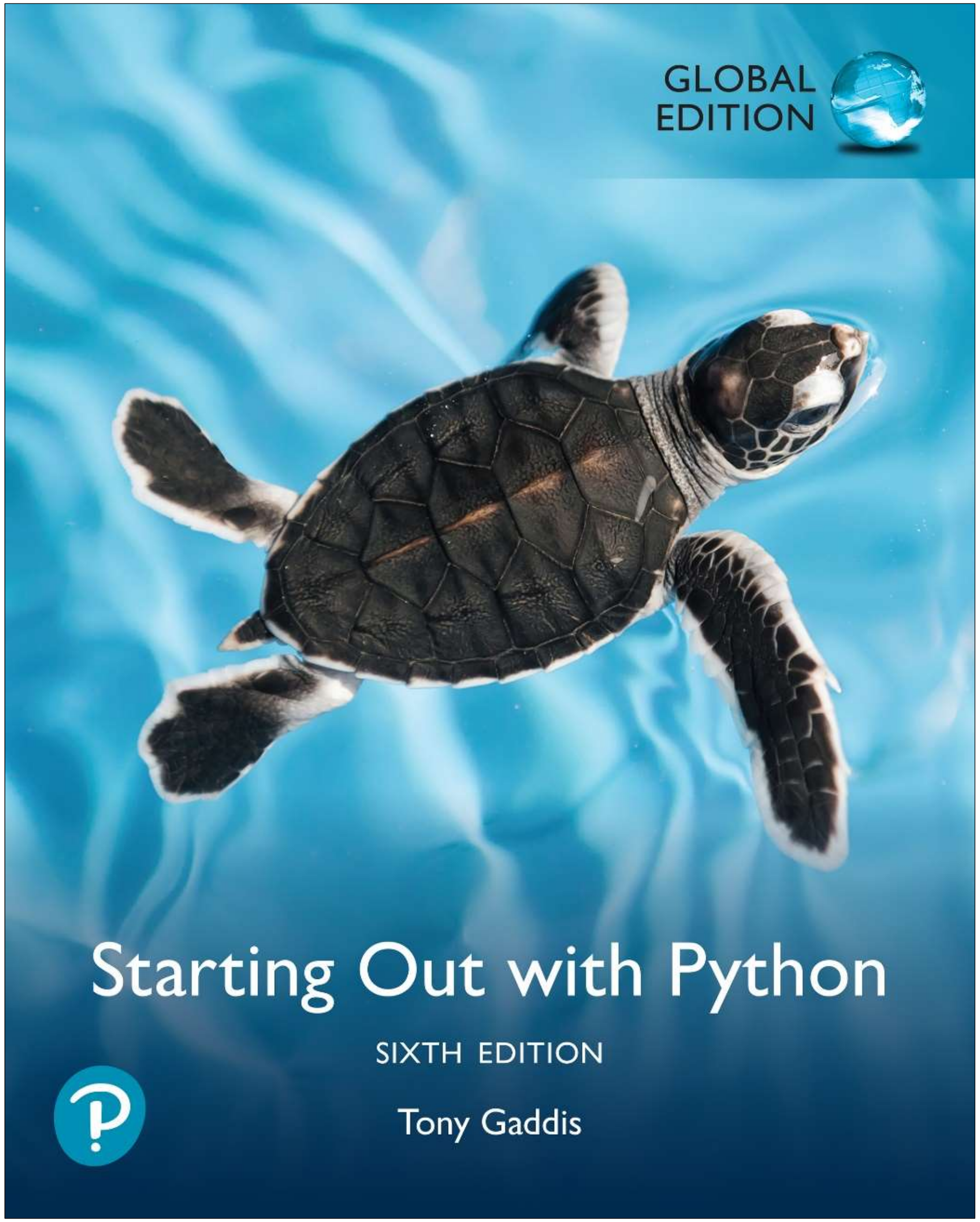
CHAPTER 4

Repetition Structures



Topics

- Introduction to Repetition Structures
- The `while` Loop: a Condition-Controlled Loop
- The `for` Loop: a Count-Controlled Loop
- Calculating a Running Total
- Sentinels
- Input Validation Loops
- Nested Loops
- Using `break`, `continue`, and `else` with Loops
- Turtle Graphics: Using Loops to Draw Designs

Introduction to Repetition Structures

- **Often must write code that performs the same task multiple times**
  - Disadvantages to duplicating code
    - Makes program large
    - Time consuming
    - May need to be corrected in many places
- **<u>Repetition structure</u>: makes computer repeat included code as necessary**

Condition-Controlled and Count-Controlled Loops

- **There are two broad categories of loops:**
  - Condition-controlled
    - uses a true/false condition to control the number of times the loop iterates
  - Count-controlled
    - repeats a specific number of times

