



Introduction to C Programming

C How to Program

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2.1 Introduction

- ▶ The C language facilitates a structured and disciplined approach to computer program design.
- ▶ In this chapter we introduce C programming and present several examples that illustrate many important features of C.
- ▶ In Chapters 3 and 4 we present an introduction to structured programming in C.



2.2 A Simple C Program: Printing a Line of Text

- ▶ We begin by considering a simple C program.
- ▶ Our first example prints a line of text (Fig. 2.1).



```
1  /* Fig. 2.1: fig02_01.c
2     A first program in C */
3  #include <stdio.h>
4
5  /* function main begins program execution */
6  int main( void )
7  {
8     printf( "Welcome to C!\n" );
9
10     return 0; /* indicate that program ended successfully */
11 } /* end function main */
```

Welcome to C!

Fig. 2.1 | A first program in C.



2.2 A Simple C Program: Printing a Line of Text (Cont.)

- ▶ Lines 1 and 2
 - `/* Fig. 2.1: fig02_01.c`
`A first program in C */`
- ▶ begin with `/*` and end with `*/` indicating that these two lines are a **comment**.
- ▶ You insert comments to **document programs** and improve program readability.
- ▶ Comments do not cause the computer to perform any action when the program is run.



2.2 A Simple C Program: Printing a Line of Text (Cont.)

- ▶ Comments are ignored by the C compiler and do not cause any machine-language object code to be generated.
- ▶ Comments also help other people read and understand your program.



Common Programming Error 2.1

*Forgetting to terminate a comment with */.*



Common Programming Error 2.2

*Starting a comment with the characters */ or ending a comment with the characters /*.*



2.2 A Simple C Program: Printing a Line of Text (Cont.)

- ▶ C99 also includes the C++ language's `//` **single-line comments** in which everything from `//` to the end of the line is a comment.
- ▶ These can be used as standalone comments on lines by themselves or as end-of-line comments to the right of a partial line of code.
- ▶ Some programmers prefer `//` comments because they're shorter and they eliminate the common programming errors that occur with `/* */` comments.
- ▶ Line 3
 - `#include <stdio.h>`
- ▶ is a directive to the **C preprocessor**.



2.2 A Simple C Program: Printing a Line of Text (Cont.)

- ▶ Lines beginning with `#` are processed by the preprocessor before the program is compiled.
- ▶ Line 3 tells the preprocessor to include the contents of the **standard input/output header** (`<stdio.h>`) in the program.
- ▶ This header contains information used by the compiler when compiling calls to standard input/output library functions such as `printf`.
- ▶ Line 6
 - `int main(void)`
- ▶ is a part of every C program.
- ▶ The parentheses after `main` indicate that `main` is a program building block called a **function**.



2.2 A Simple C Program: Printing a Line of Text (Cont.)

- ▶ C programs contain one or more functions, one of which must be `main`.
- ▶ Every program in C begins executing at the function `main`.
- ▶ The keyword `int` to the left of `main` indicates that `main` “returns” an integer (whole number) value.
- ▶ We’ll explain what it means for a function to “return a value” when we demonstrate how to create your own functions in Chapter 5.



2.2 A Simple C Program: Printing a Line of Text (Cont.)

- ▶ For now, simply include the keyword `int` to the left of `main` in each of your programs.
- ▶ Functions also can receive information when they're called upon to execute.
- ▶ The `void` in parentheses here means that `main` does not receive any information.



Good Programming Practice 2.1

Every function should be preceded by a comment describing the purpose of the function.



2.2 A Simple C Program: Printing a Line of Text (Cont.)

- ▶ A left brace, {, begins the **body** of every function (line 7).
- ▶ A corresponding **right brace** ends each function (line 11).
- ▶ This pair of braces and the portion of the program between the braces is called a block.
- ▶ Line 8
 - `printf("welcome to C!\n");`
- ▶ instructs the computer to perform an **action**, namely to print on the screen the **string** of characters marked by the quotation marks.
- ▶ A string is sometimes called a **character string**, a **message** or a **literal**.



2.2 A Simple C Program: Printing a Line of Text (Cont.)

- ▶ The entire line, including `printf`, its **argument** within the parentheses and the semicolon (`;`), is called a **statement**.
- ▶ Every statement must end with a semicolon (also known as the **statement terminator**).
- ▶ When the preceding `printf` statement is executed, it prints the message `Welcome to C!` on the screen.
- ▶ The characters normally print exactly as they appear between the double quotes in the `printf` statement.
- ▶ Notice that the characters `\n` were not printed on the screen.
- ▶ The backslash (`\`) is called an **escape character**.
- ▶ It indicates that `printf` is supposed to do something out of the ordinary.



2.2 A Simple C Program: Printing a Line of Text (Cont.)

- ▶ When encountering a backslash in a string, the compiler looks ahead at the next character and combines it with the backslash to form an **escape sequence**.
- ▶ The escape sequence `\n` means **newline**.
- ▶ When a newline appears in the string output by a `printf`, the newline causes the cursor to position to the beginning of the next line on the screen.
- ▶ Some common escape sequences are listed in Fig. 2.2.



