CHAPTER 5

METHODS

Slides by Donald W. Smith
TechNeTrain.com

Final Draft
10/29/2011

Chapter Goals

- To be able to implement methods
- To become familiar with the concept of parameter passing
- To develop strategies for decomposing complex tasks into simpler ones
- To be able to determine the scope of a variable
- To learn how to think recursively (optional)

In this chapter, you will learn how to design and implement your own methods. Using the process of stepwise refinement, you will be able to break up complex tasks into sets of cooperating methods.

Contents

- Methods as Black Boxes
- Implementing Methods
- Parameter Passing
- Return Values
- Methods without Return Values
- Problem Solving:
  - Reusable Methods
  - Stepwise Refinement
- Variable Scope
- Recursive Methods (optional)

5.1 Methods as Black Boxes

- A method is a sequence of instructions with a name
  - You declare a method by defining a named block of code

```
public static void main(String[] args)
{
   double result = Math.pow(2, 3);
   . . .
}
```

`main()` method,
`Math.pow()` method, etc.

  - You call a method in order to execute its instructions

A method packages a computation consisting of multiple steps into a form that can be easily understood and reused.

What is a method?

- Some methods you have already used are:
  - `Math.pow()`
  - `String.length()`
  - `Character.isDigit()`
  - `Scanner.nextInt()`
  - `main()`
- They have:
  - May have a capitalized name and a dot (.) before them
  - A method name
    - Follow the same rules as variable names, camelHump style
  - `( )` - a set of parenthesis at the end
    - A place to provide the method input information

Methods

- **Method**: sequence of instructions that accesses the data of an object
- You manipulate objects by calling its methods
- **Class**: declares the methods that you can apply to its objects
- Class determines legal methods:

```
String greeting = "Hello";
greeting.println() // Error
greeting.length() // OK
```

- **Public Interface**: specifies what you can do with the objects of a class

Overloaded Method

- **Overloaded method:** when a class declares two methods with the same name, but different parameters
- Example: the `PrintStream` class declares a second method, also called `println`, as

```
public void println(int output)
```