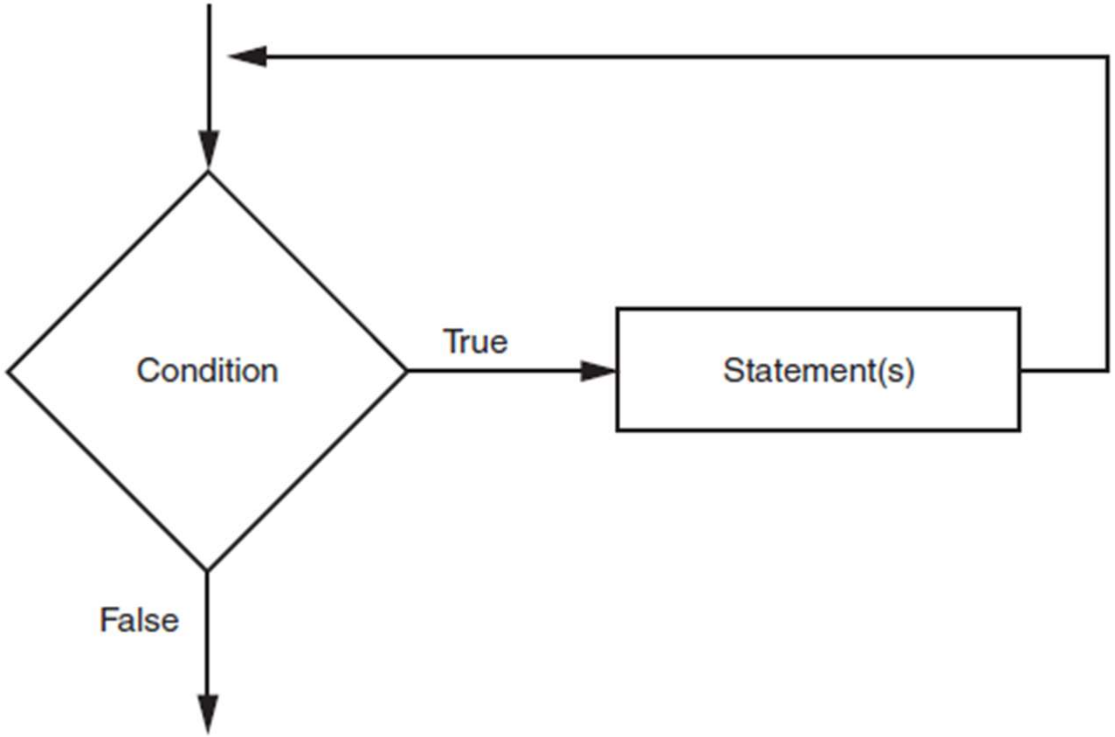
The `while` Loop: a Condition-Controlled Loop

- **`while` loop: while condition is true, do something**
  - Two parts:
    - Condition tested for true or false value
    - Statements repeated as long as condition is true
  - In flow chart, line goes back to previous part
  - General format:

```
while condition:
    statements
```

The `while` Loop: a Condition-Controlled Loop (cont’d.)

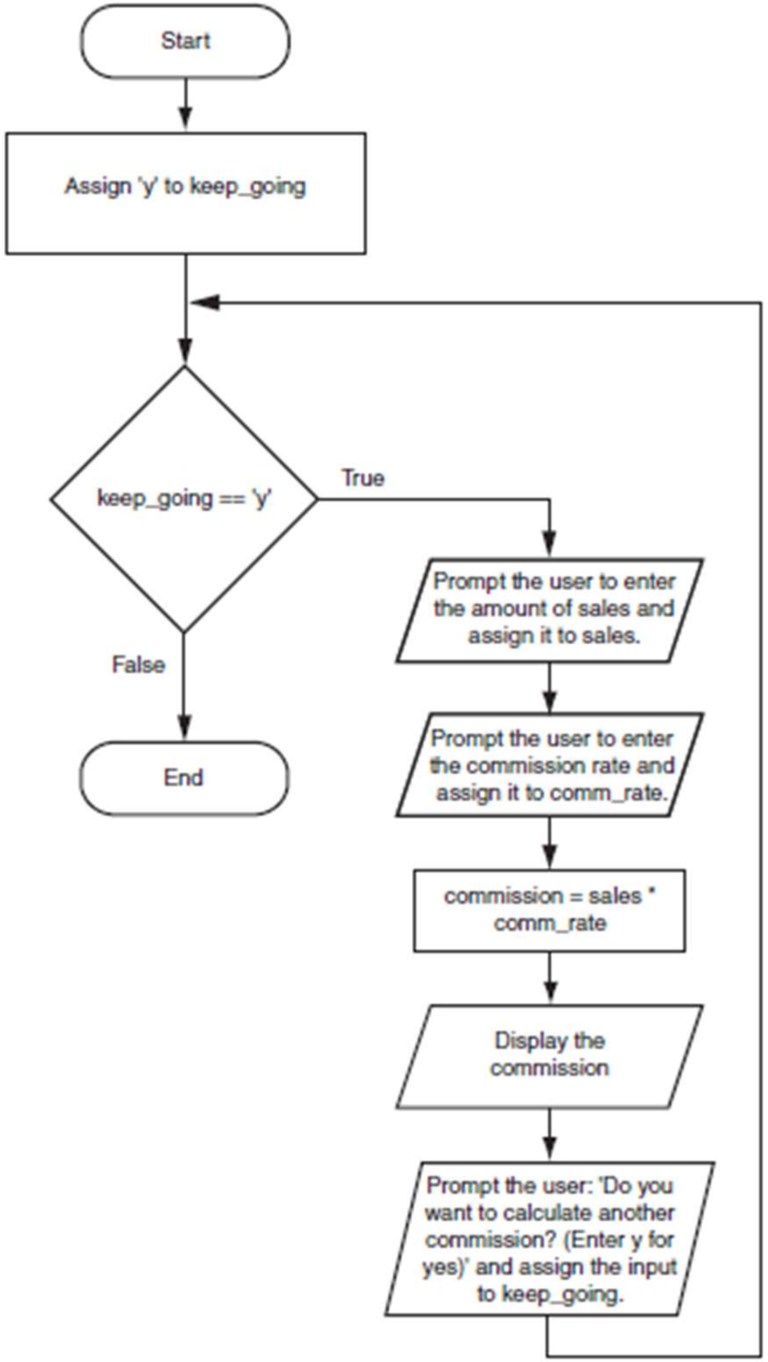
Figure 4-1 The logic of a `while` loop



The `while` Loop: a Condition-Controlled Loop (cont'd.)

