 * i + i / 2.0);
        }
    }
    else if (a == 0) {
        b = Int32.Parse(Console.ReadLine());
        while (b > 0) {
            b = Int32.Parse(Console.ReadLine());
        }
        Console.WriteLine(2 * a + b);
    }
    else {
        b = Int32.Parse(Console.ReadLine());
        while (b < 0) {
            b = Int32.Parse(Console.ReadLine());
        }
        for (i = a; i <= b; i++) {
            Console.WriteLine(i);
        }
    }
}
```

10. Design the flowchart that corresponds to the following C# program.

```
static void Main(string[] args) {
    int a, b, c, d, total, i, j;

    a = Int32.Parse(Console.ReadLine());
    b = Int32.Parse(Console.ReadLine());
    c = Int32.Parse(Console.ReadLine());
    d = Int32.Parse(Console.ReadLine());

    total = 0;
    for (i = a; i <= b - 1; i++) {
        for (j = c; j <= d - 1; j += 2) {
            total += i + j;
        }
    }
}
```

```
        Console.WriteLine(total);
    }
```

11. Design the flowchart that corresponds to the following C# program.

```
static void Main(string[] args) {
    int i;
    double s, n;

    s = 0;
    for (i = 1; i <= 50; i++) {
        do {
            n = Int32.Parse(Console.ReadLine());
        } while (n < 0);
        s += Math.Sqrt(n);
    }
    Console.WriteLine(s);
}
```

12. Design the flowchart that corresponds to the following C# program.

```
static void Main(string[] args) {
    int a, b;

    do {
        do {
            a = Int32.Parse(Console.ReadLine());
        } while (a < 0);
        do {
            b = Int32.Parse(Console.ReadLine());
        } while (b < 0);
        Console.WriteLine(Math.Abs(a - b));
    } while (Math.Abs(a - b) > 100);
}
```

13. Design the flowchart that corresponds to the following C# program.

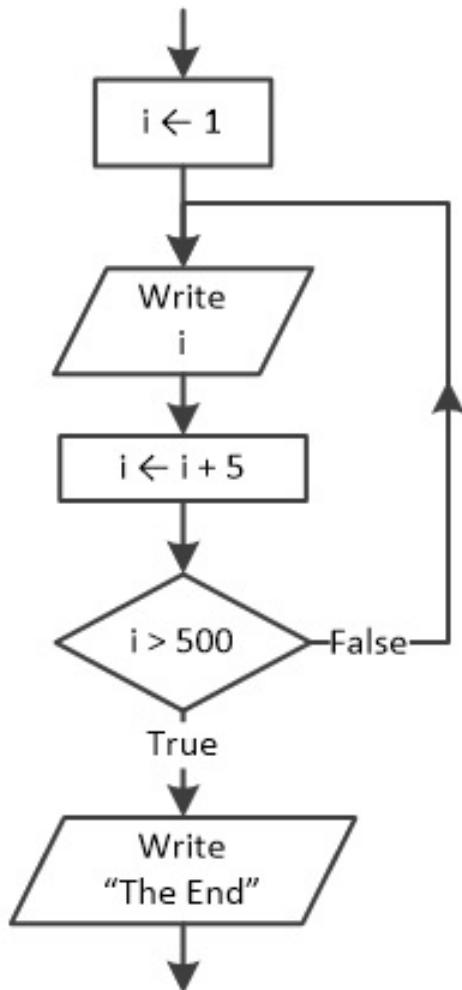
```
static void Main(string[] args) {
    int a, b;

    do {
        do {
            a = Int32.Parse(Console.ReadLine());
            b = Int32.Parse(Console.ReadLine());
        } while (a < 0 || b < 0);

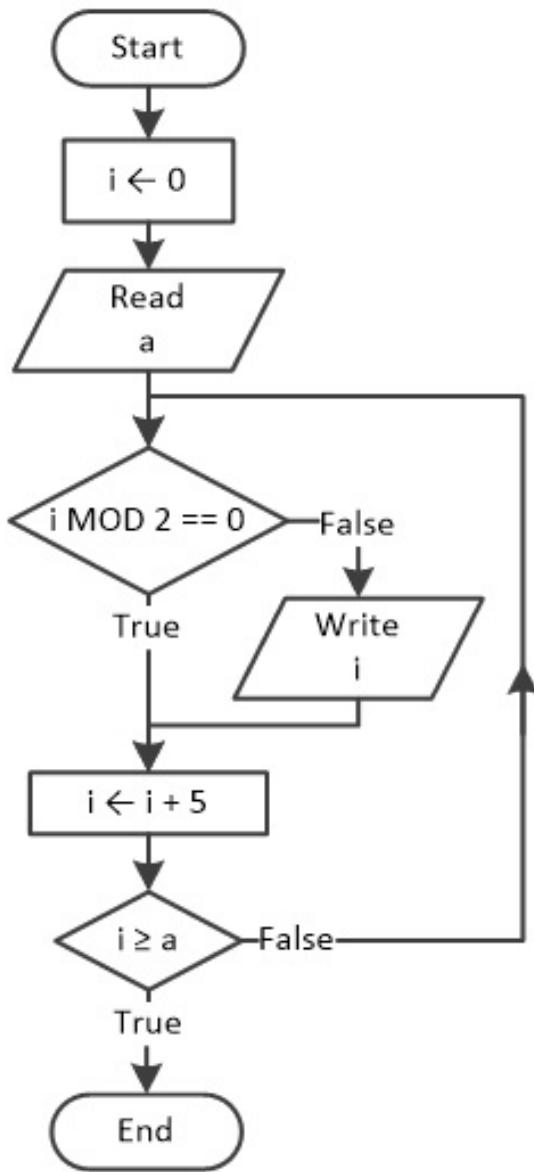
        if (a > b) {
            Console.WriteLine(a - b);
        }
    }
```

```
    else {
        Console.WriteLine(a * b);
    }
} while (Math.Abs(a - b) > 100);
}
```

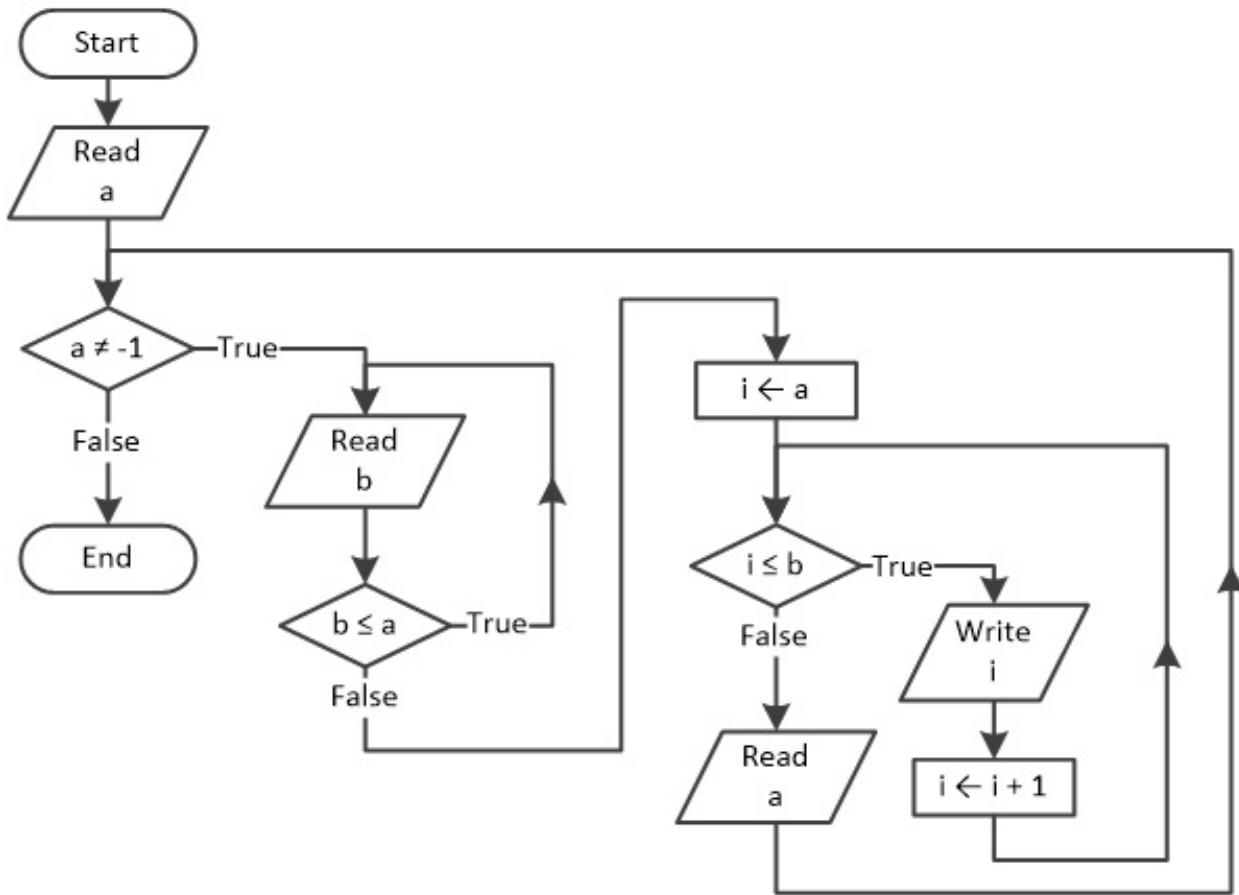
14. Write the code fragment in C# that corresponds to the following flowchart fragment.



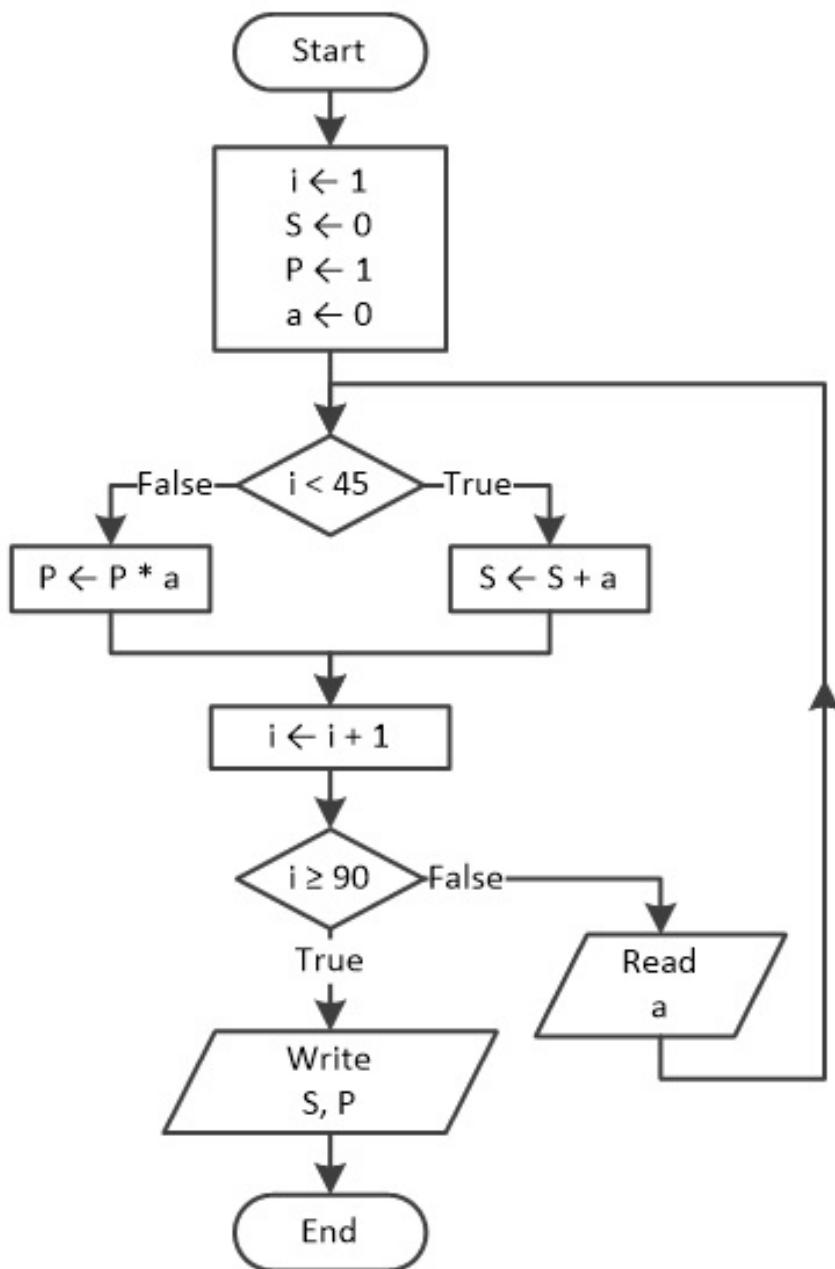
15. Write the C# program that corresponds to the following flowchart.



16. Write the C# program that corresponds to the following flowchart.



17. Write the C# program that corresponds to the following flowchart.



# Chapter 30

## More Exercises with Loop Control Structures

---

### 30.1 Simple Exercises with Loop Control Structures

#### Exercise 30.1-1 Counting the Numbers According to Which is Greater

*Write a C# program that prompts the user to enter 10 pairs of numbers and then counts and displays the number of times that the first number given was greater than the second one and the number of times that the second one was greater than the first one.*

#### Solution

The C# program is as follows. It uses variable count\_a to count the number of times that the first number given was greater than the second one and variable count\_b to count the number of times that the second one was greater than the first one.

#### project\_30\_1\_1

```
static void Main(string[] args) {
    int count_a, count_b, i, a, b;

    count_a = 0;
    count_b = 0;

    for (i = 1; i <= 10; i++) {
        Console.WriteLine("Enter number A: ");
        a = Int32.Parse(Console.ReadLine());
        Console.WriteLine("Enter number B: ");
        b = Int32.Parse(Console.ReadLine());

        if (a > b) {
            count_a++;
        }
        else if (b > a) {
            count_b++;
        }
    }
    Console.WriteLine(count_a + " " + count_b);
}
```

A reasonable question that someone may ask is “*Why is a multiple-decision*

*control structure being used? Why not use a dual-alternative decision structure instead?"*

Suppose that a dual-alternative decision structure, such as the following, is used.

```
if (a > b) {  
    count_a++;  
}  
else {  
    count_b++;  
}
```

In this decision control structure, the variable count\_b increments when variable b is greater than variable a (this is desirable) but also when variable b is equal to variable a (this is undesirable). Using a multiple-decision control structure instead ensures that variable count\_b increments only when variable b is greater than (and not when it is equal to) variable a.

### **Exercise 30.1-2 Counting the Numbers According to Their Digits**

---

*Write a C# program that prompts the user to enter 20 integers and then counts and displays the total number of one-digit, two-digit, and three-digit integers. Assume that the user enters values between 1 and 999.*

#### **Solution**

---

Using knowledge from [Exercise 18.1-2](#), the C# program is as follows.

#### **project\_30\_1\_2**

```
static void Main(string[] args) {  
    int count1, count2, count3, i, a;  
  
    count1 = count2 = count3 = 0;  
  
    for (i = 1; i <= 20; i++) {  
        Console.Write("Enter a number: ");  
        a = Int32.Parse(Console.ReadLine());  
  
        if (a <= 9) {  
            count1++;  
        }  
        else if (a <= 99) {  
            count2++;  
        }  
        else {  
            count3++;  
        }  
    }  
    Console.WriteLine("Count of one-digit numbers: " + count1);  
    Console.WriteLine("Count of two-digit numbers: " + count2);  
    Console.WriteLine("Count of three-digit numbers: " + count3);  
}
```

```

        count3++;
    }
}

Console.WriteLine(count1 + " " + count2 + " " + count3);
}

```

### ***Exercise 30.1-3 How Many Numbers Fit in a Sum***

---

*Write a C# program that lets the user enter numeric values repeatedly until the sum of them exceeds 1000. At the end, the program must display the total quantity of numbers entered.*

#### ***Solution***

---

In this case, you don't know the exact number of iterations, so you cannot use a for-loop. Let's use a while-loop instead, but, in order to make your program free of logic errors you should follow the “Ultimate” rule discussed in [paragraph 28.3](#). According to this rule, the pre-test loop structure should be as follows, given in general form.

```

Initialize total

while (total <= 1000) {
    A statement or block of statements
    Update/alter total
}

```

✎ Since loop's Boolean expression depends on variable total, this is the variable that must be initialized before the loop starts and also updated (altered) within the loop. And more specifically, the statement that updates/alters variable total must be the **last** statement of the loop.

Following this, the C# program becomes

#### **project\_30\_1\_3**

```

static void Main(string[] args) {
    int count;
    double total, x;

    count = 0;

    total = 0;           //Initialization of total
    while (total <= 1000) { //A Boolean expression dependent on total

```

```

        x = Double.Parse(Console.ReadLine());
        count++;
        total += x;           //Update/alteration of total
    }

    Console.WriteLine(count);
}

```

### ***Exercise 30.1-4 Finding the Total Number of Positive Integers***

---

*Write a C# program that prompts the user to enter integer values repeatedly until a real one is entered. At the end, the program must display the total number of positive integers entered.*

#### **Solution**

---

Once again, you don't know the exact number of iterations, so you cannot use a for-loop.

According to the “Ultimate” rule, the pre-test loop structure should be as follows, given in general form.

```

Console.WriteLine("Enter a number: ");
x = Double.Parse(Console.ReadLine());      //Initialization of x
while ( (int)(x) == x ) {                  //A Boolean expression dependent on x

    A statement or block of statements

    Console.WriteLine("Enter a number: ");
    x = Double.Parse(Console.ReadLine());  //Update/alteration of x
}

```

The final C# program is as follows.

#### project\_30\_1\_4

```

static void Main(string[] args) {
    double x;
    int count;

    count = 0;

    Console.WriteLine("Enter a number: ");
    x = Double.Parse(Console.ReadLine());
    while ((int)(x) == x) {
        if (x > 0) {
            count++;
        }
        Console.WriteLine("Enter a number: ");
    }
}

```

```

        x = Double.Parse(Console.ReadLine());
    }

    Console.WriteLine(count);
}

```

 Note that the program operates properly even if the first number given is real. The pre-test loop structure ensures that the flow of execution never enters the loop!

### **Exercise 30.1-5 Iterating as Many Times as the User Wishes**

Write a C# program that prompts the user to enter two numbers and then calculates and displays the first number raised to the power of the second one. The program must iterate as many times as the user wishes. At the end of each calculation, the program must ask the user if he or she wishes to calculate again. If the answer is “yes” the program must repeat; it must end otherwise. Make your program accept the answer in all possible forms such as “yes”, “YES”, “Yes”, or even “YeS”.

### **Solution**

According to the “Ultimate” rule, the post-test loop structure should be as follows, given in general form.

```

answer = "YES";      //Initialization of answer (redundant)
do {
    Prompt the user to enter two numbers and then
    calculate and display the first number raised to
    the power of the second one.

    Console.WriteLine("Would you like to repeat? ");
    answer = Console.ReadLine();      //Update/alteration of answer

    //The loop's Boolean expression depends on variable answer
} while (answer.ToUpper() == "YES");

```

 The ToUpper() method ensures that the program operates properly for any given answer: “yes”, “YES”, “Yes”, or even “YeS” or “yEs”!

The solution to this exercise becomes

#### **project\_30\_1\_5**

```
static void Main(string[] args) {
```

```

int a, b;
double result;
string answer;

do {
    Console.WriteLine("Enter two numbers: ");
    a = Int32.Parse(Console.ReadLine());
    b = Int32.Parse(Console.ReadLine());

    result = Math.Pow(a, b);
    Console.WriteLine("The result is: " + result);

    Console.WriteLine("Would you like to repeat? ");
    answer = Console.ReadLine();
} while (answer.ToUpper() == "YES");
}

```

### ***Exercise 30.1-6 Finding the Sum of the Digits***

---

*Write a C# program that lets the user enter an integer and then calculates the sum of its digits.*

#### **Solution**

---

In [Exercise 13.1-2](#), you learned how to split the digits of an integer when its total number of digits was known. In this exercise however, the user is allowed to enter any value, no matter how small or large; thus, the total number of the digits can be unknown.

To solve this exercise, a loop control structure could be used. However, there are two approaches that you can use.

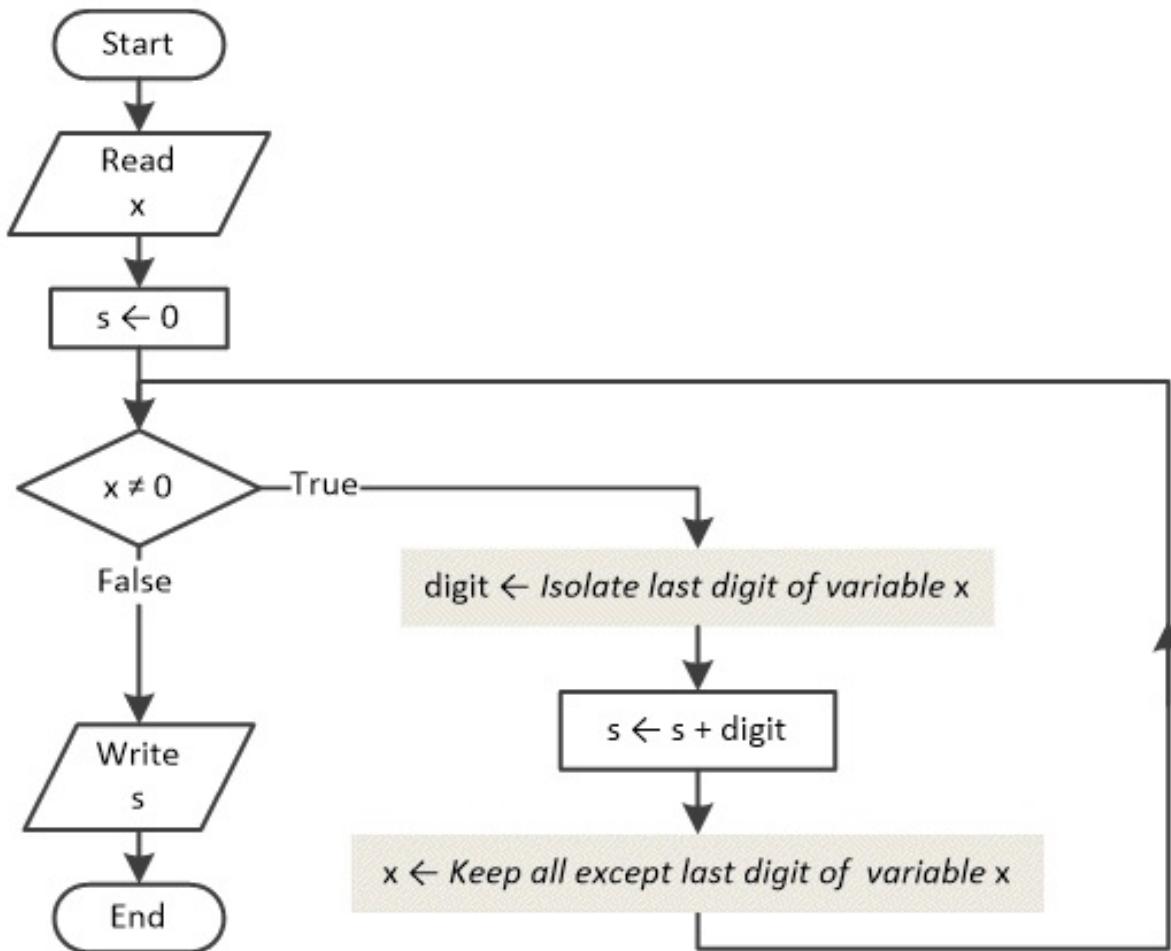
#### **First Approach**

In this approach, the main idea is to isolate one digit at each iteration. But what you don't really know is the total number of iterations that must be performed because this number depends on the given integer. So, is this a dead end? Of course not!

Inside the loop, the given integer can be getting “smaller” and “smaller” in every iteration until eventually it becomes zero. The value of zero can serve to stop the loop control structure from iterating. For example, if the given number is 4753, it can become 475 in the first iteration, then 47, then 4, and finally 0. When it becomes 0, the iterations can stop.

Let's try to comprehend the proposed solution using the following flowchart.

Some statements are written in general form.



The statement

$\text{digit} \leftarrow \text{Isolate last digit of variable } x.$

can be written using the well-known MOD 10 operation as shown here.

$\text{digit} \leftarrow x \text{ MOD } 10$

The whole concept, however, relies on the statement

$x \leftarrow \text{Keep all except last digit of variable } x.$

This is the statement that eventually zeros the value of variable  $x$ , and the flow of execution then exits the loop. To write this statement you can use a DIV 10 operation as shown here.

$x \leftarrow x \text{ DIV } 10$

Accordingly, the C# program becomes

project\_30\_1\_6a

```

static void Main(string[] args) {
    int x, s, digit;

    x = Int32.Parse(Console.ReadLine());

    s = 0;

    while (x != 0) {
        digit = x % 10;      //This is the x MOD 10 operation
        s = s + digit;
        x = (int)(x / 10);  //This is the x DIV 10 operation
    }

    Console.WriteLine(s);
}

```

Let's create a trace table for the input value 4753 to better understand what is really happening.

Step	Statement	Notes	x	digit	s
1	x = Int32.Parse(...)	User enters the value 4753	4753	?	?
2	s = 0		4753	?	0
3	while (x != 0)	This evaluates to true			
4	digit = x % 10		4753	3	0
5	s = s + digit		4753	3	3
6	x = (int)(x / 10)		475	3	3
7	while (x != 0)	This evaluates to true			
8	digit = x % 10		475	5	3
9	s = s + digit		475	5	8
10	x = (int)(x / 10)		47	5	8
11	while (x != 0)	This evaluates to true			
12	digit = x % 10		47	7	8
13	s = s + digit		47	7	15
14	x = (int)(x / 10)		4	7	15

15	<code>while (x != 0)</code>	This evaluates to true			
16	<code>digit = x % 10</code>		4	4	15
17	<code>s = s + digit</code>		4	4	19
18	<code>x = (int)(x / 10)</code>		0	4	19
19	<code>while (x != 0)</code>	This evaluates to false			
20	<code>.WriteLine(s)</code>	It displays: 19			

□ In C#, the result of the division of two integers is always an integer. Thus, in the statement `x = (int)(x / 10)`, since both variable `x` and constant value 10 are integers, the `(int)` casting operator is redundant. However, it is a good practice to keep it there just for improved readability.

## Second Approach

In this approach, the main idea is to convert the given integer to a string and then use a for-loop to iterate for all its characters (digits). In the for-loop, however, you need to convert each digit from type `char` back to type `int` before it is accumulated in variable `s`. The C# program is as follows.

### project\_30\_1\_6b

```
static void Main(string[] args) {
    int i, x, s;
    string x_str, digit;

    x = Int32.Parse(Console.ReadLine());
    x_str = "" + x; //Convert user's input to string

    s = 0;

    for (i = 0; i <= x_str.Length - 1; i++) {
        digit = "" + x_str[i]; //Get the "digit" as string
        s = s + Int32.Parse(digit);
    }

    Console.WriteLine(s);
}
```

## 30.2 Exercises with Nested Loop Control Structures

## **Exercise 30.2-1 Displaying all Three-Digit Integers that Contain a Given Digit**

---

*Write a C# program that prompts the user to enter a digit (0 to 9) and then displays all three-digit integers that contain that given digit at least once. For example, for the given value 7, the values 357, 771, and 700 are such integers.*

### **Solution**

---

There are three different approaches! The first one uses just one for-loop, the second one uses three for-loops, nested one within the other, and the last one converts all three-digit integers to strings. Let's analyze them all!

#### **First Approach – Using a for-loop and a decision control structure**

The main idea is to use a for-loop where the value of variable *counter* goes from 100 to 999. Inside the loop, the *counter* variable is split into its individual digits ( $\text{digit}_3$ ,  $\text{digit}_2$ ,  $\text{digit}_1$ ) and a decision control structure is used to check if at least one of its digits is equal to the given one. The C# program is as follows.

##### project\_30\_2\_1a

```
static void Main(string[] args) {
    int x, i, digit3, r, digit2, digit1;

    Console.WriteLine("Enter a digit 0 - 9: ");
    x = Int32.Parse(Console.ReadLine());

    for (i = 100; i <= 999; i++) {
        digit3 = (int)(i / 100);
        r = i % 100;

        digit2 = (int)(r / 10);
        digit1 = r % 10;

        if (digit3 == x || digit2 == x || digit1 == x) {
            Console.WriteLine(i);
        }
    }
}
```

#### **Second Approach – Using nested loop control structures and a decision control structure**

The main idea here is to use three for-loops, nested one within the other. In this case, there are three *counter* variables (`digit3`, `digit2`, and `digit1`) and each one of them corresponds to one digit of the three-digit integer. The C# program is as follows.

```
project_30_2_1b  
static void Main(string[] args) {  
    int x, digit3, digit2, digit1;  
  
    Console.WriteLine("Enter a digit 0 - 9: ");  
    x = Int32.Parse(Console.ReadLine());  
  
    for (digit3 = 1; digit3 <= 9; digit3++) {  
        for (digit2 = 0; digit2 <= 9; digit2++) {  
            for (digit1 = 0; digit1 <= 9; digit1++) {  
                if (digit3 == x || digit2 == x || digit1 == x) {  
                    Console.WriteLine(digit3 * 100 + digit2 * 10 + digit1);  
                }  
            }  
        }  
    }  
}
```

If you follow the flow of execution, the value 100 is the first “integer” evaluated (`digit3 = 1, digit2 = 0, digit1 = 0`). Then, the most-nested loop control structure increments variable `digit1` by one and the next value evaluated is “integer” 101. This continues until `digit1` reaches the value 9; that is, until the “integer” reaches the value 109. The flow of execution then exits the most-nested loop control structure, variable `digit2` increments by one, and the most-nested loop control structure starts over again, thus the values evaluated are the “integers” 110, 111, 112, ... 119. The process goes on until all integers up to the value 999 are evaluated.

 Note that variable `digit3` starts from 1, whereas variables `digit2` and `digit1` start from 0. This is necessary since the scale for three-digit numbers begins from 100 and not from 000.

 Note how the `Console.WriteLine()` statement composes the three-digit integer.

### Third Approach – Convert all three-digit integers to strings

Using a for-loop, the value of variable *counter* goes from 100 to 999. Inside

the loop, the *counter* variable is converted to string and the `IndexOf()` method checks if the given “digit” exists in the string. The C# program is as follows.

### project\_30\_2\_1c

```
static void Main(string[] args) {
    int i, x;
    string x_str;

    Console.WriteLine("Enter a digit 0 - 9: ");
    x = Int32.Parse(Console.ReadLine());
    x_str = "" + x; //Convert user's input to string

    for (i = 100; i <= 999; i++) {
        if (i.ToString().IndexOf(x_str) != -1) { //Or you can do the following:
            //if (("" + i).IndexOf(x_str) != -1)
            Console.WriteLine(i);
        }
    }
}
```

## Exercise 30.2-2 Displaying all Instances of a Specified Condition

*Write a C# program that displays all three-digit integers in which the first digit is smaller than the second digit and the second digit is smaller than the third digit. For example, the values 357, 456, and 159 are such integers.*

### **Solution**

There are three different approaches, actually! Let's analyze them all!

#### **First Approach – Using a for-loop and a decision control structure**

The C# program is as follows.

### project\_30\_2\_2a

```
static void Main(string[] args) {
    int i, r, digit1, digit2, digit3;

    for (i = 100; i <= 999; i++) {
        digit3 = (int)(i / 100);
        r = i % 100;

        digit2 = (int)(r / 10);
        digit1 = r % 10;
```

```

        if (digit3 < digit2 && digit2 < digit1) {
            Console.WriteLine(i);
        }
    }
}

```

## Second Approach – Using nested loop control structures and a decision control structure

The C# program is as follows.

### project\_30\_2\_2b

```

static void Main(string[] args) {
    int digit1, digit2, digit3;

    for (digit3 = 1; digit3 <= 9; digit3++) {
        for (digit2 = 0; digit2 <= 9; digit2++) {
            for (digit1 = 0; digit1 <= 9; digit1++) {
                if (digit3 < digit2 && digit2 < digit1) {
                    Console.WriteLine(digit3 * 100 + digit2 * 10 + digit1);
                }
            }
        }
    }
}

```

## Third Approach – Using nested loop control structures only

This approach is based on the previous one. The main difference between them is that in this case, variable `digit1` always begins from a value greater than `digit2`, and variable `digit2` always begins from a value greater than `digit3`. In that way, the first integer that will be displayed is 123.

 *There are no integers below the value 123 and above the value 789 that can validate the Boolean expression `digit3 < digit2 && digit2 < digit1` to true.*

The C# program is as follows.

### project\_30\_2\_2c

```

static void Main(string[] args) {
    int digit3, digit2, digit1;

    for (digit3 = 1; digit3 <= 7; digit3++) {
        for (digit2 = digit3 + 1; digit2 <= 8; digit2++) {
            for (digit1 = digit2 + 1; digit1 <= 9; digit1++) {

```

```
        Console.WriteLine(digit3 * 100 + digit2 * 10 + digit1);
    }
}
}
```

 This solution is the most efficient since it doesn't use any decision control structure and, moreover, the number of iterations is kept to a minimum!

 As you can see, one problem can have many solutions. It is up to you to find the optimal one!

### 30.3 Data Validation with Loop Control Structures

As you already know, data validation is the process of restricting data input, which forces the user to enter only valid values. You have already encountered one method of data validation using decision control structures. Let's see an example.

```
Console.Write("Enter a non-negative number: ");
x = Double.Parse(Console.ReadLine());

if (x < 0) {
    Console.Write("Error: Negative number entered!");
}
else {
    Console.WriteLine(Math.Sqrt(x));
}
```

This approach, however, is not the most appropriate because if the user does enter an invalid number, the program displays the error message and the flow of execution inevitably reaches the end. The user must then execute the program again in order to re-enter a valid number.

Next, you will see three approaches given in general form that validate data input using loop control structures. If the user persistently enters an invalid value, the main idea is to prompt him or her repeatedly, until he or she gets bored and finally enters a valid one. Of course, if the user enters a valid value right from the beginning, the flow of execution simply continues to the next part of the program.

Which approach you use depends on whether or not you wish to display an error message and whether you wish to display an individual error message for each error or just a single error message for any kind of error.

## First Approach – Validating data input without error messages

To validate data input without displaying any error messages, you can use the following code fragment given in general form.

```
do {  
    Console.WriteLine("Prompt message");  
    input_data = Console.ReadLine();  
} while (input_data test 1 fails || input_data test 2 fails || ...);
```

## Second Approach – Validating data input with one error message

To validate data input and display an error message (that is, the same error message for any type of input error), you can use the following code fragment given in general form.

```
Console.WriteLine("Prompt message");  
input_data = Console.ReadLine();  
while (input_data test 1 fails || input_data test 2 fails || ... ) {  
    Console.WriteLine("Error message");  
    Console.WriteLine("Prompt message");  
    input_data = Console.ReadLine();  
}
```

## Third Approach – Validating data input with individual error messages

To validate data input and display individual error messages (that is, one for each type of input error), you can use the following code fragment given in general form.

```
do {  
    Console.WriteLine("Prompt message");  
    input_data = Console.ReadLine();  
    failure = false;  
    if (input_data test 1 fails) {  
        Console.WriteLine("Error message 1");  
        failure = true;  
    }  
    else if (input_data test 2 fails) {  
        Console.WriteLine("Error message 2");  
        failure = true;  
    }  
    else if (...  
    ...  
    }  
} while (failure);
```

 The statement `while (failure)` is equivalent to the statement `while`

```
(failure == true).
```

### **Exercise 30.3-1 Finding Odd and Even Numbers - Validation Without Error Messages**

*Write a C# program that prompts the user to enter a non-negative integer, and then displays a message indicating whether this number is even; it must display “Odd” otherwise. Using a loop control structure, the program must also validate data input, allowing the user to enter only a non-negative integer. There is no need to display any error messages.*

#### **Solution**

First, let's write the program without data validation.

```
static void Main(string[] args) {  
    double x;  
  
    Console.WriteLine("Enter a non-negative integer: "); [More...]  
    x = Double.Parse(Console.ReadLine());  
  
    if (x % 2 == 0) {  
        Console.WriteLine("Even");  
    }  
    else {  
        Console.WriteLine("Odd");  
    }  
}
```

To validate data input without displaying any error messages you can use the first approach. All you need to do is replace the statement marked with a dashed rectangle with the following code fragment.

```
do {  
    Console.WriteLine("Enter a non-negative integer: ");  
    x = Double.Parse(Console.ReadLine());  
} while (x < 0 || (int)x != x);
```

 Variable x is declared as double. This is necessary in order to allow the user to enter either an integer or a float.

The final C# program becomes

 project\_30\_3\_1

```
static void Main(string[] args) {
```

```

double x;

do {
    [More...]
    Console.WriteLine("Enter a non-negative integer: ");
    x = Double.Parse(Console.ReadLine());
} while (x < 0 || (int)x != x);

if (x % 2 == 0) {
    Console.WriteLine("Even");
}
else {
    Console.WriteLine("Odd");
}
}

```

### **Exercise 30.3-2 Finding Odd and Even Numbers - Validation with One Error Message**

---

*Write a C# program that prompts the user to enter a non-negative integer, and then displays a message indicating whether this number is even; it must display “Odd” otherwise. Using a loop control structure, the program must also validate data input and display an error message when the user enters a negative value or a float.*

#### **Solution**

---

In the previous exercise, the statement marked with the dashed rectangle was replaced with a code fragment that validated data input without displaying any error message. The same method is followed here, except that the replacing code fragment is based on the second approach. The C# program is as follows.

#### **project\_30\_3\_2**

```

static void Main(string[] args) {
    double x;

    Console.WriteLine("Enter a non-negative integer: ");
    x = Double.Parse(Console.ReadLine());
    [More...]
    while (x < 0 || (int)x != x) {
        Console.WriteLine("Error! A negative value or a float entered.");
        Console.WriteLine("Enter a non-negative integer: ");
        x = Double.Parse(Console.ReadLine());
    }
}

```

```

if (x % 2 == 0) {
    Console.WriteLine("Even");
}
else {
    Console.WriteLine("Odd");
}

```

### ***Exercise 30.3-3 Finding Odd and Even Numbers - Validation with Individual Error Messages***

*Write a C# program that prompts the user to enter a non-negative integer, and then displays a message indicating whether this number is even; it must display “Odd” otherwise. Using a loop control structure, the program must also validate data input and display individual error messages when the user enters a negative value or a float.*

#### ***Solution***

This is the same as in the previous exercise, except that the replacing code fragment is now based on the third approach. The C# program is as follows.

#### ***project\_30\_3\_3***

```

static void Main(string[] args) {
    double x;
    bool failure;

    do {
        Console.Write("Enter a non-negative integer: ");
        x = Double.Parse(Console.ReadLine());

        failure = false;
        if (x < 0) {
            Console.WriteLine("Error! You entered a negative value");
            failure = true;
        }
        else if ((int)x != x) {
            Console.WriteLine("Error! You entered a float");
            failure = true;
        }
    } while (failure);

    if (x % 2 == 0) {

```

[\[More...\]](#)

```

        Console.WriteLine("Even");
    }
    else {
        Console.WriteLine("Odd");
    }
}

```

### ***Exercise 30.3-4 Finding the Sum of Four Numbers***

---

*Write a C# program that prompts the user to enter four positive numbers and then calculates and displays their sum. Using a loop control structure, the program must also validate data input and display an error message when the user enters any non-positive value.*

#### ***Solution***

---

This exercise was already discussed in [Exercise 26.1-4](#). The only difference here is that this program must validate data input and display an error message when the user enters invalid values. For your convenience, the solution proposed in that exercise is reproduced here.

```

total = 0;
for (i = 1; i <= 4; i++) {
    Console.Write("Enter a number: ");      [More...]
    x = Double.Parse(Console.ReadLine());
    total += x;
}
Console.WriteLine(total);

```

Now, replace the statement marked with a dashed rectangle with the following code fragment

```

Console.Write("Enter a number: ");
x = Double.Parse(Console.ReadLine());
while (x <= 0) {
    Console.WriteLine("Please enter a positive value!");
    Console.Write("Enter a number: ");
    x = Double.Parse(Console.ReadLine());
}

```

and the final C# program becomes

#### **project\_30\_3\_4**

```

static void Main(string[] args) {
    int i;
    double total, x;
}

```

```

total = 0;
for (i = 1; i <= 4; i++) {
    Console.WriteLine("Enter a number: ");
    x = Double.Parse(Console.ReadLine());
    while (x <= 0) {
        Console.WriteLine("Please enter a positive value!");
        Console.WriteLine("Enter a number: ");
        x = Double.Parse(Console.ReadLine());
    }
    total += x;
}
Console.WriteLine(total);
}

```

[More...]

 The basic purpose of this exercise was to show you how to nest the loop control structure that validates data input into other already existing loop control structures.

## 30.4 Using Loop Control Structures to Solve Mathematical Problems

### **Exercise 30.4-1 Calculating the Area of as Many Triangles as the User Wishes**

Write a C# program that prompts the user to enter the lengths of all three sides A, B, and C of a triangle and then calculates and displays its area. You can use Heron's formula,

$$\text{Area} = \sqrt{S(S - A)(S - B)(S - C)}$$

where S is the semi-perimeter

$$S = \frac{A+B+C}{2}$$

The program must iterate as many times as the user wishes. At the end of each area calculation, the program must ask the user if he or she wishes to calculate the area of another triangle. If the answer is “yes” the program must repeat; it must end otherwise. Make your program accept the answer in all possible forms such as “yes”, “YES”, “Yes”, or even “YeS”.

Moreover, using a loop control structure, the program must validate data input and display an error message when the user enters any non-positive value.

## Solution

---

According to the “Ultimate” rule, the post-test loop structure should be as follows, given in general form.

```
answer = "yes";      //Initialization of answer (redundant).
do {
    Prompt the user to enter the lengths of all three
    sides A, B, C of a triangle and then calculate and
    display its area.
    Console.WriteLine("Would you like to repeat? ");
    answer = Console.ReadLine();           //Update/alteration of answer
} while (answer.ToUpper() == "YES");
```

□ The `ToUpper()` method ensures that the programs operates properly for any given answer “Yes”, “yes”, “YES” or even “YeS” or “yEs”!

The solution to this exercise is as follows.

### project\_30\_4\_1

```
static void Main(string[] args) {
    double a, b, c, s, area;
    string answer;

    do {
        //Prompt the user to enter the length of side A
        Console.WriteLine("Enter side A: ");
        a = Double.Parse(Console.ReadLine());
        while (a <= 0) {
            Console.WriteLine("Invalid side. Enter side A: ");
            a = Double.Parse(Console.ReadLine());
        }

        //Prompt the user to enter the length of side B
        Console.WriteLine("Enter side B: ");
        b = Double.Parse(Console.ReadLine());
        while (b <= 0) {
            Console.WriteLine("Invalid side. Enter side B: ");
            b = Double.Parse(Console.ReadLine());
        }

        //Prompt the user to enter the length of side C
```

```

Console.WriteLine("Enter side C: ");
c = Double.Parse(Console.ReadLine());
while (c <= 0) {
    Console.WriteLine("Invalid side. Enter side C: ");
    c = Double.Parse(Console.ReadLine());
}

//Calculate and display the area of the triangle
s = (a + b + c) / 2;
area = Math.Sqrt(s * (s - a) * (s - b) * (s - c));
Console.WriteLine("The area is: " + area);

Console.WriteLine("Would you like to repeat? ");
answer = Console.ReadLine();
} while (answer.ToUpper() == "YES");
}

```

### ***Exercise 30.4-2 Finding x and y***

---

*Write a C# program that displays all possible integer values of x and y within the range –20 to +20 that validate the following formula:*

$$3x^2 - 6y^2 = 6$$

### ***Solution***

---

If you just want to display **all** possible combinations of variables x and y, you can use the following code fragment.

```

int x, y;

for (x = -20; x <= 20; x++) {
    for (y = -20; y <= 20; y++) {
        Console.WriteLine(x + " " + y);
    }
}

```

However, from all those combinations, you need only those that validate the expression  $3x^2 - 6y^2 = 6$ . A decision control structure is perfect for that purpose! The final C# program is as follows.

#### project\_30\_4\_2

```

static void Main(string[] args) {
    int x, y;

    for (x = -20; x <= 20; x++) {
        for (y = -20; y <= 20; y++) {

```

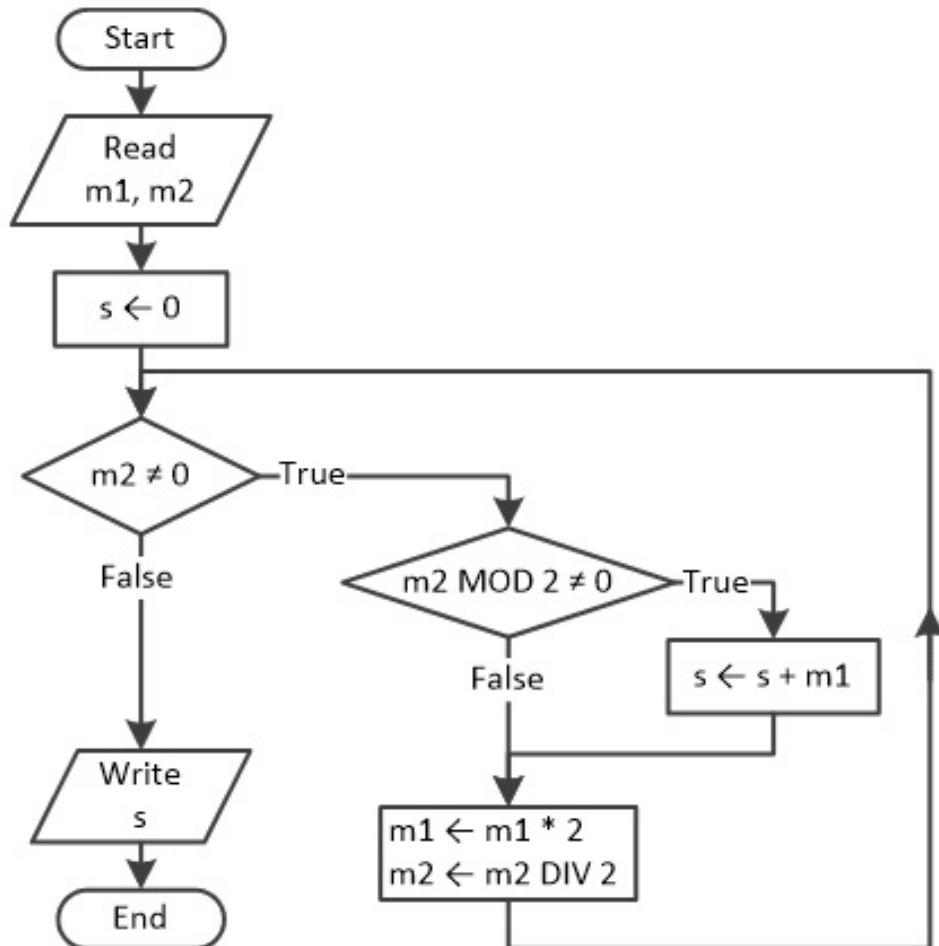
```

        if (3 * Math.Pow(x, 2) - 6 * Math.Pow(y, 2) == 6) {
            Console.WriteLine(x + " " + y);
        }
    }
}

```

### Exercise 30.4-3 The Russian Multiplication Algorithm

You can multiply two positive integers using the “Russian multiplication algorithm”, which is presented in the following flowchart.



Write the corresponding C# program and create a trace table to determine the values of the variables in each step for the input values 5 and 13.

### Solution

In the given flowchart, a single-alternative decision structure is nested within a pre-test loop structure. The corresponding C# program is as follows.

## project\_30\_4\_3

```
static void Main(string[] args) {
    int m1, m2, s;

    m1 = Int32.Parse(Console.ReadLine());
    m2 = Int32.Parse(Console.ReadLine());

    s = 0;
    while (m2 != 0) {
        if (m2 % 2 != 0) {
            s += m1;
        }
        m1 *= 2;
        m2 = (int)(m2 / 2);
    }
    Console.WriteLine(s);
}
```

For the input values of 5 and 13, the trace table looks like this.

Step	Statement	Notes	m1	m2	s
1	m1 = Int32.Parse(...)	User enters the value 5	5	?	?
2	m2 = Int32.Parse(...)	User enters the value 13	5	13	?
3	s = 0		5	13	0
4	while (m2 != 0)	This evaluates to true			
5	if (m2 % 2 != 0)	This evaluates to true			
6	s += m1		5	13	5
7	m1 *= 2		10	13	5
8	m2 = (int)(m2 / 2)		10	6	5
9	while (m2 != 0)	This evaluates to true			
10	if (m2 % 2 != 0)	This evaluates to false			

11	<code>m1 *= 2</code>		20	6	5
12	<code>m2 = (int)(m2 / 2)</code>		20	3	5
13	<code>while (m2 != 0)</code>	This evaluates to true			
14	<code>if (m2 % 2 != 0)</code>	This evaluates to true			
15	<code>s += m1</code>		20	3	25
16	<code>m1 *= 2</code>		40	3	25
17	<code>m2 = (int)(m2 / 2)</code>		40	1	25
18	<code>while (m2 != 0)</code>	This evaluates to true			
19	<code>if (m2 % 2 != 0)</code>	This evaluates to true			
20	<code>s += m1</code>		40	1	65
21	<code>m1 *= 2</code>		80	1	65
22	<code>m2 = (int)(m2 / 2)</code>		80	0	65
23	<code>while (m2 != 0)</code>	This evaluates to false			
24	<code>.WriteLine(s)</code>	The value 65 is displayed which is, of course, the result of the multiplication $5 \times 13$			

### ***Exercise 30.4-4 Finding the Number of Divisors***

---

*Write a C# program that lets the user enter a positive integer and then displays the total number of its divisors.*

### ***Solution***

---

Let's see some examples.

- The divisors of value 12 are numbers 1, 2, 3, 4, 6, 12.
- The divisors of value 15 are numbers 1, 3, 5, 15.
- The divisors of value 20 are numbers 1, 2, 4, 5, 10, 20.

- The divisors of value 50 are numbers 1, 2, 5, 10, 25, 50.

If variable *x* contains the given integer, all possible divisors of *x* are between 1 and *x*. Thus, all you need here is a for-loop where the value of variable *counter* goes from 1 to *x* and, in each iteration, a simple-alternative decision structure checks whether the value of *counter* is a divisor of *x*, The C# program is as follows.

### project\_30\_4\_4a

```
static void Main(string[] args) {
    int x, number_of_divisors, i;

    x = Int32.Parse(Console.ReadLine());

    number_of_divisors = 0;
    for (i = 1; i <= x; i++) {
        if (x % i == 0) {
            number_of_divisors++;
        }
    }
    Console.WriteLine(number_of_divisors);
}
```

This program, for input value 20, performs 20 iterations. However, wouldn't it be even better if it could perform almost the half of the iterations and achieve the same result? Of course it would! So, let's make it more efficient!

As you probably know, for any integer given (in variable *x*)

- the value 1 is always a divisor.
- the integer given is always a divisor of itself.
- except for the integer given, there are no other divisors after the middle of the range 1 to *x*.

Accordingly, for any integer there are certainly 2 divisors, the value 1 and the given integer itself. Therefore, the program must check for other possible divisors starting from the value 2 until the middle of the range 1 to *x*. The improved C# program is as follows.

### project\_30\_4\_4b

```
static void Main(string[] args) {
    int x, number_of_divisors, i;

    x = Int32.Parse(Console.ReadLine());
```

```

number_of_divisors = 2;
for (i = 2; i <= (int)(x / 2); i++) {
    if (x % i == 0) {
        number_of_divisors++;
    }
}
Console.WriteLine(number_of_divisors);
}

```

This C# program performs less than half of the iterations that the previous program did! For example, for the input value 20, this C# program performs only  $(20 - 2) \text{ DIV } 2 = 9$  iterations!

### ***Exercise 30.4-5 Is the Number a Prime?***

*Write a C# program that prompts the user to enter an integer greater than 1 and then displays a message indicating if this number is a prime. A prime number is any integer greater than 1 that has no divisors other than 1 and itself. The numbers 7, 11, and 13 are all such numbers.*

### **Solution**

This exercise is based on the previous one. It is very simple! If the given integer has only two divisors (1 and itself), the number is a prime. The C# program is as follows.

#### project\_30\_4\_5a

```

static void Main(string[] args) {
    int x, number_of_divisors, i;

    Console.Write("Enter an integer greater than 1: ");
    x = Int32.Parse(Console.ReadLine());

    number_of_divisors = 2;
    for (i = 2; i <= (int)(x / 2); i++) {
        if (x % i == 0) {
            number_of_divisors++;
        }
    }

    if (number_of_divisors == 2) {
        Console.WriteLine("Number " + x + " is prime");
    }
}

```

Now let's make the program more efficient. The flow of execution can break out of the loop when a third divisor is found, because this means that the given integer is definitely not a prime. The C# program is as follows.

### project\_30\_4\_5b

```
static void Main(string[] args) {
    int x, number_of_divisors, i;

    Console.WriteLine("Enter an integer greater than 1: ");
    x = Int32.Parse(Console.ReadLine());

    number_of_divisors = 2;
    for (i = 2; i <= (int)(x / 2); i++) {
        if (x % i == 0) {
            number_of_divisors++;
            break;
        }
    }

    if (number_of_divisors == 2) {
        Console.WriteLine("Number " + x + " is prime");
    }
}
```

### ***Exercise 30.4-6 Finding all Prime Numbers from 1 to N***

---

*Write a C# program that prompts the user to enter a positive integer and then displays all prime numbers from 1 to that given integer. Using a loop control structure, the program must also validate data input and display an error message when the user enters any values less than 1.*

### **Solution**

---

The following C# program, given in general form, solves this exercise.

### >Main Code

```
Console.WriteLine("Enter a positive integer: ");
N = Int32.Parse(Console.ReadLine());
while (N < 1) {
    Console.WriteLine("Wrong number. Enter a positive integer: ");
    N = Int32.Parse(Console.ReadLine());
}

for (x = 1; x <= N; x++) {
```

**Code Fragment 1:** Check whether variable x contains a prime number

}

**Code Fragment 1**, shown below, is taken from the previous exercise ([Exercise 30.4-5](#)). It checks whether variable x contains a prime number.

### Code Fragment 1

```
number_of_divisors = 2;
for (i = 2; i <= (int)(x / 2); i++) {
    if (x % i == 0) {
        number_of_divisors++;
        break;
    }
}

if (number_of_divisors == 2) {
    Console.WriteLine("Number " + x + " is prime");
}
```

After embedding **Code Fragment 1** in **Main Code**, the final C# program becomes

### project\_30\_4\_6

```
static void Main(string[] args) {
    int N, x, number_of_divisors, i;

    Console.Write("Enter a positive integer: ");
    N = Int32.Parse(Console.ReadLine());
    while (N < 1) {
        Console.Write("Wrong number. Enter a positive integer: ");
        N = Int32.Parse(Console.ReadLine());
    }

    for (x = 1; x <= N; x++) {
        number_of_divisors = 2;
        for (i = 2; i <= (int)(x / 2); i++) {
            if (x % i == 0) {
                number_of_divisors++;
                break;
            }
        }

        if (number_of_divisors == 2) {
            Console.WriteLine("Number " + x + " is prime");
        }
    }
}
```

```

    }
}
}
```

## Exercise 30.4-7 Heron's Square Root

*Write a C# program that prompts the user to enter a non-negative value and then calculates its square root using Heron's formula, as follows.*

$$x_{n+1} = \frac{\left(x_n + \frac{y}{x_n}\right)}{2}$$

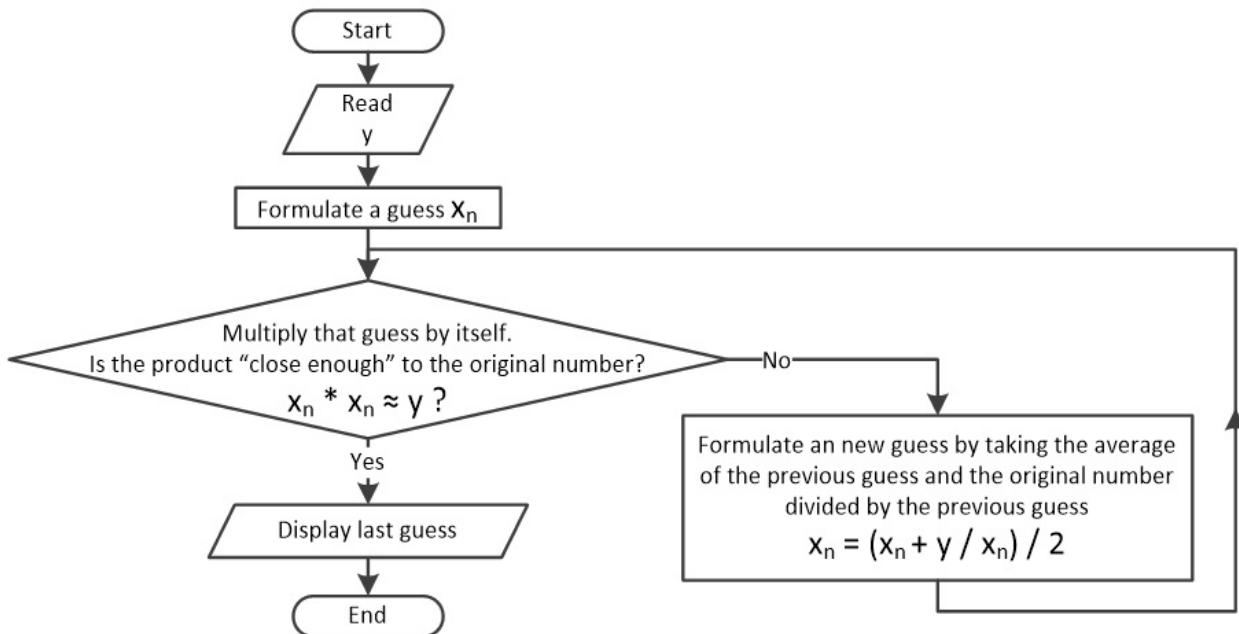
*where*

- $y$  is the number for which you want to find the square root
- $x_n$  is the  $n$ -th iteration value of the square root of  $y$

*Moreover, using a loop control structure, the program must validate data input and display an error message when the user enters any negative values.*

## Solution

It is almost certain that you are a little bit confused and you are scratching your head right now. Don't be scared by all this math stuff! You can try to understand Heron's formula through the following flowchart instead!



Still confused? Let's see an example. Let's find the square root of 25:

- ▶ Assume 8 as your first guess.
- ▶ The product of  $8 \times 8$  is 64.
- ▶ Since 64 isn't "close enough" to 25, you can create a new guess by calculating the expression

$$\frac{\left(\text{guess} + \frac{\text{number}}{\text{guess}}\right)}{2} = \frac{\left(8 + \frac{25}{8}\right)}{2} \approx 5.56$$

- ▶ The product of  $5.56 \times 5.56$  is about 30.91
  - ▶ Since 30.91 isn't "close enough" to 25 you can create a new guess by calculating the expression
- $$\frac{\left(\text{guess} + \frac{\text{number}}{\text{guess}}\right)}{2} = \frac{\left(5.56 + \frac{25}{5.56}\right)}{2} \approx 5.02$$
- ▶ The product of  $5.02 \times 5.02$  is 25.2
  - ▶ Now you can say that 25.2 is "close enough" to 25. Therefore, you can stop the whole process and say that the approximate square root of 25 is 5.02

Now, let's see the corresponding C# program.

### project\_30\_4\_7

```
const double ACCURACY = 0.0000000000001;

static void Main(string[] args) {
    double y, guess;

    Random rnd = new Random();

    Console.WriteLine("Enter a non-negative number: ");
    y = Double.Parse(Console.ReadLine());
    while (y < 0) {
        Console.WriteLine("Invalid value. Enter a non-negative number: ");
        y = Double.Parse(Console.ReadLine());
    }

    guess = rnd.Next(1, (int)y); //Make a random first guess between 1 and given value

    while (Math.Abs(guess * guess - y) > ACCURACY) { //Is it "close enough"?
```

```

        guess = (guess + y / guess) / 2;      //No, create a new "guess"!
    }
    Console.WriteLine(guess);
}

```

 Note the way that “Is it close enough” is checked. When the absolute value of the difference  $|guess^2 - y|$  becomes less than 0.0000000000001 (where  $y$  is the given value), the flow of execution exits the loop.

### Exercise 30.4-8 Calculating $\pi$

Write a C# program that calculates  $\pi$  using the Madhava–Leibniz<sup>[18],[19]</sup> series, which follows, with an accuracy of 0.00001.

$$\frac{\pi}{4} = 1 - \frac{1}{3} + \frac{1}{5} - \frac{1}{7} + \dots$$

#### Solution

The Madhava–Leibniz series can be solved for  $\pi$ , and becomes

$$\pi = \frac{4}{1} - \frac{4}{3} + \frac{4}{5} - \frac{4}{7} + \dots$$

The more fractions you have, the better the accuracy! Thus, to calculate this formula the program needs to perform many iterations so as to use as many fractions as possible. But, of course, it can't iterate forever! The loop must actually stop iterating when the current value of  $\pi$  and the one calculated in the previous iteration are ”close enough”, which means that the absolute value of their difference has become very small. The constant ACCURACY defines how small this difference must be. The C# program is shown here.

#### project\_30\_4\_8

```

const double ACCURACY = 0.00001;

static void Main(string[] args) {
    double pi, pi_previous;
    int sign, denom;

    pi = 0;

    sign = 1;          //This is the sign of the first fraction
    denom = 1;         //This is the denominator of the first fraction
    do {
        pi_previous = pi;           //Keep previous pi

```

```

        pi += sign * 4 / (double)denom; //Calculate new pi by adding an extra fraction
        sign = -sign;                //Prepare sign for the next fraction
        denom += 2;                  //Prepare denominator for the next fraction
    } while (Math.Abs(pi - pi_previous) > ACCURACY); //Is it "close enough"?

    Console.WriteLine("Pi ~= " + pi);
}

```

 Note the way in which variable sign toggles between the values  $-1$  and  $+1$  in each iteration.

If you reduce the value of the constant ACCURACY,  $\pi$  will be calculated more and more accurately. Depending on how fast your computer is, you can calculate the first five digits of  $\pi$  fairly quickly. However, the time it takes to calculate each succeeding digit of  $\pi$  goes up exponentially. To calculate 40 digits of  $\pi$  on a modern computer using this method could take years!

### ***Exercise 30.4-9 Approximating a Real with a Fraction***

*Write a C# program that prompts the user to enter a real between 0 and 100 and then tries to find the fraction  $\frac{N}{M}$  that better approximates it, where  $N$  is an integer between 0 and 100 and  $M$  is an integer between 1 and 100. Using a loop control structure, the program must also validate data input, allowing the user to enter only values between 0 and 100. There is no need to display any error messages.*

### ***Solution***

The solution is simple. All you need to do is iterate through all possible combinations of variables  $n$  and  $m$  and check which one better approximates the real given.

To iterate through all possible combinations of variables  $n$  and  $m$ , you can use a nested loop control structure, that is, two for-loops, one nested within the other, as follows.

```

for (n = 0; n <= 100; n++) {
    for (m = 1; m <= 100; m++) {
        ...
    }
}

```

☞ The total number of iterations is  $101 \times 100 = 10100$ . Quite a big number but, for a modern computer, this is peanuts!

☞ Variable `m` represents the denominator of the fraction, and a denominator cannot be zero. This is why it starts from 1, and not from 0.

The following criteria

$$\text{minimum of } \left( \left| \frac{N}{M} - \text{real given} \right| \right)$$

can evaluate how “good” an approximation is.

Confused? Let's try to approximate the value 0.333 with a fraction, iterating through all possible combinations of N and M.

- ▶ For  $N = 1, M = 1$  the criteria equals to  $\left| \frac{1}{1} - 0.333 \right| = 0.6670$
- ▶ For  $N = 1, M = 2$  the criteria equals to  $\left| \frac{1}{2} - 0.333 \right| = 0.1670$
- ▶ For  $N = 1, M = 3$  the criteria equals to  $\left| \frac{1}{3} - 0.333 \right| = 0.0003$
- ▶ For  $N = 1, M = 4$  the criteria equals to  $\left| \frac{1}{4} - 0.333 \right| = 0.0830$
- ▶ ...
- ▶ For  $N = 100, M = 99$  the criteria equals to  $\left| \frac{100}{99} - 0.333 \right| = 0.6771$
- ▶ For  $N = 100, M = 100$  the criteria equals to  $\left| \frac{100}{100} - 0.333 \right| = 0.6670$

It is obvious that the value 0.0003 is the minimum value among all possible results. Thus, the combination  $N = 1$  and  $M = 3$  (which corresponds to the fraction  $1/3$ ) is considered the best approximation for the value 0.333.

And now the C# program:

### □ project\_30\_4\_9

```
static void Main(string[] args) {  
    double x, y, minimum;
```

```

int best_n, best_m, n, m;

do {
    Console.WriteLine("Enter a real between 0 and 100: ");
    x = Double.Parse(Console.ReadLine());
} while (x < 0 || x > 100);

best_n = best_m = 1;
minimum = 100;
for (n = 0; n <= 100; n++) {
    for (m = 1; m <= 100; m++) {
        y = Math.Abs(n / (double)m - x);
        if (y < minimum) {
            minimum = y;
            best_n = n;
            best_m = m;
        }
    }
}
Console.WriteLine("The fraction is: " + best_n + " / " + best_m);
}

```

 Converting variable `m` to type `double` tricks C# and a normal division is performed (a division that returns a real). If you omit the `(double)` casting operator, since both dividend and divisor are of type `integer`, C# performs an integer division and produces incorrect results.

## 30.5 Finding Minimum and Maximum Values with Loop Control Structures

In [paragraph 23.3](#) you learned how to find the minimum and maximum values among four values using single-alternative decision structures. Now, the following code fragment does pretty much the same but uses only one variable `w` to hold all of the user's given values.

```

w = Int32.Parse(Console.ReadLine());      //User enters 1st value
maximum = w;

w = Int32.Parse(Console.ReadLine());      //User enters 2nd value
if (w > maximum) {
    maximum = w;
}

w = Int32.Parse(Console.ReadLine());      //User enters 3rd value

```

```

if (w > maximum) {
    maximum = w;
}

w = Int32.Parse(Console.ReadLine());      //User enters 4th value
if (w > maximum) {
    maximum = w;
}

```

Except for the first pair of statements, all other blocks of statements are identical; therefore, only one of those can be enclosed within a loop control structure and be executed three times, as follows.

```

w = Int32.Parse(Console.ReadLine());      //User enters 1st value
maximum = w;

for (i = 1; i <= 3; i++) {
    w = Int32.Parse(Console.ReadLine());  //User enters 2nd, 3rd and 4th value
    if (w > maximum) {
        maximum = w;
    }
}

```

Of course, if you want to allow the user to enter more values, you can simply increase the *final\_value* of the for-loop.

Accordingly, if you want a program that finds and displays the heaviest person among 10 people, the solution is presented next.

### project\_30\_5a

```

static void Main(string[] args) {
    int w, maximum, i;

    Console.Write("Enter a weight (in pounds): ");
    w = Int32.Parse(Console.ReadLine());
    maximum = w;

    for (i = 1; i <= 9; i++) {
        Console.Write("Enter a weight (in pounds): ");
        w = Int32.Parse(Console.ReadLine());
        if (w > maximum) {
            maximum = w;
        }
    }

    Console.WriteLine(maximum);
}

```

```
| }
```

 Note that the for-loop iterates one time less than the total number of values given.

Even though this C# program operates perfectly well, let's do something different. Instead of prompting the user to enter one value before the loop and nine values inside the loop, let's prompt him or her to enter all values inside the loop.

The problem that arises here is that no matter what, before the loop starts iterating, an initial value must be assigned to variable `maximum`. However, you cannot assign any initial value. It depends on the given problem. An “almost arbitrary” initial value must be chosen carefully, since a wrong one may lead to incorrect results.

In this exercise, all given values have to do with people's weight. Since there is no chance of finding any person with a negative weight (at least not on planet Earth), you can safely assign the initial value `-1` to variable `maximum`, as follows.

### project\_30\_5b

```
static void Main(string[] args) {
    int maximum, i, w;

    maximum = -1;

    for (i = 1; i <= 10; i++) {
        Console.WriteLine("Enter a weight (in pounds): ");
        w = Int32.Parse(Console.ReadLine());

        if (w > maximum) {
            maximum = w;
        }
    }
    Console.WriteLine(maximum);
}
```

As soon as the flow of execution enters the loop, the user enters the first value and the decision control structure validates to true. The value `-1` in variable `maximum` is overwritten by that first given value and after that, flow of execution proceeds normally.

 Note that this method cannot be used in every case. If an exercise needs to prompt the user to enter any number (not only a positive one) this method cannot be applied since the user could potentially enter only negative values. If this were to occur, the initial value `-1` would never be overwritten by any of the given values. You can use this method to find the maximum value only when you know the lower limit of given values or to find the minimum value only when you know the upper limit of given values. For example, if the exercise needs to find the lightest person, you can assign the initial value `+1500` to variable `minimum`, since there is no human on Earth that can be so heavy! For the record, Jon Brower Minnoch was an American who, at his peak weight, was the heaviest human being ever recorded, weighing approximately `1.400 lb!!!!`

### **Exercise 30.5-1 Validating and Finding the Minimum and the Maximum Value**

Write a C# program that prompts the user to enter the weight of 10 people and then finds the lightest and the heaviest weights. Using a loop control structure, the program must also validate data input and display an error message when the user enters any non-positive value, or any value greater than 1500.

#### **Solution**

Using the previous exercise as a guide, you should now be able to do this with your eyes closed!

To validate data input, all you have to do is replace the following two lines of code of the previous exercise,

```
Console.WriteLine("Enter a weight (in pounds): ");
w = Int32.Parse(Console.ReadLine());
```

with the following code fragment:

```
Console.WriteLine("Enter a weight (in pounds): ");
w = Int32.Parse(Console.ReadLine());
while (w < 1 || w > 1500) {
    Console.WriteLine("Invalid value! Enter a weight between 1 and 1500 (in pounds):");
    w = Int32.Parse(Console.ReadLine());
}
```

Following is the final program that finds the lightest and the heaviest weights.

## project\_30\_5\_1

```
static void Main(string[] args) {
    int minimum, maximum, i, w;

    minimum = 1500;
    maximum = 0;

    for (i = 1; i <= 10; i++) {
        Console.WriteLine("Enter a weight (in pounds): ");
        w = Int32.Parse(Console.ReadLine());
        while (w < 1 || w > 1500) {
            Console.WriteLine("Invalid value! Enter a weight between 1 and 1500 (in pounds)");
            w = Int32.Parse(Console.ReadLine());
        }

        if (w < minimum) {
            minimum = w;
        }

        if (w > maximum) {
            maximum = w;
        }
    }

    Console.WriteLine(minimum + " " + maximum);
}
```

### Exercise 30.5-2 Validating and Finding the Hottest Planet

*Write a C# program that prompts the user to repeatedly enter the names and the average temperatures of planets from space, until the word “STOP” (used as a name) is entered. In the end, the program must display the name of the hottest planet. Moreover, since  $-459.67^{\circ}$  (on the Fahrenheit scale) is the lowest temperature possible (it is called absolute zero), the program must also validate data input (using a loop control structure) and display an error message when the user enters temperature values lower than absolute zero.*

### Solution

First, let's write the C# program without using data validation. According to the “Ultimate” rule, the pre-test loop structure should be as follows, given in general form:

```

Console.WriteLine("Enter the name of a planet: ");
name = Console.ReadLine();      //Initialization of name
while (name.ToUpper() != "STOP") {
    A statement or block of statements
}

Console.WriteLine("Enter the name of a planet: ");
name = Console.ReadLine();      //Update/alteration of name
}

```

Now, let's add the rest of the statements, still without data input validation. Keep in mind that, since value  $-459.67^{\circ}$  is the lower limit of the temperature scale, you can use a value lower than this as the initial value of variable **maximum**.

```

maximum = -460;
m_name = "";

Console.WriteLine("Enter the name of a planet: ");
name = Console.ReadLine();      //Initialization of name
while (name.ToUpper() != "STOP") {
    Console.WriteLine("Enter its average temperature: ");
    t = Double.Parse(Console.ReadLine());

    if (t > maximum) {
        maximum = t;
        m_name = name;
    }

    Console.WriteLine("Enter the name of a planet: ");
    name = Console.ReadLine();      //Update/alteration of name
}

if (maximum != -460) {
    Console.WriteLine("The hottest planet is: " + m_name);
}
else {
    Console.WriteLine("Nothing Entered!");
}

```

 The `if maximum != -460` statement is required because there is a possibility that the user could enter the word “STOP” right from the beginning.

To validate the data input, all you have to do is replace the following two

lines of code:

```
Console.WriteLine("Enter its average temperature: ");
t = Double.Parse(Console.ReadLine());
```

with the following code fragment:

```
Console.WriteLine("Enter its average temperature: ");
t = Double.Parse(Console.ReadLine());
while (t < -459.67) {
    Console.WriteLine("Invalid value! Enter its average temperature: ");
    t = Double.Parse(Console.ReadLine());
}
```

The final program is as follows.

### project\_30\_5\_2

```
static void Main(string[] args) {
    double maximum, t;
    string m_name, name;

    maximum = -460;
    m_name = "";

    Console.WriteLine("Enter the name of a planet: ");
    name = Console.ReadLine();
    while (name.ToUpper() != "STOP") {
        Console.WriteLine("Enter its average temperature: ");
        t = Double.Parse(Console.ReadLine());
        while (t < -459.67) {
            Console.WriteLine("Invalid value! Enter its average temperature: ");
            t = Double.Parse(Console.ReadLine());
        }

        if (t > maximum) {
            maximum = t;
            m_name = name;
        }
    }

    Console.WriteLine("Enter the name of a planet: ");
    name = Console.ReadLine();
}

if (maximum != -460) {
    Console.WriteLine("The hottest planet is: " + m_name);
}
else {
```

```
        Console.WriteLine("Nothing Entered!");
    }
}
```

### ***Exercise 30.5-3 "Making the Grade"***

---

*In a classroom, there are 20 students. Write a C# program that prompts the teacher to enter the grades (0 – 100) that students received in a math test and then displays the highest grade as well as the number of students that got an “A” (that is, 90 to 100). Moreover, the program must validate data input. Given values must be within the range 0 to 100.*

### **Solution**

---

Let's first write the program without data validation. Since the number of students is known, you can use a for-loop. For an initial value of variable maximum, you can use value -1 as there is no grade lower than 0.

```
maximum = -1;
count = 0;

for (i = 1; i <= 20; i++) {
    Console.Write("Grade for student No " + i + ": ");
    grade = Int32.Parse(Console.ReadLine());

    if (grade > maximum) {
        maximum = grade;
    }
    if (grade >= 90) {
        count++;
    }
}
Console.WriteLine(maximum + " " + count);
```

Now, you can deal with data validation. As the wording of the exercise implies, there is no need to display any error messages. So, all you need to do is replace the following two lines of code:

```
Console.Write("Enter a grade for student No " + i + ": ");
grade = Int32.Parse(Console.ReadLine());
```

with the following code fragment:

```
do {
    Console.Write("Grade for student No " + i + ": ");
    grade = Int32.Parse(Console.ReadLine());
} while (grade < 0 || grade > 100);
```

and the final program becomes

```
project_30_5_3
static void Main(string[] args) {
    int maximum, count, i, grade;

    maximum = -1;
    count = 0;

    for (i = 1; i <= 20; i++) {
        do {
            Console.WriteLine("Grade for student No " + i + ": ");
            grade = Int32.Parse(Console.ReadLine());
        } while (grade < 0 || grade > 100);

        if (grade > maximum) {
            maximum = grade;
        }
        if (grade >= 90) {
            count++;
        }
    }
    Console.WriteLine(maximum + " " + count);
}
```

## 30.6 Exercises of a General Nature with Loop Control Structures

### Exercise 30.6-1 Fahrenheit to Kelvin, from 0 to 100

Write a C# program that displays all degrees Fahrenheit from 0 to 100 and their equivalent degrees Kelvin. Use an increment value of 0.5. It is given that

$$1.8 \cdot \text{Kelvin} = \text{Fahrenheit} + 459.67$$

### Solution

The formula, solved for Kelvin becomes

$$\text{Kelvin} = \frac{\text{Fahrenheit} + 459.67}{1.8}$$

All you need here is a for-loop that increments the value of variable fahrenheit from 0 to 100 using an offset of 0.5. The solution is presented

next.

## project\_30\_6\_1

```
static void Main(string[] args) {
    double fahrenheit, kelvin;

    for (fahrenheit = 0; fahrenheit <= 100; fahrenheit += 0.5) {
        kelvin = (fahrenheit + 459.67) / 1.8;
        Console.WriteLine("Fahrenheit: " + fahrenheit + " Kelvin: " + kelvin);
    }
}
```

### Exercise 30.6-2 Rice on a Chessboard

*There is a myth about a poor man who invented chess. The King of India was so pleased with that new game that he offered to give the poor man anything he wished for. The poor but wise man told his King that he would like one grain of rice for the first square of the board, two grains for the second, four grains for the third and so on, doubled for each of the 64 squares of the game board. This seemed to the King to be a modest request, so he ordered his servants to bring the rice.*

*Write a C# program that calculates and displays how many grains of rice, and how many pounds of rice, will be on the chessboard in the end. Suppose that one pound of rice contains about 30,000 grains of rice.*

### Solution

Assume a chessboard of only  $2 \times 2 = 4$  squares and a variable grains assigned the initial value 1 (this is the number of grains of the 1<sup>st</sup> square). A for-loop that iterates three times can double the value of variable grains in each iteration, as shown in the next code fragment.

