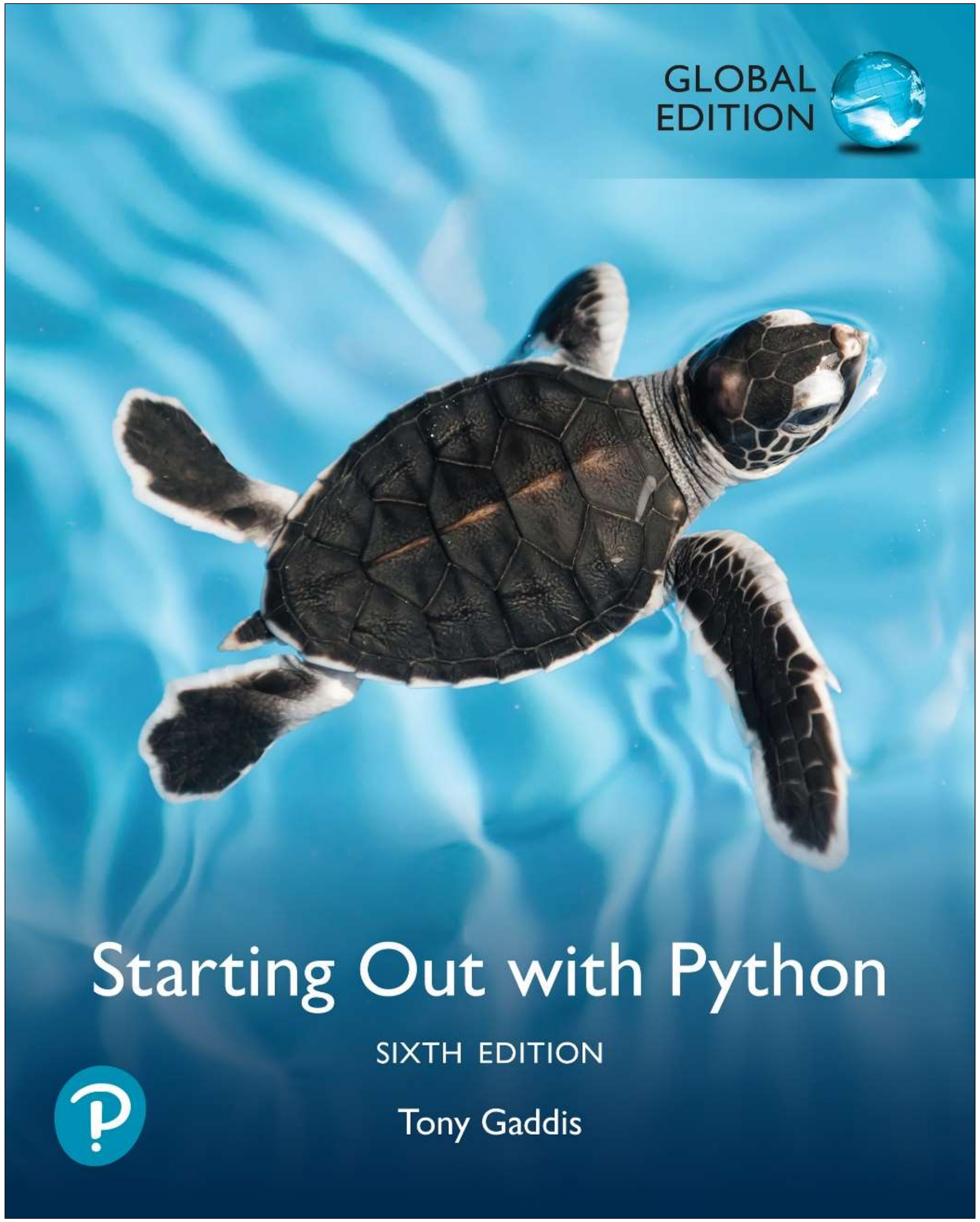
CHAPTER 5

Functions



Topics

- Introduction to Functions
- Defining and Calling a Void Function
- Designing a Program to Use Functions
- Local Variables
- Passing Arguments to Functions
- Global Variables and Global Constants
- Turtle Graphics: Modularizing Code with Functions

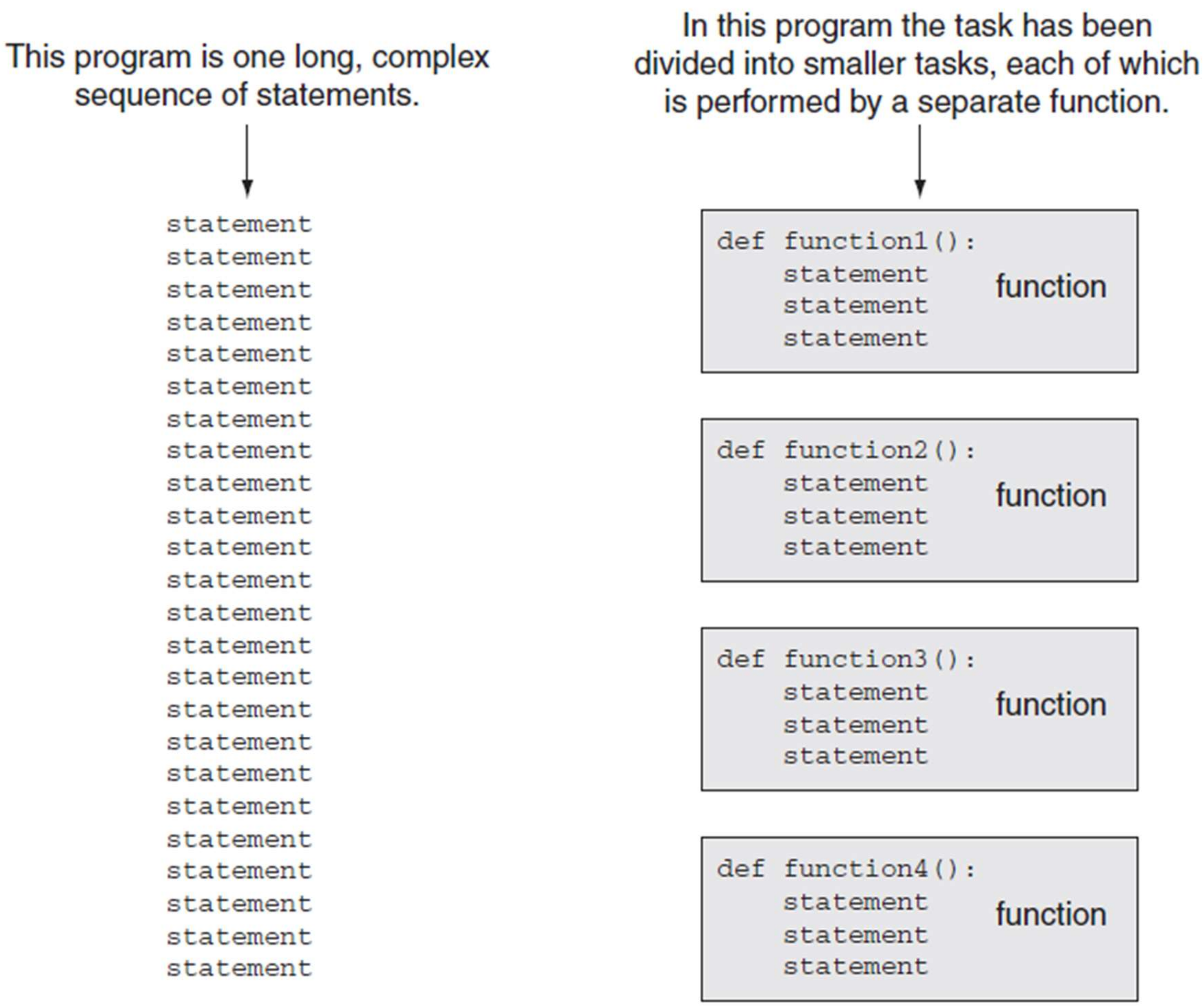
Topics (cont'd.)