- **In order for a loop to stop executing, something has to happen inside the loop to make the condition false**
- **Iteration: one execution of the body of a loop**
- **`while` loop is known as a *pretest* loop**
  - Tests condition before performing an iteration
    - Will never execute if condition is false to start with
    - Requires performing some steps prior to the loop

Figure 4-3 Flowchart for Program 4-1


Start
Assign 'y' to keep_going
keep_going == 'y'
True
False
End
Prompt the user to enter the amount of sales and assign it to sales.
Prompt the user to enter the commission rate and assign it to comm_rate.
commission = sales * comm_rate
Display the commission
Prompt the user: 'Do you want to calculate another commission? (Enter y for yes)' and assign the input to keep_going.

Infinite Loops

- **Loops must contain within themselves a way to terminate**
  - Something inside a `while` loop must eventually make the condition false
- **<u>Infinite loop</u>: loop that does not have a way of stopping**
  - Repeats until program is interrupted
  - Occurs when programmer forgets to include stopping code in the loop

Using the `while` Loop as a Count-Controlled Loop

- **The `while` loop is inherently a condition-controlled loop**
  - It repeats as long as a Boolean condition is true
- **However, you can use the `while` loop as a count-controlled loop by pairing it with a counter variable**
- **A counter variable is assigned a unique value during each iteration of a loop.**
- **It is called a *counter* variable because it can be used to count the number of times the loop iterates**

Using the `while` Loop as a Count-Controlled Loop

- **A count-controlled while loop must perform three actions:**
  - **Initialization**: The counter variable must be initialized to a suitable starting value before the loop begins.
  - **Comparison**: The loop must compare the counter variable to a suitable ending value, to determine whether the loop should iterate or not.
  - **Update**: During each iteration, the loop must update the counter variable with a new value.

Using the `while` Loop as a Count-Controlled Loop

- **Example**

```
n = 0
while n < 5:
    print(f'Inside the loop, the value of n is {n}.')
    n += 1
```

Initialization

Comparison

Update

- **Initialization**: The variable `n` is initialized with 0
- **Comparison**: The loop iterates as long as `n` is less than 5
- **Update**: 1 is added to `n`

Single-Line `while` Loops

- If there is only one statement in the body of a `while` loop, you can write the entire loop on one line.
- General format:

```
while condition: statement
```

- Example:

```
n = 0
while n < 10: n += 1
```

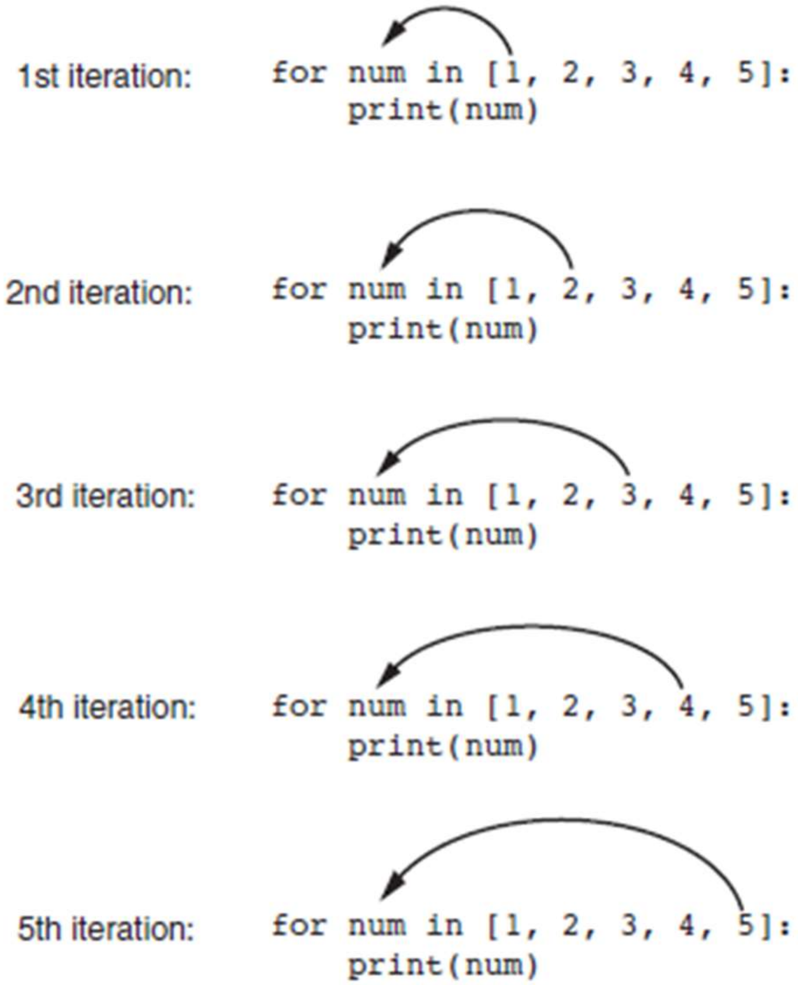
The `for` Loop: a Count-Controlled Loop

- **Count-Controlled loop: iterates a specific number of times**
  - Use a `for` statement to write count-controlled loop
    - Designed to work with sequence of data items
      - Iterates once for each item in the sequence
    - General format:

```
for variable in [val1, val2, etc]:
    statements
```