```
grains = 1;
for (i = 2; i <= 4; i++) {
    grains = 2 * grains;
}
```

The value of variable grains at the end of each iteration is shown in the next table.

Iteration	Value of grains
1st	$2 \times 1 = 2$

2nd	$2 \times 2 = 4$
3rd	$2 \times 4 = 8$

At the end of the 3<sup>rd</sup> iteration, variable grains contains the value 8. This value is not the total number of grains on the chessboard but only the number of grains on the 4<sup>th</sup> square. If you need to find the total number of grains on the chessboard you can sum up the grains on all squares, that is,  $1 + 2 + 4 + 8 = 15$ .

In the real world a real chessboard contains  $8 \times 8 = 64$  squares, thus you need to iterate for 63 times. The C# program is as follows.

### project\_30\_6\_2

```
static void Main(string[] args) {
    int i;
    ulong grains, total;
    double weight;

    grains = 1;
    total = 1;
    for (i = 2; i <= 64; i++) {
        grains = 2 * grains;
        total = total + grains;
    }

    weight = total / 30000;

    Console.WriteLine(total + " " + weight);
}
```

In case you are wondering how big these numbers are, here is your answer: On the chessboard there will be 18,446,744,073,709,551,615 grains of rice; that is, 614,891,469,123,651.8 pounds!

 *The reason for not declaring variables grains and total as int or even long is that both types are unable to hold such big numbers. The upper limit of type long is  $+2^{63} - 1$  which, unfortunately, is not enough.*

### Exercise 30.6-3 Just a Poll

A public opinion polling company asks 1000 citizens if they eat breakfast in the morning. Write a C# program that prompts the citizens to enter their gender (M for Male, F for Female) and their answer to the question (Y for

*(Yes, N for No, S for Sometimes), and then calculates and displays the number of citizens that gave “Yes” as an answer, as well as the percentage of women among the citizens that gave “No” as an answer. Using a loop control structure, the program must also validate data input and accept only values M or F for gender and Y, N, or S for answer.*

## Solution

---

The C# program is as follows.

### project\_30\_6\_3

```
const int CITIZENS = 1000;

static void Main(string[] args) {
    int total_yes, female_no, i;
    string gender, answer;

    total_yes = 0;
    female_no = 0;
    for (i = 1; i <= CITIZENS; i++) {
        do {
            Console.WriteLine("Enter Gender: ");
            gender = Console.ReadLine().ToLower();
        } while (gender != "m" && gender != "f");

        do {
            Console.WriteLine("Do you eat breakfast in the morning? ");
            answer = Console.ReadLine().ToLower();
        } while (answer != "y" && answer != "n" && answer != "s");

        if (answer == "y") {
            total_yes++;
        }
        if (gender == "f" && answer == "n") {
            female_no++;
        }
    }
    Console.WriteLine(total_yes + " " + female_no * 100 / (double)CITIZENS);
}
```



*Note how C# converts the user's input to lowercase.*

## Exercise 30.6-4 Is the Message a Palindrome?

A *palindrome* is a word or sentence that reads the same both backwards and forward. (You may recall from [Exercise 23.5-3](#) that a number can also be a palindrome!) Write a C# program that prompts the user to enter a word or sentence and then displays a message stating whether or not the given word or sentence is a palindrome. Following are some palindrome messages.

- ▶ Anna
- ▶ A nut for a jar of tuna.
- ▶ Dennis and Edna sinned.
- ▶ Murder for a jar of red rum.
- ▶ Borrow or rob?
- ▶ Are we not drawn onward, we few, drawn onward to new era?

### **Solution**

---

There are some things that you should keep in mind before you start comparing the letters one by one and checking whether the first letter is the same as the last one, the second letter is the same as the last but one, and so on.

- ▶ In a given sentence or word, some letters may be in uppercase and some in lowercase. For example, in the sentence “A nut for a jar of tuna”, even though the first and last letters are the same, unfortunately they are not considered equal. Thus, the program must first change all the letters—for example, to lowercase—and then it can start comparing them.
- ▶ There are some characters such as spaces, periods, question marks, and commas that should be removed or else the program cannot actually compare the rest of the letters one by one. For example, in the sentence “Borrow or rob?” the C# program may mistakenly assume that the sentence is not a palindrome because it will compare the first letter “B” with the last question mark “?”
- ▶ Assume that the sentence “Borrow or rob?”, after changing all letters to lowercase and after removing all unwanted spaces and the question mark, becomes “borroworrob”. These letters and their corresponding position in the string are as follows.

0	1	2	3	4	5	6	7	8	9	10
b	o	r	r	o	w	o	r	r	o	b

What you should keep in mind here is that the for-loop should iterate for only half of the letters. Can you figure out why?

The program starts the iterations and compares the letter at position 0 with the letter at position 10. Then it compares the letter at position 1 with the letter at position 9, and so on. The last iteration should be the one that compares the letters at positions 4 and 6. It is meaningless to continue checking thereafter, since all letters have already been compared.

There are many solutions to this problem. Some of them are presented below. Comments written within the programs can help you fully understand the way they operate. However, if you still have doubts about how they operate you can still use Visual Studio to execute them step by step and observe the values of the variables in each step.

## First Approach

The solution is presented here.

### project\_30\_6\_4a

```
static void Main(string[] args) {
    int i, middle_pos, j;
    string message, message_clean, letter, left_letter, right_letter;
    bool palindrome;

    Console.WriteLine("Enter a message: ");
    message = Console.ReadLine().ToLower();

    //Create a new string which contains all except spaces, commas, periods and question
    message_clean = "";
    for (i = 0; i <= message.Length - 1; i++) {
        letter = "" + message[i];
        if (letter != " " && letter != "," && letter != "." && letter != "?") {
            message_clean += letter;
        }
    }

    //This is the last position of message_clean
    j = message_clean.Length - 1;

    //This is the middle position of message_clean
    middle_pos = (int)(j / 2);

    //In the beginning, assume that sentence is palindrome
```

```

palindrome = true;

//This for-loop compares letters one by one.
for (i = 0; i <= middle_pos; i++) {
    left_letter = "" + message_clean[i];
    right_letter = "" + message_clean[j];
    //If at least one pair of letters fails to validate set variable palindrome to false
    if (left_letter != right_letter) {
        palindrome = false;
    }
    j--;
}

//If variable palindrome is still true
if (palindrome) {
    Console.WriteLine("The message is palindrome");
}
}

```

## Second Approach

The previous approach works fine, but assume that the user enters a very large sentence that is not a palindrome. Let's say, for example, that the second letter is not the same as the last but one. Unfortunately, in the previous approach the last for-loop continues to iterate until the middle of the sentence despite the fact that variable `palindrome` has been set to `false`, even from the second iteration. So, let's try to make this program even better. As you already know, you can break out of a loop before it completes all of its iterations using the `break` statement.

Furthermore, since there are just four different characters that must be removed (spaces, commas, periods, and question marks) you can avoid the first loop if you just chain four `Replace()` methods, as shown in the C# program that follows.

### project\_30\_6\_4b

```

static void Main(string[] args) {
    int i, middle_pos, j;
    string message, message_clean, left_letter, right_letter;
    bool palindrome;

    Console.Write("Enter a message: ");
    message = Console.ReadLine().ToLower();

```

```

//Create a new string which contains all except spaces, commas, periods and question
message_clean = message.Replace(" ", "").Replace(",", "").Replace(".", "").Replace("?", "")

j = message_clean.Length - 1;
middle_pos = (int)(j / 2);

palindrome = true;
for (i = 0; i <= middle_pos; i++) {
    left_letter = "" + message_clean[i];
    right_letter = "" + message_clean[j];
    if (left_letter != right_letter) {
        palindrome = false;
        break;
    }
    j--;
}

if (palindrome) {
    Console.WriteLine("The message is palindrome");
}
}

```

 It is obvious that one problem can have many solutions. It is up to you to find the optimal one!

## 30.7 Review Questions: True/False

Choose **true** or **false** for each of the following statements.

1. Data validation is the process of restricting data input, forcing the user to enter only valid values.
2. You can use a for-loop to validate data input.
3. You can use any loop control structure to validate data input.
4. To force a user to enter only positive numbers, without displaying any error messages, you can use the following code fragment.

```

do {
    Console.Write("Enter a positive number: ");
    x = Double.Parse(Console.ReadLine());
} while (x <= 0);

```

5. To force a user to enter numbers between 1 and 10, you can use the following code fragment.

```
Console.Write("Enter a number between 1 and 10: ");
```

```

x = Double.Parse(Console.ReadLine());
while (x >= 1 && x <= 10) {
    Console.WriteLine("Wrong number");
    Console.Write("Enter a number between 1 and 10: ");
    x = Double.Parse(Console.ReadLine());
}

```

6. When a C# program is used to find the maximum value among 10 given values, the loop control structure that is used must always iterate 9 times.
7. In order to find the lowest number among 10 numbers given, you can use the following code fragment.

```

minimum = 0;
for (i = 1; i <= 10; i++) {
    w = Double.Parse(Console.ReadLine());
    if (w < minimum)
        minimum = w;
}

```

8. In order to find the highest number among 10 numbers given, you can use the following code fragment.

```

maximum = 0;
for (i = 1; i <= 10; i++) {
    w = Double.Parse(Console.ReadLine());
    if (w > maximum) {
        maximum = w;
    }
}

```

9. In order to find the highest number among 10 positive numbers given, you can use the following code fragment.

```

maximum = 0;
for (i = 1; i <= 10; i++) {
    w = Double.Parse(Console.ReadLine());
    if (w > maximum) {
        maximum = w;
    }
}

```

## 30.8 Review Exercises

Complete the following exercises.

1. Design a flowchart and write the corresponding C# program that prompts the user to repeatedly enter non-negative values until their

average value exceeds 3000. At the end, the program must display the total number of zeros entered.

2. Write a C# program that prompts the user to enter an integer between 1 and 20 and then displays all four-digit integers for which the sum of their digits is less than the integer given. For example, if the user enters 15, the value 9301 is such a number, since

$$9 + 3 + 0 + 1 < 15$$

3. Write a C# program that displays all four-digit integers that satisfy all of the following conditions:

- ▶ the number's first digit is greater than its second digit
- ▶ the number's second digit is equal to its third digit
- ▶ the number's third digit is smaller than its fourth digit

For example, the values 7559, 3112, and 9889 are such numbers.

4. Write a C# program that prompts the user to enter an integer and then displays the number of its digits.

5. A student wrote the following code fragment which is supposed to validate data input, forcing the user to enter only values 0 and 1. Identify any error(s) in the code fragment.

```
while (x != 1 || x != 0) {  
    Console.WriteLine("Error");  
    x = Int32.Parse(Console.ReadLine());  
}
```

6. Using a loop control structure, write the code fragment that validates data input, forcing the user to enter a valid gender (M for Male, F for Female). Moreover, it must validate correctly both for lowercase and uppercase letters.
7. Write a C# program that prompts the user to enter a non-negative number and then calculates its square root. Using a loop control structure, the program must also validate data input and display an error message when the user enters any negative values. Additionally, the user has a maximum number of two retries. If the user enters more than three negative values, a message “Dude, you are dumb!” must be displayed and the program execution must end.
8. The area of a circle can be calculated using the following formula:

$$Area = \pi \cdot Radius^2$$

Write a C# program that prompts the user to enter the length of the radius of a circle and then calculates and displays its area. The program must iterate as many times as the user wishes. At the end of each area calculation, the program must ask the user if he or she wishes to calculate the area of another circle. If the answer is “yes” the program must repeat; it must end otherwise. Make your program accept the answer in all possible forms such as “yes”, “YES”, “Yes”, or even “YeS”.

Moreover, using a loop control structure, the program must validate data input and display an error message when the user enters any non-positive value for *Radius*.

Hint: Use the `Math.PI` constant to get the value of  $\pi$ .

9. Write a C# program that displays all possible integer values of  $x$  and  $y$  within the range  $-100$  to  $+100$  that validate the following formula:

$$5x + 3y^2 = 0$$

10. Write a C# program that displays all possible integer values of  $x$ ,  $y$ , and  $z$  within the range  $-10$  to  $+10$  that validate the following formula:

$$\frac{x+y}{2} + \frac{3z^2}{x+3y+45} = \frac{x}{3}$$

11. Write a C# program that lets the user enter three positive integers and then finds their product using the Russian multiplication algorithm.
12. Rewrite the C# program of [Exercise 30.4-4](#) to validate the data input using a loop control structure. If the user enters a non-positive integer, an error message must be displayed.
13. Rewrite the C# program of [Exercise 30.4-5](#) to validate the data input using a loop control structure. If the user enters an integer less than or equal to 1, an error message must be displayed.
14. Write a C# program that prompts the user to enter two positive integers and then displays all prime integers between them. Using a loop control structure, the program must also validate data input and display an error message when the user enters a value less than  $+2$ .

Hint: To make your C# program operate correctly, independent of which integer given is the lowest, you can swap their values (if

necessary) so that they are always in the proper order.

15. Write a C# program that prompts the user to enter two positive four-digit integers and then displays all integers between them that are palindromes. Using a loop control structure, the program must also validate data input and display an error message when the user enters any numbers other than four-digit ones.

Hint: To make your C# program operate correctly, independent of which integer given is the lowest, you can swap their values (if necessary) so that they are always in the proper order.

16. Write a C# program that displays all possible RAM sizes between 1 byte and 1GByte, such as 1, 2, 4, 8, 16, 32, 64, 128, and so on.

Hint: 1GByte equals  $2^{30}$  bytes, or 1073741824 bytes

17. Write a C# program that displays the following sequence of numbers:

$$1, 11, 23, 37, 53, 71, 91, 113, 137, \dots 401$$

18. Write a C# program that displays the following sequence of numbers:

$$-1, 1, -2, 2, -3, 3, -4, 4, \dots -100, 100$$

19. Write a C# program that displays the following sequence of numbers:

$$1, 11, 111, 1111, 11111, \dots 11111111$$

20. The Fibonacci<sup>[20]</sup> sequence is a series of numbers in the following sequence:

$$1, 1, 2, 3, 5, 8, 13, 21, 34, 55, \dots$$

By definition, the first two numbers are 1 and 1 and each subsequent number is the sum of the previous two.

Write a C# program that lets the user enter a positive integer and then displays as many Fibonacci numbers as that given integer.

21. Write a C# program that lets the user enter a positive integer and then displays all Fibonacci numbers that are less than that given integer.

22. Write a C# program that prompts the user to enter a positive integer N and then finds and displays the value of y in the following formula:

$$y = \frac{2 + 4 + 6 + \dots + 2N}{1 \cdot 2 \cdot 3 \cdot 4 \cdot \dots \cdot N}$$

Moreover, using a loop control structure, the program must validate

data input and display an error message when the user enters a value less than 1.

23. Write a C# program that prompts the user to enter a positive integer N and then finds and displays the value of y in the following formula

$$y = \frac{1 - 3 + 5 - 7 + \dots + (2N + 1)}{N}$$

Moreover, using a loop control structure, the program must validate data input and display an error message when the user enters a non-positive value.

24. Write a C# program that prompts the user to enter a positive integer N and then finds and displays the value of y in the following formula:

$$y = 1 - \frac{1}{2} + \frac{1}{3} - \frac{1}{5} + \dots + \frac{1}{N}$$

Moreover, using a loop control structure, the program must validate data input and display an error message when the user enters a non-positive value.

25. Write a C# program that prompts the user to enter a positive integer N and then finds and displays the value of y in the following formula:

$$y = \frac{1}{1^N} + \frac{1}{2^{N-1}} + \frac{1}{3^{N-2}} + \dots + \frac{1}{N^1}$$

Moreover, using a loop control structure, the program must validate data input and display an error message when the user enters a non-positive value.

26. In mathematics, the factorial of a non-negative integer N is the product of all positive integers less than or equal to N, and it is denoted by N!. The factorial of 0 is, by definition, equal to 1. In mathematics, you can write

$$N! = \begin{cases} 1 \cdot 2 \cdot 3 \cdot \dots \cdot N, & \text{for } N > 0 \\ 1, & \text{for } N = 0 \end{cases}$$

For example, the factorial of 5 is written as 5! and is equal to  $1 \times 2 \times 3 \times 4 \times 5 = 120$ .

Write a C# program that prompts the user to enter a non-negative integer N and then calculates its factorial.

27. Write a C# program that lets the user enter a value for  $x$  and then calculates and displays the exponential function  $e^x$  using the Taylor<sup>[21]</sup> series, shown next, with an accuracy of 0.00001.

$$e^x = 1 + \frac{x^1}{1!} + \frac{x^2}{2!} + \frac{x^3}{3!} + \dots$$

Hint: Keep in mind that  $\frac{x^0}{0!} = 1$ .

28. Write a C# program that lets the user enter a value for  $x$  and then calculates and displays the sine of  $x$  using the Taylor series, shown next, with an accuracy of 0.00001.

$$\sin x = x - \frac{x^3}{3!} + \frac{x^5}{5!} - \frac{x^7}{7!} + \dots$$

Hint: Keep in mind that  $x$  is in radians and  $\frac{x^1}{1!} = x$ .

29. Write a C# program that lets the user enter a value for  $x$  and then calculates and displays the cosine of  $x$  using the Taylor series, shown next, with an accuracy of 0.00001.

$$\cos x = 1 - \frac{x^2}{2!} + \frac{x^4}{4!} - \frac{x^6}{6!} + \dots$$

Hint: Keep in mind that  $x$  is in radians and  $\frac{x^0}{0!} = 1$ .

30. Write a C# program that prompts the user to enter the daily temperatures (in degrees Fahrenheit) recorded at the same hour each day in August and then calculates and displays the average as well as the highest temperature.

Since  $-459.67^\circ$  (on the Fahrenheit scale) is the lowest temperature possible (it is called absolute zero), using a loop control structure, the program must also validate data input and display an error message when the user enters a value lower than absolute zero.

31. A scientist needs a software application to record the level of the sea based on values recorded at specific times (HH:MM), in order to extract some useful information. Write a C# program that lets the scientist enter the level of the sea, the hour, and the minutes, repeatedly until the value of 9999 (used as a sea level) is entered. Then, the program must

display the highest and the lowest sea levels as well as the hour and the minutes at which these levels were recorded.

32. Suppose that the letter A corresponds to the number 1, the letter B corresponds to the number 2, and so on. Write a C# program that prompts the user to enter two integers and then displays all alphabet letters that exist between them. For example, if the user enters 3 and 6, the program must display C, D, E, F. Using a loop control structure, the program must also validate data input and display individual error messages when the user enters any negative, or any value greater than 26.

Hint: To make your C# program operate correctly, independent of which integer given is the lowest, you can swap their values (if necessary) so that they are always in the proper order.

33. Write a C# program that assigns a random secret integer between 1 and 100 to a variable and then prompts the user to guess the number. If the integer given is less than the secret one, a message "*Your guess is smaller than my secret number. Try again.*" must be displayed. If the integer given is greater than the secret one, a message "*Your guess is bigger than my secret number. Try again.*" must be displayed. This process must repeat until the user finally finds the secret number. Then, a message "*You found it!*" must be displayed, as well as the total number of the user's attempts.
34. Expand the previous exercise/game by making it operate for two players. The player that wins is the one that finds the random secret number in fewer attempts.
35. The size of a TV screen always refers to its diagonal measurement. For example, a 40-inch TV screen is 40 inches diagonally, from one corner on top to the other corner on bottom. The old TV screens had a width-to-height aspect ratio of 4:3, which means that for every 3 inches in TV screen height, there were 4 inches in TV screen width. Today, most TV screens have a width-to-height aspect ratio of 16:9, which means that for every 9 inches in TV screen height there are 16 inches in TV screen width. Using these aspect ratios and the Pythagorean Theorem, you can easily determine that:

► **for all 4:3 TVs**

Width = Diagonal × 0.8

Height = Diagonal × 0.6

► **for all 16:9 TVs**

Width = Diagonal × 0.87

Height = Diagonal × 0.49

Write a C# program that displays the following menu:

1. 4/3 TV Screen
2. 16/9 TV Screen
3. Exit

and prompts the user to enter a choice as well as the diagonal screen size in inches. Then, the C# program must display the width and the height of the TV screen. This process must continue repeatedly, until the user selects choice 3 (Exit) from the menu.

36. Write a C# program that prompts a teacher to enter the total number of students, their grades, and their gender (M for Male, F for Female), and then calculates and displays all of the following:
- a. the average value of those who got an “A” (90 - 100)
  - b. the average value of those who got a “B” (80 - 89)
  - c. the average value of boys who got an “A” (90 - 100)
  - d. the total number of girls that got less than “B”
  - e. the highest and lowest grade
  - f. the average grade of the whole class

Add all necessary checks to make the program satisfy the property of definiteness. Moreover, using a loop control structure, the program must validate data input and display an error message when the teacher enters any of the following:

- non-positive values for total number of students
- negatives, or values greater than 100 for student grades
- values other than M or F for gender

37. Write a C# program that calculates and displays the discount that a customer receives based on the amount of his or her order, according to the following table.

Amount	Discount
\$0 < amount < \$20	0%
\$20 ≤ amount < \$50	3%
\$50 ≤ amount < \$100	5%
\$100 ≤ amount	10%

At the end of each discount calculation, the program must ask the user if he or she wishes to calculate the discount of another amount. If the answer is “yes”, the program must repeat; it must end otherwise. Make your program accept the answer in all possible forms such as “yes”, “YES”, “Yes”, or even “YeS”.

Moreover, using a loop control structure the program must validate data input and display an error message when the user enters any non-positive value for amount.

38. The LAV Electricity Company charges subscribers for their electricity consumption according to the following table (monthly rates for domestic accounts).

Kilowatt-hours (kWh)	USD per kWh
0 ≤ kWh ≤ 400	\$0.11
401 ≤ kWh ≤ 1500	\$0.22
1501 ≤ kWh ≤ 3500	\$0.25
3501 ≤ kWh	\$0.50

Write a C# program that prompts the user to enter the total number of kWh consumed by a subscriber and then calculates and displays the total amount to pay. This process must repeat until the value –1 for kWh is entered.

Moreover, using a loop control structure, the program must validate data input and display an error message when the user enters any negative value for kWh. An exception for the value –1 must be made.

Transmission services and distribution charges, as well as federal, state, and local taxes, add a total of 25% to each bill.

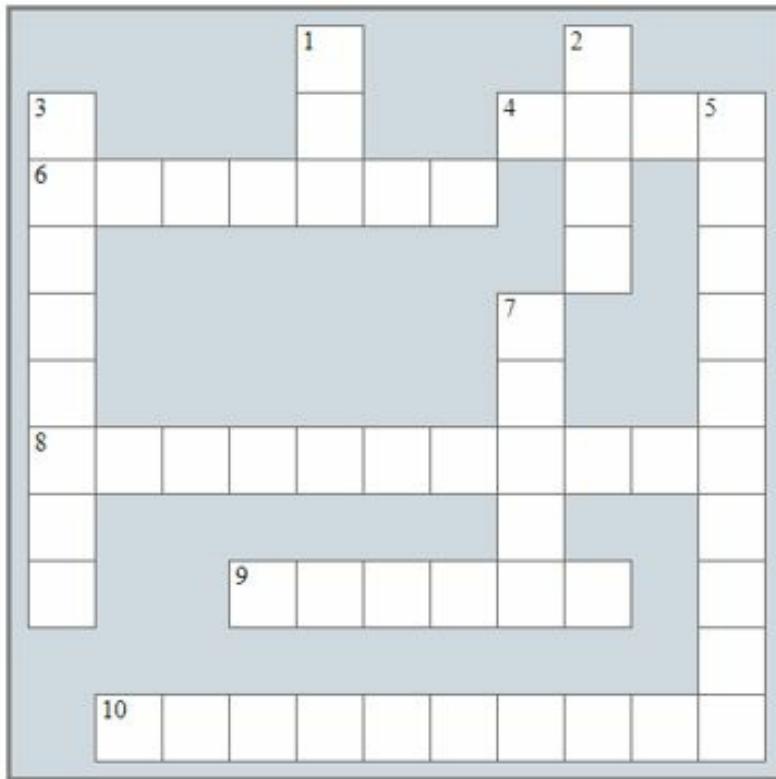
Please note that the rates are progressive.

# **Review in “Loop Control Structures”**

---

## **Review Crossword Puzzle**

1. Solve the following crossword puzzle.



### **Across**

---

4. This control structure allows the execution of a block of statements multiple times.
6. A loop that cannot stop iterating.
8. The "Ultimate" rule states that the variable that participates in a loop's Boolean expression must be \_\_\_\_\_ before entering the loop.
9. A loop within another loop.
10. In this loop structure, the number of iterations is not known before the loop starts iterating.

### **Down**

---

1. In a \_\_\_\_\_-test loop structure, first the Boolean expression is evaluated, and afterward the statement or block of statements of the

structure is executed.

2. The \_\_\_\_\_-test loop performs at least one iteration.
3. In this loop structure, the number of iterations is known before the loop starts iterating.
5. A word or sentence that reads the same both backward and forward.
7. Any integer greater than 1 that has no divisors other than 1 and itself.

## Review Questions

Answer the following questions.

1. What is a loop control structure?
2. In a flowchart, how can you distinguish a decision control structure from a loop control structure?
3. Design the flowchart and write the C# statement (in general form) of a pre-test loop structure. Explain how this loop control structure operates.
4. Why is a pre-test loop structure named this way, and what is the fewest number of iterations it may perform?
5. If the statement or block of statements of a pre-test loop structure is executed N times, how many times is the Boolean expression of the structure evaluated?
6. Design the flowchart and write the corresponding C# statement (in general form) of a post-test loop structure. Explain how this loop control structure operates.
7. Why is a post-test loop structure named this way, and what is the fewest number of iterations it may perform?
8. If the statement or block of statements of a post-test loop structure is executed N times, how many times is the Boolean expression of the structure evaluated?
9. Design the flowchart and write the corresponding C# statement (in general form) of a mid-test loop structure. Explain how this loop control structure operates.
10. Design the flowchart and write the corresponding C# statement (in general form) of a for-loop. Explain how this loop control structure operates.

11. State the rules that apply to for-loops.
12. What are nested loops?
13. Write an example of a program with nested loop control structures and explain how they are executed.
14. State the rules that apply to nested loops.
15. Design a diagram that could help someone decide on the best loop control structure to choose.
16. Describe the “Ultimate” rule and give two examples, in general form, using a pre-test and a post-test loop structure.
17. Suppose that a C# program uses a loop control structure to search for a given word in an electronic dictionary. Why is it critical to break out of the loop when the given word is found?
18. Why is it critical to clean out your loops?
19. What is an infinite loop?

# **Section 6**

## **Data Structures in C#**

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# Chapter 31

## One-Dimensional Arrays and Dictionaries

---

### 31.1 Introduction

Variables are a good way to store values in memory but they have one limitation—they can hold only one value at a time. There are many cases, however, where a program needs to keep a large amount of data in memory, and variables are not the best choice.

For example, consider the following exercise.

*Write a C# program that prompts the user to enter the names of five students. It then displays them in the exact reverse of the order in which they were given.*

In the code fragment that follows

```
Console.WriteLine("Enter five names:");
for (i = 1; i <= 5; i++) {
    name = Console.ReadLine();
}
```

when the loop finally finishes iterating, the variable name contains only that last name that was given. Unfortunately, all the previous four names have been lost! Using this code fragment, it is impossible to display them in the exact reverse of the order in which they were given.

One possible solution would be to use five individual variables, as follows.

```
Console.WriteLine("Enter five names:");
name1 = Console.ReadLine();
name2 = Console.ReadLine();
name3 = Console.ReadLine();
name4 = Console.ReadLine();
name5 = Console.ReadLine();

Console.WriteLine(name5);
Console.WriteLine(name4);
Console.WriteLine(name3);
Console.WriteLine(name2);
Console.WriteLine(name1);
```

Not a perfect solution, but it works! However, what if the wording of this exercise asked the user to enter 1,000 names instead of five? Think about it! Do you have the patience to write a similar C# program for each of those

names? Of course not! Fortunately, there are *data structures*!

 In computer science, a *data structure* is a collection of data organized so that you can perform operations on it in the most effective way.

There are quite a few data structures available in C#, such as *arrays*, *arraylists*, *linkedlists*, *lists*, *dictionaries*, and *strings*. Yes, you heard that right! Strings are data structures because a string is nothing more than a collection of alphanumeric characters!

Beyond strings (for which you have already learned enough), arrays and dictionaries are the most commonly used data structures in C#. The following chapters will analyze both of them.

## 31.2 What is an Array?

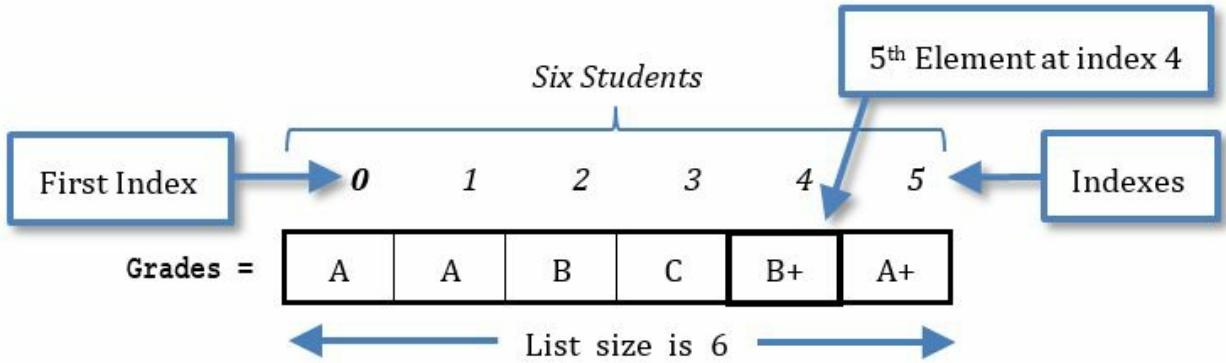
An *array* is a type of data structure that can hold multiple values under one common name. An array can be thought of as a collection of *elements* where each element is assigned a unique number known as an *index position*, or simply an *index*. Arrays are *mutable* (changeable), which means that, once the array is created, the values of their elements can be changed.

 Arrays in computer science resemble the matrices used in mathematics. A mathematical matrix is a collection of numbers or other mathematical objects, arranged in rows and columns.

There are one-dimensional and multidimensional arrays. A multidimensional array can be two-dimensional, three-dimensional, four-dimensional, and so on.

### One-Dimensional Arrays

The following example presents a one-dimensional array that holds the grades of six students. The name of the array is `Grades`. For your convenience, the corresponding index is written above each element. By default, in C#, index numbering always starts at zero.



Since index numbering starts at zero, the index of the last element of an array is 1 less than the total number of elements in the array.

You can think of an array as if it were six individual variables—`Grades0`, `Grades1`, `Grades2`, ... `Grades5`—with each variable holding the grade of one student. The advantage of the array, however, is that it can hold multiple values under one common name.

## Two-Dimensional Arrays

In general, multidimensional arrays are useful for working with multiple sets of data. For example, suppose you want to hold the daily high temperatures for California for the four weeks of April. One approach would be to use four one-dimensional arrays, one for each week. Furthermore, each array would have seven elements, one for each day of the week, as follows.

Days							
	0	1	2	3	4	5	6
Temperatures_week1 =	57	58	65	71	75	68	56
Temperatures_week2 =	64	71	74	63	61	64	57
Temperatures_week3 =	62	68	62	51	55	59	69
Temperatures_week4 =	73	60	67	54	59	62	64

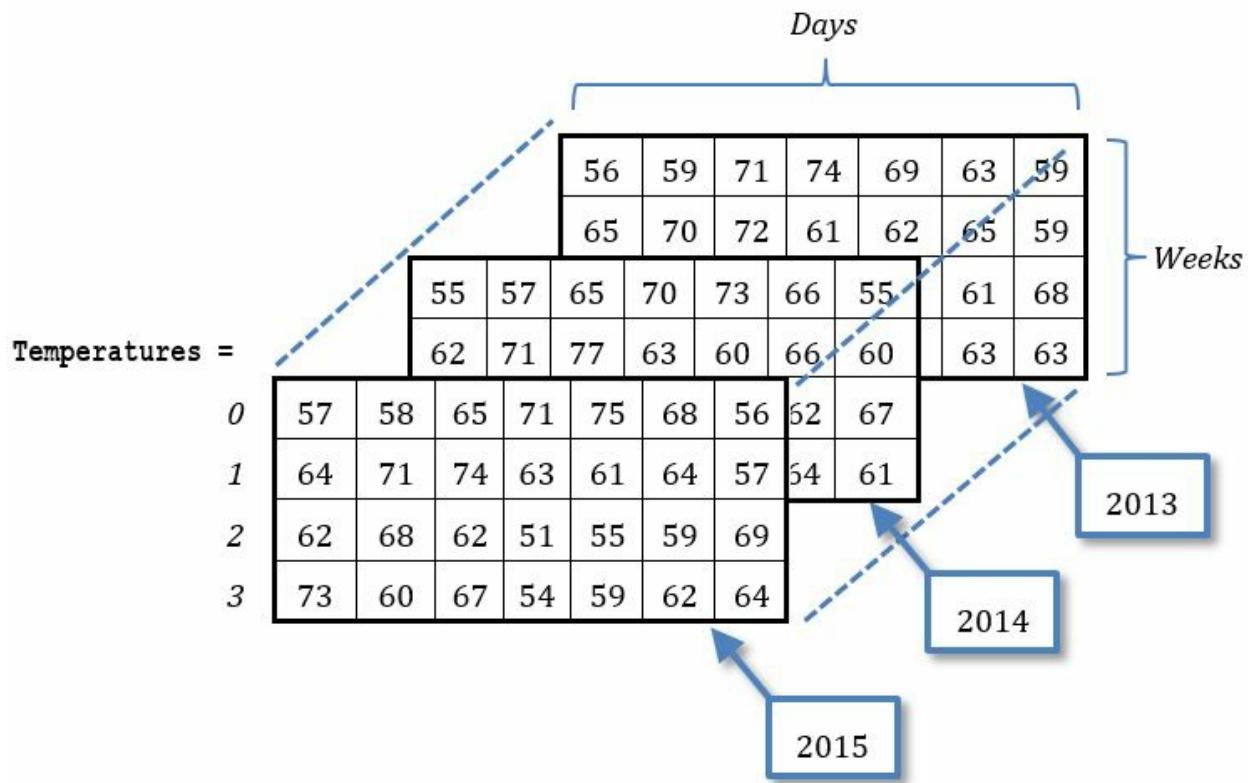
However, this approach is a bit awkward because you would have to process each array separately. A better approach would be to use a two-dimensional array with four rows (one for each week) and seven columns (one for each day of the week), as follows.

Days							
	0	1	2	3	4	5	6
0	57	58	65	71	75	68	56
1	64	71	74	63	61	64	57
2	62	68	62	51	55	59	69
3	73	60	67	54	59	62	64

Weeks

### Three-Dimensional Arrays

The next example shows a three-dimensional array that holds the daily high temperatures for California for the four weeks of April for the years 2013, 2014, and 2015.



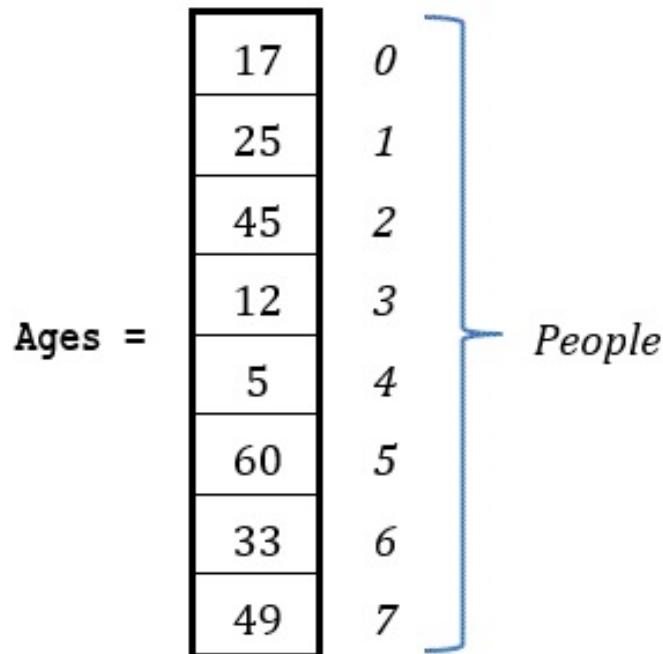
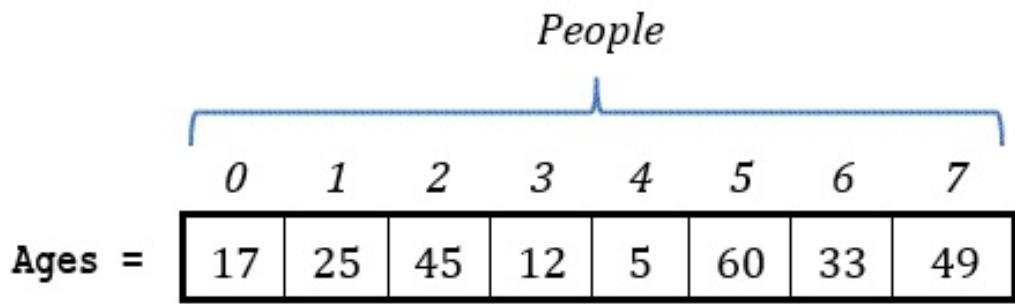
Note that four-dimensional, five-dimensional, or even one-hundred-dimensional arrays can exist. However, experience shows that the maximum array dimension that you will need in your life as a programmer is probably two or three.

### Exercise 31.2-1 Designing an Array

Design an array that can hold the ages of 8 people, and then add some typical values to the array.

### Solution

This is an easy one. All you have to do is design an array with 8 elements (indexes 0 to 7). It can be an array with either one row or one column, as follows.



Keep in mind, however, that there are no arrays with one row or one column in C#. These concepts may exist in mathematical matrices (or in your imagination!) but not in C#. The arrays in C# are one-dimensional—end of story! If you want to visualize them having one row or one column, that is up to you.

### Exercise 31.2-2 Designing Arrays

*Design the necessary arrays to hold the names and the ages of seven people, and then add some typical values to the arrays.*

### Solution

This exercise can be implemented with two arrays. Let's design them with one column each.

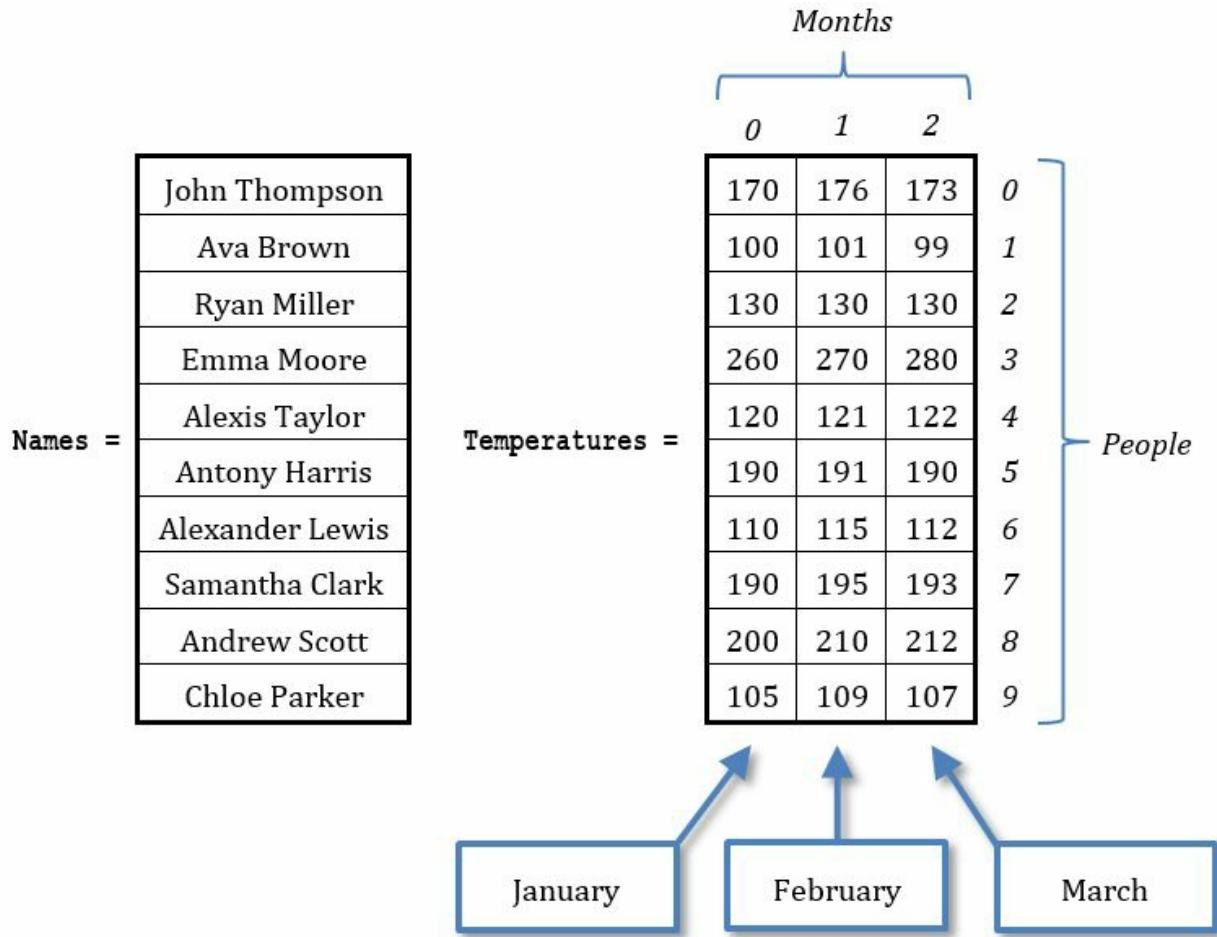
<b>Names =</b>	<table border="1"> <tr><td>John Thompson</td></tr> <tr><td>Ava Brown</td></tr> <tr><td>Ryan Miller</td></tr> <tr><td>Alexander Lewis</td></tr> <tr><td>Samantha Clark</td></tr> <tr><td>Andrew Scott</td></tr> <tr><td>Chloe Parker</td></tr> </table>	John Thompson	Ava Brown	Ryan Miller	Alexander Lewis	Samantha Clark	Andrew Scott	Chloe Parker	<b>Ages =</b>	<table border="1"> <tr><td>17</td></tr> <tr><td>25</td></tr> <tr><td>45</td></tr> <tr><td>33</td></tr> <tr><td>23</td></tr> <tr><td>21</td></tr> <tr><td>49</td></tr> </table>	17	25	45	33	23	21	49	<table border="1"> <tr><td>0</td></tr> <tr><td>1</td></tr> <tr><td>2</td></tr> <tr><td>3</td></tr> <tr><td>4</td></tr> <tr><td>5</td></tr> <tr><td>6</td></tr> </table>	0	1	2	3	4	5	6	<i>People</i>
John Thompson																										
Ava Brown																										
Ryan Miller																										
Alexander Lewis																										
Samantha Clark																										
Andrew Scott																										
Chloe Parker																										
17																										
25																										
45																										
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23																										
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49																										
0																										
1																										
2																										
3																										
4																										
5																										
6																										

### Exercise 31.2-3 Designing Arrays

*Design the necessary arrays to hold the names of ten people as well as the average weight (in pounds) of each person for January, February, and March. Then add some typical values to the arrays.*

### Solution

In this exercise, you need a one-dimensional array for names, and a two-dimensional array for people's weights.



### 31.3 Creating One-Dimensional Arrays in C#

C# has many ways to create an array and add elements (and values) to it. Depending on the given problem, it's up to you which one to use.

Let's try to create the following array using the most common approaches.

0	1	2	3
ages = [12, 25, 9, 11]			

#### First Approach

To create an array and directly assign values to its elements, you can use the next C# statement, given in general form.

```
| type[] array_name = { value0, value1, value2, ... , valueM };
```

where

- ▶ *type* can be `int`, `double`, `string` and so on.

- ▶ *array\_name* is the name of the array.
- ▶ *value<sub>0</sub>, value<sub>1</sub>, value<sub>2</sub>, … , value<sub>M</sub>* are the values of the array elements.

For this approach, you can create the array *ages* using the following statement:

```
int[] ages = {12, 25, 9, 11};
```

 *Indexes are set automatically. The value 12 is assigned to the element at index position 0, value 25 is assigned to the element at index position 1, and so on. Index numbering always starts at zero by default.*

## Second Approach

You can create an array of *size* empty elements in C# using the following statement given in general form:

```
type[] array_name = new type[size];
```

where *size* can be any positive integer value, or it can even be a variable that contains any positive integer value.

The next statement creates the array *ages* with 4 empty elements.

```
int[] ages = new int[4];
```

 *The statement int[] ages = new int[4] reserves four locations in main memory (RAM).*

To assign a value to an array element, you can use the following statement, given in general form:

```
array_name[index] = value;
```

where *index* is the index position of the element in the array.

The next code fragment creates the array *ages* (reserving four locations in main memory) and then assigns values to its elements.

```
int[] ages = new int[4];
ages[0] = 12;
ages[1] = 25;
ages[2] = 9;
ages[3] = 11;
```

 *The size of the array ages is 4.*

 In [paragraph 5.4](#) you learned about the rules that must be followed when assigning names to C# variables. Assigning names to arrays follows exactly the same rules!

Of course, instead of using constant values for *index*, you can also use variables or expressions, as follows.

```
int k;  
int[] ages = new int[4];  
  
k = 0;  
ages[k] = 12;  
ages[k + 1] = 25;  
ages[k + 2] = 9;  
ages[k + 3] = 11;
```

## 31.4 How to Get Values from a One-Dimensional Array

Getting values from an array is just a matter of pointing to a specific element. Each element of a one-dimensional array can be uniquely identified using an index. The following code fragment creates an array and displays “A+” (without the double quotes) on the screen.

```
string[] grades = {"B+", "A+", "A", "C-"};  
Console.WriteLine(grades[1]);
```

Of course, instead of using constant values for *index*, you can also use variables or expressions. The following example creates an array and displays “Aphrodite and Hera” (without the double quotes) on the screen.

```
string[] gods = {"Zeus", "Ares", "Hera", "Aphrodite", "Hermes"};  
k = 3;  
Console.WriteLine(gods[k] + " and " + gods[k - 1]);
```

### ***Exercise 31.4-1 Creating the Trace Table***

*Create the trace table for the next code fragment.*

```
int x;  
int[] a = new int[4];  
a[3] = 9;  
x = 0;  
a[x] = a[3] + 4;  
a[x + 1] = a[x] * 3;  
x++;  
a[x + 2] = a[x - 1];  
a[2] = a[1] + 5;
```

```
| a[3] = a[3] + 1;
```

## Solution

---

Don't forget that you can manipulate each element of an array as if it were a variable. Thus, when you create a trace table for a C# program that uses an array, you can have one column for each element as follows.

Step	Statement	Notes	x	a[0]	a[1]	a[2]	a[3]
1	int[] a = new int[4]	This creates array a with no values in it	?	?	?	?	?
2	a[3] = 9		?	?	?	?	<b>9</b>
3	x = 0		<b>0</b>	?	?	?	9
4	a[x] = a[3] + 4		0	<b>13</b>	?	?	9
5	a[x + 1] = a[x] * 3		0	13	<b>39</b>	?	9
6	x++		<b>1</b>	13	39	?	9
7	a[x + 2] = a[x - 1]		1	13	39	?	<b>13</b>
8	a[2] = a[1] + 5		1	13	39	<b>44</b>	13
9	a[3] = a[3] + 1		1	13	39	44	<b>14</b>

## Exercise 31.4-2 Using a Non-Existing Index

---

Which properties of an algorithm are not satisfied by the following C# program?

```
static void Main(string[] args) {
    string[] grades = {"B+", "A+", "A", "C-"};
    Console.WriteLine(grades[100]);
}
```

## Solution

---

Two properties are not satisfied by this C# program. The first one is obvious: there is no data input. The second one is the property of definiteness. You must never refer to a non-existing element of an array and,

in this exercise, there is no element at index position 100.

## 31.5 How to Alter the Value of an Array Element

To alter the value of an existing array element is a piece of cake. All you need to do is use the appropriate index and assign a new value to that element. The example that follows shows exactly this.

```
//Create an array
string[] indian_tribes = { "Navajo", "Cherokee", "Sioux" };

//Alter the value of an existing element
indian_tribes[1] = "Apache";

Console.WriteLine(indian_tribes[0]);      //It displays: Navajo
Console.WriteLine(indian_tribes[1]);      //It displays: Apache
Console.WriteLine(indian_tribes[2]);      //It displays: Sioux
```

 A string is almost identical to an array; it contains a collection of characters. However, the main difference is that strings are immutable (unchangeable). You cannot change an individual character with a statement like `x_str[2] = "r"` (although you can change the value of the whole string).

 An “immutable” data structure is a structure in which the value of its elements cannot be changed once the data structure is created.

## 31.6 How to Iterate Through a One-Dimensional Array

Now comes the interesting part. A program can iterate through the elements of an array using a loop structure (usually a for-loop). There are two approaches you can use to iterate through a one-dimensional array.

### First Approach

This approach refers to each array element using its index. Following is a code fragment, written in general form

```
for (index = 0; index <= size_of_the_array - 1; index++) {
    process array_name[index];
}
```

in which `process` is any C# statement or block of statements that processes one element of the array `array_name` at each iteration.

The following code fragment displays all elements of the array gods, one at each iteration.

```
int i;
string[] gods = {"Zeus", "Ares", "Hera", "Aphrodite", "Hermes"};

for (i = 0; i <= 4; i++) {
    Console.WriteLine(gods[i] + "\t");
}
```

☞ The name of the variable *i* is not binding. You can use any variable name you want, such as *index*, *ind*, *j*, and many more.

☞ Note that since the array gods contains five elements, the for-loop must iterate from 0 to 4 and not from 1 to 5. This is because the indexes of the four elements are 0, 1, 2, 3, and 4, correspondingly.

Since arrays are mutable, you can use a loop structure to alter all or some of its values. The following code fragment doubles the values of some elements of the array *b*.

```
int[] b = {80, 60, 60, 72, 30, 40};
for (i = 0; i <= 3; i++) {
    b[i] = b[i] * 2;
}
```

## Second Approach

This approach is very simple but not as flexible as the previous one. There are cases where it cannot be used, as you will see below. Following is a code fragment, written in general form

```
for (var element in array_name) {
    process element
}
```

in which *process* is any C# statement or block of statements that processes one element of the array *array\_name* at each iteration.

The following code fragment, displays all elements of the array *grades*, one at each iteration.

```
string[] grades = {"B+", "A+", "A", "C-"};
foreach (var grade in grades) {
    Console.WriteLine(grade);
}
```

 In the first iteration, the value of the first element is assigned to variable grade. In the second iteration, the value of the second element is assigned to variable grade and so on!

Unfortunately, this approach cannot be used to alter the values of the elements of an array. For example, if you want to double the values of all elements of the array numbers, you **cannot** do the following:

```
int[] numbers = {5, 10, 3, 2};

foreach (var number in numbers) {
    number *= 2;
}
```

 number is a simple variable where, at each iteration, each successive value of the array numbers is assigned to. However, the opposite never happens! The value of number is never assigned back to any element!

 If you want to alter the values of the elements of an array, you should use the first approach.

### **Exercise 31.6-1 Finding the Sum**

Write a C# program that creates an array with the following values

56, 12, 33, 8, 3, 2, 98

and then calculates and displays their sum.

#### **Solution**

You have learned two ways to iterate through the array elements. Let's use both ways and see the differences.

#### **First approach**

The solution is as follows.

##### project\_31\_6\_1a

```
static void Main(string[] args) {
    int i;
    double total;

    double[] values = {56, 12, 33, 8, 3, 2, 98};

    total = 0;
```

```

    for (i = 0; i <= 6; i++) {
        total += values[i]; //This is equivalent to total = total + values[i]
    }

    Console.WriteLine(total);
}

```

## Second approach

The solution is as follows.

### project\_31\_6\_1b

```

static void Main(string[] args) {
    double total;

    double[] values = {56, 12, 33, 8, 3, 2, 98};

    total = 0;
    foreach (var value in values) {
        total += value;
    }

    Console.WriteLine(total);
}

```

## 31.7 How to Add User-Entered Values to a One-Dimensional Array

There is nothing new here. Instead of reading a value from the keyboard and assigning that value to a variable, you can directly assign that value to a specific array element. The next C# program prompts the user to enter the names of three people, and assigns them to the elements at index positions 0, 1, 2, and 3, of the array names.

```

static void Main(string[] args) {
    //Pre-reserve 4 locations in main memory (RAM)
    string[] names = new string[4];

    Console.Write("Enter name No 1: ");
    names[0] = Console.ReadLine();

    Console.Write("Enter name No 2: ");
    names[1] = Console.ReadLine();

    Console.Write("Enter name No 3: ");
    names[2] = Console.ReadLine();
}

```

```
Console.WriteLine("Enter name No 4: ");
names[3] = Console.ReadLine();
}
```

Using a for-loop, this program can equivalently be written as

```
const int ELEMENTS = 4;

static void Main(string[] args) {
    int i;

    //Pre-reserve 4 locations in main memory (RAM)
    string[] names = new string[ELEMENTS];

    for (i = 0; i <= ELEMENTS - 1; i++) {
        Console.WriteLine("Enter name No " + (i + 1) + ": ");
        names[i] = Console.ReadLine();
    }
}
```

 A very good tactic for dealing with array sizes is to use constants.

### Exercise 31.7-1 Displaying Words in Reverse Order

Write a C# program that lets the user enter 20 words. The program then displays them in the exact reverse of the order in which they were given.

#### **Solution**

Arrays are perfect for problems like this one. The following is an appropriate solution.

##### project\_31\_7\_1

```
static void Main(string[] args) {
    int i;

    string[] words = new string[20];
    for (i = 0; i <= 19; i++) {
        words[i] = Console.ReadLine();
    }

    for (i = 19; i >= 0; i--) {
        Console.WriteLine(words[i]);
    }
}
```

Since index numbering starts at zero, the index of the last array element is 1 less than the total number of elements in the array.

Sometimes the wording of an exercise may say nothing about using a data structure. However, this doesn't mean that you can't use one. Use data structures (arrays, dictionaries etc.) whenever you think they are necessary.

### **Exercise 31.7-2 Displaying Positive Numbers in Reverse Order**

Write a C# program that lets the user enter 100 numbers and then displays only the positive ones in the exact reverse of the order in which they were given.

#### **Solution**

In this exercise, the program must accept all values from the user and store them in an array. However, within the for-loop that is responsible for displaying the array elements, a nested decision control structure must check for and display only the positive values. The solution is as follows.

#### **project\_31\_7\_2**

```
const int ELEMENTS = 100;

static void Main(string[] args) {
    int i;

    double[] values = new double[ELEMENTS];

    for (i = 0; i <= ELEMENTS - 1; i++) {
        values[i] = Double.Parse(Console.ReadLine());
    }

    for (i = ELEMENTS - 1; i >= 0; i--) {
        if (values[i] > 0) {
            Console.WriteLine(values[i]);
        }
    }
}
```

### **Exercise 31.7-3 Finding the Average Value**

Write a C# program that prompts the user to enter 20 numbers into an array. It then displays a message only when their average value is less than 10.

## Solution

---

To find the average value of the given numbers the program must first find their sum and then divide that sum by 20. Once the average value is found, the program must check whether to display the corresponding message.

### project\_31\_7\_3a

```
const int ELEMENTS = 20;

static void Main(string[] args) {
    int i;
    double total, average;

    double[] values = new double[ELEMENTS];
    for (i = 0; i <= ELEMENTS - 1; i++) {
        Console.WriteLine("Enter a value: ");
        values[i] = Double.Parse(Console.ReadLine());
    }

    //Accumulate values in total
    total = 0;
    for (i = 0; i <= ELEMENTS - 1; i++) {
        total += values[i];
    }

    average = total / ELEMENTS;
    if (average < 10) {
        Console.WriteLine("Average value is less than 10");
    }
}
```

If you are wondering whether or not this exercise could have been solved using just one for-loop, the answer is “yes”. An alternative solution is presented next.

### project\_31\_7\_3b

```
const int ELEMENTS = 20;

static void Main(string[] args) {
    int i;
    double total, average;

    total = 0;
    double[] values = new double[ELEMENTS];
    for (i = 0; i <= ELEMENTS - 1; i++) {
```

```

        Console.WriteLine("Enter a value: ");
        values[i] = Double.Parse(Console.ReadLine());
        total += values[i];
    }

    average = total / ELEMENTS;
    if (average < 10) {
        Console.WriteLine("Average value is less than 10");
    }
}

```

But let's clarify something! Even though many processes can be performed inside just one for-loop, it is simpler to carry out each individual process in a separate for-loop. This is probably not so efficient but, since you are still a novice programmer, try to adopt this programming style just for now. Later, when you have the experience and become a C# guru, you will be able to "merge" many processes in just one for-loop!

#### ***Exercise 31.7-4 Displaying Reals Only***

---

*Write a C# program that prompts the user to enter 10 numeric values in an array. The program then displays the indexes of the elements that contain reals.*

#### ***Solution***

---

In [Exercise 23.1-2](#) you learned how to check whether or not, a number is an integer. Accordingly, to check whether or not, a number is a real (float), you can use the Boolean expression

*number != (int)number*

The solution is as follows.

#### 📁 project\_31\_7\_4

```

const int ELEMENTS = 10;

static void Main(string[] args) {
    int i;

    double[] a = new double[ELEMENTS];
    for (i = 0; i <= ELEMENTS - 1; i++) {
        Console.WriteLine("Enter a value for element " + i + ": ");
        a[i] = Double.Parse(Console.ReadLine());
    }
}

```

```

    for (i = 0; i <= ELEMENTS - 1; i++) {
        if (a[i] != (int)a[i]) {
            Console.WriteLine("A real found at position: " + i);
        }
    }
}

```

### ***Exercise 31.7-5 Displaying Elements with Odd-Numbered Indexes***

---

*Write a C# program that prompts the user to enter 8 numeric values in an array and then displays the elements with odd-numbered indexes (that is, indexes 1, 3, 5, and 7).*

#### ***Solution***

---

Following is one possible solution.

#### ***project\_31\_7\_5a***

```

const int ELEMENTS = 8;

static void Main(string[] args) {
    int i;

    double[] a = new double[ELEMENTS];
    for (i = 0; i <= ELEMENTS - 1; i++) {
        Console.Write("Enter a value for element " + i + ": ");
        a[i] = Double.Parse(Console.ReadLine());
    }

    //Display the elements with odd-numbered indexes
    for (i = 0; i <= ELEMENTS - 1; i++) {
        if (i % 2 != 0) {
            Console.Write(a[i] + " ");
        }
    }
}

```

However, you know that only the values in odd-numbered index positions must be displayed. Therefore, the for-loop that is responsible for displaying the elements of the array, instead of starting counting from 0 and using an *offset* of +1, it can start counting from 1 and use an *offset* of +2. This modification decreases the number of iterations by half. The modified C# program follows.

#### ***project\_31\_7\_5b***

```

const int ELEMENTS = 8;

static void Main(string[] args) {
    int i;

    double[] a = new double[ELEMENTS];
    for (i = 0; i <= ELEMENTS - 1; i++) {
        Console.Write("Enter a value for element " + i + ": ");
        a[i] = Double.Parse(Console.ReadLine());
    }

    //Display the elements with odd-numbered indexes
    for (i = 1; i <= ELEMENTS - 1; i += 2) { //Start from 1 and increment by 2
        Console.Write(a[i] + " ");
    }
}

```

### **Exercise 31.7-6 Displaying Even Numbers in Odd-Numbered Index Positions**

---

*Write a C# program that lets the user enter 100 integers into an array and then displays any even values that are stored in odd-numbered index positions.*

#### **Solution**

---

Following is one possible solution.

#### □ project\_31\_7\_6

```

const int ELEMENTS = 100;

static void Main(string[] args) {
    int i;

    int[] values = new int[ELEMENTS];
    for (i = 0; i <= ELEMENTS - 1; i++) {
        values[i] = Int32.Parse(Console.ReadLine());
    }

    for (i = 1; i <= ELEMENTS - 1; i += 2) {
        if (values[i] % 2 == 0) {
            Console.WriteLine(values[i]);
        }
    }
}

```

## 31.8 What is a Dictionary?

The main difference between a *dictionary* and an array is that the dictionary elements can be uniquely identified using a key and not necessarily an integer value. Each key of a dictionary is associated (or mapped, if you prefer) to an element. The keys of a dictionary can be of type string, integer, float (real), etc.

The following example presents a dictionary that holds the names of a family. The name of the dictionary is `family` and the corresponding keys are written above each element.

	<i>father</i>	<i>mother</i>	<i>son</i>	<i>daughter</i>	Keys
<code>family</code> =	John	Maria	George	Helen	

☞ *The keys of dictionary elements must be unique within the dictionary. This means that in the dictionary `family`, for example, you cannot have two keys named `father`.*

☞ *The values of dictionary elements can be of any type.*

## 31.9 Creating Dictionaries in C#

Let's try to create the following dictionary using the most common approaches.

	<i>first_name</i>	<i>last_name</i>	<i>age</i>	<i>class</i>
<code>pupil</code> =	Ann	Fox	8	2nd

### First Approach

To create a dictionary and directly assign values to its elements, you can use the next C# statement, given in general form.

```
Dictionary<key_type, value_type> dict_name = new Dictionary<key_type, value_type> {  
    { key0, value0 },  
    { key1, value1 },  
    { key2, value3 },  
    ...  
    ...  
    { keyM, valueM }
```

```
| };
```

where

- *key\_type* is the type of the keys. It can be `string`, `int`, `double`, etc.
- *value\_type* is the type of the elements. It can be `string`, `int`, `double`, etc.
- *dict\_name* is the name of the dictionary.
- *key0, key1, key2, ..., keyM* are the keys of the dictionary elements.
- *value0, value1, value2, ..., valueM* are the values of the dictionary elements.

Using this approach, the dictionary `pupil` can be created using the following statement:

```
Dictionary<string, string> pupil = new Dictionary<string, string> {  
    {"first_name", "Ann"},  
    {"last_name", "Fox"},  
    {"age", "8"},  
    {"class", "2nd"}  
};
```

 *Each key is separated from its value by a comma ( , ), the elements are enclosed within curly brackets { } and separated by commas, and everything is enclosed within curly brackets { }.*

Keep in mind though, that the fully qualified name of the `Dictionary` data structure is `System.Collections.Generic.Dictionary`. To avoid writing fully qualified names, programmers prefer to create aliases. You can create an alias for the namespace `System.Collections.Generic` using the following directive at the beginning of your programs.

```
using System.Collections.Generic;
```

Without this directive, the correct syntax for the previous dictionary is as follows.

```
System.Collections.Generic.Dictionary<string, string> pupil = new  
    System.Collections.Generic.Dictionary<string, string> {  
        {"first_name", "Ann"},  
        {"last_name", "Fox"},  
        {"age", "8"},  
        {"class", "2nd"}  
   };
```

## Second Approach

In this approach, you can create a totally empty dictionary using the following statement, given in general form

```
Dictionary<key_type, value_type> dict_name = new Dictionary<key_type, value_type>();
```

and then add an element (key-value pair), as shown in the following C# statement, given in general form.

```
dict_name[key] = value;
```

Using this approach, the dictionary pupil can be created using the following code fragment:

```
Dictionary<string, string> pupil = new Dictionary<string, string>();

pupil["first_name"] = "Ann";
pupil["last_name"] = "Fox";
pupil["age"] = "8";
pupil["class"] = "2nd";
```

## 31.10 How to Get a Value from a Dictionary

To get the value of a specific dictionary element, you must point to that element using its corresponding key. The following code fragment creates a dictionary, and then displays “Ares is the God of War”, without the double quotes, on the screen.

```
Dictionary<string, string> olympians = new Dictionary<string, string>();

olympians["Zeus"] = "King of the Gods";
olympians["Hera"] = "Goddess of Marriage";
olympians["Ares"] = "God of War";
olympians["Poseidon"] = "God of the Sea";
olympians["Demeter"] = "Goddess of the Harvest";
olympians["Artemis"] = "Goddess of the Hunt";
olympians["Apollo"] = "God of Music and Medicine";
olympians["Aphrodite"] = "Goddess of Love and Beauty";
olympians["Hermes"] = "Messenger of the Gods";
olympians["Athena"] = "Goddess of Wisdom";
olympians["Hephaistos"] = "God of Fire and the Forge";
olympians["Dionysus"] = "God of the Wine";

Console.WriteLine("Ares is the " + olympians["Ares"]);
```

 Only keys can be used to access an element. This means that olympians["Ares"] correctly returns “God of War” but Olympians["God of

`War"] cannot return "Ares".`

### ***Exercise 31.10-1 Using a Non-Existing Key in Dictionaries***

*What is wrong in the following C# program?*

```
Dictionary<string, string> family = new Dictionary<string, string> {
    {"Father", "John"},
    {"Mother", "Maria"},
    {"Son", "George"}
};

Console.WriteLine(family["daughter"]);
```

### ***Solution***

Similar to arrays, you must never refer to a non-existing dictionary element. In this exercise, there is no key “daughter”, therefore the last statement throws a runtime error.

## **31.11 How to Alter the Value of a Dictionary Element**

To alter the value of an existing dictionary element you need to use the appropriate key and assign a new value to that element. The example that follows shows exactly this.

```
Dictionary<string, string> tribes = new Dictionary<string, string> {
    {"Indian", "Navajo"},
    {"African", "Zulu"}
};

Console.WriteLine(tribes["Indian"]);      //It displays: Navajo
Console.WriteLine(tribes["African"]);     //It displays: Zulu

//Alter the value of an existing element
tribes["Indian"] = "Apache";

Console.WriteLine(tribes["Indian"]);      //It displays: Apache
Console.WriteLine(tribes["African"]);     //It displays: Zulu
```

### ***Exercise 31.11-1 Assigning a Value to a Non-Existing Key***

*Is there anything wrong in the following code fragment?*

```
Dictionary<int, string> tribes = new Dictionary<int, string> {
    {0, "Navajo"},
    {1, "Cherokee"},
    {2, "Sioux"}
```

```
};

tribes[3] = "Apache";
```

## Solution

---

No, this time there is absolutely nothing wrong in this code fragment. At first glance, you might have thought that the last statement tries to alter the value of a non-existing key and it will throw an error. This is **not** true for C#'s dictionaries, though. Since `indian_tribes` is a dictionary and key “3” does not exist, the second statement **adds** a brand new fourth element to the dictionary!

 *The keys of a dictionary can be of type string, integer, float (real), etc.*

Keep in mind though, if `indian_tribes` were actually an array, the last statement would certainly throw an error. Take a look at the following code fragment

```
string[] indian_tribes = {"Navajo", "Cherokee", "Sioux"};
indian_tribes[3] = "Apache";
```

In this example, since `indian_tribes` is an array and index 3 does not exist, the last statement tries to **alter** the value of a non-existing element and obviously throws an error!

## 31.12 How to Iterate Through a Dictionary

To iterate through the elements of a dictionary you can use a for-loop. Following is a code fragment, written in general form

```
foreach (var element in dict_name) {
    process element.Key;
    process element.Value;
    process dict_name[element.Key]
}
```

in which `process` is any C# statement or block of statements that processes one element of the dictionary `dict_name` at each iteration.

The following C# program displays the letters A, B, C, and D, and their corresponding Morse<sup>[22]</sup> code.

```
Dictionary<string, string> morse_code = new Dictionary<string, string> {
    {"A", ".-"},
```

```

        {"B", "-..."},  

        {"C", "-.-."},  

        {"D", "-.."}  

    };  
  

foreach (var element in morse_code) {  

    Console.WriteLine(element.Key + " " + element.Value);  

}  
  

//Or you can do the following  

foreach (var element in morse_code) {  

    Console.WriteLine(element.Key + " " + morse_code[element.Key]);  

}

```

The next example gives a bonus of \$2000 to each employee of a computer software company!

```

Dictionary<string, double> salaries = new Dictionary<string, double> {  

    {"Project Manager", 83000.0},  

    {"Software Engineer", 81000.0},  

    {"Network Engineer", 64000.0},  

    {"Systems Administrator", 61000.0},  

    {"Software Developer", 70000.0}  

};  
  

foreach (var x in salaries.ToList()) {  

    salaries[x.Key] = salaries[x.Key] + 2000;  

}

```

 Note the `ToList()` method used here. It is necessary when you want to alter the values of dictionary elements.

### 31.13 Review Questions: True/False

Choose **true** or **false** for each of the following statements.

1. Arrays are structures that can hold multiple values.
2. Array elements are located in main memory (RAM).
3. There can be only one-dimensional and two-dimensional arrays.
4. There cannot be four-dimensional arrays.
5. An array is called “multidimensional” because it can hold values of different types.
6. Each array element has a unique index.

7. There can be two identical keys within a dictionary.
8. In arrays, index numbering always starts at zero by default.
9. The index of the last array element is equal to the total number of its elements.
10. A two-hundred-dimensional array can exist.
11. The next statement contains a syntax error.

```
| string[] student_names = new string[10];
```

12. In a C# program, two arrays cannot have the same name.
13. The next statement is syntactically correct.

```
| Dictionary<string, string> student = new Dictionary<string, string> {  
|     {"first_name": "Ann"},  
|     {"last_name": "Fox"},  
|     {"age": "8"}  
|};
```

14. In a C# program, two arrays cannot have the same number of elements.
15. You cannot use a variable as an index in an array.
16. You can use a mathematical expression as an index in an array.
17. You cannot use a variable as a key in a dictionary.
18. The following code fragment throws no errors.

```
| string a = "a";  
| Dictionary<string, string> fruits = new Dictionary<string, string> {  
|     {"o", "Orange"},  
|     {"a", "Apple"},  
|     {"w", "Watermelon"}  
|};  
  
| Console.WriteLine(fruits[a]);
```

19. If you use a variable as an index in an array, this variable must contain an integer value.
20. In order to calculate the sum of 20 numeric values given by a user, you must use an array.
21. You can let the user enter a value into array b using the statement `b[k] = Console.ReadLine()`
22. The following statement creates a one-dimensional array of two empty elements.

```
| string[] names = new string[3];
```

23. The following code fragment assigns the value 10 to the element at index 7.

```
| values[5] = 7;  
| values[values[5]] = 10;
```

24. The following code fragment assigns the value “Sally” without the double quotes to the element at index 3.

```
| string[] names = new string[3];  
| names[2] = "John";  
| names[1] = "George";  
| names[0] = "Sally";
```

25. The following statement assigns the value “Sally” without the double quotes to the element at index 2.

```
| string[] names = {"John", "George", "Sally"};
```

26. The following code fragment displays “Sally”, without the double quotes, on the screen.

```
| string[] names = new string[3];  
| k = 0;  
| names[k] = "John";  
| k++;  
| names[k] = "George";  
| k++;  
| names[k] = "Sally";  
| k--;  
| Console.WriteLine(names[k]);
```

27. The following code fragment is syntactically correct.

```
| string[] names = new string[3];  
| names[0] = "John";  
| names[1] = "George";  
| names[2] = "Sally";  
| Console.WriteLine(names[]);
```

28. The following code fragment displays “Maria”, without the double quotes, on the screen.

```
| string[] names = {"John", "George", "Sally", "Maria"};  
| Console.WriteLine(names[(int)Math.PI]);
```

29. The following code fragment satisfies the property of definiteness.

```
| string[] grades = {"B+", "A+", "A"};  
| Console.WriteLine(grades[3]);
```

30. The following code fragment satisfies the property of definiteness.

```
int[] v = {1, 3, 2, 9};  
Console.WriteLine(v[v[0]]);
```

31. The following code fragment displays the value of 1 on the screen.

```
int[] v = {1, 3, 2, 0};  
Console.WriteLine(v[v[v[0]]]);
```

32. The following code fragment displays all the elements of the array names.

```
string[] names = {"John", "George", "Sally", "Maria"};  
for (i = 1; i <= 4; i++) {  
    Console.WriteLine(names[i]);  
}
```

33. The following code fragment satisfies the property of definiteness.

```
string[] names = {"John", "George", "Sally", "Maria"};  
for (i = 2; i <= 4; i++) {  
    Console.WriteLine(names[i]);  
}
```

34. The following code fragment lets the user enter 100 values to array b.

```
for (i = 0; i <= 99; i++) {  
    b[i] = Int32.Parse(Console.ReadLine());  
}
```

35. If array b contains 30 elements, the following code fragment doubles the values of all of its elements.

```
for (i = 29; i >= 0; i--) {  
    b[i] = b[i] * 2;  
}
```

36. It is possible to use a for-loop to double the values of some of the elements of an array.

37. If array b contains 30 elements, the following code fragment displays all of them.

```
for (i = 0; i < 29; i++) {  
    Console.WriteLine(b[i]);  
}
```

38. If b is a dictionary, the following code fragment displays all of its elements.

```
foreach (var x in b) {  
    Console.WriteLine(b.Value);
```

```
| }
```

39. The following code fragment throws an error.

```
Dictionary<string, string> fruits = new Dictionary<string, string> {
    {"O", "Orange"},
    {"A", "Apple"},
    {"W", "Watermelon"}
};
Console.WriteLine(fruits["Orange"]);
```

### 31.14 Review Questions: Multiple Choice

Select the correct answer for each of the following statements.

1. The following statement

```
string() last_names = new string[4];
```

- a. contains a logic error.
- b. contains a syntax error.
- c. contains two syntax errors.
- d. contains three syntax errors.

2. The following code fragment

```
double x = 5;
names[x / 2] = 10;
```

- a. does not satisfy the property of definiteness.
- b. does not satisfy the property of finiteness.
- c. does not satisfy the property of effectiveness.
- d. none of the above

3. If variable *x* contains the value 4, the following statement

```
names[x + 1] = 5;
```

- a. assigns the value 4 to the element at index 5.
- b. assigns the value 5 to the element at index 4.
- c. assigns the value 5 to the element at index 5.
- d. none of the above

4. The following statement

```
int[] names = {5, 6, 9, 1, 1, 1};
```

- a. assigns the value 5 to the element at index 1.

- b. assigns the value 5 to the element at index 0.
- c. does not satisfy the property of definiteness.
- d. none of the above
5. The following code fragment
- ```
values[0] = 1;
values[values[0]] = 2;
values[values[1]] = 3;
values[values[2]] = 4;
```
- a. assigns the value 4 to the element at index 3.
- b. assigns the value 3 to the element at index 2.
- c. assigns the value 2 to the element at index 1.
- d. all of the above
- e. none of the above
6. If array `values` contains numeric values, the following statement
- ```
Console.WriteLine(values[values[1] - values[1 % 2]] - values[(int)(1 / 2)]);
```
- a. does not satisfy the property of definiteness.
- b. always displays 0.
- c. always displays 1.
- d. none of the above
7. You can iterate through a one-dimensional array with a for-loop that uses
- a. variable `i` as a counter.
- b. variable `j` as a counter.
- c. variable `k` as a counter.
- d. any variable as a counter.
8. The following code fragment
- ```
string[] names = {"George", "John", "Maria", "Sally"};
for (i = 3; i >= 1; i--) {
    Console.WriteLine(names[i]);
}
```
- a. displays all names in ascending order.
- b. displays some names in ascending order.

- c. displays all names in descending order.
- d. displays some names in descending order.
- e. none of the above

9. The following code fragment

```
string[] fruits = {"apple", "orange", "onion", "watermelon"};
Console.WriteLine(fruits[1]);
```

- a. displays "orange"
- b. displays apple
- c. displays orange
- d. throws an error because onion is not a fruit!
- e. none of the above

10. If array b contains 30 elements, the following code fragment

```
for (i = 29; i >= 1; i--) {
    b[i] = b[i] * 2;
}
```

- a. doubles the values of some of its elements.
- b. doubles the values of all of its elements.
- c. none of the above

11. The following code fragment

```
Dictionary<string, string> person = new Dictionary<string, string> {
    {"first_name", "George"},
    {"last_name", "Miles"},
    {"age", "28"}
};

foreach (var a in person) {
    Console.WriteLine(person[a.Key]);
}
```

- a. displays all the keys of the dictionary elements.
- b. displays all the values of the dictionary elements.
- c. displays all the key-value pairs of the dictionary elements.
- d. none of the above

12. The following code fragment

```
Dictionary<string, string> person = new Dictionary<string, string> {
```

```

        {"first_name", "George"},
        {"last_name", "Miles"},
        {"age", "28"}
    };

    foreach (var x in person) {
        Console.WriteLine(x.Key);
    }

```

- displays all the keys of the dictionary elements.
- displays all the values of the dictionary elements.
- displays all the key-value pairs of the dictionary elements.
- none of the above

13. The following code fragment

```

Dictionary<int, string> indian_tribes = new Dictionary<int, string> {
    {0, "Navajo"},
    {1, "Cherokee"},
    {2, "Sioux"},
    {3, "Apache"}
};

for (i = 0; i <= 3; i++) {
    Console.WriteLine(indian_tribes[i]);
}

```

- displays all the keys of the dictionary elements.
- displays all the values of the dictionary elements.
- displays all the key-value pairs of the dictionary elements.
- none of the above

14. The following code fragment

```

Dictionary<string, string> tribes = new Dictionary<string, string> {
    {"tribeA", "Navajo"},
    {"tribeB", "Cherokee"},
    {"tribeC", "Sioux"}
};

foreach (var x in tribes.ToList()) {
    tribes[x.Key] = tribes[x.Key].ToUpper();
}

```

- converts all the keys of the dictionary elements to uppercase.

- b. converts all the values of the dictionary elements to uppercase.
- c. convert all the key-value pairs of the dictionary elements to uppercase.
- d. none of the above

### 31.15 Review Exercises

Complete the following exercises.

1. Design a data structure to hold the weights (in pounds) of five people, and then add some typical values to the structure.
2. Design the necessary data structures to hold the names and the weights (in pounds) of seven people, and then add some typical values to the structure.
3. Design the necessary data structures to hold the names of five lakes as well as the average area (in square miles) of each lake in June, July, and August. Then add some typical values to the structures.
4. Design a data structure to hold the three dimensions (width, height, and depth in inches) of 10 boxes. Then add some typical values to the structure.
5. Design the necessary data structures to hold the names of eight lakes as well as the average area (in square miles) and maximum depth (in feet) of each lake. Then add some typical values to the structures.
6. Design the necessary data structures to hold the names of four lakes as well as their average areas (in square miles) for the first week of June, the first week of July, and the first week of August.
7. Create the trace table for the following code fragment.

```
int[] a = new int[3];
a[2] = 1;
x = 0;
a[x + a[2]] = 4;
a[x] = a[x + 1] * 4;
```

8. Create the trace table for the following code fragment.

```
int[] a = new int[5];
a[1] = 5;
x = 0;
a[x] = 4;
a[a[0]] = a[x + 1] % 3;
```

```

| a[a[0] / 2] = 10;
| x += 2;
| a[x + 1] = a[x] + 9;

```

9. Create the trace table for the following code fragment for three different executions.

The input values for the three executions are: (i) 3, (ii) 4, and (iii) 1.

```

int[] a = new int[4];
a[1] = Int32.Parse(Console.ReadLine());

x = 0;
a[x] = 3;
a[a[0]] = a[x + 1] % 2;
a[a[0] % 2] = 10;
x++;
a[x + 1] = a[x] + 9;

```

10. Create the trace table for the following code fragment for three different executions.

The input values for the three executions are: (i) 100, (ii) 108, and (iii) 1.

```

int[] a = new int[4];
a[1] = Int32.Parse(Console.ReadLine());
x = 0;
a[x] = 3;
a[a[0]] = a[x + 1] % 10;
if (a[3] > 5) {
    a[a[0] % 2] = 9;
    x += 1;
    a[x + 1] = a[x] + 9;
}
else {
    a[2] = 3;
}

```

11. Fill in the gaps in the following trace table. In steps 6 and 7, fill in the name of a variable; for all other cases, fill in constant values, arithmetic, or comparison operators.

| Step | Statement            | x | y | a[0] | a[1] | a[2] |
|------|----------------------|---|---|------|------|------|
| 1    | int[] a = new int[3] | ? | ? | ?    | ?    | ?    |
| 2    | x = .....            | 4 | ? | ?    | ?    | ?    |

|             |                                                                 |          |          |          |          |          |
|-------------|-----------------------------------------------------------------|----------|----------|----------|----------|----------|
| <b>3</b>    | $y = x - \dots$                                                 | <b>4</b> | <b>3</b> | ?        | ?        | ?        |
| <b>4, 5</b> | <pre>if (x ..... y)     a[0] = ..... ; else     a[0] = y;</pre> | <b>4</b> | <b>3</b> | <b>1</b> | ?        | ?        |
| <b>5</b>    | $a[1] = \dots + 3$                                              | <b>4</b> | <b>3</b> | <b>1</b> | <b>7</b> | ?        |
| <b>6</b>    | $y = \dots - 1$                                                 | <b>4</b> | <b>2</b> | <b>1</b> | <b>7</b> | ?        |
| <b>7</b>    | $a[y] = (x + 5) \dots 2$                                        | <b>4</b> | <b>2</b> | <b>1</b> | <b>7</b> | <b>1</b> |

12. Create the trace table for the following code fragment.

```
int[] a = {17, 12, 45, 12, 12, 49};

for (i = 0; i <= 5; i++) {
    if (a[i] == 12)
        a[i]--;
    else
        a[i]++;
}
```

13. Create the trace table for the following code fragment.

```
int[] a = {10, 15, 12, 23, 22, 19};

for (i = 1; i <= 4; i++) {
    a[i] = a[i + 1] + a[i - 1];
}
```

14. Try, without using a trace table, to determine the values that are displayed when the following code fragment is executed.

```
Dictionary<string, string> tribes = new Dictionary<string, string> {
    {"Indian-1", "Navajo"},
    {"Indian-2", "Cherokee"},
    {"Indian-3", "Sioux"},
    {"African-1", "Zulu"},
    {"African-2", "Maasai"},
    {"African-3", "Yoruba"}
};

foreach (var x in tribes) {
    if (x.Key.Substring(0, 6) == "Indian") {
        Console.WriteLine(x.Value);
    }
}
```

| }

15. Write a C# program that lets the user enter 100 numbers in an array and then displays these values raised to the power of three.
16. Write a C# program that lets the user enter 80 numbers in an array. Then, the program must raise the array values to the power of two, and finally display them in the exact reverse of the order in which they were given.
17. Write a C# program that lets the user enter 90 integers in an array and then displays those that are exactly divisible by 5 in the exact reverse of the order in which they were given.
18. Write a C# program that lets the user enter 50 integers in an array and then displays those that are even or greater than 10.
19. Write a C# program that lets the user enter 30 numbers in an array and then calculates and displays the sum of those that are positive.
20. Write a C# program that lets the user enter 50 integers in an array and then calculates and displays the sum of those that have two digits.  
Hint: All two-digit integers are between 10 and 99.
21. Write a C# program that lets the user enter 40 numbers in an array and then calculates and displays the sum of the positive numbers and the sum of the negative ones.
22. Write a C# program that lets the user enter 20 numbers in an array and then calculates and displays their average value.
23. Write a C# program that prompts the user to enter 50 integer values in an array. It then displays the indexes of the elements that contain values lower than 20.
24. Write a C# program that prompts the user to enter 60 numeric values in an array. It then displays the elements with even-numbered indexes (that is, indexes 0, 2, 4, 6, and so on).
25. Write a C# program that prompts the user to enter 20 numeric values in an array. It then calculates and displays the sum of the elements that have even indexes.
26. Write code fragment in C# that creates the following array of 100 elements.

|            |   |   |   |     |     |
|------------|---|---|---|-----|-----|
| <b>a =</b> | 1 | 2 | 3 | ... | 100 |
|------------|---|---|---|-----|-----|

27. Write code fragment in C# that creates the following array of 100 elements.

|            |   |   |   |     |     |
|------------|---|---|---|-----|-----|
| <b>a =</b> | 2 | 4 | 6 | ... | 200 |
|------------|---|---|---|-----|-----|

28. Write a C# program that prompts the user to enter an integer  $N$  and then creates and displays the following array of  $N$  elements. Assume that the user enters an integer greater than 1.

|            |   |   |   |     |       |
|------------|---|---|---|-----|-------|
| <b>a =</b> | 1 | 4 | 9 | ... | $N^2$ |
|------------|---|---|---|-----|-------|

29. Write a C# program that prompts the user to enter 10 numeric values in an array and then displays the indexes of the elements that contain integers.
30. Write a C# program that prompts the user to enter 50 numeric values in an array and then counts and displays the total number of negative elements.
31. Write a C# program that prompts the user to enter 50 words in an array and then displays those that contain at least 10 characters.

Hint: Use the `Length` property.

32. Write a C# program that lets the user enter 30 words in an array. It then displays those words that have less than 5 characters, then those that have less than 10 characters, and finally those that have less than 20 characters.

Hint: Try to display the words using two for-loops nested one within the other.

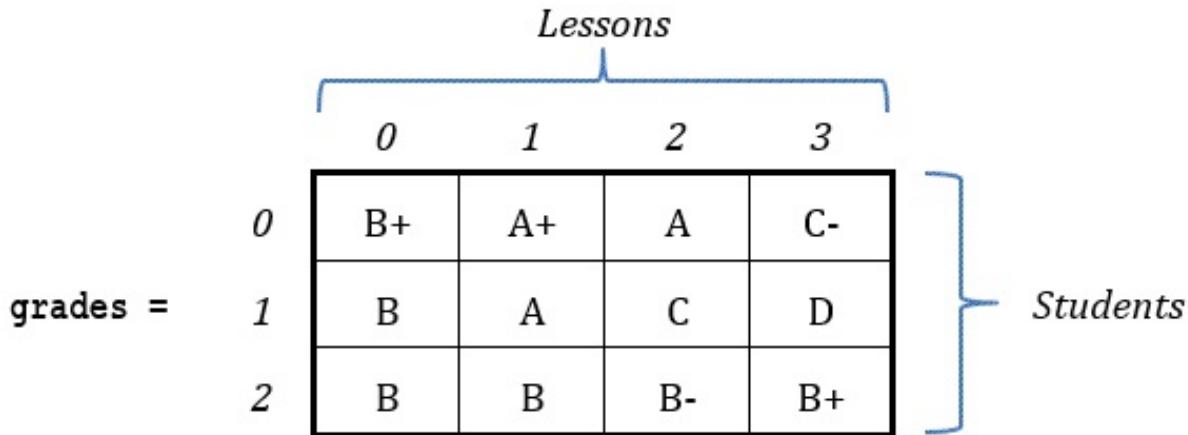
33. Write a C# program that prompts the user to enter 40 words in an array and then displays those that contain the letter “w” at least twice.

# Chapter 32

## Two-Dimensional Arrays

### 32.1 Creating Two-Dimensional Arrays in C#

An array that can hold the grades of four lessons for three students is as follows.



A two-dimensional array has rows and columns. In this particular example, array `grades` has 3 rows and 4 columns.

As in one-dimensional arrays, there are many ways to create and add elements (and values) to a two-dimensional array. Let's try to create the array `grades` using the most common approaches.

#### First Approach

To create an array and directly assign values to its elements, you can use the next C# statement, given in general form.