- Introduction to Value-Returning Functions: Generating Random Numbers
- Writing Your Own Value-Returning Functions
- The `math` Module
- Storing Functions in Modules

Introduction to Functions

- **Function: group of statements within a program that perform as specific task**
  - Usually one task of a large program
    - Functions can be executed in order to perform overall program task
  - Known as *divide and conquer* approach
- **Modularized program: program wherein each task within the program is in its own function**

Figure 5-1 Using functions to divide and conquer a large task



This program is one long, complex sequence of statements.

```
statement
statement
statement
statement
statement
statement
statement
statement
statement
statement
statement
statement
statement
statement
statement
statement
statement
statement
statement
statement
statement
statement
statement
statement
```

In this program the task has been divided into smaller tasks, each of which is performed by a separate function.

```
def function1():
    statement
    statement
    statement
```

function

```
def function2():
    statement
    statement
    statement
```

function

```
def function3():
    statement
    statement
    statement
```

function

```
def function4():
    statement
    statement
    statement
```

function

Benefits of Modularizing a Program with Functions

- **The benefits of using functions include:**
  - Simpler code
  - Code reuse
    - write the code once and call it multiple times
  - Better testing and debugging
    - Can test and debug each function individually
  - Faster development
  - Easier facilitation of teamwork
    - Different team members can write different functions

Void Functions and Value-Returning Functions

- **A <u>void function</u>:**
  - Simply executes the statements it contains and then terminates.
- **A <u>value-returning function</u>:**
  - Executes the statements it contains, and then it returns a value back to the statement that called it.
    - The `input`, `int`, and `float` functions are examples of value-returning functions.

Defining and Calling a Function

- **Functions are given names**
  - Function naming rules:
    - Cannot use keywords as a function name
    - Cannot contain spaces
    - First character must be a letter or underscore
    - All other characters must be a letter, number or underscore
    - Uppercase and lowercase characters are distinct

Defining and Calling a Function (cont’d.)

- **Function name should be descriptive of the task carried out by the function**
  - Often includes a verb
- **Function definition: specifies what function does**

```
def function_name():
        statement
        statement
```

Defining and Calling a Function (cont'd.)

- **Function header: first line of function**
  - Includes keyword `def` and function name, followed by parentheses and colon
- **Block: set of statements that belong together as a group**
  - Example: the statements included in a function

Defining and Calling a Function (cont'd.)

- **Call a function to execute it**
  - When a function is called:
    - Interpreter jumps to the function and executes statements in the block
    - Interpreter jumps back to part of program that called the function
      - Known as function return

Defining and Calling a Function (cont'd.)

- **`main` function: called when the program starts**
  - Calls other functions when they are needed
  - Defines the *mainline logic* of the program

Indentation in Python

- **Each block must be indented**
  - Lines in block must begin with the same number of spaces
    - Use tabs or spaces to indent lines in a block, but not both as this can confuse the Python interpreter
    - IDLE automatically indents the lines in a block
  - Blank lines that appear in a block are ignored

Designing a Program to Use Functions

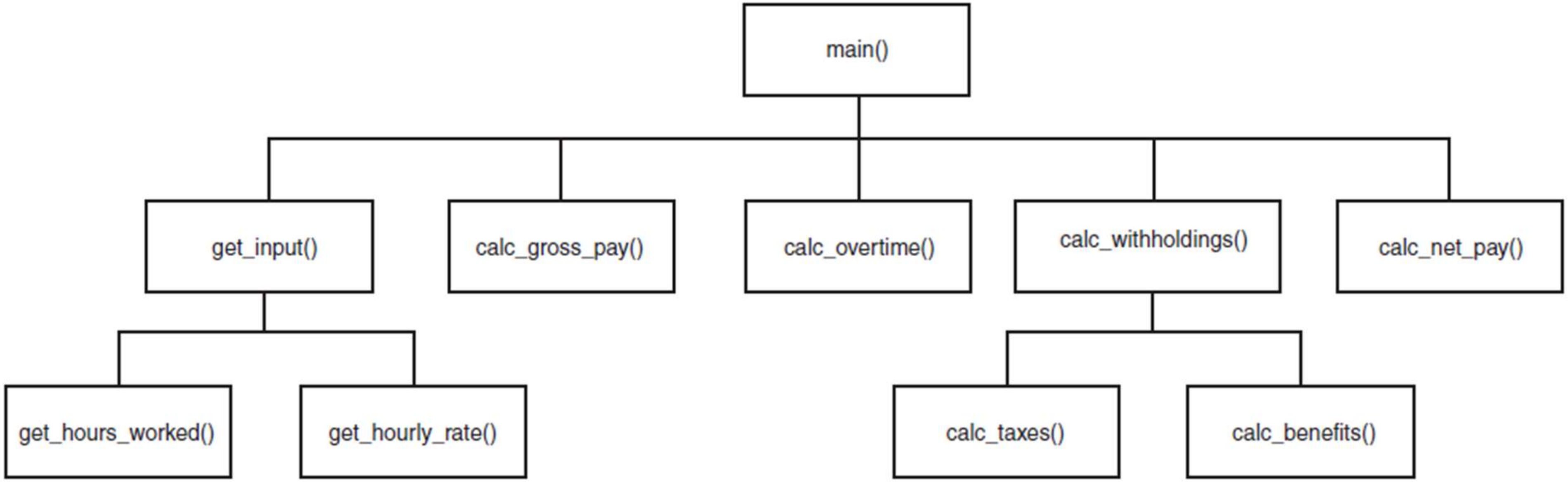
- **In a flowchart, function call shown as rectangle with vertical bars at each side**
  - Function name written in the symbol
  - Typically draw separate flow chart for each function in the program
    - End terminal symbol usually reads `Return`
- **Top-down design: technique for breaking algorithm into functions**

Designing a Program to Use Functions (cont'd.)

- **Hierarchy chart: depicts relationship between functions**
  - AKA structure chart
  - Box for each function in the program, Lines connecting boxes illustrate the functions called by each function
  - Does not show steps taken inside a function
- **Use `input` function to have program wait for user to press enter**

Designing a Program to Use Functions (cont'd.)

Figure 5-10 A hierarchy chart



Using the `pass` Keyword

- You can use the `pass` keyword to create empty functions
- The `pass` keyword is ignored by the Python interpreter
- This can be helpful when designing a program

```
def step1():
    pass

def step2():
    pass
```

Local Variables

- **<u>Local variable</u>: variable that is assigned a value inside a function**
  - Belongs to the function in which it was created
    - Only statements inside that function can access it, error will occur if another function tries to access the variable
- **<u>Scope</u>: the part of a program in which a variable may be accessed**
  - For local variable: function in which created

Local Variables (cont'd.)