    - Target variable: the variable which is the target of the assignment at the beginning of each iteration

Figure 4-4 The `for` loop



1st iteration:

```
for num in [1, 2, 3, 4, 5]:
    print(num)
```

2nd iteration:

```
for num in [1, 2, 3, 4, 5]:
    print(num)
```

3rd iteration:

```
for num in [1, 2, 3, 4, 5]:
    print(num)
```

4th iteration:

```
for num in [1, 2, 3, 4, 5]:
    print(num)
```

5th iteration:

```
for num in [1, 2, 3, 4, 5]:
    print(num)
```

Using the `range` Function with the `for` Loop

- **The `range` function simplifies the process of writing a `for` loop**
  - `range` returns an iterable object
    - Iterable: contains a sequence of values that can be iterated over
- **`range` characteristics:**
  - One argument: used as ending limit
  - Two arguments: starting value and ending limit
  - Three arguments: third argument is step value

Using the Target Variable Inside the Loop

- **Purpose of target variable is to reference each item in a sequence as the loop iterates**
- **Target variable can be used in calculations or tasks in the body of the loop**
  - Example: calculate square root of each number in a range

Letting the User Control the Loop Iterations

- **Sometimes the programmer does not know exactly how many times the loop will execute**
- **Can receive range inputs from the user, place them in variables, and call the `range` function in the for clause using these variables**
  - Be sure to consider the end cases: `range` does not include the ending limit

Generating an Iterable Sequence that Ranges from Highest to Lowest

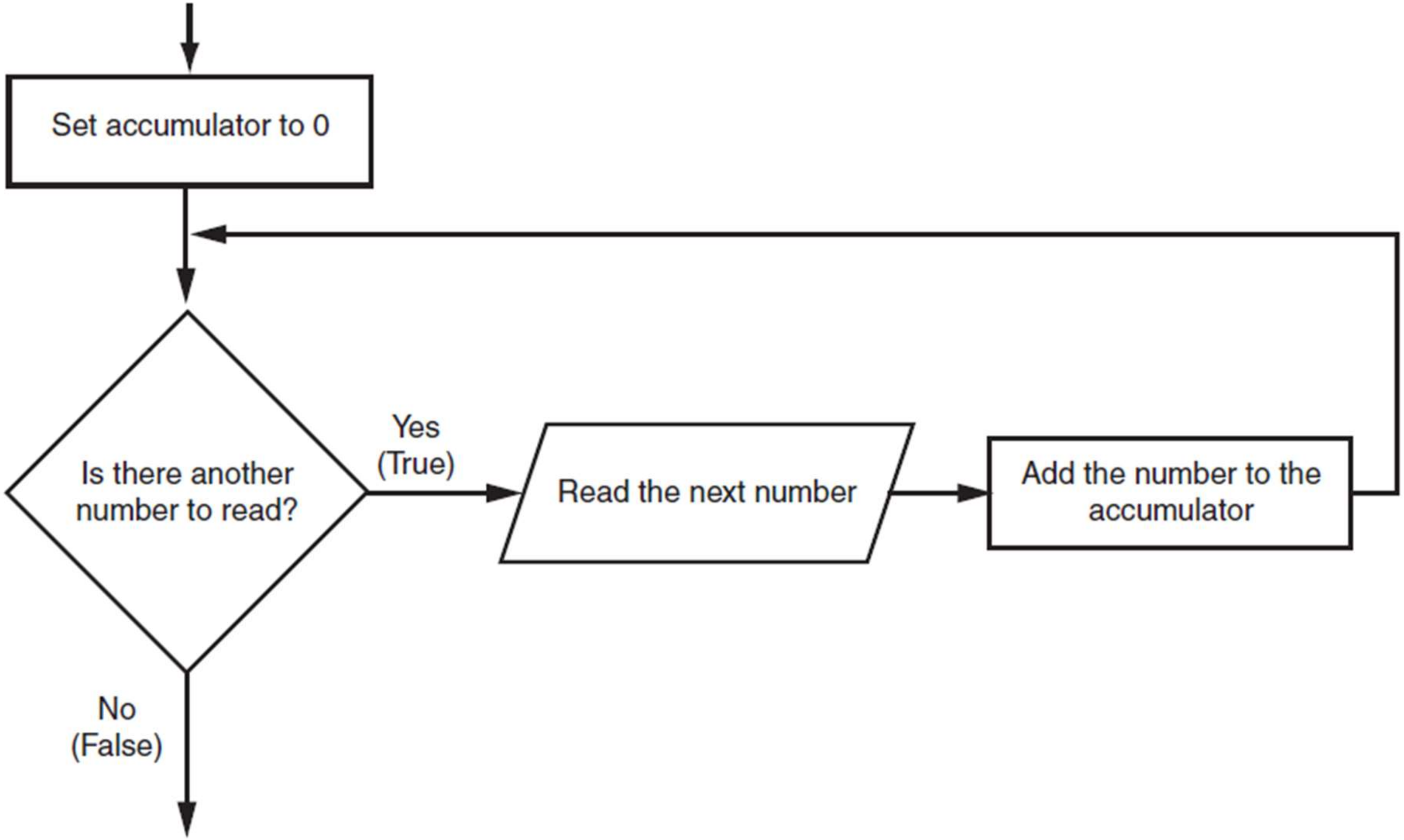
- **The `range` function can be used to generate a sequence with numbers in descending order**
  - Make sure starting number is larger than end limit, and step value is negative
  - Example: `range(10, 0, -1)`