A Representation of Two String Objects

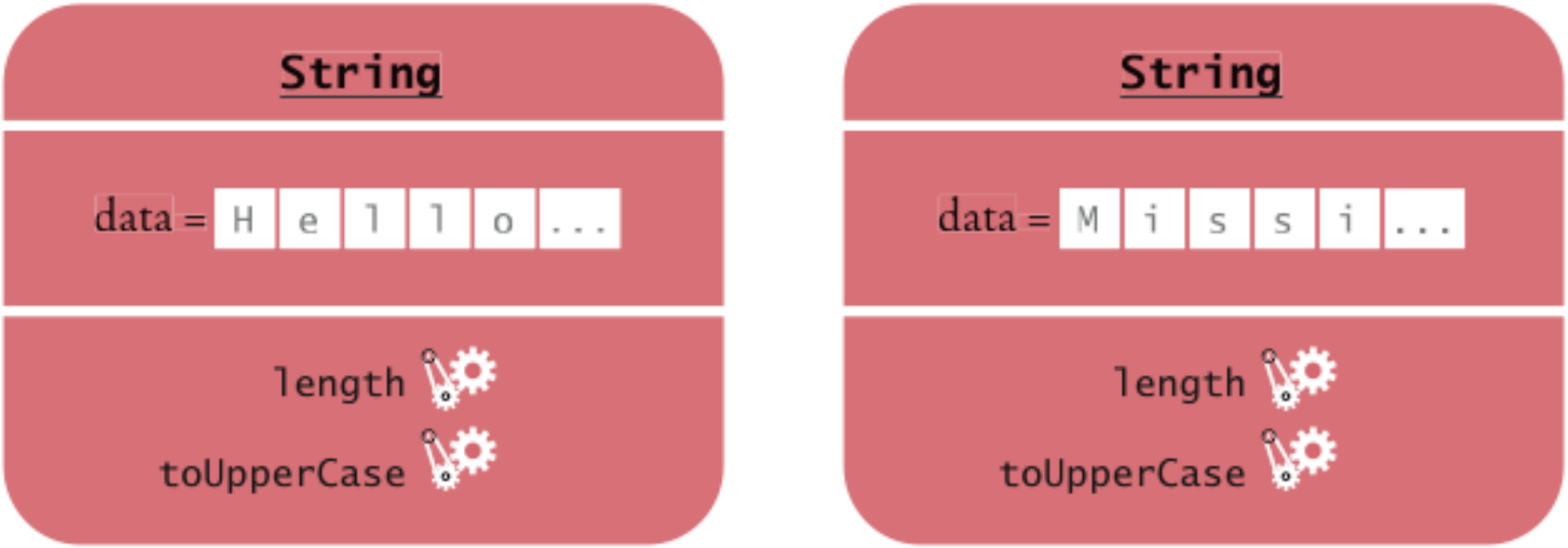


Figure 5 A Representation of Two `String` Objects

String Methods

- `length`: counts the number of characters in a string:

```
String greeting = "Hello, World!";
int n = greeting.length(); // sets n to 13
```

- `toUpperCase`: creates another String object that contains the characters of the original string, with lowercase letters converted to uppercase:

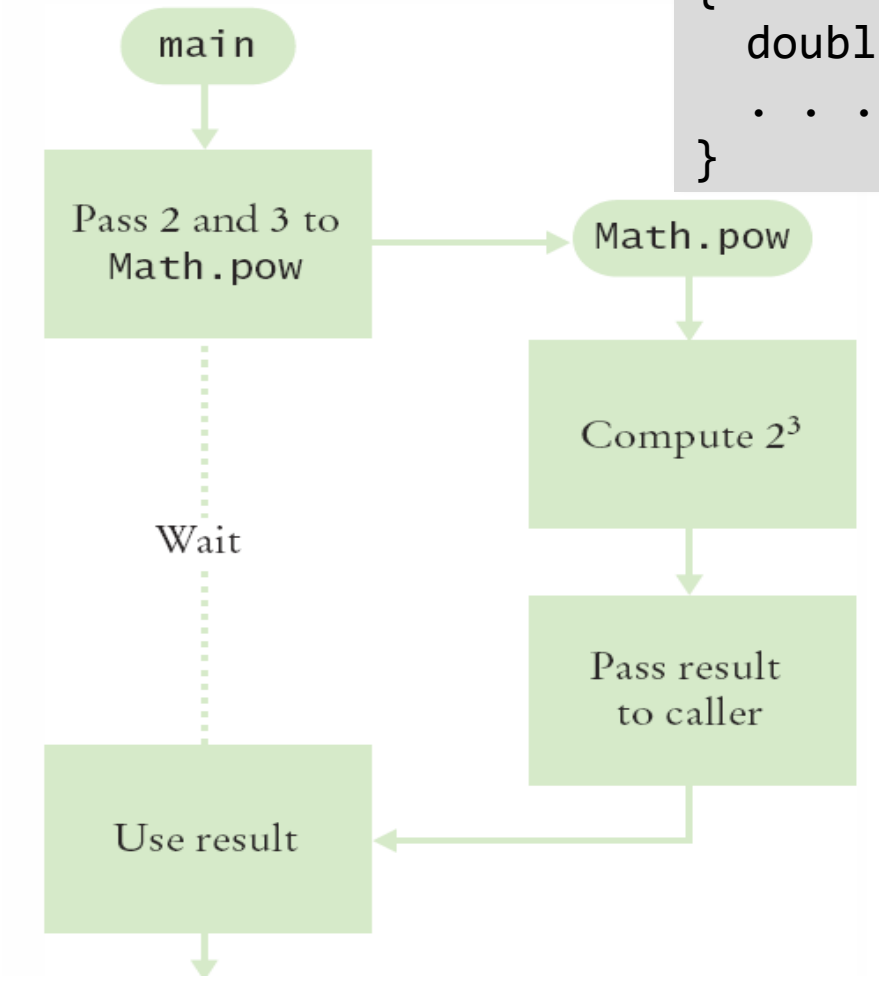
```
String river = "Mississippi";
String bigRiver = river.toUpperCase();
// sets bigRiver to "MISSISSIPPI"
```