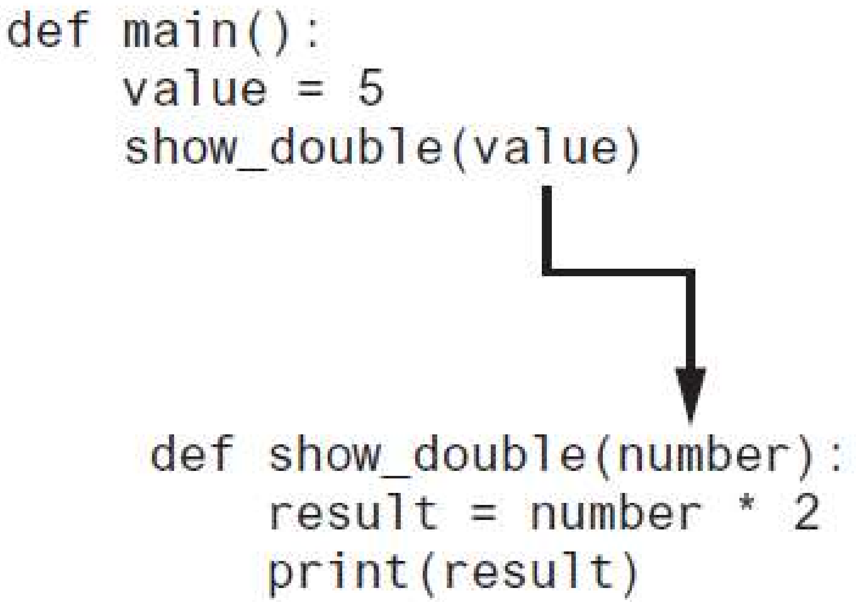
- **Local variable cannot be accessed by statements inside its function which precede its creation**
- **Different functions may have local variables with the same name**
  - Each function does not see the other function's local variables, so no confusion

Passing Arguments to Functions

- **Argument: piece of data that is sent into a function**
  - Function can use argument in calculations
  - When calling the function, the argument is placed in parentheses following the function name

Passing Arguments to Functions (cont’d.)

Figure 5-13 The value variable is passed as an argument



```
def main():
    value = 5
    show_double(value)
```

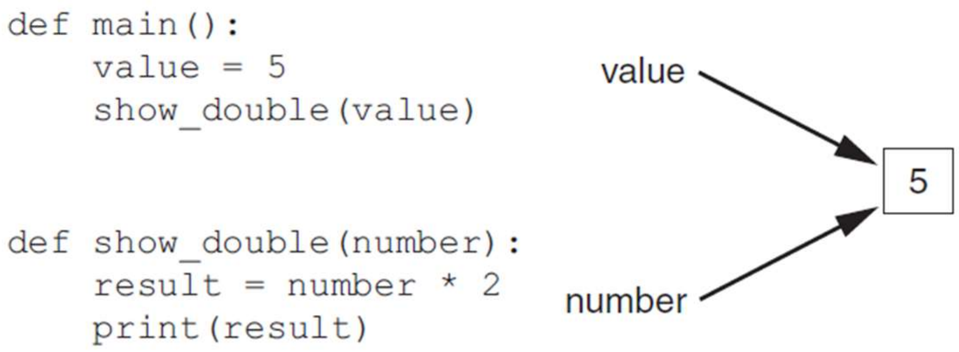
```
def show_double(number):
    result = number * 2
    print(result)
```

Passing Arguments to Functions (cont'd.)

- **Parameter variable: variable that is assigned the value of an argument when the function is called**
  - The parameter and the argument reference the same value
  - General format:
  - `def function_name(parameter):`
  - Scope of a parameter: the function in which the parameter is used

Passing Arguments to Functions (cont’d.)

Figure 5-14 The `value` variable and the `number` parameter reference the same value



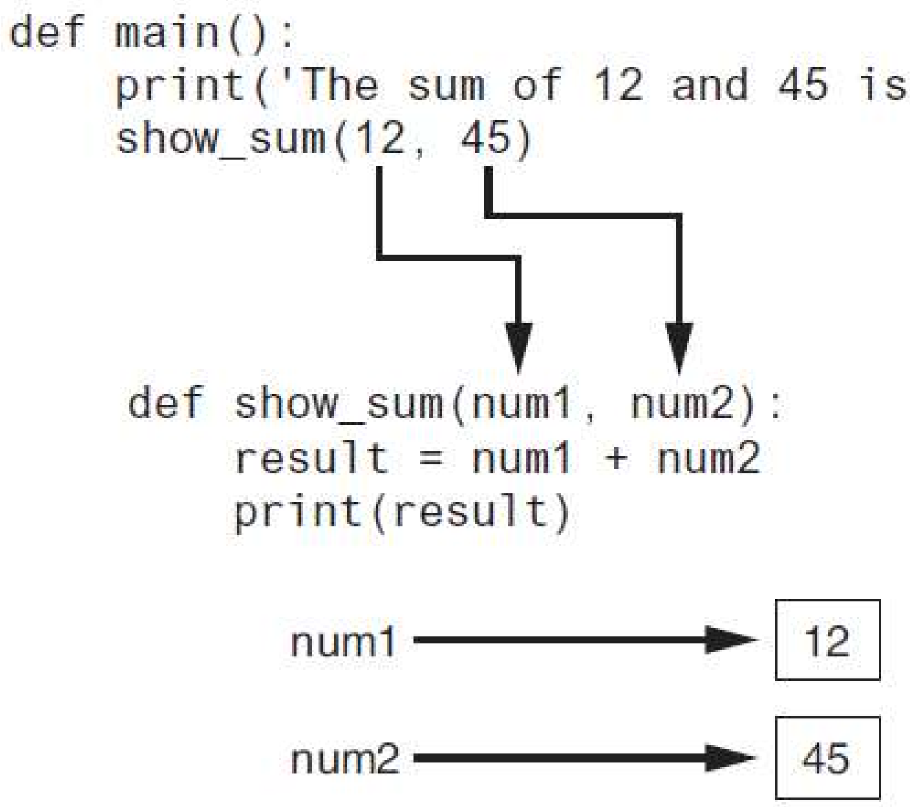
```
def main():
    value = 5
    show_double(value)


def show_double(number):
    result = number * 2
    print(result)
```

Passing Multiple Arguments

- **Python allows writing a function that accepts multiple arguments**
  - Parameter list replaces single parameter
    - Parameter list items separated by comma
- **Arguments are passed *by position* to corresponding parameters**
  - First parameter receives value of first argument, second parameter receives value of second argument, etc.

Passing Multiple Arguments (cont'd.)

Figure 5-16 Two arguments passed to two parameters



```
def main():
    print('The sum of 12 and 45 is')
    show_sum(12, 45)
```