Escape sequence	Description
<code>\n</code>	Newline. Position the cursor at the beginning of the next line.
<code>\t</code>	Horizontal tab. Move the cursor to the next tab stop.
<code>\a</code>	Alert. Sound the system bell.
<code>\\</code>	Backslash. Insert a backslash character in a string.
<code>\"</code>	Double quote. Insert a double-quote character in a string.

Fig. 2.2 | Some common escape sequences .



2.2 A Simple C Program: Printing a Line of Text (Cont.)

- ▶ Because the backslash has special meaning in a string, i.e., the compiler recognizes it as an escape character, we use a double backslash (`\\`) to place a single backslash in a string.
- ▶ Printing a double quote also presents a problem because double quotes mark the boundary of a string—such quotes are not printed.
- ▶ By using the escape sequence `\"` in a string to be output by `printf`, we indicate that `printf` should display a double quote.



2.2 A Simple C Program: Printing a Line of Text (Cont.)

- ▶ Line 10
 - `return 0; /* indicate that program ended successfully */`
- ▶ is included at the end of every `main` function.
- ▶ The keyword `return` is one of several means we'll use to [exit a function](#).
- ▶ When the return statement is used at the end of `main` as shown here, the value `0` indicates that the program has terminated successfully.
- ▶ The right brace, `}`, (line 12) indicates that the end of `main` has been reached.



Good Programming Practice 2.2

Add a comment to the line containing the right brace, }, that closes every function, including main.



2.2 A Simple C Program: Printing a Line of Text (Cont.)

- ▶ We said that `printf` causes the computer to perform an action.
- ▶ As any program executes, it performs a variety of actions and makes **decisions**.
- ▶ In Chapter 3, we discuss this **action/decision model** of programming in depth.



Common Programming Error 2.3

Typing the name of the output function `printf` as `print` in a program.



2.2 A Simple C Program: Printing a Line of Text (Cont.)

- ▶ Standard library functions like `printf` and `scanf` are not part of the C programming language.
- ▶ For example, the compiler cannot find a spelling error in `printf` or `scanf`.
- ▶ When the compiler compiles a `printf` statement, it merely provides space in the object program for a “call” to the library function.
- ▶ But the compiler does not know where the library functions are—the linker does.
- ▶ When the linker runs, it locates the library functions and inserts the proper calls to these library functions in the object program.



2.2 A Simple C Program: Printing a Line of Text (Cont.)

- ▶ Now the object program is complete and ready to be executed.
- ▶ For this reason, the linked program is called an **executable**.
- ▶ If the function name is misspelled, it's the linker that will spot the error, because it will not be able to match the name in the C program with the name of any known function in the libraries.



Good Programming Practice 2.3

Indent the entire body of each function one level of indentation (we recommend three spaces) within the braces that define the body of the function. This indentation emphasizes the functional structure of programs and helps make programs easier to read.



Good Programming Practice 2.4

Set a convention for the size of indent you prefer and then uniformly apply that convention. The tab key may be used to create indents, but tab stops may vary. We recommend using three spaces per level of indent.



2.2 A Simple C Program: Printing a Line of Text (Cont.)

- ▶ The `printf` function can print `Welcome to C!` several different ways.
- ▶ For example, the program of Fig. 2.3 produces the same output as the program of Fig. 2.1.
- ▶ This works because each `printf` resumes printing where the previous `printf` stopped printing.
- ▶ The first `printf` (line 8) prints `Welcome` followed by a space and the second `printf` (line 9) begins printing on the same line immediately following the space.



```
1  /* Fig. 2.3: fig02_03.c
2     Printing on one line with two printf statements */
3  #include <stdio.h>
4
5  /* function main begins program execution */
6  int main( void )
7  {
8     printf( "Welcome " );
9     printf( "to C!\n" );
10
11     return 0; /* indicate that program ended successfully */
12 }
```

Welcome to C!

Fig. 2.3 | Printing on one line with two `printf` statements.



2.2 A Simple C Program: Printing a Line of Text (Cont.)

- ▶ One `printf` can print several lines by using additional newline characters as in Fig. 2.4.
- ▶ Each time the `\n` (newline) escape sequence is encountered, output continues at the beginning of the next line.



```
1  /* Fig. 2.4: fig02_04.c
2     Printing multiple lines with a single printf */
3  #include <stdio.h>
4
5  /* function main begins program execution */
6  int main( void )
7  {
8     printf( "Welcome\nto\nC!\n" );
9
10     return 0; /* indicate that program ended successfully */
11 } /* end function main */
```

```
Welcome
to
C!
```

Fig. 2.4 | Printing multiple lines with a single printf.