Calculating a Running Total

- **Programs often need to calculate a total of a series of numbers**
  - Typically include two elements:
    - A loop that reads each number in series
    - An *accumulator* variable
  - Known as program that keeps a running total: accumulates total and reads in series
  - At end of loop, accumulator will reference the total

Calculating a Running Total (cont'd.)

Figure 4-6 Logic for calculating a running total



Set accumulator to 0
Is there another number to read?
Yes (True)
Read the next number
Add the number to the accumulator
No (False)

The Augmented Assignment Operators

- **In many assignment statements, the variable on the left side of the = operator also appears on the right side of the = operator**
- **<u>Augmented assignment operators</u>: special set of operators designed for this type of job**
  - Shorthand operators

The Augmented Assignment Operators (cont’d.)

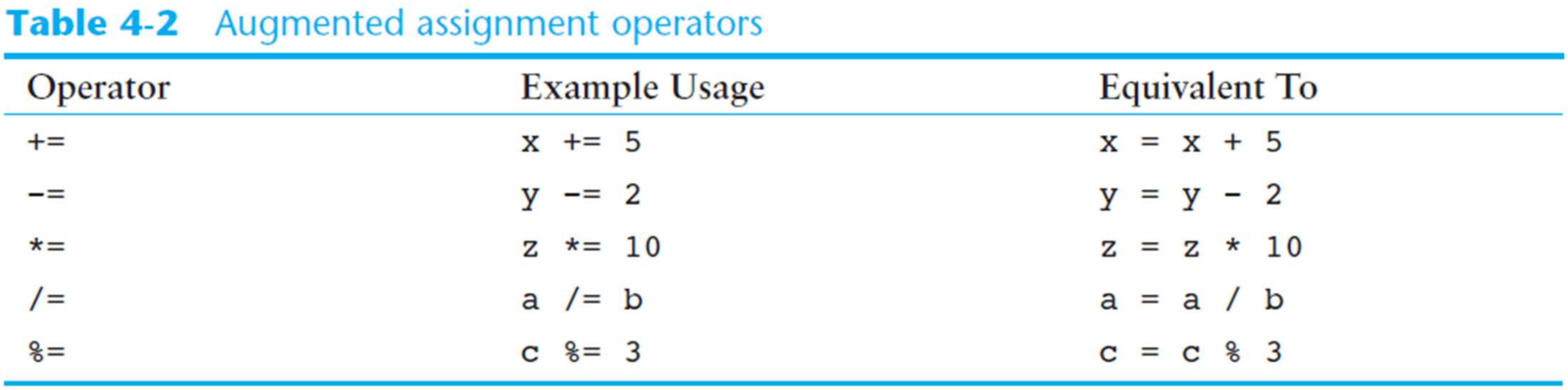


Table 4-2 Augmented assignment operators

Operator	Example Usage	Equivalent To
`+=`	`x += 5`	`x = x + 5`
`-=`	`y -= 2`	`y = y - 2`
`*=`	`z *= 10`	`z = z * 10`
`/=`	`a /= b`	`a = a / b`
`%=`	`c %= 3`	`c = c % 3`

Sentinels

- **Sentinel: special value that marks the end of a sequence of items**
  - When program reaches a sentinel, it knows that the end of the sequence of items was reached, and the loop terminates
  - Must be distinctive enough so as not to be mistaken for a regular value in the sequence
  - Example: when reading an input file, empty line can be used as a sentinel