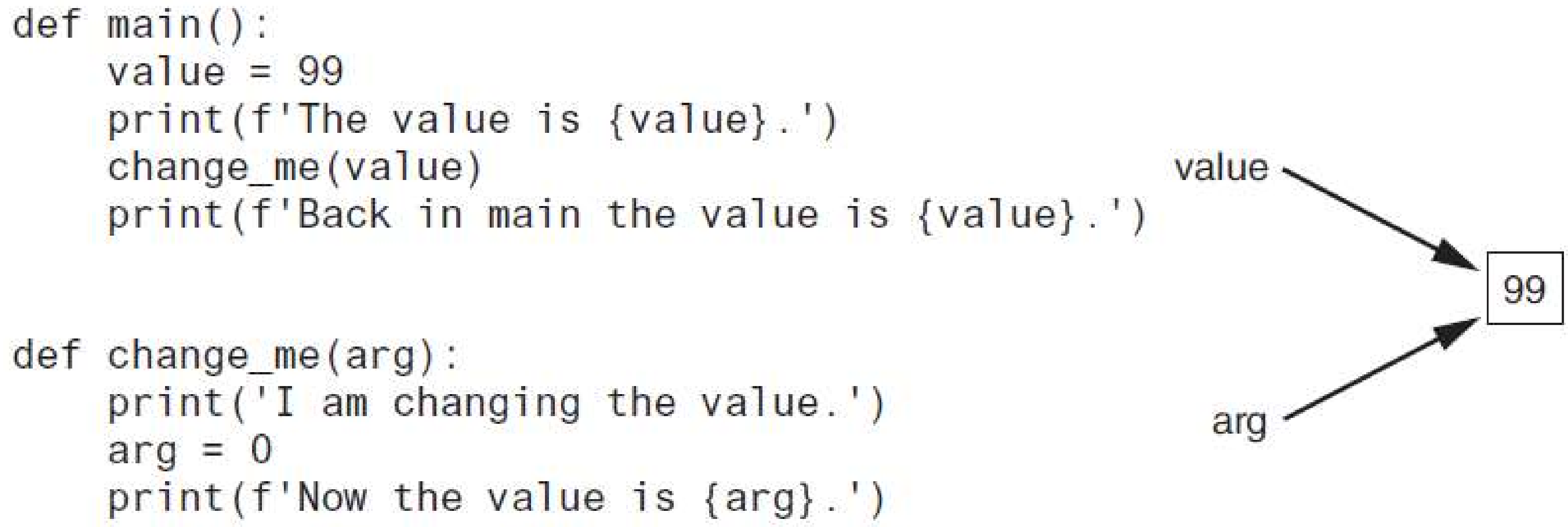
```
def show_sum(num1, num2):
    result = num1 + num2
    print(result)
```

Making Changes to Parameters

- **Changes made to a parameter value within the function do not affect the argument**
  - Known as *pass by value*
  - Provides a way for unidirectional communication between one function and another function
    - Calling function can communicate with called function

Making Changes to Parameters (cont’d.)

Figure 5-17 The value variable is passed to the change_me function

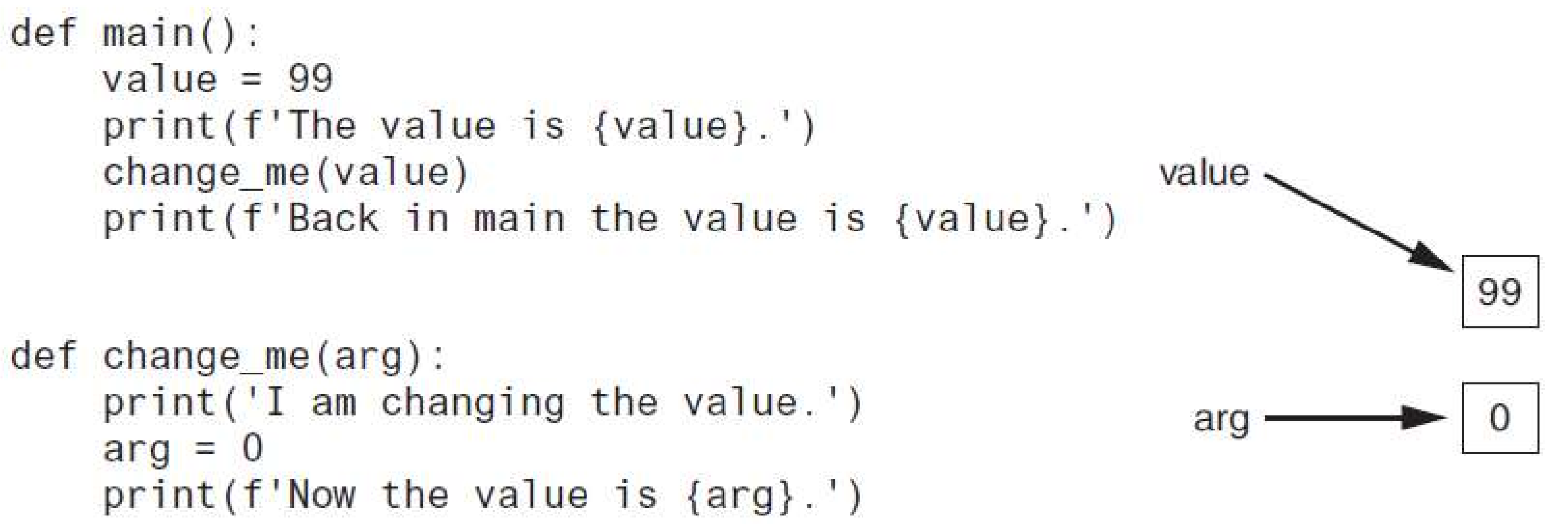


```
def main():
    value = 99
    print(f'The value is {value}.')
    change_me(value)
    print(f'Back in main the value is {value}.')


def change_me(arg):
    print('I am changing the value.')
    arg = 0
    print(f'Now the value is {arg}.')
```

Making Changes to Parameters (cont’d.)

- **Figure 5-18**
  - The `value` variable passed to the `change_me` function cannot be changed by it

Figure 5-18 The value variable is passed to the change_me function



```
def main():
    value = 99
    print(f'The value is {value}.')
    change_me(value)
    print(f'Back in main the value is {value}.')

def change_me(arg):
    print('I am changing the value.')
    arg = 0
    print(f'Now the value is {arg}.')
```

Keyword Arguments

- **Keyword argument: argument that specifies which parameter the value should be passed to**
  - Position when calling function is irrelevant
  - General Format:
  - `function_name(`*`parameter=value`*`)`
- **Possible to mix keyword and positional arguments when calling a function**
  - Positional arguments must appear first

Keyword-Only Parameters

- In a function definition, you can require that all arguments be passed as keyword arguments
- Write an asterisk, followed by a comma, at the beginning of the function's parameter list

Keyword-Only Parameters

- **Example:**

```
def show_sum(*, a, b, c, d):
    print(a + b + c + d)
```

- **All the parameters appearing after the asterisk are keyword-only parameters**
- **When the function is called, the keyword-only parameters will accept only keyword arguments**

Keyword-Only Parameters

- **Example:**

```
def show_sum(*, a, b, c, d):
    print(a + b + c + d)
```

- **This function call will work:**

```
show_sum(a=10, b=20, c=30, d=40)
```

- **But this one will not:**

```
show_sum(10, b=20, c=30, d=40)
```

Keyword-Only Parameters

- The * can appear at any position in the parameter list, but only the parameters that appear after it will become keyword-only parameters

```
def show_sum(a, b, *, c, d):
    print(a + b + c + d)
```

- In this example, only the `c` and `d` parameters are keyword-only parameters.