2.3 Another Simple C Program: Adding Two Integers

- ▶ Our next program (fig. 3.8) uses the Standard Library function `scanf` to obtain two integers typed by a user at the keyboard, computes the sum of these values and prints the result using `printf`.
- ▶ [In the input/output dialog of Fig. 2.8, we emphasize the numbers input by the user in **bold**.]



```
1  /* Fig. 2.5: fig02_05.c
2     Addition program */
3  #include <stdio.h>
4
5  /* function main begins program execution */
6  int main( void )
7  {
8     int integer1; /* first number to be input by user */
9     int integer2; /* second number to be input by user */
10    int sum; /* variable in which sum will be stored */
11
12    printf( "Enter first integer\n" ); /* prompt */
13    scanf( "%d", &integer1 ); /* read an integer */
14
15    printf( "Enter second integer\n" ); /* prompt */
16    scanf( "%d", &integer2 ); /* read an integer */
17
18    sum = integer1 + integer2; /* assign total to sum */
19
20    printf( "Sum is %d\n", sum ); /* print sum */
21
22    return 0; /* indicate that program ended successfully */
23 } /* end function main */
```

Fig. 2.5 | Addition program. (Part I of 2.)



```
Enter first integer  
45  
Enter second integer  
72  
Sum is 117
```

Fig. 2.5 | Addition program. (Part 2 of 2.)



2.3 Another Simple C Program: Adding Two Integers (Cont.)

- ▶ Lines 8–10
 - ```
int integer1; /* first number to be input by user
*/
int integer2; /* second number to be input by user
*/
int sum; /* variable in which sum will be stored */
```
- ▶ are **definitions**.
- ▶ The names `integer1`, `integer2` and `sum` are the names of **variables**.
- ▶ A variable is a location in memory where a value can be stored for use by a program.
- ▶ These definitions specify that the variables `integer1`, `integer2` and `sum` are of type `int`, which means that these variables will hold **integer** values, i.e., whole numbers such as 7, -11, 0, 31914 and the like.



## 2.3 Another Simple C Program: Adding Two Integers (Cont.)

- ▶ All variables must be defined with a name and a data type immediately after the left brace that begins the body of `main` before they can be used in a program.
- ▶ The preceding definitions could have been combined into a single definition statement as follows:
  - `int integer1, integer2, sum;`
- ▶ but that would have made it difficult to describe the variables in corresponding comments as we did in lines 8–10.
- ▶ A variable name in C is any valid **identifier**.
- ▶ An identifier is a series of characters consisting of letters, digits and underscores (`_`) that does not begin with a digit.



## 2.3 Another Simple C Program: Adding Two Integers (Cont.)

- ▶ An identifier can be of any length, but only the first 31 characters are required to be recognized by C compilers according to the C standard.
- ▶ C is **case sensitive**—uppercase and lowercase letters are different in C, so `a1` and `A1` are different identifiers.



## Common Programming Error 2.4

*Using a capital letter where a lowercase letter should be used (for example, typing `Main` instead of `main`).*



## **Error-Prevention Tip 2.1**

*Avoid starting identifiers with the underscore character (`_`) to prevent conflicts with compiler-generated identifiers and standard library identifiers.*



## **Portability Tip 2.1**

*Use identifiers of 31 or fewer characters. This helps ensure portability and can avoid some subtle programming errors.*



### **Good Programming Practice 2.5**

*Choosing meaningful variable names helps make a program self-documenting, i.e., fewer comments are needed.*





### **Good Programming Practice 2.6**

*The first letter of an identifier used as a simple variable name should be a lowercase letter. Later in the text we'll assign special significance to identifiers that begin with a capital letter and to identifiers that use all capital letters.*



### **Good Programming Practice 2.7**

*Multiple-word variable names can help make a program more readable. Avoid running the separate words together as in `totalcommissions`. Rather, separate the words with underscores as in `total_commissions`, or, if you do wish to run the words together, begin each word after the first with a capital letter as in `totalCommissions`. The latter style is preferred.*



## 2.3 Another Simple C Program: Adding Two Integers (Cont.)

- ▶ Definitions must be placed after the left brace of a function and before *any executable statements*.
- ▶ A **syntax error** is caused when the compiler cannot recognize a statement.
- ▶ The compiler normally issues an error message to help you locate and fix the incorrect statement.
- ▶ Syntax errors are violations of the language.
- ▶ Syntax errors are also called **compile errors**, or **compile-time errors**.



## Common Programming Error 2.5

*Placing variable definitions among executable statements causes syntax errors.*



### **Good Programming Practice 2.8**

*Separate the definitions and executable statements in a function with one blank line to emphasize where the definitions end and the executable statements begin.*



## 2.3 Another Simple C Program: Adding Two Integers (Cont.)

- ▶ Line 12
  - `printf( "Enter first integer\n" ); /* prompt */`
- ▶ prints the literal `Enter first integer` on the screen and positions the cursor to the beginning of the next line.
- ▶ This message is called a **prompt** because it tells the user to take a specific action.
- ▶ The next statement
  - `scanf( "%d", &integer1 ); /* read an integer */`
- ▶ uses `scanf` to obtain a value from the user.
- ▶ The `scanf` function reads from the standard input, which is usually the keyboard.



## 2.3 Another Simple C Program: Adding Two Integers (Cont.)

- ▶ This `scanf` has two arguments, `"%d"` and `&integer1`.
- ▶ The first argument, the **format control string**, indicates the type of data that should be input by the user.
- ▶ The **%d conversion specifier** indicates that the data should be an integer (the letter `d` stands for “decimal integer”).
- ▶ The `%` in this context is treated by `scanf` (and `printf` as we’ll see) as a special character that begins a conversion specifier.
- ▶ The second argument of `scanf` begins with an ampersand (`&`)—called the **address operator** in C—followed by the variable name.