- When applying a method to an object, make sure method is defined in the appropriate class:

```
System.out.length(); // This method call is an error
```

Flowchart of Calling a Method

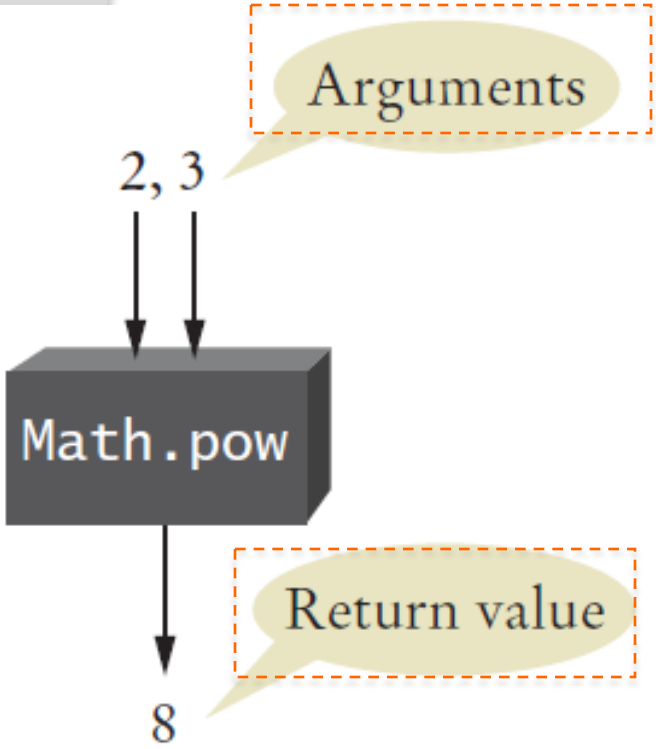
```
public static void main(String[] args)
{
   double result = Math.pow(2, 3);
   . . .
}
```



- One method 'calls' another
  - main calls `Math.pow()`
  - Passes two arguments
    - 2 and 3
  - `Math.pow` starts
    - Uses variables (2, 3)
    - Does its job
    - Returns the answer
  - main uses result

Arguments and Return Values

```
public static void main(String[] args)
{
   double result = Math.pow(2,3);
   . . .
}
```



- Methods can receive multiple arguments (or no argument like *Math.random*), but they return only one value

- `main` 'passes' two arguments (2 and 3) to `Math.pow`
- `Math.pow` calculates and returns a value of 8 to `main`
- `main` stores the return value to variable 'result'

Black Box Analogy

- A thermostat is a ‘black box’
  - Set a desired temperature
  - Turns on heater/AC as required
  - You don’t have to know how it really works!
    - How does it know the current temp?
    - What signals/commands does it send to the heater or A/C?
- Use methods like ‘black boxes’
  - Pass the method what it needs to do its job
  - Receive the answer

5.2 Implementing Methods

- A method to calculate the volume of a cube
  - What does it need to do its job?
  - What does it answer with?
- When writing this method:
  - Pick a name for the method (`cubeVolume`).
  - Declare a variable for each incoming argument (`double sideLength`) (called parameter variables)
  - Specify the type of the return value (`double`)
  - Add modifiers such as `public static`
    - (see Chapter 8)

When declaring a method, you provide a name for the method, a variable for each argument, and a type for the result

```
public static double cubeVolume(double sideLength)
```

Header of the method

Inside the Box

- Then write the body of the method
  - The body is surrounded by curly braces { }
  - The body contains the variable declarations and statements that are executed when the method is called
  - It will also return the calculated answer