Positional-Only Parameters

- **A positional-only parameter will accept only positional arguments**
- **To declare positional-only parameters, insert a forward-slash into the parameter list**
- **All the parameters that appear before the forward-slash will be positional-only parameters**

Positional-Only Parameters

- **Example:**

```
def show_sum(a, b, c, d, /):
    print(a + b + c + d)
```

- **The `a`, `b`, `c`, and `d` parameters are positional-only**
- **These parameters will not accept keyword arguments**

Positional-Only Parameters

- **Example:**

```
def show_sum(a, b, c, d, /):
    print(a + b + c + d)
```

- **This function call will work:**

```
show_sum(10, 20, 30, 40)
```

- **But this one will not:**

```
show_sum(10, 20, 30, d=40)
```

Positional-Only Parameters

- The / can appear at any position in the parameter list, but only the parameters that appear before it will become positional-only parameters

```
def show_sum(a, b, /, c, d):
    print(a + b + c + d)
```

- In this example, only the `a` and `b` parameters are positional-only parameters
- The `c` and `d` parameters can accept keyword arguments or positional arguments

Positional-Only Parameters

- **When you call a function in Python, you cannot pass a positional argument after a keyword argument**

```
def show_sum(a, b, /, c, d):
    print(a + b + c + d)
```

- **In this example, if you pass a keyword argument to `c`, you must also pass a keyword argument to `d`**

Default Arguments

- **In a function definition, you can provide a default argument for a parameter**

Default argument

```
def show_tax(price, tax_rate=0.07):
    tax = price * tax_rate
    print(f'The tax is {tax}.')
```

- **In this example, the default argument 0.07 is provided for the `tax_rate` parameter**
- **When we call the function, we must pass an argument for the `price` parameter, but we have the option of omitting the argument for the `tax_rate` parameter**

Default Arguments

- **Example:**

```
def show_tax(price, tax_rate=0.07):
    tax = price * tax_rate
    print(f'The tax is {tax}.')
```

- **The following statement calls the function, passing 100 to the `price` parameter. The `tax_rate` parameter will be given the value 0.07:**

```
show_tax(100)
```

Default Arguments

- **Example:**

```
def show_tax(price, tax_rate=0.07):
    tax = price * tax_rate
    print(f'The tax is {tax}.')
```

- **The following statement calls the function, passing 100 to the `price` parameter and 0.08 to the `tax_rate` parameter:**

```
show_tax(100, 0.08)
```

Default Arguments

- In a function's parameter list, the parameters without default arguments must appear first, followed by the parameters with default arguments.
- This is an invalid function:

```
def show_tax(price=10, tax_rate):
    tax = price * tax_rate
    print(f'The tax is {tax}.')
```

Default Arguments

- **You can provide default arguments for all of a function's parameters, as shown here:**

```
def show_tax(price=10, tax_rate=0.07):
    tax = price * tax_rate
    print(f'The tax is {tax}.')
```

- **We can call the function without passing any arguments:**

```
show_tax()
```

- **In this example, the function's parameters will be given their default arguments**

Global Variables and Global Constants

- **Global variable: created by assignment statement written outside all the functions**
  - Can be accessed by any statement in the program file, including from within a function
  - If a function needs to assign a value to the global variable, the global variable must be redeclared within the function
    - General format: `global` *`variable_name`*

Global Variables and Global Constants (cont'd.)

- **Reasons to avoid using global variables:**
  - Global variables making debugging difficult
    - Many locations in the code could be causing a wrong variable value
  - Functions that use global variables are usually dependent on those variables
    - Makes function hard to transfer to another program
  - Global variables make a program hard to understand

Global Constants

- **Global constant: global name that references a value that cannot be changed**
  - Permissible to use global constants in a program
  - To simulate global constant in Python, create global variable and do not re-declare it within functions

Introduction to Value-Returning Functions: Generating Random Numbers

- **<u>void function</u>: group of statements within a program for performing a specific task**
  - Call function when you need to perform the task
- **<u>Value-returning function</u>: similar to void function, returns a value**
  - Value returned to part of program that called the function when function finishes executing

Standard Library Functions and the `import` Statement

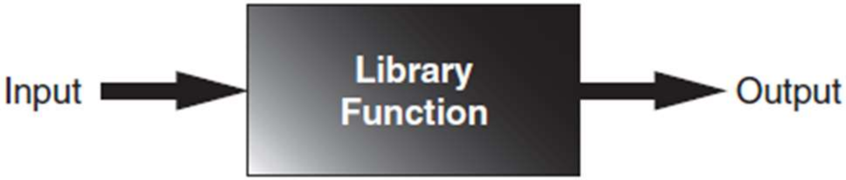
- **Standard library: library of pre-written functions that comes with Python**
  - *Library functions* perform tasks that programmers commonly need
    - Example: `print`, `input`, `range`
    - Viewed by programmers as a “black box”
- **Some library functions built into Python interpreter**
  - To use, just call the function

Standard Library Functions and the `import` Statement (cont’d.)

- **<u>Modules</u>: files that stores functions of the standard library**
  - Help organize library functions not built into the interpreter
  - Copied to computer when you install Python
- **To call a function stored in a module, need to write an `import` statement**
  - Written at the top of the program
  - Format: `import` *`module_name`*

Standard Library Functions and the `import` Statement (cont'd.)

Figure 5-19 A library function viewed as a black box



Generating Random Numbers

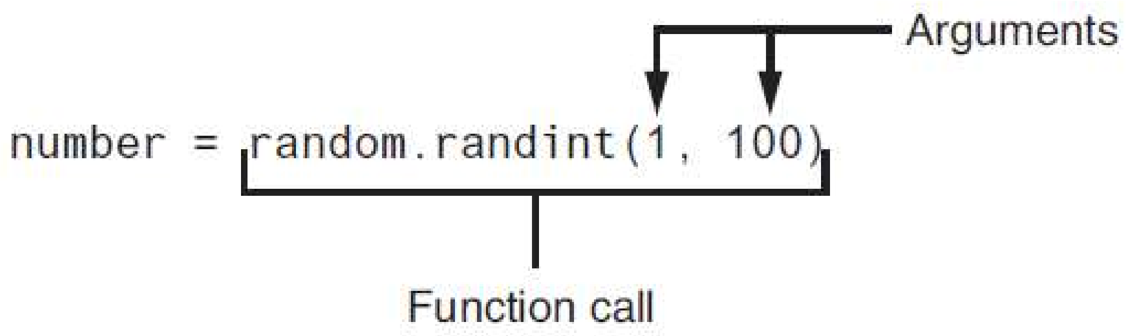
- Random number are useful in a lot of programming tasks
- `random` module: includes library functions for working with random numbers
- Dot notation: notation for calling a function belonging to a module
  - Format: `module_name.function_name()`

Generating Random Numbers (cont’d.)

- **`randint` function: generates a random number in the range provided by the arguments**
  - Returns the random number to part of program that called the function
  - Returned integer can be used anywhere that an integer would be used
  - You can experiment with the function in interactive mode

Generating Random Numbers (cont’d.)

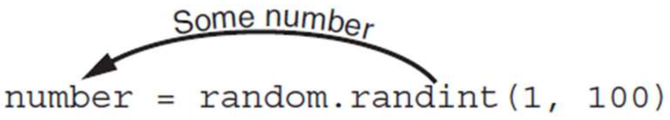
Figure 5-20 A statement that calls the random function



```
number = random.randint(1, 100)
```

Generating Random Numbers (cont’d.)

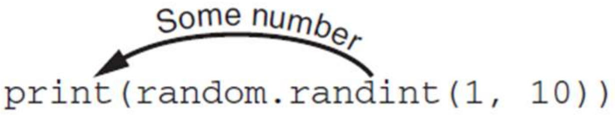
Figure 5-21 The `random` function returns a value



```
number = random.randint(1, 100)
```

A random number in the range of 1 through 100 will be assigned to the `number` variable.

Figure 5-22 Displaying a random number



```
print(random.randint(1, 10))
```

A random number in the range of 1 through 10 will be displayed.

Generating Random Numbers (cont’d.)