```
type[,] array_name = { {value0-0, value0-1, value0-2, ..., value0-M},  
                      {value1-0, value1-1, value1-2, ..., value1-M},  
                      {value2-0, value2-1, value2-2, ..., value2-M},  
                      ...  
                      {valueN-0, valueN-1, valueN-2, ..., valueN-M}  
};
```

where

- ▶ `type` can be `int`, `double`, `string` and so on
- ▶ `array_name` is the name of the array.
- ▶ `value0-0, value0-1, value0-2, ..., valueN-M` are the values of the

array elements.

For this approach, you can create the array grades using the following statement:

```
string[,] grades = { {"B+", "A+", "A", "C-"},  
                     {"B", "A", "C", "A+"},  
                     {"B", "B", "B-", "B+"}  
};
```

which can also be written as

```
string[,] grades = { {"B+", "A+", "A", "C-"}, {"B", "A", "C", "A+"}, {"B", "B", "B-", "B+"} };
```

 *Indexes are set automatically. The first value “B+” is assigned to the element at row index 0 and column index 0, second value “A+” is assigned to the element at row index 0 and column index 1, and so on.*

## Second Approach

You can create a two-dimensional array with empty elements in C# using the following statement, given in general form,

```
type[,] array_name = new type[number_of_rows, number_of_columns];
```

where *number\_of\_rows* and *number\_of\_columns* can be any positive integer value

Then you can assign a value to an array element using the following statement, given in general form:

```
array_name[row_index, column_index] = value;
```

where *row\_index* and *column\_index* are the row index and the column index positions, respectively, of the element in the array.

The following code fragment creates the array grades with 12 empty elements arranged in 3 rows and 4 columns and then assigns values to its elements.

```
string[,] grades = new string[3, 4];  
grades[0, 0] = "B+";  
grades[0, 1] = "A+";  
grades[0, 2] = "A";  
grades[0, 3] = "C-";  
grades[1, 0] = "B";  
grades[1, 1] = "A";  
grades[1, 2] = "C";  
grades[1, 3] = "A+";  
grades[2, 0] = "B";
```

```
grades[2, 1] = "B";
grades[2, 2] = "B-";
grades[2, 3] = "B+";
```

## 32.2 How to Get Values from Two-Dimensional Arrays

A two-dimensional array consists of rows and columns. The following example shows a two-dimensional array with three rows and four columns.

|              | <i>Column 0</i> | <i>Column 1</i> | <i>Column 2</i> | <i>Column 3</i> |
|--------------|-----------------|-----------------|-----------------|-----------------|
| <i>Row 0</i> |                 |                 |                 |                 |
| <i>Row 1</i> |                 |                 |                 |                 |
| <i>Row 2</i> |                 |                 |                 |                 |

Each element of a two-dimensional array can be uniquely identified using a pair of indexes: a row index, and a column index, as shown next.

*array\_name[row\_index, column\_index]*

The following code fragment creates the two-dimensional array *grades* having three rows and four columns, and then displays some of its elements.

```
string[,] grades = { {"B+", "A+", "A", "C-"},  
                     {"B", "A", "C", "D"},  
                     {"B", "B", "B-", "B+"}  
};  
  
Console.WriteLine(grades[1, 2]); //It displays: C  
Console.WriteLine(grades[2, 2]); //It displays: B-  
Console.WriteLine(grades[0, 0]); //It displays: B+
```

### ***Exercise 32.2-1 Creating the Trace Table***

---

*Create the trace table for the next code fragment.*

```
int[,] a = { {0, 0},  
            {0, 0},  
            {0, 0}  
};  
  
a[1, 0] = 9;  
a[0, 1] = 1;  
a[0, 0] = a[0, 1] + 6;  
x = 2;  
a[x, 1] = a[0, 0] + 4;
```

```
a[x - 1, 1] = a[0, 1] * 3;
a[x, 0] = a[x - 1, 1] - 3;
```

## Solution

---

This code fragment uses a  $3 \times 2$  array, that is, an array that has 3 rows and 2 columns. The trace table is as follows.

| Step | Statement                                         | Notes                                            | x | a                                                                                                                     |   |   |   |   |   |   |
|------|---------------------------------------------------|--------------------------------------------------|---|-----------------------------------------------------------------------------------------------------------------------|---|---|---|---|---|---|
| 1    | int[,] a = { {0,<br>0},<br>{0, 0},<br>{0, 0}<br>} | This creates the array a with zero values in it. | ? | <table border="1"> <tr><td>0</td><td>0</td></tr> <tr><td>0</td><td>0</td></tr> <tr><td>0</td><td>0</td></tr> </table> | 0 | 0 | 0 | 0 | 0 | 0 |
| 0    | 0                                                 |                                                  |   |                                                                                                                       |   |   |   |   |   |   |
| 0    | 0                                                 |                                                  |   |                                                                                                                       |   |   |   |   |   |   |
| 0    | 0                                                 |                                                  |   |                                                                                                                       |   |   |   |   |   |   |
| 2    | a[1, 0] = 9                                       |                                                  | ? | <table border="1"> <tr><td>0</td><td>0</td></tr> <tr><td>9</td><td>0</td></tr> <tr><td>0</td><td>0</td></tr> </table> | 0 | 0 | 9 | 0 | 0 | 0 |
| 0    | 0                                                 |                                                  |   |                                                                                                                       |   |   |   |   |   |   |
| 9    | 0                                                 |                                                  |   |                                                                                                                       |   |   |   |   |   |   |
| 0    | 0                                                 |                                                  |   |                                                                                                                       |   |   |   |   |   |   |
| 3    | a[0, 1] = 1                                       |                                                  | ? | <table border="1"> <tr><td>0</td><td>1</td></tr> <tr><td>9</td><td>0</td></tr> <tr><td>0</td><td>0</td></tr> </table> | 0 | 1 | 9 | 0 | 0 | 0 |
| 0    | 1                                                 |                                                  |   |                                                                                                                       |   |   |   |   |   |   |
| 9    | 0                                                 |                                                  |   |                                                                                                                       |   |   |   |   |   |   |
| 0    | 0                                                 |                                                  |   |                                                                                                                       |   |   |   |   |   |   |
| 4    | a[0, 0] = a[0, 1] +<br>6                          |                                                  | ? | <table border="1"> <tr><td>7</td><td>1</td></tr> <tr><td>9</td><td>0</td></tr> <tr><td>0</td><td>0</td></tr> </table> | 7 | 1 | 9 | 0 | 0 | 0 |
| 7    | 1                                                 |                                                  |   |                                                                                                                       |   |   |   |   |   |   |
| 9    | 0                                                 |                                                  |   |                                                                                                                       |   |   |   |   |   |   |
| 0    | 0                                                 |                                                  |   |                                                                                                                       |   |   |   |   |   |   |
| 5    | x = 2                                             |                                                  | 2 | <table border="1"> <tr><td>7</td><td>1</td></tr> <tr><td>9</td><td>0</td></tr> <tr><td>0</td><td>0</td></tr> </table> | 7 | 1 | 9 | 0 | 0 | 0 |
| 7    | 1                                                 |                                                  |   |                                                                                                                       |   |   |   |   |   |   |
| 9    | 0                                                 |                                                  |   |                                                                                                                       |   |   |   |   |   |   |
| 0    | 0                                                 |                                                  |   |                                                                                                                       |   |   |   |   |   |   |
| 6    | a[x, 1] = a[0, 0] +<br>4                          |                                                  | 2 | <table border="1"> <tr><td>7</td><td>1</td></tr> <tr><td>9</td><td>0</td></tr> <tr><td></td><td></td></tr> </table>   | 7 | 1 | 9 | 0 |   |   |
| 7    | 1                                                 |                                                  |   |                                                                                                                       |   |   |   |   |   |   |
| 9    | 0                                                 |                                                  |   |                                                                                                                       |   |   |   |   |   |   |
|      |                                                   |                                                  |   |                                                                                                                       |   |   |   |   |   |   |

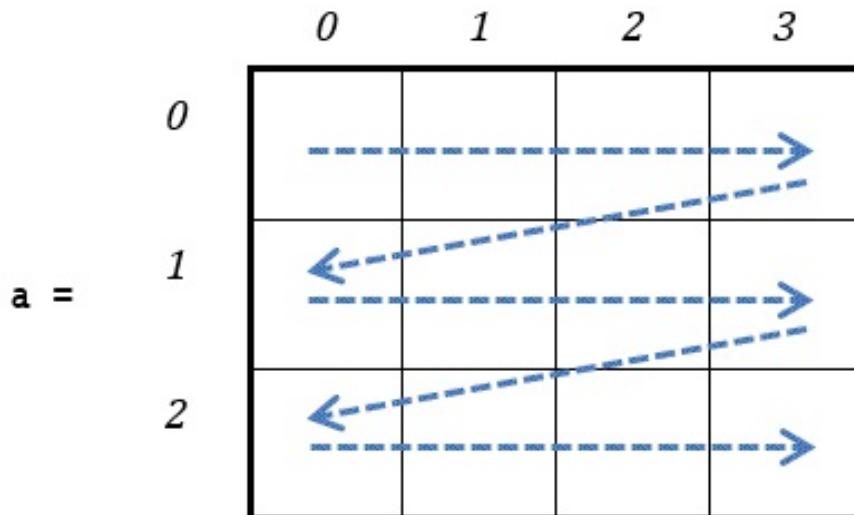
|   |                             |  |  |   |                           |
|---|-----------------------------|--|--|---|---------------------------|
|   |                             |  |  | 0 | 11                        |
| 7 | $a[x - 1, 1] = a[0, 1]$ * 3 |  |  | 2 | 7 1<br>9 3<br>0 11        |
| 8 | $a[x, 0] = a[x - 1, 1] - 3$ |  |  | 2 | 7 1<br>9 3<br><b>0 11</b> |

### 32.3 How to Iterate Through a Two-Dimensional Array

Since a two-dimensional array consists of rows and columns, a program can iterate either through rows or through columns.

#### Iterating through rows

Iterating through rows means that row 0 is processed first, row 1 is process next, row 2 afterwards, and so on. Next there is an example of a  $3 \times 4$  array. The arrows show the “path” that is followed when iteration through rows is performed or in other words, they show the order in which the elements are processed.



☞ A  $3 \times 4$  array is a two-dimensional array that has 3 rows and 4 columns. In the notation  $Y \times X$ , the first number (Y) always represents the total

*number of rows and the second number (X) always represents the total number of columns.*

When iterating through rows, the elements of the array are processed as follows:

- the elements of row 0 are processed in the following order  
 $a[0, 0] \rightarrow a[0, 1] \rightarrow a[0, 2] \rightarrow a[0, 3]$
- the elements of row 1 are processed in the following order  
 $a[1, 0] \rightarrow a[1, 1] \rightarrow a[1, 2] \rightarrow a[1, 3]$
- the elements of row 2 are processed in the following order  
 $a[2, 0] \rightarrow a[2, 1] \rightarrow a[2, 2] \rightarrow a[2, 3]$

Using C# statements, let's try to process all elements of a  $3 \times 4$  array (3 rows  $\times$  4 columns) iterating through rows.

```
i = 0;                                //Variable i refers to Row 0.  
for (j = 0; j <= 3; j++) { //This loop control structure processes all elements of Row 0  
    process a[i, j];  
}  
  
i = 1;                                //Variable i refers to Row 1.  
for (j = 0; j <= 3; j++) { //This loop control structure processes all elements of Row 1  
    process a[i, j];  
}  
  
i = 2;                                //Variable i refers to Row 2.  
for (j = 0; j <= 3; j++) { //This loop control structure processes all elements of Row 2  
    process a[i, j];  
}
```

Of course, the same results can be achieved using a nested loop control structure as shown next.

```
for (i = 0; i <= 2; i++) {  
    for (j = 0; j <= 3; j++) {  
        process a[i, j];  
    }  
}
```

Let's see some examples. The following code fragment lets the user enter 10

$\times 10 = 100$  values to array b.

```
for (i = 0; i <= 9; i++) {  
    for (j = 0; j <= 9; j++) {  
        b[i, j] = Console.ReadLine();  
    }  
}
```

The following code fragment decreases all values of array b by one.

```
for (i = 0; i <= 9; i++) {  
    for (j = 0; j <= 9; j++) {  
        b[i, j]--;           //Equivalent to: b[i, j] = b[i, j] - 1  
    }  
}
```

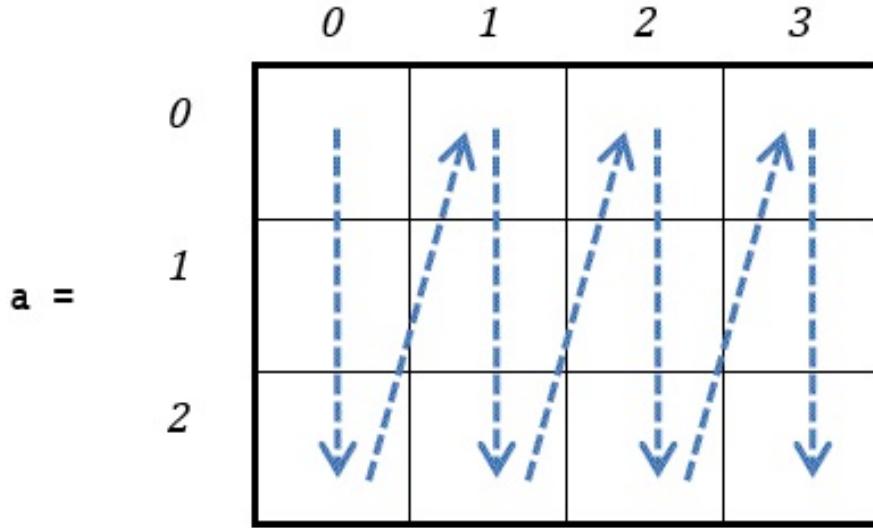
The following code fragment displays all elements of array b.

```
for (i = 0; i <= 9; i++) {  
    for (j = 0; j <= 9; j++) {  
        Console.WriteLine(b[i, j] + "\t");  
    }  
    Console.WriteLine();  
}
```

 The `Console.WriteLine()` statement is used to “display” a line break between rows.

## Iterating Through Columns

Iterating through columns means that column 0 is processed first, column 1 is processed next, column 2 afterwards, and so on. Next there is an example of a  $3 \times 4$  array. The arrows show the order in which the elements are processed.



When iterating through columns, the elements of the array are processed as follows:

- ▶ the elements of column 0 are processed in the following order  
 $a[0, 0] \rightarrow a[1, 0] \rightarrow a[2, 0]$
- ▶ the elements of column 1 are processed in the following order  
 $a[0, 1] \rightarrow a[1, 1] \rightarrow a[2, 1]$
- ▶ the elements of column 2 are processed in the following order  
 $a[0, 2] \rightarrow a[1, 2] \rightarrow a[2, 2]$
- ▶ the elements of column 3 are processed in the following order  
 $a[0, 3] \rightarrow a[1, 3] \rightarrow a[2, 3]$

Using C# statements, let's try to process all elements of a  $3 \times 4$  array (3 rows  $\times$  4 columns) by iterating through columns.

```
j = 0;                                //Variable j refers to Column 0.
for (i = 0; i <= 2; i++) { //This loop control structure processes all elements of column 0
    process a[i, j];
}

j = 1;                                //Variable j refers to Column 1.
for (i = 0; i <= 2; i++) { //This loop control structure processes all elements of column 1
    process a[i, j];
}

j = 2;                                //Variable j refers to Column 2.
for (i = 0; i <= 2; i++) { //This loop control structure processes all elements of column 2
    process a[i, j];
}
```

```

    process a[i, j];
}

j = 3;                                //Variable j refers to column 3.
for (i = 0; i <= 2; i++) { //This loop control structure processes all elements of Column 3
    process a[i, j];
}

```

Of course, the same result can be achieved using a nested loop control structure as shown next.

```

for (j = 0; j <= 3; j++) {
    for (i = 0; i <= 2; i++) {
        process a[i, j];
    }
}

```

As you can see, this code fragment differs on only one single point from the one that iterates through rows: the two for-loops have switched places. Be careful though. Don't try switching places of the two index variables *i* and *j* in the statement *process a[i, j]*. Take the following code fragment, for example. It tries to iterate through columns in a  $3 \times 4$  array (3 rows  $\times$  4 columns) but it does not satisfy the property of definiteness. Can you find out why?

```

for (j = 0; j <= 3; j++) {
    for (i = 0; i <= 2; i++) {
        process a[j, i];
    }
}

```

The trouble arises when variable *j* becomes equal to 3. The statement *process a[j, i]* tries to process the elements at **row** index 3 (this is the fourth row) which, of course, does not exist! Still confused? Don't be! There is no row index 3 in a  $3 \times 4$  array! Why? Since row index numbering starts at 0, only rows 0, 1, and 2 actually exist!

## 32.4 How to Add User-Entered Values to a Two-Dimensional Array

Just as in one-dimensional arrays, instead of reading a value entered from the keyboard and assigning that value to a variable, you can directly assign

that value to a specific array element. The next code fragment creates a two-dimensional array names, prompts the user to enter six values, and assigns those values to the elements of the array.

```
static void Main(string[] args) {
    string[,] names = new string[3, 2];

    Console.WriteLine("Name for Row 0, Column 0: ");
    names[0, 0] = Console.ReadLine();

    Console.WriteLine("Name for Row 0, Column 1: ");
    names[0, 1] = Console.ReadLine();

    Console.WriteLine("Name for Row 1, Column 0: ");
    names[1, 0] = Console.ReadLine();

    Console.WriteLine("Name for Row 1, Column 1: ");
    names[1, 1] = Console.ReadLine();

    Console.WriteLine("Name for Row 2, Column 0: ");
    names[2, 0] = Console.ReadLine();

    Console.WriteLine("Name for Row 2, Column 1: ");
    names[2, 1] = Console.ReadLine();

    ...
}
```

Using nested for-loops, this code fragment can equivalently be written as

```
const int ROWS = 3;
const int COLUMNS = 2;

static void Main(string[] args) {
    int i, j;
    string[,] names = new string[ROWS, COLUMNS];

    for (i = 0; i <= ROWS - 1; i++) {
        for (j = 0; j <= COLUMNS - 1; j++) {
            Console.WriteLine("Name for Row " + i + ", Column " + j + ": ");
            names[i, j] = Console.ReadLine();
        }
    }
}
```

---

### ***Exercise 32.4-1 Displaying Reals Only***

*Write a C# program that prompts the user to enter numeric values in a  $5 \times 7$  array and then displays the indexes of the elements that contain reals.*

## **Solution**

---

Iterating through rows is the most popular approach, so let's use it. The solution is as follows.

### project\_32\_4\_1

```
const int ROWS = 5;
const int COLUMNS = 7;

static void Main(string[] args) {
    int i, j;

    double[,] a = new double[ROWS, COLUMNS];
    for (i = 0; i <= ROWS - 1; i++) {
        for (j = 0; j <= COLUMNS - 1; j++) {
            Console.WriteLine("Enter a value for element " + i + ", " + j + ": ");
            a[i, j] = Double.Parse(Console.ReadLine());
        }
    }

    for (i = 0; i <= ROWS - 1; i++) {
        for (j = 0; j <= COLUMNS - 1; j++) {
            if (a[i, j] != (int)(a[i, j])) { //Check if it is real (float)
                Console.WriteLine("A real found at position: " + i + ", " + j);
            }
        }
    }
}
```

## **Exercise 32.4-2 Displaying Odd Columns Only**

---

*Write a C# program that prompts the user to enter numeric values in a 5 × 7 array and then displays the elements of the columns with odd-numbered indexes (that is, column indexes 1, 3, and 5).*

## **Solution**

---

The C# program is presented next.

### project\_32\_4\_2

```
const int ROWS = 5;
const int COLUMNS = 7;

static void Main(string[] args) {
    int i, j;
```

```

double[,] a = new double[ROWS, COLUMNS];
for (i = 0; i <= ROWS - 1; i++) {
    for (j = 0; j <= COLUMNS - 1; j++) {
        Console.WriteLine("Enter a value for element " + i + ", " + j + ": ");
        a[i, j] = Double.Parse(Console.ReadLine());
    }
}

//Iterate through columns
for (j = 1; j <= COLUMNS - 1; j += 2) { //Start from 1 and increment by 2
    for (i = 0; i <= ROWS - 1; i++) {
        Console.Write(a[i, j] + " ");
    }
}
}

```

 This book tries to use, as often as possible, variable *i* as the row index and variable *j* as the column index. Of course, you can use other variable names as well, such as *row*, *r* for row index, or *column*, *c* for column index, but variables *i* and *j* are widely used by the majority of programmers. After using them for a while, your brain will relate *i* to rows and *j* to columns. Thus, every algorithm or program that uses these variable names as indexes in two-dimensional arrays will be more readily understood.

## 32.5 What's the Story on Variables *i* and *j*?

Many programmers believe that the name of variable *i* stands for “index” and *j* is used just because it is after *i*. Others believe that the name *i* stands for “integer”. Probably the truth lies somewhere in the middle.

Mathematicians were using *i*, *j*, and *k* to designate integers in mathematics long before computers were around. Later, in FORTRAN, one of the first high-level computer languages, variables *i*, *j*, *k*, *l*, *m*, and *n* were integers by default. Thus, the first programmers picked up the habit of using variables *i* and *j* in their programs and it became a convention in most computer languages.

## 32.6 Square Matrices

In mathematics, a matrix that has the same number of rows and columns is called a *square matrix*. Following are some examples of square matrices.

|   | 0 | 1 | 2 |
|---|---|---|---|
| 0 |   |   |   |
| 1 |   |   |   |
| 2 |   |   |   |

a =

|   | 0 | 1 | 2 | 3 | 4 |
|---|---|---|---|---|---|
| 0 |   |   |   |   |   |
| 1 |   |   |   |   |   |
| 2 |   |   |   |   |   |
| 3 |   |   |   |   |   |
| 4 |   |   |   |   |   |

b =

### Exercise 32.6-1 Finding the Sum of the Elements of the Main Diagonal

Write a C# program that lets the user enter numeric values into a  $10 \times 10$  array and then calculates the sum of the elements of its main diagonal.

#### Solution

In mathematics, the main diagonal of a square matrix is the collection of those elements that runs from the top left corner to the bottom right corner. Following are some examples of square matrices with their main diagonals highlighted by a dark background.

|   | 0  | 1  | 2  |
|---|----|----|----|
| 0 | 10 | 12 | 11 |
| 1 | 23 | 50 | 9  |
| 2 | 12 | 11 | -3 |

a =

|   | 0  | 1  | 2   | 3  | 4   |
|---|----|----|-----|----|-----|
| 0 | -3 | 44 | -12 | 25 | 22  |
| 1 | 10 | -1 | 29  | 12 | -9  |
| 2 | 5  | -3 | 16  | 22 | -8  |
| 3 | 11 | 25 | 12  | 25 | -5  |
| 4 | 12 | 22 | 53  | 44 | -15 |

b =

 Note that the elements of the main diagonal have their row index equal to their column index.

You can calculate the sum of the elements of the main diagonal using two

different approaches. Let's study them both.

## First Approach – Iterating through all elements

In this approach, the program iterates through rows and checks if the row index is equal to the column index. For square matrices (in this case, arrays) represented as  $N \times N$ , the number of rows and columns is equal, so you can define just one constant,  $n$ . The solution is as follows.

### project\_32\_6\_1a

```
const int N = 10;

static void Main(string[] args) {
    int i, j;
    double total;

    double[,] a = new double[N, N];
    for (i = 0; i <= N - 1; i++) {
        for (j = 0; j <= N - 1; j++) {
            a[i, j] = Double.Parse(Console.ReadLine());
        }
    }

    //Calculate the sum
    total = 0;
    for (i = 0; i <= N - 1; i++) {
        for (j = 0; j <= N - 1; j++) {
            if (i == j) {
                total += a[i, j];      //This is equivalent to: total = total + a[i, j]
            }
        }
    }

    Console.WriteLine("Sum = " + total);
}
```

- ☞ Note that the program iterates through rows and checks if the row index is equal to the column index. Alternatively, the same result can be achieved by iterating through columns.
- ☞ In this approach, the nested loop control structure that is responsible for calculating the sum performs  $10 \times 10 = 100$  iterations.

## Second Approach – Iterating directly through the main diagonal

In this approach, one single loop control structure iterates directly through the main diagonal. The solution is as follows.

### project\_32\_6\_1b

```
const int N = 10;

static void Main(string[] args) {
    int i, j, k;
    double total;

    double[,] a = new double[N, N];
    for (i = 0; i <= N - 1; i++) {
        for (j = 0; j <= N - 1; j++) {
            a[i, j] = Double.Parse(Console.ReadLine());
        }
    }

    //Calculate the sum
    total = 0;
    for (k = 0; k <= N - 1; k++) {
        total += a[k, k];
    }

    Console.WriteLine("Sum = " + total);
}
```

 This approach is much more efficient than the first one since the total number of iterations performed by the for-loop that is responsible for calculating the sum is just 10.

### Exercise 32.6-2 Finding the Sum of the Elements of the Antidiagonal

Write a C# program that lets the user enter numeric values in a  $5 \times 5$  array and then calculates the sum of the elements of its antidiagonal.

### Solution

In mathematics, the antidiagonal of a square matrix is the collection of those elements that runs from the top right corner to the bottom left corner of the array. Next, you can find an example of a  $5 \times 5$  square matrix with its antidiagonal highlighted by a dark background.

|            | <i>i</i> | 0  | 1  | 2   | 3  | 4   |
|------------|----------|----|----|-----|----|-----|
| <i>j</i>   | 0        | -3 | 44 | -12 | 25 | 22  |
|            | 1        | 10 | -1 | 29  | 12 | -9  |
| <i>a</i> = | 2        | 5  | -3 | 16  | 22 | -8  |
|            | 3        | 11 | 25 | 12  | 25 | -5  |
|            | 4        | 12 | 22 | 53  | 44 | -15 |

Any element of the antidiagonal of an  $N \times N$  array satisfies the following equation:

$$i + j = N - 1$$

where variables *i* and *j* correspond to the row and column indexes of the element respectively.

If you solve for *j*, the equation becomes

$$j = N - i - 1$$

Using this formula, you can calculate, for any value of variable *i*, the corresponding value of variable *j*. For example, in the previous  $5 \times 5$  square array in which *N* equals 5, when *i* is 0 the value of variable *j* is

$$j = N - i - 1 \Leftrightarrow j = 5 - 0 - 1 \Leftrightarrow j = 4$$

Using all this knowledge, let's now write the corresponding C# program.

### project\_32\_6\_2

```
const int N = 5;

static void Main(string[] args) {
    int i, j;
    double total;

    double[,] a = new double[N, N];
    for (i = 0; i <= N - 1; i++) {
        for (j = 0; j <= N - 1; j++) {
            a[i, j] = Double.Parse(Console.ReadLine());
        }
    }
}
```

```

//Calculate the sum
total = 0;
for (i = 0; i <= N - 1; i++) {
    j = N - i - 1;
    total += a[i, j];
}

Console.WriteLine("Sum = " + total);
}

```

 Note that the for-loop that is responsible for finding the sum of the elements of the antidiagonal iterates directly through the antidiagonal.

### ***Exercise 32.6-3 Filling in the Array***

*Write a C# program that creates and displays the following array.*

|   | 0  | 1  | 2  | 3  | 4  |
|---|----|----|----|----|----|
| 0 | -1 | 20 | 20 | 20 | 20 |
| 1 | 10 | -1 | 20 | 20 | 20 |
| 2 | 10 | 10 | -1 | 20 | 20 |
| 3 | 10 | 10 | 10 | -1 | 20 |
| 4 | 10 | 10 | 10 | 10 | -1 |

### ***Solution***

As you can see, in the main diagonal, there is the value of -1. You already know that the main diagonal of a square matrix is the collection of those elements that have their row index equal to their column index. Now, what you also need is to find a common characteristic between all elements that contain the value 10, and another such common characteristic between all elements that contain the value 20. And actually there are! The row index of any of the elements that contains the value 10 is always greater than its corresponding column index and, similarly, the row index of any of the elements that contains the value 20 is always less than its corresponding column index.

Accordingly, the C# program is as follows.

### project\_32\_6\_3

```
const int N = 5;

static void Main(string[] args) {
    int i, j;

    int[,] a = new int[N, N];
    for (i = 0; i <= N - 1; i++) {
        for (j = 0; j <= N - 1; j++) {
            if (i == j) {
                a[i, j] = -1;
            }
            else if (i > j) {
                a[i, j] = 10;
            }
            else {
                a[i, j] = 20;
            }
        }
    }

    for (i = 0; i <= N - 1; i++) {
        for (j = 0; j <= N - 1; j++) {
            Console.WriteLine(a[i, j] + "\t");
        }
        Console.WriteLine();
    }
}
```

## 32.7 Review Questions: True/False

Choose **true** or **false** for each of the following statements.

1. All the elements of a two-dimensional array must contain different values.
2. In order to refer to an element of a two-dimensional array you need two indexes.
3. The two indexes of a two-dimensional array must be either both variables, or both constant values.
4. A  $5 \times 6$  array is a two-dimensional array that has five columns and six rows.

5. To refer to an element of array `b` that exists at the second row and third column, you would write `b[2, 3]`.
6. Iterating through rows means that first row of a two-dimensional array is processed first, the second row is process next, and so on.
7. You cannot use variables other than `i` and `j` to iterate through a two-dimensional array.
8. The following C# statement creates a two-dimensional array.

```
int[,] names = new int[3, 7];
```

9. The following code fragment creates a two-dimensional array of four elements.

```
string[,] names = new string[2, 2];
names[0, 0] = "John";
names[0, 1] = "George";
names[1, 0] = "Sally";
names[1, 1] = "Angelina";
```

10. The following code fragment assigns the value 10 to an element that exists in the row with index 0.

```
values[0, 0] = 7;
values[0, values[0, 0]] = 10;
```

11. The following statement adds the name “Sally” to an element that exists in the row with index 1.

```
string[,] names = { {"John", "George"}, {"Sally", "Angelina"} };
```

12. The following code fragment displays the name “Sally” on the screen.

```
string[,] names = new string[2, 2];
k = 0;
names[0, k] = "John";
k++;
names[0, k] = "George";
names[1, k] = "Sally";
k--;
names[1, k] = "Angelina";
Console.WriteLine(names[1, 1]);
```

13. The following code fragment satisfies the property of definiteness.

```
string[,] grades = { {"B+", "A+"}, {"A", "C-"} };
Console.WriteLine(grades[2, 2]);
```

14. The following code fragment satisfies the property of definiteness.

```
int[,] values = { {1, 0}, {2, 0} };
```

```
    Console.WriteLine(values[values[0, 0], values[0, 1]]);
```

15. The following code fragment displays the value 2 on the screen.

```
int[,] values = { {0, 1}, {2, 0} };
Console.WriteLine(values[values[0, 1], values[0, 0]]);
```

16. The following code fragment displays all the elements of a  $3 \times 4$  array.

```
for (k = 0; k <= 11; k++) {
    i = (int)(k / 4);
    j = k % 4;
    Console.WriteLine(names[i, j]);
}
```

17. The following code fragment lets the user enter 100 values to array b.

```
for (i = 0; i <= 9; i++) {
    for (j = 0; j <= 9; j++) {
        b[i, j] = Console.ReadLine();
    }
}
```

18. If array b contains  $10 \times 20$  elements, the following code fragment doubles the values of all of its elements.

```
for (i = 9; i >= 0; i--) {
    for (j = 19; j >= 0; j--) {
        b[i, j] *= 2;
    }
}
```

19. If array b contains  $10 \times 20$  elements, the following code fragment displays some of them.

```
for (i = 0; i <= 8; i += 2) {
    for (j = 0; j <= 19; j++) {
        Console.WriteLine(b[i, j]);
    }
}
for (i = 1; i <= 9; i += 2) {
    for (j = 0; j <= 19; j++) {
        Console.WriteLine(b[i, j]);
    }
}
```

20. The following code fragment displays only the columns with even-numbered indexes.

```
for (j = 0; j <= 10; j += 2) {
    for (i = 0; i <= 9; i++) {
        Console.WriteLine(a[i, j]);
    }
}
```

```
| }
```

21. A  $5 \times 5$  array is a square array.
22. In the main diagonal of a  $N \times N$  array, all elements have their row index equal to their column index.
23. In mathematics, the antidiagonal of a square matrix is the collection of those elements that runs from the top left corner to the bottom right corner of the array.
24. Any element of the antidiagonal of an  $N \times N$  array satisfies the equation  $i + j = N - 1$ , where variables  $i$  and  $j$  correspond to the row and column indexes of the element respectively.
25. The following code fragment calculates the sum of the elements of the main diagonal of a  $N \times N$  array.

```
total = 0;  
for (k = 0; k <= N - 1; k++) {  
    total += a[k, k];  
}
```

26. The following code fragment displays all the elements of the antidiagonal of an  $N \times N$  array.

```
for (i = N - 1; i >= 0; i--) {  
    Console.WriteLine(a[i, N - i - 1]);  
}
```

27. The column index of any element of a  $N \times N$  array that is below the main diagonal is always greater than its corresponding row index.

## 32.8 Review Questions: Multiple Choice

Select the correct answer for each of the following statements.

1. The following statement

```
string last_names = string[5, 4];
```

- a. contains a logic error.
- b. contains a syntax error.
- c. none of the above

2. The following code fragment

```
int[,] values = { {1, 0} {2, 0} };  
Console.WriteLine(values[values[0, 0], values[0, 1]]);
```

- a. contains logic error(s).

b. contains syntax error(s).

c. none of the above

3. The following code fragment

```
x = Int32.Parse(Console.ReadLine());  
y = Int32.Parse(Console.ReadLine());  
names[x, y] = 10;
```

a. does not satisfy the property of finiteness.

b. does not satisfy the property of effectiveness.

c. does not satisfy the property of definiteness.

d. none of the above

4. If variable *x* contains the value 4, the following statement

```
names[x + 1, x] = 5;
```

a. assigns the value 5 to the element with row index 5 and column index 4.

b. assigns the value 5 to the element with row index 4 and column index 5.

c. assigns the value 5 to the element with row index 5 and column index 5.

d. none of the above

5. The following statement

```
int[,] names = { {3, 5, 2} };
```

a. assigns the value 5 to the element with row index 0 and column index 1.

b. assigns the value 3 to the element with row index 0 and column index 0.

c. assigns the value 2 to the element with row index 0 and column index 2.

d. all of the above

e. none of the above

6. The following statement

```
int[,] values = new int[1, 2];
```

a. creates a  $1 \times 2$  array.

- b. creates a  $2 \times 1$  array.
  - c. creates a one-dimensional array.
  - d. none of the above
7. You can iterate through a two-dimensional array with two nested loop control structures that use
- a. variables *i* and *j* as counters.
  - b. variables *k* and *l* as counters.
  - c. variables *m* and *n* as counters.
  - d. any variables as counters.
8. The following code fragment
- ```
string[,] names = { {"John", "Sally"}, {"George", "Maria"} };  
for (j = 0; j <= 1; j++) {  
    for (i = 1; i >= 0; i--) {  
        Console.WriteLine(names[i, j]);  
    }  
}
```
- a. displays all names in descending order.
  - b. displays some names in descending order.
  - c. displays all names in ascending order.
  - d. displays some names in ascending order.
  - e. none of the above
9. If array *b* contains  $30 \times 40$  elements, the following code fragment
- ```
for (i = 30; i >= 1; i--) {  
    for (j = 40; j >= 1; j--) {  
        b[i, j] *= 3;  
    }  
}
```
- a. triples the values of some of its elements.
  - b. triples the values of all of its elements.
  - c. none of the above
10. If array *b* contains  $30 \times 40$  elements, the following code fragment
- ```
total = 0;  
for (i = 29; i >= 0; i--) {  
    for (j = 39; j >= 0; j--) {
```

```
        total += b[i, j];
    }
}
average = total / 120;
```

- a. calculates the sum of all of its elements.
  - b. calculates the average value of all of its elements.
  - c. all of the above
11. The following two code fragments calculate the sum of the elements of the main diagonal of an  $N \times N$  array,

```
total = 0;
for (i = 0; i <= N - 1; i++) {
    for (j = 0; j <= N - 1; j++) {
        if (i == j) {
            total += a[i, j];
        }
    }
}
```

```
total = 0;
for (k = 0; k <= N - 1; k++) {
    total += a[k, k];
}
```

- a. but the first one is more efficient.
- b. but the second one is more efficient.
- c. none of the above; both code fragments perform equivalently

## 32.9 Review Exercises

Complete the following exercises.

1. Create the trace table for the following code fragment.

```
int[,] a = new int[2, 3];
a[0, 2] = 1;
x = 0;
a[0, x] = 9;
a[0, x + a[0, 2]] = 4;
a[a[0, 2], 2] = 19;
a[a[0, 2], x + 1] = 13;
a[a[0, 2], x] = 15;
```

2. Create the trace table for the following code fragment.

```
int[,] a = new int[2, 3];
for (i = 0; i <= 1; i++) {
    for (j = 0; j <= 2; j++) {
        a[i, j] = (i + 1) * 5 + j;
    }
}
```

3. Create the trace table for the following code fragment.

```
int[,] a = new int[3, 3];
for (j = 0; j <= 2; j++) {
    for (i = 0; i <= 2; i++) {
        a[i, j] = (i + 1) * 2 + j * 4;
    }
}
```

4. Try, without using a trace table, to determine the values that the array will contain when the following code fragment is executed. Do this for three different executions. The corresponding input values are: (i) 5, (ii) 9, and (iii) 3.

```
int[,] a = new int[2, 3];
x = Int32.Parse(Console.ReadLine());
for (i = 0; i <= 1; i++) {
    for (j = 0; j <= 2; j++) {
        a[i, j] = (x + i) * j;
    }
}
```

5. Try, without using a trace table, to determine the values that the array will contain when the following code fragment is executed. Do this for three different executions. The corresponding input values are: (i) 13, (ii) 10, and (iii) 8.

```
int[,] a = new int[2, 3];
x = Int32.Parse(Console.ReadLine());
for (i = 0; i <= 1; i++) {
    for (j = 0; j <= 2; j++) {
        if (j < x % 4)
            a[i, j] = (x + i) * j;
        else
            a[i, j] = (x + j) * i + 3;
    }
}
```

6. Try, without using a trace table, to determine the values that the array will contain when the following code fragment is executed.

```

double[,] a = { {18, 10, 35}, {32, 12, 19} };

for (j = 0; j <= 2; j++) {
    for (i = 0; i <= 1; i++) {
        if (a[i, j] < 13)
            a[i, j] /= 2;
        else if (a[i, j] < 20)
            a[i, j]++;
        else
            a[i, j] -= 4;
    }
}

```

7. Try, without using a trace table, to determine the values that the array will contain when the following code fragment is executed.

```

int[,] a = { {11, 10}, {15, 19}, {22, 15} };

for (j = 0; j <= 1; j++) {
    for (i = 0; i <= 2; i++) {
        if (i == 2)
            a[i, j] += a[i - 1, j];
        else
            a[i, j] += a[i + 1, j];
    }
}

```

8. Assume that array a contains the following values.

	<i>0</i>	<i>1</i>	<i>2</i>	<i>3</i>
<i>0</i>	-1	15	22	3
<i>1</i>	25	12	16	14
<i>2</i>	7	9	1	45
<i>3</i>	40	17	11	13

What displays on the screen after executing each of the following code fragments?

- i. **for** (i = 0; i <= 2; i++) {  
     **for** (j = 0; j <= 2; j++) {  
         Console.WriteLine(a[i, j]);  
         Console.WriteLine(" "));

```
        }
    }

ii.   for (i = 2; i >= 0; i--) {
      for (j = 0; j <= 2; j++) {
          Console.WriteLine(a[i, j]);
          Console.WriteLine(" ");
      }
}

iii.  for (i = 0; i <= 2; i++) {
      for (j = 2; j >= 0; j--) {
          Console.WriteLine(a[i, j]);
          Console.WriteLine(" ");
      }
}

iv.   for (i = 2; i >= 0; i--) {
      for (j = 2; j >= 0; j--) {
          Console.WriteLine(a[i, j]);
          Console.WriteLine(" ");
      }
}

v.    for (j = 0; j <= 2; j++) {
      for (i = 0; i <= 2; i++) {
          Console.WriteLine(a[i, j]);
          Console.WriteLine(" ");
      }
}

vi.   for (j = 0; j <= 2; j++) {
      for (i = 2; i >= 0; i--) {
          Console.WriteLine(a[i, j]);
          Console.WriteLine(" ");
      }
}

vii.  for (j = 2; j >= 0; j--) {
      for (i = 0; i <= 2; i++) {
          Console.WriteLine(a[i, j]);
          Console.WriteLine(" ");
      }
}

viii. for (j = 2; j >= 0; j--) {
      for (i = 2; i >= 0; i--) {
          Console.WriteLine(a[i, j]);
          Console.WriteLine(" ");
      }
}
```

}

9. Write a C# program that lets the user enter integer values in a  $10 \times 15$  array and then displays the indexes of the elements that contain odd numbers.
10. Write a C# program that lets the user enter numeric values in a  $10 \times 6$  array and then displays the elements of the columns with even-numbered indexes (that is, column indexes 0, 2, and 4).
11. Write a C# program that lets the user enter numeric values in a  $12 \times 8$  array and then calculates and displays the sum of the elements that have even column indexes and odd row indexes.
12. Write a C# program that lets the user enter numeric values in an  $8 \times 8$  square array and then calculates the average value of the elements of its main diagonal and the average value of the elements of its antidiagonal. Try to calculate both average values within the same loop control structure.
13. Write a C# program that creates and displays the following array.

	0	1	2	3	4
0	11	11	11	11	5
1	11	11	11	5	88
a = 2	11	11	5	88	88
3	11	5	88	88	88
4	5	88	88	88	88

14. Write a C# program that creates and displays the following array.

	<i>0</i>	<i>1</i>	<i>2</i>	<i>3</i>	<i>4</i>
<i>0</i>	0	11	11	11	5
<i>1</i>	11	0	11	5	88
<i>2</i>	11	11	0	88	88
<i>3</i>	11	5	88	0	88
<i>4</i>	5	88	88	88	0

- a =**
15. Write a C# program that lets the user enter numeric values in a  $5 \times 4$  array and then displays the row and column indexes of the elements that contain integers.
  16. Write a C# program that lets the user enter numeric values in a  $10 \times 4$  array and then counts and displays the total number of negative elements.
  17. Write a C# program that lets the user enter words in a  $3 \times 4$  array and then displays them with a space character between them.
  18. Write a C# program that lets the user enter words in a  $20 \times 14$  array and then displays those who have less than five characters.

Hint: Use the `Length` property.

19. Write a C# program that lets the user enter words in a  $20 \times 14$  array and displays those that have less than 5 characters, then those that have less than 10 characters, and finally those that have less than 20 characters. Assume that the user enters only words with less than 20 characters.

Hint: Try to display the words using three for-loops nested one within the other.

# Chapter 33

## Tips and Tricks with Arrays

---

### 33.1 Introduction

Since arrays are handled with the same sequence, decision, and loop control structures that you learned about in previous chapters, there is no need to repeat all of that information here. However, what you will discover in this chapter is how to process each row or column of a two-dimensional array individually, how to solve problems that require the use of more than one array, how to create a two-dimensional array from a one-dimensional array (and vice versa), and some useful built-in array methods that C# supports.

### 33.2 Processing Each Row Individually

Processing each row individually means that every row is processed separately and the result of each row (which can be the sum, the average value, and so on) can be used individually for further processing.

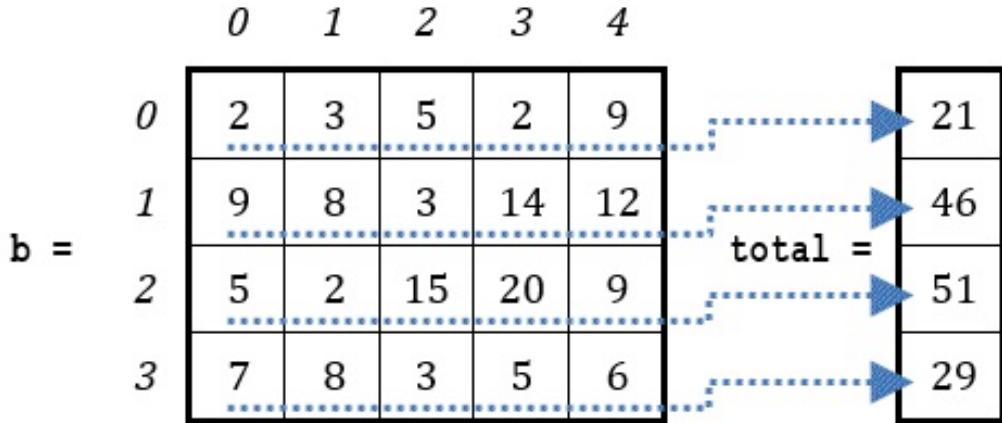
Suppose you have the following  $4 \times 5$  array.

	0	1	2	3	4
0	2	3	5	2	9
1	9	8	3	14	12
2	5	2	15	20	9
3	7	8	3	5	6

Let's try to find the sum of each row individually. Each of the following four approaches iterates through rows.

#### First Approach – Creating an auxiliary array

In this approach, the program processes each row individually and creates an auxiliary array in which each element stores the sum of one row. This approach gives you much flexibility since you can use this new array later in your program for further processing. The auxiliary array `total` is shown on the right.



Now, let's write the corresponding code fragment. To more easily understand the process, the “from inner to outer” method is used. The following code fragment calculates the sum of the first row (row index 0) and stores the result in the element at position 0 of the auxiliary array total. Assume variable i contains the value 0.

```
s = 0;
for (j = 0; j <= COLUMNS - 1; j++) {
    s += b[i, j];
}
total[i] = s;
```

This code fragment can equivalently be written as

```
total[i] = 0;
for (j = 0; j <= COLUMNS - 1; j++) {
    total[i] += b[i, j];
}
```

Now, nesting this code fragment in a for-loop that iterates for all rows results in the following.

```
for (i = 0; i <= ROWS - 1; i++) {
    total[i] = 0;
    for (j = 0; j <= COLUMNS - 1; j++) {
        total[i] += b[i, j];
    }
}
```

### Second Approach – Just find it and process it.

This approach uses no auxiliary array; it just calculates and directly processes the sum. The code fragment is as follows.

```
for (i = 0; i <= ROWS - 1; i++) {
    total = 0;
```

```

    for (j = 0; j <= COLUMNS - 1; j++) {
        total += b[i, j];
    }
    process total;
}

```

What does *process total* mean? It depends on the given problem. It may just display the sum, it may calculate the average value of each individual row and display it, or it may use the sum for calculating even more complex mathematical expressions.

For instance, the following example calculates and displays the average value of each row of array *b*.

```

for (i = 0; i <= ROWS - 1; i++) {
    total = 0;
    for (j = 0; j <= COLUMNS - 1; j++) {
        total += b[i, j];
    }
    average = total / COLUMNS;
    Console.WriteLine(average);
}

```

### ***Exercise 33.2-1 Finding the Average Value***

---

*There are 20 students and each one of them has received his or her grades for 10 lessons. Write a C# program that prompts the user to enter the grades of each student for all lessons and then calculates and displays, for each student, all average values that are greater than 89.*

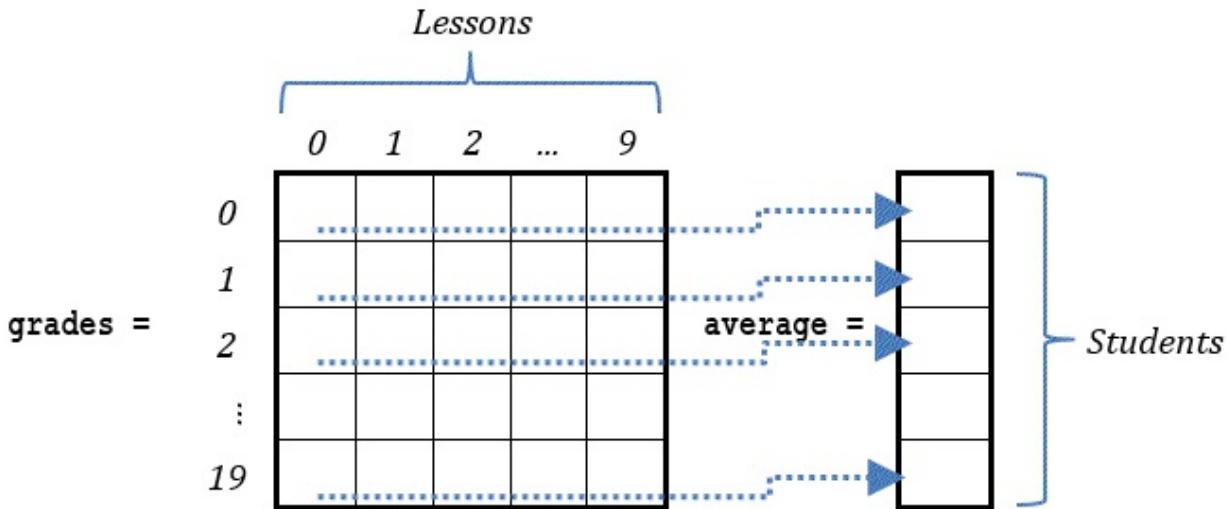
### ***Solution***

---

Since you've learned two approaches for processing each row individually, let's use them both.

#### ***First Approach – Creating an auxiliary array***

In this approach, the program processes each row individually and creates an auxiliary array in which each element stores the average value of one row. The two required arrays are shown next.



After the array average is created, the program can find and display all average values that are greater than 89. The C# program is as follows.

### project\_33\_2\_1a

```

const int STUDENTS = 20;
const int LESSONS = 10;

static void Main(string[] args) {
    int i, j;
    int[,] grades = new int[STUDENTS, LESSONS];
    for (i = 0; i <= STUDENTS - 1; i++) {
        Console.WriteLine("For student No. " + (i + 1) + "...");
        for (j = 0; j <= LESSONS - 1; j++) {
            Console.Write("enter grade for lesson No. " + (j + 1) + ": ");
            grades[i, j] = Int32.Parse(Console.ReadLine());
        }
    }

    //Create array average. Iterate through rows
    double[] average = new double[STUDENTS];
    for (i = 0; i <= STUDENTS - 1; i++) {
        average[i] = 0;
        for (j = 0; j <= LESSONS - 1; j++) {
            average[i] += grades[i, j];
        }
        average[i] /= LESSONS;
    }

    //Display all average values that are greater than 89
    for (i = 0; i <= STUDENTS - 1; i++) {
        if (average[i] > 89) {
    
```

```
        Console.WriteLine(average[i]);
    }
}
}
```

## **Second Approach – Just find it and display it!**

This approach uses no auxiliary array; it just calculates and directly displays all average values that are greater than 89. The C# program is as follows.

 project\_33\_2\_1b

```
const int STUDENTS = 20;
const int LESSONS = 10;

static void Main(string[] args) {
    int i, j;
    double average;
    int[,] grades = new int[STUDENTS, LESSONS];
    for (i = 0; i <= STUDENTS - 1; i++) {
        Console.WriteLine("For student No. " + (i + 1) + "...");
        for (j = 0; j <= LESSONS - 1; j++) {
            Console.Write("enter grade for lesson No. " + (j + 1) + ": ");
            grades[i, j] = Int32.Parse(Console.ReadLine());
        }
    }

    //Calculate the average value of each row
    //and directly display those who are greater than 89
    for (i = 0; i <= STUDENTS - 1; i++) {
        average = 0;
        for (j = 0; j <= LESSONS - 1; j++) {
            average += grades[i, j];
        }
        average /= LESSONS;
        if (average > 89) {
            Console.WriteLine(average);
        }
    }
}
```

### 33.3 Processing Each Column Individually

Processing each column individually means that every column is processed separately and the result of each column (which can be the sum, the average value, and so on) can be used individually for further processing. Suppose

you have the following  $4 \times 5$  array.

	0	1	2	3	4
0	2	3	5	2	9
1	9	8	3	14	12
2	5	2	15	20	9
3	7	8	3	5	6

As before, let's try to find the sum of each column individually. Yet again, there are two approaches that you can use. Both of these approaches iterate through columns.

### First Approach – Creating an auxiliary array

In this approach, the program processes each column individually and creates an auxiliary array in which each element stores the sum of one column. This approach gives you much flexibility since you can use this new array later in your program for further processing. The auxiliary array `total` is shown at the bottom.

	0	1	2	3	4
0	2	3	5	2	9
1	9	8	3	14	12
2	5	2	15	20	9
3	7	8	3	5	6

`b =`

`total =`

23	21	26	41	36
----	----	----	----	----

Now, let's write the corresponding code fragment. To more easily understand the process, the “from inner to outer” method is used again. The following code fragment calculates the sum of the first column (column

index 0) and stores the result in the element at position 0 of the auxiliary array total. Assume variable j contains the value 0.

```
s = 0;  
for (i = 0; i <= ROWS - 1; i++) {  
    s += a[i, j];  
}  
total[j] = s;
```

This program can equivalently be written as

```
total[j] = 0;  
for (i = 0; i <= ROWS - 1; i++) {  
    total[j] += a[i, j];  
}
```

Now, nesting this code fragment in a for-loop that iterates for all columns results in the following.

```
for (j = 0; j <= COLUMNS - 1; j++) {  
    total[j] = 0;  
    for (i = 0; i <= ROWS - 1; i++) {  
        total[j] += a[i, j];  
    }  
}
```

### Second Approach – Just find it and process it.

This approach uses no auxiliary array; it just calculates and directly processes the sum. The code fragment is as follows.

```
for (j = 0; j <= COLUMNS - 1; j++) {  
    total = 0;  
    for (i = 0; i <= ROWS - 1; i++) {  
        total += a[i, j];  
    }  
    process total;  
}
```

Accordingly, the following code fragment calculates and displays the average value of each column.

```
for (j = 0; j <= COLUMNS - 1; j++) {  
    total = 0;  
    for (i = 0; i <= ROWS - 1; i++) {  
        total += a[i, j];  
    }  
    Console.WriteLine(total / ROWS);  
}
```

### ***Exercise 33.3-1 Finding the Average Value***

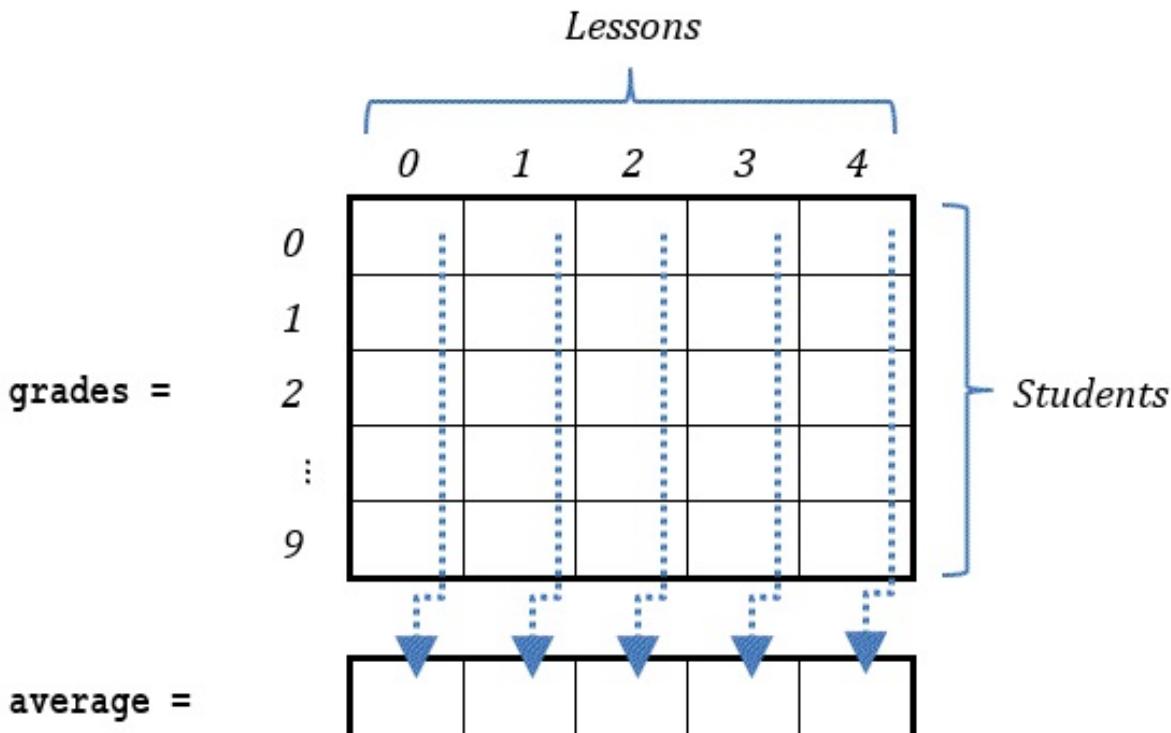
*There are 10 students and each one of them has received his or her grades for five lessons. Write a C# program that prompts the user to enter the grades of each student for all lessons and then calculates and displays, for each lesson, all average values that are greater than 89.*

#### **Solution**

Since you've learned two approaches for processing each column individually, let's use them both.

#### **First Approach – Creating an auxiliary array**

In this approach, the program processes each column individually and creates an auxiliary array in which each element stores the average value of one column. The two required arrays are shown next.



After the array average is created, the program can find and display all average values that are greater than 89. The C# program is as follows.

#### **project\_33\_3\_1a**

```
const int STUDENTS = 10;  
const int LESSONS = 5;
```

```

static void Main(string[] args) {
    int i, j;

    int[,] grades = new int[STUDENTS, LESSONS];
    for (i = 0; i <= STUDENTS - 1; i++) {
        Console.WriteLine("For student No. " + (i + 1) + "...");
        for (j = 0; j <= LESSONS - 1; j++) {
            Console.Write("enter grade for lesson No. " + (j + 1) + ": ");
            grades[i, j] = Int32.Parse(Console.ReadLine());
        }
    }

    //Create array average. Iterate through columns
    double[] average = new double[LESSONS];
    for (j = 0; j <= LESSONS - 1; j++) {
        average[j] = 0;
        for (i = 0; i <= STUDENTS - 1; i++) {
            average[j] += grades[i, j];
        }
        average[j] /= STUDENTS;
    }

    //Display all average values than are greater than 89
    for (j = 0; j <= LESSONS - 1; j++) {
        if (average[j] > 89) {
            Console.WriteLine(average[j]);
        }
    }
}
}

```

## Second Approach – Just find it and display it!

This approach uses no auxiliary array; it just calculates and directly displays all average values that are greater than 89. The C# program is as follows.

### project\_33\_3\_1b

```

const int STUDENTS = 10;
const int LESSONS = 5;

static void Main(string[] args) {
    int i, j;
    double average;

    int[,] grades = new int[STUDENTS, LESSONS];
    for (i = 0; i <= STUDENTS - 1; i++) {
        Console.WriteLine("For student No. " + (i + 1) + "...");
    }
}

```

```

        for (j = 0; j <= LESSONS - 1; j++) {
            Console.Write("enter grade for lesson No. " + (j + 1) + ": ");
            grades[i, j] = Int32.Parse(Console.ReadLine());
        }
    }

    //Calculate the average value of each column
    //and directly display those who are greater than 89
    for (j = 0; j <= LESSONS - 1; j++) {
        average = 0;
        for (i = 0; i <= STUDENTS - 1; i++) {
            average += grades[i, j];
        }
        average /= STUDENTS;
        if (average > 89) {
            Console.WriteLine(average);
        }
    }
}

```

### 33.4 How to Use More Than One Data Structures in a Program

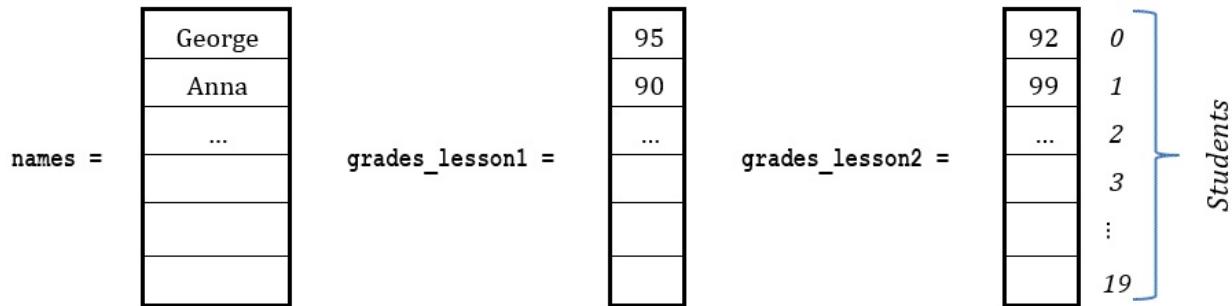
So far, every example or exercise has used just one array or one dictionary. But what if a problem requires you to use two arrays, or one array and one dictionary, or one array and two dictionaries? Next you will find some exercises that show you how various data structures can be used together to solve a particular problem.

#### Exercise 33.4-1 Finding the Average Value of Two Grades

*There are 20 students and each one of them has received his or her grades for two lessons. Write a C# program that prompts the user to enter the name and the grades of each student for all lessons. It then calculates and displays the names of all students who have an average grade greater than 89.*

#### Solution

Following are the required arrays containing some typical values.



As you can see, there is a one-to-one match between the index positions of the elements of array names and those of arrays grades\_lesson1, and grades\_lesson2. The first of the twenty students is George and the grades he received for the two lessons are 95 and 92. The name “George” is stored at index 0 of the array names, and exactly at the same index, in the arrays grades\_lesson1 and grades\_lesson2, there are stored his grades for the two lessons. The next student (Anna) and her grades are stored at index 1 of the arrays names, grades\_lesson1, and grades\_lesson2 correspondingly, and so on.

The C# program is as follows.

### project\_33\_4\_1

```
const int STUDENTS = 20;

static void Main(string[] args) {
    int i, total;
    double average;

    string[] names = new string[STUDENTS];
    int[] grades_lesson1 = new int[STUDENTS];
    int[] grades_lesson2 = new int[STUDENTS];

    for (i = 0; i <= STUDENTS - 1; i++) {
        Console.WriteLine("Enter student name No" +(i + 1) + ": ");
        names[i] = Console.ReadLine();

        Console.WriteLine("Enter grade for lesson 1: ");
        grades_lesson1[i] = Int32.Parse(Console.ReadLine());

        Console.WriteLine("Enter grade for lesson 2: ");
        grades_lesson2[i] = Int32.Parse(Console.ReadLine());
    }

    //Calculate the average grade for each student
}
```

```

//and display the names of those who are greater than 89
for (i = 0; i <= STUDENTS - 1; i++) {
    total = grades_lesson1[i] + grades_lesson2[i];
    average = total / 3.0;
    if (average > 89) {
        Console.WriteLine(names[i]);
    }
}
}

```

### ***Exercise 33.4-2 Finding the Average Value of More than Two Grades***

---

*There are 10 students and each one of them has received his or her grades for five lessons. Write a C# program that prompts the user to enter the name of each student and the grades for all lessons and then calculates and displays the names of the students who have more than one grade greater than 89.*

#### **Solution**

---

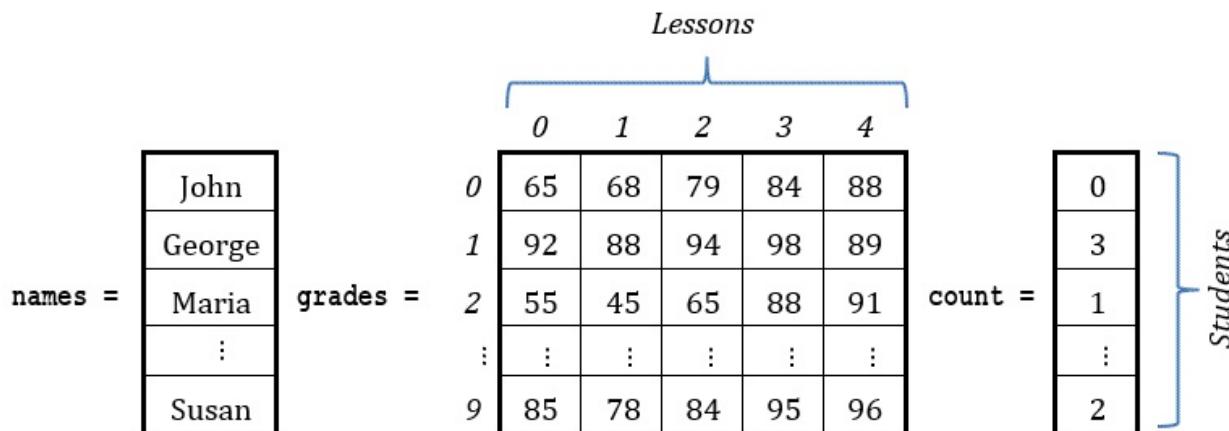
In this exercise, you can do what you did in the previous one. You can use a one-dimensional array to store the names of the students and five one-dimensional arrays to store the grades for each student for each lesson. Not very convenient, but it can work. Obviously, when there are more than two grades, this is not the most suitable approach.

The best approach here is to use a one-dimensional array to store the names of the students and a two-dimensional array to store the grades for each student for each lesson.

There are actually two approaches. Which one to use depends clearly on you! If you decide that, in the two-dimensional array, the rows should refer to students and the columns should refer to lessons then you can use the first approach discussed below. If you decide that the rows should refer to lessons and the columns should refer to students then you can use the second approach.

#### **First Approach – Rows for students, columns for lessons**

In this approach, the two-dimensional array must have 10 rows, one for every student and 5 columns, one for every lesson. All other arrays can be placed in relation to this two-dimensional array as follows.



The auxiliary array `count` is created by the program and contains the number of grades for each student that are greater than 89.

Now, let's see how to read values and store them in the arrays `names` and `grades`. One simple solution would be to use one loop control structure for reading names, and another, independent, loop control structure for reading grades. However, it is not very practical for the user to first enter all names and later enter all grades. A more practical way would be to prompt the user to enter one student name and then all of his or her grades, then another student name and again all of his or her grades, and so on. The solution is as follows.

### project\_33\_4\_2a

```
const int STUDENTS = 10;
const int LESSONS = 5;

static void Main(string[] args) {
    int i, j;

    //Read names and grades all together. Iterate through rows in array grades
    string[] names = new string[STUDENTS];
    int[,] grades = new int[STUDENTS, LESSONS];
    for (i = 0; i <= STUDENTS - 1; i++) {
        Console.WriteLine("Enter name for student No. " + (i + 1) + ": ");
        names[i] = Console.ReadLine();
        for (j = 0; j <= LESSONS - 1; j++) {
            Console.WriteLine("Enter grade No. " + (j + 1) + " for " + names[i] + ": ");
            grades[i, j] = Int32.Parse(Console.ReadLine());
        }
    }
}
```

```

//Create array count. Iterate through rows
int[] count = new int[STUDENTS];
for (i = 0; i <= STUDENTS - 1; i++) {
    count[i] = 0;
    for (j = 0; j <= LESSONS - 1; j++) {
        if (grades[i, j] > 89) {
            count[i]++;
        }
    }
}

//Displays the names of the students who have more than one grade greater than 89
for (i = 0; i <= STUDENTS - 1; i++) {
    if (count[i] > 1) {
        Console.WriteLine(names[i]);
    }
}
}

```

## **Second Approach – Rows for lessons, columns for students**

In this approach, the two dimensional array must have 5 rows, one for every lesson and 10 columns, one for every student. All other arrays can be placed in relation to this two-dimensional array, as shown next.

## Students

The diagram illustrates three arrays:

- names =** An array of strings representing student names: John, George, Maria, ..., Susan.
- grades =** A 2D array representing student grades. The columns are indexed from 0 to 9, and the rows are indexed from 0 to 4. The data is as follows:

0	65	92	55	...	85
1	68	88	45	...	78
2	79	94	65	...	84
3	84	98	88	...	95
4	88	89	91	...	96
- count =** An array representing the count of grades greater than 89 for each student. The data is as follows:

0	3	1	...	2
---	---	---	-----	---

The auxiliary array count is created by the program and contains the number of grades for each lesson that are greater than 89.

The solution is as follows.

### project\_33\_4\_2b

```
const int STUDENTS = 10;
const int LESSONS = 5;

static void Main(string[] args) {
    int i, j;

    //Read names and grades together. Iterate through columns in array grades
    string[] names = new string[STUDENTS];
    int[,] grades = new int[LESSONS, STUDENTS];
    for (j = 0; j <= STUDENTS - 1; j++) {
        Console.WriteLine("Enter name for student No. " + (j + 1) + ": ");
        names[j] = Console.ReadLine();
        for (i = 0; i <= LESSONS - 1; i++) {
            Console.WriteLine("Enter grade No. " + (i + 1) + " for " + names[j] + ": ");
            grades[i, j] = int.Parse(Console.ReadLine());
        }
    }
}
```

```

        grades[i, j] = Int32.Parse(Console.ReadLine());
    }
}

//Create array count. Iterate through columns
int[] count = new int[STUDENTS];
for (j = 0; j <= STUDENTS - 1; j++) {
    count[j] = 0;
    for (i = 0; i <= LESSONS - 1; i++) {
        if (grades[i, j] > 89) {
            count[j]++;
        }
    }
}

//Displays the names of the students who have more than one grade greater than 89
for (j = 0; j <= STUDENTS - 1; j++) {
    if (count[j] > 1) {
        Console.WriteLine(names[j]);
    }
}
}

```

### **Exercise 33.4-3 Using an Array Along with a Dictionary**

*There are 30 students and each one of them has received his or her grades for a test. Write a C# program that prompts the user to enter the grades (as a letter) for each student. It then displays, for each student, the grade as a percentage according to the following table.*

Grade	Percentage
A	90 - 100
B	80 - 89
C	70 - 79
D	60 - 69
E / F	0 - 59

### **Solution**

A dictionary that holds the given table can be used. The solution is as follows.

## project\_33\_4\_3

```
const int STUDENTS = 30;

static void Main(string[] args) {
    int i;
    string grade, grade_as_percentage;

    Dictionary<string, string> grades_table = new Dictionary<string, string> {
        {"A", "90-100"},
        {"B", "80-89"},
        {"C", "70-79"},
        {"D", "60-69"},
        {"E", "0-59"}, 
        {"F", "0-59"}
    };

    string[] names = new string[STUDENTS];
    string[] grades = new string[STUDENTS];

    for (i = 0; i <= STUDENTS - 1; i++) {
        Console.WriteLine("Enter student name No" + (i + 1) + ": ");
        names[i] = Console.ReadLine();

        Console.WriteLine("Enter his or her grade: ");
        grades[i] = Console.ReadLine();
    }

    for (i = 0; i <= STUDENTS - 1; i++) {
        grade = grades[i];
        grade_as_percentage = grades_table[grade];

        Console.WriteLine(names[i] + " " + grade_as_percentage);
    }
}
```

Now, if you fully understood how the last for-loop works, then take a look in the code fragment that follows. It is equivalent to that last for-loop, but it performs more efficiently, since it uses fewer variables!

```
for (i = 0; i <= STUDENTS - 1; i++) {
    Console.WriteLine(names[i] + " " + grades_table[grades[i]]);
}
```

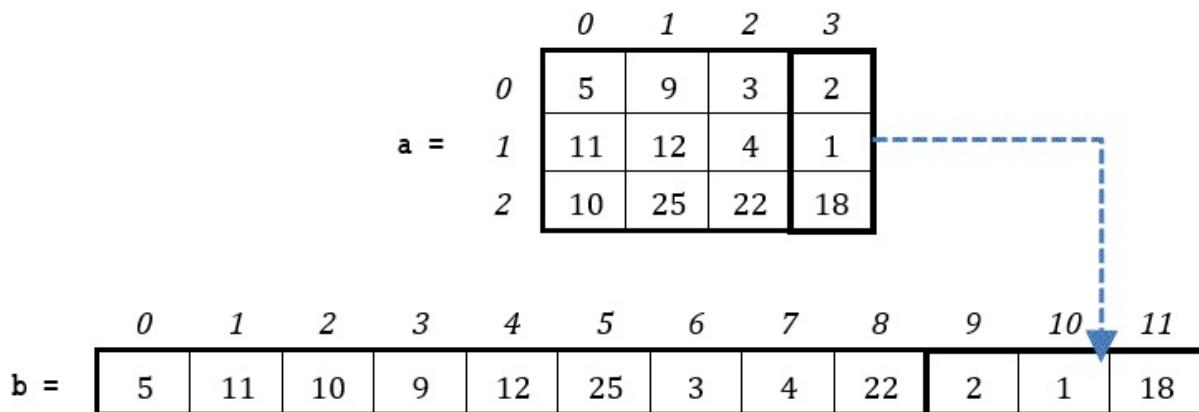
### 33.5 Creating a One-Dimensional Array from a Two-

## Dimensional Array

To more easily understand how to create a one-dimensional array from a two-dimensional array, let's use an example.

*Write a program that creates a one-dimensional array of 12 elements from an existing two-dimensional array of  $3 \times 4$  (shown below), as follows: The elements of the first column of the two-dimensional array must be placed in the first three positions of the one-dimensional array, the elements of the second column must be placed in the next three positions, and so on.*

The two-dimensional  $3 \times 4$  array and the new one-dimensional array are as follows.



The C# program that follows creates the new one-dimensional array, iterating through columns, which is more convenient. It uses the existing array given in the example.

### project\_33\_5

```
const int ROWS = 3;
const int COLUMNS = 4;

static void Main(string[] args) {
    int i, j, k;

    int[,] a = { {5, 9, 3, 2},
                {11, 12, 4, 1},
                {10, 25, 22, 18}
              };

    int[] b = new int[ROWS * COLUMNS];

    k = 0; //This is the index of the new array.
```

```
    for (j = 0; j <= COLUMNS - 1; j++) { //Iterate through columns
        for (i = 0; i <= ROWS - 1; i++) {
            b[k] = a[i, j];
            k++;
        }
    }

    for (k = 0; k <= b.Length - 1; k++) {
        Console.WriteLine(b[k] + "\t");
    }
}
```

 Note the Length attribute in the last for-loop. It contains the number of the elements of an array. In this exercise, it contains the value of 12.

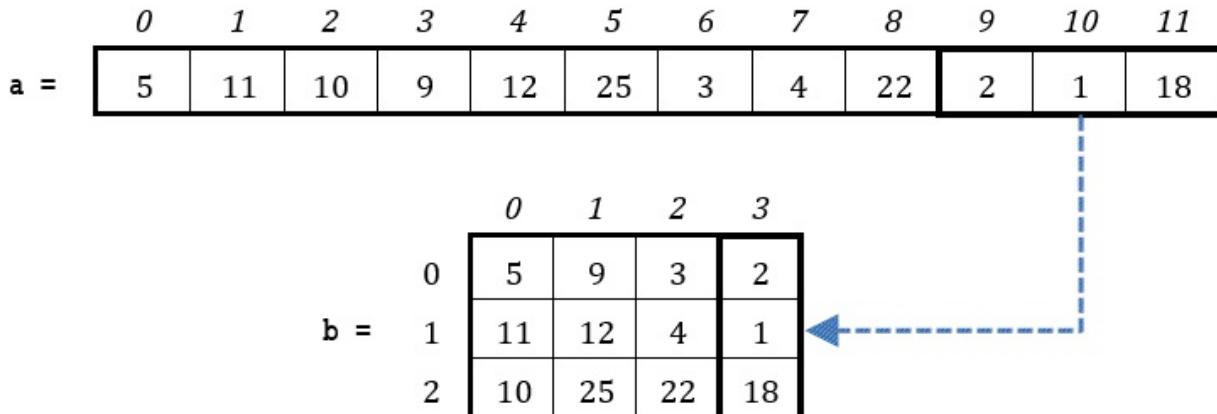
 Note that Length is an attribute, not a method. Therefore, you must not put parentheses at the end. You will learn more about attributes in [Section 8](#).

## 33.6 Creating a Two-Dimensional Array from a One-Dimensional Array

To more easily understand how to create a two-dimensional array from a one-dimensional array, let's use an example.

Write a C# program that creates a two-dimensional array of  $3 \times 4$  from an existing one-dimensional array of 12 elements (shown below), as follows:  
The first three elements of the one-dimensional array must be placed in the first column of the two-dimensional array, the next three elements of the one-dimensional array must be placed in the next column of the two-dimensional array, and so on.

The one-dimensional array of 12 elements and the new two-dimensional array are as follows.



The C# program that follows creates the new two-dimensional array, iterating through columns, which is more convenient. It uses the existing array given in the example.

### project\_33\_6

```

const int ROWS = 3;
const int COLUMNS = 4;

static void Main(string[] args) {
    int k, j, i;

    int[] a = {5, 11, 10, 9, 12, 25, 3, 4, 22, 2, 1, 18};

    int[,] b = new int[ROWS, COLUMNS];
    k = 0;          //This is the index of array a.
    for (j = 0; j <= COLUMNS - 1; j++) { //Iterate through columns
        for (i = 0; i <= ROWS - 1; i++) {
            b[i, j] = a[k];
            k++;
        }
    }

    for (i = 0; i <= ROWS - 1; i++) { //Iterate through rows
        for (j = 0; j <= COLUMNS - 1; j++) {
            Console.WriteLine(b[i, j] + "\t");
        }
        Console.WriteLine();
    }
}

```

## 33.7 Review Questions: True/False

Choose **true** or **false** for each of the following statements.

1. Processing each row individually means that every row is processed separately, and the result of each row can then be used individually for further processing.
2. The following code fragment displays the word “Okay” when the sum of the elements of each column is less than 100.

```
for (i = 0; i <= ROWS - 1; i++) {  
    total = 0;  
    for (j = 0; j <= COLUMNS - 1; j++) {  
        total += a[i, j];  
    }  
    if (total < 100) Console.WriteLine("Okay");  
}
```

3. Processing each column individually means that every column is processed separately and the result of each column can be then used individually for further processing.
4. The following code fragment displays the sum of the elements of each column.

```
total = 0;  
for (j = 0; j <= COLUMNS - 1; j++) {  
    for (i = 0; i <= ROWS - 1; i++) {  
        total += a[i, j];  
    }  
  
    Console.WriteLine(total);  
}
```

5. Suppose that there are 10 students and each one of them has received his or her grades for five lessons. Given this information, it is possible to design an array so that the rows refer to students and the columns refer to lessons, but not the other way around.
6. A one-dimensional array can be created from a two-dimensional array, but not the opposite.
7. A one-dimensional array can be created from a three-dimensional array.
8. The following two code fragments display the same value.

```
int[] a = {1, 6, 12, 2, 1};  
Console.WriteLine(a.Length);
```

```
string a = "Hello";  
Console.WriteLine(a.Length);
```

9. The following code fragment displays three values.

```
int[] a = {10, 20, 30, 40, 50};  
for (i = 3; i <= a.Length - 1; i++) {  
    Console.WriteLine(a[i]);  
}
```

10. The following code fragment displays the values of all elements of the array b.