Input Validation Loops

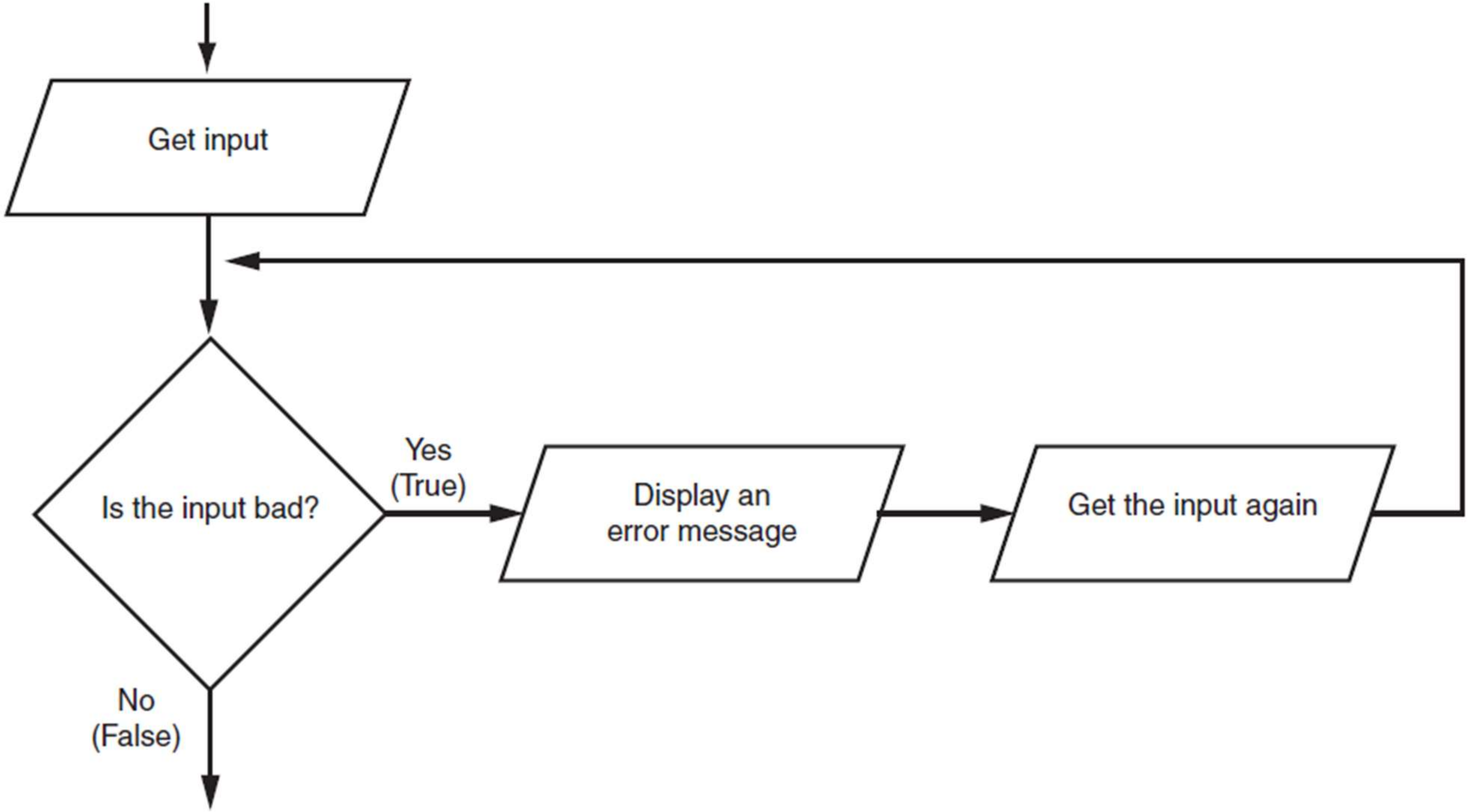
- **Computer cannot tell the difference between good data and bad data**
  - If user provides bad input, program will produce bad output
  - GIGO: garbage in, garbage out
  - It is important to design program such that bad input is never accepted

Input Validation Loops (cont'd.)

- **Input validation: inspecting input before it is processed by the program**
  - If input is invalid, prompt user to enter correct data
  - Commonly accomplished using a `while` loop which repeats as long as the input is bad
    - If input is bad, display error message and receive another set of data
    - If input is good, continue to process the input

Input Validation Loops (cont'd.)

Figure 4-7 Logic containing an input validation loop



Input Validation Loops (cont'd.)

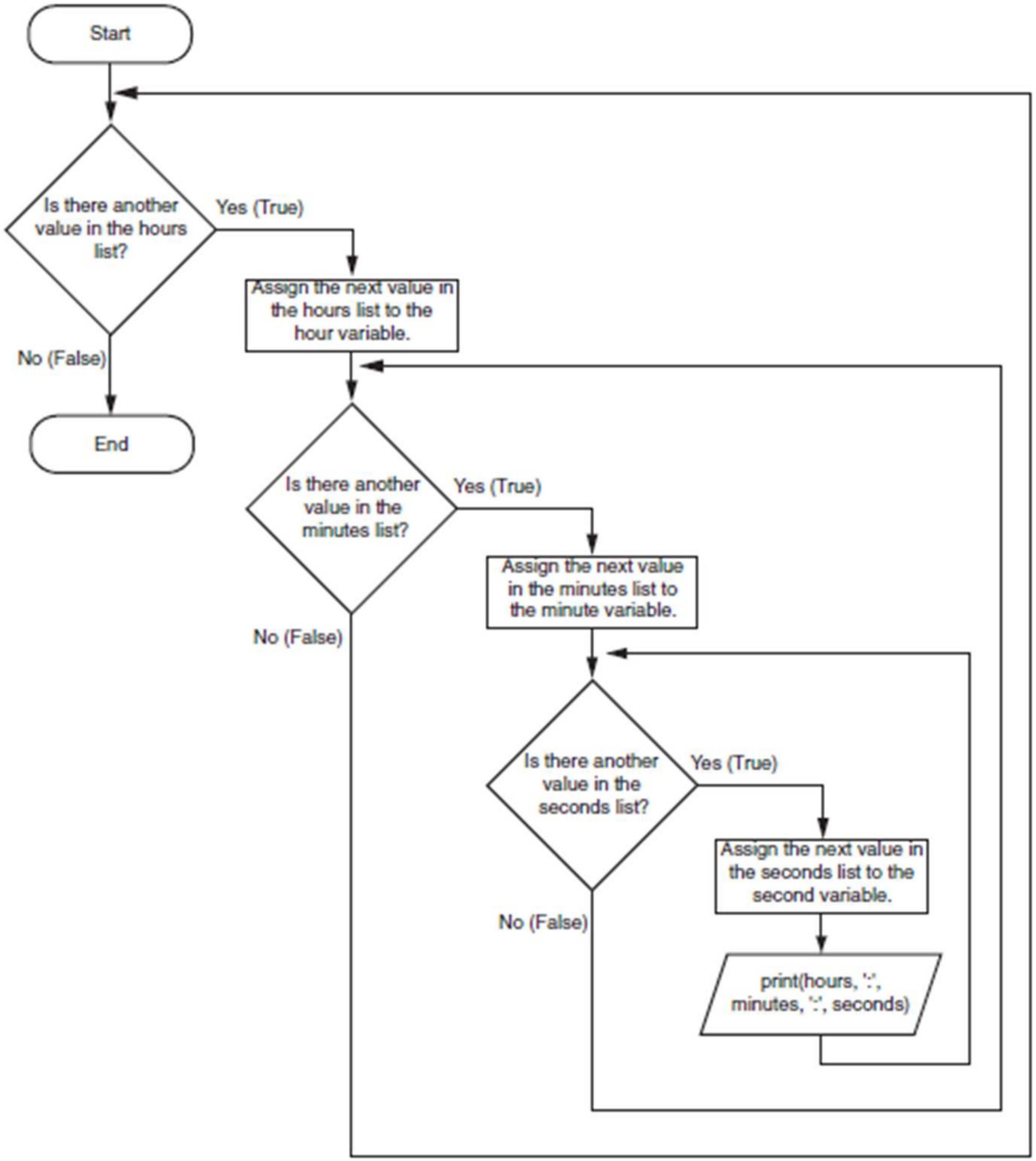
- **Using the walrus operator in an input validation loop**
  - You can use the walrus operator to create an assignment expression that combines the priming read with the input validation loop
  - **Example**:

```
while (score := int(input('Enter your score: '))) < 0:
       print('The score cannot be negative.'
```