- **`randrange` function: similar to `range` function, but returns randomly selected integer from the resulting sequence**
  - Same arguments as for the `range` function
- **`random` function: returns a random float in the range of 0.0 and 1.0**
  - Does not receive arguments
- **`uniform` function: returns a random float but allows user to specify range**

Random Number Seeds

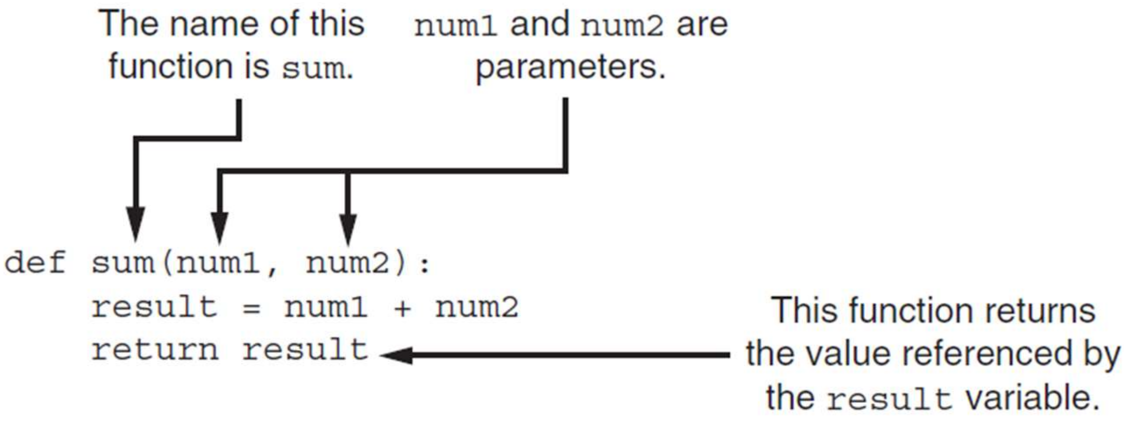
- **Random number created by functions in random module are actually pseudo-random numbers**
- **<u>Seed value</u>: initializes the formula that generates random numbers**
  - Need to use different seeds in order to get different series of random numbers
    - By default uses system time for seed
    - Can use `random.seed()` function to specify desired seed value

Writing Your Own Value-Returning Functions

- **To write a value-returning function, you write a simple function and add one or more `return` statements**
  - Format: `return` *`expression`*
    - The value for *`expression`* will be returned to the part of the program that called the function
  - The expression in the `return` statement can be a complex expression, such as a sum of two variables or the result of another value-returning function

Writing Your Own Value-Returning Functions (cont’d.)

Figure 5-23 Parts of the function



The name of this function is `sum`.

`num1` and `num2` are parameters.

```
def sum(num1, num2):
    result = num1 + num2
    return result
```

This function returns the value referenced by the `result` variable.

How to Use Value-Returning Functions

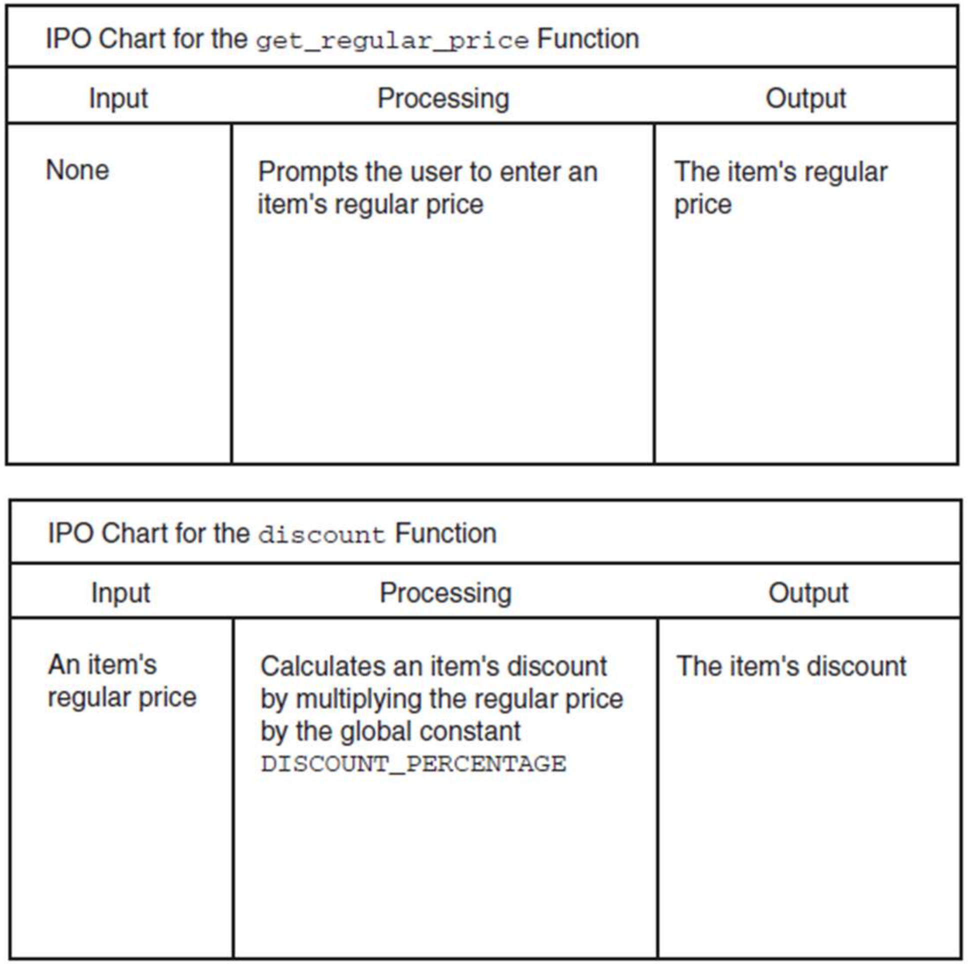
- **Value-returning function can be useful in specific situations**
  - Example: have function prompt user for input and return the user’s input
  - Simplify mathematical expressions
  - Complex calculations that need to be repeated throughout the program
- **Use the returned value**
  - Assign it to a variable or use as an argument in another function

Using IPO Charts

- **IPO chart: describes the input, processing, and output of a function**
  - Tool for designing and documenting functions
  - Typically laid out in columns
  - Usually provide brief descriptions of input, processing, and output, without going into details
    - Often includes enough information to be used instead of a flowchart

Using IPO Charts (cont’d.)