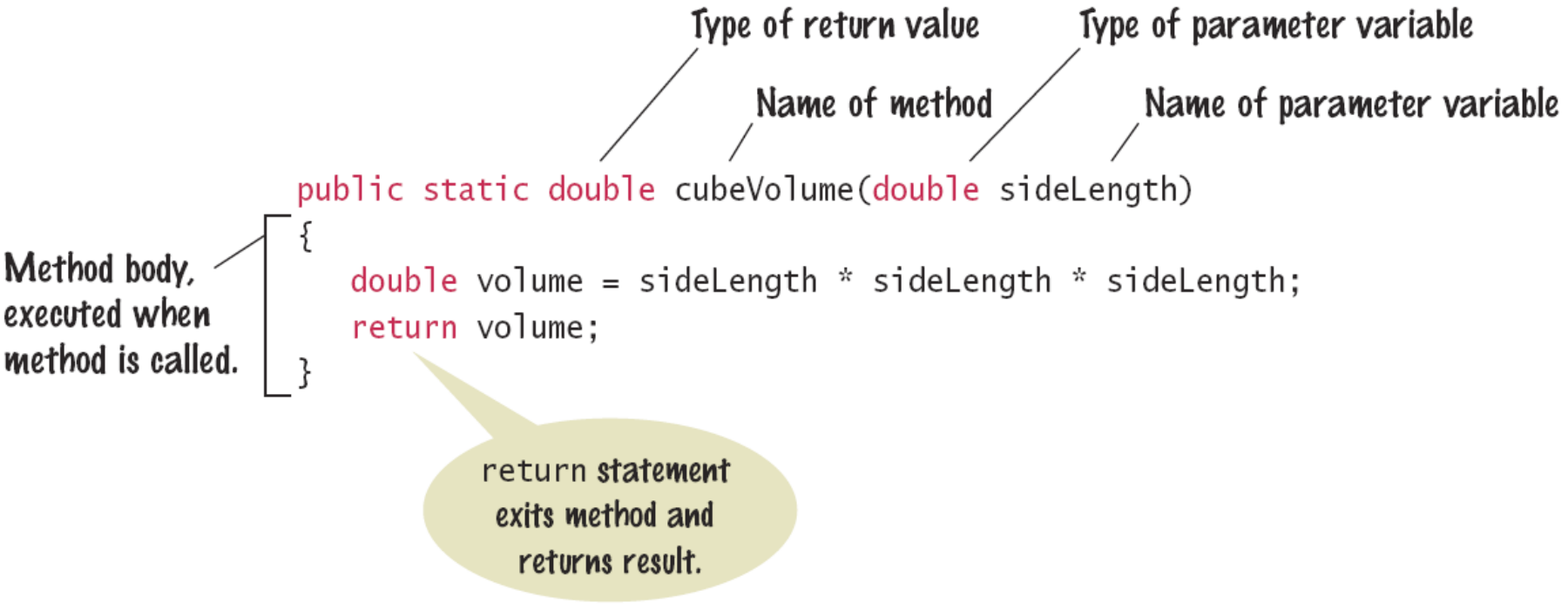
```
public static double cubeVolume(double sideLength)
{
   double volume = sideLength * sideLength * sideLength;
   return volume;
}
```

Back from the Box

- The values returned from `cubeVolume` are stored in local variables inside `main`
- The results are then printed out

```
public static void main(String[] args)
{
   double result1 = cubeVolume(2);
   double result2 = cubeVolume(10);
   System.out.println("A cube of side length 2 has volume
         "  + result1);
   System.out.println("A cube of side length 10 has volume
         " + result2);
}
```

Syntax 5.1: Method Declaration



- Static variables:
  - There is one copy of a `static` variable that is shared among all objects of the Class
- Static methods usually return a value. They can only access static variables and methods.

Cubes.java

```
1  /**
2     This program computes the volumes of two cubes.
3  */
4  public class Cubes
5  {
6     public static void main(String[] args)
7     {
8        double result1 = cubeVolume(2);
9        double result2 = cubeVolume(10);
10       System.out.println("A cube with side length 2 has volume " + result1);
11       System.out.println("A cube with side length 10 has volume " + result2);
12    }
13
14    /**
15       Computes the volume of a cube.
16       @param sideLength the side length of the cube
17       @return the volume
18    */
19    public static double cubeVolume(double sideLength)
20    {
21       double volume = sideLength * sideLength * sideLength;
22       return volume;
23    }
24 }
```

Program Run

```
A cube with side length 2 has volume 8
A cube with side length 10 has volume 1000
```