```
int[] b = {10, 20, 30, 40, 50};  
for (i = 0; i <= b.Length - 1; i++) {  
    Console.WriteLine(i);  
}
```

11. The following code fragment doubles the values of all elements of the array b.

```
for (i = 0; i <= b.Length - 1; i++) {  
    b[i] *= 2;  
}
```

### 33.8 Review Questions: Multiple Choice

Select the correct answer for each of the following statements.

1. The following code fragment

```
int[] total = new int[ROWS];  
for (i = 0; i <= ROWS - 1; i++) {  
    total[i] = 0;  
    for (j = 0; j <= COLUMNS - 1; j++) {  
        total[i] += a[i, j];  
    }  
    Console.WriteLine(total[i]);  
}
```

- a. displays the sum of the elements of each row.
- b. displays the sum of the elements of each column.
- c. displays the sum of all the elements of the array.
- d. none of the above

2. The following code fragment

```
for (j = 0; j <= COLUMNS - 1; j++) {  
    total = 0;  
    for (i = 0; i <= ROWS - 1; i++) {  
        total += a[i, j];  
    }
```

```
    Console.WriteLine(total);
}
```

- a. displays the sum of the elements of each row.
  - b. displays the sum of the elements of each column.
  - c. displays the sum of all the elements of the array.
  - d. none of the above
3. The following code fragment
- ```
k = 0;
for (i = ROWS - 1; i >= 0; i++) {
    for (j = 0; j <= COLUMNS - 1; j--) {
        b[k] = a[i, j];
        k++;
    }
}
```
- a. creates a one-dimensional array from a two-dimensional array.
  - b. creates a two-dimensional array from a one-dimensional array.
  - c. none of the above
4. The following code fragment
- ```
k = 0;
for (i = 0; i <= ROWS - 1; i++) {
    for (j = COLUMNS - 1; j >= 0; j--) {
        b[i, j] = a[k];
        k++;
    }
}
```
- a. creates a one-dimensional array from a two-dimensional array.
  - b. creates a two-dimensional array from a one-dimensional array.
  - c. none of the above
5. The following two code fragments

```
int[] a = {3, 6, 10, 2, 4, 12, 1};
for (i = 0; i < 7; i++) {
    Console.WriteLine(a[i]);
}
```

```
int[] a = {3, 6, 10, 2, 4, 12, 1};
for (i = 0; i <= a.Length - 1; i++) {
    Console.WriteLine(a[i]);
```

| }

- a. produce the same results, but the left program is faster.
  - b. produce the same results, but the right program is faster.
  - c. do not produce the same results.
  - d. none of the above
6. The following two code fragments

```
int[] a = {3, 6, 10, 2, 4, 12, 1};  
for (i = 0; i < a.Length; i++) {  
    Console.WriteLine(a[i]);  
}
```

```
int[] a = {3, 6, 10, 2, 4, 12, 1};  
foreach (var element in a) {  
    Console.WriteLine(element);  
}
```

- a. produce the same results.
- b. do not produce the same results.
- c. none of the above

### 33.9 Review Exercises

Complete the following exercises.

1. There are 15 students and each one of them has received his or her grades for five tests. Write a C# program that lets the user enter the grades (as a percentage) for each student for all tests. It then calculates and displays, for each student, the average grade as a letter grade according to the following table.

Grade	Percentage
A	90 - 100
B	80 - 89
C	70 - 79
D	60 - 69
E / F	0 - 59

- On Earth, a free-falling object has an acceleration of  $9.81 \text{ m/s}^2$
2. downward. This value is denoted by  $g$ . A student wants to calculate that value using an experiment. She allows five different objects to fall downward from a known height and measures the time they need to reach the floor. She does this 10 times for each object. Then, using a formula she calculates  $g$  for each object, for each fall. But since her chronometer is not so accurate, she needs a C# program that lets her enter all calculated values of  $g$  in a  $5 \times 10$  array and then, it calculates and displays
    - a. for each object, the average value of  $g$  (per fall)
    - b. for each fall, the average value of  $g$  (per object)
    - c. the overall average value of  $g$
  3. A basketball team with 15 players plays 12 matches. Write a C# program that lets the user enter, for each player, the number of points scored in each match. The program must then display
    - a. for each player, the total number of points scored
    - b. for each match, the total number of points scored
  4. Write a C# program that lets the user enter the hourly measured temperatures of 20 cities for a period of one day, and then displays the hours in which the average temperature of all the cities was below 10 degrees Fahrenheit.
  5. In a football tournament, a football team with 24 players plays 10 matches. Write a C# program that lets the user enter, for each player, a name as well as the number of goals scored in each match. The program must then display
    - a. for each player, his name and the average number of goals scored
    - b. for each match, the index number of the match (1, 2, 3, and so on) and the total number of goals scored
  6. There are 12 students and each one of them has received his or her grades for six lessons. Write a C# program that lets the user enter the name of the student as well as his or her grades in all lessons and then displays
    - a. for each student, his or her name and average grade
    - b. for each lesson, the average grade

- c. the names of the students who have an average grade less than 60
- d. the names of the students who have an average grade greater than 89, and the message “Bravo!” next to it

Assume that the user enters values between 0 and 100.

7. In a song contest, each artist sings a song of his or her choice. There are five judges and 15 artists, each of whom is scored for his or her performance. Write a C# program that prompts the user to enter the names of the judges, the names of the artists, the title of the song that each artist sings, and the score they get from each judge. The program must then display
  - a. for each artist, his or her name, the title of the song, and his or her total score
  - b. for each judge, his or her name and the average value of the score he or she gave (per artist)
8. The Body Mass Index (BMI) is often used to determine whether a person is overweight or underweight for his or her height. The formula used to calculate BMI is

$$BMI = \frac{weight \cdot 703}{height^2}$$

Write a C# program that lets the user enter into two arrays the weight (in pounds) and height (in inches) of 30 people, measured on a monthly basis, for a period of one year (January to December). The program must then calculate and display

- a. for each person, his or her average weight, average height, and average BMI
- b. for each person, his or her BMI in May and in August

Please note that all people are adults but some of them are between the ages of 18 and 25. This means they may still grow taller, thus their height might be different each month!

9. Write a C# program that lets the user enter the electric meter reading in kilowatt-hours (kWh) at the beginning and at the end of a month for 1000 consumers. The program must calculate and display
  - a. for each consumer, the amount of kWh consumed and the amount

- of money that must be paid given a cost of each kWh of \$0.07 and a value added tax (VAT) of 19%
- the total consumption and the total amount of money that must be paid.
10. Write a C# program that prompts the user to enter an amount in US dollars and calculates and displays the corresponding currency value in Euros, British Pounds Sterling, Australian Dollars, and Canadian Dollars. The tables below contain the exchange rates for each currency for a one-week period. The program must calculate the average value of each currency and do the conversions based on that average value.

<b>currency =</b>	<b>British Pound Sterling</b>	<b>rate =</b>	1.320	1.321	1.332	1.331	1.341
	Euro		1.143	1.156	1.138	1.122	1.129
	Canadian Dollar		0.757	0.764	0.760	0.750	0.749
	Australian Dollar		0.720	0.725	0.729	0.736	0.739

- the names of the employees who worked overtime
  - for each employee, his or her name and the average gross pay (per day)
  - for each employee, his or her name, the name of the day he or she worked overtime (more than 8 hours), and the message “Overtime!”
  - for each day, the name of the day and the total gross pay
12. Write a C# program to create a one-dimensional array of 12 elements from the two-dimensional array shown below, as follows: the first row of the two-dimensional array must be placed in the first four positions of the one-dimensional array, the second row of the two-dimensional array must be placed in the next four positions of the one-dimensional array, and the last row of the two-dimensional array must be placed in

the last four positions of the one-dimensional array.

<b>a =</b>	9	9	2	6
	4	1	10	11
	12	15	7	3

13. Write a C# program to create a  $3 \times 3$  array from the one-dimensional array shown below, as follows: the first three elements of the one-dimensional array must be placed in the last row of the two-dimensional array, the next three elements of the one-dimensional array must be placed in the second row of the two-dimensional array, and the last three elements of the one-dimensional array must be placed in the first row of the two-dimensional array.

<b>a =</b>	16	12	3	5	6	9	18	19	20
------------	----	----	---	---	---	---	----	----	----

# Chapter 34

## More Exercises with Arrays

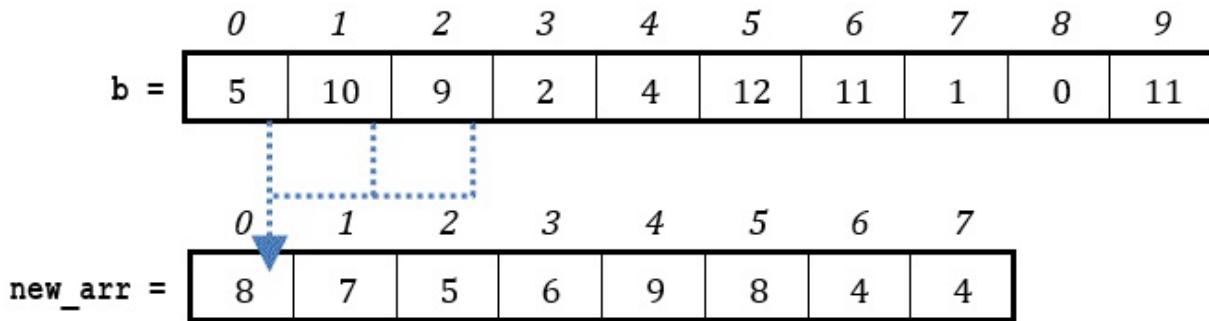
### 34.1 Simple Exercises with Arrays

#### *Exercise 34.1-1 Creating an Array that Contains the Average Values of its Neighboring Elements*

*Write a C# program that lets the user enter 100 positive numerical values into an array. Then, the program must create a new array of 98 elements. This new array must contain, in each position the average value of the three elements that exist in the current and the next two positions of the given array.*

#### **Solution**

Let's try to understand this exercise through an example using 10 elements.



Array `new_arr` is the new array that is created. In array `new_arr`, the element at position 0 is the average value of the elements in the current and the next two positions of array `b`; that is,  $(5 + 10 + 9) / 3 = 8$ . The element at position 1 is the average value of the elements in the current and the next two positions of array `b`; that is,  $(10 + 9 + 2) / 3 = 7$ , and so on.

The C# program is as follows.

#### project\_34\_1\_1

```
const int ELEMENTS_OF_A = 100;
const int ELEMENTS_OF_NEW = ELEMENTS_OF_A - 2;

static void Main(string[] args) {
    int i;

    double[] a = new double[ELEMENTS_OF_A];
```

```

for (i = 0; i <= ELEMENTS_OF_A - 1; i++) {
    a[i] = Double.Parse(Console.ReadLine());
}

double[] new_arr = new double[ELEMENTS_OF_NEW];
for (i = 0; i <= ELEMENTS_OF_NEW - 1; i++) {
    new_arr[i] = (a[i] + a[i + 1] + a[i + 2]) / 3;
}

for (i = 0; i <= ELEMENTS_OF_NEW - 1; i++) {
    Console.WriteLine(new_arr[i] + "\t");
}
}

```

### ***Exercise 34.1-2 Creating an Array with the Greatest Values***

---

*Write a C# program that lets the user enter numerical values into arrays a and b of 20 elements each. Then the program, must create a new array new\_arr of 20 elements. The new array must contain in each position the greatest value of arrays a and b of the corresponding position.*

### **Solution**

---

Nothing new here! You need two for-loops to read the values for arrays a and b, one for creating the array new\_arr, and one to display array new\_arr on the screen.

The C# program is shown here.

#### project\_34\_1\_2

```

const int ELEMENTS = 20;

static void Main(string[] args) {
    int i;

    //Read arrays a and b
    double[] a = new double[ELEMENTS];
    for (i = 0; i <= ELEMENTS - 1; i++) {
        a[i] = Double.Parse(Console.ReadLine());
    }
    double[] b = new double[ELEMENTS];
    for (i = 0; i <= ELEMENTS - 1; i++) {
        b[i] = Double.Parse(Console.ReadLine());
    }
}

```

```

//Create array new_arr
double[] new_arr = new double[ELEMENTS];
for (i = 0; i <= ELEMENTS - 1; i++) {
    if (a[i] > b[i]) {
        new_arr[i] = a[i];
    }
    else {
        new_arr[i] = b[i];
    }
}

//Display array new_arr
for (i = 0; i <= ELEMENTS - 1; i++) {
    Console.WriteLine(new_arr[i]);
}
}

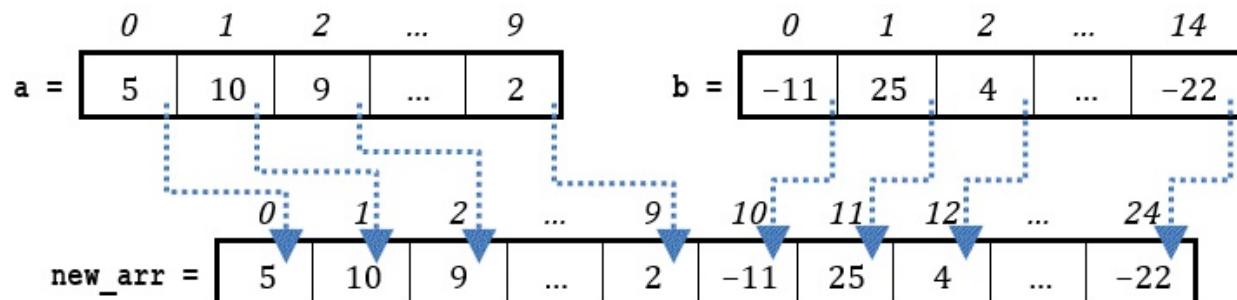
```

### Exercise 34.1-3 Merging One-Dimensional Arrays

*Write a C# program that, for two given arrays a and b of 10 and 15 elements, respectively, creates a new array new\_arr of 25 elements. This new array must contain in the first 10 positions the elements of array a, and in the next 15 positions the elements of array b.*

#### **Solution**

As you can see in the example presented next, there is a one-to-one match between the index positions of the elements of array a and those of array new\_arr . The element from position 0 of array a is stored in position 0 of array new\_arr , the element from position 1 of array a is stored in position 1 of array new\_arr , and so on. However, there is no one-to-one match between the index positions of the elements of array b and those of array new\_arr . The element from position 0 of array b must be stored in position 10 of array new\_arr , the element from position 1 of array b must be stored in position 11 of array new\_arr , and so on.



In order to assign the values of array `a` to array `new_arr` you can use the following code fragment.

```
for (i = 0; i <= a.Length - 1; i++) {  
    new_arr[i] = a[i];  
}
```

However, to assign the values of array `b` to array `new_arr` your code fragment should be quite different as shown here.

```
for (i = 0; i <= b.Length - 1; i++) {  
    new_arr[a.Length + i] = b[i];  
}
```

The final C# program is as follows.

### project\_34\_1\_3

```
static void Main(string[] args) {  
    int i;  
  
    //Create arrays a and b  
    int[] a = {5, 10, 9, 6, 7, -6, 13, 12, 11, 2};  
    int[] b = {-11, 25, 4, 45, 67, 87, 34, 23, 33, 55, 13, 15, -4, -2, -22};  
  
    //Create array new_arr  
    int[] new_arr = new int[a.Length + b.Length];  
    for (i = 0; i <= a.Length - 1; i++) {  
        new_arr[i] = a[i];  
    }  
    for (i = 0; i <= b.Length - 1; i++) {  
        new_arr[a.Length + i] = b[i];  
    }  
  
    //Display array new_arr  
    for (i = 0; i <= new_arr.Length - 1; i++) {  
        Console.WriteLine(new_arr[i] + "\t");  
    }  
}
```

 The `Length` attribute contains the number of the elements of an array. `Length` is an attribute. Therefore, you must not put parentheses at the end. You will learn more about attributes in [Section 8](#).

### Exercise 34.1-4 Merging Two-Dimensional Arrays

Write a C# program that for two given arrays `a` and `b` of  $3 \times 4$  and  $5 \times 4$

*elements respectively it creates a new array new\_arr of  $8 \times 4$  elements. In this new array, the first 3 rows must contain the elements of array a and the next 5 rows must contain the elements of array b.*

## **Solution**

---

Using knowledge from the previous exercise, the proposed solution is as follows. In the beginning, the two given arrays a and b are created with randomly chosen values.

### project\_34\_1\_4

```
const int COLUMNS = 4;

static void Main(string[] args) {
    int i, j;

    int[,] a = { {10, 11, 12, 85}, {3, 1, 5, 10}, {-1, 2, -5, -10} };

    int[,] b = { {10, 11, 16, 33}, {11, 13, 5, 55}, {-1, -2, -4, 44},
                 {55, 33, 77, 12}, {-110, 120, 132, 43}
               };

    //Create array new_arr
    int[,] new_arr = new int[a.Length + b.Length, COLUMNS];
    for (i = 0; i <= a.Length - 1; i++) {
        for (j = 0; j <= COLUMNS - 1; j++) {
            new_arr[i, j] = a[i, j];
        }
    }
    for (i = 0; i <= b.Length - 1; i++) {
        for (j = 0; j <= COLUMNS - 1; j++) {
            new_arr[a.Length + i, j] = b[i, j];
        }
    }

    //Display array new_arr
    for (i = 0; i <= new_arr.Length - 1; i++) {
        for (j = 0; j <= COLUMNS - 1; j++) {
            Console.WriteLine(new_arr[i, j] + "\t");
        }
        Console.WriteLine();
    }
}
```

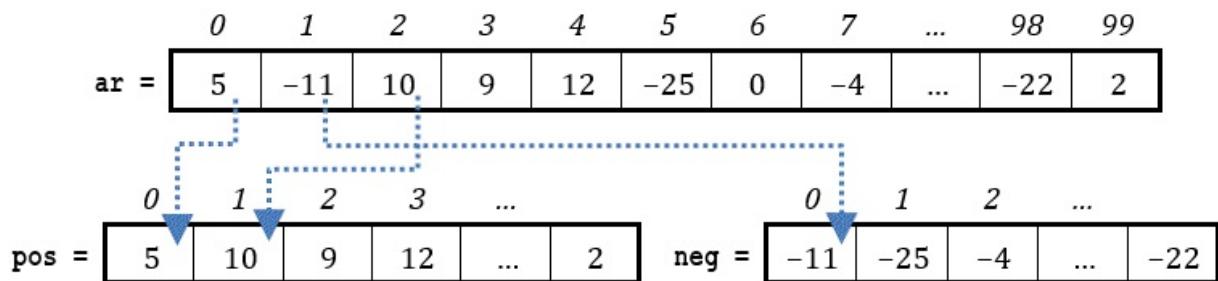
## **Exercise 34.1-5 Creating Two Arrays – Separating Positive from Negative**

## Values

Write a C# program that lets the user enter 100 numerical values into an array and then creates two new arrays, pos and neg. Array pos must contain positive values, whereas array neg must contain the negative ones. The value 0 (if any) must not be added to either of the final arrays, pos or neg.

## Solution

Let's analyze this approach using the following example.



In this exercise, there is no one-to-one match between the index positions of the elements of array **ar** and the arrays **pos** and **neg**. For example, the element from position 1 of array **ar** is not stored in position 1 of array **neg**, or the element from position 2 of array **ar** is not stored in position 2 of array **pos**. Thus, you **cannot** do the following,

```
for (i = 0; i <= ELEMENTS - 1; i++) {  
    if (ar[i] > 0) {  
        pos[i] = ar[i];  
    }  
    else if (ar[i] < 0) {  
        neg[i] = ar[i];  
    }  
}
```

because it will result in the following two arrays.

	0	1	2	3	4	5	6	7	...	98	99
<b>pos =</b>	5		10	9	12				...		2
<b>neg =</b>		-11				-25		-4	...	-22	

What you need here are two independent index variables: **pos\_index** for the array **pos**, and **neg\_index** for the array **neg**. These index variables must be incremented independently, and only when an element is added to the

corresponding array. The index variable pos\_index must be incremented only when an element is added to the array pos, and the index variable neg\_index must be incremented only when an element is added to the array neg, as shown in the code fragment that follows.

```
pos_index = 0;
neg_index = 0;
for (i = 0; i <= ELEMENTS - 1; i++) {
    if (ar[i] > 0) {
        pos[pos_index] = ar[i];
        pos_index++;
    }
    else if (ar[i] < 0) {
        neg[neg_index] = ar[i];
        neg_index++;
    }
}
```

which can equivalently be written as

```
pos_index = 0;
neg_index = 0;
for (i = 0; i <= ELEMENTS - 1; i++) {
    if (ar[i] > 0) {
        pos[pos_index++] = ar[i];
    }
    else if (ar[i] < 0) {
        neg[neg_index++] = ar[i];
    }
}
```

When this loop finishes iterating, the two arrays become as follows.

	0	1	2	3	...		0	1	2	...	
pos =	5	10	9	12	...	2	-11	-25	-4	...	-22

 Note that variables pos\_index and neg\_index have dual roles. When the loop iterates, each points to the next position in which a new element must be placed. But when the loop finishes iterating, variables pos\_index and neg\_index also contain the total number of elements in each corresponding array!

The complete solution is presented next.

 project\_34\_1\_5

```

const int ELEMENTS = 100;

static void Main(string[] args) {
    int i, pos_index, neg_index;

    double[] ar = new double[ELEMENTS];
    for (i = 0; i <= ELEMENTS - 1; i++) {
        ar[i] = Double.Parse(Console.ReadLine());
    }

    //Create arrays pos and neg
    double[] pos = new double[ELEMENTS];
    double[] neg = new double[ELEMENTS];
    pos_index = 0;
    neg_index = 0;
    for (i = 0; i <= ELEMENTS - 1; i++) {
        if (ar[i] > 0) {
            pos[pos_index++] = ar[i];
        }
        else if (ar[i] < 0) {
            neg[neg_index++] = ar[i];
        }
    }
}

for (i = 0; i <= pos_index - 1; i++) {
    Console.Write(pos[i] + "\t");
}
Console.WriteLine();
for (i = 0; i <= neg_index - 1; i++) {
    Console.Write(neg[i] + "\t");
}
}
}

```

 Note that the arrays pos and neg contain a total number of pos\_index and neg\_index elements respectively. This is why the two last loop control structures iterate until variable i reaches values pos\_index - 1 and neg\_index - 1, respectively, and not until ELEMENTS - 1, as you may mistakenly expect. Obviously the sum of pos\_index + neg\_index equals to ELEMENTS.

### ***Exercise 34.1-6 Creating an Array with Those who Contain Digit 5***

*Write a C# program that lets the user enter 100 two-digit integers into an array and then creates a new array of only the integers that contain at least*

*one of the digit 5.*

## **Solution**

---

This exercise requires some knowledge from the past. In [Exercise 13.1-2](#) you learned how to use the quotient and the remainder to split an integer into its individual digits. Here, the integer has two digits; therefore, you can use the following code fragment to split any two-digit integer contained in variable `x`.

```
last_digit = x % 10;  
first_digit = (int)(x / 10);
```

The program that follows uses an extra variable that becomes the index for the new array. This is necessary when you want to create a new array using values from an old array and there is no one-to-one match between their index positions. Of course, this variable must increase by 1 only when a new element is added into the new array. Moreover, when the loop that creates the new array finishes iterating, the value of this variable also matches the total number of elements in the new array! The final C# program is as follows.

### project\_34\_1\_6

```
const int ELEMENTS = 100;  
  
static void Main(string[] args) {  
    int i, k, last_digit, first_digit;  
  
    int[] a = new int[ELEMENTS];  
    for (i = 0; i <= ELEMENTS - 1; i++) {  
        a[i] = Int32.Parse(Console.ReadLine());  
    }  
  
    int[] b = new int[ELEMENTS];  
    k = 0;  
    for (i = 0; i <= ELEMENTS - 1; i++) {  
        last_digit = a[i] % 10;  
        first_digit = (int)(a[i] / 10);  
  
        if (last_digit == 5 || first_digit == 5) {  
            b[k++] = a[i];  
        }  
    }  
}
```

```
    for (i = 0; i <= k - 1; i++) {
        Console.WriteLine(b[i] + "\t");
    }
}
```

## 34.2 Data Validation with Arrays

As you have already been taught in [paragraph 30.3](#), there are three approaches that you can use to validate data input. Your approach will depend on whether or not you wish to display an error message, and whether you wish to display individual error messages for each error or just a single error message for any kind of error. Let's see how those three approaches can be adapted and used with arrays.

### First Approach – Validating data input without error messages

In [paragraph 30.3](#), you learned how to validate one single value entered by the user without displaying any error messages. For your convenience, the code fragment given in general form is presented once again.

```
do {
    Console.WriteLine("Prompt message");
    input_data = Console.ReadLine();
} while (input_data test 1 fails || input_data test 2 fails || ...);
```

Do you remember how this operates? If the user persistently enters an invalid value, the main idea is to prompt him or her repeatedly, until he or she gets bored and finally enters a valid one. Of course, if the user enters a valid value right from the beginning, the flow of execution simply continues to the next part of the program.

You can use the same principle when entering data into arrays. If you use a for-loop to iterate for all elements of the array, the code fragment becomes as follows.

```
for (i = 0; i <= ELEMENTS - 1; i++) {
    do {
        Console.WriteLine("Prompt message");
        input_data = Console.ReadLine();
    } while (input_data test 1 fails || input_data test 2 fails || ...);
    input_array[i] = input_data;
}
```

As you can see, when the flow of execution exits the post-test loop structure, the variable *input\_data* definitely contains a valid value which in turn is assigned to an element of the array *input\_array*. However, the same process

can be implemented more simply, without using the extra variable *input\_data*, as follows.

```
for (i = 0; i <= ELEMENTS - 1; i++) {  
    do {  
        Console.WriteLine("Prompt message");  
        input_array[i] = Console.ReadLine();  
    } while (input_array[i] test 1 fails || input_array[i] test 2 fails || ... );  
}
```

## Second Approach – Validating data input with one single error message

As before, the next code fragment is taken from [paragraph 30.3](#) and adapted to operate with an array. It validates data input and displays an error message (that is, the same error message for any type of input error).

```
for (i = 0; i <= ELEMENTS - 1; i++) {  
    Console.WriteLine("Prompt message");  
    input_array[i] = Console.ReadLine();  
    while (input_array[i] test 1 fails || input_array[i] test 2 fails || ... ) {  
        Console.WriteLine("Error message");  
        Console.WriteLine("Prompt message");  
        input_array[i] = Console.ReadLine();  
    }  
}
```

## Third Approach – Validating data input with individual error messages

Once again, the next code fragment is taken from [paragraph 30.3](#) and adapted to operate with an array. It validates data input and displays individual error messages (that is, one for each type of input error).

```
for (i = 0; i <= ELEMENTS - 1; i++) {  
    do {  
        Console.WriteLine("Prompt message");  
        input_array[i] = Console.ReadLine();  
  
        failure = false;  
        if (input_array[i] test 1 fails) {  
            Console.WriteLine("Error message 1");  
            failure = true;  
        }  
        else if (input_array[i] test 2 fails) {  
            Console.WriteLine("Error message 2");  
            failure = true;  
        }  
        else if (...  
        ...  
    }
```

```
        }
    } while (failure);
}
```

## **Exercise 34.2-1 Displaying Odds in Reverse Order – Validation Without Error Messages**

---

*Write a C# program that prompts the user to enter 20 odd positive integers into an array and then displays them in the exact reverse of the order in which they were given. The program must also validate data input, not allowing the user to enter a non-positive value, a float, or an even integer. There is no need to display any error messages.*

### **Solution**

---

As the wording of the exercise implies, not all entered values should be added in the array—only the odd positive integers. The C# program is presented next.

#### project\_34\_2\_1

```
const int ELEMENTS = 20;

static void Main(string[] args) {
    int i;
    double x;

    int[] odds = new int[ELEMENTS];
    for (i = 0; i <= ELEMENTS - 1; i++) {
        do {
            Console.Write("Enter an odd positive integer: ");
            x = Double.Parse(Console.ReadLine());
        } while (x <= 0 || x != (int)x || x % 2 == 0);
        odds[i] = (int)x;
    }

    //Display elements backwards
    for (i = ELEMENTS - 1; i >= 0; i--) {
        Console.Write(odds[i] + "\t");
    }
}
```

[More...]

 Variable *x* must be of type *double*. This is necessary in order to allow the user to enter either an integer or a float (real).

## **Exercise 34.2-2 Displaying Odds in Reverse Order – Validation with One Error Message**

---

*Write a C# program that prompts the user to enter 20 odd positive integers into an array and then displays them in the exact reverse of the order in which they were given. The program must also validate data input and display an error message when the user enters any non-positive values, any floats, or any even integers.*

### **Solution**

---

This is the same as you've previously seen, except for data validation. The second approach is used, according to which an error message is displayed when the user enters a non-positive value, a float, or an even integer. The C# program is presented next.

#### project\_34\_2\_2

```
const int ELEMENTS = 20;

static void Main(string[] args) {
    int i;
    double x;

    int[] odds = new int[ELEMENTS];
    for (i = 0; i <= ELEMENTS - 1; i++) {
        Console.WriteLine("Enter an odd positive integer: ");
        x = Double.Parse(Console.ReadLine());
        while (x <= 0 || x != (int)x || x % 2 == 0) {
            Console.WriteLine("Invalid value!");
            Console.WriteLine("Enter an odd positive integer: ");
            x = Double.Parse(Console.ReadLine());
        }
        odds[i] = (int)x;
    }

    //Display elements backwards
    for (i = ELEMENTS - 1; i >= 0; i--) {
        Console.Write(odds[i] + "\t");
    }
}
```

[More...]

## **Exercise 34.2-3 Displaying Odds in Reverse Order – Validation with Individual Error Messages**

---

*Write a C# program that prompts the user to enter 20 odd positive integers in an array and then displays them in the exact reverse of the order in which they were given. The program must also validate data input and display individual error messages when the user enters any non-positive values, any floats, or any even integers.*

## Solution

---

The third approach is used, according to which individual error messages are displayed when the user enters any non-positive values, any floats, or any even integers. The C# program is as follows.

### project\_34\_2\_3

```
const int ELEMENTS = 20;

static void Main(string[] args) {
    int i;
    bool failure;
    double x;

    int[] odds = new int[ELEMENTS];

    for (i = 0; i <= ELEMENTS - 1; i++) {
        do {
            Console.WriteLine("Enter an odd positive integer: ");
            x = Double.Parse(Console.ReadLine());
            failure = false;
            if (x <= 0) {
                Console.WriteLine("Invalid value: Non-positive entered!");
                failure = true;
            }
            else if (x != (int)x) {
                Console.WriteLine("Invalid value: Float entered!");
                failure = true;
            }
            else if (x % 2 == 0) {
                Console.WriteLine("Invalid value: Even entered!");
                failure = true;
            }
        } while (failure);
        odds[i] = (int)x;
    }

    //Display elements backwards
```

[More...]

```

    for (i = ELEMENTS - 1; i >= 0; i--) {
        Console.WriteLine(odds[i] + "\t");
    }
}

```

### 34.3 Finding Minimum and Maximum Values in Arrays

This is the third and last time that this subject is raked up in this book. The first time was in [paragraph 23.3](#) using decision control structures and the second time was in [paragraph 30.5](#) using loop control structures. So, there is not much left to discuss except that when you want to find the minimum or maximum value of a data structure that already contains some values, you needn't worry about the initial values of variables `minimum` or `maximum` because you can just assign to them the value of the first element of the data structure!

#### Exercise 34.3-1 Which Depth is the Greatest?

*Write a C# program that lets the user enter the depths of 20 lakes and then displays the depth of the deepest one.*

#### Solution

After the user enters the depths of the 20 lakes in the array `depths`, the initial value of variable `maximum` can be the value of the first element of array `depths`, that is `depths[0]`. The program can then search (starting from index 1) for any value thereafter greater than this. The final solution is quite simple and is presented next without further explanation.

#### 📁 project\_34\_3\_1

```

const int LAKES = 20;

static void Main(string[] args) {
    int i;
    double maximum;

    double[] depths = new double[LAKES];
    for (i = 0; i <= LAKES - 1; i++) {
        depths[i] = Double.Parse(Console.ReadLine());
    }

    maximum = depths[0]; //Initial value

    //Search thereafter, starting from index 1
}

```

```

    for (i = 1; i <= LAKES - 1; i++) {
        if (depths[i] > maximum) {
            maximum = depths[i];
        }
    }

    Console.WriteLine(maximum);
}

```

 *It wouldn't be wrong to start iterating from position 0 instead of 1, though the program would perform one useless iteration.*

 *It wouldn't be wrong to assign an “almost arbitrary” initial value to variable maximum but there is no reason to do so. The value of the first element is just fine! If you insist though, you can assign an initial value of 0, since there is no lake on planet Earth with a negative depth.*

### **Exercise 34.3-2 Which Lake is the Deepest?**

*Write a C# program that lets the user enter the names and the depths of 20 lakes and then displays the name of the deepest one.*

#### **Solution**

If you don't know how to find the name of the deepest lake, you may need to refresh your memory by re-reading [Exercise 30.5-2](#).

In this exercise, you need two one-dimensional arrays: one to hold the names, and one to hold the depths of the lakes. The solution is presented next.

#### project\_34\_3\_2

```

const int LAKES = 20;

static void Main(string[] args) {
    int i;
    double maximum;
    string m_name;

    string[] names = new string[LAKES];
    double[] depths = new double[LAKES];
    for (i = 0; i <= LAKES - 1; i++) {
        names[i] = Console.ReadLine();
        depths[i] = Double.Parse(Console.ReadLine());
    }
}

```

```

maximum = depths[0];
m_name = names[0];
for (i = 1; i <= LAKES - 1; i++) {
    if (depths[i] > maximum) {
        maximum = depths[i];
        m_name = names[i];
    }
}

Console.WriteLine(m_name);
}

```

### ***Exercise 34.3-3 Which Lake, in Which Country, Having Which Average Area, is the Deepest?***

---

*Write a C# program that lets the user enter the names and the depths of 20 lakes as well as the country in which they belong, and their average area. The program must then display all available information about the deepest lake.*

#### ***Solution***

---

In this exercise, you need four one-dimensional arrays: one to hold the names, one to hold the depths, one to hold the names of the countries, and one to hold the lakes' average areas. There are two approaches, actually. Let's study them both!

#### ***First Approach – One variable for each***

This is pretty much the same as the one used in the previous exercise. The solution is presented next.

#### **project\_34\_3\_3a**

```

const int LAKES = 20;

static void Main(string[] args) {
    int i;
    double maximum, m_area;
    string m_name, m_country;

    string[] names = new string[LAKES];
    double[] depths = new double[LAKES];
    string[] countries = new string[LAKES];
    double[] areas = new double[LAKES];
}

```

```

for (i = 0; i <= LAKES - 1; i++) {
    names[i] = Console.ReadLine();
    depths[i] = Double.Parse(Console.ReadLine());
    countries[i] = Console.ReadLine();
    areas[i] = Double.Parse(Console.ReadLine());
}

maximum = depths[0];
m_name = names[0];
m_country = countries[0];
m_area = areas[0];
for (i = 1; i <= LAKES - 1; i++) {
    if (depths[i] > maximum) {
        maximum = depths[i];
        m_name = names[i];
        m_country = countries[i];
        m_area = areas[i];
    }
}

Console.WriteLine(maximum + " " + m_name + " " + m_country + " " + m_area);
}

```

## Second Approach – One index for everything

This approach is more efficient than the first one since it uses fewer variables. Instead of using all those variables (`m_name`, `m_country`, and `m_area`), you can use just one variable, a variable that holds the index in which the maximum value exists!

Confused? Let's look at the next example of six lakes. The depths are expressed in feet and the average areas in square miles.

<code>names =</code>	<table border="1"> <tr><td>0</td><td>Toba</td></tr> <tr><td>1</td><td>Issyk Kul</td></tr> <tr><td>2</td><td>Baikal</td></tr> <tr><td>3</td><td>Crater</td></tr> <tr><td>4</td><td>Karakul</td></tr> <tr><td>5</td><td>Quesnel</td></tr> </table>	0	Toba	1	Issyk Kul	2	Baikal	3	Crater	4	Karakul	5	Quesnel	<code>depths =</code>	<table border="1"> <tr><td>1660</td></tr> <tr><td>2192</td></tr> <tr><td>5380</td></tr> <tr><td>1950</td></tr> <tr><td>750</td></tr> <tr><td>2000</td></tr> </table>	1660	2192	5380	1950	750	2000	<code>countries =</code>	<table border="1"> <tr><td>Indonesia</td></tr> <tr><td>Kyrgyzstan</td></tr> <tr><td>Russia</td></tr> <tr><td>USA</td></tr> <tr><td>Tajikistan</td></tr> <tr><td>Canada</td></tr> </table>	Indonesia	Kyrgyzstan	Russia	USA	Tajikistan	Canada	<code>areas =</code>	<table border="1"> <tr><td>440</td></tr> <tr><td>2408</td></tr> <tr><td>12248</td></tr> <tr><td>21</td></tr> <tr><td>150</td></tr> <tr><td>103</td></tr> </table>	440	2408	12248	21	150	103
0	Toba																																				
1	Issyk Kul																																				
2	Baikal																																				
3	Crater																																				
4	Karakul																																				
5	Quesnel																																				
1660																																					
2192																																					
5380																																					
1950																																					
750																																					
2000																																					
Indonesia																																					
Kyrgyzstan																																					
Russia																																					
USA																																					
Tajikistan																																					
Canada																																					
440																																					
2408																																					
12248																																					
21																																					
150																																					
103																																					

Obviously the deepest lake is Lake Baikal at position 2. However, instead of holding the name “Baikal” in variable `m_name`, the country “Russia” in variable `m_country`, and the area “12248” in variable `m_area` as in the previous approach, you can use just one variable to hold the index position

in which these values actually exist (in this case, this is value 2). The solution is presented next.

### project\_34\_3\_3b

```
const int LAKES = 20;

static void Main(string[] args) {
    int i, index_of_max;
    double maximum;

    string[] names = new string[LAKES];
    double[] depths = new double[LAKES];
    string[] countries = new string[LAKES];
    double[] areas = new double[LAKES];
    for (i = 0; i <= LAKES - 1; i++) {
        names[i] = Console.ReadLine();
        depths[i] = Double.Parse(Console.ReadLine());
        countries[i] = Console.ReadLine();
        areas[i] = Double.Parse(Console.ReadLine());
    }

    //Find the maximum depth and the index in which this maximum depth exists
    maximum = depths[0];
    index_of_max = 0;
    for (i = 1; i <= LAKES - 1; i++) {
        if (depths[i] > maximum) {
            maximum = depths[i];
            index_of_max = i;
        }
    }

    //Display information using index_of_max as index
    Console.WriteLine(depths[index_of_max] + " " + names[index_of_max]);
    Console.WriteLine(countries[index_of_max] + " " + areas[index_of_max]);
}
```

 Assigning an initial value of 0 to variable `index_of_max` is necessary since there is always a possibility that the maximum value does exist in position 0.

### Exercise 34.3-4 Which Students Have got the Greatest Grade?

Write a C# program that prompts the user to enter the names and the grades of 200 students and then displays the names of all those who share

*the one greatest grade. Using a loop control structure, the program must also validate data input and display an error message when the user enters an empty name or any negative values or values greater than 100 for grades.*

## Solution

---

In this exercise, you need to validate both the names and the grades. A code fragment, given in general form, shows the data input stage.

```
const int STUDENTS = 100;

static void Main(string[] args) {
    ...

    for (i = 0; i <= STUDENTS - 1; i++) {
        Prompt the user to enter a name and validate it.
        It cannot be empty!

        Prompt the user to enter a grade and validate it.
        It cannot be negative or greater than 100.
    }
    ...
}
```

After data input stage, a loop control structure must search for the greatest value, and then, another loop control structure must search the array grades for all values that are equal to that greatest value.

The solution is presented next.

### project\_34\_3\_4

```
const int STUDENTS = 100;

static void Main(string[] args) {
    int i, maximum;

    string[] names = new string[STUDENTS];
    int[] grades = new int[STUDENTS];
    for (i = 0; i <= STUDENTS - 1; i++) {
        //Prompt the user to enter a name and validate it.
        Console.WriteLine("Enter name for student No " + (i + 1) + ": ");
        names[i] = Console.ReadLine();
        while (names[i] == "") {
            Console.WriteLine("Error! Name cannot be empty!");
        }
    }
}
```

```

        Console.WriteLine("Enter name for student No " + (i + 1) + ": ");
        names[i] = Console.ReadLine();
    }

    //Prompt the user to enter a grade and validate it.
    Console.Write("Enter his or her grade: ");
    grades[i] = Int32.Parse(Console.ReadLine());
    while (grades[i] < 0 || grades[i] > 100) {
        Console.WriteLine("Invalid value!");
        Console.Write("Enter his or her grade: ");
        grades[i] = Int32.Parse(Console.ReadLine());
    }
}

//Find the greatest grade
maximum = grades[0];
for (i = 1; i <= STUDENTS - 1; i++) {
    if (grades[i] > maximum) {
        maximum = grades[i];
    }
}

//Displays the names of all those who share the one greatest grade
Console.WriteLine("The following students have got the greatest grade:");
for (i = 0; i <= STUDENTS - 1; i++) {
    if (grades[i] == maximum) {
        Console.WriteLine(names[i]);
    }
}
}

```

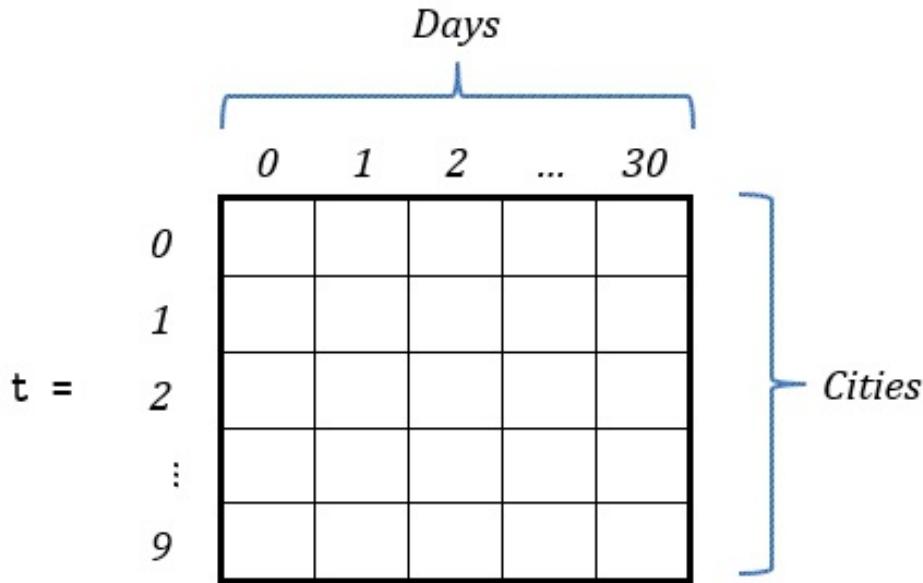
 Note that this exercise could not have been solved without the use of an array.

### Exercise 34.3-5 Finding the Minimum Value of a Two-Dimensional Array

Write a C# program that lets the user enter the temperatures (in degrees Fahrenheit) recorded at the same hour each day in January in 10 different cities. The C# program must display the lowest temperature.

#### Solution

In this exercise, you need the following array.



The array  $t$  has 31 columns (0 to 30), as many as there are days in January.

There is nothing new here. The initial value of variable `minimum` can be the value of the element  $t[0, 0]$ . Then, the program can iterate through rows, or even through columns, to search for the minimum value. The solution is presented next.

### project\_34\_3\_5

```
const int CITIES = 10;
const int DAYS = 31;

static void Main(string[] args) {
    int i, j, minimum;

    //Read array t
    int[,] t = new int[CITIES, DAYS];
    for (i = 0; i <= CITIES - 1; i++) {
        for (j = 0; j <= DAYS - 1; j++) {
            t[i, j] = Int32.Parse(Console.ReadLine());
        }
    }

    //Find minimum
    minimum = t[0, 0];
    for (i = 0; i <= CITIES - 1; i++) {
        for (j = 0; j <= DAYS - 1; j++) {
```

```

        if (t[i, j] < minimum) {
            minimum = t[i, j];
        }
    }

Console.WriteLine(minimum);
}

```

 In this exercise you **cannot** do the following because if you do, and variable *j* starts from 1, the whole column with index 0 won't be checked!

```

//Find minimum
minimum = t[0, 0];
for (i = 0; i <= CITIES - 1; i++) {
    for (j = 1; j <= DAYS - 1; j++) {
        if (t[i, j] < minimum) {
            minimum = t[i, j];
        }
    }
}

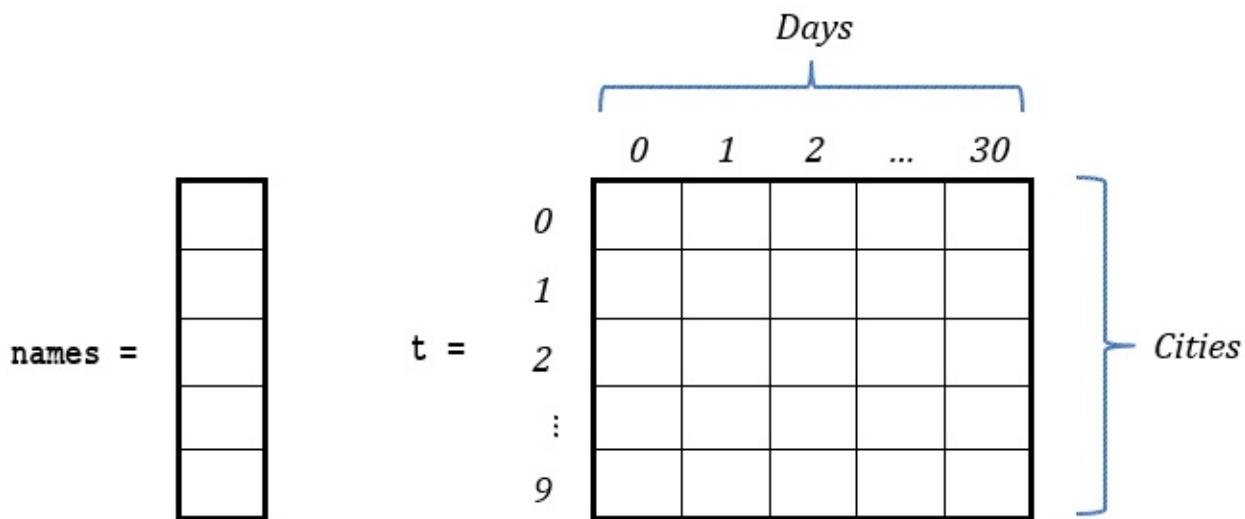
```

### Exercise 34.3-6 Finding the City with the Coldest Day

Write a C# program that lets the user enter the temperatures (in degrees Fahrenheit) recorded at the same hour each day in January in 10 different cities. The C# program must display the name of the city that had the lowest temperature and on which day it was recorded.

#### Solution

In this exercise, the following two arrays are needed.



The solution is simple. Every time variable `minimum` updates its value, two variables, `m_i` and `m_j`, can hold the values of variables `i` and `j` respectively. In the end, these two variables will contain the row index and the column index of the position in which the minimum value exists. The solution is as follows.

### project\_34\_3\_6

```
const int CITIES = 10;
const int DAYS = 31;

static void Main(string[] args) {
    int i, j, minimum, m_i, m_j;

    string[] names = new string[CITIES];
    int[,] t = new int[CITIES, DAYS];
    for (i = 0; i <= CITIES - 1; i++) {
        names[i] = Console.ReadLine();
        for (j = 0; j <= DAYS - 1; j++) {
            t[i, j] = Int32.Parse(Console.ReadLine());
        }
    }

    minimum = t[0, 0];
    m_i = 0;
    m_j = 0;
    for (i = 0; i <= CITIES - 1; i++) {
        for (j = 0; j <= DAYS - 1; j++) {
            if (t[i, j] < minimum) {
                minimum = t[i, j];
                m_i = i;
                m_j = j;
            }
        }
    }

    Console.WriteLine("Minimum temperature: " + minimum);
    Console.WriteLine("City: " + names[m_i]);
    Console.WriteLine("Day: " + (m_j + 1));
}
```

 Assigning an initial value of 0 to variables `m_i` and `m_j` is necessary since there is always a possibility that the minimum value is the value of the element `t[0, 0]`.

## **Exercise 34.3-7 Finding the Minimum and the Maximum Value of Each Row**

---

*Write a C# program that lets the user enter values in a  $20 \times 30$  array and then finds and displays the minimum and the maximum values of each row.*

### **Solution**

---

There are two approaches, actually. The first approach creates two auxiliary one-dimensional arrays, `minimum` and `maximum`, and then displays them. Arrays `minimum` and `maximum` will contain, in each position, the minimum and the maximum values of each row respectively. On the other hand, the second approach finds and directly displays the minimum and maximum values of each row. Let's study both approaches.

#### **First Approach – Creating auxiliary arrays**

To better understand this approach, let's use the “from inner to outer” method. When the following code fragment completes its iterations, the auxiliary one-dimensional arrays `minimum` and `maximum` contain at position 0 the minimum and the maximum values of the first row (row index 0) of array `b` respectively. Assume variable `i` contains value 0.

```
minimum[i] = b[i, 0];
maximum[i] = b[i, 0];
for (j = 1; j <= COLUMNS - 1; j++) {
    if (b[i, j] < minimum[i]) {
        minimum[i] = b[i, j];
    }
    if (b[i, j] > maximum[i]) {
        maximum[i] = b[i, j];
    }
}
```

 *Note that variable `j` starts from 1. It wouldn't be wrong to start iterating from column index 0 instead of 1, though the program would perform one useless iteration.*

Now that everything has been clarified, in order to process the whole array `b`, you can just nest this code fragment into a for-loop which iterates for all rows as shown next.

```
for (i = 0; i <= ROWS - 1; i++) {
    minimum[i] = b[i, 0];
```

```

maximum[i] = b[i, 0];
for (j = 1; j <= COLUMNS - 1; j++) {
    if (b[i, j] < minimum[i]) {
        minimum[i] = b[i, j];
    }
    if (b[i, j] > maximum[i]) {
        maximum[i] = b[i, j];
    }
}
}

```

The final C# program is as follows.

### project\_34\_3\_7a

```

const int ROWS = 30;
const int COLUMNS = 20;

static void Main(string[] args) {
    int i, j;

    double[,] b = new double[ROWS, COLUMNS];
    for (i = 0; i <= ROWS - 1; i++) {
        for (j = 0; j <= COLUMNS - 1; j++) {
            b[i, j] = Double.Parse(Console.ReadLine());
        }
    }

    double[] minimum = new double[ROWS];
    double[] maximum = new double[ROWS];
    for (i = 0; i <= ROWS - 1; i++) {
        minimum[i] = b[i, 0];
        maximum[i] = b[i, 0];
        for (j = 1; j <= COLUMNS - 1; j++) {
            if (b[i, j] < minimum[i]) {
                minimum[i] = b[i, j];
            }
            if (b[i, j] > maximum[i]) {
                maximum[i] = b[i, j];
            }
        }
    }

    for (i = 0; i <= ROWS - 1; i++) {
        Console.WriteLine(minimum[i] + " " + maximum[i]);
    }
}

```

## Second Approach – Finding and directly displaying minimum and maximum values

Let's use the “from inner to outer” method once again. The next code fragment finds and directly displays the minimum and the maximum values of the first row (row index 0) of array b. Assume variable i contains the value 0.

```
minimum = b[i, 0];
maximum = b[i, 0];
for (j = 1; j <= COLUMNS - 1; j++) {
    if (b[i, j] < minimum) {
        minimum = b[i, j];
    }
    if (b[i, j] > maximum) {
        maximum = b[i, j];
    }
}

Console.WriteLine(minimum + " " + maximum);
```

Now that everything has been clarified, in order to process the whole array b, you can just nest this code fragment into a for-loop which iterates for all rows, as follows.

```
for (i = 0; i <= ROWS - 1; i++) {
    minimum = b[i, 0];
    maximum = b[i, 0];
    for (j = 1; j <= COLUMNS - 1; j++) {
        if (b[i, j] < minimum) {
            minimum = b[i, j];
        }
        if (b[i, j] > maximum) {
            maximum = b[i, j];
        }
    }

    Console.WriteLine(minimum + " " + maximum);
}
```

The final C# program is as follows.

### project\_34\_3\_7b

```
const int ROWS = 30;
const int COLUMNS = 20;
```

```
static void Main(string[] args) {
    int i, j;
    double minimum, maximum;

    double[,] b = new double[ROWS, COLUMNS];
    for (i = 0; i <= ROWS - 1; i++) {
        for (j = 0; j <= COLUMNS - 1; j++) {
            b[i, j] = Double.Parse(Console.ReadLine());
        }
    }

    for (i = 0; i <= ROWS - 1; i++) {
        minimum = b[i, 0];
        maximum = b[i, 0];
        for (j = 1; j <= COLUMNS - 1; j++) {
            if (b[i, j] < minimum) {
                minimum = b[i, j];
            }
            if (b[i, j] > maximum) {
                maximum = b[i, j];
            }
        }
        Console.WriteLine(minimum + " " + maximum);
    }
}
```

## 34.4 Sorting Arrays

Sorting algorithms are an important topic in computer science. A *sorting algorithm* is an algorithm that puts elements of an array in a certain order. There are many sorting algorithms and each one of them has particular strengths and weaknesses.

Most sorting algorithms work by comparing the elements of the array. They are usually evaluated by their efficiency and their memory requirements.

There are many sorting algorithms. Some of them are:

- ▶ the bubble sort algorithm
- ▶ the modified bubble sort algorithm
- ▶ the selection sort algorithm
- ▶ the insertion sort algorithm
- ▶ the heap sort algorithm
- ▶ the merge sort algorithm
- ▶ the quicksort algorithm

As regards their efficiency, the bubble sort algorithm is considered the least efficient, while each succeeding algorithm in the array performs better than the preceding one. The quicksort algorithm is considered one of the best and fastest sorting algorithms, especially for large scale data operations.

Sorting algorithms can be used for more than just displaying data in ascending or descending order. For example, if an exercise requires you to display the three biggest numbers of an array, the C# program can sort the array in descending order and then display only the first three elements, that is, those at index positions 0, 1, and 2.

Sorting algorithms can also help you find the minimum and the maximum values from a set of given values. If an array is sorted in ascending order, the minimum value exists at the first index position and the maximum value exists at the last index position. Of course, it is very inefficient to sort an array so as to find minimum and maximum values; you have already learned a more efficient method. But if for some reason an exercise requires that an array be sorted and you need the minimum or the maximum value, you know where you can find them!

## ***Exercise 34.4-1 The Bubble Sort Algorithm – Sorting One-Dimensional Arrays with Numeric Values***

---

*Write a C# program that lets the user enter 20 numerical values into an array and then sorts them in ascending order using the bubble sort algorithm.*

### **Solution**

---

The *bubble sort algorithm* is probably one of the most inefficient sorting algorithms but it is widely used for teaching purposes. The main idea (when asked to sort an array in ascending order) is to repeatedly move the smallest elements of the array to the positions of lowest index. This works as follows: the algorithm iterates through the elements of the array, compares each pair of adjacent elements, and then swaps their contents (if they are in the wrong order). This process is repeated many times until the array is sorted.

For example, let's try to sort the following array in ascending order.

<b>A =</b>	<table border="1" style="border-collapse: collapse; text-align: center;"><tbody><tr><td>17</td><td>0</td></tr><tr><td>25</td><td>1</td></tr><tr><td>8</td><td>2</td></tr><tr><td>5</td><td>3</td></tr><tr><td>49</td><td>4</td></tr><tr><td>12</td><td>5</td></tr></tbody></table>	17	0	25	1	8	2	5	3	49	4	12	5
17	0												
25	1												
8	2												
5	3												
49	4												
12	5												

The lowest value is the value 5. According to the bubble sort algorithm, this value must gradually “bubble” or “rise” to position 0, like bubbles rising in a glass of cola. When the value 5 has been moved into position 0, the next smallest value is the value 8. Now, the value 8 must “bubble” to position 1. Next is the value 12, which must “bubble” to position 2, and so on. This process repeats until all elements are placed in proper position.

But how can this “bubbling” be done using an algorithm? Let's see the whole process in more detail. For the previous array A of six elements, five passes must be performed.

## First Pass

### 1st Compare

Initially, elements at index positions 4 and 5 are compared. Since the value 12 is less than the value 49, these two elements swap their content.

### 2nd Compare

Elements at index positions 3 and 4 are compared. Since the value 12 is **not** less than the value 5, **no** swapping is done.

### 3rd Compare

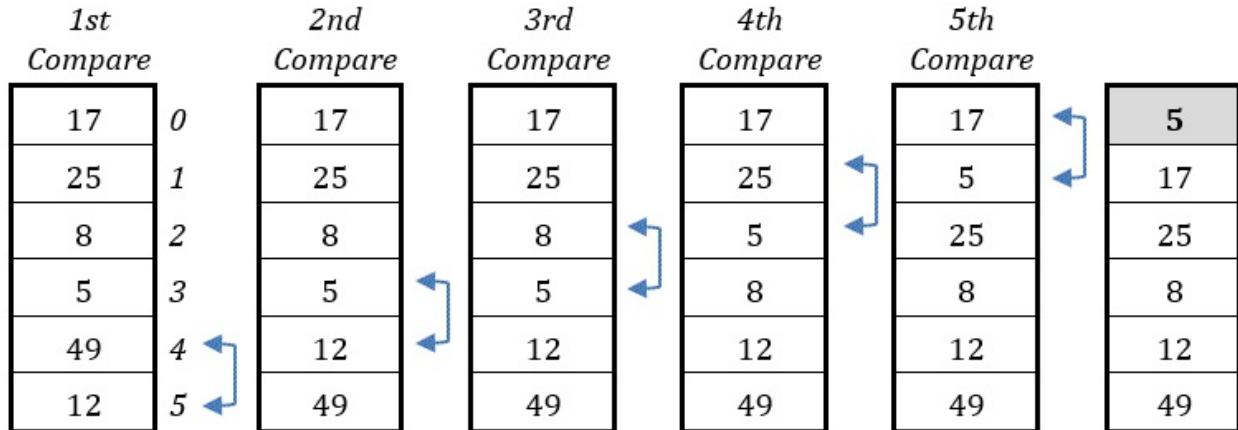
Elements at index positions 2 and 3 are compared. Since the value 5 is less than the value 8, these two elements swap their content.

### 4th Compare

Elements at index positions 1 and 2 are compared. Since the value 5 is less than the value 25, these two elements swap their content.

### 5th Compare

Elements at index positions 0 and 1 are compared. Since the value 5 is less than the value 17, these two elements swap their content.



The first pass has been completed but, as you can see, the array has not been sorted yet. The only value that has actually been placed in proper position is the value 5. However, since more passes will follow, there is no need for the value 5 to take part in the subsequent compares. In the pass that follows, one less compare will be performed—that is, four compares.

## Second Pass

### 1st Compare

Elements at index positions 4 and 5 are compared. Since the value 49 is **not**

less than the value 12, **no** swapping is done.

### 2nd Compare

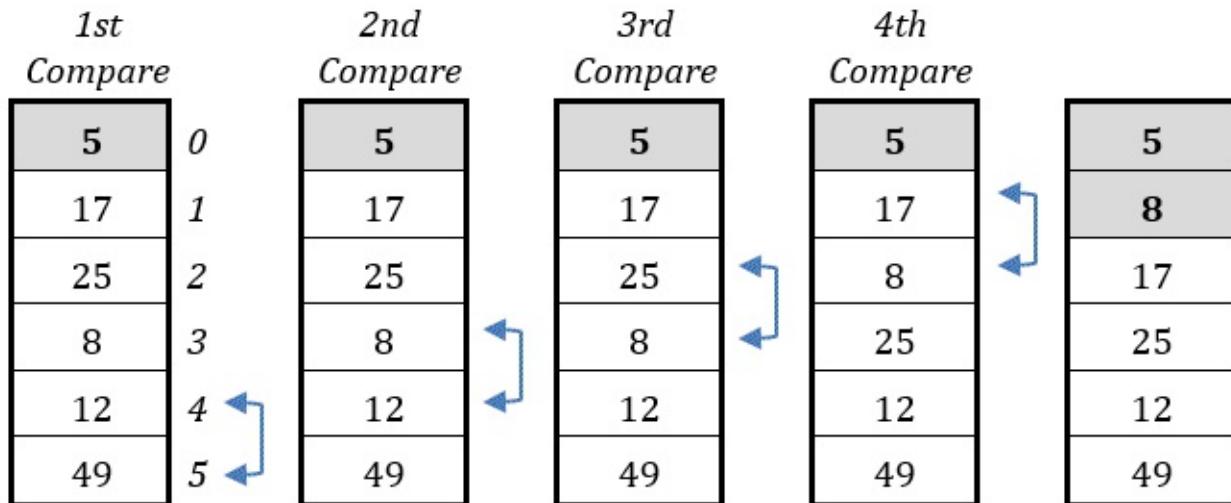
Elements at index positions 3 and 4 are compared. Since the value 12 is **not** less than the value 8, **no** swapping is done.

### 3rd Compare

Elements at index positions 2 and 3 are compared. Since the value 8 is less than the value 25, these two elements swap their content.

### 4th Compare

Elements at index positions 1 and 2 are compared. Since the value 8 is less than the value 17, these two elements swap their content.



The second pass has been completed and the value of 8 has been placed in proper position. However, since more passes will follow, there is no need for the value 8 (nor 5, of course) to take part in the subsequent compares. In the pass that follows, one less compare will be performed—that is, three compares.

## Third Pass

### 1st Compare

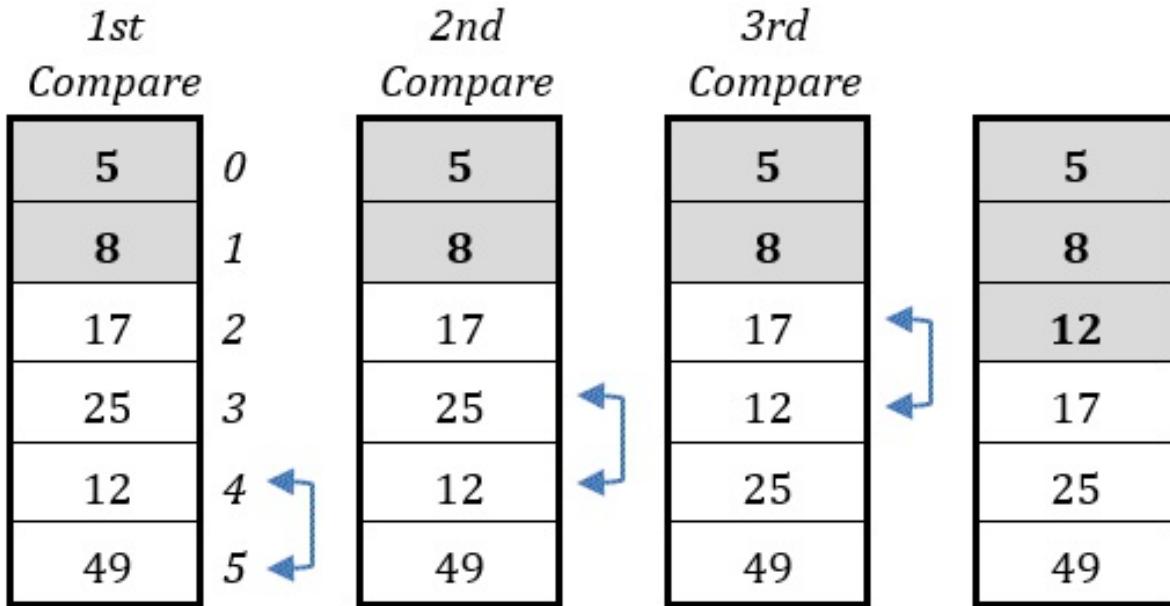
Elements at index positions 4 and 5 are compared. Since the value 49 is **not** less than the value 12, **no** swapping is done.

### 2nd Compare

Elements at index positions 3 and 4 are compared. Since the value 12 is less than the value 25, these two elements swap their content.

### 3rd Compare

Elements at index positions 2 and 3 are compared. Since the value 12 is less than the value 17, these two elements swap their content.



The third pass has been completed and the value of 12 has been placed in proper position. As previously, since more passes will follow there is no need for the value 12 (nor the values 5 and 8, of course) to take part in the subsequent compares. In the pass that follows, one compare less will be performed—that is, two compares.

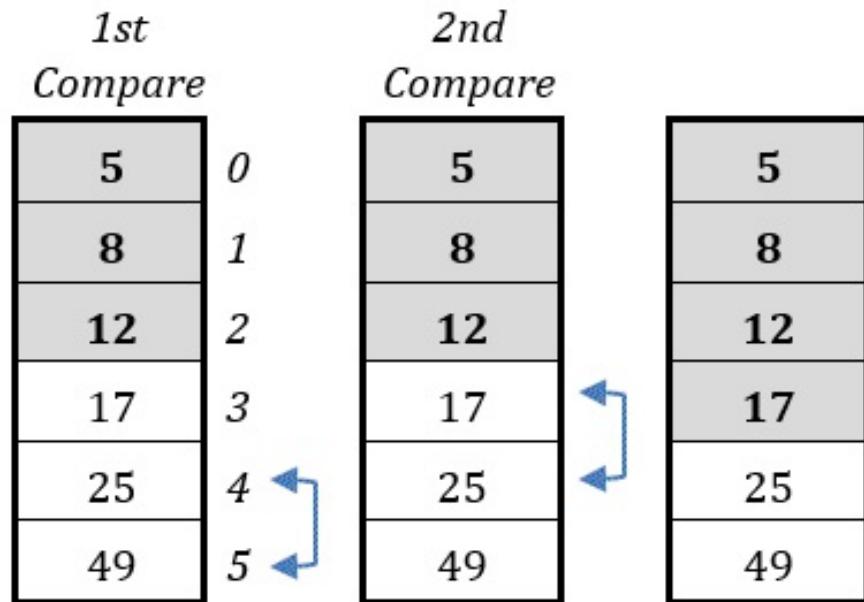
## Fourth Pass

### 1st Compare

Elements at index positions 4 and 5 are compared. Since the value 49 is **not** less than the value 25, **no** swapping is done.

### 2nd Compare

Elements at index positions 3 and 4 are compared. Since the value 25 is **not** less than the value 17, **no** swapping is done.

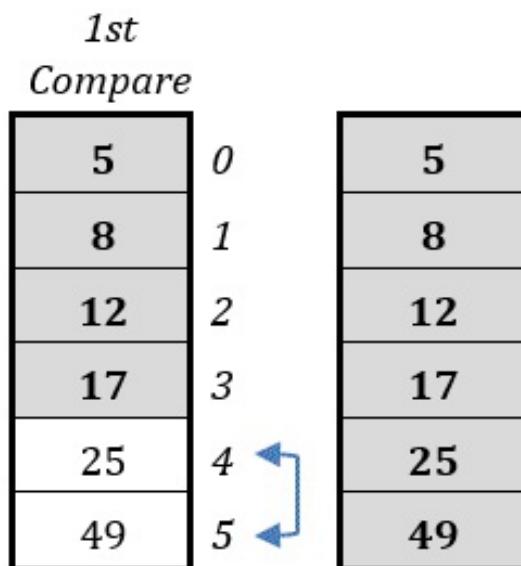


The fourth pass has been completed and the value 17 has been placed in proper position. As previously, since one last pass will follow, there is no need for the value 17 (nor the values 5, 8, and 12, of course) to take part in the subsequent compares. In the last pass that follows, one compare less will be performed—that is one compare.

## Fifth pass

### 1st Compare

Elements at index positions 4 and 5 are compared. Since the value 49 is **not** less than the value 25, **no** swapping is done.



The fifth pass has been completed and the final two values (25 and 49) have

been placed in proper position. The bubble sort algorithm has finished and the array is sorted in ascending order!

Now you need a C# program that can do the whole previous process. Let's use the “from inner to outer” method. The code fragment that performs only the first pass is shown below. Please note that this is the inner (nested) loop control structure. Assume variable  $m$  contains the value 1.

```
for (n = ELEMENTS - 1; n >= m; n--) {  
    if (a[n] < a[n - 1]) {  
        temp = a[n];  
        a[n] = a[n - 1];  
        a[n - 1] = temp;  
    }  
}
```

 In the first pass, variable  $m$  must contain the value 1. This assures that at the last iteration, the elements that are compared are those at positions 1 and 0.

 Swapping the contents of two elements uses a method you have already learned! Please recall the two glasses of orange juice and lemon juice. If this doesn't ring a bell, you need to refresh your memory and re-read the corresponding [Exercise 8.1-2](#).

The second pass can be performed if you just re-execute the previous code fragment. Variable  $m$ , however, needs to contain the value 2. This will ensure that the element at position 0 won't be compared again. Similarly, for the third pass, the previous code fragment can be re-executed but variable  $m$  needs to contain the value 3 for the same reason.

Accordingly, the previous code fragment needs to be executed five times (one for each pass), and each time variable  $m$  must be incremented by 1. The final code fragment that sorts array  $a$  using the bubble sort algorithm is as follows.

```
for (m = 1; m <= ELEMENTS - 1; m++) {  
    for (n = ELEMENTS - 1; n >= m; n--) {  
        if (a[n] < a[n - 1]) {  
            temp = a[n];  
            a[n] = a[n - 1];  
            a[n - 1] = temp;  
        }  
    }  
}
```

| }

❑ For  $N$  elements, the algorithm needs to perform  $N - 1$  passes. For example, if array  $a$  contains 20 elements, the statement `for (m = 1; m <= ELEMENTS - 1; m++)` performs 19 passes.

The complete C# program is as follows.

### ❑ project\_34\_4\_1

```
const int ELEMENTS = 20;

static void Main(string[] args) {
    int i, m, n;
    double temp;

    double[] a = new double[ELEMENTS];
    for (i = 0; i <= ELEMENTS - 1; i++) {
        a[i] = Double.Parse(Console.ReadLine());
    }

    for (m = 1; m <= ELEMENTS - 1; m++) {
        for (n = ELEMENTS - 1; n >= m; n--) {
            if (a[n] < a[n - 1]) {
                temp = a[n];
                a[n] = a[n - 1];
                a[n - 1] = temp;
            }
        }
    }

    for (i = 0; i <= ELEMENTS - 1; i++) {
        Console.WriteLine(a[i] + "\t");
    }
}
```

❑ The bubble sort algorithm is very inefficient. The total number of compares that it performs is  $\frac{N(N-1)}{2}$ , where  $N$  is the total number of array elements.

❑ The total number of swaps depends on the given array. The worst case is when you want to sort in ascending order an array that is already sorted in descending order, or vice versa.

## **Exercise 34.4-2 Sorting One-Dimensional Arrays with Alphanumeric Values**

---

*Write a code fragment that sorts the alphanumeric values of an array in descending order using the bubble sort algorithm.*

### **Solution**

---

Comparing this exercise to the previous one, two things are different. First, the bubble sort algorithm needs to sort alphanumeric values, such as names of people or names of cities; and second, it has to sort them in descending order.

In C# you cannot compare strings using comparison operators such as the less than (`<`), or the greater than (`>`) operators. Actually, C# supports the method `CompareTo()`, that can be used for this purpose. For this method the letter “A” is considered “less than” the letter “B”, the letter “B” is considered “less than” the letter “C”, and so on. Of course, if the array contains words in which the first letter is identical, C# moves on and compares their second letters and perhaps their third letter (if there is need to do so). For example, the name “John” is considered “less than” the name “Jonathan” because the third letter “h” is “less than” the third letter “n”. In conclusion, if you replace the Boolean expression `a[n] < a[n - 1]` with the expression `a[n].CompareTo(a[n - 1]) < 0`, then the bubble sort algorithm becomes able to sort alphanumeric values in ascending order.

 When you are thinking of alphanumeric sorting, think of your dictionary and how words are sorted there.

And now let's see what you need to change so that the algorithm can sort in descending order. Do you remember how the bubble sort algorithm actually works? Elements gradually “bubble” to positions of lowest index, like bubbles rise in a glass of cola. What you want in this exercise is to make the bigger (instead of the smaller) elements “bubble” to lower index positions. Therefore, all you need to do is simply reverse the comparison operator of the decision control structure!

The code fragment that sorts alphanumeric values in descending order is as follows.

```
string temp_str;  
for (m = 1; m <= ELEMENTS - 1; m++) {
```

```

for (n = ELEMENTS - 1; n >= m; n--) {
    if (a[n].CompareTo(a[n - 1]) > 0) {
        temp_str = a[n];
        a[n] = a[n - 1];
        a[n - 1] = temp_str;
    }
}
}

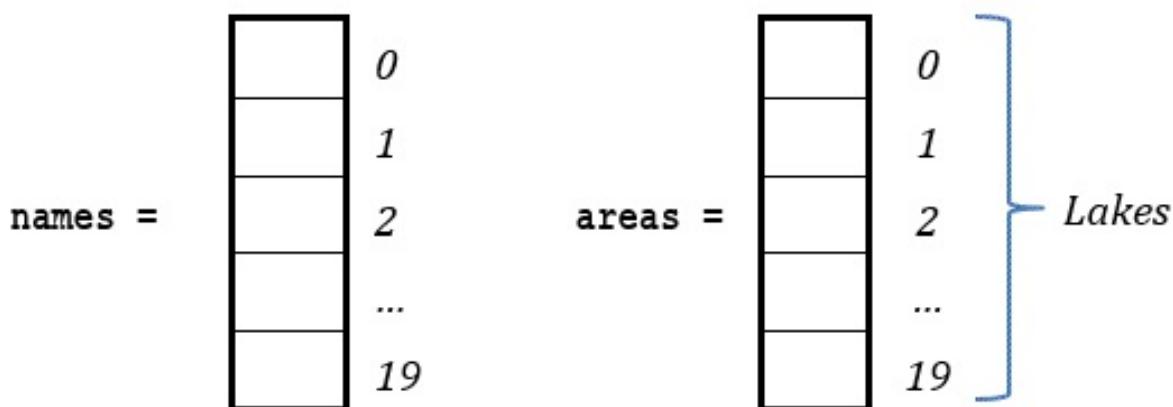
```

### ***Exercise 34.4-3 Sorting One-Dimensional Arrays While Preserving the Relationship with a Second Array***

*Write a C# program that lets the user enter the names of 20 lakes and their corresponding average area. The program must then sort them by average area in ascending order using the bubble sort algorithm.*

#### **Solution**

In this exercise you need the following two arrays.



If you want to sort array `areas` while preserving the relationship between the elements of the two arrays, you must rearrange the elements of the array `names` as well. This means that every time two elements of the array `areas` swap contents, the corresponding elements of the array `names` must swap contents as well. The C# program is as follows.

#### **project\_34\_4\_3**

```

const int LAKES = 20;

static void Main(string[] args) {
    int i, m, n;
    double temp;
    string temp_str;
}
}

```

```

string[] names = new string[LAKES];
double[] areas = new double[LAKES];
for (i = 0; i <= LAKES - 1; i++) {
    names[i] = Console.ReadLine();
    areas[i] = Double.Parse(Console.ReadLine());
}

for (m = 1; m <= LAKES - 1; m++) {
    for (n = LAKES - 1; n >= m; n--) {
        if (areas[n] < areas[n - 1]) {
            temp = areas[n];
            areas[n] = areas[n - 1];
            areas[n - 1] = temp;

            temp_str = names[n];
            names[n] = names[n - 1];
            names[n - 1] = temp_str;
        }
    }
}

for (i = 0; i <= LAKES - 1; i++) {
    Console.WriteLine(names[i] + "\t" + areas[i]);
}
}

```

 Note that you cannot use the variable `temp` for swapping the contents of two elements of the array `names`; this is because variable `temp` is declared as `double` while array `names` contains strings. So, you need a second variable (`temp_str`) declared as `string` for this purpose.

### Exercise 34.4-4 Sorting Last and First Names

Write a C# program that prompts the user to enter the last and first names of 100 people and then displays them with the last names sorted in alphabetical order. Moreover, if two or more people have the same last name, their first names must be displayed in alphabetical order as well.

### Solution

You already know how to sort an array while preserving the relationship with the elements of a second array. Now, you have to handle the case when two last names in the first array are equal. According to the wording of the

exercise, the corresponding first names in the second array must be also sorted alphabetically. For example, the following array `last_nm` contains the last names of 100 people. It is sorted in alphabetical order and it contains the last name “Parker” three times. The corresponding first names “Andrew”, “Anna”, and “Chloe” in array `first_nm` are also sorted alphabetically.

	Brown	0	Samantha	0
	Clark	1	Ryan	1
	Lewis	2	Ava	2
	Parker	3	Andrew	3
last_nm =	Parker	4	Anna	4
	Parker	5	Chloe	5
	...	:	...	:
	Zimmerman	99	John	99

`first_nm =`

--	--	--	--	--

} *People*

For your convenience, the basic version of the bubble sort algorithm is presented once again. Please note that this algorithm preserves the relationship between the elements of arrays `last_nm` and `first_nm`.

```

for (m = 1; m <= PEOPLE - 1; m++) {
    for (n = PEOPLE - 1; n >= m; n--) {
        if (last_nm[n].CompareTo(last_nm[n - 1]) < 0) {
            temp_str = last_nm[n];
            last_nm[n] = last_nm[n - 1];
            last_nm[n - 1] = temp_str;

            temp_str = first_nm[n];
            first_nm[n] = first_nm[n - 1];
            first_nm[n - 1] = temp_str;
        }
    }
}

```

⚠ Note that variable `temp_str` is used for swapping the contents of the elements of both arrays `last_nm` and `first_nm`. This is acceptable since both arrays contain strings.

To solve this exercise, however, this bubble sort algorithm must be adapted

accordingly. According to this basic version of the bubble sort algorithm, when the last name at position  $n$  is “less” than the last name at position  $n - 1$ , the algorithm swaps the corresponding contents. However, when the last name at position  $n$  is equal to the last name at position  $n - 1$ , the algorithm then must check if the corresponding first names are in the proper order. If not, they must swap their contents. The adapted bubble sort algorithm is shown in the next code fragment.

```
for (m = 1; m <= PEOPLE - 1; m++) {
    for (n = PEOPLE - 1; n >= m; n--) {
        if (last_nm[n].CompareTo(last_nm[n - 1]) < 0) {
            temp_str = last_nm[n];
            last_nm[n] = last_nm[n - 1];
            last_nm[n - 1] = temp_str;

            temp_str = first_nm[n];
            first_nm[n] = first_nm[n - 1];
            first_nm[n - 1] = temp_str;
        }
        else if (last_nm[n] == last_nm[n - 1]) {
            if (first_nm[n].CompareTo(first_nm[n - 1]) < 0) {
                temp_str = first_nm[n];
                first_nm[n] = first_nm[n - 1];
                first_nm[n - 1] = temp_str;
            }
        }
    }
}
```

The final C# program is presented next.

#### project\_34\_4\_4

```
const int PEOPLE = 100;

static void Main(string[] args) {
    int i, m, n;
    string temp_str;

    //Read arrays first_nm and last_nm
    string[] first_nm = new string[PEOPLE];
    string[] last_nm = new string[PEOPLE];
    for (i = 0; i <= PEOPLE - 1; i++) {
        Console.Write("First name for person No. " + (i + 1) + ": ");
        first_nm[i] = Console.ReadLine();
        Console.Write("Last name for person No. " + (i + 1) + ": ");
```

```

        last_nm[i] = Console.ReadLine();
    }

//Sort arrays last_nm and first_nm
for (m = 1; m <= PEOPLE - 1; m++) {
    for (n = PEOPLE - 1; n >= m; n--) {
        if (last_nm[n].CompareTo(last_nm[n - 1]) < 0) {
            temp_str = last_nm[n];
            last_nm[n] = last_nm[n - 1];
            last_nm[n - 1] = temp_str;

            temp_str = first_nm[n];
            first_nm[n] = first_nm[n - 1];
            first_nm[n - 1] = temp_str;
        }
        else if (last_nm[n] == last_nm[n - 1]) {
            if (first_nm[n].CompareTo(first_nm[n - 1]) < 0) {
                temp_str = first_nm[n];
                first_nm[n] = first_nm[n - 1];
                first_nm[n - 1] = temp_str;
            }
        }
    }
}

//Display arrays last_nm and first_nm
for (i = 0; i <= PEOPLE - 1; i++) {
    Console.WriteLine(last_nm[i] + "\t" + first_nm[i]);
}
}

```

### **Exercise 34.4-5 Sorting a Two-Dimensional Array**

*Write a code fragment that sorts each column of a two-dimensional array in ascending order. Assume that the array contains numerical values.*

### **Solution**

An example of a two-dimension array is as follows.

	0	1	2	3	4	5	6
0							
1							
2							
3							
4							

**a =**

Since this array has seven columns, the bubble sort algorithm needs to be executed seven times, one for each column. Therefore, the whole bubble sort algorithm should be nested within a for-loop that iterates seven times.

But let's get things in the right order. Using the “from inner to outer” method, the next code fragment sorts only the first column (column index 0) of the two-dimensional array a. Assume variable j contains the value 0.

```

for (m = 1; m <= ROWS - 1; m++) {
    for (n = ROWS - 1; n >= m; n--) {
        if (a[n, j] < a[n - 1, j]) {
            temp = a[n, j];
            a[n, j] = a[n - 1, j];
            a[n - 1, j] = temp;
        }
    }
}

```

Now, in order to sort all columns, you can nest this code fragment in a for-loop that iterates for all of them, as follows.

