

CHAPTER 5

Functions

starting out with >>>

PYTHON®

FOURTH EDITION



TONY GADDIS



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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.

[illegible]

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
```

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

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 void function:**
 - Simply executes the statements it contains and then terminates.
- **A value-returning function:**
 - 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 key words 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**

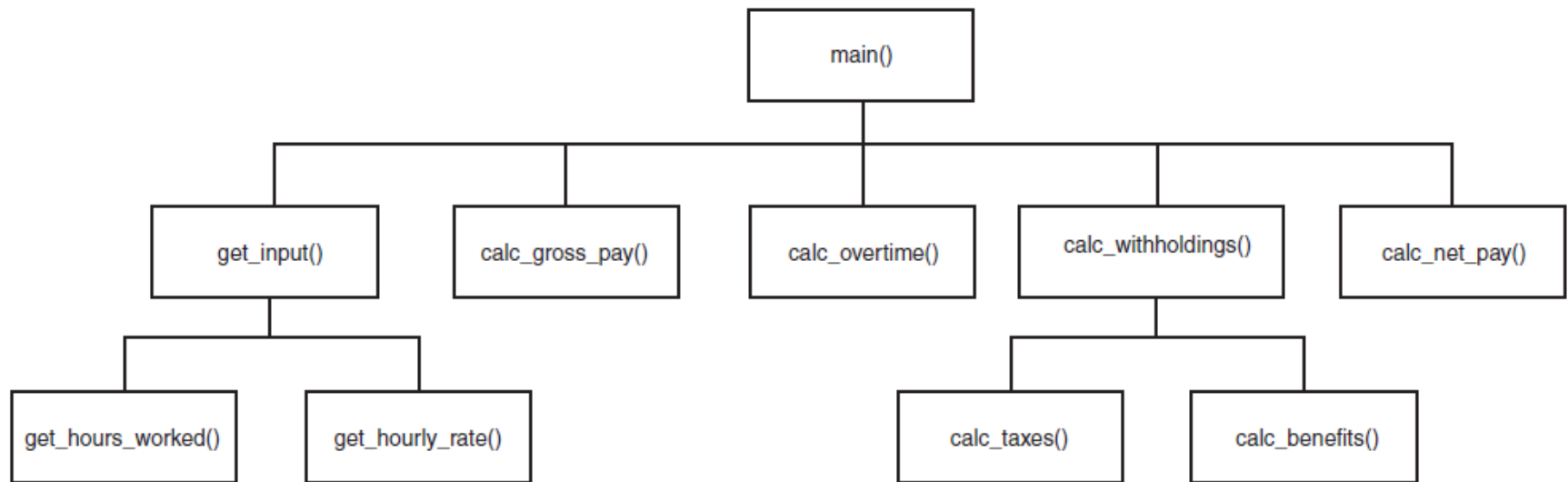


Designing a Program to Use Functions (cont'd.)

- **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



Local Variables

- **Local variable: 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
- **Scope: 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)
```



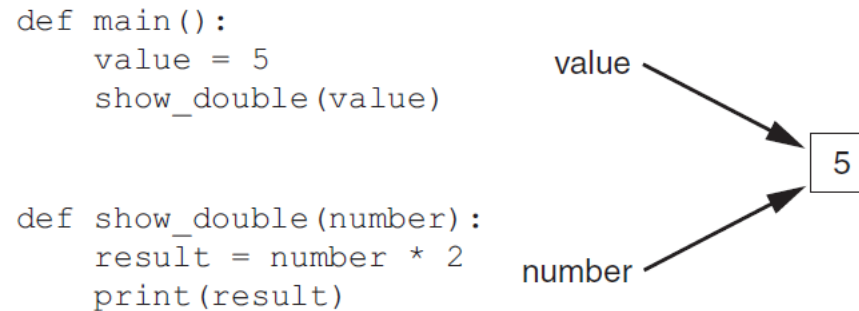
A diagram consisting of a vertical line segment extending downwards from the `show_double(value)` call in the `main` function, followed by a horizontal line segment extending to the right, and finally a vertical line segment extending downwards to an arrowhead pointing at the `number` parameter in the `show_double` function definition.

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



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)
```

num1 → 12

num2 → 45

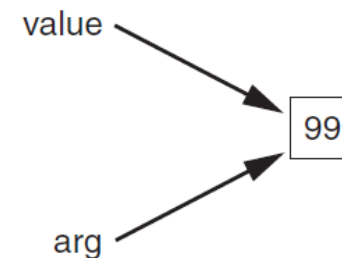
Making Changes to Parameters

- **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('The value is', value)  
    change_me(value)  
    print('Back in main the value is', value)  
  
def change_me(arg):  
    print('I am changing the value.')  
    arg = 0  
    print('Now the value is', arg)
```

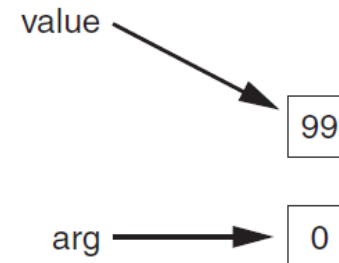


Making Changes to Parameters (cont'd.)