## 2.3 Another Simple C Program: Adding Two Integers (Cont.)

- ▶ The ampersand, when combined with the variable name, tells `scanf` the location (or address) in memory at which the variable `integer1` is stored.
- ▶ The computer then stores the value for `integer1` at that location.
- ▶ The use of ampersand (&) is often confusing to novice programmers or to people who have programmed in other languages that do not require this notation.
- ▶ For now, just remember to precede each variable in every call to `scanf` with an ampersand.





## Good Programming Practice 2.9

*Place a space after each comma (,) to make programs more readable.*



## 2.3 Another Simple C Program: Adding Two Integers (Cont.)

- ▶ When the computer executes the preceding `scanf`, it waits for the user to enter a value for variable `integer1`.
- ▶ The user responds by typing an integer, then pressing the **Enter key** to send the number to the computer.
- ▶ The computer then assigns this number, or value, to the variable `integer1`.
- ▶ Any subsequent references to `integer1` in this program will use this same value.
- ▶ Functions `printf` and `scanf` facilitate interaction between the user and the computer.
- ▶ Because this interaction resembles a dialogue, it is often called **conversational computing** or **interactive computing**.



## 2.3 Another Simple C Program: Adding Two Integers (Cont.)

- ▶ Line 15
  - `printf( "Enter second integer\n" ); /*  
prompt */`
- ▶ displays the message `Enter second integer` on the screen, then positions the cursor to the beginning of the next line.
- ▶ This `printf` also prompts the user to take action.
- ▶ The statement
  - `scanf( "%d", &integer2 ); /* read an integer  
*/`
- ▶ obtains a value for variable `integer2` from the user.



## 2.3 Another Simple C Program: Adding Two Integers (Cont.)

- ▶ The **assignment statement** in line 18
  - `sum = integer1 + integer2; /* assign total to sum */`
- ▶ calculates the sum of variables `integer1` and `integer2` and assigns the result to variable `sum` using the assignment operator `=`.
- ▶ The statement is read as, “`sum` gets the value of `integer1 + integer2`.” Most calculations are performed in assignments.
- ▶ The `=` operator and the `+` operator are called binary operators because each has two **operands**.
- ▶ The `+` operator’s two operands are `integer1` and `integer2`.
- ▶ The `=` operator’s two operands are `sum` and the value of the expression `integer1 + integer2`.



### **Good Programming Practice 2.10**

*Place spaces on either side of a binary operator. This makes the operator stand out and makes the program more readable.*



## Common Programming Error 2.6

*A calculation in an assignment statement must be on the right side of the = operator. It is a compilation error to place a calculation on the left side of an assignment operator.*



## 2.3 Another Simple C Program: Adding Two Integers (Cont.)

- ▶ Line 20
  - `printf( "Sum is %d\n", sum ); /* print sum */`
- ▶ calls function `printf` to print the literal `Sum is` followed by the numerical value of variable `sum` on the screen.
- ▶ This `printf` has two arguments, `"Sum is %d\n"` and `sum`.
- ▶ The first argument is the format control string.
- ▶ It contains some literal characters to be displayed, and it contains the conversion specifier `%d` indicating that an integer will be printed.
- ▶ The second argument specifies the value to be printed.
- ▶ Notice that the conversion specifier for an integer is the same in both `printf` and `scanf`.



## 2.3 Another Simple C Program: Adding Two Integers (Cont.)

- ▶ We could have combined the previous two statements into the statement
  - `printf( "Sum is %d\n", integer1 + integer2 );`
- ▶ Line 22
  - `return 0; /* indicate that program ended successfully */`
- ▶ passes the value 0 back to the operating-system environment in which the program is being executed.
- ▶ This value indicates to the operating system that the program executed successfully.
- ▶ For information on how to report a program failure, see the manuals for your particular operating-system environment.
- ▶ The right brace, `}`, at line 24 indicates that the end of function `main` has been reached.





## **Common Programming Error 2.7**

*Forgetting one or both of the double quotes surrounding the format control string in a printf or scanf.*



## Common Programming Error 2.8

*Forgetting the % in a conversion specification in the format control string of a printf or scanf.*



## Common Programming Error 2.9

*Placing an escape sequence such as `\n` outside the format control string of a `printf` or `scanf`.*



## Common Programming Error 2.10

*Forgetting to include the expressions whose values are to be printed in a `printf` containing conversion specifiers.*



## Common Programming Error 2.11

*Not providing a conversion specifier when one is needed in a printf format control string to print the value of an expression.*



## Common Programming Error 2.12

*Placing inside the format control string the comma that is supposed to separate the format control string from the expressions to be printed.*



## Common Programming Error 2.13

*Using the incorrect format conversion specifier when reading data with scanf.*



## Common Programming Error 2.14

*Forgetting to precede a variable in a scanf statement with an ampersand when that variable should, in fact, be preceded by an ampersand.*