```

for (j = 0; j <= COLUMNS - 1; j++) {
    for (m = 1; m <= ROWS - 1; m++) {
        for (n = ROWS - 1; n >= m; n--) {
            if (a[n, j] < a[n - 1, j]) {
                temp = a[n, j];
                a[n, j] = a[n - 1, j];
                a[n - 1, j] = temp;
            }
        }
    }
}

```

That wasn't so difficult, was it?

## ***Exercise 34.4-6 The Modified Bubble Sort Algorithm – Sorting One-Dimensional Arrays***

---

*Write a C# program that lets the user enter the weights of 20 people and then displays the three heaviest weights and the three lightest weights. Use the **modified** bubble sort algorithm.*

### **Solution**

---

To solve this exercise, the C# program can sort the given data in ascending order and then display the elements at index positions 27, 28, and 29 (for the three heaviest weights) and the elements at index positions 0, 1 and 2 (for the three lightest weights).

But how does the modified version of the bubble sort algorithm actually work? Suppose you have the following array containing the weights of six people.

0	1	2	3	4	5	
w =	165	170	180	190	182	200

If you look closer, you can confirm for yourself that the only elements that are not in proper position are those at index positions 3 and 4. If you swap their values, the array *w* immediately becomes sorted! However, the bubble sort algorithm doesn't operate this way. Unfortunately, for this given array of six elements, it will perform five passes either way, with a total of

$$\frac{N(N-1)}{2} = 15 \text{ compares, where } N \text{ is the total number of array elements.}$$

For bigger arrays, the total number of compares that the bubble sort algorithm performs increases exponentially! For example, for a given array of 1000 elements, the bubble sort algorithm performs 499,500 compares!

Of course the modified bubble sort algorithm can overcome this situation as follows: if a complete pass is performed and no swaps have been made, then this indicates that the array is sorted and there is no need for further passes. To accomplish this, the C# program can use a flag variable that indicates if any swaps were made. At the beginning of a pass, a value of `false` can be assigned to the flag variable; when a swap is made, a value of `true` is assigned. If, at the end of the pass, the flag is still `false`, this indicates that no swaps have been made, thus iterations must stop. The modified bubble

sort is shown next. It uses the break statement and a flag variable (`swaps`).

```
for (m = 1; m <= ELEMENTS - 1; m++) {  
    //Assign false to variable swaps  
    swaps = false;  
  
    //Perform a new pass  
    for (n = ELEMENTS - 1; n >= m; n--) {  
        if (w[n] < w[n - 1]) {  
            temp = w[n];  
            w[n] = w[n - 1];  
            w[n - 1] = temp;  
  
            swaps = true;  
        }  
    }  
  
    //If variable swaps is still false, no swaps have been  
    //made in the last pass. Stop iterations!  
    if (!swaps) break;  
}
```

 The value `false` must be assigned to variable `swaps` each time a new pass starts. This is why the statement `swaps = false` must be placed between the two `for` statements.

 The statement `if (!swaps)` is equivalent to the statement `if (swaps == false)`.

The final C# program is shown next.

### project\_34\_4\_6

```
const int ELEMENTS = 20;  
  
static void Main(string[] args) {  
    int i, m, n;  
    bool swaps;  
    double temp;  
  
    double[] w = new double[ELEMENTS];  
    for (i = 0; i <= ELEMENTS - 1; i++) {  
        w[i] = Double.Parse(Console.ReadLine());  
    }  
  
    for (m = 1; m <= ELEMENTS - 1; m++) {
```

```

        swaps = false;
    for (n = ELEMENTS - 1; n >= m; n--) {
        if (w[n] < w[n - 1]) {
            temp = w[n];
            w[n] = w[n - 1];
            w[n - 1] = temp;

            swaps = true;
        }
    }
    if (!swaps) break;
}

Console.WriteLine("The three heaviest weights are:");
Console.WriteLine(w[ELEMENTS - 3] + " " + w[ELEMENTS - 2] + " " + w[ELEMENTS - 1]);
Console.WriteLine("The three lightest weights are:");
Console.WriteLine(w[0] + " " + w[1] + " " + w[2]);
}

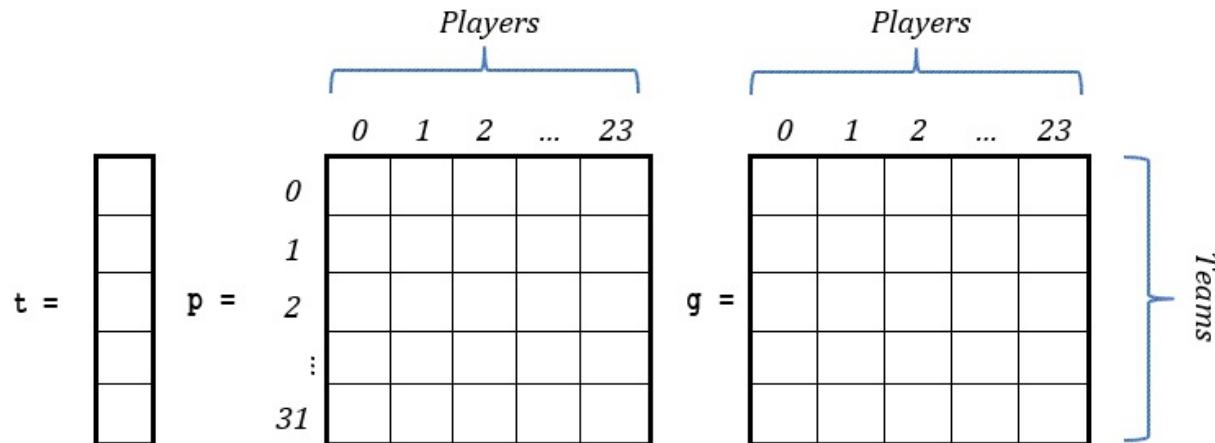
```

### **Exercise 34.4-7 The Five Best Scorers**

*Write a C# program that prompts the user to enter the names of the 32 national teams of the FIFA World Cup, the names of the 24 players for each team, and the total number of goals each player scored. The program must then display the name of each team along with its five best scorers. Use the modified bubble sort algorithm.*

#### **Solution**

In this exercise you need the following three arrays.



To save paper short array names are used, but it is more or less obvious

*that array t holds the names of the 32 national teams, array p holds the names of the 24 players of each team, and array g holds the total number of goals each player scored.*

Since you need to find the five best scorers for each team, the C# program must sort each row of array g in descending order but it must also take care to preserve the relationship with the elements of arrays p. This means that, every time the bubble sort algorithm swaps the contents of two elements of array g, the corresponding elements of array p must be swapped as well. When sorting is completed, the five best scorers should appear in the first five columns.

The “from inner to outer” method is used again. The following code fragment sorts the first row (row index 0) of array g in descending order and, at the same time, takes care to preserve the relationship with elements of array p. Assume variable i contains the value 0.

```
for (m = 1; m <= PLAYERS - 1; m++) {  
    swaps = false;  
    for (n = PLAYERS - 1; n >= m; n--) {  
        if (g[i, n] < g[i, n - 1]) {  
            temp = g[i, n];  
            g[i, n] = g[i, n - 1];  
            g[i, n - 1] = temp;  
  
            temp_str = p[i, n];  
            p[i, n] = p[i, n - 1];  
            p[i, n - 1] = temp_str;  
        }  
    }  
    if (!swaps) break;  
}
```

Now, in order to sort all rows, you need to nest this code fragment in a for-loop that iterates for all of them, as shown next.

```
for (i = 0; i <= TEAMS - 1; i++) {  
    swaps = false;  
    for (m = 1; m <= PLAYERS - 1; m++) {  
        for (n = PLAYERS - 1; n >= m; n--) {  
            if (g[i, n] < g[i, n - 1]) {  
                temp = g[i, n];  
                g[i, n] = g[i, n - 1];  
                g[i, n - 1] = temp;
```

```

        temp_str = p[i, n];
        p[i, n] = p[i, n - 1];
        p[i, n - 1] = temp_str;
    }
}
}
if (!swaps) break;
}

```

The final C# program is as follows.

### project\_34\_4\_7

```

const int TEAMS = 32;
const int PLAYERS = 24;

static void Main(string[] args) {
    int i, j, m, n, temp;
    bool swaps;
    string temp_str;

    //Read team names, player names and goals all together
    string[] t = new string[TEAMS];
    string[,] p = new string[TEAMS, PLAYERS];
    int[,] g = new int[TEAMS, PLAYERS];
    for (i = 0; i <= TEAMS - 1; i++) {
        Console.WriteLine("Enter name for team No. " + (i + 1) + ": ");
        t[i] = Console.ReadLine();
        for (j = 0; j <= PLAYERS - 1; j++) {
            Console.WriteLine("Enter name of player No. " + (j + 1) + ": ");
            p[i, j] = Console.ReadLine();
            Console.WriteLine("Enter goals of player No. " + (j + 1) + ": ");
            g[i, j] = Int32.Parse(Console.ReadLine());
        }
    }

    //Sort array g
    for (i = 0; i <= TEAMS - 1; i++) {
        for (m = 1; m <= PLAYERS - 1; m++) {
            swaps = false;
            for (n = PLAYERS - 1; n >= m; n--) {
                if (g[i, n] > g[i, n - 1]) {
                    temp = g[i, n];
                    g[i, n] = g[i, n - 1];
                    g[i, n - 1] = temp;

                    temp_str = p[i, n];

```

```

        p[i, n] = p[i, n - 1];
        p[i, n - 1] = temp_str;
    }
}
if (!swaps) break;
}

//Display 5 best scorers of each team
for (i = 0; i <= TEAMS - 1; i++) {
    Console.WriteLine("Best scorers of " + t[i]);
    Console.WriteLine("-----");
    for (j = 0; j <= 4; j++) {
        Console.WriteLine(p[i, j] + " scored " + g[i, j] + " goals");
    }
}
}

```

### ***Exercise 34.4-8 The Selection Sort Algorithm – Sorting One-Dimensional Arrays***

---

*Write a code fragment that sorts the elements of an array in ascending order using the selection sort algorithm. Assume that the array contains numerical values.*

#### ***Solution***

---

The *selection sort algorithm* is inefficient for large scale data, as is the bubble sort algorithm, but it generally performs better than the latter. It is the simplest of all the sorting algorithms and performs well on computer systems in which limited main memory (RAM) comes into play.

The algorithm finds the smallest (or largest, depending on sorting order) element of the array and swaps its content with that at position 0. Then the process is repeated for the remainder of the array; the next smallest (or largest) element is found and put into the next position, until all elements are examined.

For example, let's try to sort the following array in ascending order.

0	1	2	3	4	5
A =	18	19	39	36	4

The lowest value is the value 4 at position 4. According to the selection sort

algorithm, this element swaps its content with that at position 0. The array A becomes

	0	1	2	3	4	5
A =	4	19	41	36	18	9

The lowest value in the remainder of the array is the value 9 at position 5. This element swaps its content with that at position 1. The array A becomes

	0	1	2	3	4	5
A =	4	9	41	36	18	19

The lowest value in the remainder of the array is the value 18 at position 4. This element swaps its content with that at position 2. The array A becomes

	0	1	2	3	4	5
A =	4	9	18	36	41	19

Proceeding the same way, the next lowest value is the value 19 at position 5. The array A becomes

	0	1	2	3	4	5
A =	4	9	18	19	41	36

Finally, the next lowest value is the value 36 at position 5. The array A becomes finally sorted in ascending order!

	0	1	2	3	4	5
A =	4	9	18	19	36	41

Now, let's write the corresponding C# program. The "from inner to outer" method is used in order to help you better understand the whole process. The next code fragment finds the smallest element and then swaps its content with that at position 0. Please note that this is the inner (nested) loop control structure. Assume variable m contains the value 0.

```
minimum = a[m];
index_of_min = m;
for (n = m; n <= ELEMENTS - 1; n++) {
```

```

    if (a[n] < minimum) {
        minimum = a[n];
        index_of_min = n;
    }
}
//Minimum found! Now, swap values.
temp = a[m];
a[m] = a[index_of_min];
a[index_of_min] = temp;

```

Now, in order to repeat the process for all elements of the array, you can nest this code fragment within a for-loop that iterates for all elements. The final selection sort algorithm that sorts an array in ascending order is as follows.

```

for (m = 0; m <= ELEMENTS - 1; m++) {
    minimum = a[m];
    index_of_min = m;
    for (n = m; n <= ELEMENTS - 1; n++) {
        if (a[n] < minimum) {
            minimum = a[n];
            index_of_min = n;
        }
    }

    temp = a[m];
    a[m] = a[index_of_min];
    a[index_of_min] = temp;
}

```

 If you wish to sort an array in descending order, all you need to do is search for maximum instead of minimum values.

 As in a bubble sort algorithm, in order to sort alphanumeric data in C#, you can simply replace the Boolean expression `a[n] < minimum` with the expression `a[n].CompareTo(minimum) < 0`.

### ***Exercise 34.4-9 Sorting One-Dimensional Arrays While Preserving the Relationship with a Second Array***

Write a C# program that prompts the user to enter the electric meter reading recorded at the end of each month for a period of one year. It then displays each reading (in descending order) along with the name of the corresponding month. Use the selection sort algorithm.

#### **Solution**

In this exercise you need the following two one-dimensional arrays.

months =	<table border="1"><tr><td>January</td><td>0</td></tr><tr><td>February</td><td>1</td></tr><tr><td>March</td><td>2</td></tr><tr><td>...</td><td>...</td></tr><tr><td>December</td><td>11</td></tr></table>	January	0	February	1	March	2	...	...	December	11	kwh =	<table border="1"><tr><td>0</td></tr><tr><td>1</td></tr><tr><td>2</td></tr><tr><td>...</td></tr><tr><td>11</td></tr></table>	0	1	2	...	11
January	0																	
February	1																	
March	2																	
...	...																	
December	11																	
0																		
1																		
2																		
...																		
11																		

The approach is the same as in the bubble sort algorithm. While the selection sort algorithm sorts the elements of array kwh, the relationship with the elements of array months must also be preserved. This means that every time two elements of array kwh swap contents, the corresponding elements of array months must swap their contents as well. The C# program is as follows.

#### project\_34\_4\_9

```
static void Main(string[] args) {
    int i, m, index_of_max, n;
    double maximum, temp;
    string temp_str;

    string[] months = {"January", "February", "March", "April", "May", "June", "July",
                        "August", "September", "October", "November", "December"};

    double[] kwh = new double[months.Length];
    for (i = 0; i <= months.Length - 1; i++) {
        Console.WriteLine("Enter kwh for " + months[i] + ": ");
        kwh[i] = Double.Parse(Console.ReadLine());
    }

    for (m = 0; m <= months.Length - 1; m++) {
        maximum = kwh[m];
        index_of_max = m;
        for (n = m; n <= months.Length - 1; n++) {
            if (kwh[n] > maximum) {
                maximum = kwh[n];
                index_of_max = n;
            }
        }
    }
}
```

```

    }

    //Swap values of kwh
    temp = kwh[m];
    kwh[m] = kwh[index_of_max];
    kwh[index_of_max] = temp;

    //Swap values of months
    temp_str = months[m];
    months[m] = months[index_of_max];
    months[index_of_max] = temp_str;
}

for (i = 0; i <= months.Length - 1; i++) {
    Console.WriteLine(months[i] + ":" + kwh[i]);
}
}

```

### ***Exercise 34.4-10 The Insertion Sort Algorithm – Sorting One-Dimensional Arrays***

---

*Write a code fragment that sorts the elements of an array in ascending order using the insertion sort algorithm. Assume that the array contains numerical values.*

#### ***Solution***

---

The *insertion sort algorithm* is inefficient for large scale data, as are the selection and the bubble sort algorithms, but it generally performs better than either of them. Moreover, the insertion sort algorithm can prove very fast when sorting very small arrays— even faster than the quicksort algorithm.

The insertion sort algorithm resembles the way you might sort playing cards. You start with all the cards face down on the table. The cards on the table represent the unsorted “array”. In the beginning your left hand is empty, but in the end this hand will hold the sorted cards. The process goes as follows: you remove from the table one card at a time and insert it into the correct position in your left hand. To find the correct position for a card, you compare it with each of the cards already in your hand, from right to left. At the end, there must be no cards on the table and your left hand will hold all the cards, sorted.

For example, let's try to sort the following array in ascending order. To

to better understand this example, the first three elements of the array are already sorted for you.

$0$	$1$	$2$	$3$	$4$	$5$	$6$	
$A =$	3	15	24	8	10	18	9

The element at position 3 (which is 8) is removed from the array and all elements on its left with a value greater than 8 are shifted to the right. The array A becomes

$0$	$1$	$2$	$3$	$4$	$5$	$6$	
$A =$	3		15	24	10	18	9

Now that a position has been released, the value 8 is inserted in there. The array becomes

$0$	$1$	$2$	$3$	$4$	$5$	$6$	
$A =$	3	8	15	24	10	18	9

The element at position 4 (which is 10) is removed from the array and all elements on its left with a value greater than 10 are shifted to the right. The array A becomes

$0$	$1$	$2$	$3$	$4$	$5$	$6$	
$A =$	3	8		15	24	18	9

Now that a position has been released, the value of 10 is inserted in there. The array becomes

$0$	$1$	$2$	$3$	$4$	$5$	$6$	
$A =$	3	8	10	15	24	18	9

The element at position 5 (which is 18) is removed from the array and all elements on its left with a value greater than 18 are shifted to the right. The array A becomes

	0	1	2	3	4	5	6
A =	3	8	10	15		24	9

Now that a position has been released, the value of 18 is inserted in there. The array becomes

	0	1	2	3	4	5	6
A =	3	8	10	15	18	24	9

The element at position 6 (which is 9) is removed from the array and all elements on its left with a value greater than 9 are shifted to the right. The array A becomes

	0	1	2	3	4	5	6
A =	3	8		10	15	18	24

Now that a position has been released, the value of 9 is inserted in there. This is the last step of the process. The algorithm finishes and the array is now sorted.

	0	1	2	3	4	5	6
A =	3	8	9	10	15	18	24

 What the algorithm actually does is to check the unsorted elements one by one and insert each one in the appropriate position among those considered already sorted.

The code fragment that sorts an array in ascending order using the insertion sort algorithm is as follows.

```

for (m = 1; m <= ELEMENTS - 1; m++) {
    // "Remove" the element at index position m from the array and keep it in variable ele
    element = a[m];

    //Shift appropriate elements to the right
    n = m;
    while (n > 0 && a[n - 1] > element) {
        a[n] = a[n - 1];
        n--;
    }
    a[n] = element;
}

```

```

        a[n] = a[n - 1];
        n--;
    }

    //Insert the previously "removed" element at index position n
    a[n] = element;
}

```

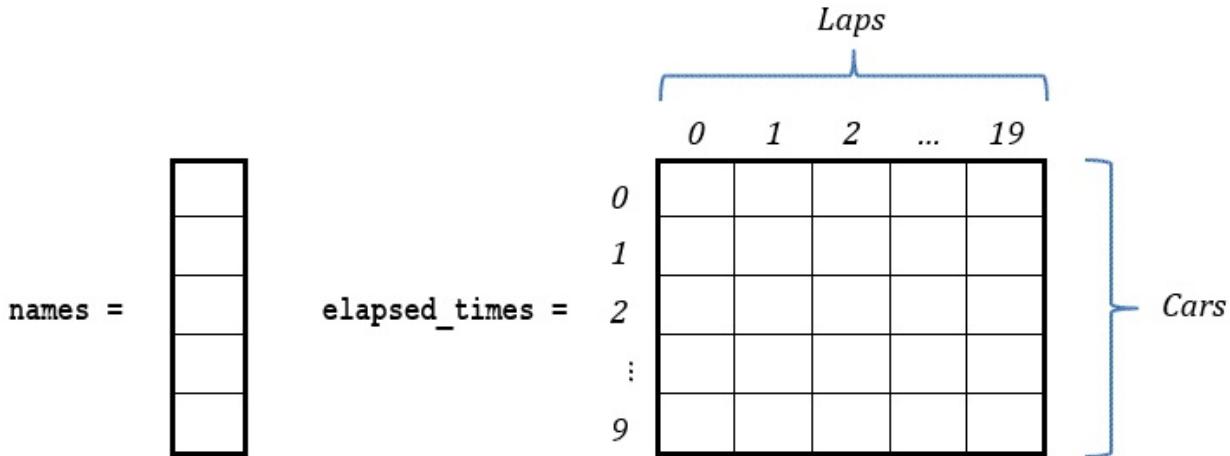
-  Please note that the element at index position  $m$  is not actually removed from the array but is in fact overwritten when shifting to the right is performed. This is why its value is kept in variable `element` before shifting the elements.
-  If you wish to sort an array in descending order, all you need to do is alter the Boolean expression of the while statement to `n > 0 && a[n - 1] < element`.
-  As in previous sort algorithms, in order to sort alphanumeric data in C#, you can simply replace the Boolean expression `n > 0 && a[n - 1] > element` with the expression `n > 0 && a[n - 1].CompareTo(element) > 0`.

### **Exercise 34.4-11 The Three Worst Elapsed Times**

Ten race car drivers run their cars as fast as possible on a racing track. Each car runs 20 laps and for each lap the corresponding elapsed time (in seconds) is recorded. Write a C# program that prompts the user to enter the name of each driver and their elapsed time for each lap. The program must then display the name of each driver along with his or her three worst elapsed times. Use the insertion sort algorithm.

#### **Solution**

In this exercise, you need the following two arrays.



After the user enters all data, the C# program must sort each row of the array in descending order but, in the end, must display only the first three columns.

Using the “from inner to outer” method, the next code fragment sorts only the first row (row index 0) of the two-dimensional array `elapsed_times` in descending order using the insertion sort algorithm. Assume variable `i` contains the value 0.

```
for (m = 1; m <= LAPS - 1; m++) {
    element = elapsed_times[i, m];
    n = m;
    while (n > 0 && elapsed_times[i, n - 1] < element) {
        elapsed_times[i, n] = elapsed_times[i, n - 1];
        n--;
    }
    elapsed_times[i, n] = element;
}
```

Now, in order to sort all rows, you need to nest this code fragment in a for-loop that iterates for all of them, as follows.

```
for (i = 0; i <= CARS - 1; i++) {
    for (m = 1; m <= LAPS - 1; m++) {
        element = elapsed_times[i, m];
        n = m;
        while (n > 0 && elapsed_times[i, n - 1] < element) {
            elapsed_times[i, n] = elapsed_times[i, n - 1];
            n--;
        }
        elapsed_times[i, n] = element;
    }
}
```

And now, let's focus on the given exercise. The final C# program is as follows.

### project\_34\_4\_11

```
const int CARS = 10;
const int LAPS = 20;

static void Main(string[] args) {
    int i, j, m, n;
    double element;

    //Read names and elapsed times all together
    string[] names = new string[CARS];
    double[,] elapsed_times = new double[CARS, LAPS];
    for (i = 0; i <= CARS - 1; i++) {
        Console.WriteLine("Enter name for driver No. " + (i + 1) + ": ");
        names[i] = Console.ReadLine();
        for (j = 0; j <= LAPS - 1; j++) {
            Console.WriteLine("Enter elapsed time for lap No. " + (j + 1) + ": ");
            elapsed_times[i, j] = Double.Parse(Console.ReadLine());
        }
    }

    //Sort array elapsed_times
    for (i = 0; i <= CARS - 1; i++) {
        for (m = 1; m <= LAPS - 1; m++) {
            element = elapsed_times[i, m];
            n = m;
            while (n > 0 && elapsed_times[i, n - 1] < element) {
                elapsed_times[i, n] = elapsed_times[i, n - 1];
                n--;
            }
            elapsed_times[i, n] = element;
        }
    }

    //Display 3 worst elapsed times
    for (i = 0; i <= CARS - 1; i++) {
        Console.WriteLine("Worst elapsed times of " + names[i]);
        Console.WriteLine("-----");
        for (j = 0; j <= 2; j++) {
            Console.WriteLine(elapsed_times[i, j]);
        }
    }
}
```

## 34.5 Searching Elements in Data Structures

In computer science, a *search algorithm* is an algorithm that searches for an item with specific features within a set of data. In the case of a data structure, a search algorithm searches the data structure to find the element, or elements, that equal a given value.

When searching in a data structure, there can be two situations.

- ▶ You want to search for a given value in a data structure that may contain the same value multiple times. Therefore, you need to find **all** the elements (or their corresponding indexes) that are equal to that given value.
- ▶ You want to search for a given value in a data structure where each value is unique. Therefore, you need to find **just one** element (or its corresponding index), the one that is equal to that given value, and then stop searching any further!

The most commonly used search algorithms are:

- ▶ the linear (or sequential) search algorithm
- ▶ the binary search algorithm

Both linear and binary search algorithms have advantages and disadvantages.

### ***Exercise 34.5-1 The Linear Search Algorithm – Searching in a One-Dimensional Array that may Contain the Same Value Multiple Times***

---

*Write a code fragment that searches a one-dimensional array for a given value. Assume that the array contains numerical values and may contain the same value multiple times. Use the linear search algorithm.*

#### **Solution**

---

The *linear (or sequential) search algorithm* checks if the first element of the array is equal to a given value, then checks the second element, then the third, and so on until the end of the array. Since this process of checking elements one by one is quite slow, the linear search algorithm is suitable for arrays with few elements.

The code fragment is shown next. It looks for a given value *needle* in the array *haystack*!

```
Console.WriteLine("Enter a value to search: ");
```

```

needle = Double.Parse(Console.ReadLine());

found = false;
for (i = 0; i <= ELEMENTS - 1; i++) {
    if (haystack[i] == needle) {
        Console.WriteLine(needle + " found at position: " + i);
        found = true;
    }
}

if (!found) {
    Console.WriteLine("Nothing found!");
}

```

### ***Exercise 34.5-2 Display the Last Names of All Those People Who Have the Same First Name***

---

*Write a C# program that prompts the user to enter the names of 20 people: their first names in the array `first_names`, and their last names in the array `last_names`. The program must then ask the user for a first name, upon which it will search and display the last names of all those whose first name equals the given one.*

#### ***Solution***

---

Even though it is not very clear in the wording of the exercise, it is true that the array `first_names` may contain a value multiple times. How rare is it to meet two people named “John”, for example?

The program must search for the first name given in array `first_names` and every time it finds it, it must display the corresponding last name from the other array.

The solution is as follows.

#### project\_34\_5\_2

```

const int PEOPLE = 20;

static void Main(string[] args) {
    int i;
    string needle;
    bool found;

    string[] first_names = new string[PEOPLE];
    string[] last_names = new string[PEOPLE];

```

```

for (i = 0; i <= PEOPLE - 1; i++) {
    Console.WriteLine("Enter first name: ");
    first_names[i] = Console.ReadLine();
    Console.WriteLine("Enter last name: ");
    last_names[i] = Console.ReadLine();
}

//Get name to search and convert it to uppercase
Console.WriteLine("Enter a first name to search: ");
needle = Console.ReadLine().ToUpper();

//Search for given value in array first_names
found = false;
for (i = 0; i <= PEOPLE - 1; i++) {
    if (first_names[i].ToUpper() == needle) {
        Console.WriteLine(last_names[i]);
        found = true;
    }
}

if (!found) {
    Console.WriteLine("No one found!");
}
}

```

 Since the program works with alphanumeric data, the `ToUpper()` method is required so that the program can operate correctly for any given value. For example, if the value “John” exists in the array `first_names` and the user wants to search for the value “JOHN”, the `ToUpper()` method ensures that the program finds all Johns.

### **Exercise 34.5-3 The Linear Search Algorithm – Searching in a One-Dimensional Array that Contains Unique Values**

Write a code fragment that searches a one-dimensional array for a given value. Assume that the array contains numerical values and each value in the array is unique. Use the linear search algorithm.

#### **Solution**

This case is quite different from the previous ones. Since each value in the array is unique, when the given value is found, there is no need to iterate without reason until the end of the array, thus wasting CPU time. There are

three approaches, actually! Let's analyze them all!

## First Approach – Using the **break** statement

In this approach, when the given value is found, a break statement is used to break out of the for-loop. The solution is as follows.

```
Console.WriteLine("Enter a value to search: ");
needle = Double.Parse(Console.ReadLine());

found = false;
for (i = 0; i <= ELEMENTS - 1; i++) {
    if (haystack[i] == needle) {
        Console.WriteLine(needle + " found at position: " + i);
        found = true;
        break;
    }
}

if (!found) {
    Console.WriteLine("Nothing found!");
}
```

Or you can do the same, in a little bit different way.

```
Console.WriteLine("Enter a value to search: ");
needle = Double.Parse(Console.ReadLine());

index_position = -1;
for (i = 0; i <= ELEMENTS - 1; i++) {
    if (haystack[i] == needle) {
        index_position = i;
        break;
    }
}

if (index_position == -1) {
    Console.WriteLine("Nothing found!");
}
else {
    Console.WriteLine(needle + " found at position: " + index_position);
}
```

## Second Approach – Using a flag

The break statement doesn't actually exist in all computer languages; and since this book's intent is to teach you “Algorithmic Thinking” (and not just special statements that only C# supports), let's look at an alternate approach.

In the next code fragment, when the given value is found within array haystack, the variable found forces the flow of execution to immediately exit the loop.

```
Console.WriteLine("Enter a value to search: ");
needle = Double.Parse(Console.ReadLine());

found = false;
i = 0;
while (i <= ELEMENTS - 1 && !found) {
    if (haystack[i] == needle) {
        found = true;
        index_position = i;
    }
    i++;
}

if (!found) {
    Console.WriteLine("Nothing found!");
}
else {
    Console.WriteLine(needle + " found at position: " + index_position);
}
```

### Third Approach – Using only a pre-test loop structure

This approach is probably the most efficient one. Also, it is so easy to understand the way it works that there is no need to explain anything. The code fragment is as follows.

```
Console.WriteLine("Enter a value to search: ");
needle = Double.Parse(Console.ReadLine());

i = 0;
while (i < ELEMENTS - 1 && haystack[i] != needle) {
    i++;
}

if (haystack[i] != needle) {
    Console.WriteLine("Nothing found!");
}
else {
    Console.WriteLine(needle + " found at position: " + i);
}
```

### Exercise 34.5-4 Searching for a Given Social Security Number

*In the United States, the Social Security Number (SSN) is a nine-digit identity number applied to all U.S. citizens in order to identify them for the purposes of Social Security. Write a C# program that prompts the user to enter the SSN and the first and last names of 100 people. The program must then ask the user for an SSN, upon which it will search and display the first and last name of the person who holds that SSN.*

## **Solution**

---

In the United States, there is no possibility that two or more people will have the same SSN. Thus, even though it is not very clear in the wording of the exercise, each value in the array that holds the SSNs is unique!

According to everything you learned so far, the solution to this exercise is as follows.

### project\_34\_5\_4

```
const int PEOPLE = 100;

static void Main(string[] args) {
    int i;
    string needle;

    string[] SSNs = new string[PEOPLE];
    string[] first_names = new string[PEOPLE];
    string[] last_names = new string[PEOPLE];
    for (i = 0; i <= PEOPLE - 1; i++) {
        Console.WriteLine("Enter SSN: ");
        SSNs[i] = Console.ReadLine();
        Console.WriteLine("Enter first name: ");
        first_names[i] = Console.ReadLine();
        Console.WriteLine("Enter last name: ");
        last_names[i] = Console.ReadLine();
    }

    Console.WriteLine("Enter an SSN to search: ");
    needle = Console.ReadLine();

    //Search for given value in array SSNs
    i = 0;
    while (i < PEOPLE - 1 && SSNs[i] != needle) {
        i++;
    }
}
```

```

    if (SSNs[i] != needle) {
        Console.WriteLine("Nothing found!");
    }
    else {
        Console.WriteLine(first_names[i] + " " + last_names[i]);
    }
}

```

### ***Exercise 34.5-5 The Linear Search Algorithm – Searching in a Two-Dimensional Array that May Contain the Same Value Multiple Times***

---

*Write a code fragment that searches each row of a two-dimensional array for a given value. Assume that the array contains numerical values and may contain the same value multiple times. Use the linear search algorithm.*

#### ***Solution***

---

This code fragment must search for the given number in each row of a two-dimensional array that may contain the same value multiple times. This means that the code fragment must search in the first row and display all the columns where the given number is found; otherwise, it must display a message that the given number was not found in the first row. Then, it must search in the second row, and this process must continue until all rows have been examined.

To better understand this exercise, the “inner to outer” method is used. The following code fragment searches for a given value (variable `needle`) only in the first row of the two-dimensional array named `haystack`. Assume variable `i` contains the value 0.

```

found = false;
for (j = 0; j <= COLUMNS - 1; j++) {
    if (haystack[i, j] == needle) {
        Console.WriteLine("Found at column " + j);
        found = true;
    }
}

if (!found) {
    Console.WriteLine("Nothing found in row " + i);
}

```

Now, in order to search in all rows, you need to nest this code fragment in a for-loop that iterates for all of them, as follows.

```
Console.WriteLine("Enter a value to search: ");
```

```
needle = Double.Parse(Console.ReadLine());  
  
for (i = 0; i <= ROWS - 1; i++) {  
    found = false;  
    for (j = 0; j <= COLUMNS - 1; j++) {  
        if (haystack[i, j] == needle) {  
            Console.WriteLine("Found at column " + j);  
            found = true;  
        }  
    }  
  
    if (!found) {  
        Console.WriteLine("Nothing found in row " + i);  
    }  
}
```

### ***Exercise 34.5-6 Searching for Wins, Losses and Ties***

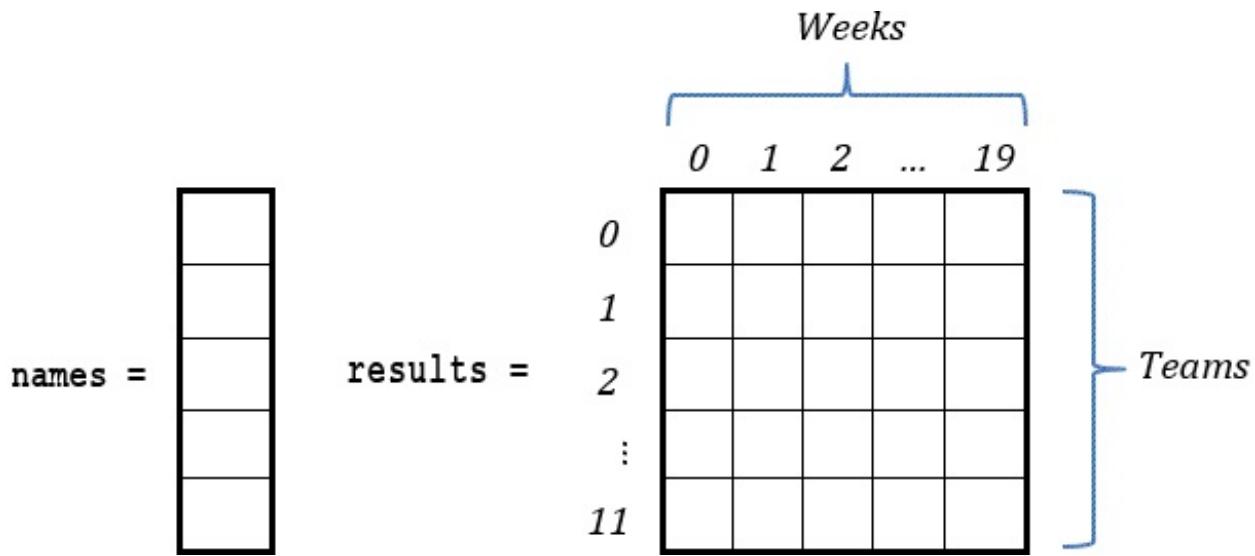
---

*Twelve teams participate in a football tournament, and each team plays 20 games, one game each week. Write a C# program that prompts the user to enter the name of each team and the letter “W” for win, “L” for loss, or “T” for tie (draw) for each game. Then the program must prompt the user for a letter (W, L, or T) and display, for each team, the week number(s) in which the team won, lost, or tied respectively. For example, if the user enters “L”, the C# program must search and display, for each team, the week numbers (e.g., Week 3, Week 14, and so on) in which the team lost the game.*

### ***Solution***

---

In this exercise, you need the following two arrays.



Using knowledge from the previous exercise, the solution to this exercise is as follows.

### project\_34\_5\_6

```

const int TEAMS = 20;
const int WEEKS = 12;

static void Main(string[] args) {
    int i, j;
    string needle;
    bool found;

    string[] names = new string[TEAMS];
    string[,] results = new string[TEAMS, WEEKS];
    for (i = 0; i <= TEAMS - 1; i++) {
        Console.Write("Enter name for team No. " + (i + 1) + ": ");
        names[i] = Console.ReadLine();
        for (j = 0; j <= WEEKS - 1; j++) {
            Console.Write("Enter result for");
            Console.Write(" week No. " + (j + 1) + " for " + names[i] + ": ");
            results[i, j] = Console.ReadLine();
        }
    }

    //Get value to search and convert it to uppercase
    Console.Write("Enter a result to search: ");
    needle = Console.ReadLine().ToUpper();

    for (i = 0; i <= TEAMS - 1; i++) {
        found = false;
    }
}

```

```

Console.WriteLine("Found results for " + names[i]);
for (j = 0; j <= WEEKS - 1; j++) {
    if (results[i, j].ToUpper() == needle) {
        Console.WriteLine("Week " + (j + 1));
        found = true;
    }
}

if (!found) {
    Console.WriteLine("No results!");
}
}
}

```

### ***Exercise 34.5-7 The Linear Search Algorithm – Searching in a Two-Dimensional Array that Contains Unique Values***

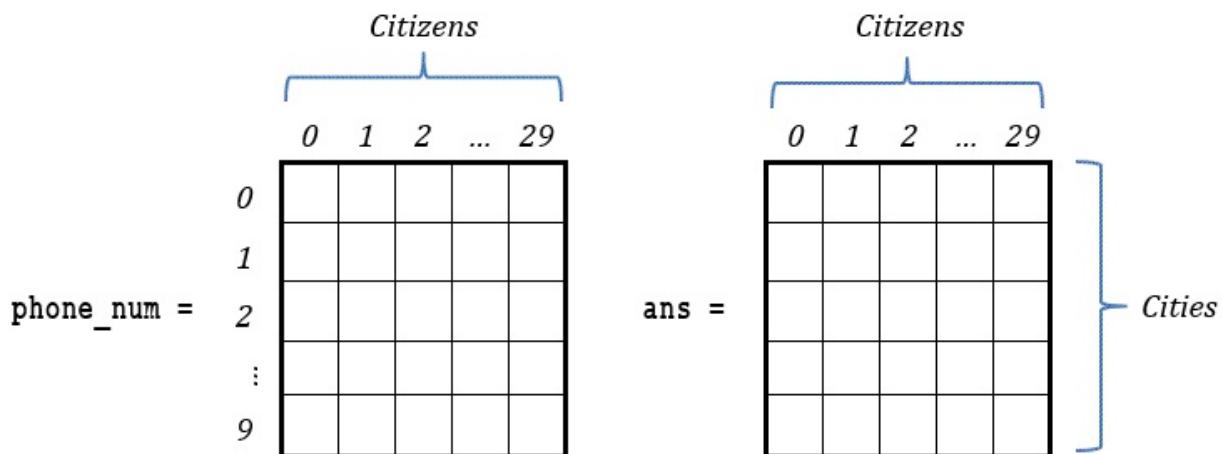
---

*A public opinion polling company makes phone calls in 10 cities and asks 30 citizens in each city whether or not they exercise. Write a C# program that prompts the user to enter each citizen's phone number and their answer (Y for Yes, N for No, S for Sometimes). The program must then prompt the user to enter a phone number, and it will search and display the answer that was given at this phone number. The program must also validate data input and accept only the values Y, N, or S as an answer.*

#### ***Solution***

---

In this exercise, you need the following two arrays.



Even though it is not very clear from the wording of the exercise, each value in the array `phone_num` is unique! The program must search for the given number and if it finds it, it must stop searching thereafter. The solution is as

follows.

## project\_34\_5\_7

```
const int CITIES = 10;
const int CITIZENS = 30;

static void Main(string[] args) {
    int i, j, position_i, position_j;
    bool found;
    string needle;

    string[,] phone_num = new string[CITIES, CITIZENS];
    string[,] ans = new string[CITIES, CITIZENS];
    for (i = 0; i <= CITIES - 1; i++) {
        Console.WriteLine("City No. " + (i + 1));
        for (j = 0; j <= CITIZENS - 1; j++) {
            Console.Write("Enter phone number of citizen No. " + (j + 1) + ": ");
            phone_num[i, j] = Console.ReadLine();

            Console.Write("Enter the answer of citizen No. " + (j + 1) + ": ");
            ans[i, j] = Console.ReadLine().ToUpper();
            while (ans[i, j] != "Y" && ans[i, j] != "N" && ans[i, j] != "S") {
                Console.Write("Wrong answer. Enter a valid one: ");
                ans[i, j] = Console.ReadLine().ToUpper();
            }
        }
    }

    Console.WriteLine("Enter a phone number to search: ");
    needle = Console.ReadLine();

    found = false;
    position_i = -1;
    position_j = -1;
    for (i = 0; i <= CITIES - 1; i++) {
        for (j = 0; j <= CITIZENS - 1; j++) {
            if (phone_num[i, j] == needle) { //If it is found
                found = true;
                position_i = i; //Keep row index where needle was found
                position_j = j; //Keep column index where needle was found
                break; //Exit the inner loop
            }
        }
        if (found)
            break; //If it is found, exit the outer loop as well
    }
}
```

```

    }

    if (!found) {
        Console.WriteLine("Phone number not found!");
    }
    else {
        Console.Write("Phone number " + phone_num[position_i, position_j] + " gave ''");

        switch (ans[position_i, position_j]) {
            case "Y":
                Console.Write("Yes");
                break;
            case "N":
                Console.Write("No");
                break;
            default:
                Console.Write("Sometimes");
                break;
        }

        Console.Write("' as an answer");
    }
}

```

### ***Exercise 34.5-8 Checking if a Value Exists in all Columns***

---

*Write a C# program that lets the user enter numeric values into a  $20 \times 30$  array. After all of the values have been entered, the program then lets the user enter a value. In the end, a message must be displayed if the given value exists, at least once, in each column of the array.*

### ***Solution***

---

This exercise can be solved using the linear search algorithm and a counter variable count. The C# program will iterate through the first column; if the given value is found, the C# program must stop searching in the first column thereafter and the variable count must increment by one. Then, the program will iterate through the second column; if the given value is found again, the C# program must stop searching in the second column thereafter and the variable count must again increment by one. This process must repeat until all columns have been examined. At the end of the process, if the value of count is equal to the total number of columns, this means that the given value exists, at least once, in each column of the array.

Let's use the “from inner to outer” method. The following code fragment searches in first column (column index 0) of the array and if the given value is found, the flow of execution exits the for-loop and variable count increments by one. Assume variable j contains the value 0.

```
found = false;
for (i = 0; i <= ROWS - 1; i++) {
    if (haystack[i, j] == needle) {
        found = true;
        break;
    }
}

if (found) {
    count++;
}
```

Now you can nest this code fragment in a for-loop that iterates for all columns.

```
for (j = 0; j <= COLUMNS - 1; j++) {
    found = false;
    for (i = 0; i <= ROWS - 1; i++) {
        if (haystack[i, j] == needle) {
            found = true;
            break;
        }
    }

    if (found) {
        count++;
    }
}
```

You are almost ready—but think about it first! If the inner for-loop doesn't find the given value in a column, the outer for-loop must stop iterating. It is pointless to continue because the given value does not exist in at least one column. Thus, a better approach would be to use a break statement for the outer loop as shown in the code fragment that follows.

```
for (j = 0; j <= COLUMNS - 1; j++) {
    found = false;
    for (i = 0; i <= ROWS - 1; i++) {
        if (haystack[i, j] == needle) {
            found = true;
            break;
        }
    }

    if (found) {
        count++;
    }
}
```

```

        }
    }

    if (found) {
        count++;
    }
    else {
        break;
    }
}

```

The final C# program is as follows.

### project\_34\_5\_8

```

const int ROWS = 20;
const int COLUMNS = 30;

static void Main(string[] args) {
    int i, j, count;
    bool found;
    double needle;

    double[,] haystack = new double[ROWS, COLUMNS];
    for (i = 0; i <= ROWS - 1; i++) {
        for (j = 0; j <= COLUMNS - 1; j++) {
            haystack[i, j] = Double.Parse(Console.ReadLine());
        }
    }

    Console.WriteLine("Enter a value to search: ");
    needle = Double.Parse(Console.ReadLine());

    count = 0;
    for (j = 0; j <= COLUMNS - 1; j++) {
        found = false;
        for (i = 0; i <= ROWS - 1; i++) {
            if (haystack[i, j] == needle) {
                found = true;
                break;
            }
        }

        if (found) {
            count++;
        }
    }
}

```

```

        break;
    }
}

if (count == COLUMNS) {
    Console.WriteLine(needle + " found in every column!");
}
}

```

 If you need a message to be displayed when a given value exists at least once in each **row** (instead of each column), the C# program can do the same as previously shown; however, instead of iterating through columns, it has to iterate through rows.

### ***Exercise 34.5-9 The Binary Search Algorithm – Searching in a Sorted One-Dimensional Array***

*Write a code fragment that searches a sorted one-dimensional array for a given value. Use the binary search algorithm.*

#### **Solution**

The *binary search algorithm* is considered very fast and can be used with large scale data. Its main disadvantage, though, is that the data need to be sorted.

The main idea of the binary search algorithm is to check the value of the element in the middle of the array. If it is not the “needle in the haystack” that you are looking for, and what you are looking for is actually smaller than the value of the middle element, it means that the “needle” must be in the first half of the array. On the other hand, if what you are looking for is larger than the value of the middle element, it means that the “needle” must be in the last half of the array.

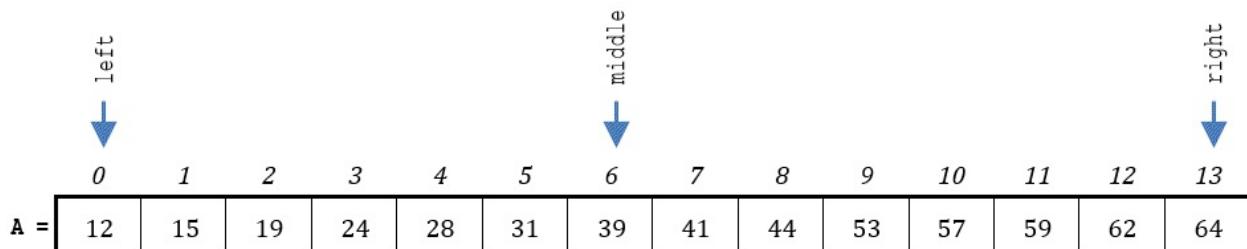
The binary search algorithm continues by checking the value of the middle element in the remaining half part of the array. If it's still not the “needle”, the search narrows to the half of the remaining part of the array that the “needle” could be in. This “splitting” process continues until the “needle” is found or the remaining part of the array consists of only one element. If that element is not the “needle”, then the given value is not in the array.

Confused? Let's try to analyze the binary search algorithm through an example. The following array contains numeric values in ascending order.

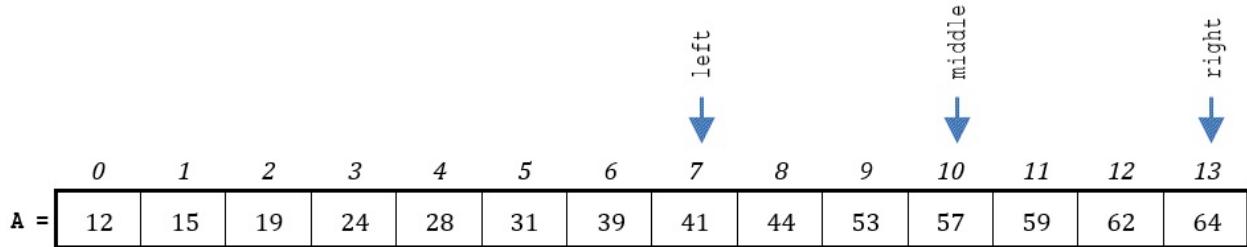
Assume that the “needle” that you are looking for is the value 44.

0	1	2	3	4	5	6	7	8	9	10	11	12	13
A = 12	15	19	24	28	31	39	41	44	53	57	59	62	64

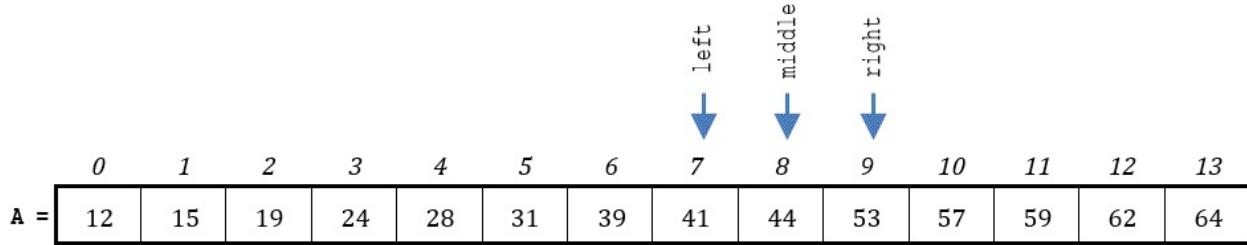
Three variables are used. Initially, variable `left` contains the value 0 (this is the index of the first element), variable `right` contains the value 13 (this is the index of the last element) and variable `middle` contains the value 6 (this is approximately the index of the middle element).



The “needle” (value 44) that you are looking for is larger than the value of 39 in the middle, thus the element that you are looking for must be in the last half of the array. Therefore, variable `left` is updated to point to index position 7 and variable `middle` is updated to a point in the middle between `left` (the new one) and `right`.



Now, the “needle” (value 44) that you are looking for is smaller than the value of 57 in the middle, thus the element that you are looking for must be in the first half of the remaining part of the array. Therefore, it is the variable `right` that is now updated to point to index position 9, and variable `middle` is updated to point to the middle between `left` and `right` (the new one).



You are done! The “needle” has been found at index position 8 and the

whole process can stop!

☞ *Each unsuccessful comparison reduces the number of elements left to check by half!*

Now, let's see the corresponding code fragment.

```
left = 0;
right = ELEMENTS - 1;
found = false;
while (left <= right && !found) {
    middle = (int)((left + right) / 2); //This is a DIV 2 operation

    if (haystack[middle] > needle) {
        right = middle - 1;
    }
    else if (haystack[middle] < needle) {
        left = middle + 1;
    }
    else {
        found = true;
        index_position = middle;
    }
}

if (!found) {
    Console.WriteLine("Nothing found!");
}
else {
    Console.WriteLine(needle + " found at position: " + index_position);
}
```

☞ *Using the binary search algorithm on the array of the example, the value of 44 can be found within just three iterations. On the other hand, for the same data, the linear search algorithm would need nine iterations!*

☞ *If the array contains a value multiple times, the binary search algorithm can find only one occurrence.*

### **Exercise 34.5-10 Display all the Historical Events for a Country**

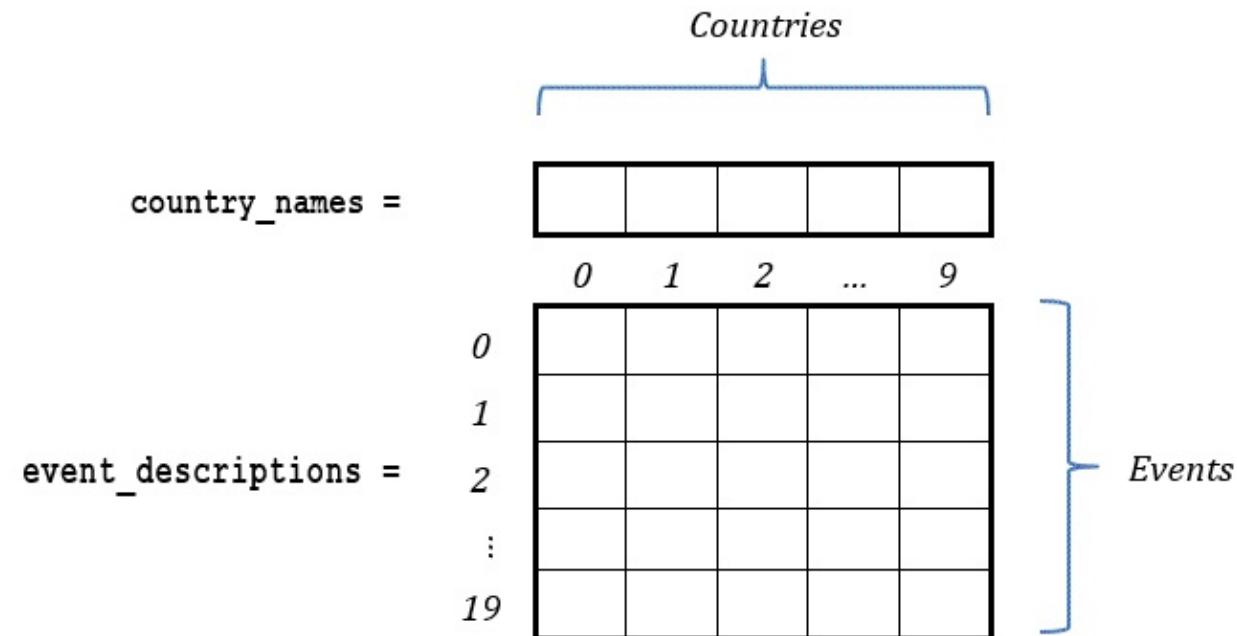
*Write a C# program that prompts the user to enter the names of 10 countries and 20 important historical events for each country, including a brief description of each event. The C# program must then prompt the user*

*to enter a country, and it will search and display all events for that country. Use the binary search algorithm. Assume that the user enters the names of the countries alphabetically.*

### **Solution**

---

In this exercise, the following two arrays are required.



Assume that the user enters a country to search for, and the binary search algorithm finds that country, for example, at index position 2 of array `country_names`. The program can then use this value of 2 as a column index for the array `event_descriptions`, and it will display all the event descriptions of column 2.

The C# program is as follows.

#### project\_34\_5\_10

```
const int EVENTS = 20;
const int COUNTRIES = 10;

static void Main(string[] args) {
    int j, i, left, right, middle, index_position;
    bool found;
    string needle;

    string[] country_names = new string[COUNTRIES];
    string[,] event_descriptions = new string[EVENTS, COUNTRIES];
```

```

        for (j = 0; j <= COUNTRIES - 1; j++) {
            Console.WriteLine("Enter Country No. " + (j + 1) + ": ");
            country_names[j] = Console.ReadLine();
            for (i = 0; i <= EVENTS - 1; i++) {
                Console.WriteLine("Enter description for event No. " + (i + 1) + ": ");
                event_descriptions[i, j] = Console.ReadLine();
            }
        }

        Console.WriteLine("Enter a country to search: ");
        needle = Console.ReadLine().ToUpper();

        //Country names are entered alphabetically.
        //Use the binary search algorithm to search for needle.
        index_position = -1;
        left = 0;
        right = EVENTS - 1;
        found = false;
        while (left <= right && !found) {
            middle = (int)((left + right) / 2);

            if (country_names[middle].ToUpper().CompareTo(needle) > 0) {
                right = middle - 1;
            }
            else if (country_names[middle].ToUpper().CompareTo(needle) < 0) {
                left = middle + 1;
            }
            else {
                found = true;
                index_position = middle;
            }
        }

        if (!found) {
            Console.WriteLine("No country found!");
        }
        else {
            for (i = 0; i <= EVENTS - 1; i++) {
                Console.WriteLine(event_descriptions[i, index_position]);
            }
        }
    }
}

```

### Exercise 34.5-11 Searching in Each Column of a Two-Dimensional Array

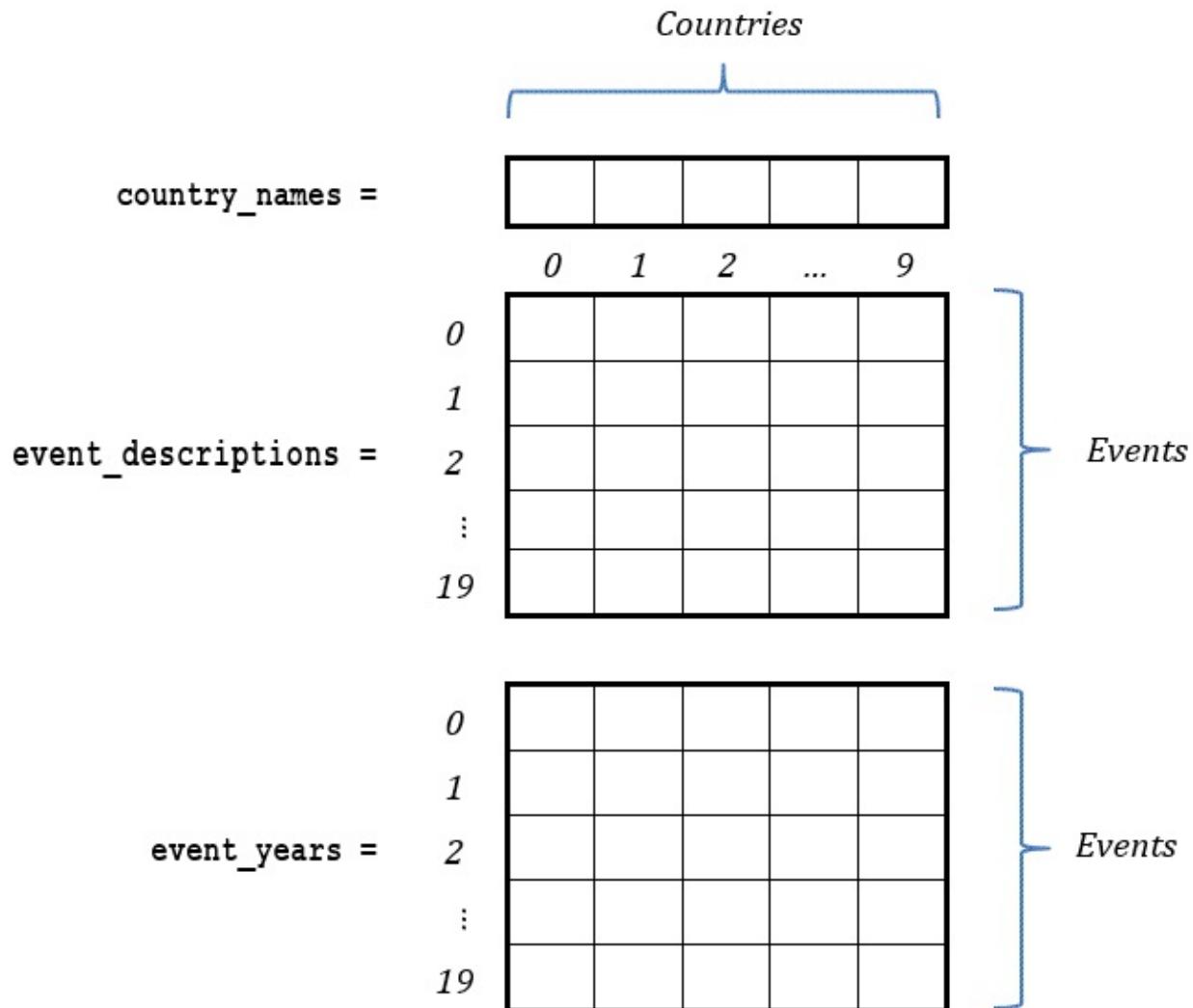
Write a C# program that prompts the user to enter the names of 10

*countries and 20 important historical events for each country, including a brief description and the corresponding year of each event. The C# program must then prompt the user to enter a year, and it will search and display all events that happened that year for each country. Use the binary search algorithm. Assume that for each country there is only one event in each year and that the user enters the events ordered by year in ascending order.*

## Solution

---

In this exercise, the following three arrays are required.



In order to write the code fragment that searches in each column of the array `event_years`, let's use the “from inner to outer” method. The next binary search algorithm searches in the first column (column index 0) for a given year. Assume variable `j` contains the value 0. Since the search is performed vertically, and in order to increase program's readability, variables `left` and

right have been replaced by variables top and bottom correspondingly.

```
top = 0;
bottom = EVENTS - 1;
found = false;
while (top <= bottom && !found) {
    middle = (int)((top + bottom) / 2);

    if (event_years[middle, j] > needle) {
        bottom = middle - 1;
    }
    else if (event_years[middle, j] < needle) {
        top = middle + 1;
    }
    else {
        found = true;
        row_index = middle;
    }
}

if (!found) {
    Console.WriteLine("No event found for country " + country_names[j]);
}
else {
    Console.WriteLine("Country: " + country_names[j]);
    Console.WriteLine("Year: " + event_years[row_index, j]);
    Console.WriteLine("Event: " + event_descr[row_index, j]);
}
```

Now, nesting this code fragment in a for-loop that iterates for all columns results in the following.

```
for (j = 0; j <= COUNTRIES - 1; j++) {
    top = 0;
    bottom = EVENTS - 1;
    found = false;
    while (top <= bottom && !found) {
        middle = (int)((top + bottom) / 2);

        if (event_years[middle, j] > needle) {
            bottom = middle - 1;
        }
        else if (event_years[middle, j] < needle) {
            top = middle + 1;
        }
        else {
```

```

        found = true;
        row_index = middle;
    }
}

if (!found) {
    Console.WriteLine("No event found for country " + country_names[j]);
}
else {
    Console.WriteLine("Country: " + country_names[j]);
    Console.WriteLine("Year: " + event_years[row_index, j]);
    Console.WriteLine("Event: " + event_descr[row_index, j]);
}
}

```

The final C# program is as follows.

### project\_34\_5\_11

```

const int EVENTS = 20;
const int COUNTRIES = 10;

static void Main(string[] args) {
    int j, i, needle, top, bottom, middle, row_index;
    bool found;

    string[] country_names = new string[COUNTRIES];
    string[,] event_descriptions = new string[EVENTS, COUNTRIES];
    int[,] event_years = new int[EVENTS, COUNTRIES];
    for (j = 0; j <= COUNTRIES - 1; j++) {
        Console.Write("Enter Country No. " + (j + 1) + ": ");
        country_names[j] = Console.ReadLine();
        for (i = 0; i <= EVENTS - 1; i++) {
            Console.Write("Enter description for event No. " + (i + 1) + ": ");
            event_descriptions[i, j] = Console.ReadLine();
            Console.Write("Enter year for event No. " + (i + 1) + ": ");
            event_years[i, j] = Int32.Parse(Console.ReadLine());
        }
    }

    Console.WriteLine("Enter a year to search: ");
    needle = Int32.Parse(Console.ReadLine());
    row_index = -1;

    for (j = 0; j <= COUNTRIES - 1; j++) {
        top = 0;
        bottom = EVENTS - 1;
        while (top < bottom) {
            middle = (top + bottom) / 2;
            if (event_years[middle, j] < needle)
                top = middle + 1;
            else
                bottom = middle;
        }
        if (event_years[row_index, j] == needle)
            break;
        row_index++;
    }
}

```

```

        found = false;
    while (top <= bottom && !found) {
        middle = (int)((top + bottom) / 2);

        if (event_years[middle, j] > needle) {
            bottom = middle - 1;
        }
        else if (event_years[middle, j] < needle) {
            top = middle + 1;
        }
        else {
            found = true;
            row_index = middle;
        }
    }

    if (!found) {
        Console.WriteLine("No event found for country " + country_names[j]);
    }
    else {
        Console.WriteLine("Country: " + country_names[j]);
        Console.WriteLine("Year: " + event_years[row_index, j]);
        Console.WriteLine("Event: " + event_descriptions[row_index, j]);
    }
}
}

```

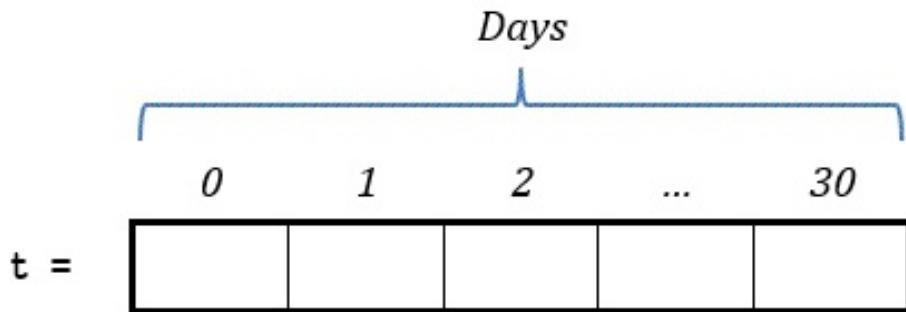
## 34.6 Exercises of a General Nature with Arrays

### Exercise 34.6-1 On Which Days was There a Possibility of Snow?

*Write a C# program that lets the user enter the temperatures (in degrees Fahrenheit) recorded at the same hour each day for the 31 days of January. The C# program must then display the numbers of those days (1, 2, ..., 31) on which there was a possibility of snow, that is, those on which temperatures were below 36 degrees Fahrenheit (about 2 degrees Celsius).*

### Solution

The one-dimensional array for this exercise is shown next.



and the C# program is as follows.

### project\_34\_6\_1

```

const int DAYS = 31;

static void Main(string[] args) {
    int i;

    int[] t = new int[DAYS];
    for (i = 0; i <= DAYS - 1; i++) {
        t[i] = Int32.Parse(Console.ReadLine());
    }

    for (i = 0; i <= DAYS - 1; i++) {
        if (t[i] < 36) {
            Console.WriteLine((i + 1) + "\t");
        }
    }
}

```

#### Exercise 34.6-2 Was There Any Possibility of Snow?

*Write a C# program that lets the user enter the temperatures (in degrees Fahrenheit) recorded at the same hour each day for the 31 days of January. The C# program must then display a message indicating if there was a possibility of snow, that is, if there were any temperatures below 36 degrees Fahrenheit (about 2 degrees Celsius).*

#### Solution

The code fragment that follows is **incorrect**. You **cannot** do what you did in the previous exercise.

```

for (i = 0; i <= DAYS - 1; i++) {
    if (t[i] < 36) {
        Console.WriteLine("There was a possibility of snow in January!");
    }
}

```

```
    }
}
```

If January had more than one day with a temperature below 36 degrees Fahrenheit, the same message would be displayed multiple times—and obviously you do not want this! You actually want to display a message once, regardless of whether January had one, two, or even more days below 36 degrees Fahrenheit.

There are two approaches, actually. Let's study them both.

### First Approach – Counting all temperatures below 36 degrees Fahrenheit

In this approach, you can use a variable in the program to count all the days on which the temperature was below 36 degrees Fahrenheit. After all of the days have been examined, the program can check the value of this variable. If the value is not zero, it means that there was at least one day where there was a possibility of snow.

#### project\_34\_6\_2a

```
const int DAYS = 31;

static void Main(string[] args) {
    int i, count;

    int[] t = new int[DAYS];
    for (i = 0; i <= DAYS - 1; i++) {
        t[i] = Int32.Parse(Console.ReadLine());
    }

    count = 0;
    for (i = 0; i <= DAYS - 1; i++) {
        if (t[i] < 36) {
            count++;
        }
    }

    if (count != 0) {
        Console.WriteLine("There was a possibility of snow in January!");
    }
}
```

### Second Approach – Using a flag

In this approach, instead of counting all those days that had a temperature

below 36 degrees Fahrenheit, you can use a Boolean variable (a flag). The solution is presented next.

### project\_34\_6\_2b

```
const int DAYS = 31;

static void Main(string[] args) {
    int i;
    bool found;

    int[] t = new int[DAYS];
    for (i = 0; i <= DAYS - 1; i++) {
        t[i] = Int32.Parse(Console.ReadLine());
    }

    found = false;
    for (i = 0; i <= DAYS - 1; i++) {
        if (t[i] < 36) {
            found = true;
            break;
        }
    }

    if (found) {
        Console.WriteLine("There was a possibility of snow in January!");
    }
}
```

☞ Imagine the variable `found` as if it's a real flag. Initially, the flag is not hoisted (`found = false`). Within the `for`-loop, however, when a temperature below 36 degrees Fahrenheit is found, the flag is hoisted (the value `true` is assigned to the variable `found`) and it is never lowered again.

☞ Note the `break` statement! Once a temperature below 36 degrees Fahrenheit is found, it is meaningless to continue checking thereafter.

☞ If the loop performs all of its iterations and no temperature below 36 degrees Fahrenheit is found, the variable `found` will still contain its initial value (`false`) since the flow of execution never entered the decision control structure.

### Exercise 34.6-3 In Which Cities was There a Possibility of Snow?

Write a C# program that prompts the user to enter the names of ten cities

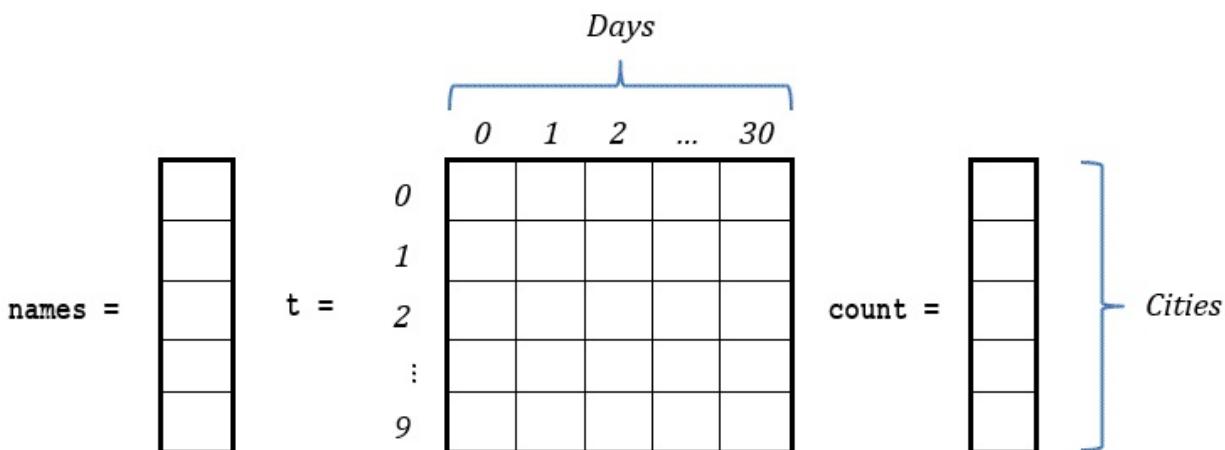
*and their temperatures (in degrees Fahrenheit) recorded at the same hour each day for the 31 days of January. The C# program must display the names of the cities in which there was a possibility of snow, that is, those in which temperatures were below 36 degrees Fahrenheit (about 2 degrees Celsius).*

## Solution

---

As in the previous exercise, you need to display each city name once, regardless of whether it may had one, two, or even more days below 36 degrees Fahrenheit.

This exercise needs the following arrays. In the first approach, the auxiliary array count is created by the program to count the total number of days on which each city had temperatures lower than 36 degrees Fahrenheit. The second approach, however, doesn't create the auxiliary array count. It uses just one extra Boolean variable (a flag). Obviously the second one is more efficient. But let's study them both.



### First Approach – Using an auxiliary array

You were taught in [paragraph 33.2](#) how to process each row individually. The nested loop control structure that can create the auxiliary array count is as follows.

```
int[] count = new int[CITIES];
for (i = 0; i <= CITIES - 1; i++) {
    count[i] = 0;
    for (j = 0; j <= DAYS - 1; j++) {
        if (t[i, j] < 36) {
            count[i]++;
        }
    }
}
```

```
    }
}
```

After array count is created you can iterate through it, and when an element contains a value other than zero, it means that the corresponding city had at least one day below 36 degrees Fahrenheit; thus the program must display the name of that city. The final C# program is presented next

### project\_34\_6\_3a

```
const int CITIES = 10;
const int DAYS = 31;

static void Main(string[] args) {
    int i, j;

    string[] names = new string[CITIES];
    int[,] t = new int[CITIES, DAYS];
    for (i = 0; i <= CITIES - 1; i++) {
        Console.WriteLine("Enter a name for city No: " + (i + 1) + ": ");
        names[i] = Console.ReadLine();
        for (j = 0; j <= DAYS - 1; j++) {
            Console.WriteLine("Enter a temperature for day No: " + (j + 1) + ": ");
            t[i, j] = Int32.Parse(Console.ReadLine());
        }
    }

    int[] count = new int[CITIES];
    for (i = 0; i <= CITIES - 1; i++) {
        count[i] = 0;
        for (j = 0; j <= DAYS - 1; j++) {
            if (t[i, j] < 36) {
                count[i]++;
            }
        }
    }

    Console.WriteLine("Cities in which there was a possibility of snow in January: ");
    for (i = 0; i <= CITIES - 1; i++) {
        if (count[i] != 0) {
            Console.WriteLine(names[i]);
        }
    }
}
```

## Second Approach – Using a flag

This approach does not use an auxiliary array. It processes array *t* and directly displays any city name that had a temperature below 36 degrees Fahrenheit. But how can this be done without displaying a city name twice, or even more than twice? This is where you need a flag, that is, an extra Boolean variable.

To better understand this approach, let's use the “from inner to outer” method. The following code fragment checks if the first row of array *t* (row index 0) contains at least one temperature below 36 degrees Fahrenheit; if so, it displays the corresponding city name that exists at position 0 of the array *names*. Assume variable *i* contains the value 0.

```
found = false;
for (j = 0; j <= DAYS - 1; j++) {
    if (t[i, j] < 36) {
        found = true;
        break;
    }
}

if (found) {
    Console.WriteLine(names[i]);
}
```

Now that everything has been clarified, in order to process the whole array *t*, you can just nest this code fragment in a for-loop that iterates for all cities, as follows.

```
for (i = 0; i <= CITIES - 1; i++) {
    found = false;
    for (j = 0; j <= DAYS - 1; j++) {
        if (t[i, j] < 36) {
            found = true;
            break;
        }
    }

    if (found) {
        Console.WriteLine(names[i]);
    }
}
```

The final C# program is as follows.

### project\_34\_6\_3b

```
const int CITIES = 10;
```

```

const int DAYS = 31;

static void Main(string[] args) {
    int i, j;
    bool found;

    int[] names = new int[CITIES];
    int[,] t = new int[CITIES, DAYS];
    for (i = 0; i <= CITIES - 1; i++) {
        Console.WriteLine("Enter a name for city No: " + (i + 1) + ": ");
        names[i] = Int32.Parse(Console.ReadLine());
        for (j = 0; j <= DAYS - 1; j++) {
            Console.WriteLine("Enter a temperature for day No: " + (j + 1) + ": ");
            t[i, j] = Int32.Parse(Console.ReadLine());
        }
    }

    Console.WriteLine("Cities in which there was a possibility of snow in January: ");
    for (i = 0; i <= CITIES - 1; i++) {
        found = false;
        for (j = 0; j <= DAYS - 1; j++) {
            if (t[i, j] < 36) {
                found = true;
                break;
            }
        }

        if (found) {
            Console.WriteLine(names[i]);
        }
    }
}

```

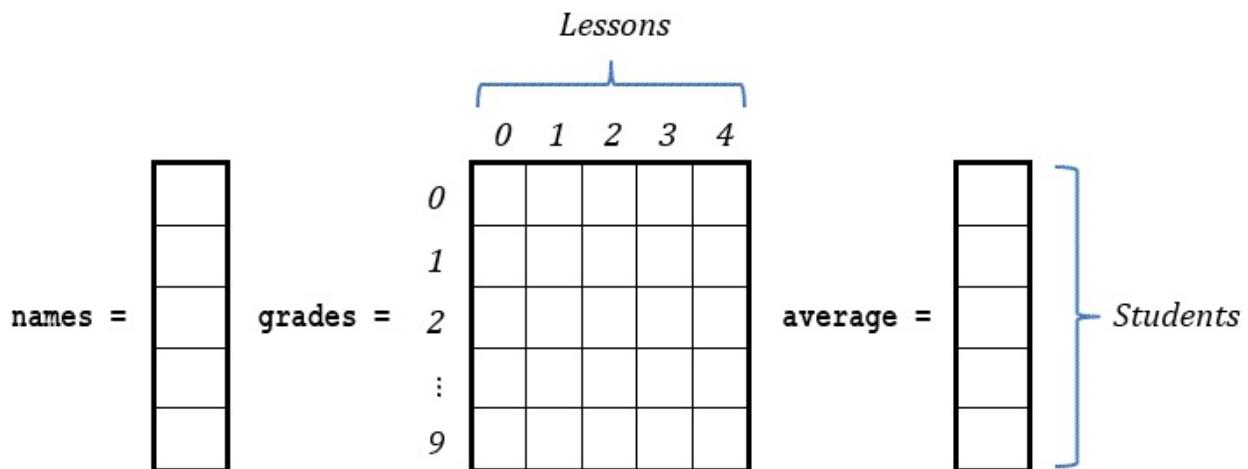
### ***Exercise 34.6-4 Display from Highest to Lowest Grades by Student, and in Alphabetical Order***

---

*There are 10 students and each one of them has received his or her grades for five lessons. Write a C# program that prompts a teacher to enter the name of each student and his or her grades for all lessons. The program must then calculate each student's average grade, and display the names of the students sorted by their average grade in descending order. Moreover, if two or more students have the same average grade, their names must be displayed in alphabetical order. Use the bubble sort algorithm, adapted accordingly.*

## Solution

In this exercise, you need the following three arrays. The values for the arrays names and grades will be entered by the user, whereas the auxiliary array average will be created by the C# program.



You already know how to do everything in this exercise. You know how to create the auxiliary array average (see [paragraph 33.2](#)), you know how to sort the array average while preserving the relationship with the elements of the array names (see [Exercise 34.4-3](#)), and you know how to handle the case in which, if two average grades are equal, the corresponding student names must be sorted alphabetically (see [Exercise 34.4-4](#)). The final C# program is as follows.

### project\_34\_6\_4

```
const int STUDENTS = 10;
const int LESSONS = 5;

static void Main(string[] args) {
    int i, j, m, n;
    double temp;
    string temp_str;

    //Read array names and grades
    string[] names = new string[STUDENTS];
    int[,] grades = new int[STUDENTS, LESSONS];
    for (i = 0; i <= STUDENTS - 1; i++) {
        Console.WriteLine("Enter name for student No. " + (i + 1) + ": ");
        names[i] = Console.ReadLine();
        for (j = 0; j <= LESSONS - 1; j++) {
            Console.WriteLine("Enter grade for lesson No. " + (j + 1) + ": ");
            temp = Convert.ToDouble(Console.ReadLine());
            grades[i, j] = temp;
        }
    }

    //Calculate average grades
    double[] average = new double[STUDENTS];
    for (i = 0; i <= STUDENTS - 1; i++) {
        m = 0;
        for (j = 0; j <= LESSONS - 1; j++)
            m += grades[i, j];
        average[i] = m / LESSONS;
    }

    //Sort average grades and names
    for (i = 0; i <= STUDENTS - 1; i++)
        for (m = i + 1; m <= STUDENTS - 1; m++)
            if (average[m] < average[i]) {
                temp = average[i];
                average[i] = average[m];
                average[m] = temp;
                temp = names[i];
                names[i] = names[m];
                names[m] = temp;
            }
}
```

```

        grades[i, j] = Int32.Parse(Console.ReadLine());
    }
}

//Create array average
double[] average = new double[STUDENTS];
for (i = 0; i <= STUDENTS - 1; i++) {
    average[i] = 0;
    for (j = 0; j <= LESSONS - 1; j++) {
        average[i] += grades[i, j];
    }
    average[i] /= LESSONS;
}

//Sort arrays average and names
for (m = 1; m <= STUDENTS - 1; m++) {
    for (n = STUDENTS - 1; n >= m; n--) {
        if (average[n] > average[n - 1]) {
            temp = average[n];
            average[n] = average[n - 1];
            average[n - 1] = temp;

            temp_str = names[n];
            names[n] = names[n - 1];
            names[n - 1] = temp_str;
        }
        else if (average[n] == average[n - 1]) {
            if (names[n].CompareTo(names[n - 1]) < 0) {
                temp_str = names[n];
                names[n] = names[n - 1];
                names[n - 1] = temp_str;
            }
        }
    }
}

//Display arrays names and average
for (i = 0; i <= STUDENTS - 1; i++) {
    Console.WriteLine(names[i] + "\t" + average[i]);
}
}

```

### Exercise 34.6-5 Archery at the Summer Olympics

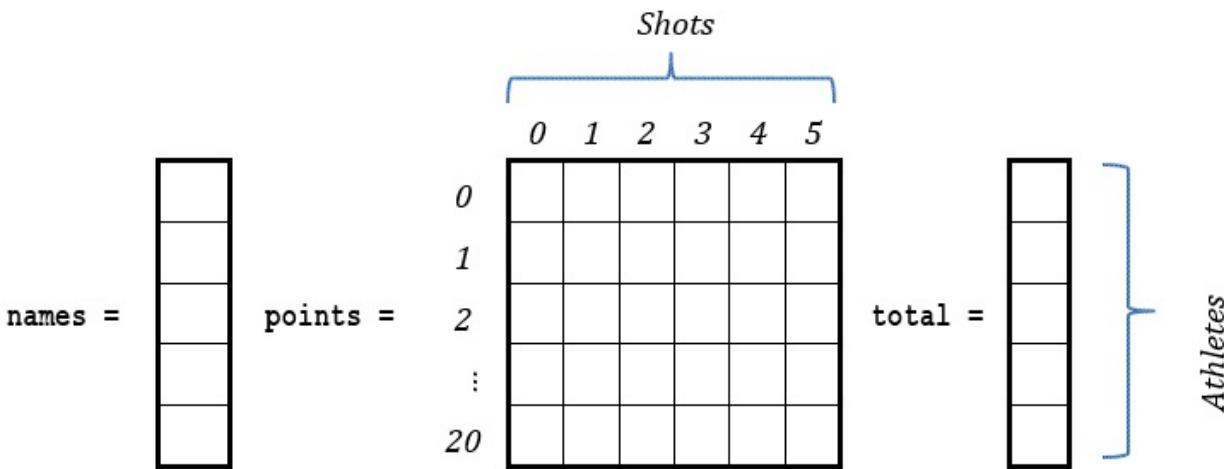
In archery at the Summer Olympics, 20 athletes each shoot six arrows.

*Write a C# program that prompts the user to enter the name of each athlete, and the points awarded for each shot. The program must then display the names of the three athletes that won the gold, silver, and bronze medals depending on which athlete obtained the highest sum of points. Assume that no two athletes have an equal sum of points.*

### Solution

---

In this exercise, you need the following three arrays. The values for the arrays names and points will be entered by the user, whereas the auxiliary array total will be created by the C# program.



After the auxiliary array total is created, a sorting algorithm can sort the array total in descending order (while preserving the relationship with the elements of the array names). The C# program can then display the names of the three athletes at index positions 0, 1, and 2 (since these are the athletes that should win the gold, the silver, and the bronze medals, respectively).

The following program uses the bubble sort algorithm to sort the array total. Since the algorithm must sort in descending order, bigger elements must gradually “bubble” to positions of lowest index, like bubbles rise in a glass of cola. However, instead of performing 19 passes (there are 20 athletes), given that only the three best athletes must be found, the algorithm can perform just 3 passes. Doing this, only the first three bigger elements will gradually “bubble” to the first three positions in the array.

The solution is presented next.

#### project\_34\_6\_5

```
const int ATHLETES = 20;
```

```

const int SHOTS = 6;

static void Main(string[] args) {
    int i, j, m, n, temp;
    string temp_str;

    //Read array names and points
    string[] names = new string[ATHLETES];
    int[,] points = new int[ATHLETES, SHOTS];
    for (i = 0; i <= ATHLETES - 1; i++) {
        Console.Write("Enter name for athlete No. " + (i + 1) + ": ");
        names[i] = Console..ReadLine();
        for (j = 0; j <= SHOTS - 1; j++) {
            Console.Write("Enter points for shot No. " + (j + 1) + ": ");
            points[i, j] = Int32.Parse(Console..ReadLine());
        }
    }

    //Create array total
    int[] total = new int[ATHLETES];
    for (i = 0; i <= ATHLETES - 1; i++) {
        total[i] = 0;
        for (j = 0; j <= SHOTS - 1; j++) {
            total[i] += points[i, j];
        }
    }

    //Sort arrays names and total. Perform only 3 passes
    for (m = 1; m <= 3; m++) {
        for (n = ATHLETES - 1; n >= m; n--) {
            if (total[n] > total[n - 1]) {
                temp = total[n];
                total[n] = total[n - 1];
                total[n - 1] = temp;

                temp_str = names[n];
                names[n] = names[n - 1];
                names[n - 1] = temp_str;
            }
        }
    }

    //Display gold, silver and bronze metal
    for (i = 0; i <= 2; i++) {
        Console.WriteLine(names[i] + "\t" + total[i]);
    }
}

```

```
    }  
}
```

## 34.7 Review Questions: True/False

Choose **true** or **false** for each of the following statements.

1. The main idea of the bubble sort algorithm (when sorting an array in ascending order) is to repeatedly move the smallest elements of the array to the lowest index positions.
2. In an array sorted in ascending order, the first element is the greatest of all.
3. When using the bubble sort algorithm, the total number of swaps depends on the given array.
4. When using the modified bubble sort algorithm, the case in which the algorithm performs the greatest number of swaps is when you want to sort in descending order an array that is already sorted in ascending order.
5. In the bubble sort algorithm, when the decision control structure tests the Boolean expression  $A[n] > A[n - 1]$ , it means that the elements of array A are being sorted in descending order.
6. In C#, sorting algorithms compare letters not in the same way that they compare numbers.
7. If you want to sort an array A but preserve the relationship with the elements of an array B, you must rearrange the elements of array B as well.
8. The bubble sort algorithm sometimes performs better than the modified bubble sort algorithm.
9. According to the bubble sort algorithm, in each pass (except the last one) only one element is placed in proper position.
10. The bubble sort algorithm can be implemented only by using for-loops.
11. The quick sort algorithm cannot be used to sort each column of a two-dimensional array.
12. The insertion sort algorithm can sort in either descending or ascending order.
13. One of the fastest sorting algorithms is the modified bubble sort

algorithm.

14. The bubble sort algorithm, for a one-dimensional array of N elements, performs  $\frac{N-1}{N}$  compares.
15. The bubble sort algorithm, for a one-dimensional array of N elements, performs  $\frac{N(N-1)}{2}$  passes.
16. When using the modified bubble sort algorithm, if a complete pass is performed and no swaps have been done, then the algorithm knows the array is sorted and there is no need for further passes.
17. When using the selection sort algorithm, if you wish to sort an array in descending order, you need to search for maximum values.
18. The selection sort algorithm performs very well on computer systems in which the limited main memory comes into play.
19. The selection sort algorithm is suitable for large scale data operations.
20. The selection sort algorithm is a very complex algorithm.
21. The insertion sort algorithm generally performs better than the selection and the bubble sort algorithm.
22. The insertion sort algorithm can sometimes prove even faster than the quicksort algorithm.
23. The quicksort algorithm is considered one of the best and fastest sorting algorithms.
24. A sorted array contains only elements that are different from each other.
25. A search algorithm is an algorithm that searches for an item with specific features within a set of data.
26. The sequential search algorithm can be used only on arrays that contain arithmetic values.
27. One of the most commonly used search algorithms is the quick search algorithm.
28. One search algorithm is called the heap algorithm.
29. A linear (or sequential) search algorithm can work as follows: it can check if the last element of the array is equal to a given value, then it can check the last but one element, and so on, until the beginning of the

array or until the given value is found.

30. The linear search algorithm can, in certain situations, find an element faster than the binary search algorithm.
31. The linear search algorithm can be used in large scale data operations.
32. The linear search algorithm cannot be used in sorted arrays.
33. The binary search algorithm can be used in large scale data operations.
34. If an array contains a value multiple times, the binary search algorithm can find only the first occurrence of a given value.
35. When using search algorithms, if an array contains unique values and the element that you are looking for is found, there is no need to check any further.
36. The main disadvantage of the binary search algorithm is that data needs to be sorted.
37. The binary search algorithm can be used only in arrays that contain arithmetic values.
38. If the element that you are looking for is in the last position of an array, the linear search algorithm will examine all the elements of the array.
39. The linear search algorithm can be used on two-dimensional arrays.
40. When using the binary search algorithm, if the element that you are looking for is at the first position of an array that contains at least three elements, the algorithm will find it in just one iteration.

## 34.8 Review Exercises

Complete the following exercises.

1. Design the flowchart that corresponds to the following C# program.