Figure 5-25 IPO charts for the `getRegularPrice` and `discount` functions



IPO Chart for the `get_regular_price` Function

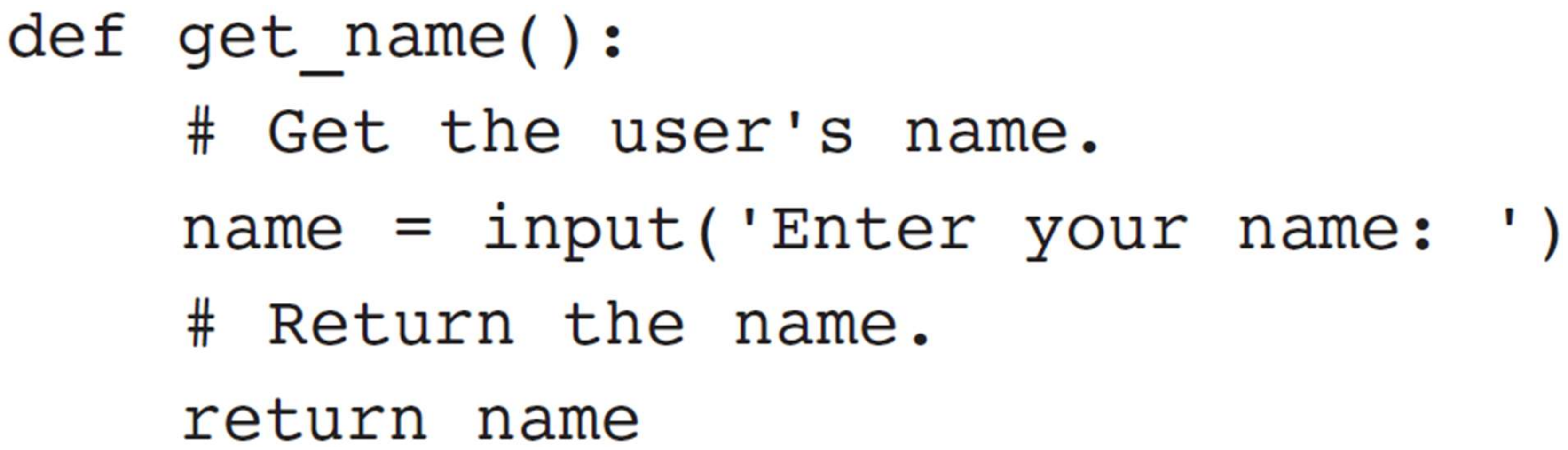
Input	Processing	Output
None	Prompts the user to enter an item's regular price	The item's regular price

IPO Chart for the `discount` Function

Input	Processing	Output
An item's regular price	Calculates an item's discount by multiplying the regular price by the global constant `DISCOUNT_PERCENTAGE`	The item's discount

Returning Strings

- You can write functions that return strings
- For example:



```
def get_name():
    # Get the user's name.
    name = input('Enter your name: ')
    # Return the name.
    return name
```

Returning Boolean Values

- **Boolean function: returns either `True` or `False`**
  - Use to test a condition such as for decision and repetition structures
    - Common calculations, such as whether a number is even, can be easily repeated by calling a function
  - Use to simplify complex input validation code

Returning Multiple Values

- **In Python, a function can return multiple values**
  - Specified after the `return` statement separated by commas
    - Format: `return` *`expression1,`*
      `expression2, etc.`
  - When you call such a function in an assignment statement, you need a separate variable on the left side of the = operator to receive each returned value

Returning `None` From a Function

- **The special value `None` means "no value"**
- **Sometimes it is useful to return `None` from a function to indicate that an error has occurred**

```
def divide(num1, num2):
    if num2 == 0:
        result = None
    else:
        result = num1 / num2
    return result
```

The `math` Module

- **`math` module: part of standard library that contains functions that are useful for performing mathematical calculations**
  - Typically accept one or more values as arguments, perform mathematical operation, and return the result
  - Use of module requires an `import math` statement

The `math` Module (cont’d.)

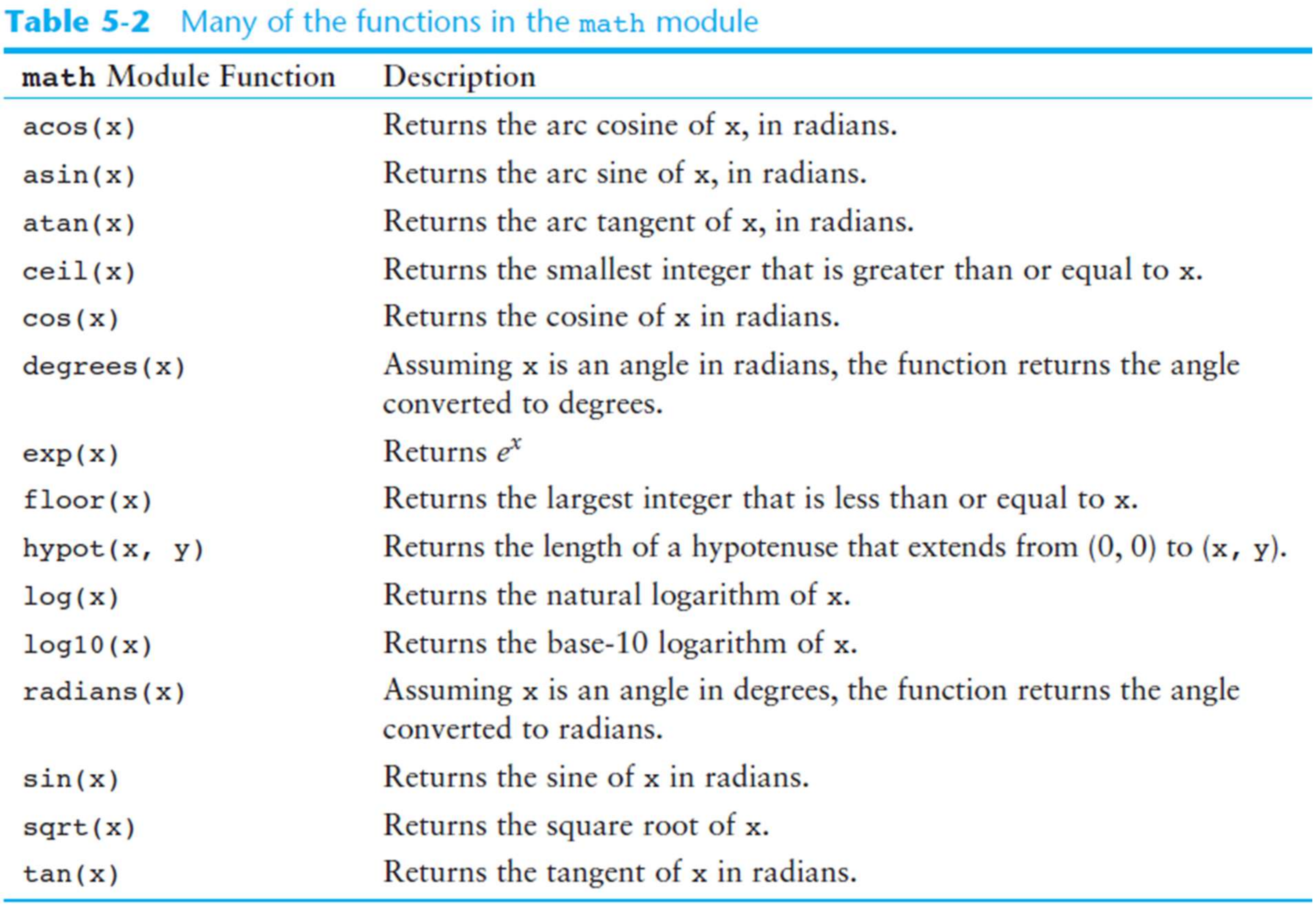


Table 5-2 Many of the functions in the `math` module

`math` Module Function	Description
`acos(x)`	Returns the arc cosine of `x`, in radians.
`asin(x)`	Returns the arc sine of `x`, in radians.
`atan(x)`	Returns the arc tangent of `x`, in radians.
`ceil(x)`	Returns the smallest integer that is greater than or equal to `x`.
`cos(x)`	Returns the cosine of `x` in radians.
`degrees(x)`	Assuming `x` is an angle in radians, the function returns the angle converted to degrees.
`exp(x)`	Returns e^x
`floor(x)`	Returns the largest integer that is less than or equal to `x`.
`hypot(x, y)`	Returns the length of a hypotenuse that extends from (0, 0) to (`x, y`).
`log(x)`	Returns the natural logarithm of `x`.
`log10(x)`	Returns the base-10 logarithm of `x`.
`radians(x)`	Assuming `x` is an angle in degrees, the function returns the angle converted to radians.
`sin(x)`	Returns the sine of `x` in radians.
`sqrt(x)`	Returns the square root of `x`.
`tan(x)`	Returns the tangent of `x` in radians.