## Common Programming Error 2.15

*Preceding a variable included in a `printf` statement with an ampersand when, in fact, that variable should not be preceded by an ampersand.*



## 2.4 Memory Concepts

- ▶ Variable names such as `integer1`, `integer2` and `sum` actually correspond to locations in the computer's memory.
- ▶ Every variable has a name, a **type** and a **value**.
- ▶ In the addition program of Fig. 2.5, when the statement (line 13)
  - `scanf( "%d", &integer1 ); /* read an integer */`
- ▶ is executed, the value typed by the user is placed into a memory location to which the name `integer1` has been assigned.
- ▶ Suppose the user enters the number 45 as the value for `integer1`.
- ▶ The computer will place 45 into location `integer1` as shown in Fig. 2.6.



---

integer1

45

---

**Fig. 2.6** | Memory location showing the name and value of a variable.



## 2.4 Memory Concepts (Cont.)

- ▶ Whenever a value is placed in a memory location, the value replaces the previous value in that location; thus, placing a new value into a memory location is said to be **destructive**.
- ▶ Returning to our addition program again, when the statement (line 16)
  - `scanf( "%d", &integer2 ); /* read an integer */`
- ▶ executes, suppose the user enters the value 72.
- ▶ This value is placed into location `integer2`, and memory appears as in Fig. 2.7.
- ▶ These locations are not necessarily adjacent in memory.



## 2.4 Memory Concepts (Cont.)

- ▶ Once the program has obtained values for `integer1` and `integer2`, it adds these values and places the sum into variable `sum`.
- ▶ The statement (line 18)
  - `sum = integer1 + integer2; /* assign total to sum */`
- ▶ that performs the addition also replaces whatever value was stored in `sum`.



## 2.4 Memory Concepts (Cont.)

- ▶ This occurs when the calculated sum of `integer1` and `integer2` is placed into location `sum` (destroying the value already in `sum`).
- ▶ After `sum` is calculated, memory appears as in Fig. 2.8.
- ▶ The values of `integer1` and `integer2` appear exactly as they did before they were used in the calculation.



---

|          |    |
|----------|----|
| integer1 | 45 |
| integer2 | 72 |

---

**Fig. 2.7** | Memory locations after both variables are input.



---

|          |     |
|----------|-----|
| integer1 | 45  |
| integer2 | 72  |
| sum      | 117 |

---

**Fig. 2.8** | Memory locations after a calculation.





## 2.4 Memory Concepts (Cont.)

- ▶ They were used, but not destroyed, as the computer performed the calculation.
- ▶ Thus, when a value is read from a memory location, the process is said to be **nondestructive**.



## 2.5 Arithmetic in C

- ▶ The C **arithmetic operators** are summarized in Fig. 2.9.
- ▶ Note the use of various special symbols not used in algebra.
- ▶ The **asterisk** (**\***) indicates multiplication and the **percent sign** (**%**) denotes the remainder operator, which is introduced below.
- ▶ In algebra, if we want to multiply *a times b*, we can simply place these single-letter variable names side by side as in *ab*.
- ▶ In C, however, if we were to do this, **ab** would be interpreted as a single, two-letter name (or identifier).
- ▶ Therefore, C requires that multiplication be explicitly denoted by using the **\*** operator as in **a \* b**.



| C operation    | Arithmetic operator | Algebraic expression                   | C expression       |
|----------------|---------------------|----------------------------------------|--------------------|
| Addition       | +                   | $f + 7$                                | <code>f + 7</code> |
| Subtraction    | -                   | $p - c$                                | <code>p - c</code> |
| Multiplication | *                   | $bm$                                   | <code>b * m</code> |
| Division       | /                   | $x / y$ or $\frac{x}{y}$ or $x \div y$ | <code>x / y</code> |
| Remainder      | %                   | $r \text{ mod } s$                     | <code>r % s</code> |

**Fig. 2.9** | Arithmetic operators.



## 2.5 Arithmetic in C (Cont.)

- ▶ The arithmetic operators are all binary operators.
- ▶ For example, the expression  $3 + 7$  contains the binary operator  $+$  and the operands  $3$  and  $7$ .
- ▶ **Integer division** yields an integer result.
- ▶ For example, the expression  $7 / 4$  evaluates to  $1$  and the expression  $17 / 5$  evaluates to  $3$ .
- ▶ C provides the **remainder operator**,  $\%$ , which yields the remainder after integer division.
- ▶ The remainder operator is an integer operator that can be used only with integer operands.
- ▶ The expression  $x \% y$  yields the remainder after  $x$  is divided by  $y$ .
- ▶ Thus,  $7 \% 4$  yields  $3$  and  $17 \% 5$  yields  $2$ .



## Common Programming Error 2.16

*An attempt to divide by zero is normally undefined on computer systems and generally results in a fatal error, i.e., an error that causes the program to terminate immediately without having successfully performed its job. Nonfatal errors allow programs to run to completion, often producing incorrect results.*



## 2.5 Arithmetic in C (Cont.)

- ▶ Arithmetic expressions in C must be written in **straight-line form** to facilitate entering programs into the computer.
- ▶ Thus, expressions such as “a divided by b” must be written as  $a/b$  so that all operators and operands appear in a straight line.
- ▶ The algebraic notation
- ▶ is generally not acceptable to compilers, although some special-purpose software packages do support more natural notation for complex mathematical expressions.