```
const int ELEMENTS = 30;

static void Main(string[] args) {
    int i, digit1, digit2;

    int[] values = new int[ELEMENTS];
    for (i = 0; i <= ELEMENTS - 1; i++) {
        Console.Write("Enter a two-digit integer: ");
        values[i] = Int32.Parse(Console.ReadLine());
    }
    for (i = 0; i <= ELEMENTS - 1; i++) {
```

```

        digit1 = (int)(values[i] / 10);
        digit2 = values[i] % 10;
        if (digit1 < digit2) {
            Console.WriteLine(values[i]);
        }
    }
}

```

2. Design the flowchart that corresponds to the following C# program.

```

const int ELEMENTS = 20;

static void Main(string[] args) {
    int i, total, digit3, r, digit2, digit1;

    int[] values = new int[ELEMENTS];
    for (i = 0; i <= ELEMENTS - 1; i++) {
        Console.Write("Enter a three-digit integer: ");
        values[i] = Int32.Parse(Console.ReadLine());
    }
    total = 0;
    for (i = 0; i <= ELEMENTS - 1; i++) {
        digit3 = values[i] % 10;
        r = (int)(values[i] / 10);
        digit2 = r % 10;
        digit1 = (int)(r / 10);

        if (values[i] == digit3 * 100 + digit2 * 10 + digit1) {
            total += values[i];
        }
    }
    Console.WriteLine(total);
}

```

3. Design the flowchart that corresponds to the following C# program.

```

const int ELEMENTS = 50;

static void Main(string[] args) {
    int i;

    int[] evens = new int[ELEMENTS];
    for (i = 0; i <= ELEMENTS - 1; i++) {
        do {
            evens[i] = Int32.Parse(Console.ReadLine());
        } while (evens[i] % 2 != 0);
    }
}

```

```
    for (i = 0; i <= ELEMENTS - 1; i++) {
        Console.WriteLine(evens[i]);
    }
}
```

4. Design the flowchart that corresponds to the following C# program.

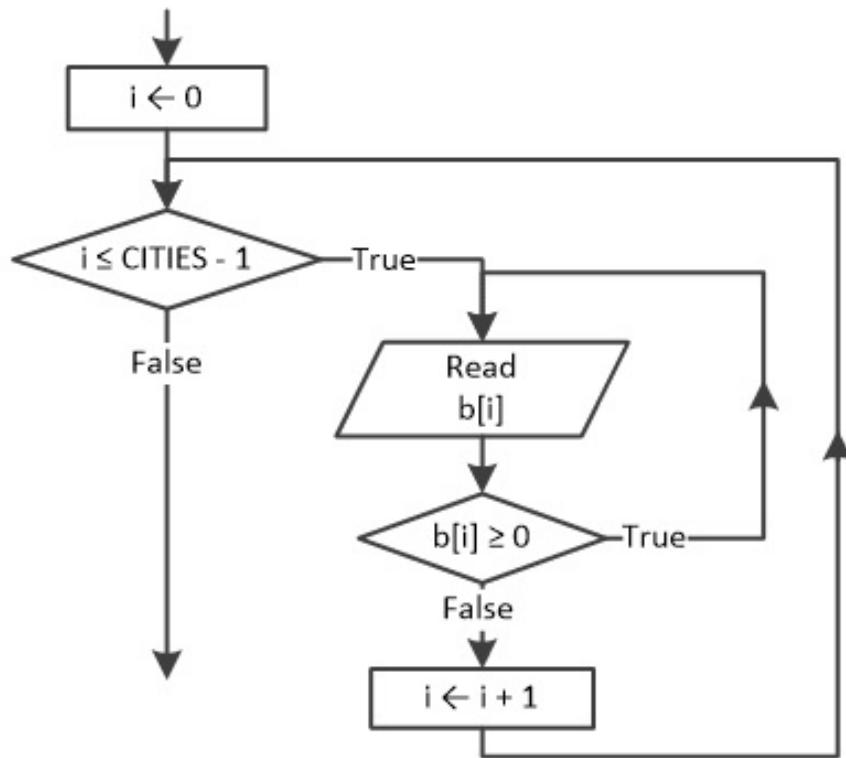
```
const int N = 10;

static void Main(string[] args) {
    int i, j, total, k;

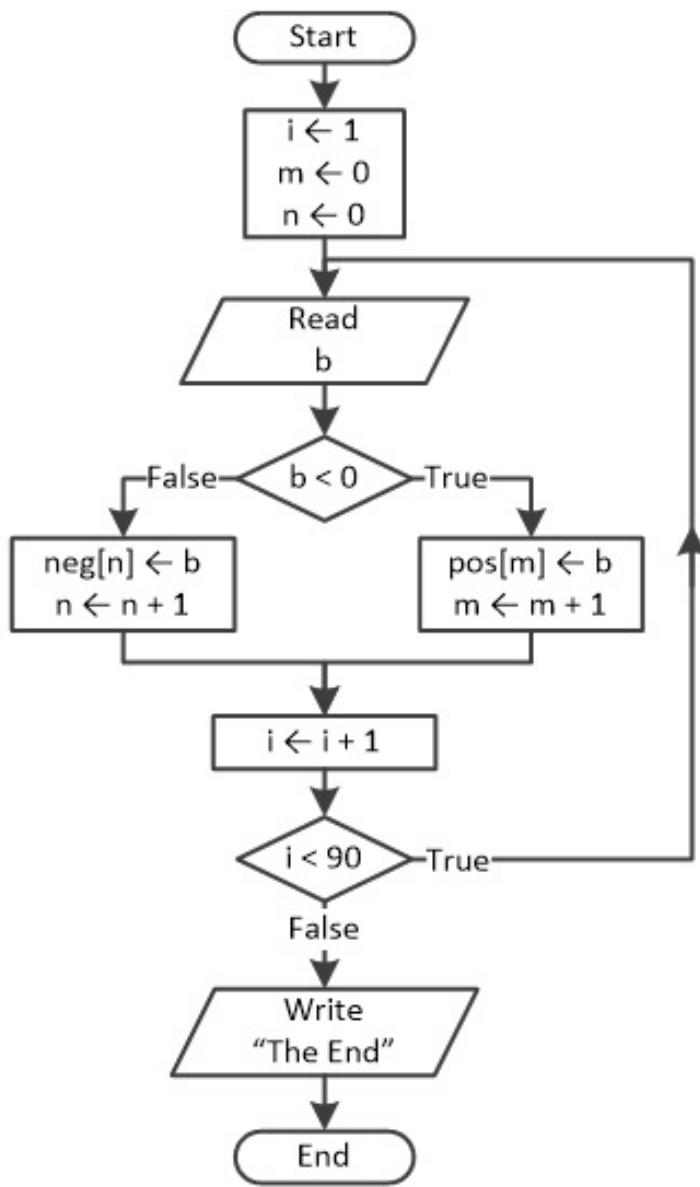
    int[,] a = new int[N, N];
    for (i = 0; i <= N - 1; i++) {
        for (j = 0; j <= N - 1; j++) {
            a[i, j] = Int32.Parse(Console.ReadLine());
        }
    }
    total = 0;
    for (k = 0; k <= N - 1; k++) {
        total += a[k, k];
    }

    Console.WriteLine("Sum = " + total);
}
```

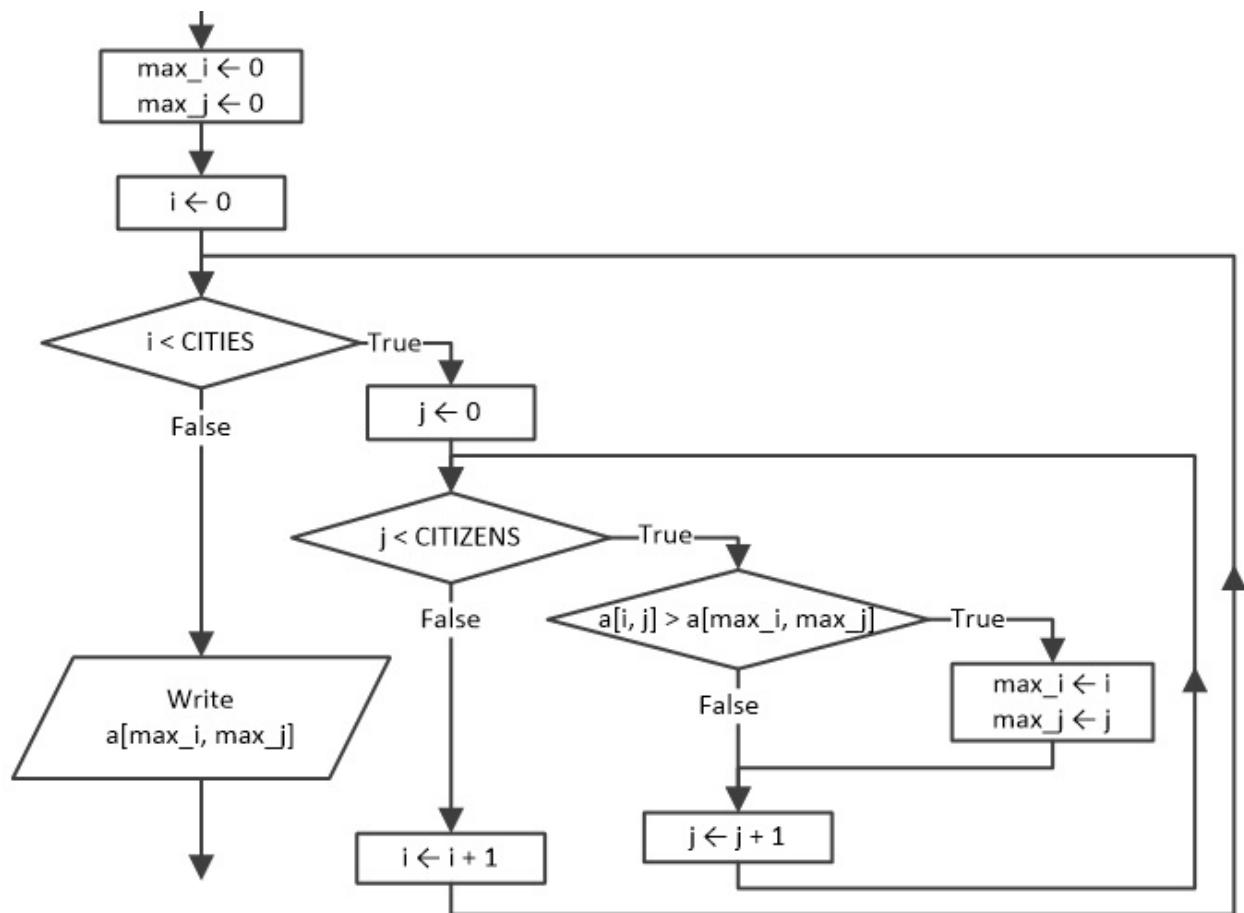
5. Write the C# program that corresponds to the following flowchart fragment.



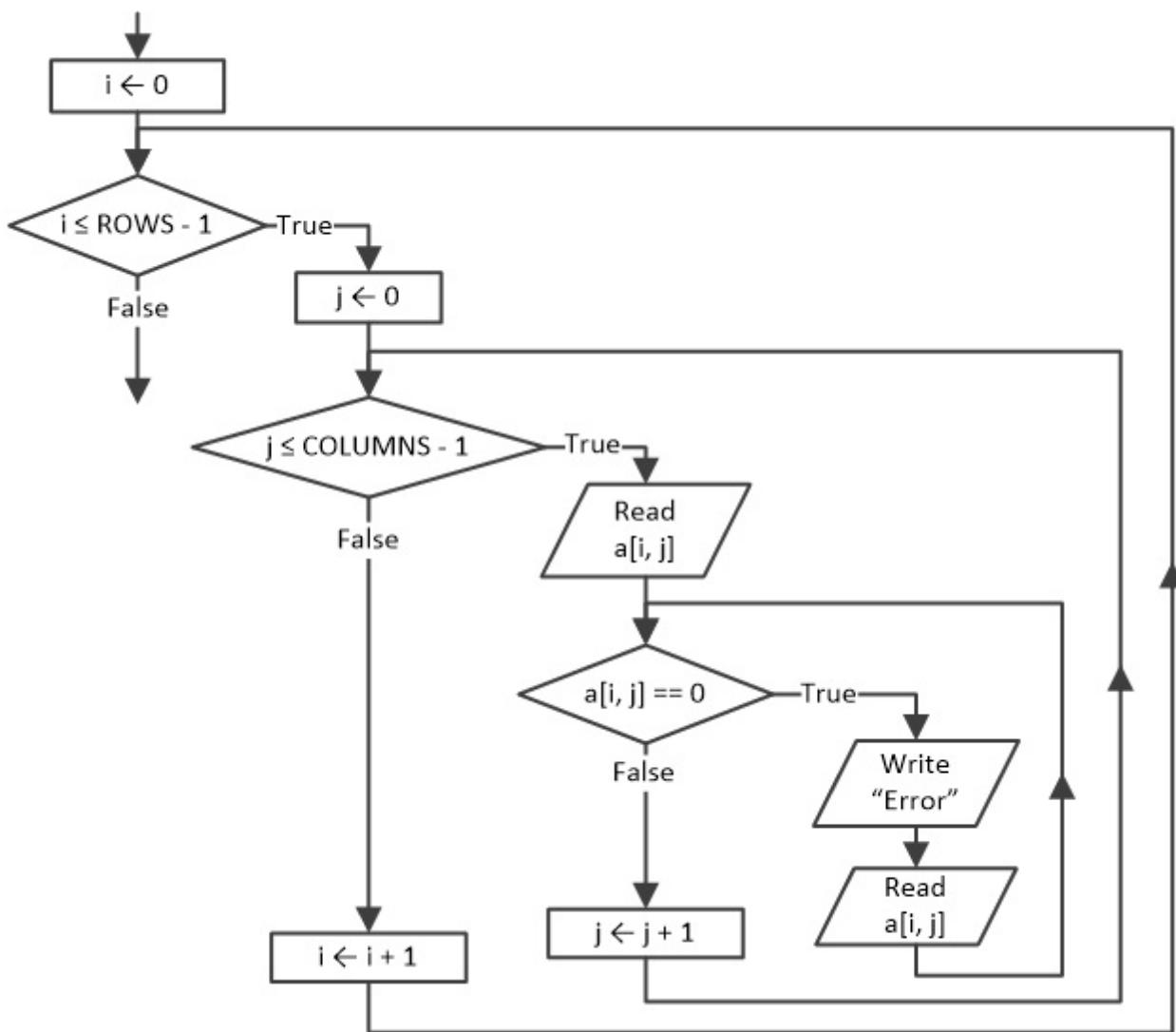
6. Write the C# program that corresponds to the following flowchart.



7. Write the C# program that corresponds to the following flowchart fragment.



8. Write the C# program that corresponds to the following flowchart fragment.



9. Design a flowchart and write the corresponding C# program that lets the user enter 50 positive numerical values into an array. The algorithm, and consequently the C# program, must then create a new array of 47 elements. In this new array, each position must contain the average value of four elements: the values that exist in the current and the next three positions of the given array.
10. Write a C# program that lets the user enter numerical values into arrays  $a$ ,  $b$ , and  $c$ , of 15 elements each. The program must then create a new array  $\text{new\_arr}$  of 15 elements. In this new array, each position must contain the lowest value of arrays  $a$ ,  $b$ , and  $c$ , for the corresponding position.

Next, design the corresponding flowchart fragment for only that part of your program that creates the array  $\text{new\_arr}$ .

11. Write a C# program that lets the user enter numerical values into arrays *a*, *b*, and *c*, of 10, 5, and 15 elements respectively. The program must then create a new array *new\_arr* of 30 elements. In this new array, the first 15 positions must contain the elements of array *c*, the next five positions must contain the elements of array *b*, and the last 10 positions must contain the elements of array *a*.

Next, design the corresponding flowchart fragment for only that part of your program that creates the array *new\_arr*.

12. Write a C# program that lets the user enter numerical values into arrays *a*, *b*, and *c*, of  $5 \times 10$ ,  $5 \times 15$ , and  $5 \times 20$  elements, respectively. The program must then create a new array *new\_arr* of  $5 \times 45$  elements. In this new array, the first 10 columns must contain the elements of array *a*, the next 15 columns must contain the elements of array *b*, and the last 20 rows must contain the elements of array *c*.
13. Write a C# program that lets the user enter 50 numerical values into an array and then creates two new arrays, *reals* and *integers*. The array *reals* must contain the real values given, whereas the array *integers* must contain the integer values. The value 0 (if any) must not be added to any of the final arrays, either *reals* or *integers*.

Next, design the corresponding flowchart fragment for only that part of your program that creates the arrays *reals* and *integers*.

14. Write a C# program that lets the user enter 50 three-digit integers into an array and then creates a new array containing only the integers in which the first digit is less than the second digit and the second digit is less than the third digit. For example, the values 357, 456, and 159 are such integers.
15. A public opinion polling company asks 200 citizens to each score 10 consumer products. Write a C# program that prompts the user to enter the name of each product and the score each citizen gave (A, B, C, or D). The program must then calculate and display the following:
- for each product, the name of the product and the number of citizens that gave it an “A”
  - for each citizen, the number of “B” responses he or she gave
  - which product or products are considered the best

Moreover, using a loop control structure, the program must validate data input and display an error message when the user enters any score with a value other than A, B, C, or D.

16. Write a C# program that prompts the user to enter the names of 20 U.S. cities and the names of 20 Canadian cities and then, for each U.S. city, the distance (in miles) from each Canadian city. Finally, the program must display, for each U.S. city, its closest Canadian city.
17. Design a flowchart and write the corresponding C# program that lets the user enter the names and the heights of 30 mountains, as well as the country in which each one belongs. The algorithm, and consequently the C# program, must then display all available information about the highest and the lowest mountain.
18. Design the flowchart fragment of an algorithm that, for a given array A of  $N \times M$  elements, finds and displays the maximum value as well as the row and the column in which this value was found.
19. Twenty-six teams participate in a football tournament. Each team plays 15 games, one game each week. Write a C# program that lets the user enter the name of each team and the letter "W" for win, "L" for loss, and "T" for tie (draw) for each game. If a win receives 3 points and a tie 1 point, the C# program must find and display the name of the team that wins the championship based on which team obtained the greatest sum of points. Assume that no two teams have an equal sum of points.
20. On Earth, a free-falling object has an acceleration of  $9.81 \text{ m/s}^2$  downward. This value is denoted by  $g$ . A student wants to calculate that value using an experiment. She allows 10 different objects to fall downward from a known height, and measures the time they need to reach the floor. She does this 20 times for each object. She needs a C# program that allows her to enter the height (from which objects are left to fall), as well as the measured times that they take to reach the floor. The program must then calculate  $g$  and store all calculated values in a  $10 \times 20$  array. However, her chronometer is not so accurate, so she needs the program to find and display the minimum and the maximum calculated values of  $g$  for each object, as well as the overall minimum and maximum calculated values of  $g$  of all objects.

The required formula is

$$S = u_o + \frac{1}{2}at^2$$

where

- ▶  $S$  is the distance that the free-falling objects traveled, in meters (m)
  - ▶  $u_o$  is the initial velocity (speed) of the free-falling objects in meters per second (m/sec). However, since the free-falling objects start from rest, the value of  $u_0$  must be zero.
  - ▶  $t$  is the time that it took the free-falling object to reach the floor, in seconds (sec)
  - ▶  $g$  is the acceleration, in meters per second<sup>2</sup> (m/sec<sup>2</sup>)
21. Ten measuring stations, one in each city, record the daily CO<sub>2</sub> levels for a period of a year. Write a C# program that lets the user enter the name of each city and the CO<sub>2</sub> levels recorded at the same hour each day. The C# program then displays the name of the city that has the clearest atmosphere (on average).
22. Design the flowchart fragment of an algorithm that, for a given array A of N × M elements, finds and displays the minimum and the maximum values of each row.
23. Write a C# program that lets the user enter values into a 20 × 30 array and then finds and displays the minimum and the maximum values of each column.
24. Twenty teams participate in a football tournament, and each team plays 10 games, one game each week. Write a C# program that prompts the user to enter the name of each team and the letter “W” for win, “L” for loss, and “T” for tie (draw) for each game. If a win receives 3 points and a tie 1 point, the C# program must find and display the names of the teams that win the gold, the silver, and the bronze medals based on which team obtained the greatest sum of points. Use the modified bubble sort algorithm. Assume that no two teams have an equal sum of points.
- Moreover, using a loop control structure, the program must validate data input and display an error message when the user enters any letter other than W, L, or T.
25. Write a C# program that prompts the user to enter the names and the

heights of 50 people. The program must then display this information, sorted by height, in descending order. Moreover, if two or more people have the same height, their names must be displayed in alphabetical order. Use the bubble sort algorithm, adapted accordingly.

26. In a song contest there are 10 judges, each of whom scores 12 artists for their performance. However, according to the rules of this contest, the total score is calculated after excluding the maximum and the minimum score. Write a C# program that prompts the user to enter the names of the artists and the score they get from each judge. The program must then display
  - a. for each artist, his or her name and total score, after excluding the maximum and the minimum scores. Assume that the maximum and the minimum scores are unique in each artist's scores. (For example, let's say that artist No 1 has a maximum score of 98. This artist cannot have two or more scores of 98, just one.)
  - b. the final classification, starting with the artist that has the greatest score. However, if two or more artists have the same score, their names must be displayed in alphabetical order. Use the bubble sort algorithm, adapted accordingly.
27. Design the flowchart fragment of an algorithm that, for a given array A of  $20 \times 8$  elements, sorts each row in descending order using the bubble sort algorithm. Assume that the array contains numerical values.
28. Design the flowchart fragment of an algorithm that, for a given array A of  $5 \times 10$  elements, sorts each column in ascending order using the bubble sort algorithm. Assume that the array contains numerical values.
29. Design the flowchart fragment of an algorithm that, for a given array A of  $20 \times 8$  elements, sorts each row in descending order using the insertion sort algorithm. Assume that the array contains numerical values.
30. Design the flowchart fragment of an algorithm that, for a given array A of  $5 \times 10$  elements, sorts each column in ascending order using the selection sort algorithm. Assume that the array contains numerical values.
31. In a Sudoku contest, 10 people each try to solve as quickly as possible eight different Sudoku puzzles. Write a C# program that lets the user

enter the name of each contestant and their time to complete each puzzle. The program must then display

- a. for each contestant, his or her name and his or her three best times.
- b. the names of the three contestants that win the gold, the silver, and the bronze medals based on which contestant obtained the lowest average time. Assume that no two contestants have an equal average time.

Use the selection sort algorithm when necessary

32. Five measuring stations, one in each area of a large city, record the daily carbon dioxide ( $\text{CO}_2$ ) levels on an hourly basis. Write a C# program that lets the user enter the name of each area and the  $\text{CO}_2$  levels recorded every hour (00:00 to 23:00) for a period of two days. The C# program then must calculate and display
  - a. for each area, its name and its average  $\text{CO}_2$  level
  - b. for each hour, the average  $\text{CO}_2$  level of the city
  - c. the hour in which the city atmosphere was most polluted (on average)
  - d. the hour and the area in which the highest level of  $\text{CO}_2$  was recorded
  - e. the three areas with the dirtiest atmosphere (on average), using the insertion sort algorithm
33. Design the flowchart fragment of the linear search algorithm that searches array  $a$  of  $N$  elements for the value  $\text{needle}$  and displays the position index(es) at which  $\text{needle}$  is found. If  $\text{needle}$  is not found, the message “Not found” must be displayed. Assume that the array contains numerical values.
34. Design the flowchart fragment of the binary search algorithm that searches array  $a$  of  $N$  elements for the value  $\text{needle}$  and displays the position at which  $\text{needle}$  is found. If  $\text{needle}$  is not found, the message “Not found” must be displayed. Assume that the array contains numerical values.
35. Ten teams participate in a football tournament, and each team plays 16 games, one game each week. Write a C# program that prompts the user to enter the name of each team, the number of goals the team scored,

and the number of goals the team let in for each match. A win receives 3 points and a tie receives 1 point. The C# program must prompt the user for a team name and then it finds and displays the total number of points for this team. If the given team name is not found, the message “This team does not exist” must be displayed.

Moreover, using a loop control structure, the program must validate data input and display an error message when the user enters any negative number of goals.

Assume that no two teams have the same name.

36. In a high school, there are two classes, with 20 and 25 students respectively. Write a C# program that prompts the user to enter the names of the students in two separate arrays. The program then displays the names of each class independently in ascending order. Afterwards, the program prompts the user to enter a name and it searches for that given name in both arrays. If the student's name is found, the program must display the message “Student found in Class No NN”, where NN can be either 1 or 2; otherwise the message “Student not found in either class” must be displayed. Assume that both arrays contain unique names.

Hint: Since the arrays are sorted and the names are unique, you can use the binary search algorithm.

37. Suppose there are two arrays, `usernames` and `passwords`, that contain the login information of 100 employees of a company. Write a code fragment that prompts the user to enter a username and a password and then displays the message “Login OK!” when the combination of username and password is valid; the message “Login Failed!” must be displayed otherwise. Assume that usernames are unique but passwords are not. Moreover, both usernames and passwords are not case sensitive.
38. Suppose there are two arrays, `names` and `ssns`, that contain the names and the SSNs (Social Security Numbers) of 1000 U.S. citizens. Write a code fragment that prompts the user to enter a value (it can be either a name or an SSN) and then searches for and displays the names of all the people that have this name or this SSN. If the given value is not found, the message “This value does not exist” must be displayed.

39. There are 12 students and each one of them has received his or her grades for six lessons. Write a C# program that lets the user enter the grades for all lessons and then displays a message indicating whether or not there is at least one student that has an average value below 70. Moreover, using a loop control structure, the program must validate data input and display individual error messages when the user enters any negative value, or a value greater than 100.
40. Write a C# program that prompts the user to enter an English word, and then, using the table that follows, displays the corresponding Morse code using dots and dashes.

Morse Code			
A	- .	N	- .
B	- - . .	O	--
C	- - .	P	. - -
D	- - .	Q	- - .
E	.	R	. - .
F	. - - .	S	... .
G	- - .	T	-
H	....	U	... -
I	..	V	... - -
J	. - - -	W	. - -
K	- - .	X	- . - -
L	. - - .	Y	- . -
M	--	Z	- - .

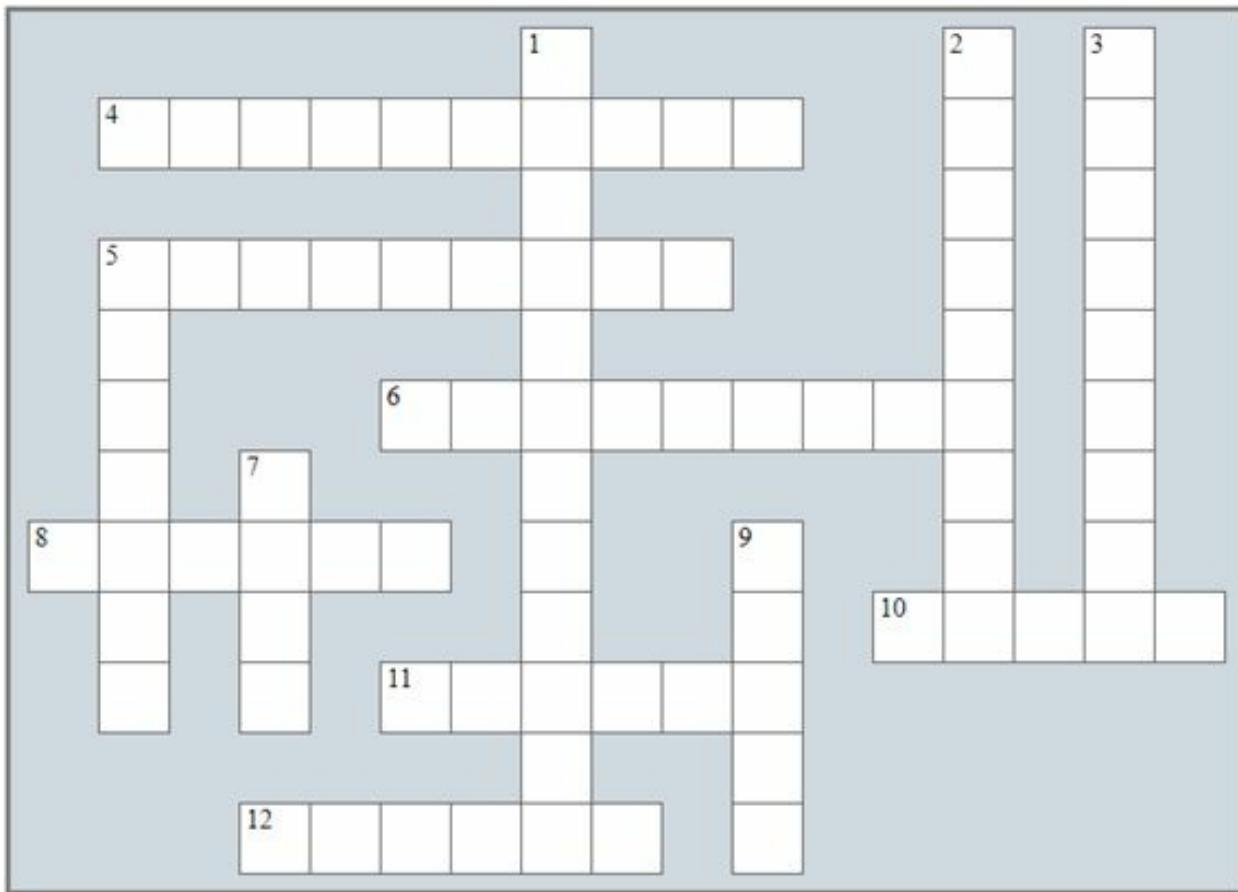
Hint: Use a dictionary to hold the Morse code.

# **Review in “Data Structures in C#**

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## **Review Crossword Puzzle**

1. Solve the following crossword puzzle.



### **Across**

---

4. Its elements can be uniquely identified using a key and not necessarily an integer value.
5. This sorting algorithm performs well on computer systems in which limited main memory (RAM) comes into play.
6. It is considered one of the best and fastest sorting algorithms.
8. A search algorithm.
10. Each array element is assigned a unique number known as an \_\_\_\_\_.
11. Another name for the sequential search algorithm.
12. A sorting algorithm.

## **Down**

---

1. In a square matrix, the collection of those elements that runs from the top right corner to the bottom left corner.
2. This sorting algorithm can prove very fast when sorting very small arrays - even faster than the quicksort algorithm.
3. A data \_\_\_\_\_ is a collection of data organized so that you can perform operations on it in the most effective way.
5. The process of putting the elements of an array in a certain order
7. In this diagonal, the elements have their row index equal to their column index.
9. A mutable data structure in C#.

## **Review Questions**

Answer the following questions.

1. What limitation do variables have that arrays don't?
2. What is a data structure?
3. What is each item of a data structure called?
4. Name six known data structures that C# supports.
5. What is an array in C#?
6. What is a dictionary in C#?
7. What does it mean when we say that an array is "mutable"?
8. What happens when a statement tries to display the value of a non-existing array element?
9. What happens when a statement tries to assign a value to a non-existing dictionary element?
10. In an array of 100 elements, what is the index of the last element?
11. What does "iterating through rows" mean?
12. What does "iterating through columns" mean?
13. What is a square matrix?
14. What is the main diagonal of a square matrix?
15. What is the antidiagonal of a square matrix?

16. Write the code fragment in general form that validates data input to an array without displaying any error messages.
17. Write the code fragment in general form that validates data input to an array and displays an error message, regardless of the type of error.
18. Write the code fragment in general form that validates data input to an array and displays an individual error message for each error.
19. What is a sorting algorithm?
20. Name five sorting algorithms.
21. Which sorting algorithm is considered the most inefficient?
22. Can a sorting algorithm be used to find the minimum or the maximum value of an array?
23. Why is a sorting algorithm not the best option to find the minimum or the maximum value of an array?
24. Write the code fragment that sorts array  $a$  of  $N$  elements in ascending order, using the bubble sort algorithm. Assume that the array contains numerical values.
25. How many compares does the bubble sort algorithm perform?
26. When does the bubble sort algorithm perform the maximum number of swaps?
27. Using the bubble sort algorithm, write the code fragment that sorts array  $a$  but preserves the relationship with the elements of array  $b$  of  $N$  elements in ascending order. Assume that the array contains numerical values.
28. Using the modified bubble sort algorithm, write the code fragment that sorts array  $a$  of  $N$  elements in ascending order. Assume that the array contains numerical values.
29. Using the selection sort algorithm, write the code fragment that sorts array  $a$  of  $N$  elements in ascending order. Assume that the array contains numerical values.
30. Using the insertion sort algorithm, write the code fragment that sorts array  $a$  of  $N$  elements in ascending order. Assume that the array contains numerical values.
31. What is a search algorithm?

32. Name the two most commonly used search algorithms.
33. What are the advantages and disadvantages of the linear search algorithm?
34. Using the linear search algorithm, write the code fragment that searches array a for value needle. Assume that the array contains numerical values.
35. What are the advantages and disadvantages of the binary search algorithm?
36. Using the binary search algorithm, write the code fragment that searches array a for value needle. Assume that the array contains numerical values and is sorted in ascending order.

# **Section 7**

## **Subprograms**

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# Chapter 35

## Introduction to Subprograms

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### 35.1 What Exactly is a Subprogram?

In computer science, a *subprogram* is a block of statements packaged as a unit that performs a specific task. A subprogram can be called in a program several times, whenever that specific task needs to be performed.

In C#, a *built-in method* is an example of such a subprogram. Take the already known `Math.Abs()` method, for example. It consists of a block of statements that are packaged as a unit under the name “abs”, and they perform a specific task—they return the absolute value of a number.

 If you are wondering what kind of statements might exist inside method `Math.Abs()`, here is a possible block of statements.

```
if (number < 0)
    return number * (-1);
else
    return number;
```

Generally speaking, there are two kinds of subprograms: *functions* and *procedures*. The difference between a function and a procedure is that a function returns a result, whereas a procedure doesn't. However, in some computer languages, this distinction may not quite be apparent. There are languages in which a function can also behave as a procedure and return no result, and there are languages in which a procedure can return one or even more than one result.

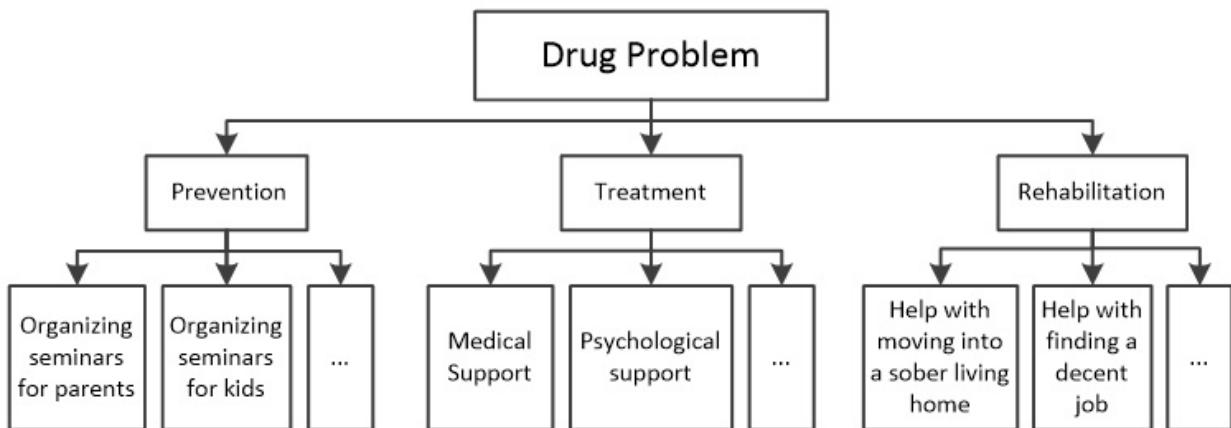
 Depending on the computer language being used, the terms “function” and “procedure” may be different. For example, in Visual Basic you can find them as “functions” and “subprocedures”, in FORTRAN as “functions” and “subroutines”, whereas in C#, the preferred terms are usually “methods” and “void methods”.

### 35.2 What is Procedural Programming?

Suppose you were assigned a project to solve the drug abuse problem in your area. One possible approach (which could prove very difficult or even

impossible) would be to try to solve this problem by yourself!

A better approach, however, would be to subdivide the large problem into smaller subproblems such as prevention, treatment, and rehabilitation, each of which could be further subdivided into even smaller subproblems, as shown in. Then, with the help of specialists from a variety of fields, you would build a team to help solve the drug problem. The following diagram shows how each subproblem could be further subdivided into even smaller subproblems, as shown in **Figure 35–1**.



**Figure 35–1** A problem can be subdivided into smaller problems

Then, as the supervisor of this project, you could rent a building and establish within it three departments: the prevention department, with all of its subdepartments; the treatment department, with all of its subdepartments; and the rehabilitation department with all of its subdepartments. Finally, you would hire staff and employ them to do the job for you!

*Procedural programming* does exactly the same thing. It subdivides an initial problem into smaller subproblems, and each subproblem is further subdivided into smaller subproblems. Finally, for each subproblem a small subprogram is written, and the main program (as does the supervisor), calls (employs) each of them to do a different part of the job.

Procedural programming has several advantages:

- ▶ It enables programmers to reuse the same code whenever it is necessary without having to copy it.
- ▶ It is relatively easy to implement.
- ▶ It helps programmers follow the flow of execution more easily.

 A very large program can prove very difficult to debug and maintain

*when it is all in one piece. For this reason, it is often easier to subdivide it into smaller subprograms, each of which performs a clearly defined process.*

### 35.3 What is Modular Programming?

In *modular programming*, subprograms of common functionality can be grouped together into separate modules, and each module can have its own set of data. Therefore, a program can consist of more than one part, and each of those parts (modules) can contain one or more smaller parts (subprograms).

☞ *The built-in Math library of C# is such an example. It contains subprograms of common functionality (related to Math), such as Abs(), Sqrt(), Sin(), Cos(), Tan(), and many more.*

If you were to use modular programming in the previous drug problem example, then you could have three separate buildings—one to host the prevention department and all of its subdepartments, a second one to host the treatment department and all of its subdepartments, and a third one to host the rehabilitation department and all of its subdepartments (as shown in **Figure 35–2**). These three buildings could be thought of as three different modules in modular programming, each of which contains subprograms of common functionality.



**Figure 35–2** Subprograms of common functionality can be grouped together into separate modules.

### 35.4 Review Questions: True/False

Choose **true** or **false** for each of the following statements.

1. A subprogram is a block of statements packaged as a unit that performs a specific task.

2. In general, there are two kinds of subprograms: functions and procedures.
3. In many computer languages, the difference between a function and a procedure is that a procedure returns a result, whereas a function does not.
4. C# supports only procedures.
5. Procedural programming subdivides the initial problem into smaller subproblems.
6. An advantage of procedural programming is the ability to reuse the same code whenever it is necessary without having to copy it.
7. Procedural programming helps programmers follow the flow of execution more easily.
8. Modular programming improves a program's execution speed.
9. In modular programming, subprograms of common functionality are grouped together into separate modules.
10. In modular programming, each module can have its own set of data.
11. Modular programming uses different structures than structured programming does.
12. A program can consist of more than one module.

# Chapter 36

## User-Defined Subprograms

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### 36.1 Subprograms that Return Values

In many computer languages, a subprogram that returns a value is called a *function*. C# calls them *methods* and there are two categories of methods. There are the *built-in methods*, such as `Math.Abs()`, `Math.Sqrt()`, and there are the *user-defined methods*, those that you actually write and use in your own programs.

The general form of a C# method that returns a value is shown here.

```
static return_type name([type1 arg1, type2 arg2, type3 arg3, ...]) {  
    Local variables declaration section  
  
    A statement or block of statements  
    return value;  
}
```

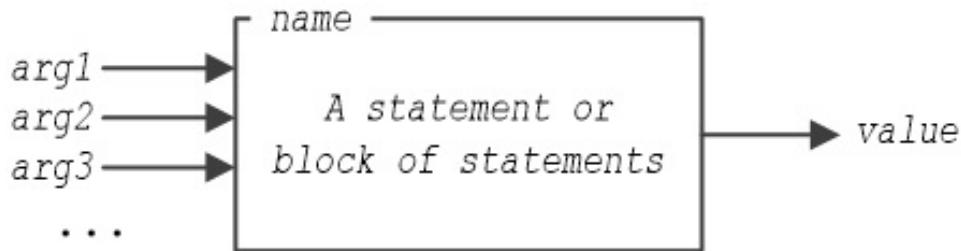
where

- ▶ *return\_type* is the data type of the value that the method returns.
- ▶ *name* is the name of the method. It follows the same rules as those used for variable names
- ▶ *arg1, arg2, arg3, ...* is a list of arguments (variables, arrays etc.) used to pass values from the caller to the method. There can be as many arguments as you need.
- ▶ *type1, type2, type3, ...* is the data type of each argument. Each argument must have a data type.
- ▶ *value* is the value returned to the caller. It can be a constant value, a variable, an expression, or even a data structure. Its data type must match the *return\_type* of the method.

 Note that arguments are optional; that is, a method may contain no arguments.

The method *name* can be likened to a box (see **Figure 36–1**) which contains a statement or block of statements. It accepts the arguments *arg1, arg2,*

`arg3, ...` as input values and returns `value` as output value.



**Figure 36–1** A method can be likened to a box

For example, the next method accepts two numbers through the arguments `num1` and `num2`, then calculates their sum and returns the result.

```
static double get_sum(double num1, double num2) {  
    double result;  
  
    result = num1 + num2;  
    return result;  
}
```

Of course, this can also be written as

```
static double get_sum(double num1, double num2) {  
    return num1 + num2;  
}
```

## 36.2 How to Make a Call to a Method

Every call to a method is as follows: you write the name of the method followed by a list of arguments (if required), either within a statement that assigns the method's returned value to a variable or directly within an expression.

Let's see some examples. The following method accepts an argument (a numeric value) and returns the result of that value raised to the power of three.

```
static double cube(double num) {  
    result = num * num * num;  
    return result;  
}
```

Now, suppose that you want to calculate a result using the following expression

$$y = \sqrt[3]{x} + \frac{1}{x}$$

You can either assign the returned value from the method `cube()` to a variable, as shown here

```
x = Double.Parse(Console.ReadLine());  
  
cb = cube(x);      //Assign the returned value to a variable  
y = cb + 1 / x;    //and use that variable  
  
Console.WriteLine(y);
```

or you can call the method directly in an expression,

```
x = Double.Parse(Console.ReadLine());  
  
y = cube(x) + 1 / x; //Call the method directly in an expression  
  
Console.WriteLine(y);
```

or you can even call the method directly in a `Console.WriteLine()` statement.

```
x = Double.Parse(Console.ReadLine());  
Console.WriteLine(cube(x) + 1 / x); //Call the method directly in a WriteLine() stateme
```

 *User-defined methods can be called just like the built-in methods of C#.*

Now let's see another example. The next C# program defines the method `get_message()` and then the main code calls it. The returned value is assigned to variable `a`.

### project\_36\_2a

```
//Define the method  
static string get_message() {  
    string msg;  
  
    msg = "Hello Zeus";  
    return msg;  
}  
  
//Main code starts here  
static void Main(string[] args) {  
    string a;  
  
    Console.WriteLine("Hi there!");  
    a = get_message();  
    Console.WriteLine(a);  
}
```

If you run this program, the following messages are displayed.



- ☞ Note that subprograms must be written outside of the main method.
- ☞ Note that a method does not execute immediately when a program starts running. The first statement that actually executes in this example is the statement `Console.WriteLine("Hi there!")`.

You can pass (send) values to a method, as long as at least one argument exists within the method's parentheses. In the next example, the method `display()` is called three times but each time a different value is passed through the argument `color`.

### project\_36\_2b

```
//Define the method
static string display(string color) {
    return "There is " + color + " in the rainbow";
}

//Main code starts here
static void Main(string[] args) {
    Console.WriteLine(display("red"));
    Console.WriteLine(display("yellow"));
    Console.WriteLine(display("blue"));
}
```

If you run this program, the following messages are displayed.



In the next example, two values must be passed to method `display()`.

### project\_36\_2c

```
static string display(string color, bool exists) {
    string neg = "";
    if (!exists) {
        neg = "n't any";
    }
    return "There is" + neg + " " + color + " in the rainbow";
}

static void Main(string[] args) {
    Console.WriteLine(display("red", true));
    Console.WriteLine(display("yellow", true));
    Console.WriteLine(display("black", false));
}
```

If you run this program the following messages are displayed.



 In C#, you can place your methods either above or below your main code. Most programmers, though, prefer to have them all on the top for better observation.

### 36.3 Subprograms that Return no Values

In computer science, a subprogram that returns no values can be known as a procedure, subprocedure, subroutine, void function, and more. In C#, the preferred term is usually *void method*.

The general form of a C# void method is

```
static void name([type1 arg1, type2 arg2, type3 arg3, ...]) {  
    Local variables declaration section  
    A statement or block of statements  
}
```

where

- ▶ *name* is the name of the void method. It follows the same rules as those used for variable names.
- ▶ *arg1, arg2, arg3, ...* is a list of arguments (variables, arrays, etc.) used to pass values from the caller to the void method. There can be as many arguments as you want.
- ▶ *type1, type2, type3, ...* is the data type of each argument. Each

argument must have a data type.

 *Note that arguments are optional; that is, a void method may contain no arguments.*

For example, the next void method accepts two numbers through the arguments num1 and num2, then calculates their sum and displays the result.

```
static void display_sum(double num1, double num2) {  
    double result;  
  
    result = num1 + num2;  
    Console.WriteLine(result);  
}
```

## 36.4 How to Make a Call to a void Method

You can call a void method by just writing its name. The next example defines the void method `display_line()` and the main code calls the void method whenever it needs to display a horizontal line.

### project\_36\_4a

```
//Define the void method  
static void display_line() {  
    Console.WriteLine("-----");  
}  
  
static void Main(string[] args) {  
    Console.WriteLine("Hello there!");  
    display_line();  
    Console.WriteLine("How do you do?");  
    display_line();  
    Console.WriteLine("What is your name?");  
    display_line();  
}
```

You can also pass (send) values to a void method, as long as at least one argument exists within void method's parentheses. In the next example, the void method `display_line()` is called three times but each time a different value is passed through the variable `length`, resulting in three printed lines of different length.

### project\_36\_4b

```
static void display_line(int length) {
```

```

int i;
for (i = 1; i <= length; i++) {
    Console.WriteLine("-");
}
Console.WriteLine();
}

static void Main(string[] args) {
    Console.WriteLine("Hello there!");
    display_line(12);
    Console.WriteLine("How do you do?");
    display_line(14);
    Console.WriteLine("What is your name?");
    display_line(18);
}

```

▀ Since the void method `display_line()` returns no value, the following line of code is **wrong**. You **cannot** assign the void method to a variable because there isn't any returned value!

```
y = display_line(12);
```

Also, you **cannot** call it within a statement. The following line of code is also **wrong**.

```
System.out.println( "Hello there!\n" + display_line(12) );
```

## 36.5 Formal and Actual Arguments

Each method (or void method) contains an argument list called a *formal argument list*. As already stated, arguments in this list are optional; the formal argument list may contain no arguments, one argument, or more than one argument.

When a subprogram (method, or void method) is called, an argument list may be passed to the subprogram. This list is called an *actual argument list*.

In the next example, variables `n1` and `n2` constitute the formal argument list whereas variables `x` and `y` as well as the expressions `x + y` and `y / 2` constitute the actual argument lists.

### ▀ project\_36\_5

```

//Define the method multiply().
//The two arguments n1 and n2 are called formal arguments.
static double multiply( [double n1, double n2] ) { [More...]

```

```

double result;

result = n1 * n2;
return result;
}

//Main code starts here
static void Main(string[] args) {
    double x, y, w;

    x = Double.Parse(Console.ReadLine());
    y = Double.Parse(Console.ReadLine());

    //Call the method multiply().
    //The two arguments x and y are called actual arguments.
    w = multiply( x, y );      [More...]
    Console.WriteLine(w);

    //Call the method multiply().
    //The two arguments x + y and y / 2 are called actual arguments.
    Console.WriteLine(multiply( x + 2, y / 2 ));      [More...]
}

```

 Note that there is a one-to-one match between the formal and the actual arguments. In the first call, the value of argument x is passed to argument n1 and the value of argument y is passed to argument n2. In the second call, the result of the expression x + 2 is passed to argument n1 and the result of the expression y / 2 is passed to argument n2.

## 36.6 How Does a Method Execute?

When the main code calls a method the following steps are performed:

- ▶ The execution of the statements of the main code is interrupted.
- ▶ The values of the variables or the result of the expressions that exist in the actual argument list are passed (assigned) to the corresponding arguments (variables) in the formal argument list, and the flow of execution goes to where the method is written.
- ▶ The statements of the method are executed.
- ▶ When the flow of execution reaches the end of the method, a value is returned from the method to the main code and the flow of execution

continues from where it was before calling the method.

In the next C# program, the method `maximum()` accepts two arguments (numeric values) and returns the greater of the two values.

### project\_36\_6

```
static double maximum(double val1, double val2) {
    double m;

    m = val1;
    if (val2 > m) {
        m = val2;
    }
    return m;
}

//Main code starts here
static void Main(string[] args) {
    double a, b, maxim;

    a = Double.Parse(Console.ReadLine());
    b = Double.Parse(Console.ReadLine());
    maxim = maximum(a, b);
    Console.WriteLine(maxim);
}
```

When the C# program starts running, the first statement executed is the statement `a = Double.Parse(Console.ReadLine())` (this is considered the first statement of the program). Suppose the user enters the values 3 and 8. Below is a trace table that shows the exact flow of execution, how the values of the variables `a` and `b` are passed from the main code to the method, and how the method returns its result.

Step	Statements of the Main Code	a	b	maxim
1	<code>a = Double.Parse(...)</code>	<b>3.0</b>	?	?
2	<code>b = Double.Parse(...)</code>	3.0	<b>8.0</b>	?
3	<code>maxim = maximum(a, b)</code>			

When the call to the method `maximum()` is made, the execution of the statements of the main code is interrupted and the values of the variables `a` and `b` are passed (assigned, if you prefer) to the corresponding arguments (variables) `val1` and `val2` and the flow of execution goes to where the

method is written. Then the statements of the method are executed.

Step	Statements of Method <code>maximum()</code>	val1	val2	m
4	<code>m = val1</code>	3.0	8.0	<b>3.0</b>
5	<code>if (val2 &gt; m)</code>	This evaluates to true		
6	<code>m = val2</code>	3.0	8.0	<b>8.0</b>
7	<code>return m</code>			

When the flow of execution reaches the end of the method, the value 8 is returned from the method to the main code (and assigned to the variable `maxim`) and the flow of execution continues from where it was before calling the method. The main code displays the value of 8 on the user's screen.

Step	Statements of the Main Code	a	b	maxim
8	<code>.WriteLine(maxim)</code>	3.0	8.0	<b>8.0</b>

### ***Exercise 36.6-1 Back to Basics – Calculating the Sum of Two Numbers***

---

*Do the following:*

- i. Write a subprogram named `total` that accepts two numeric values through its formal argument list and then calculates and returns their sum.
- ii. Using the subprogram cited above, write a C# program that lets the user enter two numbers and then displays their sum. Next, create a trace table to determine the values of the variables in each step of the C# program for two different executions.

*The input values for the two executions are: (i) 2, 4; and (ii) 10, 20.*

### ***Solution***

---

In this exercise you need to write a method that accepts two values from the caller (this is the main code) and then calculates and returns their sum. The solution is shown here.

#### **project\_36\_6\_1**

```
static double total(double a, double b) {
    double s;
```

```

        s = a + b;
        return s;
    }

    static void Main(string[] args) {
        double num1, num2, result;

        num1 = Double.Parse(Console.ReadLine());
        num2 = Double.Parse(Console.ReadLine());

        result = total(num1, num2);
        Console.WriteLine("The sum of " + num1 + " + " + num2 + " is " + result);
    }
}

```

Now, let's create the corresponding trace tables. Since you have become more experienced with them, the column "Notes" has been removed.

- For the input values of 2, 4, the trace table looks like this.

Step	Statement	Main Code			Method total()		
		num1	num2	result	a	b	s
1	num1 = Double.Parse(...)	2.0	?	?			
2	num2 = Double.Parse(...)	2.0	4.0	?			
3	result = total(num1, num2)				2.0	4.0	?
4	s = a + b				2.0	4.0	6.0
5	return s	2.0	4.0	6.0			
6	.WriteLine("The sum of "+ ...)	It displays: The sum of 2 + 4 is 6					

- For the input values of 10, 20, the trace table looks like this.

Step	Statement	Main Code			Method total()		
		num1	num2	result	a	b	s
1	num1 = Double.Parse(...)	10.0	?	?			
2	num2 = Double.Parse(...)	10.0	20.0	?			

3	result = total(num1, num2)				10.0	20.0	?
4	s = a + b				10.0	20.0	30.0
5	return s	10.0	20.0	30.0			
6	.WriteLine("The sum of "+ ...)	It displays: The sum of 10 + 20 is 30					

## ***Exercise 36.6-2 Calculating the Sum of Two Numbers Using Fewer Lines of Code!***

Rewrite the C# program of the previous exercise using fewer lines of code.

### **Solution**

The solution is shown here.

```
project_36_6_2
static double total(double a, double b) {
    return a + b;
}

static void Main(string[] args) {
    double num1, num2;

    num1 = Double.Parse(Console.ReadLine());
    num2 = Double.Parse(Console.ReadLine());

    Console.WriteLine("The sum of " + num1 + " + " + num2 + " is " + total(num1, num2));
}
```

Contrary to the solution of the previous exercise, in this method `total()` the sum is not assigned to variable `s` but it is directly calculated and returned. Furthermore, this main code doesn't assign the returned value to a variable but directly displays it.

 User-defined methods can be called just like the built-in methods of C#.

## **36.7 How Does a void Method Execute?**

When the main code calls a void method, the following steps are performed:

- ▶ The execution of the statements of the main code is interrupted.
- ▶ The values of the variables or the result of the expressions that exist in

the actual argument list are passed (assigned) to the corresponding arguments (variables) in the formal argument list and the flow of execution goes to where the void method is written.

- The statements of the void method are executed.
- When the flow of execution reaches the end of the void method, the flow of execution continues from where it was before calling the void method.

In the next C# program, the void method `minimum()` accepts three arguments (numeric values) through its formal argument list and displays the lowest value.

### project\_36\_7

```
static void minimum(double val1, double val2, double val3) {  
    double minim;  
  
    minim = val1;  
    if (val2 < minim) {  
        minim = val2;  
    }  
    if (val3 < minim) {  
        minim = val3;  
    }  
  
    Console.WriteLine(minim);  
}  
  
static void Main(string[] args) {  
    double a, b, c;  
  
    a = Double.Parse(Console.ReadLine());  
    b = Double.Parse(Console.ReadLine());  
    c = Double.Parse(Console.ReadLine());  
  
    minimum(a, b, c);  
  
    Console.WriteLine("The end");  
}
```

When the C# program starts running, the first statement executed is the statement `a = Double.Parse(Console.ReadLine())` (this is considered the first statement of the program). Suppose the user enters the values 9, 6, and 8.

Step	Statements of the Main Code	a	b	c
1	a = Double.Parse(...)	9.0	?	?
2	b = Double.Parse(...)	9.0	6.0	?
3	c = Double.Parse(...)	9.0	6.0	8.0
4	minimum(a, b, c)			

When a call to the void method `minimum()` is made, the execution of the statements of the main code is interrupted and the values of the variables a, b, and c are copied (assigned) to the corresponding arguments (variables) `val1`, `val2`, and `val3`, and the flow of execution goes to where the void method is written. Then the statements of the void method are executed.

Step	Statements of void Method <code>minimum()</code>	val1	val2	val3	minim
5	<code>minim = val1</code>	9.0	6.0	8.0	9.0
6	<code>if (val2 &lt; minim)</code>	This evaluates to true			
7	<code>minim = val2</code>	9.0	6.0	8.0	6.0
8	<code>if (val3 &lt; minim)</code>	This evaluates to false			
9	<code>.WriteLine(minim)</code>	It displays: 6			

When the flow of execution reaches the end of the void method the flow of execution simply continues from where it was before calling the void method.

Step	Statements of the Main Code	a	b	c
10	<code>.WriteLine("The end")</code>	It displays: The end		

 Note that at step 10 no values are returned from the void method to the main code.

### **Exercise 36.7-1 Back to Basics – Displaying the Absolute Value of a Number**

*Do the following:*

- i. Write a subprogram named `display_abs` that accepts a numeric value

*through its formal argument list and then displays its absolute value.  
Do not use the built-in Math.Abs() method of C#.*

- ii. *Using the subprogram cited above, write a C# program that lets the user enter a number and then displays its absolute value followed by the initial value given. Next, create a trace table to determine the values of the variables in each step of the C# program for two different executions.*

*The input values for the two executions are: (i) 5, and (ii) -5.*

## Solution

---

In this exercise you need to write a void method that accepts a value from the caller (this is the main code) and then calculates and displays its absolute value. The solution is shown here.

### project\_36\_7\_1

```
static void display_abs(double n) {
    if (n < 0) {
        n = (-1) * n;
    }
    Console.WriteLine(n);
}

static void Main(string[] args) {
    double a;

    a = Double.Parse(Console.ReadLine());
    display_abs(a);           //This displays the absolute value of given number.
    Console.WriteLine(a);      //This displays the initial number given.
}
```

Now, let's create the corresponding trace tables.

- i. For the input value of 5, the trace table looks like this.

Step Statement	Main Code	void Method display_abs()
	a	n
1	a = Double.Parse(...)	5.0
2	display_abs(a)	5.0
3	if (n < 0)	This evaluates to false

4	.WriteLine(n)	It displays: 5
5	.WriteLine(a)	It displays: 5

ii. For the input value of  $-5$ , the trace table looks like this.

Step	Statement	Main Code	void Method display_abs()
		a	n
1	a = Double.Parse(...)	-5.0	
2	display_abs(a)		-5.0
3	if (n < 0)	This evaluates to true	
4	n = (-1) * n		5.0
5	.WriteLine(n)	It displays: 5	
6	.WriteLine(a)	It displays: -5	

 Note that at step 5 the variable n of the void method contains the value 5.0 but when the flow of execution returns to the main code at step 6, the variable a of the main code contains the value  $-5.0$ . Actually, the value of variable a of the main code had never changed!

## 36.8 Review Questions: True/False

Choose **true** or **false** for each of the following statements.

1. There are two categories of subprograms that return values in C#.
2. The variables that are used to pass values to a method are called arguments.
3. The method `Trim()` is a user-defined method.
4. Every call to a user-defined method is made in the same way as a call to the built-in methods of C#.
5. There can be as many arguments as you wish in a method's formal argument list.
6. In a method, the formal argument list must contain at least one argument.

7. In a method, the formal argument list is optional.

8. A method cannot return an array.

9. The statement

```
| return x + 1;
```

is a valid C# statement.

10. A formal argument can be an expression.

11. An actual argument can be an expression.

12. A method can have no arguments in the actual argument list.

13. The next statement calls the method `cube_root()` three times.

```
| cb = cube_root(x) + cube_root(x) / 2 + cube_root(x) / 3;
```

14. The following code fragment

```
| cb = cube_root(x);  
| y = cb + 5;  
| Console.WriteLine(y);
```

displays exactly the same value as the statement

```
| Console.WriteLine(cube_root(x) + 5);
```

15. A method must always include a `return` statement whereas a void method mustn't.

16. The name `play-the-guitar` can be a valid method name.

17. In C#, you cannot place your methods below your main code.

18. When the main code calls a method, the execution of the statements of the main code is interrupted.

19. In general, it is possible for a function to return no values to the caller.

20. The method `IndexOf()` is a built-in method of C#.

21. The following code fragment

```
| static double divide(double a, double b) {  
|     return a / b;  
| }  
  
| static void Main(string[] args) {  
|     double a = 10;  
|     double b = 5;  
|     Console.WriteLine(divide(b, a));  
| }
```

displays the value 0.5.

22. In computer science, a subprogram that returns no result is known as a void function.
23. In C#, you can call a void method just by writing its name.
24. In a void method call that is made in main code, within the actual argument list there must be only variables of the main code.
25. In a void method, all formal arguments must have different names.
26. A void method must always include at least one argument in its formal argument list.
27. There is a one-to-one match between the formal and the actual arguments.
28. You can call a void method within a statement.
29. When the flow of execution reaches the end of a void method, the flow of execution continues from where it was before calling the void method.
30. A void method returns no values to the caller.
31. It is possible for a void method to accept no values from the caller.
32. A call to a void method is made differently from a call to a method.
33. In the following C# program

```
static void message() {
    Console.WriteLine("Hello Aphrodite!");
}

static void Main(string[] args) {
    Console.WriteLine("Hi there!");
    message();
}
```

the first statement that executes is the statement

`Console.WriteLine("Hello Aphrodite!");`.

## 36.9 Review Exercises

Complete the following exercises.

1. The following method contains some errors. Can you spot them?

```
static int find_max(int a int b)
    if (a > b) {
```

```
        maximum = a;
    }
    else {
        maximum = b;
    }
}
```

2. Create a trace table to determine the values of the variables in each step of the following C# program.

```
static int sum_digits(int a) {
    int d1, d2;

    d1 = a % 10;
    d2 = (int)(a / 10);
    return d1 + d2;
}

static void Main(string[] args) {
    int s, i;

    s = 0;
    for (i = 25; i <= 27; i++) {
        s += sum_digits(i);
    }
    Console.WriteLine(s);
}
```

3. Create a trace table to determine the values of the variables in each step of the following C# program.

```
static int sss(int a) {
    int k, total;

    total = 0;
    for (k = 1; k <= a; k++) {
        total += k;
    }
    return total;
}

static void Main(string[] args) {
    int i, s;

    i = 1;
    s = 0;
    while (i < 6) {
```

```

        if (i % 2 == 1) {
            s += 1;
        }
        else {
            s += sss(i);
        }
        i++;
    }
    Console.WriteLine(s);
}

```

4. Create a trace table to determine the values of the variables in each step of the following C# program when the value 12 is entered.

```

static int custom_div(int b, int d) {
    return (int)((b + d) / 2);
}

static void Main(string[] args) {
    int k, m, a, x;

    k = Int32.Parse(Console.ReadLine());
    m = 2;
    a = 1;
    while (a < 6) {
        if (k % m != 0) {
            x = custom_div(a, m);
        }
        else {
            x = a + m + custom_div(m, a);
        }
        Console.WriteLine(m + " " + a + " " + x);
        a += 2;
        m++;
    }
}

```

5. Create a trace table to determine the values of the variables in each step of the following C# program when the values 3, 7, 9, 2, and 4 are entered.

```

static void display(int a) {
    if (a % 2 == 0) {
        Console.WriteLine(a + " is even");
    }
    else {
        Console.WriteLine(a + " is odd");
    }
}

```

```

        }
    }

static void Main(string[] args) {
    int i, x;

    for (i = 1; i <= 5; i++) {
        x = Int32.Parse(Console.ReadLine());
        display(x);
    }
}

```

6. Create a trace table to determine the values of the variables in each step of the following C# program.

```

static void division(int a, int b) {
    b = (int)(b / a);
    Console.WriteLine(a * b);
}

```

```

static void Main(string[] args) {
    int x, y;

    x = 20;
    y = 30;
    while (x % y < 30) {
        division(y, x);
        x = 4 * y;
        y++;
    }
}

```

7. Create a trace table to determine the values of the variables in each step of the following C# program when the values 2, 3, and 4 are entered.