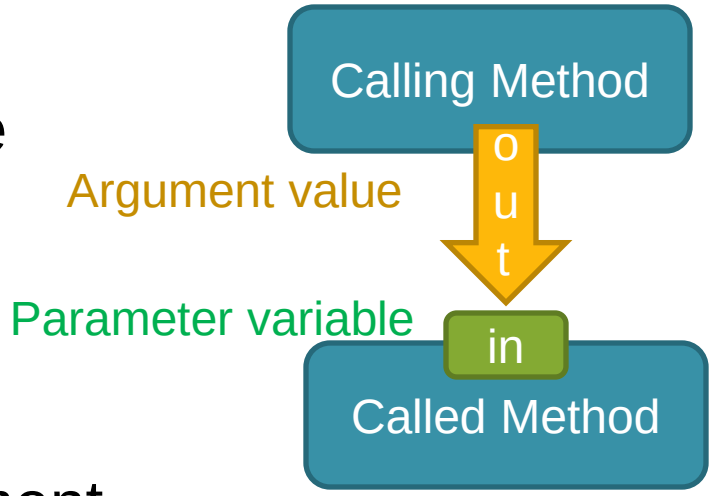
Method Comments

- Write a Javadoc comment above each method
- Start with `/**`
  - Note the purpose of the method
  - `@param` Describe each parameter variable
  - `@return` Describe the return value
- End with `*/`

```
/**
   Computes the volume of a cube.
   @param sideLength the side length of the cube
   @return the volume
*/
public static double cubeVolume(double sideLength)
```

5.3 Parameter Passing

- Parameter variables receive the argument values supplied in the method call
  - They both must be the same type
- The argument value may be:
  - The contents of a variable
  - A 'literal' value (2)
  - aka. 'actual parameter' or argument
- The parameter variable is:
  - **Declared in the called method**
  - Initialized with the value of the argument value
  - Used as a **variable inside the called method**
  - aka. 'formal parameter'



Recall: Cubes.java

```
1  /**
2     This program computes the volumes of two cubes.
3  */
4  public class Cubes
5  {
6     public static void main(String[] args)
7     {
8        double result1 = cubeVolume(2);
9        double result2 = cubeVolume(10);
10       System.out.println("A cube with side length 2 has volume " + result1);
11       System.out.println("A cube with side length 10 has volume " + result2);
12    }
13
14    /**
15       Computes the volume of a cube.
16       @param sideLength the side length of the cube
17       @return the volume
18    */
19    public static double cubeVolume(double sideLength)
20    {
21       double volume = sideLength * sideLength * sideLength;
22       return volume;
23    }
24 }
```

Argument value

Parameter variable

Program Run

```
A cube with side length 2 has volume 8
A cube with side length 10 has volume 1000
```

Parameter Passing Steps

```
public static void main(String[] args)
{
   double result1 = cubeVolume(2);
   . . .
}
```

result1 = 8

- The method returns. **All of its variables are removed.** The return value is transferred to the *caller*, that is, the method calling the CubeVolume method. The caller puts the return value in the *result1* variable

```
public static double cubeVolume(double sideLength)
{
   double volume = sideLength * sideLength * sideLength;
   return volume;
}
```

sideLength = 2

volume = 8

- The parameter variable *sideLength* is created when the method is called

Common Error 5.1

- Trying to Modify Arguments
  - A copy of the argument values is passed
  - Called method (`addTax`) can modify local copy (`price`)
    - But not original in calling method
      - `total`

```
public static void main(String[] args)
{
   double total = 10;
   addTax(total,       7.5);
}
```

`total` 10.0

copy

```
public static int addTax(double price, double rate)
{
   double tax = price * rate / 100;
   price = price + tax; // Has no effect outside the method
   return tax;
}
```