## 2.5 Arithmetic in $\mathbb{C}$ (Cont.)

- ▶ Parentheses are used in  $\mathbb{C}$  expressions in the same manner as in algebraic expressions.
- ▶ For example, to multiply  $a$  times the quantity  $b + c$  we write  $a * ( b + c )$ .



## 2.5 Arithmetic in C (Cont.)

- ▶ C applies the operators in arithmetic expressions in a precise sequence determined by the following **rules of operator precedence**, which are generally the same as those in algebra:
  - Operators in expressions contained within pairs of parentheses are evaluated first. Thus, *parentheses may be used to force the order of evaluation to occur in any sequence you desire. Parentheses are said to be at the “highest level of precedence.”* In cases of *nested*, or *embedded*, parentheses, such as
    - $( ( a + b ) + c )$
  - the operators in the innermost pair of parentheses are applied first.





## 2.5 Arithmetic in C (Cont.)

- Multiplication, division and remainder operations are applied first. If an expression contains several multiplication, division and remainder operations, evaluation proceeds from left to right. Multiplication, division and remainder are said to be on the same level of precedence.
- Addition and subtraction operations are evaluated next. If an expression contains several addition and subtraction operations, evaluation proceeds from left to right. Addition and subtraction also have the same level of precedence, which is lower than the precedence of the multiplication, division and remainder operations.



## 2.5 Arithmetic in C (Cont.)

- ▶ The rules of operator precedence specify the order C uses to evaluate expressions. When we say evaluation proceeds from left to right, we're referring to the **associativity** of the operators.
- ▶ We'll see that some operators associate from right to left.
- ▶ Figure 2.10 summarizes these rules of operator precedence.



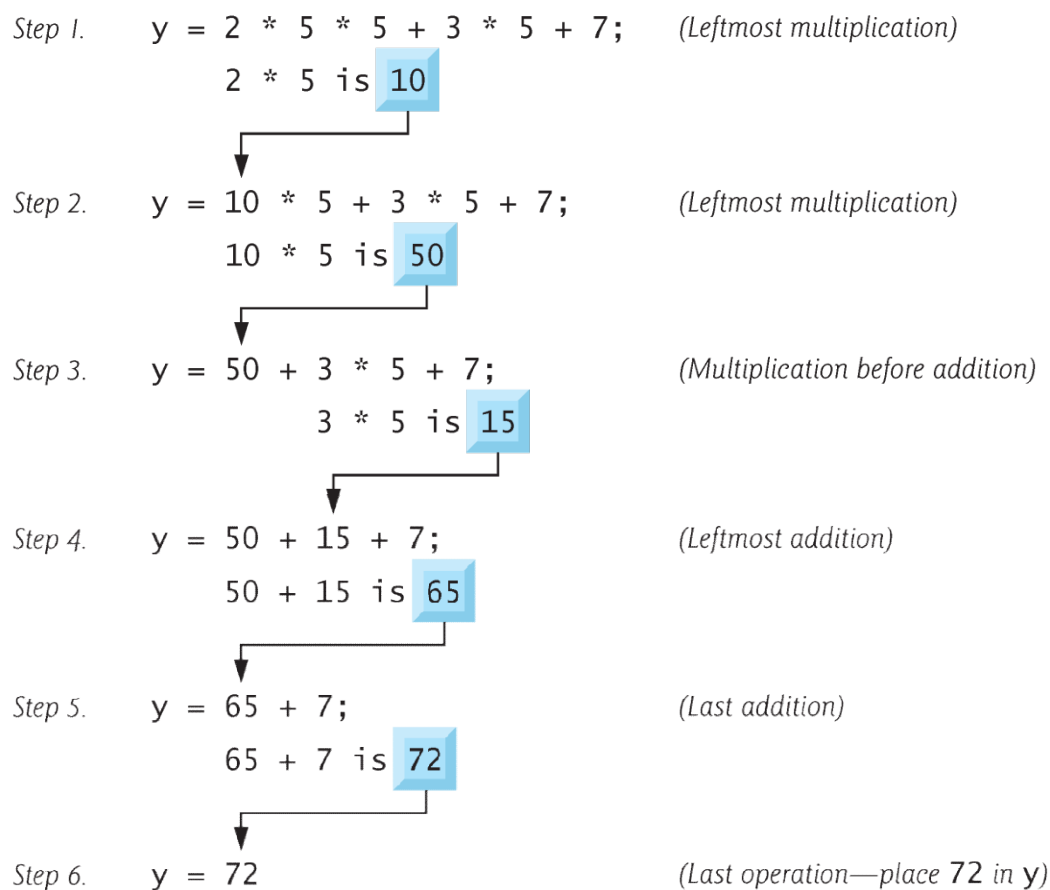
| Operator(s) | Operation(s)   | Order of evaluation (precedence)                                                                                                                                                                                            |
|-------------|----------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| ( )         | Parentheses    | Evaluated first. If the parentheses are nested, the expression in the innermost pair is evaluated first. If there are several pairs of parentheses “on the same level” (i.e., not nested), they’re evaluated left to right. |
| *           | Multiplication | Evaluated second. If there are several, they’re evaluated left to right.                                                                                                                                                    |
| /           | Division       |                                                                                                                                                                                                                             |
| %           | Remainder      |                                                                                                                                                                                                                             |
| +           | Addition       | Evaluated last. If there are several, they’re evaluated left to right.                                                                                                                                                      |
| -           | Subtraction    |                                                                                                                                                                                                                             |