```

static void calculate(int n) {
    int j;
    double s;

    s = 0;
    for (j = 2; j <= 2 * n; j += 2) {
        s = s + Math.Pow(j, 2);
    }
    Console.WriteLine(s);
}

static void Main(string[] args) {

```

```
int i, m;

for (i = 1; i <= 3; i++) {
    m = Int32.Parse(Console.ReadLine());
    calculate(m);
}
}
```

8. Write a subprogram that accepts three numbers through its formal argument list and then returns their sum.
9. Write a subprogram that accepts four numbers through its formal argument list and then returns their average.
10. Write a subprogram that accepts three numbers through its formal argument list and then returns the greatest value.
11. Write a subprogram that accepts five numbers through its formal argument list and then displays the greatest value.
12. Write a subprogram named `my_round` that accepts a real through its formal argument list and returns it rounded to two decimal places. Try not to use the `Math.Round()` method of C#.
13. Do the following:
  - i. Write a subprogram named `find_min` that accepts two numbers through its formal argument list and returns the lowest one.
  - ii. Using the subprogram cited above, write a C# program that prompts the user to enter four numbers and then displays the lowest one.
14. Do the following:
  - i. Write a subprogram named `Kelvin_to_Fahrenheit` that accepts a temperature in degrees Kelvin through its formal argument list and returns its degrees Fahrenheit equivalent.
  - ii. Write a subprogram named `Kelvin_to_Celsius` that accepts a temperature in degrees Kelvin through its formal argument list and returns its degrees Celsius equivalent.
  - iii. Using the subprograms cited above, write a C# program that prompts the user to enter a temperature in degrees Kelvin and then displays its degrees Fahrenheit and its degrees Celsius equivalent.

It is given that

$$Kelvin = \frac{Fahrenheit + 459.67}{1.8}$$

and

$$Kelvin = Celsius + 273.15$$

15. The Body Mass Index (BMI) is often used to determine whether a person is overweight or underweight for his or her height. The formula used to calculate the BMI is

$$BMI = \frac{weight \cdot 703}{height^2}$$

Do the following:

- i. Write a subprogram named `bmi` that accepts a weight and a height through its formal argument list and then returns an action (a message) according to the following table.

BMI	Action
$BMI < 16$	You must add weight.
$16 \leq BMI < 18.5$	You should add some weight.
$18.5 \leq BMI < 25$	Maintain your weight.
$25 \leq BMI < 30$	You should lose some weight.
$30 \leq BMI$	You must lose weight.

- ii. Using the subprogram cited above, write a C# program that prompts the user to enter his or her weight (in pounds), age (in years), and height (in inches), and then displays the corresponding message. Using a loop control structure, the program must also validate data input and display an error message when the user enters
  - a. any negative value for weight
  - b. any value less than 18 for age
  - c. any negative value for height

16. Do the following:

- i. Write a subprogram named `num_of_days` that accepts a year and a

month (1 – 12) through its formal argument list and then displays the number of days in that month. Take special care when a year is a leap year; that is, a year in which February has 29 instead of 28 days.

Hint: A year is a leap year when it is exactly divisible by 4 and not by 100, or when it is exactly divisible by 400.

- ii. Using the subprogram cited above, write a C# program that prompts the user to enter a year and then displays the number of the days in each month of that year.
17. Do the following:
- i. Write a subprogram named `display_menu` that displays the following menu.
    1. Convert meters to miles
    2. Convert miles to meters
    3. Exit
  - ii. Write a subprogram named `meters_to_miles` that accepts a value in meters through its formal argument list and then displays the message “XX meters equals YY miles” where XX and YY must be replaced by actual values.
  - iii. Write a subprogram named `miles_to_meters` that accepts a value in miles through its formal argument list and then displays the message “YY miles equals XX meters” where XX and YY must be replaced by actual values.
  - iv. Using the subprograms cited above, write a C# program that displays the previously mentioned menu and prompts the user to enter a choice (of 1, 2, or 3) and a distance. The program must then calculate and display the required value. The process must repeat as many times as the user wishes. It is given that 1 mile = 1609.344 meters.
18. The LAV Cell Phone Company charges customers a basic rate of \$10 per month, and additional rates are charged based on the total number of seconds a customer talks on his or her cell phone within the month. Use the rates shown in the following table.

**Additional Rates**

<b>Number of Seconds a Customer Talks on his or her Cell Phone</b>	<b>(in USD per second)</b>
1 - 600	Free of charge
601 - 1200	\$0.01
1201 and above	\$0.02

Do the following:

- i. Write a subprogram named `amount_to_pay` that accepts a number in seconds through its formal argument list and then displays the total amount to pay. Please note that the rates are progressive. Moreover, federal, state, and local taxes add a total of 11% to each bill
- ii. Using the subprogram cited above, write a C# program that prompts the user to enter the number of seconds he or she talks on the cell phone and then displays the total amount to pay.

# Chapter 37

## Tips and Tricks with Subprograms

---

### 37.1 Can Two Subprograms use Variables of the Same Name?

Each subprogram uses its own memory space to hold the values of its variables. Even the main code has its own memory space! This means that you can have a variable named test in main code, another variable named test in a subprogram, and yet another variable named test in another subprogram. Pay attention! Those three variables are three completely different variables, in different memory locations, and they can hold completely different values.

As you can see in the program that follows, there are three variables named test in three different memory locations and each one of them holds a completely different value. The trace table below can help you understand what really goes on.

#### project\_37\_1

```
static bool f1() {
    int test;

    test = 22;
    Console.WriteLine(test);
    return true;
}

static void f2(int test) {
    Console.WriteLine(test);
}

//Main code starts here
static void Main(string[] args) {
    int test;
    bool ret;

    test = 5;
    Console.WriteLine(test);
    ret = f1();
    f2(10);
    Console.WriteLine(test);
}
```

The trace table is shown here.

Step	Statement	Notes	Main Code		Method f1()	void Method f2()
			test	ret	test	test
2	test = 5		5	?		
3	.WriteLine(test)	It displays: 5	5	?		
4	ret = f1()	f1() is called			?	
5	test = 22				22	
6	.WriteLine(test)	It displays: 22			22	
7	return true	It returns to the main code	5	true		
8	f2(10)	f2() is called				10
9	.WriteLine(test)	It displays: 10				10
10	.WriteLine(test)	It displays: 5	5	true		

 Note that variables used in a subprogram “live” as long as the subprogram is being executed. This means that before calling the subprogram, none of its variables (including those in the formal argument list) exists in main memory (RAM). They are all defined in the main memory when the subprogram is called, and they are all removed from the main memory when the subprogram finishes and the flow of execution returns to the caller. The only variables that “live” forever, or at least for as long as the C# program is being executed, are the variables of the main code and the global variables! You will learn more about global variables in [paragraph 37.7](#).

## 37.2 Can a Subprogram Call Another Subprogram?

All the time you've been reading this section, you may have had the impression that only the main code can call a subprogram. Of course, this is not true!

A subprogram can call any other subprogram which in turn can call another subprogram, and so on. You can make whichever combination you wish. For example, you can write a method that calls a void method, a void method that calls a method, a method that calls another method, or even a method that calls one of the built-in methods of the computer language that you are using to write your programs.

The next example presents exactly this situation. The main code calls the void method `display_sum()`, which in turn calls the method `add()`.

### project\_37\_2

```
static int add(int number1, int number2) {
    int result;

    result = number1 + number2;
    return result;
}

static void display_sum(int num1, int num2) {
    Console.WriteLine(add(num1, num2));
}

static void Main(string[] args) {
    int a, b;

    a = Int32.Parse(Console.ReadLine());
    b = Int32.Parse(Console.ReadLine());

    display_sum(a, b);
}
```

 When the flow of execution reaches the end of the method `add()`, it returns to its caller, that is to the void method `display_sum()`. Then, when the flow of execution reaches the end of the void method `display_sum()`, it returns to its caller, that is, to the main code.

 Note that there is no restriction on the order in which the two subprograms should be written. It would have been exactly the same if the void method `display_sum()` had been written before the method `add()`.

## 37.3 Passing Arguments by Value and by Reference

In C#, variables are passed to subprograms *by value*. This means that if the

value of an argument is changed within the subprogram, it does not get changed outside of it. Take a look at the following example.

### project\_37\_3a

```
static void f1(int b) {  
    b++;      //This is a variable of void method f1()  
    Console.WriteLine(b);      //It displays: 11  
}  
  
static void Main(string[] args) {  
    int a;  
  
    a = 10;      //This is a variable of the main code  
    f1(a);  
    Console.WriteLine(a);      //It displays: 10  
}
```

The value 10 of variable a is passed to void method f1() through argument b. However, although the content of variable b is altered within the void method, when the flow of execution returns to the main code this change does not affect the value of variable a.

In the previous example, the main code and the void method are using two variables with different names. Yet, the same would have happened if, for example, both the main code and the void method had used two variables of the same name. The next C# program operates exactly the same way and displays exactly the same results as previous program did.

### project\_37\_3b

```
static void f1(int a) {  
    a++;      //This is a variable of void method f1()  
    Console.WriteLine(a);      //It displays: 11  
}  
  
static void Main(string[] args) {  
    int a;  
  
    a = 10;      //This is a variable of the main code  
    f1(a);  
    Console.WriteLine(a);      //It displays: 10  
}
```

Still, if you want a subprogram to change the value of its arguments and also reflect this change outside of the subprogram, you must pass the arguments

by reference. To do so, you must prepend (attach) the keyword `ref` at the beginning of the argument's type both in the formal and in the actual argument lists. Take a look at the following example, in which the keyword `ref` is prepended to the argument `b` both in the formal and in the actual argument lists.

### project\_37\_3c

```
static void f1(ref int b) {
    b++;
    Console.WriteLine(b); //Value 11 is displayed
}

static void Main(string[] args) {
    int a;

    a = 10;
    f1(ref a);
    Console.WriteLine(a); //Value 11 is displayed
}
```

Be careful about one thing though: only variables can be passed by reference. You cannot pass by reference a constant value or an expression, as shown here.

### project\_37\_3d

```
static void f1(ref int b) {
    b++;
}

static void Main(string[] args) {
    int x;

    x = 9;
    f1(ref x); //This works fine!

    f1(ref 10); //This is wrong!

    f1(ref x + 1); //This is also wrong!
}
```

The second and third calls to the void method are wrong. When the flow of execution returns from the void method to the main code, the value of variable `b` must be assigned back to an argument in the actual argument list. Obviously, this cannot be done when the argument is either a constant value

or an expression.

So, as you have probably realized, passing values by reference can provide an indirect way for a subprogram to “return” one or more than one value. In the next example, the method `div_mod()` divides variable `a` by variable `b` and finds their integer quotient and their integer remainder. If all goes well, it returns true; otherwise, it returns false. Moreover, through the two arguments `int_quotient` and `int_remainder`, the method also indirectly returns the calculated quotient and the calculated remainder.

### project\_37\_3e

```
static bool div_mod(int a, int b, ref int int_quotient, ref int int_remainder) {
    bool return_value = true;
    if (b == 0) {
        return_value = false;
    }
    else {
        int_quotient = (int)(a / b);
        int_remainder = a % b;
    }
    return return_value;
}

static void Main(string[] args) {
    int val1, val2;
    int int_q = 0, int_r = 0;
    bool ret;

    val1 = Int32.Parse(Console.ReadLine());
    val2 = Int32.Parse(Console.ReadLine());
    ret = div_mod(val1, val2, ref int_q, ref int_r);
    if (ret == true) {
        Console.WriteLine(int_q + " " + int_r);
    }
    else {
        Console.WriteLine("Sorry, wrong values entered!");
    }
}
```

 *The `ref` keyword must be prepended to the argument's type, both in the formal and in the actual argument lists.*

 *A very good tactic regarding the arguments in the formal argument list is to have all of those being passed by value written before those being passed*

*by reference.*

### ***Exercise 37.3-1 Finding the Logic Error***

The following C# program is supposed to prompt the user to enter an integer and then display the product of that integer multiplied by its number of digits. For example, if the user enters the value 401, the script should display a result of  $401 \times 3 = 1203$ . Unfortunately, the C# program displays 0. Can you find out why?

#### project\_37\_3\_1

```
static int get_num_of_digits(ref int x) {
    int count = 0;
    while (x != 0) {
        count++;
        x = (int)(x / 10);
    }
    return count;
}

static void Main() {
    int val;

    val = Int32.Parse(Console.ReadLine());

    Console.WriteLine(val * get_num_of_digits(ref val));
    Console.ReadKey();
}
```

### ***Solution***

The method `get_num_of_digits()` counts the number of digits of the argument `x` using an already known method proposed in [Exercise 30.1-6](#). But before you read the answer below, can you try to find the logic error by yourself?

No? Come on, it isn't that difficult!

Still No? Do you want to give up?

So, let it be!

The problem is that, within the method `get_num_of_digits()`, variable `x` eventually becomes 0, and since the variable `val` is passed to the method by reference, that 0 also reflects back to the main code. So, when the flow of

execution returns to the main code, the value of variable val is zeroed!

To resolve this issue, all you have to do is remove the `ref` keyword at the beginning of the arguments `x` and `val`. If you do so, the variable `val` is passed to the method by value, so that no matter what happens to variable `x` within the method, nothing can affect the value of the variable `val` of the main code.

## 37.4 Passing and/or Returning an Array

Passing a data structure to a subprogram as an argument is as easy as passing a simple variable. The next example passes array `a` to the void method `display()`, and the latter displays the array.

### project\_37\_4a

```
const int ELEMENTS = 10;

static void display(int[] b) {
    int i;

    for (i = 0; i <= ELEMENTS - 1; i++) {
        Console.WriteLine(b[i] + "\t");
    }
}

static void Main(string[] args) {
    int i;

    int[] a = new int[ELEMENTS];
    for (i = 0; i <= ELEMENTS - 1; i++) {
        a[i] = Int32.Parse(Console.ReadLine());
    }

    display(a);
}
```

Contrary to variables, data structures in C# are passed by reference. This means that if you pass, for example, an array to a subprogram, and that subprogram changes the value of one or more elements of the array, these changes are also reflected outside the subprogram. Take a look at the following example.

### project\_37\_4b

```
static void f1(int[] x) {
```

```

        x[0]++;
        Console.WriteLine(x[0]); //It displays: 6
    }

    static void Main(string[] args) {
        int[] y = {5, 10, 15, 20};

        Console.WriteLine(y[0]); //It displays: 5
        f1(y);
        Console.WriteLine(y[0]); //It displays: 6
    }
}

```

 *Passing an array to a subprogram actually passes a reference to the array, not a copy of the array. The array y and the argument x are actually aliases of the same array. Since the array is shared by two references, there is only one copy in main memory (RAM). If a subprogram changes the value of an element, this change is also reflected in the main program.*

In the next example, the C# program must find the three lowest values of array t. To do so, the program calls and passes the array to the void method get\_array() through its formal argument x, which in turn sorts array x using the insertion sort algorithm. When the flow of execution returns to the main code, array t also gets sorted. This happens because, as already stated, arrays in C# are passed by reference. So what the main code finally does is just display the values of the first three elements of the array.

### project\_37\_4c

```

const int ELEMENTS = 10;

static void get_array( int[] x ) { [More...]
    int m, n, element;

    for (m = 1; m <= ELEMENTS - 1; m++) {
        element = x[m];

        n = m;
        while (n > 0 && x[n - 1] > element) {
            x[n] = x[n - 1];
            n--;
        }
        x[n] = element;
    }
}

```

```

}

static void Main(string[] args) {
    int i;

    int[] t = {75, 73, 78, 70, 71, 74, 72, 69, 79, 77};

    get_array(t);

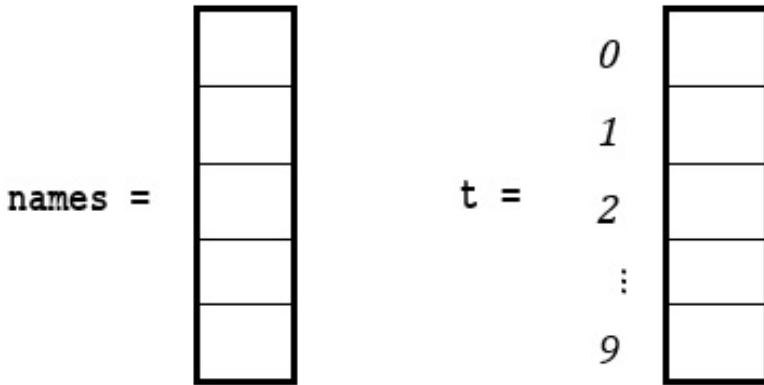
    Console.WriteLine("Three lowest values are: ");
    Console.WriteLine(t[0] + " " + t[1] + " " + t[2]);

    //In this step, array t is sorted
    for (i = 0; i <= ELEMENTS - 1; i++) {
        Console.WriteLine(t[i]);
    }
}

```

 Note that, since the array *t* of the main code is passed to the void method by reference, when the flow of execution returns to the main code, array *t* also gets sorted.

However, there are many times when passing an array by reference can be completely disastrous. Suppose you have the following two arrays. Array *names* contains the names of 10 cities, and array *t* contains their corresponding temperatures recorded at a specific hour on a specific day.



Now, suppose that for array *t* you wish to display the three lowest temperatures. If you call void method *get\_array()* of the previous C# program, you have a problem. Although the three lowest temperatures can be displayed as required, the array *t* becomes sorted; therefore, the relationship between its elements and the elements of array *names* is lost.

forever!

One possible solution would be to write a method in which the array is copied to an auxiliary array and the method would return a smaller array that contains only the three lowest values. The proposed solution is shown here.

### project\_37\_4d

```
const int ELEMENTS = 10;

static int[] get_array(int[] x) {
    int m, n, element;
    int[] aux_x = new int[ELEMENTS];

    //Copy array x to array aux_x
    for (m = 0; m <= ELEMENTS - 1; m++) {
        aux_x[m] = x[m];
    }

    //and sort array aux_x
    for (m = 1; m <= ELEMENTS - 1; m++) {
        element = aux_x[m];

        n = m;
        while (n > 0 && aux_x[n - 1] > element) {
            aux_x[n] = aux_x[n - 1];
            n--;
        }
        aux_x[n] = element;
    }

    int[] ret_array = {aux_x[0], aux_x[1], aux_x[2]};
    return ret_array;
}

static void Main(string[] args) {
    int i;

    int[] t = {75, 73, 78, 70, 71, 74, 72, 69, 79, 77};

    int[] low = get_array(t);

    Console.WriteLine("Three lowest values are: ");
    Console.WriteLine(low[0] + " " + low[1] + " " + low[2]);

    //In this step, array t is NOT sorted
```

```

    for (i = 0; i <= ELEMENTS - 1; i++) {
        Console.WriteLine(t[i]);
    }
}

```

 Note that you cannot use a statement such as `int[] aux_x = x` to copy the elements of array `x` to `aux_x`. This statement just creates two aliases of the same array. This is why a for-loop is used in the previous example to copy the elements of array `x` to the array `aux_x`.

## 37.5 Default Argument Values (Optional Arguments) and Named Arguments

If you use a default value to an argument within the formal argument list, it means that if no value is passed for that argument then the default value is used. In the next example, the function `prepend_title()` is designed to prepend (add a prefix to) a title before the name. However, if no value for argument `title` is passed, the function uses the default value “Mr”.

### project\_37\_5a

```

static string prepend_title(string name, string title = "Mr") {
    return title + " " + name;
}

static void Main(string[] args) {
    Console.WriteLine(prepend_title("John King")); //It displays: Mr John King
    Console.WriteLine(prepend_title("Maria Miller", "Ms")); // It displays: Ms Maria Mil
}

```

 When a default value is assigned to an argument within the formal argument list, this argument is called an “optional argument”.

 Within the formal argument list, any optional arguments must be on the right side of any non-optional arguments; to do the opposite of this would be incorrect.

Moreover, in C#, subprograms can be called using named arguments with the form

`argument_name: value`

C# assumes that named arguments are optional. If no argument is given in a subprogram call, the default value is used. Take a look at the following C#

program. The method `prepend_title()` is called four times. In the last call however, a named argument is used.

### project\_37\_5b

```
static string prepend_title(string first_name, string last_name,
                           string title = "Mr", bool reverse = false) {
    string return_value;
    if (!reverse)
        return_value = title + " " + first_name + " " + last_name;
    else
        return_value = title + " " + last_name + " " + first_name;

    return return_value;
}

static void Main(string[] args) {
    Console.WriteLine(prepend_title("John", "King"));           //It displays: Mr John King
    Console.WriteLine(prepend_title("Maria", "Miller", "Ms")); //It displays: Ms Maria Miller

    //Display: Ms Miller Maria
    Console.WriteLine(prepend_title("Maria", "Miller", "Ms", true));

    //Call the method using a named argument
    Console.WriteLine(prepend_title("John", "King", reverse: true)); //It displays: Mr King
}
```

 Note that the argument `reverse` is the fourth in order in the formal argument list. Using a named argument though, you can bypass this order.

 Instead of using the term “named arguments”, many computer languages such as Python and JavaScript (to name a few), prefer to use the term “keyword arguments”.

## 37.6 Overloading Methods

Method overloading is a feature that allows you to have two or more methods with the same name, as long as their formal argument lists are different. This means that you can perform overloading as long as:

- ▶ the number of arguments in each formal argument list is different; or
- ▶ the data type of the arguments in each formal argument list is different; or
- ▶ the sequence of the data type of the arguments in each formal argument

list is different.

To better understand all these concepts, let's try to analyze them using one example for each.

### Different number of arguments in each formal argument list

In the following example, there are two methods `display()`, but they have different numbers of formal arguments. The first method accepts one string through its formal argument list, while the second accepts two strings.

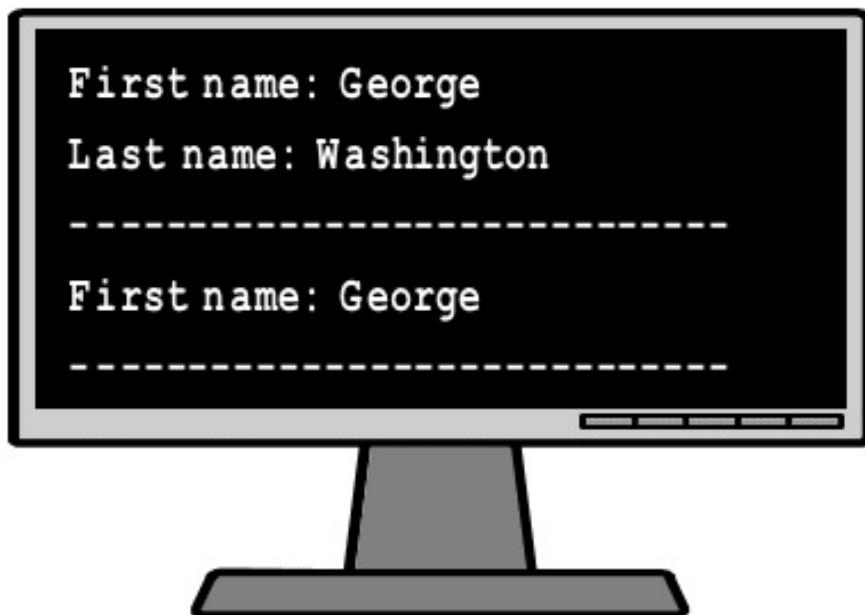
```
project_37_6a

static void display(string first_name) {
    Console.WriteLine("First name: " + first_name);
    Console.WriteLine("-----");
}

static void display(string first_name, string last_name) {
    Console.WriteLine("First name: " + first_name);
    Console.WriteLine("Last name: " + last_name);
    Console.WriteLine("-----");
}

static void Main(string[] args) {
    display("George", "Washington"); //This calls the second method
    display("George"); //This calls the first method
}
```

The output result is as follows.



## Different data type of arguments in each formal argument list

In the following example, there are two methods `my_abs()`, but their formal arguments are of different types. The first one method accepts an integer, while the second one accepts a real (a double) through its formal argument list.

### project\_37\_6b

```
static int my_abs(int a) {
    if (a < 0) {
        a *= -1;
    }
    Console.WriteLine("An integer passed: ");
    return a;
}

static double my_abs(double a) {
    if (a < 0) {
        a *= -1;
    }
    Console.WriteLine("A real passed: ");
    return a;
}

static void Main(string[] args) {
    Console.WriteLine(my_abs(-5));      //This calls the first method
    Console.WriteLine(my_abs(-5.5));    //This calls the second method
    Console.WriteLine(my_abs(-5.0));    //This calls the second method
}
```

The output result is shown here.



## Different sequence of the data types of arguments in each formal argument list

Last but not least, in the following example, there are two methods `display_date()`, but the sequence of the data types of the arguments in each formal argument list is different. The first one method accepts three arguments in the order string–integer–integer, while the second one accepts three arguments in the order integer–string–integer.

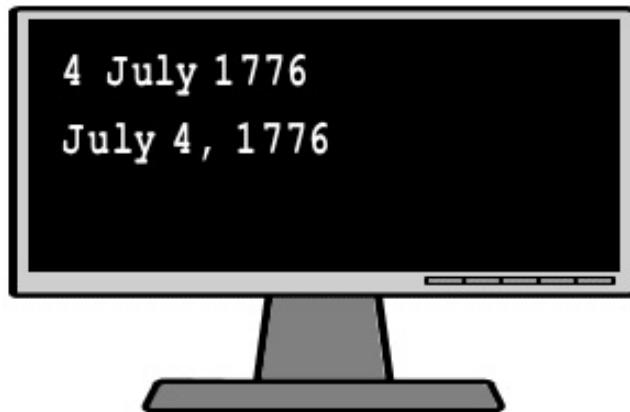
### project\_37\_6c

```
static void display_date(string month, int day, int year) {
    Console.WriteLine(month + " " + day + ", " + year);
}

static void display_date(int day, string month, int year) {
    Console.WriteLine(day + " " + month + " " + year);
}

static void Main(string[] args) {
    display_date(4, "July", 1776); //This calls the second method
    display_date("July", 4, 1776); //This calls the first method
}
```

The output result is shown here.



## 37.7 The Scope of a Variable

The *scope of a variable* refers to the range of effect of that variable. In C#, a variable can have a *local* or *global scope*. A variable declared within a subprogram has a local scope and can be accessed only from within that subprogram. On the other hand, a variable declared outside of a subprogram has a global scope and can be accessed from within **any** subprogram, as well as from the main code.

Let's see some examples. The next example declares a global variable test. The value of this global variable, though, is accessed and displayed within the void method.

### project\_37\_7a

```
static int test; //Declare test as global

static void display_value() {
    Console.WriteLine(test); //It displays: 10
}

static void Main(string[] args) {
    test = 10; //This is a global variable
    display_value();
    Console.WriteLine(test); //It displays: 10
}
```

- ☞ To declare a global variable you must prepend the C# keyword static.
- ☞ Global variables must be declared outside of the main method. Most programmers prefer to have them all on the top for better observation.

Be careful though! If the value of a global variable is altered within a subprogram, this change is also reflected outside of the subprogram. In the next example, the void method `display_value()` increases the value of variable `test` to 11, and when the flow of execution returns to the main code, variable `test` still contains the value 11.

### project\_37\_7b

```
static int test; //Declare test as global

static void display_value() {
    test++;
    Console.WriteLine(test); //It displays: 11
}

static void Main(string[] args) {
    test = 10;
    Console.WriteLine(test); //It displays: 10
    display_value();
    Console.WriteLine(test); //It displays: 11
}
```

The next program declares a global variable `test`, a local variable `test`

within the void method `display_valueA()`, and another local variable test within the void method `display_valueB()`. Keep in mind that the global variable test and the two local variables test are three different variables! Furthermore, the third method `display_valueC()` uses and alters the value of the global variable test. This is because there isn't any local variable test declared within this method.

### project\_37\_7c

```
static int test; //Global variable test

static void display_valueA() {
    int test; //Local variable test

    test = 7;
    Console.WriteLine(test); //It displays: 7
}

static void display_valueB() {
    int test; //Local variable test

    test = 9;
    Console.WriteLine(test); //It displays: 9
}

static void display_valueC() {
    //Use the value of the global variable test
    Console.WriteLine(test); //It displays: 10
    test++; //Increase the value of the global variable test
}

static void Main(string[] args) {
    test = 10; //This is the global variable test

    Console.WriteLine(test); //It displays: 10
    display_valueA();
    Console.WriteLine(test); //It displays: 10
    display_valueB();
    Console.WriteLine(test); //It displays: 10
    display_valueC();
    Console.WriteLine(test); //It displays: 11
}
```

 You can have variables of local scope of the same name within different

*subprograms, because they are recognized only by the subprogram in which they are declared.*

## 37.8 Converting Parts of Code into Subprograms

Writing large programs without subdividing them into smaller subprograms results in a code that cannot be easily understood or maintained. Suppose you have a large program and you wish to subdivide it into smaller subprograms. The next program is an example explaining the steps that must be followed. The parts of the program marked with a dashed rectangle must be converted into subprograms.

### project\_37\_8a

```
static void Main(string[] args) {
    int total_yes, female_no, i;
    string temp1, gender, temp2, answer;

    total_yes = 0;
    female_no = 0;
    for (i = 1; i <= 100; i++) {
        do {
            Console.WriteLine("Enter gender for citizen No " + i + ": ");
            temp1 = Console.ReadLine();
            gender = temp1.ToLower();
        } while (gender != "male" && gender != "female");
    }

    do {
        Console.WriteLine("Do you go jogging in the afternoon? ");
        temp2 = Console.ReadLine();
        answer = temp2.ToLower();
    } while (answer != "yes" && answer != "no" && answer != "sometimes");

    if (answer == "yes") {
        total_yes++;
    }

    if (gender == "female" && answer == "no") {
        female_no++;
    }
}
```

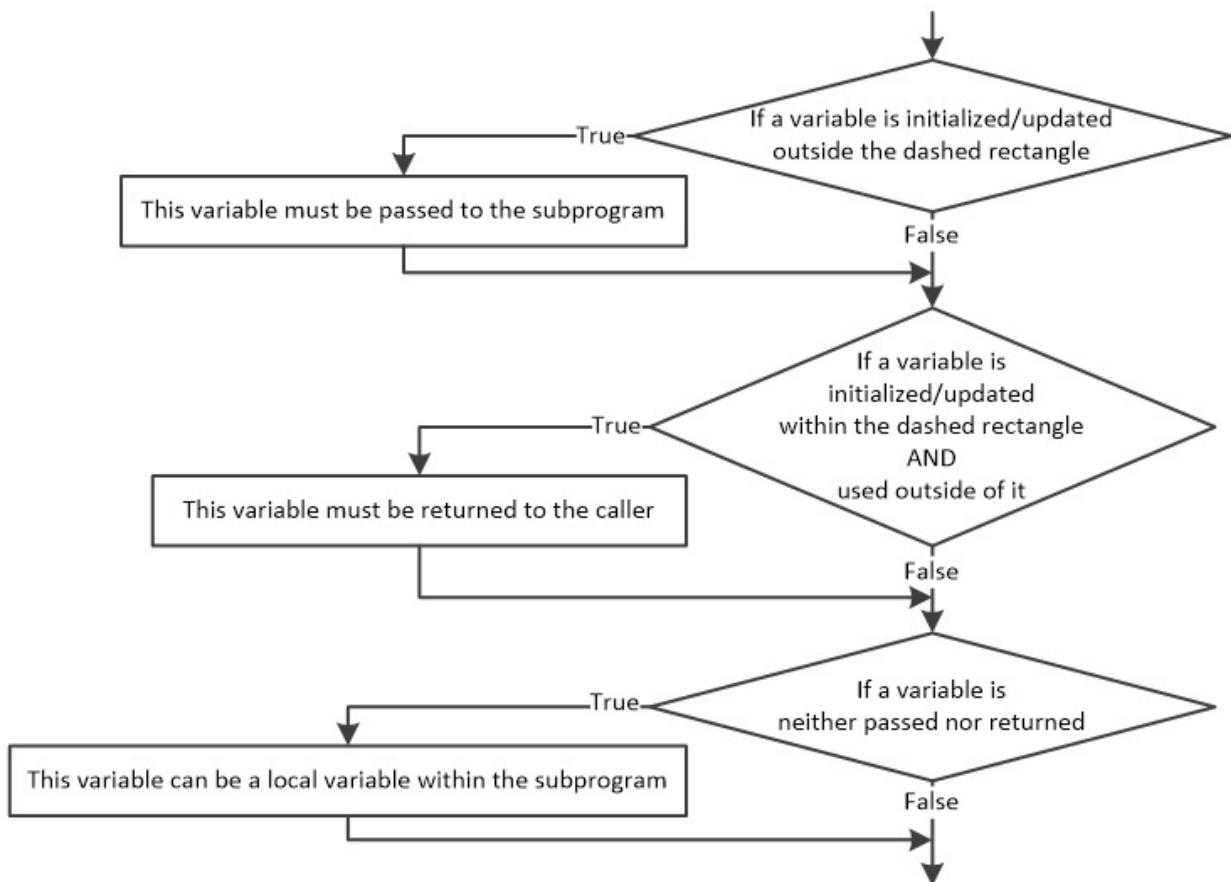
```

        Console.WriteLine("Total positive answers: " + total_yes);
        Console.WriteLine("Women's negative answers: " + female_no);
    }
}

```

To convert parts of this program into subprograms you must:

- ▶ decide, for each dashed rectangle, whether to use a method or a void method. This depends on whether or not, the subprogram will return a result.
- ▶ determine which variables exist in each dashed rectangle and their roles in that dashed rectangle. The flowchart that follows can help you decide what to do with each variable, whether it must be passed to the subprogram and/or returned from the subprogram, or if it must just be a local variable within the subprogram.



So, with the help of this flowchart, let's discuss each dashed rectangle independently! The parts that are **not** marked with a dashed rectangle will comprise the main code.

## First part

In the first dashed rectangle, there are three variables: `i`, `temp1`, and `gender`. However, not all of them must be included in the formal argument list of the subprogram that will replace the dashed rectangle. Let's find out why!

► Variable `i`:

- is initialized/updated outside the dashed rectangle; thus, it must be passed to the subprogram
- is not updated within the dashed rectangle; thus, it should not be returned to the caller

► Variable `temp1`:

- is not initialized/updated outside of the dashed rectangle; thus, it should not be passed to the subprogram
- is initialized within the dashed rectangle but its value is not used outside of it; thus, it should not be returned to the caller

According to the flowchart, since variable `temp1` should neither be passed nor returned, this variable can just be a local variable within the subprogram.

► Variable `gender`:

- is not initialized/updated outside of the dashed rectangle; thus, it should not be passed to the subprogram
- is initialized within the dashed rectangle and its value is used outside of it; thus, it must be returned to the caller

Therefore, since one value must be returned to the main code, a method can be used as shown here.

```
static string part1(int i) {
    string gender, temp1;

    do {
        Console.WriteLine("Enter gender for citizen No " + i + ": ");
        temp1 = Console.ReadLine();
        gender = temp1.ToLower();
    } while (gender != "male" && gender != "female");

    return gender;
}
```

 Method's data type must match the data type of the value returned.

## Second part

In the second dashed rectangle there are two variables, `temp2` and `answer`, but they do not both need to be included in the formal argument list of the subprogram that will replace the dashed rectangle. Let's find out why!

► Variable `temp2`:

- is not initialized/updated outside of the dashed rectangle; thus, it should not be passed to the subprogram
- is initialized/updated within the dashed rectangle but its value is not used outside of it; thus, it should not be returned to the caller

According to the flowchart, since variable `temp2` should neither be passed nor returned, this variable can just be a local variable within the subprogram.

► Variable `answer`:

- is not initialized/updated outside of the dashed rectangle; thus, it should not be passed to the subprogram
- is initialized within the dashed rectangle and its value is used outside of it; thus, it must be returned to the caller

Therefore, since one value must be returned to the main code, a method can be used, as shown here.

```
static string part2() {
    string temp2, answer;

    do {
        Console.WriteLine("Do you go jogging in the afternoon? ");
        temp2 = Console.ReadLine();
        answer = temp2.ToLower();
    } while (answer != "yes" && answer != "no" && answer != "sometimes");

    return answer;
}
```

## Third part

In the third dashed rectangle there are four variables: `answer`, `total_yes`, `gender` and `female_no`. Let's see what you should do with them.

► Both variables `answer` and `gender`:

- are initialized/updated outside of the subprogram; thus, they must

- be passed to the subprogram
- are not updated within the subprogram; thus, they should not be returned to the caller
- Both variables `total_yes` and `female_no`:
  - are initialized outside of the subprogram; thus, they must be passed to the subprogram
  - are updated within the subprogram and their value is used outside of it; thus, they must be returned to the caller

Therefore, since two values must be returned to the main code, a void method can be used. The variables `total_yes` and `female_no` must be passed by reference so that their values can be returned to the main code (indirectly), as shown here.

```
static void part3(string answer, string gender, ref int total_yes, ref int female_no) {
    if (answer == "yes") {
        total_yes++;
    }

    if (gender == "female" && answer == "no") {
        female_no++;
    }
}
```

 A very good tactic regarding the argument in the formal argument list is to have all of those being passed by value before those being passed by reference.

## Fourth part

In the fourth dashed rectangle of the example, there are two variables: `total_yes` and `female_no`. Let's see what you should do with them.

- Both variables `total_yes` and `female_no`:
  - are updated outside of the dashed rectangle; thus, they must be passed to the subprogram
  - are not updated within the dashed rectangle; thus, they should not be returned to the caller

Therefore, since no value should be returned to the main code, a void method can be used, as follows.

```
static void part4(int total_yes, int female_no) {
    Console.WriteLine("Total positive answers: " + total_yes);
    Console.WriteLine("Women's negative answers: " + female_no);
}
```

## The final program

The final program, including the main code and all the subprograms cited above, is shown here.

### project\_37\_8b

```
static string part1(int i) {
    string gender, temp1;

    do {
        Console.Write("Enter gender for citizen No " + i + ": ");
        temp1 = Console.ReadLine();
        gender = temp1.ToLower();
    } while (gender != "male" && gender != "female");

    return gender;
}

static string part2() {
    string temp2, answer;

    do {
        Console.Write("Do you go jogging in the afternoon? ");
        temp2 = Console.ReadLine();
        answer = temp2.ToLower();
    } while (answer != "yes" && answer != "no" && answer != "sometimes");

    return answer;
}

static void part3(string answer, string gender, ref int total_yes, ref int female_no) {
    if (answer == "yes") {
        total_yes++;
    }

    if (gender == "female" && answer == "no") {
        female_no++;
    }
}

static void part4(int total_yes, int female_no) {
```

```

        Console.WriteLine("Total positive answers: " + total_yes);
        Console.WriteLine("Women's negative answers: " + female_no);
    }

    static void Main(string[] args) {
        int i, total_yes, female_no;
        string gender, answer;

        total_yes = 0;
        female_no = 0;
        for (i = 1; i <= 100; i++) {
            gender = part1(i);
            answer = part2();

            part3(answer, gender, ref total_yes, ref female_no);
        }

        part4(total_yes, female_no);
    }
}

```

## 37.9 Recursion

*Recursion* is a programming technique in which a subprogram calls itself. This might initially seem like an endless loop, but of course this is not true; a subprogram that uses recursion must be written in a way that obviously satisfies the property of finiteness.

Imagine that the next C# program helps you find your way home. In this program, recursion occurs because the void method `find_your_way_home()` calls itself within the method.

```

static void find_your_way_home() {
    if (you_are_already_at_home) {
        stop_walking();
    }
    else {
        take_one_step_toward_home();
        find_your_way_home();
    }
}

static void Main(string[] args) {
    find_your_way_home();
}

```

Now, let's try to analyze recursion through a real example. The next C#

program calculates the factorial of 5 using recursion.

### project\_37\_9

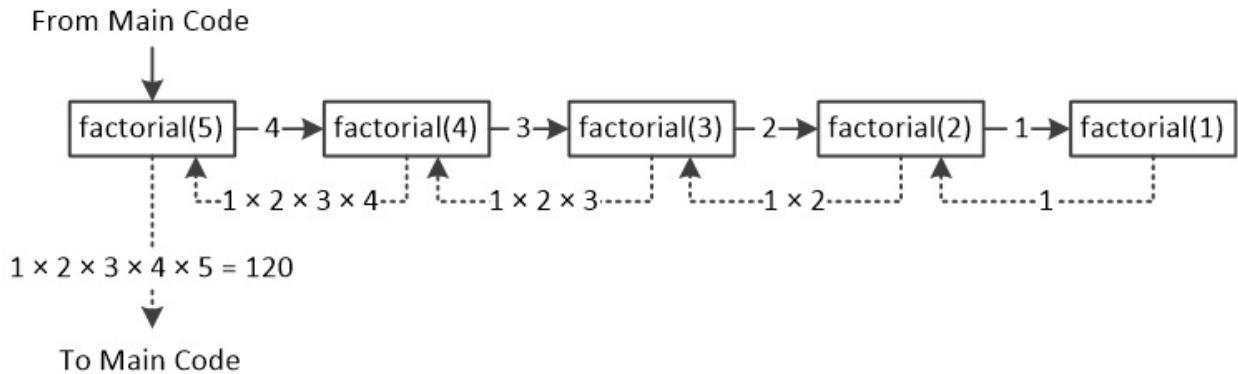
```
static int factorial(int value) {  
    int return_value;  
  
    if (value == 1) {  
        return_value = 1;  
    }  
    else {  
        return_value = value * factorial(value - 1);  
    }  
  
    return return_value;  
}  
  
static void Main(string[] args) {  
    Console.WriteLine(factorial(5));      //It displays: 120  
}
```

 In mathematics, the factorial of a non-negative integer  $N$  is the product of all positive integers less than or equal to  $N$ . It is denoted by  $N!$  and the factorial of 0 is, by definition, equal to 1. For example, the factorial of 5 is  $1 \times 2 \times 3 \times 4 \times 5 = 120$ .

 Recursion occurs because the method `factorial()` calls itself within the method.

 Note that there isn't any loop control structure!

You are probably confused right now. How on Earth is the product  $1 \times 2 \times 3 \times 4 \times 5$  calculated without using a loop control structure? The next diagram may help you understand. It shows the multiplication operations that are performed as method `factorial(5)` works its way backwards through the series of calls.



Let's see how this diagram works. The main code calls the method `factorial(5)`, which in turn calls the method `factorial(4)`, and the latter calls the method `factorial(3)`, and so on. The last call (`factorial(1)`) returns to its caller (`factorial(2)`) the value 1, which in turn returns to its caller (`factorial(3)`) the value  $1 \times 2 = 2$ , and so on. When the method `factorial(5)` returns from the topmost call, you have the final solution.

In conclusion, all recursive subprograms must follow three important rules.

1. They must have a base case
2. They must change their state and move toward the base case
3. They must call themselves

where

- ▶ the base case is the condition that "tells" the subprogram to stop recursions. The base case is usually a very small problem that can be solved directly. It is the solution to the "simplest" possible problem. In the method `factorial()` of the previous example, the base case is the factorial of 1. When `factorial(1)` is called, the Boolean expression (`value == 1`) evaluates to true and marks the end of the recursions.
- ▶ a change of state means that the subprogram alters some of its data. Usually, data are getting smaller and smaller in some way. In the method `factorial()` of the previous example, since the base case is the factorial of 1, the whole concept relies on the idea of moving toward that base case.
- ▶ The last rule just states the obvious; the subprogram must call itself.

### **Exercise 37.9-1 Calculating the Fibonacci Sequence Recursively**

*The Fibonacci sequence is a series of numbers in the following sequence:*

1, 1, 2, 3, 5, 8, 13, 21, 34, 55, ...

*By definition, the first two numbers are 1 and 1 and each subsequent number is the sum of the previous two.*

*Write a C# program that lets the user enter a positive integer N and then calculates recursively and finally displays the N<sup>th</sup> term of the Fibonacci series.*

## **Solution**

---

In the following C# program, the method `fib()` calculates the N<sup>th</sup> term of the Fibonacci series recursively. This is probably not the best algorithm in the world. It is mentioned here, however, just to show you how recursion can sometimes make things worse!

### project\_37\_9\_1

```
static int fib(int n) {
    int return_value;

    if (n == 0 || n == 1) {
        return_value = n;
    }
    else {
        return_value = fib(n - 1) + fib(n - 2);
    }
    return return_value;
}

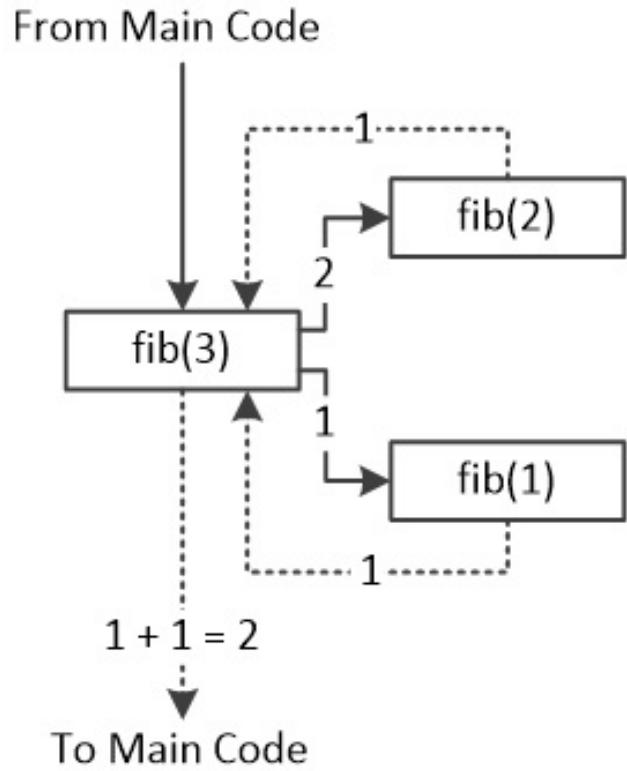
static void Main(string[] args) {
    int num;

    num = Int32.Parse(Console.ReadLine());
    Console.WriteLine(fib(num));
}
```

To explain how this method works, the best thing to do is use some input values.

### **For input value 3**

If the user enters a value of 3, the following recursive calls are made.



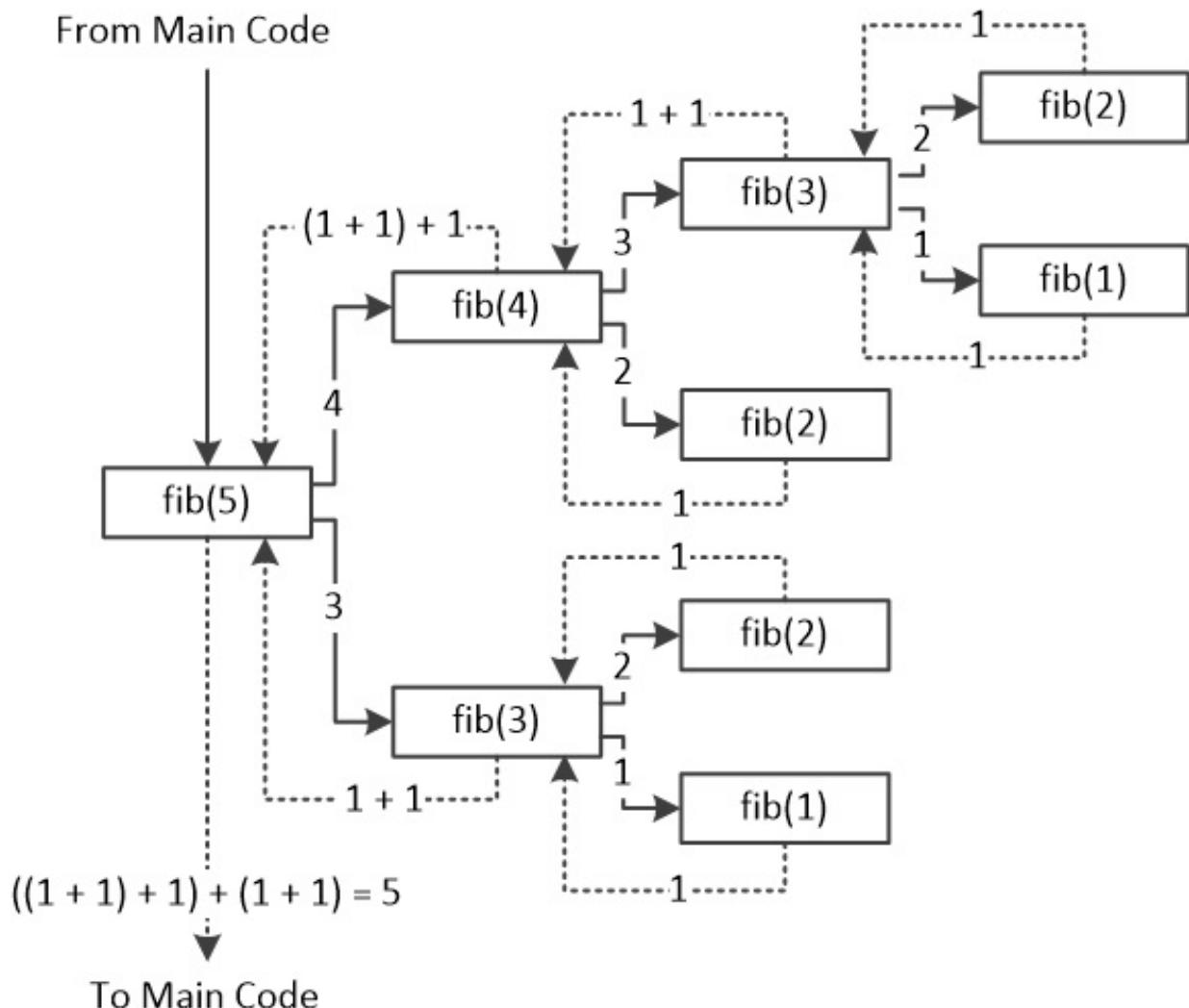
If you calculate the results of these recursive calls, you have

$$1 + 1 = 2$$

This is correct! The 3<sup>rd</sup> term of the Fibonacci series is 2.

### For input value 5

If the user enters a value of 5, the following recursive calls are made.



If you calculate the results of these recursive calls, you have

$$((1+1)+1)+(1+1)=5$$

This is also correct! The 5<sup>th</sup> term of the Fibonacci series is 5.

 Please note that for each succeeding term of the Fibonacci series, the number of calls increments exponentially. For example, the calculation of the 50<sup>th</sup> or the 60<sup>th</sup> term of the Fibonacci series using this method can prove tragically slow!

Recursion helps you write more creative and more elegant programs, but keep in mind that it is not always the best option. The main disadvantage of recursion is that it is hard for a programmer to think through the logic, and therefore it is difficult to debug a code that contains a recursive subprogram.

Furthermore, a recursive algorithm may prove worse than a non-recursive algorithm because it may consume too much CPU time and/or too much main memory (RAM). So, there are times where it would be better to follow the KISS principle and, instead of using a recursion, solve the algorithm using loop control structures.

 *For you who don't know what the KISS principle is, it is an acronym for "Keep It Simple, Stupid"! It states that most systems work best if they are kept simple, avoiding any unnecessary complexity!*

### 37.10 Review Questions: True/False

Choose **true** or **false** for each of the following statements.

1. Each subprogram uses its own memory space to hold the values of its variables.
2. Variables used in a subprogram "live" as long as the subprogram is being executed.
3. The only variables that "live" for as long as the C# program is being executed are the variables of the main code and the global variables.
4. A subprogram can call the main code.
5. If an argument is passed by value and its value is changed within the subprogram, it does not get changed outside of it.
6. The name of an actual argument and the name of the corresponding formal argument must be the same.
7. Supposing that there are no optional arguments, the total number of formal arguments cannot be greater than the total number of actual arguments.
8. An expression cannot be passed to a subprogram.
9. Arrays in C# are passed by reference.
10. You can pass an array to a void method but a void method cannot return an array to the caller.
11. A method can accept an array through its formal argument list.
12. In general, a void function can call any function.
13. In general, a function can call any void function.

14. Within a statement, a method can be called only once.
15. A void method can return a value through its formal argument list.
16. A subprogram can be called by another subprogram or by the main code.
17. Optional arguments should be on the left side of any non-optional arguments.
18. Overloading is a feature in C# that allows you to have two or more arguments with the same name.
19. Overloading is a feature in C# that allows you to have two or more methods of different names as long as they have exactly the same formal argument list.
20. You cannot perform overloading when the sequence of the data type of the arguments in the formal argument lists is different.
21. The scope of a variable refers to the range of effect of that variable.
22. If the value of a global variable is altered within a subprogram, this change is reflected outside the subprogram as well.
23. You can have two variables of global scope of the same name.
24. Recursion is a programming technique in which a subprogram calls itself.
25. A recursive algorithm must have a base case.
26. Using recursion to solve a specific problem is not always the best option.

## 37.11 Review Exercises

Complete the following exercises.

1. Without using a trace table, can you find out what the next C# program displays?

```
static void f1() {
    int a = 22;
}

static void f2() {
    int a = 33;
}
```

```
static void Main(string[] args) {
    int a;

    a = 5;
    f1();
    f2();

    Console.WriteLine(a);
}
```

2. Without using a trace table, can you find out what the next C# program displays?

```
static int f1(int number1) {
    return 2 * number1;
}

static int f2(int number1, int number2) {
    return f1(number1) + f1(number2);
}

static void Main(string[] args) {
    int a, b;

    a = 3;
    b = 4;

    Console.WriteLine(f2(a, b));
}
```

3. Without using a trace table, can you find out what the next C# program displays?

```
static int f1(int number1) {
    return 2 * number1;
}

static int f2(int number1, int number2) {
    number1 = f1(number1);
    number2 = f1(number2);

    return number1 + number2;
}

static void Main(string[] args) {
    int a, b;
```

```

    a = 2;
    b = 5;

    Console.WriteLine(f2(a, b));
}

```

4. Create a trace table to determine the values of the variables in each step of the following C# program when the value 12 is entered.

```

static int[] arr = new int[2];

static void swap(int x, int y) {
    int temp;

    temp = arr[x];
    arr[x] = arr[y];
    arr[y] = temp;
}

static void Main(string[] args) {
    int x, k;

    k = Int32.Parse(Console.ReadLine());
    arr[1] = 1;
    arr[0] = 1;
    while (arr[0] < 8) {
        if (k % arr[1] != 0) {
            x = arr[0] % arr[1];
            swap(1, 0);
        }
        else {
            x = arr[0] + arr[1] + (int)(arr[0] - arr[1]);
        }

        Console.WriteLine(arr[1] + " " + arr[0] + " " + x);

        arr[0] += 2;
        arr[1]++;
        swap(0, 1);
    }
}

```

5. Without using a trace table, can you find out what the next C# program displays?

```

static void display(string str) {
    str = str.Replace("a", "e");
}

```

```

        Console.WriteLine(str);
    }

    static void display() {
        Console.WriteLine("hello");
    }

    static void Main(string[] args) {
        display("hello");
        display();
        display("hallo");
    }
}

```

6. Without using a trace table, can you find out what the next C# program displays?

```

static int a, b;

static void f1() {
    a = a + b;
}

static void Main(string[] args) {
    a = 10;
    b = 5;
    f1();
    b--;

    Console.WriteLine(a);
}

```

7. Without using a trace table, can you find out what the next C# program displays?

```

static int a, b;

static void f1() {
    a = a + b;
    f2();
}

static void f2() {
    a = a + b;
}

static void Main(string[] args) {
    a = 3;
}

```

```
b = 4;  
f1();  
Console.WriteLine(a + " " + b);  
}
```

8. For the following C# program, convert the parts marked with a dashed rectangle into subprograms.

```
const int STUDENTS = 10;  
const int LESSONS = 5;  
  
static void Main(string[] args) {  
    int i, j, m, n;  
    double temp;  
    string temp_str;  
  
    string[] names = new string[STUDENTS];  
    int[,] grades = new int[STUDENTS, LESSONS];  
  
    for (i = 0; i <= STUDENTS - 1; i++) {  
        Console.Write("Enter name No" + (i + 1) + ": ");  
        names[i] = Console.ReadLine();  
        for (j = 0; j <= LESSONS - 1; j++) {  
            Console.Write("Enter grade for lesson No" + (j + 1) + ": ");  
            grades[i, j] = Int32.Parse(Console.ReadLine());  
        }  
    }  
  
    double[] average = new double[STUDENTS];  
    for (i = 0; i <= STUDENTS - 1; i++) {  
        average[i] = 0;  
        for (j = 0; j <= LESSONS - 1; j++) {  
            average[i] += grades[i, j];  
        }  
        average[i] /= LESSONS;  
    }  
}
```

```

    for (m = 1; m <= STUDENTS - 1; m++) {
        for (n = STUDENTS - 1; n >= m; n--) {
            if (average[n] > average[n - 1]) {
                temp = average[n];
                average[n] = average[n - 1];
                average[n - 1] = temp;

                temp_str = names[n];
                names[n] = names[n - 1];
                names[n - 1] = temp_str;
            }
            else if (average[n] == average[n - 1]) {
                if (names[n].CompareTo(names[n - 1]) < 0) {
                    temp_str = names[n];
                    names[n] = names[n - 1];
                    names[n - 1] = temp_str;
                }
            }
        }
    }

    for (i = 0; i <= STUDENTS - 1; i++) {
        Console.WriteLine(names[i] + "\t" + average[i]);
    }
}

```

9. For the following C# program, convert the parts marked with a dashed rectangle into subprograms.

```

static void Main(string[] args) {
    int i, middle_pos, j;
    string message, message_clean, letter, left_letter, right_letter;
    bool palindrome;

    Console.Write("Enter a message: ");
    message = Console.ReadLine().ToLower(),
}

```

```

message_clean = "";
for (i = 0; i <= message.Length - 1; i++) {
    letter = "" + message[i];
    if (letter != " " && letter != "," && letter != "." && letter != "?") {
        message_clean += letter;
    }
}

middle_pos = (int)((message_clean.Length - 1) / 2);
j = message_clean.Length - 1;
palindrome = true;
for (i = 0; i <= middle_pos; i++) {
    left_letter = "" + message_clean[i];
    right_letter = "" + message_clean[j];
    if (left_letter != right_letter) {
        palindrome = false;
        break;
    }
    j--;
}
}

if (palindrome) {
    Console.WriteLine("The message is palindrome");
}
}

```

10. The next C# program finds the greatest value among four values given. Rewrite the program without using subprograms.

```

static int my_max(int n, int m) {
    if (n > m) {
        m = n;
    }
    return m;
}

static void Main(string[] args) {
    int a, b, c, d, maximum;

    a = Int32.Parse(Console.ReadLine());
    b = Int32.Parse(Console.ReadLine());
    c = Int32.Parse(Console.ReadLine());
    d = Int32.Parse(Console.ReadLine());

    maximum = a;
}

```

```
maximum = my_max(b, maximum);
maximum = my_max(c, maximum);
maximum = my_max(d, maximum);

Console.WriteLine(maximum);
}
```

11. Write a void method that accepts three numbers through its formal argument list and then returns their sum and their average.  
Hint: Use an array within the formal argument list to “return” the required values.
12. Write a subprogram named `my_round` that accepts a real (a float) and an integer through its formal argument list and then returns the real rounded to as many decimal places as the integer indicates. Moreover, if no value is passed for the integer, the subprogram must return the real rounded to two decimal places by default. Try not to use the `Math.Round()` method of C#.
13. Do the following:
  - i. Write a subprogram named `get_input` that prompts the user to enter an answer “yes” or “no” and then returns the value `true` or `false` correspondingly to the caller. Make the subprogram accept the answer in all possible forms such as “yes”, “YES”, “Yes”, “No”, “NO”, “nO”, and so on.
  - ii. Write a subprogram named `find_area` that accepts the base and the height of a parallelogram through its formal argument list and then returns its area.
  - iii. Using the subprograms cited above, write a C# program that prompts the user to enter the base and the height of a parallelogram and then calculates and displays its area. The program must iterate as many times as the user wishes. At the end of each calculation, the program must ask the user whether he or she wishes to calculate the area of another parallelogram. If the answer is “yes” the program must repeat.
14. Do the following:
  - i. Write a subprogram named `get_arrays` that prompts the user to enter the grades and the names of 100 students into the arrays `grades` and `names`, correspondingly. The two arrays must be

- returned to the caller.
- ii. Write a subprogram named `get_average` that accepts the array `grades` through its formal argument list and returns the average grade.
  - iii. Write a subprogram named `sort_arrays` that accepts the arrays `grades` and `names` through its formal argument list and sorts the array `grades` in descending order using the insertion sort algorithm. The subprogram must preserve the relationship between the elements of the two arrays.
  - iv. Using the subprograms cited above, write a C# program that prompts the user to enter the grades and the names of 100 students and then displays all student names whose grade is less than the average grade, sorted by grade in descending order.
15. In a song contest, there is an artist who is scored by 10 judges. However, according to the rules of this contest, the total score is calculated after excluding the maximum and the minimum score. Do the following:
- i. Write a subprogram named `get_array` that prompts the user to enter the scores of the 10 judges into an array and then returns the array to the caller. Assume that each score is unique.
  - ii. Write a subprogram named `find_min_max` that accepts an array through its formal argument list and then returns the maximum and the minimum value.
  - iii. Using the subprograms cited above, write a C# program that prompts the user to enter the name of the artist and the score he or she gets from each judge. The program must then display the message “Artist NN got XX points” where NN and XX must be replaced by actual values.
16. On a chessboard you must place grains of wheat on each square, such that one grain is placed on the first square, two on the second, four on the third, and so on (doubling the number of grains on each subsequent square). Do the following:
- i. Write a recursive method named `woc` that accepts the index of a square and returns the number of grains of wheat that are on this square. Since a chessboard contains  $8 \times 8 = 64$  squares, assume that

the index is an integer between 1 and 64.

- ii. Using the subprogram cited above, write a C# program that calculates and displays the total number of grains of wheat that are on the chessboard in the end.

17. Do the following:

- i. Write a recursive method named `factorial` that accepts an integer through its formal argument list and then returns its factorial.
- ii. Using the method cited above, write a recursive method named `my_cos` that calculates and returns the cosine of  $x$  using the Taylor series, shown next.

$$\cos x = 1 - \frac{x^2}{2!} + \frac{x^4}{4!} - \frac{x^6}{6!} + \dots + \frac{x^{40}}{40!}$$

Hint: Keep in mind that  $x$  is in radians and  $\frac{x^0}{0!} = 1$ .

- iii. Using the method `my_cos()` cited above, write a C# program that calculates and displays the cosine of  $45^\circ$ .

# Chapter 38

## More Exercises with Subprograms

---

### 38.1 Simple Exercises with Subprograms

#### *Exercise 38.1-1 Designing the Flowchart*

---

*Design the flowchart that corresponds to the following C# program.*

```
static int find_sum(int n) {
    int i;
    int s = 0;

    for (i = 1; i <= n; i++) {
        s = s + i;
    }
    return s;
}

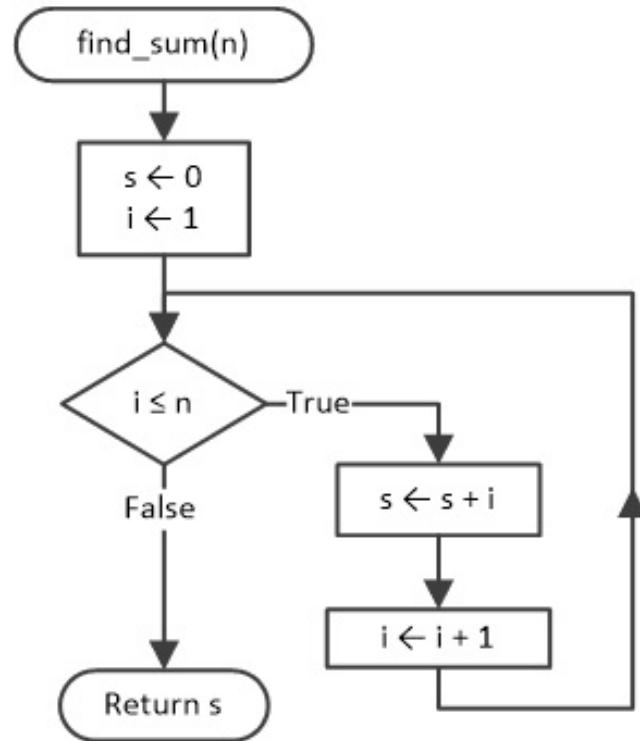
static void Main(string[] args) {
    int n;

    Console.WriteLine("Enter a positive integer ");
    n = Int32.Parse(Console.ReadLine());
    while (n > 0) {
        Console.WriteLine(find_sum(n));
        Console.WriteLine("Enter a positive integer ");
        n = Int32.Parse(Console.ReadLine());
    }
}
```

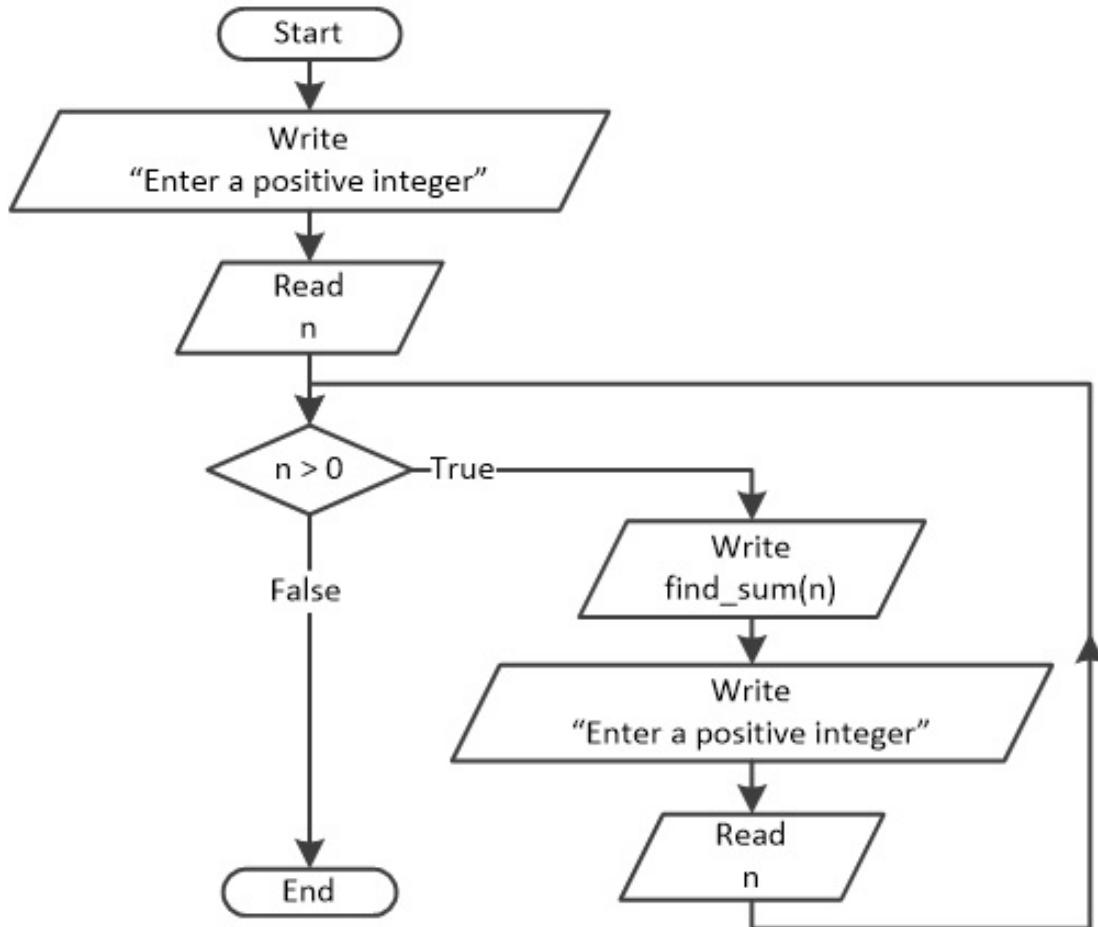
#### **Solution**

---

The flowchart that corresponds to the method `find_sum()` is as follows.



And the flowchart of the main code is as follows.



### ***Exercise 38.1-2 Designing the Flowchart***

---

*Design the flowchart that corresponds to the following C# program.*

```

static void display_divmod(int a, int b) {
    Console.WriteLine((int)(a / b));
    Console.WriteLine(a % b);
}

static void Main(string[] args) {
    int val1, val2;

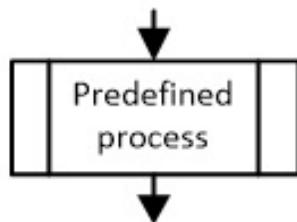
    val1 = Int32.Parse(Console.ReadLine());
    val2 = Int32.Parse(Console.ReadLine());
    while (val1 > 0 && val2 > 0) {
        display_divmod(val1, val2);

        val1 = Int32.Parse(Console.ReadLine());
        val2 = Int32.Parse(Console.ReadLine());
    }
}
  
```

## **Solution**

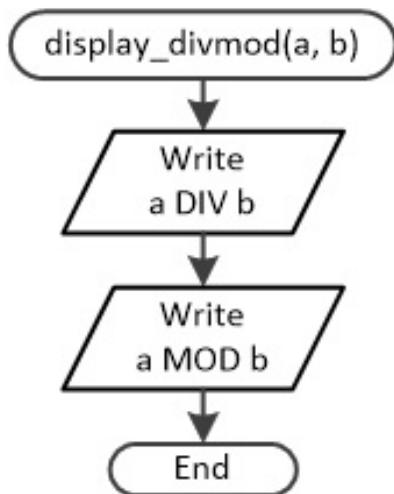
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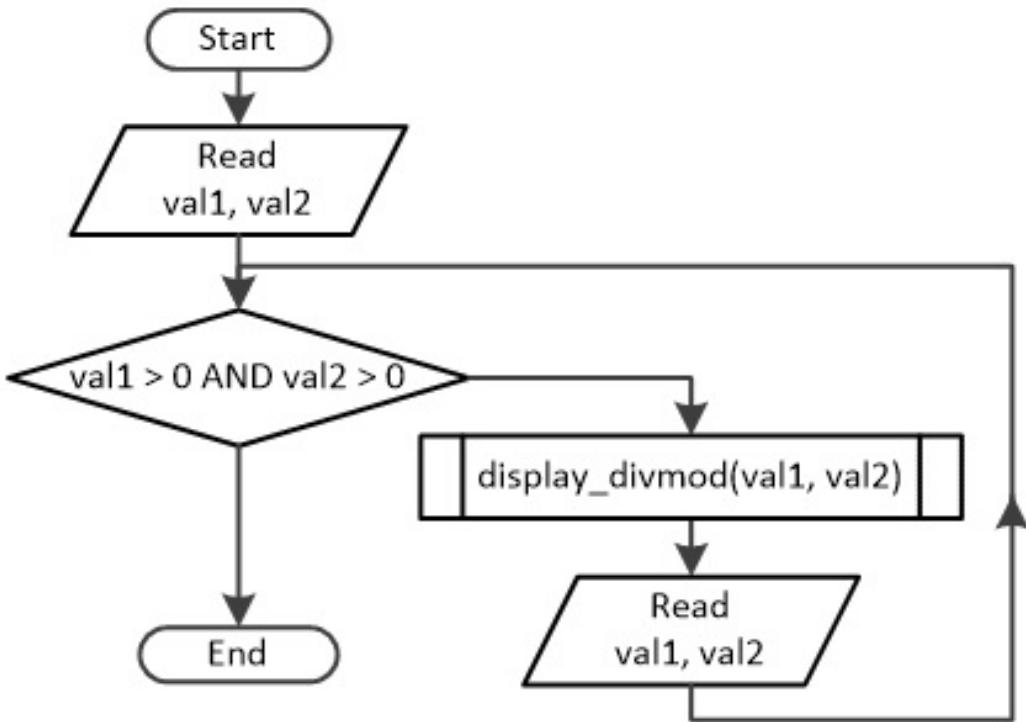
In [paragraph 4.7](#) (back when you first started reading this book), you learned that the following symbol in flowcharts depicts a call to a subprogram that is formally defined elsewhere, such as in a separate flowchart.



The time to use this symbol has come! The subprogram `display_divmod()` of this exercise is a void method, so you can use this flowchart symbol to call it.

The flowchart that corresponds to the void method `display_divmod()`, and the main code is as follows.





### ***Exercise 38.1-3 A Simple Currency Converter***

---

*Do the following:*

- i. Write a subprogram named `display_menu` that displays the following menu.
  1. Convert USD to Euro (EUR)
  2. Convert Euro (EUR) to USD
  3. Exit
- ii. Using the subprogram cited above, write a C# program that displays the previously mentioned menu and prompts the user to enter a choice (of 1, 2, or 3) and an amount of money. The program must then calculate and display the required value. The process must repeat as many times as the user wishes. It is given that \$1 = 0.87 EUR (€).

### ***Solution***

---

According to the “Ultimate” rule, the while-loop of the main code must be as follows, given in general form.

*Display the menu*

```

choice = Int32.Parse(Console.ReadLine());      //Initialization of choice.
while (choice != 3) {
  
```

*Prompt the user to enter an amount of money, and then calculate and display the required value.*

*Display the menu*

```
choice = Int32.Parse(Console.ReadLine()); //Update/alteration of choice  
}
```

The solution is as follows.

### project\_38\_1\_3

```
static void display_menu() {  
    Console.WriteLine("1. Convert USD to Euro (EUR)");  
    Console.WriteLine("2. Convert Euro (EUR) to USD");  
    Console.WriteLine("3. Exit");  
    Console.WriteLine("-----");  
    Console.Write("Enter a choice: ");  
}  
  
static void Main(string[] args) {  
    int choice;  
    double amount;  
  
    display_menu();  
    choice = Int32.Parse(Console.ReadLine());  
    while (choice != 3) {  
        Console.Write("Enter an amount: ");  
        amount = Double.Parse(Console.ReadLine());  
        if (choice == 1) {  
            Console.WriteLine(amount + " USD = " + amount * 0.87 + " Euro");  
        }  
        else {  
            Console.WriteLine(amount + " Euro = " + amount / 0.87 + " USD");  
        }  
  
        display_menu();  
        choice = Int32.Parse(Console.ReadLine());  
    }  
}
```

## Exercise 38.1-4 A More Complete Currency Converter

*Do the following:*

- i. Write a subprogram named `display_menu` that displays the following

*menu.*

1. *Convert USD to Euro (EUR)*
  2. *Convert USD to British Pound Sterling (GBP)*
  3. *Convert USD to Japanese Yen (JPY)*
  4. *Convert USD to Canadian Dollar (CAD)*
  5. *Exit*
- ii. *Write four different subprograms named `USD_to_EU`, `USD_to_GBP`, `USD_to_JPY`, and `USD_to_CAD`, that accept a currency through their formal argument list and then return the corresponding converted value.*
- iii. *Using the subprograms cited above, write a C# program that displays the previously mentioned menu and then prompts the user to enter a choice (of 1, 2, 3, 4, or 5) and an amount in US dollars. The program must then display the required value. The process must repeat as many times as the user wishes. It is given that*
- $\$1 = 0.87 \text{ EUR} (\text{\euro})$
  - $\$1 = 0.78 \text{ GBP} (\text{\pound})$
  - $\$1 = ¥ 108.55 \text{ JPY}$
  - $\$1 = 1.33 \text{ CAD} (\text{\$})$

## **Solution**

---

This solution combines the use of both methods and void methods. The four methods that convert currencies accept a value through an argument and then they return the corresponding value. The solution is shown here.

### project\_38\_1\_4

```
static void display_menu() {
    Console.WriteLine("1. Convert USD to Euro (EUR)");
    Console.WriteLine("2. Convert USD to British Pound Sterling (GBP)");
    Console.WriteLine("3. Convert USD to Japanese Yen (JPY)");
    Console.WriteLine("4. Convert USD to Canadian Dollar (CAD)");
    Console.WriteLine("5. Exit");
    Console.WriteLine("-----");
    Console.Write("Enter a choice: ");
}

static double USD_to_EU(double value) {
```

```

        return value * 0.87;
    }

static double USD_to_GBP(double value) {
    return value * 0.78;
}

static double USD_to_JPY(double value) {
    return value * 108.55;
}

static double USD_to_CAD(double value) {
    return value * 1.33;
}

static void Main(string[] args) {
    int choice;
    double amount;

    display_menu();
    choice = Int32.Parse(Console.ReadLine());
    while (choice != 5) {
        Console.WriteLine("Enter an amount in US dollars: ");
        amount = Double.Parse(Console.ReadLine());
        switch (choice) {
            case 1:
                Console.WriteLine(amount + " USD = " + USD_to_EU(amount) + " Euro");
                break;
            case 2:
                Console.WriteLine(amount + " USD = " + USD_to_GBP(amount) + " GBP");
                break;
            case 3:
                Console.WriteLine(amount + " USD = " + USD_to_JPY(amount) + " JPY");
                break;
            case 4:
                Console.WriteLine(amount + " USD = " + USD_to_CAD(amount) + " CAD");
                break;
        }
        display_menu();
        choice = Int32.Parse(Console.ReadLine());
    }
}

```

### Exercise 38.1-5 Finding the Average Values of Positive Integers

*Do the following:*

- i. Write a subprogram named `test_integer` that accepts a number through its formal argument list and returns true when the passed number is an integer; it must return false otherwise.
- ii. Using the subprogram cited above, write a C# program that lets the user enter numeric values repeatedly until a real one is entered. In the end, the program must display the average value of positive integers entered.

## **Solution**

---

The solution is presented next.

### project\_38\_1\_5

```
static bool test_integer(double number) {
    bool return_value = false;

    if (number == (int)(number)) {
        return_value = true;
    }
    return return_value;
}

static void Main(string[] args) {
    int count;
    double total, x;

    total = 0;
    count = 0;
    x = Double.Parse(Console.ReadLine()); //Initialization of x
    while (test_integer(x)) { //The Boolean Expression depends on x
        if (x > 0) {
            total += x;
            count++;
        }
        x = Double.Parse(Console.ReadLine()); //Update/alteration of x
    }

    if (count > 0) {
        Console.WriteLine(total / count);
    }
}
```

 The statement `while (test_integer(x))` is equivalent to the statement `while (test_integer(x) == true)`

 Note the last single-alternative decision structure, `if count > 0`. It is necessary in order for the program to satisfy the property of definiteness. Think about it! If the user enters a real (float) right from the beginning, the variable `count`, in the end, will contain a value of zero.

 The following method can be used as an alternative to the previous one. It directly returns the result (true or false) of the Boolean expression `number == (int)(number)`.

```
static boolean test_integer(double number) {  
    return number == (int)(number);  
}
```

### ***Exercise 38.1-6 Finding the Sum of Odd Positive Integers***

*Do the following:*

- i. Write a subprogram named `test_integer` that accepts a number through its formal argument list and returns true when the passed number is an integer; it must return false otherwise.
- ii. Write a subprogram named `test_odd` that accepts a number through its formal argument list and returns true when the passed number is odd; it must return false otherwise.
- iii. Write a subprogram named `test_positive` that accepts a number through its formal argument list and returns true when the passed number is positive; it must return false otherwise.
- iv. Using the subprograms cited above, write a C# program that lets the user enter numeric values repeatedly until a negative one is entered. In the end, the program must display the sum of odd positive integers entered.

### ***Solution***

This exercise is pretty much the same as the previous one. Each subprogram returns one value (which can be true or false). The solution is presented here.

#### project\_38\_1\_6

```
static bool test_integer(double number) {
```

```

    return number == (int)(number);
}

static bool test_odd(double number) {
    return number % 2 != 0;
}

static bool test_positive(double number) {
    return number > 0;
}

static void Main(string[] args) {
    int total;
    double x;

    total = 0;
    x = Double.Parse(Console.ReadLine());
    while (test_positive(x)) {
        if (test_integer(x) && test_odd(x)) {
            total += (int)x;
        }
        x = Double.Parse(Console.ReadLine());
    }

    Console.WriteLine(total);
}

```

 The statement `if (test_integer(x) && test_odd(x))` is equivalent to the statement `if (test_integer(x) == true && test_odd(x) == true)`

### Exercise 38.1-7 Finding the Values of y

Write a C# program that finds and displays the value of  $y$  (if possible) in the following formula.

$$y = \begin{cases} \frac{3x}{x-5} + \frac{7-x}{2x}, & x \geq 1 \\ \frac{45-x}{x+2} + 3x, & x < 1 \end{cases}$$

For each part of the formula, write a subprogram that accepts  $x$  through its formal argument list and then calculates and displays the result. An error message must be displayed when the calculation is not possible.

## Solution

---

Each subprogram must calculate and display the result of the corresponding formula or display an error message when the calculation is not possible. As these two subprograms return no result, they can both be written as void methods. The solution is shown here.

### project\_38\_1\_7

```
static void formula1(double x) {
    double y;

    if (x == 5) {
        Console.WriteLine("Error! Division by zero");
    }
    else {
        y = 3 * x / (x - 5) + (7 - x) / (2 * x);
        Console.WriteLine(y);
    }
}

static void formula2(double x) {
    double y;

    if (x == -2) {
        Console.WriteLine("Error! Division by zero");
    }
    else {
        y = (45 - x) / (x + 2) + 3 * x;
        Console.WriteLine(y);
    }
}

static void Main(string[] args) {
    double x;

    Console.Write("Enter a value for x: ");
    x = Double.Parse(Console.ReadLine());
    if (x >= 1) {
        formula1(x);
    }
    else {
        formula2(x);
    }
}
```

## 38.2 Exercises of a General Nature with Subprograms

### Exercise 38.2-1 Validating Data Input Using a Subprogram

*Do the following:*

- i. Write a subprogram named `get_age` that prompts the user to enter his or her age and returns it. Using a loop control structure, the subprogram must also validate data input and display an error message when the user enters any non-positive values.
- ii. Write a subprogram named `find_max` that accepts an array through its formal argument list and returns the index position of the maximum value of the array.
- iii. Using the subprograms cited above, write a C# program that prompts the user to enter the first names, last names, and ages of 50 people into three arrays and then displays the name of the oldest person.

### Solution

Since the subprogram `get_age()` returns one value, it can be written as a method. The same applies to subprogram `find_max()` because it also returns one value. The main code must prompt the user to enter the first names, the last names, and the ages of 50 people into arrays `first_names`, `last_names`, and `ages` respectively. Then, with the help of method `find_max()`, it can find the index position of the maximum value of array `ages`. The solution is shown here.

#### project\_38\_2\_1

```
const int PEOPLE = 50;

static int get_age() {
    int age;

    Console.WriteLine("Enter an age: ");
    age = Int32.Parse(Console.ReadLine());
    while (age <= 0) {
        Console.WriteLine("Error: Invalid age\nEnter a positive number: ");
        age = Int32.Parse(Console.ReadLine());
    }

    return age;
}
```

```

static int find_max(int[] a) {
    int i, maximum, max_i;

    maximum = a[0];
    max_i = 0;
    for (i = 1; i <= PEOPLE - 1; i++) {
        if (a[i] > maximum) {
            maximum = a[i];
            max_i = i;
        }
    }
    return max_i;
}

static void Main(string[] args) {
    int i, index_of_max;

    string[] first_names = new string[PEOPLE];
    string[] last_names = new string[PEOPLE];
    int[] ages = new int[PEOPLE];
    for (i = 0; i <= PEOPLE - 1; i++) {
        Console.WriteLine("Enter first name of person No " + (i + 1) + ": ");
        first_names[i] = Console.ReadLine();
        Console.WriteLine("Enter last name of person No " + (i + 1) + ": ");
        last_names[i] = Console.ReadLine();
        ages[i] = get_age();
    }

    index_of_max = find_max(ages);

    Console.WriteLine("The oldest person is:");
    Console.WriteLine(first_names[index_of_max] + last_names[index_of_max]);
    Console.WriteLine("He or she is " + ages[index_of_max] + " years old!");
}

```

### Exercise 38.2-2 Sorting an Array Using a Subprogram

*Do the following:*

- i. *Write a subprogram named my\_swap that accepts an array of strings through its formal argument list, as well as two indexes. The subprogram then swaps the values of the elements at the corresponding index positions.*
- ii. *Using the subprogram my\_swap() cited above, write a subprogram*

*named my\_sort that accepts an array of strings through its formal argument list and then sorts the array using the bubble sort algorithm. It must be able to sort in either ascending or descending order. To do this, include an addition Boolean argument within the formal argument list.*

- iii. Write a subprogram named display\_array that accepts an array through its formal argument list and then displays it.*
- iv. Using the subprograms my\_sort() and display\_array() cited above, write a C# program that prompts the user to enter the names of 20 people and then displays them twice: once sorted in ascending order, and once in descending order.*

## **Solution**

---

As you can see in the C# program below, the void method `my_sort()` uses an adapted version of the bubble sort algorithm. When the value `true` is passed to the argument `ascending`, the algorithm sorts array `a` in ascending order. When the value `false` is passed, the algorithm sorts array `a` in descending order.

Moreover, the void method `my_sort()` calls the void method `my_swap()` every time a swap is required between the contents of two elements.

### project\_38\_2\_2

```
const int PEOPLE = 20;

static void my_swap(string[] a, int index1, int index2) {
    string temp;

    temp = a[index1];
    a[index1] = a[index2];
    a[index2] = temp;
}

static void my_sort(string[] a, bool ascending) {
    int m, n;

    for (m = 1; m <= PEOPLE - 1; m++) {
        for (n = PEOPLE - 1; n >= m; n--) {
            if (ascending) {
                if (a[n].CompareTo(a[n - 1]) < 0) {
                    my_swap(a, n, n - 1);
                }
            }
        }
    }
}
```

```

        }
    }
    else {
        if (a[n].CompareTo(a[n - 1]) > 0) {
            my_swap(a, n, n - 1);
        }
    }
}

static void display_array(string[] a) {
    int i;

    for (i = 0; i <= PEOPLE - 1; i++) {
        Console.WriteLine(a[i]);
    }
}

static void Main(string[] args) {
    int i;

    string[] names = new string[PEOPLE];
    for (i = 0; i <= PEOPLE - 1; i++) {
        Console.Write("Enter a name: ");
        names[i] = Console.ReadLine();
    }

    my_sort(names, true);           //Sort names in ascending order
    display_array(names);          //and display them

    my_sort(names, false);         //Sort names in descending order
    display_array(names);          //and display them.
}

```

 In C#, arrays are passed by reference. This is why there is no need to include a return statement in the subprogram `my_sort()`.

### ***Exercise 38.2-3 Progressive Rates and Electricity Consumption***

The LAV Electricity Company charges subscribers for their electricity consumption according to the following table (monthly rates for domestic accounts).

Kilowatt-hours (kWh)	USD per kWh
----------------------	-------------

$kWh \leq 400$	\$0.08
$401 < kWh \leq 1500$	\$0.22
$1501 < kWh \leq 2000$	\$0.35
$2001 < kWh$	\$0.50

*Do the following:*

- i. Write a subprogram named `get_consumption` that prompts the user to enter the total number of kWh consumed and then returns it. Using a loop control structure, the subprogram must also validate data input and display an error message when the user enters any negative values.
- ii. Write a subprogram named `find_amount` that accepts kWh consumed through its formal argument list and then returns the total amount to pay.
- iii. Using the subprograms cited above, write a C# program that prompts the user to enter the total number of kWh consumed and then displays the total amount to pay. The program must iterate as many times as the user wishes. At the end of each calculation, the program must ask the user if he or she wishes to calculate the total amount to pay for another consumer. If the answer is “yes” the program must repeat; it must end otherwise. Make your program accept the answer in all possible forms such as “yes”, “YES”, “Yes”, or even “YeS”.

*Please note that the rates are progressive and that transmission services and distribution charges, as well as federal, state, and local taxes, add a total of 26% to each bill.*

### **Solution**

---

There is nothing new here. Processing progressive rates is something that you have already learned! If this doesn't ring any bells, you need to refresh your memory and review the corresponding [Exercise 23.4-5](#).

The C# program is as follows.

#### project\_38\_2\_3

```
static int get_consumption() {
    int consumption ;

    Console.Write("Enter kWh consumed: ");
```

```

consumption = Int32.Parse(Console.ReadLine());
while (consumption < 0) {
    Console.WriteLine("Error: Invalid number!");
    Console.Write("Enter a non-negative number: ");
    consumption = Int32.Parse(Console.ReadLine());
}
return consumption;
}

static double find_amount(int kwh) {
    double amount;

    if (kwh <= 400) {
        amount = kwh * 0.08;
    }
    else if (kwh <= 1500) {
        amount = 400 * 0.08 + (kwh - 400) * 0.22;
    }
    else if (kwh <= 2000) {
        amount = 400 * 0.08 + 1100 * 0.22 + (kwh - 1500) * 0.35;
    }
    else {
        amount = 400 * 0.08 + 1100 * 0.22 + 500 * 0.35 + (kwh - 2000) * 0.50;
    }

    amount += 0.26 * amount;
    return amount;
}

static void Main(string[] args) {
    int kwh;
    string answer;

    do {
        kwh = get_consumption();
        Console.WriteLine("You need to pay: " + find_amount(kwh));

        Console.Write("Would you like to repeat? ");
        answer = Console.ReadLine();
    } while (answer.ToUpper() == "YES");
}

```

### Exercise 38.2-4 Roll, Roll, Roll the... Dice!

*Do the following:*

- i. Write a subprogram named dice that returns a random integer between 1 and 6.
- ii. Write a subprogram named search\_and\_count that accepts an integer and an array of integers through its formal argument list and returns the number of times the integer exists in the array.
- iii. Using the subprograms cited above, write a C# program that fills an array with 100 random integers (between 1 and 6) and then lets the user enter an integer. The program must display how many times that given integer exists in the array.

### **Solution**

---

Both subprograms can be written as methods because they both return one value each. Method dice() returns a random integer between 1 and 6, and method search\_and\_count() returns a number that indicates the number of times an integer exists in an array. The solution is presented here.

#### project\_38\_2\_4

```
const int ELEMENTS = 100;

static int dice() {
    Random rnd = new Random();
    return rnd.Next(1, 7);
}

static int search_and_count(int x, int[] a) {
    int count = 0;
    int i;

    for (i = 0; i <= ELEMENTS - 1; i++) {
        if (a[i] == x) {
            count++;
        }
    }
    return count;
}

static void Main(string[] args) {
    int x, i;

    int[] a = new int[ELEMENTS];
    for (i = 0; i <= ELEMENTS - 1; i++) {
```

```

        a[i] = dice();
    }

    x = Int32.Parse(Console.ReadLine());
    Console.WriteLine("Given value exists in the array");
    Console.WriteLine(search_and_count(x, a) + " times");
}

```

### Exercise 38.2-5 How Many Times Does Each Number of the Dice Appear?

*Using the methods dice() and search\_and\_count() cited in the previous exercise, write a C# program that fills an array with 100 random integers (between 1 and 6) and then displays how many times each of the six numbers appears in the array, as well as which number appears most often.*

#### **Solution**

---

If you were to solve this exercise without using a loop control structure, it would be something like the following.

```

//Assign to n1 the number of times that value 1 exists in array a
n1 = search_and_count(1, a);
//Assign to n2 the number of times that value 2 exists in array a
n2 = search_and_count(2, a);

.

.

.

//Assign to n6 the number of times that value 6 exists in array a
n6 = search_and_count(6, a);

//Display how many times each of the six numbers appears in array a
Console.WriteLine(n1 + " " + n2 + " " + n3 + " " + n4 + " " + n5 + " " + n6);

//Find maximum of n1, n2,... n6
maximum = n1;
max_i = 1;

if (n2 > maximum) {
    maximum = n2;
    max_i = 2;
}
if (n3 > maximum) {
    maximum = n3;
    max_i = 3;
}
.
.
```

```

.
.

if (n6 > maximum) {
    maximum = n6;
    max_i = 6;
}

//Display which number appears in the array most often.
Console.WriteLine(max_i);

```

But now that you are reaching the end of the book, of course, you can do something more creative. Instead of assigning each result of the `search_and_count()` method to individual variables `n1`, `n2`, `n3`, `n4`, `n5`, and `n6`, you can assign those results to the positions 0, 1, 2, 3, 4, and 5 of an array named `n`, as shown here.