Nested Loops

- **<u>Nested loop</u>: loop that is contained inside another loop**
  - Example: analog clock works like a nested loop
    - Hours hand moves once for every twelve movements of the minutes hand: for each iteration of the "hours," do twelve iterations of "minutes"
    - Seconds hand moves 60 times for each movement of the minutes hand: for each iteration of "minutes," do 60 iterations of "seconds"

Figure 4-8 Flowchart for a clock simulator


Start
Is there another value in the hours list?
Yes (True)
Assign the next value in the hours list to the hour variable.
No (False)
End
Is there another value in the minutes list?
Yes (True)
Assign the next value in the minutes list to the minute variable.
No (False)
Is there another value in the seconds list?
Yes (True)
Assign the next value in the seconds list to the second variable.
No (False)
print(hours, ':', minutes, ':', seconds)

Nested Loops (cont'd.)

- **Key points about nested loops:**
  - Inner loop goes through all of its iterations for each iteration of outer loop
  - Inner loops complete their iterations faster than outer loops
  - Total number of iterations in nested loop:

number of iterations of inner loop X *number of iterations of outer loop*

The `break` Statement

- The **`break`** statement causes a loop to terminate

```
n = 0
while n < 100:
    print(n)
    if n == 5:
        break
    n += 1

print(f'The loop stopped and n is {n}.')
```

This statement causes the loop to stop

Program Output

```
0
1
2
3
4
5
The loop stopped and n is 5.
```

The `continue` Statement

- **The `continue` statement causes the current iteration of a loop to end early**

- **When the `continue` statement is executed, all the statements in the body of the loop that appear after it are ignored, and the loop begins its next iteration (if there is a next iteration)**

The `continue` Statement

- **Example:**

```
n = 0
while n < 10:
    n += 1
    if n % 3 == 0:
        continue
    print(n)
```

This statement ends the current iteration and causes the loop to skip to the next iteration.

Program Output

```
1
2
4
5
7
8
10
```

The `else` Clause with a Loop

- **Loops in Python can have an optional `else` clause.**

```
while condition:
     statement
     statement
     etc.
else:
     statement
     statement
     etc.
```

```
for variable in [value1, value2, etc.]:
     statement
     statement
     etc.
else:
     statement
     statement
     etc.
```

The `else` Clause with a Loop

- An `else` clause in a loop is useful only when the loop contains a `break` statement.
- The block of statements that appears after the `else` clause executes only when the loop terminates normally, without encountering a `break` statement.
- If the loop terminates because of a `break` statement, the `else` clause will not execute its block of statements.

The `else` Clause with a Loop

- **Example:**

```
for n in range(10):
    if n == 5:
        print('Breaking out of the loop.')
        break
    print(n)
else:
    print(f'After the loop, n is {n}.')
```

Program Output

```
0
1
2
3
4
Breaking out of the loop.
```

The `else` clause did not execute because the `break` statement executed

The `else` Clause with a Loop

- **Example:**

```
for n in range(3):
    if n == 5:
        print('Breaking out of the loop.')
        break
    print(n)
else:
    print(f'After the loop, n is {n}.')
```

Program Output

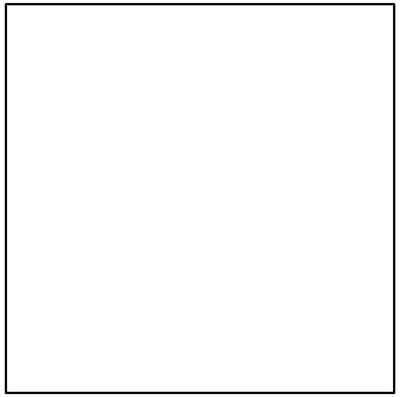
```
0
1
2
After the loop, n is 2.
```

The `break` statement did not execute, so the `else` clause executed.