**Fig. 2.10** | Precedence of arithmetic operators.



## 2.5 Arithmetic in C (Cont.)

- ▶ Figure 2.11 illustrates the order in which the operators are applied.



**Fig. 2.11** | Order in which a second-degree polynomial is evaluated.



## 2.5 Arithmetic in C (Cont.)

- ▶ As in algebra, it is acceptable to place unnecessary parentheses in an expression to make the expression clearer.
- ▶ These are called **redundant parentheses**.



## Good Programming Practice 2.11

*Using redundant parentheses in complex arithmetic expressions can make the expressions clearer.*



## 2.6 Decision Making: Equality and Relational Operators

- ▶ Executable C statements either perform actions (such as calculations or input or output of data) or make **decisions** (we'll soon see several examples of these).
- ▶ We might make a decision in a program, for example, to determine if a person's grade on an exam is greater than or equal to 60 and if it is to print the message "Congratulations! You passed."
- ▶ This section introduces a simple version of C's **if statement** that allows a program to make a decision based on the truth or falsity of a statement of fact called a **condition**.





## 2.6 Arithmetic in C (Cont.)

- ▶ If the condition is met (i.e., the condition is **true**) the statement in the body of the **if** statement is executed.
- ▶ If the condition is not met (i.e., the condition is **false**) the body statement is not executed.
- ▶ Whether the body statement is executed or not, after the **if** statement completes, execution proceeds with the next statement after the **if** statement.
- ▶ Conditions in **if** statements are formed by using the **equality operators** and **relational operators** summarized in Fig. 2.12.



## 2.6 Arithmetic in C (Cont.)

- ▶ The relational operators all have the same level of precedence and they associate left to right.
- ▶ The equality operators have a lower level of precedence than the relational operators and they also associate left to right.
- ▶ In C, a condition may actually be any expression that generates a zero (false) or nonzero (true) value.



| Algebraic equality or relational operator | C equality or relational operator | Example of C condition | Meaning of C condition          |
|-------------------------------------------|-----------------------------------|------------------------|---------------------------------|
| <i>Equality operators</i>                 |                                   |                        |                                 |
| =                                         | ==                                | $x == y$               | x is equal to y                 |
| ≠                                         | !=                                | $x != y$               | x is not equal to y             |
| <i>Relational operators</i>               |                                   |                        |                                 |
| >                                         | >                                 | $x > y$                | x is greater than y             |
| <                                         | <                                 | $x < y$                | x is less than y                |
| ≥                                         | >=                                | $x >= y$               | x is greater than or equal to y |
| ≤                                         | <=                                | $x <= y$               | x is less than or equal to y    |

**Fig. 2.12** | Equality and relational operators.



## Common Programming Error 2.17

*A syntax error occurs if the two symbols in any of the operators ==, !=, >= and <= are separated by spaces.*



### **Common Programming Error 2.18**

*A syntax error occurs if the two symbols in any of the operators  $!=$ ,  $>=$  and  $<=$  are reversed as in  $=!$ ,  $=>$  and  $=<$ , respectively.*



## Common Programming Error 2.19

*Confusing the equality operator `==` with the assignment operator.*



## 2.6 Arithmetic in C (Cont.)

- ▶ To avoid this confusion, the equality operator should be read “double equals” and the assignment operator should be read “gets” or “is assigned the value of.”
- ▶ As we’ll soon see, confusing these operators may not necessarily cause an easy-to-recognize compilation error, but may cause extremely subtle logic errors.



## **Common Programming Error 2.20**

*Placing a semicolon immediately to the right of the right parenthesis after the condition in an `if` statement.*





## 2.6 Arithmetic in C (Cont.)

- ▶ Figure 2.13 uses six `if` statements to compare two numbers input by the user.
- ▶ If the condition in any of these `if` statements is true, the `printf` statement associated with that `if` executes.



```
1 /* Fig. 2.13: fig02_13.c
2 Using if statements, relational
3 operators, and equality operators */
4 #include <stdio.h>
5
6 /* function main begins program execution */
7 int main(void)
8 {
9 int num1; /* first number to be read from user */
10 int num2; /* second number to be read from user */
11
12 printf("Enter two integers, and I will tell you\n");
13 printf("the relationships they satisfy: ");
14
15 scanf("%d%d", &num1, &num2); /* read two integers */
16
17 if (num1 == num2) {
18 printf("%d is equal to %d\n", num1, num2);
19 } /* end if */
20
21 if (num1 != num2) {
22 printf("%d is not equal to %d\n", num1, num2);
23 } /* end if */
```