```

int[] n = new int[6];
for (i = 0; i <= 5; i++) {
    n[i] = search_and_count(i + 1, a);
}

```

After that, you can find the maximum of the array `n` using what you have learned in [paragraph 34.3](#).

The complete solution is shown here.

## project\_38\_2\_5

```

const int ELEMENTS = 100;

static int dice() {
    Random rnd = new Random();
    return rnd.Next(1, 7);
}

static int search_and_count(int x, int[] a) {
    int count = 0;
    int i;

    for (i = 0; i <= ELEMENTS - 1; i++) {
        if (a[i] == x) {
            count++;
        }
    }
    return count;
}

```

```

static void Main(string[] args) {
    int i, maximum, max_i;

    //Create array a of random integers between 1 and 6
    int[] a = new int[ELEMENTS];
    for (i = 0; i <= ELEMENTS - 1; i++) {
        a[i] = dice();
    }

    //Create array n and display how many times each of the six numbers appears in array
    int[] n = new int[6];
    for (i = 0; i <= 5; i++) {
        n[i] = search_and_count(i + 1, a);
        Console.WriteLine("Value " + (i + 1) + " appears " + n[i] + " times");
    }

    //Find maximum of array n
    maximum = n[0];
    max_i = 0;
    for (i = 1; i <= 5; i++) {
        if (n[i] > maximum) {
            maximum = n[i];
            max_i = i;
        }
    }

    //Display which number appears in the array most often.
    Console.WriteLine("Value " + (max_i + 1) + " appears in the array " + maximum + " times");
}

```

### 38.3 Review Exercises

Complete the following exercises.

1. Design the flowchart that corresponds to the following C# program.

```

static int get_num_of_digits(int x) {
    int count = 0;

    while (x != 0) {
        count++;
        x = (int)(x / 10);
    }
    return count;
}

```

```

static void Main(string[] args) {
    int val;

    do {
        Console.Write("Enter a four-digit integer ");
        val = Int32.Parse(Console.ReadLine());
    } while (get_num_of_digits(val) != 4);

    Console.WriteLine("Congratulations!");
}

```

2. Design the flowchart that corresponds to the following code fragment.

```

static void my_divmod(int a, int b, ref int quotient,
                      ref int remainder,
                      ref bool ret_value) {
    ret_value = true;
    if (b == 0) {
        ret_value = false;
    }
    else {
        quotient = (int)(a / b);
        remainder = a % b;
    }
}

static void Main(string[] args) {
    int val1, val2;
    int q = 0, r = 0;
    bool ret = false;

    val1 = Int32.Parse(Console.ReadLine());
    val2 = Int32.Parse(Console.ReadLine());
    div_mod(val1, val2, ref q, ref r, ref ret);
    if (ret == true) {
        Console.WriteLine(q + " " + r);
    }
    else {
        Console.WriteLine("Sorry, wrong values entered!");
    }
}

```

3. Design the flowchart that corresponds to the following C# program.

```

static bool test_integer(double number) {
    bool return_value = false;
}

```

```

    if (number == (int)(number)) {
        return_value = true;
    }
    return return_value;
}

static bool test_positive(double number) {
    bool return_value = false;

    if (number > 0) {
        return_value = true;
    }
    return return_value;
}

static void Main(string[] args) {
    double total, x;
    int count;

    total = 0;
    count = 0;
    x = Double.Parse(Console.ReadLine());
    while (test_positive(x)) {
        if (test_integer(x)) {
            total += x;
            count++;
        }
        x = Double.Parse(Console.ReadLine());
    }

    if (count > 0) {
        Console.WriteLine(total / count);
    }
}

```

4. Design the flowchart that corresponds to the following C# program.

```

const int PEOPLE = 30;

static int get_age() {
    int x;
    do {
        x = Int32.Parse(Console.ReadLine());
    } while (x <= 0);

    return x;

```

```

}

static int find_max(int[] a) {
    int max_i = 0;

    int i;
    for (i = 1; i <= PEOPLE - 1; i++) {
        if (a[i] > a[max_i]) {
            max_i = i;
        }
    }
    return max_i;
}

static void Main(string[] args) {
    int i, index_of_max;

    string[] first_names = new string[PEOPLE];
    string[] last_names = new string[PEOPLE];
    int[] ages = new int[PEOPLE];
    for (i = 0; i <= PEOPLE - 1; i++) {
        first_names[i] = Console.ReadLine();
        last_names[i] = Console.ReadLine();
        ages[i] = get_age();
    }

    index_of_max = find_max(ages);

    Console.WriteLine(first_names[index_of_max]);
    Console.WriteLine(last_names[index_of_max]);
    Console.WriteLine(ages[index_of_max]);
}

```

5. Design the flowchart that corresponds to the following C# program.

```

const int PEOPLE = 40;

static void my_swap(string[] a, int index1, int index2) {
    string temp;

    temp = a[index1];
    a[index1] = a[index2];
    a[index2] = temp;
}

static void my_sort(string[] a) {

```

```

int m, n;

for (m = 1; m <= PEOPLE - 1; m++) {
    for (n = PEOPLE - 1; n >= m; n--) {
        if (a[n].CompareTo(a[n - 1]) < 0) {
            my_swap(a, n, n-1);
        }
    }
}

static void display_array(string[] a, bool ascending) {
    int i;

    if (ascending) {
        for (i = 0; i <= PEOPLE - 1; i++) {
            Console.WriteLine(a[i]);
        }
    }
    else {
        for (i = PEOPLE - 1; i >= 0; i--) {
            Console.WriteLine(a[i]);
        }
    }
}

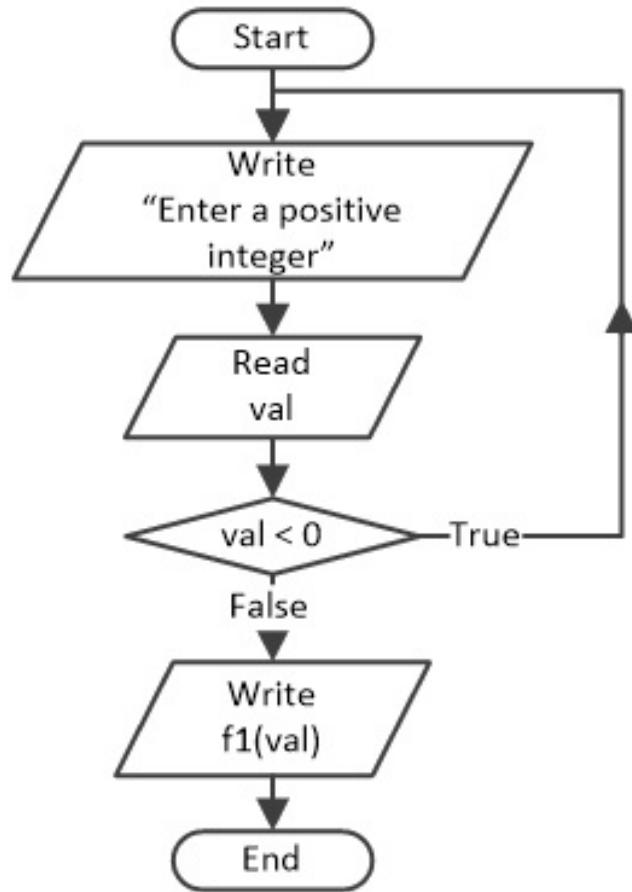
static void Main(string[] args) {
    int i;

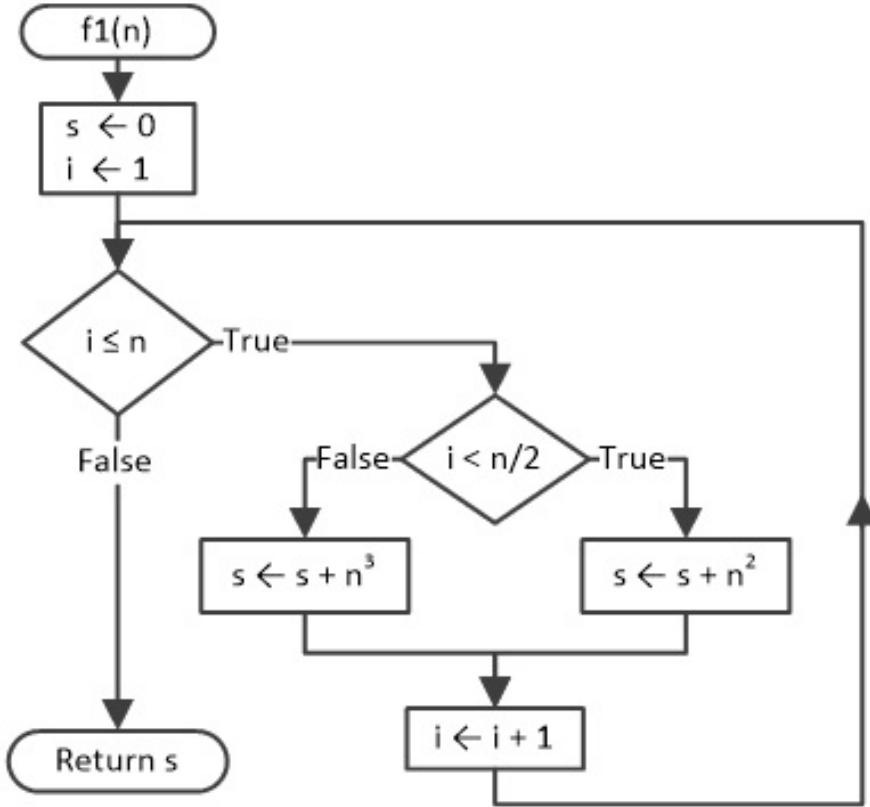
    string[] names = new string[PEOPLE];
    for (i = 0; i <= PEOPLE - 1; i++) {
        names[i] = Console.ReadLine();
    }

    my_sort(names);
    display_array(names, true);
    display_array(names, false);
}

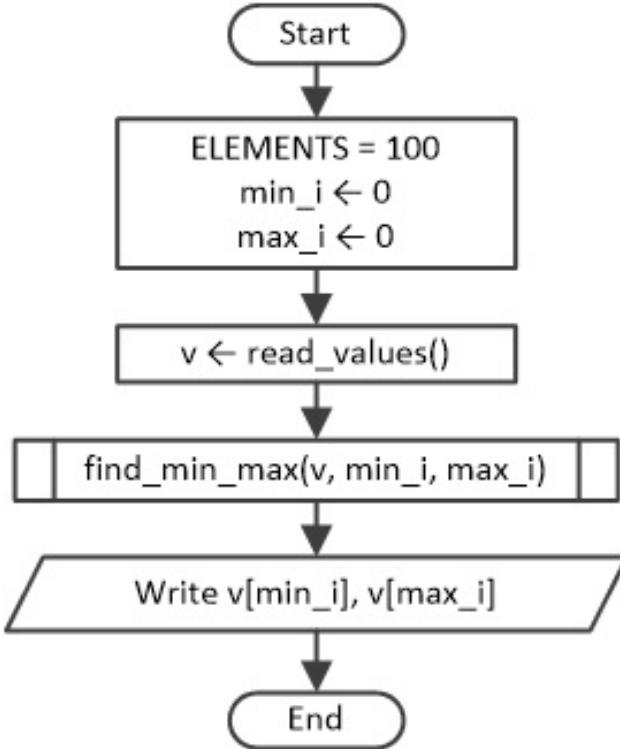
```

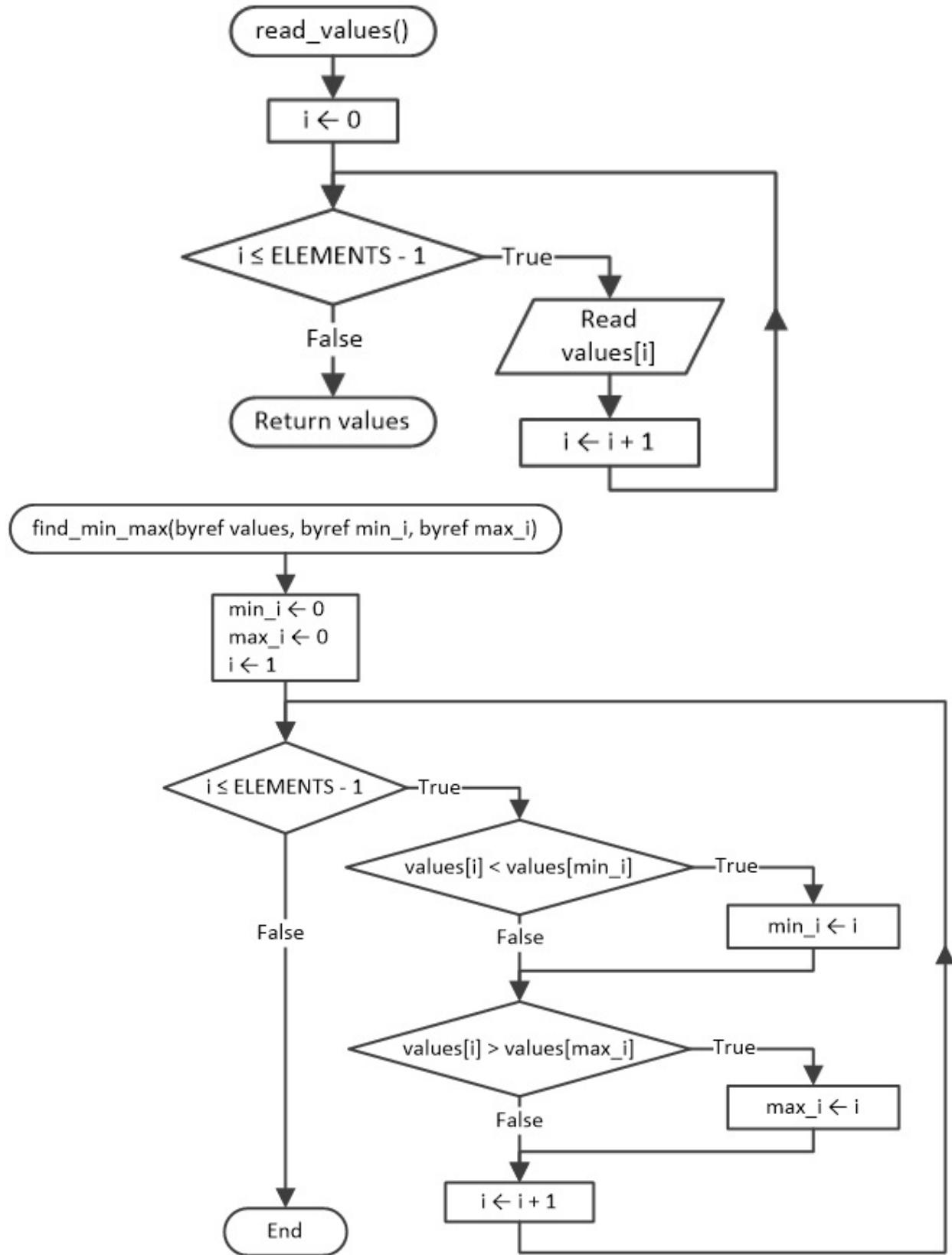
6. Write the C# program that corresponds to the following flowchart.





7. Write the C# program that corresponds to the following flowchart.





Hint: In flowcharts, a `byref` (or `inout`) keyword in front of an argument

denotes that the argument is passed by reference.

8. Do the following:
  - i. Write a subprogram named `factorial` that accepts an integer through its formal argument list and returns its factorial.
  - ii. Using the subprogram `factorial()` cited above, write a subprogram named `my_sin` that accepts a value through its formal argument list and returns the sine of  $x$ , using the Taylor series (shown next) with an accuracy of 0.0000000001.

$$\sin x = x - \frac{x^3}{3!} + \frac{x^5}{5!} - \frac{x^7}{7!} + \dots$$

Hint: Keep in mind that  $x$  is in radians, and  $\frac{x^1}{1!} = x$ .

- iii. Write a subprogram named `degrees_to_rad` that accepts an angle in degrees through its formal argument list and returns its radian equivalent. It is given that  $2\pi = 360^\circ$ .
- iv. Using the subprograms `my_sin()` and `degrees_to_rad()` cited above, write a C# program that displays the sine of all integers from  $0^\circ$  to  $360^\circ$ .

9. Do the following:

- i. Write a subprogram named `is_leap` that accepts a year through its formal argument list and returns `true` or `false` depending on whether or not that year is a leap year.
- ii. Write a subprogram named `num_of_days` that accepts a month and a year and returns the number of the days in that month. If that month is February and the year is a leap year, the subprogram must return the value of 29.

Hint: Use the subprogram `is_leap()` cited above.

- iii. Write a subprogram named `check_date` that accepts a day, a month, and a year and returns `true` or `false` depending on whether or not that date is valid.
- iv. Using the subprograms cited above, write a C# program that prompts the user to enter a date (a day, a month, and a year) and then calculates and displays the number of days that have passed

between the beginning of the given year and the given date. Using a loop control structure, the program must also validate data input and display an error message when the user enters any non-valid date.

10. Do the following:

- i. Write a subprogram named `display_menu` that displays the following menu.
  1. Convert USD to Euro (EUR)
  2. Convert USD to British Pound Sterling (GBP)
  3. Convert EUR to USD
  4. Convert EUR to GBP
  5. Convert GBP to USD
  6. Convert GBP to EUR
  7. Exit
- ii. Write two different subprograms named `USD_to_EUR`, and `USD_to_GBP`, that accept a currency through their formal argument list and then return the corresponding converted value.
- iii. Using the subprograms cited above, write a C# program that displays the previously mentioned menu and then prompts the user to enter a choice (of 1, 2, 3, 4, 5, 6, or 7) and an amount. The program must then display the required value. The process must repeat as many times as the user wishes. It is given that
  - \$1 = 0.87 EUR (€)
  - \$1 = 0.76 GBP (£)

11. In a computer game, players roll two dice. The player who gets the greatest sum of dice gets one point. After ten rolls, the player that wins is the one with the greatest sum of points. Do the following:

- i. Write a subprogram named `dice` that returns a random integer between 1 and 6.
- ii. Using the subprogram cited above, write a C# program that prompts two players to enter their names and then each player consecutively “rolls” two dice. This process repeats ten times and the player that wins is the one with the greatest sum of points.

12. The LAV Car Rental Company has rented 40 cars, which are divided into three categories: hybrid, gas, and diesel. The company charges for a car according to the following table.

Days	Car Type		
	Gas	Diesel	Hybrid
1 - 5	\$24 per day	\$28 per day	\$30 per day
6 - 8	\$22 per day	\$25 per day	\$28 per day
9 and above	\$18 per day	\$21 per day	\$23 per day

Do the following:

- Write a subprogram named `get_choice` that displays the following menu.
  - Gas
  - Diesel
  - Hybrid
 The subprogram then prompts the user to enter the type of the car (1, 2, or 3) and returns it to the caller.
- Write a subprogram named `get_days` that prompts the user to enter the total number of rental days and returns it to the caller.
- Write a subprogram named `get_charge` that accepts the type of the car (1, 2, or 3) and the total number of rental days through its formal argument list and then returns the amount of money to pay according to the previous table. Federal, state, and local taxes add a total of 10% to each bill.
- Using the subprograms cited above, write a C# program that prompts the user to enter all necessary information about the rented cars and then displays the following:
  - for each car, the total amount to pay including taxes
  - the total number of hybrid cars rented
  - the total net profit the company gets after removing taxes

Please note that the rates are progressive.

13. TAM (Television Audience Measurement) is the specialized branch of

media research dedicated to quantify and qualify television audience information.

The LAV Television Audience Measurement Company counts the number of viewers of the main news program on each of 10 different TV channels. The company needs a software application in order to get some useful information. Do the following:

- i. Write a subprogram named `get_data` that prompts the user to enter into two arrays the names of the channels and the number of viewers of the main news program for each day of the week (Monday to Sunday). It then returns these arrays to the caller.
  - ii. Write a subprogram `get_average` that accepts a one-dimensional array of seven numeric elements through its formal argument list and returns the average value of the first five elements.
  - iii. Using the subprograms cited above, write a C# program that prompts the user to enter the names of the channels and the number of viewers for each day of the week and then displays the following:
    - a. the name of the channels whose average viewer numbers on the weekend were at least 20% higher than the average viewer numbers during the rest of the week.
    - b. the name of the channels (if any) that, from day to day, showed constantly increasing viewer numbers. If there is no such channel, a corresponding message must be displayed.
14. A public opinion polling company asks 300 citizens whether they have been hospitalized during the last year. Do the following:
- i. Write a subprogram named `input_data` that prompts the user to enter the citizen's SSN (Social Security Number) and their answer (Yes, No) into two arrays, `SSNs` and `answers`, respectively. The two arrays must be returned to the caller.
  - ii. Write a subprogram named `sort_arrays` that accepts the arrays `SSNs` and `answers` through its formal argument list. It then sorts array `SSNs` in ascending order using the selection sort algorithm. The subprogram must preserve the relationship between the elements of the two arrays.

- iii. Write a subprogram named `search_array` that accepts array SSNs and an SSN through its formal argument list and then returns the index position of that SSN in the array. If the SSN is not found, a message “SSN not found” must be displayed and the value `-1` must be returned. Use the binary search algorithm.
- iv. Write a subprogram named `count_answers` that accepts the array `answers` and an answer through its formal argument list. It then returns the number of times this answer exists in the array.
- v. Using the subprograms cited above, write a C# program that prompts the user to enter the SSNs and the answers of the citizens. It must then prompt the user to enter an SSN and display the answer that the citizen with this SSN gave, as well as the percentage of citizens that gave the same answer. The program must then ask the user if he or she wishes to search for another SSN. If the answer is “Yes” the process must repeat; it must end otherwise.
15. Eight teams participate in a football tournament, and each team plays 12 games, one game each week. Do the following:
- Write a subprogram named `input_data` that prompts the user to enter into two arrays the name of each team and the letter “W” for win, “L” for loss, or “T” for tie (draw) for each game. It then returns the arrays to the caller.
  - Write a subprogram named `display_result` that prompts the user for a letter (W, L, or T) and then displays, for each team, the week number(s) in which the team won, lost, or tied respectively. For example, if the user enters “L”, the subprogram must search and display, for each team, the week numbers (e.g., week 3, week 14, and so on) in which the team lost the game.
  - Write a subprogram named `find_team` that prompts the user to enter the name of a team and returns the index position of that team in the array. If the given team name does not exist, the value `-1` must be returned.
  - Using the subprograms cited above, write a C# program that prompts the user to enter the name of each team and the letter “W”

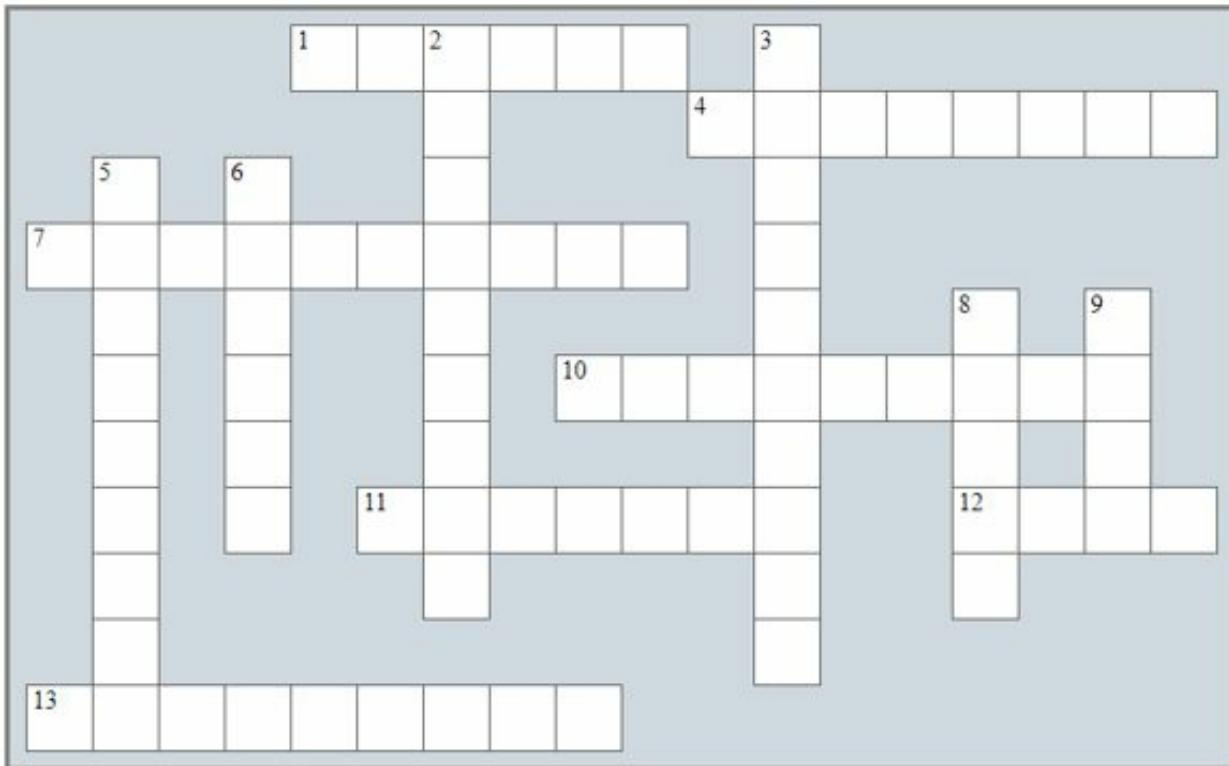
for win, “L” for loss, or “T” for tie (draw) for each game. It must then prompt the user for a letter (W, L, or T) and display, for each team, the week number(s) in which the team won, lost, or tied respectively. Finally, the program must prompt the user to enter the name of a team. If the given team is found, the program must display the total number of points for this team and then prompt the user to enter the name of another team. This process must repeat as long as the user enters an existing team name. If given team name is not found, the message “Team not found” must be displayed and the program must end.

It is given that a win receives 3 points and a tie receives 1 point.

# **Review in “Subprograms”**

## **Review Crossword Puzzle**

1. Solve the following crossword puzzle.



### **Across**

1. Each method contains an argument list called a \_\_\_\_\_ argument list.
4. Generally speaking, this subprogram returns a result.
7. In this kind of programming, a problem is subdivided into smaller subproblems.
10. A sequence of numbers where the first two numbers are 1 and 1, and each subsequent number is the sum of the previous two.
11. In this kind of programming, subprograms of common functionality are grouped together into separate modules.
12. Send a value to a method.
13. Arrays in C# are passed by \_\_\_\_\_.

### **Down**

2. A programming technique in which a subprogram calls itself.
3. A block of statements packaged as a unit that performs a specific task.
5. Generally speaking, this subprogram returns no result.
6. When a subprogram is called, the passed argument list is called an \_\_\_\_\_ argument list.
8. It refers to the range of effect of a variable.
9. The principle which states that most systems work best if they are kept simple, avoiding any unnecessary complexity!

## Review Questions

Answer the following questions.

1. What is a subprogram? Name some built-in subprograms of C#.
2. What is procedural programming?
3. What are the advantages of procedural programming?
4. What is modular programming?
5. What is the general form of a C# method?
6. How do you make a call to a method?
7. Describe the steps that are performed when the main code makes a call to a method.
8. What is a void method?
9. What is the general form of a C# void method?
10. How do you make a call to a void method?
11. Describe the steps that are performed when the main code makes a call to a void method.
12. What is the difference between a method and a void method?
13. What is the formal argument list?
14. What is the actual argument list?
15. Can two subprograms use variables of the same name?
16. How long does a subprogram's variable "live" in main memory?
17. How long does a main code's variable "live" in main memory?

18. Can a subprogram call another subprogram? If yes, give some examples.
19. What does it mean to “pass an argument by value”?
20. What does it mean to “pass an argument by reference”?
21. What is an optional argument?
22. What is a named argument?
23. What is meant by the term “scope” of a variable?
24. What happens when a variable has a local scope?
25. What happens when a variable has a global scope?
26. What is the difference between a local and a global variable?
27. What is recursion?
28. What are the three rules that all recursive algorithms must follow?

# **Section 8**

## **Object-Oriented Programming**

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# **Chapter 39**

## **Introduction to Object-Oriented Programming**

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### **39.1 What is Object-Oriented Programming?**

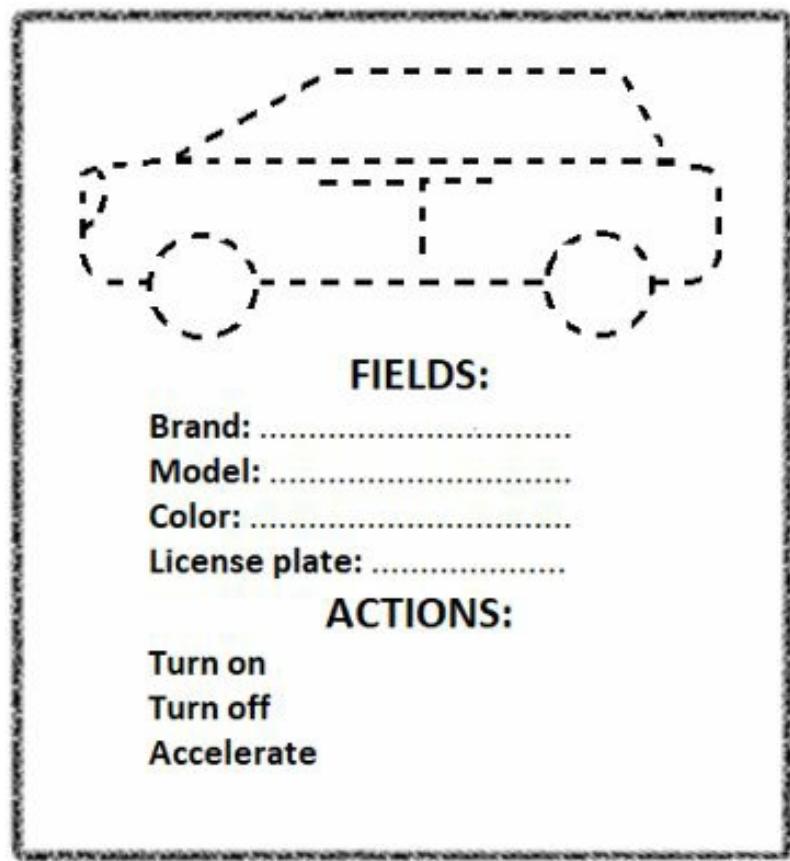
In [Section 7](#) all the programs that you read or even wrote, were using subprograms (methods and void methods). This programming style is called procedural programming and most of the time it is just fine! But when it comes to writing large programs, or working in a big company such as Microsoft, Facebook, or Google, object-oriented programming is a must use programming style!

*Object-oriented programming*, usually referred as OOP, is a style of programming that focuses on *objects*. In OOP, you can combine data and functionality and enclose them inside something called an object. Using object-oriented programming techniques enables you to maintain your code more easily, and write code that can be easily used by others.

But what does the phrase “*OOP focuses on objects*” really mean? Let's take a look at an example from the real world. Imagine a car. How can you describe a specific car? It has some attributes, such as the brand, the model, the color, and the license plate. Also, there are some actions this car can perform, or can have performed on it. For example, someone can turn it on or off, accelerate or brake, or park.

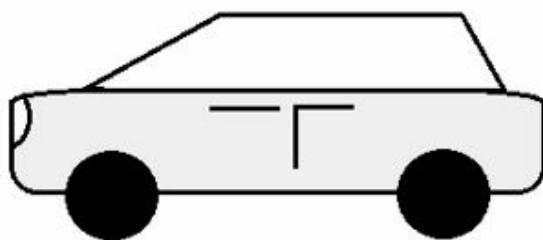
In OOP, this car can be an object with specific attributes (usually called *fields*) that performs specific actions (called *methods*).

Obviously, you may now be asking yourself, “*How can I create objects in the first place?*” The answer is simple! All you need is a *class*. A class resembles a “rubber inkpad stamp”! In **Figure 39-1** there is a stamp (this is the class) with four empty fields.



**Figure 39-1** A class resembles a “rubber inkpad stamp”

Someone who uses this stamp can stamp-out many cars (these are the objects). In **Figure 39-2**, for example, a little boy stamped-out those two cars and then he colored them and filled out each car's fields with specific attributes.

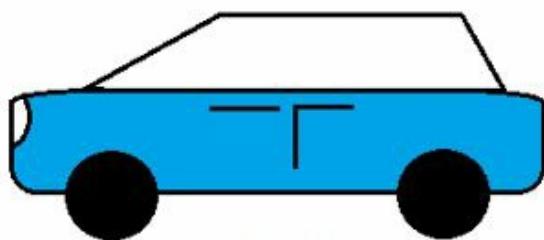


**FIELDS:**

Brand: Mazda.....  
Model: 6.....  
Color: Gray.....  
License plate: AB1234.....

**ACTIONS:**

Turn on  
Turn off  
Accelerate



**FIELDS:**

Brand: Ford.....  
Model: Focus.....  
Color: Blue.....  
License plate: XY9876.....

**ACTIONS:**

Turn on  
Turn off  
Accelerate

**Figure 39-2** You can use the same rubber stamp as a template to stamp-out many cars

- ☞ The process of creating a new object (a new instance of a class) is called “instantiation”.
- ☞ A class is a template and every object is created from a class. Each class should be designed to carry out one, and only one, task! This is why, most of the time, more than one class is used to build an entire application!
- ☞ In OOP, the rubber stamp is the class. You can use the same class as a template to create (instantiate) many objects!

## 39.2 Classes and Objects in C#

Now that you know some theoretical stuff about classes and objects let's see how to write a real class in C#! The following code fragment creates the class Car. There are four fields and three methods within the class.

```
class Car {  
    //Define four fields (attributes)  
    public string brand = "";  
    public string model = "";  
    public string color = "";  
    public string license_plate = "";  
  
    //Define method turn_on()  
    public void turn_on() {  
        Console.WriteLine("The car turns on");  
    }  
  
    //Define method turn_off()  
    public void turn_off() {  
        Console.WriteLine("The car turns off");  
    }  
  
    //Define method accelerate()  
    public void accelerate() {  
        Console.WriteLine("The car accelerates");  
    }  
}
```

Yes, it's true. Fields within classes are just ordinary variables!

- ☞ The class Car is just a template. No objects are created yet!
- ☞ An object is nothing more than an instance of a class, and this is why,

*many times, it may be called a “class instance” or “class object”.*

 *The keyword public in front of a field or method specifies that this field or method can be accessed from outside the class using an instance of the class.*

To create two objects (or in other words to create two instances of the class Car), you need the following two lines of code.

```
Car car1 = new Car();
Car car2 = new Car();
```

 *When you create a new object (a new instance of a class) the process is called “instantiation”.*

Now, that you have created (instantiated) two objects, you can assign values to their fields. To do that, you have to use the dot notation, which means that you have to write the name of the object, followed by a dot and then the name of the field or the method you want to access. The next code fragment creates two objects, car1 and car2, and assigns values to their fields.

```
static void Main(string[] args) {
    Car car1 = new Car();
    Car car2 = new Car();

    car1.brand = "Mazda";
    car1.model = "6";
    car1.color = "Gray";
    car1.license_plate = "AB1234";

    car2.brand = "Ford";
    car2.model = "Focus";
    car2.color = "Blue";
    car2.license_plate = "XY9876";

    Console.WriteLine(car1.brand); //It displays: Mazda
    Console.WriteLine(car2.brand); //It displays: Ford
}
```

 *In the previous example, car1 and car2 are two instances of the same class. Using car1 and car2 with dot notation allows you to refer to only one instance at a time. If you make any changes to one instance they will not affect any other instances!*

---

The next code fragment calls the methods `turn_off()` and `accelerate()` of the objects `car1` and `car2` respectively.

```
car1.turn_off();
car2.accelerate();
```

❑ A class is a template that cannot be executed, whereas an object is an instance of a class that can be executed!

❑ One class can be used to create (instantiate) as many objects as you want!

### 39.3 The Constructor and the Keyword `this`

In C#, there is a method that has a special role and is called *constructor*. The constructor is executed automatically whenever an instance of a class (an object) is created. Any initialization that you want to do with your object can be done within this method.

 In C#, the constructor is a method whose name is the same as the name of its class.

Take a look at the following example. The constructor method `Person()` is called twice automatically, once when the object `p1` is created and once when the object `p2` is created, which means that the message “An object was created” is displayed twice.

#### project\_39\_3a

```
class Person {
    //Define the constructor
    public Person() {
        Console.WriteLine("An object was created");
    }
}

class Program {
    static void Main(string[] args) {
        Person p1 = new Person();
        Person p2 = new Person();
    }
}
```

 Note that there is no keyword void in front of the name of the constructor.

Now let's talk about the this keyword. The keyword this is nothing more than a reference to the object itself! Take a look at the following example.

### project\_39\_3b

```
class Person {  
    public string name;  
    public int age;  
  
    //Define the constructor  
    public Person() {  
        Console.WriteLine("An object was created");  
    }  
  
    public void say_info() {  
        Console.WriteLine("I am " + this.name);  
        Console.WriteLine("I am " + this.age + " years old");  
    }  
}  
  
class Program {  
    static void Main(string[] args) {  
        Person person1 = new Person();  
  
        //Assign values to its fields  
        person1.name = "John";  
        person1.age = 14;  
  
        person1.say_info(); //Call the method say_info() of the object person1  
    }  
}
```

 Note that when declaring the fields name and age outside of a method (but within the class), you need to write the field name without dot notation. To access the fields, however, from within a method, you should use dot notation (for example, this.name and this.age).

A question that is probably spinning around in your head right now is “Why is it necessary to refer to these fields name and age within the method say\_info() as this.name and this.age correspondingly? Is it really

*necessary to use the keyword this in front of them?"* A simple answer is that there is always a possibility that you could have two extra local variables of the same name (name and age) within the method. So you need a way to distinguish among those local variables and the object's fields. If you are confused, try to understand the following example. There is a field b within the class MyClass and a local variable b within the method myMethod() of the class. The this keyword is used to distinguish among the local variable and the field.

### project\_39\_3c

```
class MyClass {  
    public string b;    //This is a field  
  
    public void myMethod() {  
        string b = " *** ";  //This is a local variable  
  
        Console.WriteLine(b + this.b + b);  
    }  
}  
  
class Program {  
    static void Main(string[] args) {  
        MyClass x = new MyClass();      //Create object x  
  
        x.b = "Hello!";   //Assign a value to its field  
  
        x.myMethod();     //It displays: *** Hello! ***  
    }  
}
```

 *The keyword this can be used to refer to any member (field or method) of a class from within a method of the class.*

## 39.4 Passing Initial Values to the Constructor

Any method, including the constructor method can have formal arguments within its formal argument list. For example, you can use these arguments to pass some initial values to the constructor of an object during creation. The example that follows creates four objects, each of which represents a Titan<sup>[23]</sup> from Greek mythology.

### project\_39\_4

```

class Titan {
    public string name;
    public string gender;

    //Define the constructor
    public Titan(string n, string g) {
        this.name = n;
        this.gender = g;
    }
}

class Program {
    static void Main(string[] args) {
        Titan titan1 = new Titan("Cronus", "male");
        Titan titan2 = new Titan("Oceanus", "male");
        Titan titan3 = new Titan("Rhea", "female");
        Titan titan4 = new Titan("Phoebe", "female");
    }
}

```

In C#, it is legal to have one field and one local variable (or even a formal argument) with the same name. So, the class `Titan` can also be written as follows

```

class Titan {
    public string name;
    public string gender;

    //Define the constructor
    public Titan(string name, string gender) {
        this.name = name;      //Fields and arguments can have the same name
        this.gender = gender;
    }
}

```

The variables `name` and `gender` are arguments used to pass values to the constructor whereas `this.name` and `this.gender` are fields used to store values within the object.

### Exercise 39.4-1 Historical Events

*Do the following:*

- i. Write a class named `HistoryEvents` which includes
  - a. a public string field named `day`.
  - b. a public string array field named `events`.

- c. a constructor that accepts an initial value for the field day through its formal argument list.
- ii. Write a C# program that creates two objects of the class *HistoryEvents* for the following historical events:  
*4th of July*
  - i. 1776: Declaration of Independence in United States
  - ii. 1810: French troops occupy Amsterdam*28th of October*
  - i. 969: Byzantine troops occupy Antioch
  - ii. 1940: Ohi Day in Greece
and then displays all available information.

## **Solution**

---

The solution is as follows.

### project\_39\_4\_1

```
class HistoryEvents {
    public string day;
    public string[] events = new string[2];

    //Define the constructor
    public HistoryEvents (string day) {
        this.day = day;
    }
}

class Program {
    static void Main(string[] args) {
        HistoryEvents h1 = new HistoryEvents("4th of July");
        h1.events[0] = "1776: Declaration of Independence in United States";
        h1.events[1] = "1810: French troops occupy Amsterdam";

        HistoryEvents h2 = new HistoryEvents("28th of October");
        h2.events[0] = "969: Byzantine troops occupy Antioch";
        h2.events[1] = "1940: Ohi Day in Greece";

        Console.WriteLine(h1.day);
        Console.WriteLine(h1.events[0]);
        Console.WriteLine(h1.events[1]);
    }
}
```

```

        Console.WriteLine();

        Console.WriteLine(h2.day);
        Console.WriteLine(h2.events[0]);
        Console.WriteLine(h2.events[1]);
    }
}

```

## 39.5 Getter and Setter Methods vs Properties

A field is a variable declared directly in a class. The principles of the object-oriented programming, though, state that the data of a class should be hidden and safe from accidental alteration. Think that one day you will probably be writing classes that other programmers will use in their programs. So, you don't want them to know what is inside your classes! The internal operation of your classes should be kept hidden from the outside world. By not exposing a field, you manage to hide the internal implementation of your class. Fields should be kept private to a class and accessed through *get* and *set* methods (or through properties).

 *Generally speaking, programmers should use fields only for data that have private or protected accessibility. In C# you can set a field (or a method) as private or protected using the special keywords private or protected correspondingly.*

Let's try to understand all of this new stuff through an example. Suppose you write the following class that converts a degrees Fahrenheit temperature into its degrees Celsius equivalent.

### project\_39\_5a

```

class FahrenheitToCelsius {
    public double temperature;

    //Define the constructor
    public FahrenheitToCelsius(double value) {
        this.temperature = value;    //Field is initialized
    }

    //This method gets the temperature
    public double getTemperature() {
        return 5.0 / 9.0 * (this.temperature - 32.0);
    }
}

```

```

    }

class Program {
    static void Main(string[] args) {
        FahrenheitToCelsius x = new FahrenheitToCelsius(-68); //Create object x
        Console.WriteLine(x.getTemperature());
    }
}

```

This class is almost perfect but has a main disadvantage. It doesn't take into consideration that a temperature cannot go below  $-459.67$  degrees Fahrenheit ( $-273.15$  degrees Celsius). This temperature is called *absolute zero*. So a novice programmer who knows absolutely nothing about physics, might pass a value of  $-500$  degrees Fahrenheit to the constructor, as shown in the code fragment that follows

```

FahrenheitToCelsius x = new FahrenheitToCelsius(-500);
Console.WriteLine(x.getTemperature());

```

Even though the program can run perfectly well and display a value of  $-295.55$  degrees Celsius, unfortunately this temperature cannot exist in the entire universe! So a slightly different version of this class might partially solve the problem.

### project\_39\_5b

```

class FahrenheitToCelsius {
    public double temperature;

    //Define the constructor
    public FahrenheitToCelsius(double value) {
        this.setTemperature(value); //Use a method to set the value of the field temperature
    }

    //This method gets the temperature
    public double getTemperature() {
        return 5.0 / 9.0 * (this.temperature - 32.0);
    }

    //This method sets the temperature
    public void setTemperature(double value) {
        if (value >= -459.67) {
            this.temperature = value;
        }
        else {
            throw new Exception("There is no temperature below -459.67");
        }
    }
}

```

```

        }
    }
}

class Program {
    static void Main(string[] args) {
        FahrenheitToCelsius x = new FahrenheitToCelsius(-500); //Create object x
        Console.WriteLine(x.getTemperature());
    }
}

```

 *The throw statement forces the program to throw an exception (a runtime error) causing the flow of execution to stop.*

This time, a method called `setTemperature()` is used to set the value of the field `temperature`. This is better, but not exactly perfect, because the programmer must be careful and always remember to use the method `setTemperature()` each time he or she wishes to change the value of the field `temperature`. The problem is that the value of the field `temperature` can still be directly changed using its name, as shown in the code fragment that follows.

```

FahrenheitToCelsius x = new FahrenheitToCelsius(-50); //Create object x
Console.WriteLine(x.getTemperature());

x.setTemperature(-65);      //This is okay!
Console.WriteLine(x.getTemperature());

x.temperature = -500;       //Unfortunately, this is still permitted!
Console.WriteLine(x.getTemperature());

```

This problem can be completely solved if you declare the field `temperature` as `private`! When a field is declared as `private`, the caller (here the object `x`) cannot get direct access to the field, as shown in the C# program that follows.

### project\_39\_5c

```

class FahrenheitToCelsius {
    private double _temperature; //Declare field temperature as private

    //Define the constructor
    public FahrenheitToCelsius(double value) {
        this.setTemperature(value); //Call the setter
    }
}

```

```

//This method gets the temperature
public double getTemperature() {
    return 5.0 / 9.0 * (this._temperature - 32.0);
}

//This method sets the temperature
public void setTemperature(double value) {
    if (value >= -459.67) {
        this._temperature = value;
    }
    else {
        throw new Exception("There is no temperature below -459.67");
    }
}

class Program {
    static void Main(string[] args) {
        FahrenheitToCelsius x = new FahrenheitToCelsius(-50); //Create object x. The cons
            //called which, in turn,
            //calls the setter
        Console.WriteLine(x.getTemperature()); //This calls the getter.

        x.setTemperature(-65); //This calls the setter.
        Console.WriteLine(x.getTemperature()); //This calls the getter.

        x._temperature = -50; //This is NOT permitted!
        Console.WriteLine(x._temperature); //This is NOT permitted as well!
    }
}

```

 Many programmers prefer to have private fields prefixed with an underscore (\_).

Last but not least, instead of using methods to get and set the value of the private field `temperature`, you can use a property! A *property* is a class member that provides a flexible mechanism to read, write, or compute the value of a field that you want to keep private. Properties expose fields, but hide implementation! To create a property you still need a private field. The private field stores the data exposed by the property. The general form of a public property is as follows.

```
private type _field_name; //This defines a private field
```

```

public type property_name { //This defines a public property
    //Define the getter
    get {
        return _field_name;
    }
    //Define the setter
    set {
        _field_name = value;
    }
}

```

where

- ▶ *type* is the data type of the private field as well as of the public property. Both types must match.
- ▶ *\_field\_name* is the name of the private field. It follows the same rules as those used for variable names.
- ▶ *property\_name* is the name of the public property. It follows the same rules as those used for variable names.

The C# program that follows uses the property Temperature (instead of methods) to get and set the value of the private field *\_temperature*. When a statement tries to access the value of the property Temperature, the getter is called automatically and similarly, when a statement tries to assign a value to the property Temperature the setter is called automatically!

### project\_39\_5d

```

class FahrenheitToCelsius {
    private double _temperature; //This defines a private field

    //Define the constructor
    public FahrenheitToCelsius(double value) {
        this.Temperature = value; //Property is initialized
    }

    //Define a public property
    public double Temperature {
        //Define the getter
        get {
            return 5.0 / 9.0 * (this._temperature - 32.0);
        }

        //Define the setter
    }
}

```

```

    set {
        if (value >= -459.67) {
            this._temperature = value;
        }
        else {
            throw new Exception("There is no temperature below -459.67");
        }
    }
}

class Program {
    static void Main(string[] args) {
        FahrenheitToCelsius x = new FahrenheitToCelsius(-50); //This calls the constructor
                                                                //which, in turn, calls the
                                                                //setter.
        Console.WriteLine(x.Temperature); //This calls the getter.

        x.Temperature = -60;           //This calls the setter
        Console.WriteLine(x.Temperature); //This calls the getter

        x.Temperature = -700;          //This calls the setter and throws an error
        Console.WriteLine(x.Temperature); //This is never executed. The flow of execution
                                         //is stopped due to the previous statement.
    }
}

```

### ***Exercise 39.5-1 The Roman Numerals***

---

*Roman numerals are shown in the following table.*

Number	Roman Numeral
1	I
2	II
3	III
4	IV
5	V

*Do the following:*

- i. Write a class named Romans which includes
  - a. a private integer field named \_number.

- b. a public property named Number. It will be used to get and set the value of the field \_number in integer format. The setter must throw an error when the number is not recognized.
  - c. a public property named Roman. It will be used to get and set the value of the field \_number in Roman numeral format. The setter must throw an error when the Roman numeral is not recognized.
- ii. Using the class cited above, write a C# program that displays the Roman numeral that corresponds to the value of 3 as well as the number that corresponds to the Roman numeral value of “V”.

### **Solution**

---

The getter and the setter of the property Number are very simple so there is nothing special to explain. The getter and the setter of the property Roman, however, need some explanation.

The getter of the property Roman can be written as follows

```
//Define the getter
get {
    if (this._number == 1) {
        return "I";
    }
    else if (this._number == 2) {
        return "II";
    }
    else if (this._number == 3) {
        return "III";
    }
    else if (this._number == 4) {
        return "IV";
    }
    else if (this._number == 5) {
        return "V";
    }
}
```

However, this approach is quite long and it could get even longer, if you want to expand your program so it can work with more Roman numerals. So, since you now know many about dictionaries, you can use a better approach, as shown in the code fragment that follows.

```
//Define the getter
get {
```

```

Dictionary<int, string> number2roman = new Dictionary<int, string> {
    { 1, "I" }, { 2, "II" }, { 3, "III" }, { 4, "IV"}, { 5, "V" }
};
return number2roman[this._number];
}

```

Accordingly, the setter can be as follows

```

//Define the setter
set {
    Dictionary<string, int> roman2number = new Dictionary<string, int> {
        { "I", 1 }, { "II", 2 }, { "III", 3 }, { "IV", 4}, { "V", 5}
    };

    if (roman2number.ContainsKey(value)) {
        this._number = roman2number[value];
    }
    else {
        throw new Exception("Roman numeral not recognized");
    }
}

```

 The C# built-in method `ContainsKey(value)` returns true when the dictionary `roman2number` contains the specified value.

 The statement `if (roman2number.ContainsKey(value))` is equivalent to the statement `if (roman2number.ContainsKey(value) == true)`.

The final C# program is as follows

### project\_39\_5\_1

```

class Romans {
    private int _number;

    //Define public property Number
    public int Number {
        //Define the getter
        get {
            return this._number;
        }

        //Define the setter
        set {
            if (value >= 1 && value <= 5) {
                this._number = value;
            }
        }
    }
}

```

```

        else {
            throw new Exception("Number not recognized");
        }
    }
}

//Define public property Roman
public string Roman {
    //Define the getter
    get {
        Dictionary<int, string> number2roman = new Dictionary<int, string> {
            { 1, "I" }, { 2, "II" }, { 3, "III" }, { 4, "IV" }, { 5, "V" }
        };
        return number2roman[this._number];
    }

    //Define the setter
    set {
        Dictionary<string, int> roman2number = new Dictionary<string, int> {
            { "I", 1 }, { "II", 2 }, { "III", 3 }, { "IV", 4 }, { "V", 5 }
        };

        if (roman2number.ContainsKey(value)) {
            this._number = roman2number[value];
        }
        else {
            throw new Exception("Roman numeral not recognized");
        }
    }
}

class Program {
    static void Main(string[] args) {
        Romans x = new Romans();

        x.Number = 3;
        Console.WriteLine(x.Number); //It displays: 3
        Console.WriteLine(x.Roman); //It displays: III

        x.Roman = "V";
        Console.WriteLine(x.Number); //It displays: 5
        Console.WriteLine(x.Roman); //It displays: V
    }
}

```

## 39.6 Can a Method Call Another Method of the Same Class?

In [paragraph 37.2](#) you learned that a subprogram can call another subprogram. Obviously, the same applies when it comes to class methods—a method can call another method of the same class! Methods are nothing more than subprograms after all! So, if you want a method to call another method of the same class you should use the keyword `this` in front of the method that you want to call (using dot notation) as shown in the example that follows.

### project\_39\_6

```
class JustAClass {
    public void foo1() {
        Console.WriteLine("foo1 was called");
        this.foo2();      //Call foo2() using dot notation
    }

    public void foo2() {
        Console.WriteLine("foo2 was called");
    }
}

class Program {
    static void Main(string[] args) {
        JustAClass x = new JustAClass();
        x.foo1();      //Call foo1() which, in turn, will call foo2()
    }
}
```

### Exercise 39.6-1 Doing Math

Do the following:

- i. Write a class named `DoingMath` which includes
  - a private void method named `square` that accepts a number through its formal argument list and then calculates its square and displays the message “The square of XX is YY”, where XX and YY must be replaced by actual values.
  - a private void method named `square_root` that accepts a number through its formal argument list and then calculates its square root and displays the message “The square root of XX is YY” where XX and YY must be replaced by actual values. However, if the number is less than zero, the method must display an error message.

- c. a public void method named `display_results` that accepts a number through its formal argument list and then calls the methods `square()` and `square_root()` to display the results.
- ii. Using the class cited above, write a C# program that prompts the user to enter a number. The program then displays the root and the square root of that number.

## **Solution**

---

This exercise is quite simple. The methods `square()`, `square_root()`, and `display_results()` must have a formal argument within their formal argument list so as to accept a passed value. The solution is as follows.

### project\_39\_6\_1

```

class DoingMath {
    private void square(double x) { //Argument x accepts passed value
        Console.WriteLine("The square of " + x + " is " + (x * x));
    }

    private void square_root(double x) { //Argument x accepts passed value
        if (x < 0) {
            Console.WriteLine("Cannot calculate square root");
        }
        else {
            Console.WriteLine("Square root of " + x + " is " + Math.Sqrt(x));
        }
    }

    public void display_results(double x) { //Argument x accepts passed value
        this.square(x);
        this.square_root(x);
    }
}

class Program {
    static void Main(string[] args) {
        double b;

        DoingMath dm = new DoingMath();

        Console.Write("Enter a number: ");
        b = Double.Parse(Console.ReadLine());
        dm.display_results(b);
    }
}

```

| }

## 39.7 Class Inheritance

*Class inheritance* is one of the main concepts of OOP. It lets you write a class using another class as a base. When a class is based on another class, the programmers use to say “it inherits the other class”. The class that is inherited is called the *parent class*, the *base class*, or the *superclass*. The class that does the inheriting is called the *child class*, the *derived class*, or the *subclass*.

A child class automatically inherits all the methods and fields of the parent class. The best part, however, is that you can add additional characteristics (methods or fields) to the child class. Therefore, you use inheritance when you need several classes that aren't exactly identical but have many characteristics in common. To do this, you work as follows. First, you write a parent class that contains all the common characteristics. Second, you write child classes that inherit all those common characteristics from the parent class. Finally, you add additional characteristics to each child class. After all, these additional characteristics are what distinguishes a child class from its parent class!

Let's say that you want to write a program that keeps track of the teachers and students in a school. They have some characteristics in common, such as name and age, but they also have specific characteristics such as salary for teachers and grades for students that are not in common. What you can do here is write a parent class named `SchoolMember` that contains all those characteristics that both teachers and students have in common. Then you can write two child classes named `Teacher` and `Student`, one for teachers and one for students. Both child classes can inherit the class `SchoolMember` but additional fields, named `salary` and `grades`, must be added to the child classes `Teacher` and `Student` correspondingly.

The parent class `SchoolMember` is shown here

```
class SchoolMember {  
    public string name;  
    public int age;  
  
    //Define the constructor  
    public SchoolMember(string name, int age) {  
        this.name = name;  
        this.age = age;
```

```
        Console.WriteLine("A school member was initialized");
    }
}
```

If you want a class to inherit the class `SchoolMember`, it must be defined as follows

```
class Name : SchoolMember {
    Define additional fields for this class

    //Define the constructor
    public Name(string name, int age [, ...]) : base(name, age) {
        A statement or block of statements
    }

    Define additional methods for this class
}
```

where `Name` is the name of the child class.

So, the class `Teacher` can be as follows

```
class Teacher : SchoolMember {
    public double salary; //This is an additional field for class Teacher

    //Define the constructor
    public Teacher(string name, int age, double salary) : base(name, age) {
        this.salary = salary;
        Console.WriteLine("A teacher was initialized");
    }
}
```

 The keyword `base` calls the constructor of the class `SchoolMember` and initializes the fields `name` and `age` of the class `Teacher`.

Similarly, the class `Student` can be as follows

```
class Student : SchoolMember {
    public int[] grades = new int[3]; //This is an additional field for class Student

    //Define the constructor
    public Student(string name, int age, int[] grades) : base(name, age) {
        this.grades = grades;
        Console.WriteLine("A student was initialized");
    }
}
```

| }

 The keyword base calls the constructor of the class SchoolMember and initializes the fields name and age of the class Student.

The complete C# program is as follows. Please note that all fields have been declared as private and public properties are included for each field.

### project\_39\_7

```
class SchoolMember {  
    private string _name;  
    private int _age;  
  
    //Define the constructor  
    public SchoolMember(string name, int age) {  
        this.Name = name;  
        this.Age = age;  
        Console.WriteLine("A school member was initialized");  
    }  
  
    //Define public property Name  
    public string Name {  
        //Define the getter  
        get {  
            return this._name;  
        }  
  
        //Define the setter  
        set {  
            if (value != "")  
                this._name = value;  
            else  
                throw new Exception("Name cannot be empty");  
        }  
    }  
  
    //Define public property Age  
    public int Age {  
        //Define the getter  
        get {  
            return this._age;  
        }  
  
        //Define the setter
```

```

        set {
            if (value > 0)
                this._age = value;
            else
                throw new Exception("Age cannot be negative or zero");
        }
    }

class Teacher : SchoolMember {
    private double _salary; //This is an additional field for class Teacher

    //Define the constructor
    public Teacher(string name, int age, double salary) : base(name, age) {
        this.Salary = salary;
        Console.WriteLine("A teacher was initialized");
    }

    //Define public property Name
    public double Salary {
        //Define the getter
        get {
            return this._salary;
        }

        //Define the setter
        set {
            if (value >= 0)
                this._salary = value;
            else
                throw new Exception("Salary cannot be negative");
        }
    }
}

class Student : SchoolMember {
    private int[] _grades = new int[3]; //This is an additional field for class Student

    //Define the constructor
    public Student(string name, int age, int[] grades) : base(name, age) {
        this.Grades = grades;
        Console.WriteLine("A student was initialized");
    }

    //Define public property Grades
}

```

```

public int[] Grades {
    //Define the getter
    get {
        return this._grades;
    }

    //Define the setter
    set {
        //value here is an array. Check if negative grade exists in value
        bool negative_found = false;
        foreach (var v in value) {
            if (v < 0)
                negative_found = true;
        }

        if (!negative_found)
            this._grades = value;
        else
            throw new Exception("Grades cannot be negative");
    }
}

class Program {
    static void Main(string[] args) {
        Teacher teacher1 = new Teacher("Mr. John Scott", 43, 35000);
        Teacher teacher2 = new Teacher("Mrs. Ann Carter", 5, 32000);

        Student student1 = new Student("Mark Nelson", 14, new int[] {90, 95, 92});
        Student student2 = new Student("Mary Morgan", 13, new int[] {92, 97, 94});

        Console.WriteLine(teacher1.Name);
        Console.WriteLine(teacher1.Age);
        Console.WriteLine(teacher1.Salary);

        Console.WriteLine(student2.Name);
        Console.WriteLine(student2.Age);
        foreach (var grade in student2.Grades) {
            Console.WriteLine(grade);
        }
    }
}

```

 Note how values for the argument grades are passed to the constructor of the class

---

## 39.8 Review Questions: True/False

Choose **true** or **false** for each of the following statements.

1. Procedural programming is better than object-oriented programming when it comes to writing large programs.
2. Object-oriented programming focuses on objects.
3. An object combines data and functionality.
4. Object-oriented programming enables you to maintain your code more easily but your code cannot be used easily by others.
5. You can create an object without using a class.
6. The process of creating a new instance of a class is called “installation”.
7. In OOP, you always have to create at least two instances of the same class.
8. The constructor method is executed when an object is instantiated.
9. When you create two instances of the same class, the constructor method of the class will be executed twice.
10. The keyword `private` in front of a field specifies that this field can be accessed from outside the class.
11. The keyword `public` in front of a method specifies that this method can be called from outside the class.
12. The principles of the object-oriented programming state that the data of a class should be hidden and safe from accidental alteration.
13. A property is a class member that provides a flexible mechanism to read, write, or compute the value of a field.
14. A property exposes the internal implementation of a class.
15. Class inheritance is one of the main concepts of OOP.
16. When a class is inherited, it is called the “derived class”.
17. A parent class automatically inherits all the methods and fields of the child class.

## 39.9 Review Exercises

Complete the following exercises.

1. Do the following
  - i. Write a class named `Trigonometry` that includes
    - a. a public method named `square_area` that accepts the side of a square through its formal argument list and then calculates and returns its area.
    - b. a public method named `rectangle_area` that accepts the base and the height of a rectangle through its formal argument list and then calculates and returns its area.
    - c. a public method named `triangle_area` that accepts the base and the height of a triangle through its formal argument list and then calculates and returns its area. It is given that

$$area = \frac{base \times height}{2}$$

- ii. Using the class cited above, write a C# program that prompts the user to enter the side of a square, the base and the height of a rectangle, and the base and the height of a triangle, and then displays the area for each one of them.
2. Do the following
  - i. Write a class named `Pet` which includes
    - a. a public string field named `kind`
    - b. a public integer field named `legs_number`
    - c. a public void method named `start_running` that displays the message “Pet is running”
    - d. a public void method named `stop_running` that displays the message “Pet stopped”
  - ii. Write a C# program that creates two instances of the class `Pets` (for example, a dog and a monkey) and then calls some of their methods.
3. Do the following
  - i. In the class `Pet` of the previous exercise
    - a. alter the fields `kind` and `legs_number` to private fields `_kind` and `_legs_number` correspondingly.

- b. add a property named `Kind`. It will be used to get and set the value of the field `_kind`. The setter must throw an error when the field is set to an empty value.
    - c. add a property named `Legs_number`. It will be used to get and set the value of the field `_legs_number`. The setter must throw an error when the field is set to a negative value.
    - d. add a constructor to accept initial values for the properties `Kind` and `Legs_number` through its formal argument list.
  - ii. Write a C# program that creates one instance of the class `Pets` (for example, a dog) and then calls both of its methods. Then try to set erroneous values for properties `Kind` and `Legs_number` and see what happens.
4. Do the following
- i. Write a class named `Box` that includes
    - a. three private float (real) fields named `_width`, `_length`, and `_height`.
    - b. a constructor that accepts initial values for the three fields `_width`, `_length`, and `_height` through its formal argument list.
    - c. a public void method named `display_volume` that calculates and displays the volume of a box whose dimensions are `_width`, `_length`, and `_height`. It is given that
$$volume = width \times length \times height$$
    - d. a public void method named `display_dimensions` that displays box's dimensions.
  - ii. Using the class cited above, write a C# program that prompts the user to enter the dimensions of three boxes, and then displays their dimensions and their volume.
5. In the class `Box` of the previous exercise add three properties named `Width`, `Length`, and `Height`. They will be used to get and set the values of the fields `_width`, `_length`, and `_height`. The setters must throw an error when the corresponding field is set to a negative value or zero.
6. Do the following
- i. Write a class named `Cube` that includes

- a. a private float (real) field named `_edge`.
- b. a constructor that accepts an initial value for the field `_edge` through its formal argument list.
- c. a public void method named `display_volume` that calculates and displays the volume of a cube whose edge length is `_edge`. It is given that

$$volume = edge^3$$

- d. a public void method named `display_one_surface` that calculates and displays the surface area of one side of a cube whose edge length is `_edge`.
- e. a public void method named `display_total_surface` that calculates and displays the total surface area of a cube whose edge length is `_edge`. It is given that

$$total\ surface = 6 \times edge^2$$

- ii. Using the class cited above, write a C# program that prompts the user to enter the edge length of a cube, and then displays its volume, the surface area of one of its sides, and its total surface area.
7. In the class `Cube` of the previous exercise add a property named `Edge`. It will be used to get and set the value of the field `_edge`. The setter must throw an error when the field is set to a negative value or zero.
8. Do the following
- i. Write a class named `Circle` that includes
    - a. a private float (real) field named `_radius` with an initial value of `-1`.
    - b. a property named `Radius`. It will be used to get and set the value of the field `_radius`. The getter must throw an error when the field has not yet been set, and the setter must throw an error when the field is set to a negative value or zero.
    - c. a public method named `get_diameter` that calculates and returns the diameter of a circle whose radius is `Radius`. It is given that

$$diameter = 2 \times radius$$

- d. a public method named `get_area` that calculates and returns the area of a circle whose radius is `Radius`. It is given that

$$area = 3.14 \times radius^2$$

- e. a public method named `get_perimeter` that calculates and returns the perimeter of a circle whose radius is `Radius`. It is given that

$$perimeter = 2 \times 3.14 \times radius$$

- ii. Write a subprogram named `display_menu` that displays the following menu.
1. Enter radius
  2. Display radius
  3. Display diameter
  4. Display area
  5. Display perimeter
  6. Exit
- iii. Using the class and the subprogram cited above, write a C# program that displays the previously mentioned menu and prompts the user to enter a choice (of 1 to 6). If choice 1 is selected, the program must prompt the user to enter a radius. If choice 2 is selected, the program must display the radius entered in choice 1. If choices 3, 4, or 5 are selected, the program must display the diameter, the area, or the perimeter correspondingly of a circle whose radius is equal to the radius entered in choice 1. The process must repeat as many times as the user wishes.
9. Assume that you work in a computer software company that is going to create a word processor application. You are assigned to write a class that will be used to provide information to the user.
- i. Write a class named `Info` that includes
    - a. a private string field named `_user_text`.
    - b. a property named `User_text`. It will be used to get and set the value of the field `_user_text`. The setter must throw an error when the field is set to an empty value.
    - c. a public method named `get_spaces_count` that returns the

- total number of spaces that exist in property User\_text.
- d. a public method named get\_words\_count that returns the total number of words that exist in property User\_text.
  - e. a public method named get\_vowels\_count that returns the total number of vowels that exist in property User\_text.
  - f. a public method named get\_letters\_count that returns the total number of characters (excluding spaces) that exist in property User\_text.
- ii. Using the class cited above, write a testing program that prompts the user to enter a text and then displays all available information. Assume that the user enters only space characters or letters (uppercase or lowercase) and the words are separated by a single space character.

Hint: In a text of three words, there are two spaces, which means that the total number of words is one more than the total number of spaces. Count the total number of spaces, and then you can easily find the total number of words!

- 10. During the Cold War after World War II, messages were encrypted so that if the enemies intercepted them, they could not decrypt them without the decryption key. A very simple encryption algorithm is alphabetic rotation. The algorithm moves all letters N steps "up" in the alphabet, where N is the encryption key. For example, if the encryption key is 2, you can encrypt a message by replacing the letter A with the letter C, the letter B with the letter D, the letter C with the letter E, and so on. Do the following:
  - i. Write a class named EncryptDecrypt that includes
    - a. private integer field named encr\_decr\_key.
    - b. a property named Encr\_decr\_key. It will be used to get and set the value of the field encr\_decr\_key. The getter must throw an error when the field has not yet been set, and the setter must throw an error when the field is not set to a value between 1 and 26.
    - c. A public method named encrypt that accepts a message through its formal argument list and then returns the encrypted

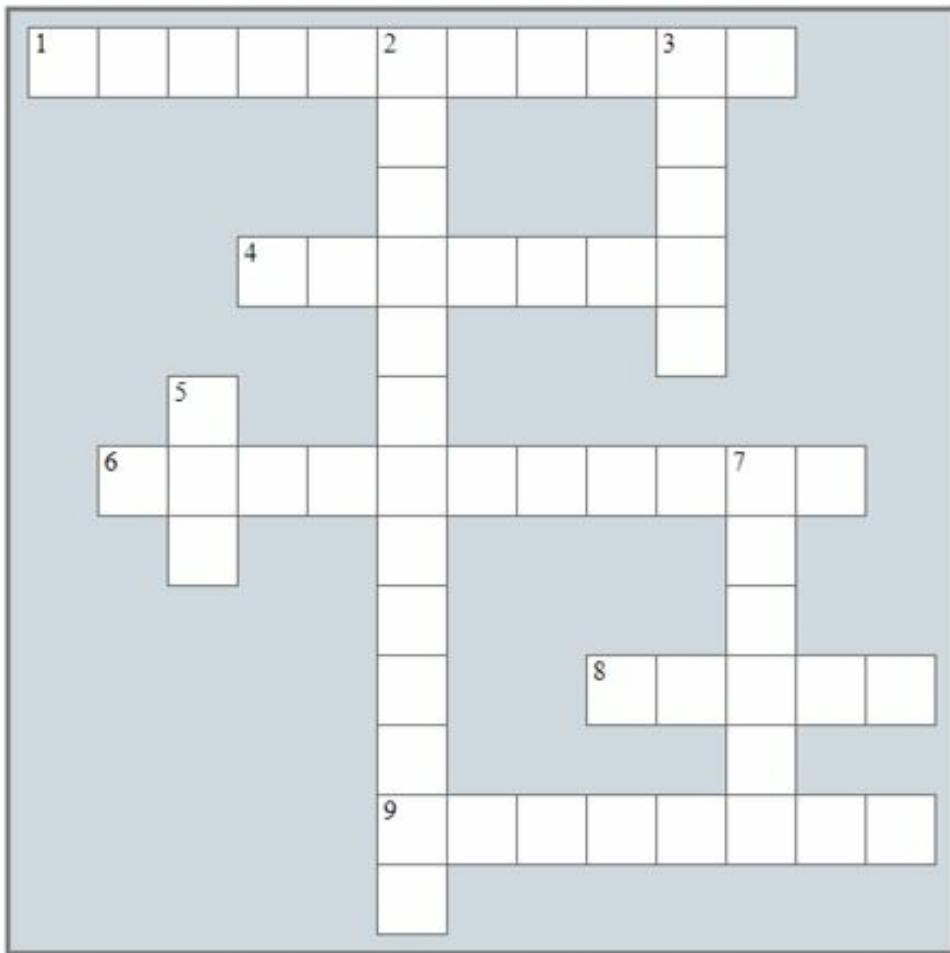
message.

- d. A public method named `decrypt` that accepts an encrypted message through its formal argument list and then returns the decrypted message.
- ii. Write a subprogram named `display_menu` that displays the following menu:
  - 1. Enter encryption/decryption key
  - 2. Encrypt a message
  - 3. Decrypt a message
  - 4. Exit
- iii. Using the class and the subprogram cited above, write a C# program that displays the menu previously mentioned and then prompts the user to enter a choice (of 1 to 4). If choice 1 is selected, the program must prompt the user to enter an encryption/decryption key. If choice 2 is selected, the program must prompt the user to enter a message and then display the encrypted message. If choice 2 is selected, the program must prompt the user to enter an encrypted message and then display the decrypted message. The process must repeat as many times as the user wishes. Assume that the user enters only lowercase letters or a space for the message.

# **Review in “Object-Oriented Programming”**

## **Review Crossword Puzzle**

1. Solve the following crossword puzzle.



### **Across**

1. Class \_\_\_\_\_ lets you write a class using another class as a base.
4. The actions that an object performs.
6. This method is executed automatically whenever an object is created.
8. An object's attribute.
9. Object-\_\_\_\_\_ programming is a style of programming that focuses on objects.

### **Down**

- 
2. The process of creating a new object.
  3. Every object is created from a \_\_\_\_\_.
  5. In \_\_\_\_\_ you can combine data and functionality and enclose them inside something called an object.
  7. A class instance.

## Review Questions

Answer the following questions.

1. What is object-oriented programming?
2. What is the constructor of a class?
3. When do you have to write a field name using dot notation?
4. What is the `this` keyword?
5. Why a field should not be exposed in OOP?
6. What is meant by the term “class inheritance”?

# **Some Final Words from the Author**

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I hope you really enjoyed reading this book. I made every possible effort to make it comprehensible even by people that probably have no previous experience in programming.

So if you liked this book, please visit the web store where you bought it and show me your gratitude by writing a good review and giving me as many stars as possible. By doing this, you will encourage me to continue writing and of course you'll help other readers to reach me.

And remember: Learning is a process within an endless loop. It begins at birth and continues throughout your lifetime!

## **Footnotes**

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[1] Aristides (530 BC–468 BC) was an ancient Athenian statesman and general. The ancient historian Herodotus cited him as “the best and most honorable man in Athens”. He was so fair in all that he did that he was often referred to as “Aristides the Just”. He flourished in the early quarter of Athens’s Classical period and helped Athenians defeat the Persians at the battles of Salamis and Plataea.

[\[RETURN\]](#)

**[2]** The word "algorithm" derives from the word "algorism" and the Greek word "arithmos" .The word "algorism" comes from the Latinization of the name of Al-Khwārizmī<sup>[3]</sup> whereas the Greek word “arithmos” means “number”.

**[3]** Muḥammad ibn Al-Khwārizmī (780–850) was a Persian mathematician, astronomer, and geographer. He is considered one of the fathers of algebra.

[\[RETURN\]](#)

**[4]** Corrado Böhm (1923–2017) was a computer scientist known especially for his contribution to the theory of structured programming, and for the implementation of functional programming languages.

[\[RETURN\]](#)

[5] Giuseppe Jacopini (1936–2001) was a computer scientist. His most influential contribution is the theorem about structured programming, published along with Corrado Böhm in 1966, under the title *Flow Diagrams, Turing Machines, and Languages with Only Two Formation Rules*.

[\[RETURN\]](#)

**[6]** George Boole (1815–1864) was an English mathematician, philosopher, and logician. He is best known as the architect of what is now called Boolean logic (Boolean algebra), the basis of the modern digital computer.

[\[RETURN\]](#)

[7] Grace Murray Hopper (1906–1992) was an American computer scientist and US Navy admiral. She was one of the first programmers of the Harvard Mark I computer, and developed the first compiler for a computer programming language known as A-0 and later a second one, known as B-0 or FLOW-MATIC.

[\[RETURN\]](#)

**[8]** Daniel Gabriel Fahrenheit (1686–1736) was a German physicist, engineer, and glass blower who is best known for inventing both the alcohol and the mercury thermometers, and for developing the temperature scale now named after him.

[\[RETURN\]](#)

**[9]** William Thomson, 1st Baron Kelvin (1824–1907), was an Irish-born British mathematical physicist and engineer. He is widely known for developing the basis of absolute zero (the Kelvin temperature scale), and for this reason a unit of temperature measure is named after him. He discovered the Thomson effect in thermoelectricity and helped develop the second law of thermodynamics.

[\[RETURN\]](#)

**[10]** Anders Celsius (1701–1744) was a Swedish astronomer, physicist, and mathematician. He founded the Uppsala Astronomical Observatory in Sweden and proposed the Celsius temperature scale, which takes his name.

[\[RETURN\]](#)

**[11]** Heron of Alexandria (c. 10–c. 70 AD) was an ancient Greek mathematician, physicist, astronomer, and engineer. He is considered the greatest experimenter of ancient times. He described the first recorded steam turbine engine, called an “aeolipile” (sometimes called a "Hero engine"). Heron also described a method of iteratively calculating the square root of a positive number. Today, though, he is known best for the proof of “Heron's Formula” which finds the area of a triangle from its side lengths.

[\[RETURN\]](#)

**[12]** Pythagoras of Samos (c. 571–c. 497 BC) was a famous Greek mathematician, philosopher, and astronomer. He is best known for the proof of the important Pythagorean theorem. He was an influence for Plato. His theories are still used in mathematics today.

[\[RETURN\]](#)

**[13]** William Shakespeare (1564–1616) was an English poet, playwright, and actor. He is often referred to as England's national poet. He wrote about 40 plays and several long narrative poems. His works are counted among the best representations of world literature. His plays have been translated into every major living language and are still performed today.

[\[RETURN\]](#)

**[14]** A quantity that is either zero or positive.

[\[RETURN\]](#)

**[15]** Francis Beaufort (1774–1857) was an Irish hydrographer and officer in Britain's Royal Navy. He is the inventor of the Beaufort wind force scale.

[\[RETURN\]](#)

**[16]** The value of  $-459.67^{\circ}$  (on the Fahrenheit scale) is the lowest temperature possible and it is called *absolute zero*. Absolute zero corresponds to  $-273.15^{\circ}\text{C}$  on the Celsius temperature scale and to 0 K on the Kelvin temperature scale.

[\[RETURN\]](#)

**[17]** A quantity that is either zero or negative.

[\[RETURN\]](#)

**[18]** Madhava of Sangamagrama (c. 1340–c. 1425), was an Indian mathematician and astronomer from the town of Sangamagrama (present day Irinjalakuda) of India. He founded the Kerala School of Astronomy and Mathematics and was the first to use infinite series approximations for various trigonometric functions. He is often referred to as the “father of mathematical analysis”.

[\[RETURN\]](#)

**[19]** Gottfried Wilhelm von Leibniz (1646–1716) was a German mathematician and philosopher. He made important contributions to the fields of metaphysics, logic, and philosophy, as well as mathematics, physics, and history. In one of his works, *On the Art of Combination* (*Dissertatio de Arte Combinatoria*), published in 1666, he formulated a model that is considered the theoretical ancestor of modern computers.

[\[RETURN\]](#)

**[20]** Leonardo Pisano Bigollo (c. 1170–c. 1250), also known as Fibonacci, was an Italian mathematician. In his book *Liber Abaci* (published in 1202), Fibonacci used a special sequence of numbers to try to determine the growth of a rabbit population. Today, that sequence of numbers is known as the Fibonacci sequence. He was also one of the first people to introduce the Arabic numeral system to Europe; this is the numeral system we use today, based on ten digits with a decimal point and a symbol for zero. Before then, the Roman numeral system was being used, making numerical calculations difficult.

[\[RETURN\]](#)

**[21]** Brook Taylor (1685–1731) was an English mathematician who is best known for the Taylor series and his contributions to the theory of finite differences.

[\[RETURN\]](#)

**[22]** Samuel Finley Breese Morse (1791–1872) was an American painter and inventor. Morse contributed to the invention of a single-wire telegraph system and he was a co-developer of the Morse code.

[\[RETURN\]](#)

**[23]** In Greek mythology, the Titans and Titanesses were the children of Uranus and Gaea. They were giant gods who ruled during the legendary Golden Age (immediately preceding the Olympian gods). The male Titans were Coeus, Oceanus, Crius, Cronus, Hyperion, and Iapetus whereas the female Titanesses were Tethys, Mnemosyne, Themis, Theia, Rhea, and Phoebe. In a battle, known as the Titanomachy, fought to decide which generation of gods would rule the Universe, the Olympians won over the Titans!

[\[RETURN\]](#)

## **More...**

---

This is the nested decision control structure

[\[RETURN\]](#)

This is a nested case decision structure.

[\[RETURN\]](#)

This is a nested single-alternative decision structure

[\[RETURN\]](#)

This is a nested dual-alternative decision structure

[\[RETURN\]](#)

This statement is not affected by the previous decision control structure and does not affect the next one.

[\[RETURN\]](#)

The previous and next decision control structures are affected by this statement

[\[RETURN\]](#)

$-5 < x \leq 0$

[\[RETURN\]](#)

$0 < x \leq 6$

[\[RETURN\]](#)

$6 < x \leq 20$

[\[RETURN\]](#)

All other values of x

[\[RETURN\]](#)

This pair of statements is executed 4 times forcing the user to enter 4 numbers.

[\[RETURN\]](#)

This is the part of the program that actually repeats.

[\[RETURN\]](#)

This must be written 20 times

[RETURN]

Nested loop

[\[RETURN\]](#)

This code fragment calculates the denominator.

[\[RETURN\]](#)

This is the dual-alternative decision structure

[\[RETURN\]](#)

This is the post-test loop structure

[\[RETURN\]](#)

This is the dual-alternative decision structure

[\[RETURN\]](#)

A statement or block of statements 1

[\[RETURN\]](#)

A statement or block of statements 2

[\[RETURN\]](#)

A statement or block of statements 1

[\[RETURN\]](#)

A statement or block of statements 2

[\[RETURN\]](#)

A statement or block of statements 1

[\[RETURN\]](#)

Data input stage without validation.

[\[RETURN\]](#)

Data input validation without error messages.

[\[RETURN\]](#)

Data input validation with one single error message.

[\[RETURN\]](#)

Data input validation with individual error messages, one for each type of error.

[\[RETURN\]](#)

Data input stage without validation

[\[RETURN\]](#)

Data input validation with one single error message

[\[RETURN\]](#)

Data input and validation

[\[RETURN\]](#)

Data input and validation

[\[RETURN\]](#)

Data input and validation

[\[RETURN\]](#)

This is called a “formal argument list”

[\[RETURN\]](#)

This is called an “actual argument list”

[\[RETURN\]](#)

This is called an “actual argument list”

[\[RETURN\]](#)

By default, arrays in C# are passed by reference.

[\[RETURN\]](#)