- **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('The value is', value)  
    change_me(value)  
    print('Back in main the value is', value)  
  
def change_me(arg):  
    print('I am changing the value.')  
    arg = 0  
    print('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



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

- **void function**: group of statements within a program for performing a specific task
 - Call function when you need to perform the task
- **Value-returning function**: 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.)

- **Modules**: 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 numbers 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.)

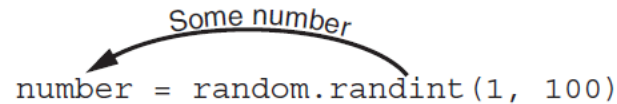
Figure 5-20 A statement that calls the `random` function

number = random.randint(1, 100)

The diagram shows the code `number = random.randint(1, 100)`. A horizontal bracket underneath the `random.randint(1, 100)` portion is labeled "Function call". Above the closing parenthesis of the function call, a horizontal line with two downward-pointing arrows is labeled "Arguments", pointing to the values `1` and `100`.

Generating Random Numbers (cont'd.)

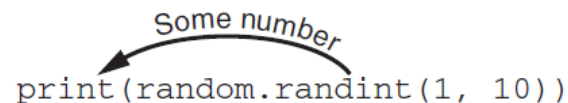
Figure 5-21 The `random` function returns a value



```
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
- **Seed value**: 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

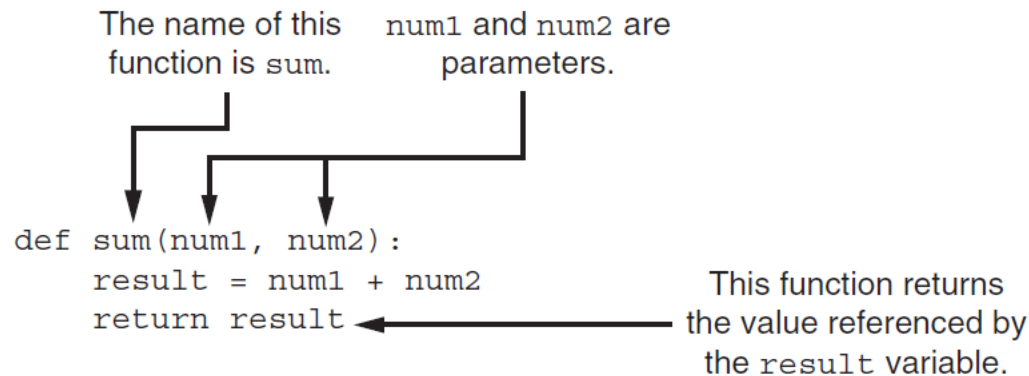


Writing Your Own Value-Returning Functions

- **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



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 <code>get_regular_price</code> Function		
Input	Processing	Output
None	Prompts the user to enter an item's regular price	The item's regular price

IPO Chart for the <code>discount</code> Function		
Input	Processing	Output
An item's regular price	Calculates an item's discount by multiplying the regular price by the global constant <code>DISCOUNT_PERCENTAGE</code>	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

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

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



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.**

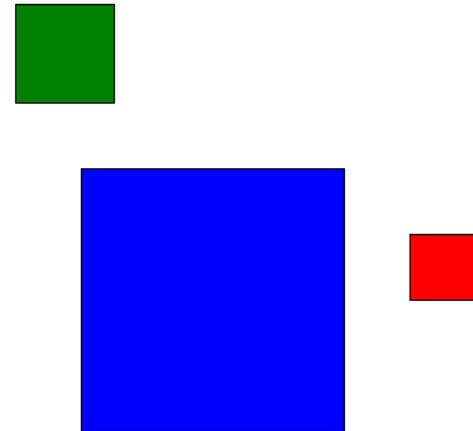
```
def square(x, y, width, color):  
    turtle.penup()           # Raise the pen  
    turtle.goto(x, y)        # Move to (X,Y)  
    turtle.fillcolor(color)   # Set the fill color  
    turtle.pendown()         # Lower the pen  
    turtle.begin_fill()       # Start filling  
    for count in range(4):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

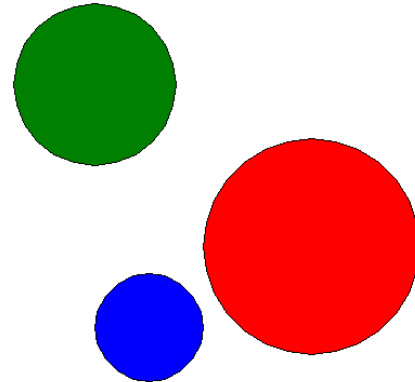
- The following function draws a circle. The parameters specify the location, radius, and color.

```
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

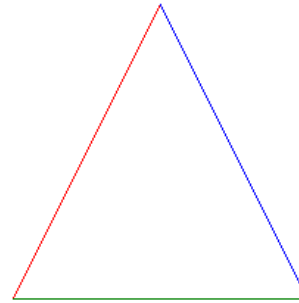
- The following function draws a line. The parameters specify the starting and ending locations, and color.

```
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