**Fig. 2.13** | Using if statements, relational operators, and equality operators. (Part 1 of 3.)



```
24
25 if (num1 < num2) {
26 printf("%d is less than %d\n", num1, num2);
27 } /* end if */
28
29 if (num1 > num2) {
30 printf("%d is greater than %d\n", num1, num2);
31 } /* end if */
32
33 if (num1 <= num2) {
34 printf("%d is less than or equal to %d\n", num1, num2);
35 } /* end if */
36
37 if (num1 >= num2) {
38 printf("%d is greater than or equal to %d\n", num1, num2);
39 } /* end if */
40
41 return 0; /* indicate that program ended successfully */
42 } /* end function main */
```

**Fig. 2.13** | Using if statements, relational operators, and equality operators. (Part 2 of 3.)



```
Enter two integers, and I will tell you
the relationships they satisfy: 3 7
3 is not equal to 7
3 is less than 7
3 is less than or equal to 7
```

```
Enter two integers, and I will tell you
the relationships they satisfy: 12 12
22 is not equal to 12
22 is greater than 12
22 is greater than or equal to 12
```

```
Enter two integers, and I will tell you
the relationships they satisfy: 7 7
7 is equal to 7
7 is less than or equal to 7
7 is greater than or equal to 7
```

**Fig. 2.13** | Using if statements, relational operators, and equality operators. (Part 3 of 3.)



## 2.6 Arithmetic in C (Cont.)

- ▶ The program uses `scanf` (line 15) to input two numbers.
- ▶ Each conversion specifier has a corresponding argument in which a value will be stored.
- ▶ The first `%d` converts a value to be stored in variable `num1`, and the second `%d` converts a value to be stored in variable `num2`.
- ▶ Indenting the body of each `if` statement and placing blank lines above and below each `if` statement enhances program readability.



## Good Programming Practice 2.12

*Indent the statement(s) in the body of an if statement.*



### **Good Programming Practice 2.13**

*Place a blank line before and after every `if` statement in a program for readability.*



## **Good Programming Practice 2.14**

*Although it is allowed, there should be no more than one statement per line in a program.*





## Common Programming Error 2.2 I

*Placing commas (when none are needed) between conversion specifiers in the format control string of a scanf statement.*



## 2.6 Arithmetic in C (Cont.)

- ▶ A left brace, {, begins the body of each `if` statement (e.g., line 17).
- ▶ A corresponding right brace, }, ends each `if` statement's body (e.g., line 19).
- ▶ Any number of statements can be placed in the body of an `if` statement.
- ▶ The comment (lines 1–3) in Fig. 2.13 is split over three lines.
- ▶ In C programs, **white space** characters such as tabs, newlines and spaces are normally ignored.
- ▶ So, statements and comments may be split over several lines.
- ▶ It is not correct, however, to split identifiers.



### **Good Programming Practice 2.15**

*A lengthy statement may be spread over several lines. If a statement must be split across lines, choose breaking points that make sense (such as after a comma in a comma-separated list). If a statement is split across two or more lines, indent all subsequent lines.*



## 2.6 Arithmetic in C (Cont.)

- ▶ Figure 2.14 lists the precedence of the operators introduced in this chapter.
- ▶ Operators are shown top to bottom in decreasing order of precedence.
- ▶ The equals sign is also an operator.
- ▶ All these operators, with the exception of the assignment operator `=`, associate from left to right.
- ▶ The assignment operator (`=`) associates from right to left.



### **Good Programming Practice 2.16**

*Refer to the operator precedence chart when writing expressions containing many operators. Confirm that the operators in the expression are applied in the proper order. If you're uncertain about the order of evaluation in a complex expression, use parentheses to group expressions or break the statement into several simpler statements. Be sure to observe that some of C's operators such as the assignment operator (=) associate from right to left rather than from left to right.*



| Operators | Associativity |
|-----------|---------------|
| ()        | left to right |
| * / %     | left to right |
| + -       | left to right |
| < <= > >= | left to right |
| == !=     | left to right |
| =         | right to left |

**Fig. 2.14** | Precedence and associativity of the operators discussed so far.



## 2.6 Arithmetic in C (Cont.)

- ▶ Some of the words we have used in the C programs in this chapter—in particular `int`, `return` and `if`—are **keywords** or reserved words of the language.
- ▶ Figure 2.15 contains the C keywords.
- ▶ These words have special meaning to the C compiler, so you must be careful not to use these as identifiers such as variable names.



## Keywords

|          |        |          |          |
|----------|--------|----------|----------|
| auto     | double | int      | struct   |
| break    | else   | long     | switch   |
| case     | enum   | register | typedef  |
| char     | extern | return   | union    |
| const    | float  | short    | unsigned |
| continue | for    | signed   | void     |
| default  | goto   | sizeof   | volatile |
| do       | if     | static   | while    |

### *Keywords added in C99*

`_Bool` `_Complex` `_Imaginary` `inline` `restrict`

**Fig. 2.15** | C's keywords.