Turtle Graphics: Using Loops to Draw Designs

- You can use loops with the turtle to draw both simple shapes and elaborate designs. For example, the following for loop iterates four times to draw a square that is 100 pixels wide:

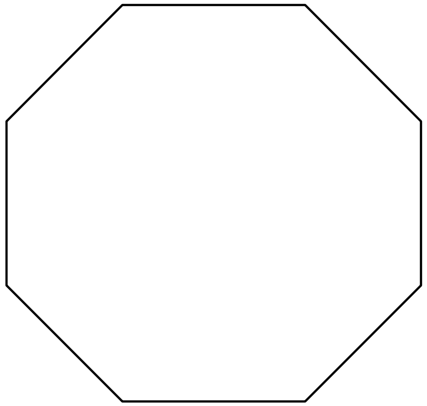
```
for x in range(4):
    turtle.forward(100)
    turtle.right(90)
```



Turtle Graphics: Using Loops to Draw Designs

- This `for` loop iterates eight times to draw the octagon:

```
for x in range(8):
    turtle.forward(100)
    turtle.right(45)
```

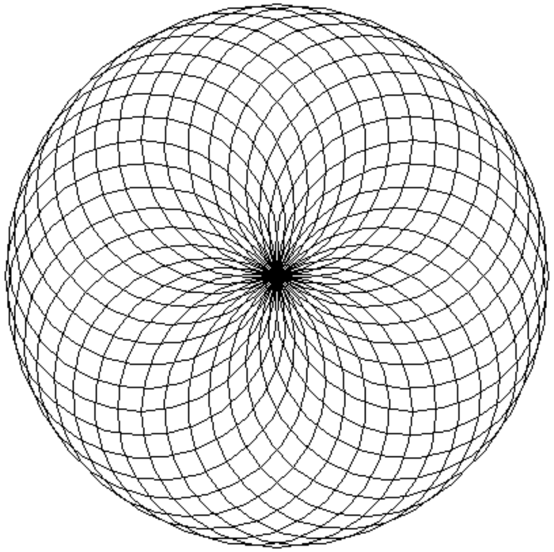


Turtle Graphics: Using Loops to Draw Designs

- **You can create interesting designs by repeatedly drawing a simple shape, with the turtle tilted at a slightly different angle each time it draws the shape.**

```
NUM_CIRCLES = 36     # Number of circles to draw
RADIUS = 100         # Radius of each circle
ANGLE = 10           # Angle to turn

for x in range(NUM_CIRCLES):
    turtle.circle(RADIUS)
    turtle.left(ANGLE)
```



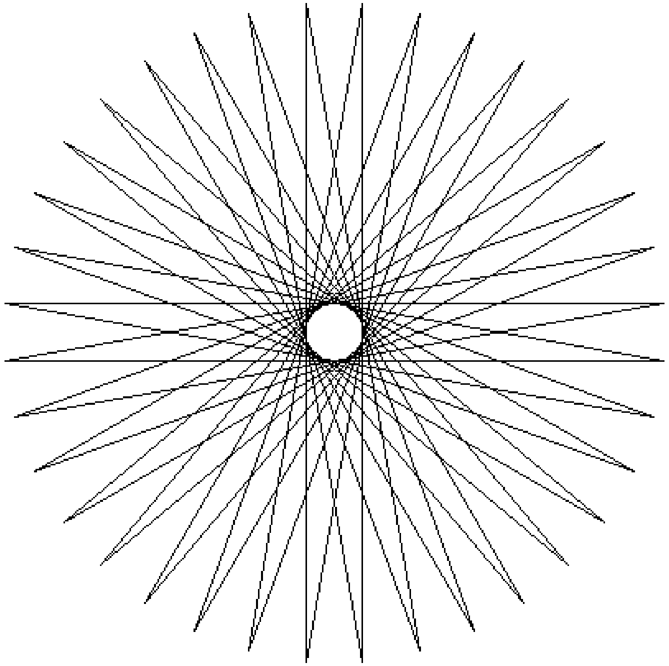
Turtle Graphics: Using Loops to Draw Designs

- **This code draws a sequence of 36 straight lines to make a "starburst" design.**

```
START_X = -200       # Starting X coordinate
START_Y = 0          # Starting Y coordinate
NUM_LINES = 36       # Number of lines to draw
LINE_LENGTH = 400    # Length of each line
ANGLE = 170          # Angle to turn

turtle.hideturtle()
turtle.penup()
turtle.goto(START_X, START_Y)
turtle.pendown()

for x in range(NUM_LINES):
    turtle.forward(LINE_LENGTH)
    turtle.left(ANGLE)
```



Summary

- **This chapter covered:**
  - Repetition structures, including:
    - Condition-controlled loops
    - Count-controlled loops
    - Nested loops
  - Infinite loops and how they can be avoided
  - `range` function as used in `for` loops
  - Calculating a running total and augmented assignment operators
  - Use of sentinels to terminate loops
  - Using loops to draw turtle graphic designs