The `math` Module (cont’d.)

- **The `math` module defines variables `pi` and `e`, which are assigned the mathematical values for *pi* and *e***
  - Can be used in equations that require these values, to get more accurate results
- **Variables must also be called using the dot notation**
  - Example:

```
circle_area = math.pi * radius**2
```

Storing Functions in Modules

- **In large, complex programs, it is important to keep code organized**
- **<u>Modularization</u>: grouping related functions in modules**
  - Makes program easier to understand, test, and maintain
  - Make it easier to reuse code for multiple different programs
    - Import the module containing the required function to each program that needs it

Storing Functions in Modules (cont’d.)

- **Module is a file that contains Python code**
  - Contains function definition but does not contain calls to the functions
    - Importing programs will call the functions
- **Rules for module names:**
  - File name should end in `.py`
  - Cannot be the same as a Python keyword
- **Import module using `import` statement**

Menu Driven Programs

- **Menu-driven program: displays a list of operations on the screen, allowing user to select the desired operation**
  - List of operations displayed on the screen is called a *menu*
- **Program uses a decision structure to determine the selected menu option and required operation**
  - Typically repeats until the user quits

Conditionally Executing the `main` Function

- It is possible to create a module that can be run as a standalone program or imported into another program
- Suppose *Program A* defines several functions that you want to use in *Program B*
- So, you import *Program A* into *Program B*
- However, you do not want *Program A* to execute its `main` function when you import it

Conditionally Executing the `main` Function

- **In the aforementioned scenario, you write each module so it executes its `main` function only when the module is being run as the main program**
  - When a source code file is loaded into the Python interpreter, a special variable called `__name__` is created
  - If the source code file has been imported as a module, the `__name__` variable will be set to the name of the module.
  - If the source code file is being executed as the main program, the `__name__` variable will be set to the value `'__main__'`.

Conditionally Executing the `main` Function

- **To prevent the `main` function from being executed when the file is imported as a module, you can conditionally execute `main`**

```
def main():
    statement
    statement

def my_function():
    statement
    statement

if __name__ == '__main__':
    main()
```

Turtle Graphics: Modularizing Code with Functions

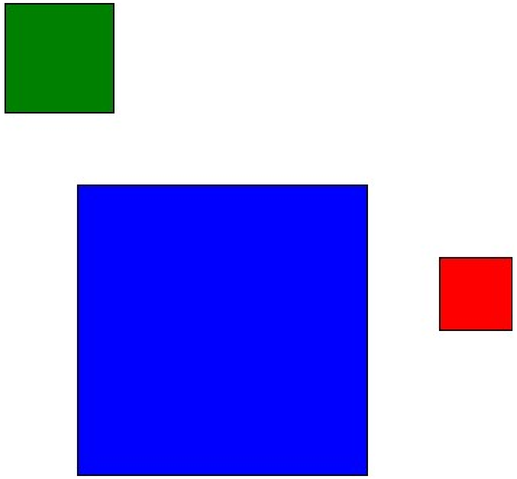
- Commonly needed turtle graphics operations can be stored in functions and then called whenever needed.
- For example, the following function draws a square. The parameters specify the location, width, and color.

```
def square(x, y, width, color):
    turtle.penup()              # Raise the pen
    turtle.goto(x, y)           # Move to (X,Y)
    turtle.fillcolor(color)     # Set the fill color
    turtle.pendown()            # Lower the pen
    turtle.begin_fill()         # Start filling
    for count in range(4):      # Draw a square
        turtle.forward(width)
        turtle.left(90)
    turtle.end_fill()           # End filling
```

Turtle Graphics: Modularizing Code with Functions

- The following code calls the previously shown `square` function to draw three squares:

```
square(100, 0, 50, 'red')
square(-150, -100, 200, 'blue')
square(-200, 150, 75, 'green')
```



Turtle Graphics: Modularizing Code with Functions

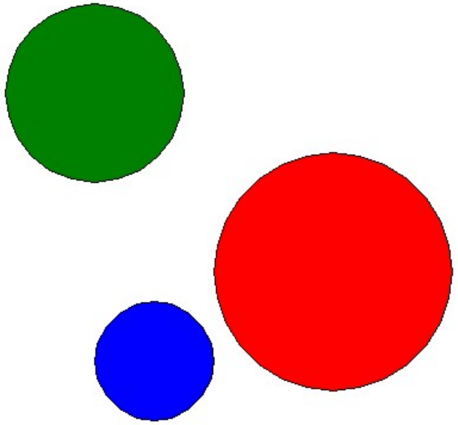
- **The following function draws a circle. The parameters specify the location, radius, and color.**

```
def circle(x, y, radius, color):
    turtle.penup()                  # Raise the pen
    turtle.goto(x, y - radius) # Position the turtle
    turtle.fillcolor(color)       # Set the fill color
    turtle.pendown()               # Lower the pen
    turtle.begin_fill()          # Start filling
    turtle.circle(radius)         # Draw a circle
    turtle.end_fill()              # End filling
```

Turtle Graphics: Modularizing Code with Functions

- **The following code calls the previously shown `circle` function to draw three circles:**

```
circle(0, 0, 100, 'red')
circle(-150, -75, 50, 'blue')
circle(-200, 150, 75, 'green')
```



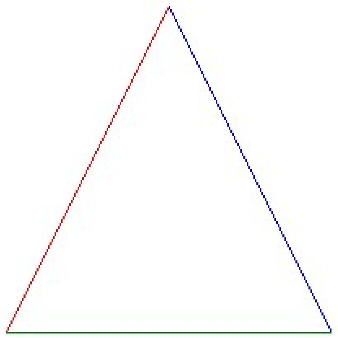
Turtle Graphics: Modularizing Code with Functions

- **The following function draws a line. The parameters specify the starting and ending locations, and color.**

```
def line(startX, startY, endX, endY, color):
    turtle.penup()              # Raise the pen
    turtle.goto(startX, startY) # Move to the starting point
    turtle.pendown()            # Lower the pen
    turtle.pencolor(color)      # Set the pen color
    turtle.goto(endX, endY)     # Draw a square
```

Turtle Graphics: Modularizing Code with Functions

- **The following code calls the previously shown `line` function to draw a triangle:**



```
TOP_X = 0
TOP_Y = 100
BASE_LEFT_X = -100
BASE_LEFT_Y = -100
BASE_RIGHT_X = 100
BASE_RIGHT_Y = -100
line(TOP_X, TOP_Y, BASE_LEFT_X, BASE_LEFT_Y, 'red')
line(TOP_X, TOP_Y, BASE_RIGHT_X, BASE_RIGHT_Y, 'blue')
line(BASE_LEFT_X, BASE_LEFT_Y, BASE_RIGHT_X, BASE_RIGHT_Y, 'green')
```

Summary

- **This chapter covered:**
  - The advantages of using functions
  - The syntax for defining and calling a function
  - Methods for designing a program to use functions
  - Use of local variables and their scope
  - Syntax and limitations of passing arguments to functions
  - Global variables, global constants, and their advantages and disadvantages

Summary (cont’d.)

- Value-returning functions, including:
  - Writing value-returning functions
  - Using value-returning functions
  - Functions returning multiple values
- Using library functions and the `import` statement
- Modules, including:
  - The `random` and `math` modules
  - Grouping your own functions in modules
- Modularizing Turtle Graphics Code