`price` 10.75

- Also do not modify parameter variables

5.4 Return Values

- Methods can (optionally) return one value
  - Declare a return type in the method declaration
  - Add a return statement that returns a value
    - A return statement does two things:
      1) Immediately terminates the method
      2) Passes the return value back to the calling method

return type

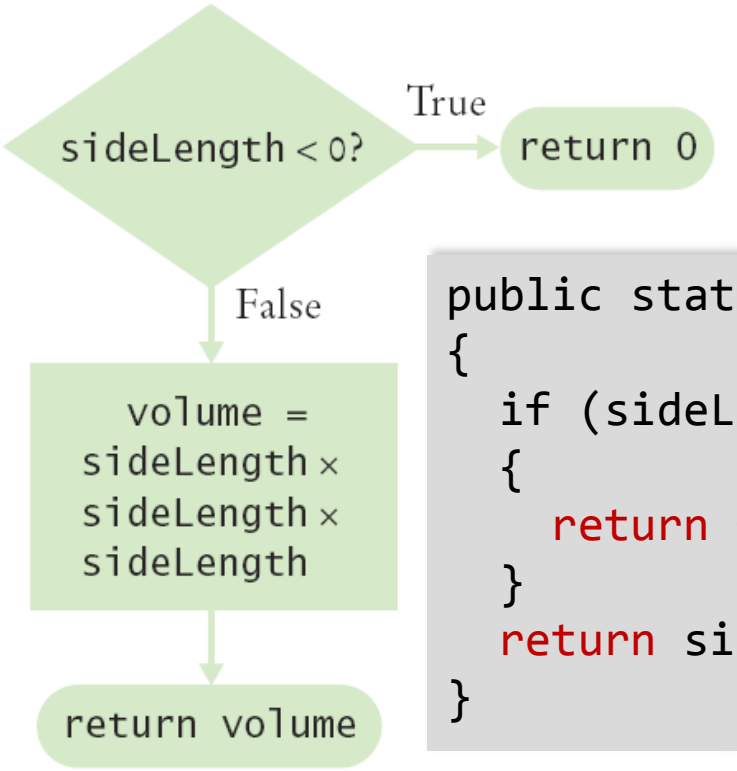
```
public static double cubeVolume (double sideLength)
{
   double volume = sideLength * sideLength * sideLength;
   return volume;
}
```

return statement

- The return value may be a value, a variable or a calculation
  - Type must match return type

Multiple `return` Statements

- A method can use multiple `return` statements
  - But every branch must have a `return` statement




```
public static double cubeVolume(double sideLength)
{
   if (sideLength < 0)
   {
      return 0;
   }
   return sideLength * sideLength * sideLength;
}
```

Common Error 5.2

- Missing `return` Statement
  - Make sure all conditions are handled
  - In this case, `x` could be equal to 0
    - No `return` statement for this condition
    - The compiler will complain if any branch has no `return` statement

```
public static int sign(double x)
{
  if (x < 0) { return -1; }
  if (x > 0) { return 1; }
  // Error: missing return value if x equals 0
}
```

Implementing a Method: Steps

1) Describe what the method should do.
2) Determine the method's "inputs".
3) Determine the types of parameter values and the return value.
4) Write pseudocode for obtaining the desired result.
5) Implement the method body.

```
public static double pyramidVolume(double height,
   double baseLength)
{
   double baseArea = baseLength * baseLength;
   return height * baseArea / 3;
}
```

6) Test your method.
   - Design test cases and code

```
Volume: 300
Expected: 300
Volume: 0
Expected: 0
```

5.5 Methods without Return Values

- Methods are not required to return a value
  - The return type of void means nothing is returned
  - No `return` statement is required
  - The method can generate output though!

```
...
boxString("Hello");
...
```

```
-------
!Hello!
-------
```

This method doesn't compute any value. It performs some actions and then returns to the caller

```
public static void boxString(String str)
{
   int n = str.length();
   for (int i = 0; i < n + 2; i++)
      { System.out.print("-"); }
   System.out.println();
   System.out.println("!" + str + "!");
   for (int i = 0; i < n + 2; i++)
      { System.out.print("-"); }
   System.out.println();
}
```

Cont'd

- Because there is no return value, you CANNOT use boxString in an expression.
  - You can call

    boxString("Hello");
  - But not

    Result = boxString("Hello");

    // Error: boxString doesn't return a result

Using `return` Without a Value

- You can use the `return` statement without a value
  - In methods with void return type
  - The method will terminate immediately!

```
public static void boxString(String str)
{
  int n = str.length();
  if (n == 0)
  {
    return; // Return immediately
  }
  for (int i = 0; i < n + 2; i++) { System.out.print("-"); }
  System.out.println();
  System.out.println("!" + str + "!");
  for (int i = 0; i < n + 2; i++) { System.out.print("-"); }
  System.out.println();
}
```

5.6 Problem Solving: Reusable Methods

- Find Repetitive Code
  - May have different values but same logic

1 - 12

0 - 59

```
int hours;
do
{
   System.out.print("Enter a value between 1 and 12: ");
   hours = in.nextInt();
}
while (hours < 1 || hours > 12);

int minutes;
do
{
   System.out.print("Enter a value between 0 and 59: ");
   minutes = in.nextInt();
}
while (minutes < 0 || minutes > 59);
```

Cont'd

- Extract the common behavior into a method:

```
Public static int readIntUpTo(int high)
{
        int input;
        Scanner in = new Scanner(System.in);
        do
        {
           System.out.print("Enter a value between 0 and " +high+ " : ");
           input = in.nextInt();
        }
        while(input < 0 || input > high);
        return input;
}
```

- Then use this method twice:

```
        int hours = readIntUpTo(23);
        int minutes= readIntUpTo(59);
```

Write a 'Parameterized' Method

```
/**
   Prompts a user to enter a value in a given range until the user
   provides a valid input.
   @param low the low end of the range
   @param high the high end of the range
   @return the value provided by the user
*/
public static int readValueBetween(int low, int high)
{
   int input;
   do
   {
      System.out.print("Enter between " + low + " and " + high + ": ");
      Scanner in = new Scanner(System.in);
      input = in.nextInt();
   }
   while (input < low || input > high);
   return input;
}
```

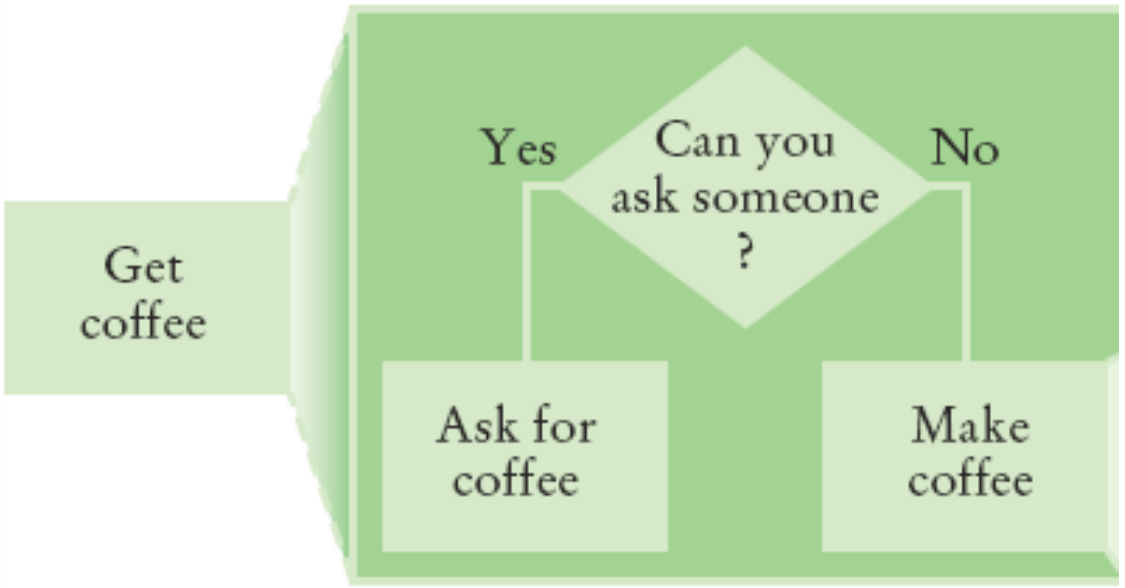
1, 12

0, 59

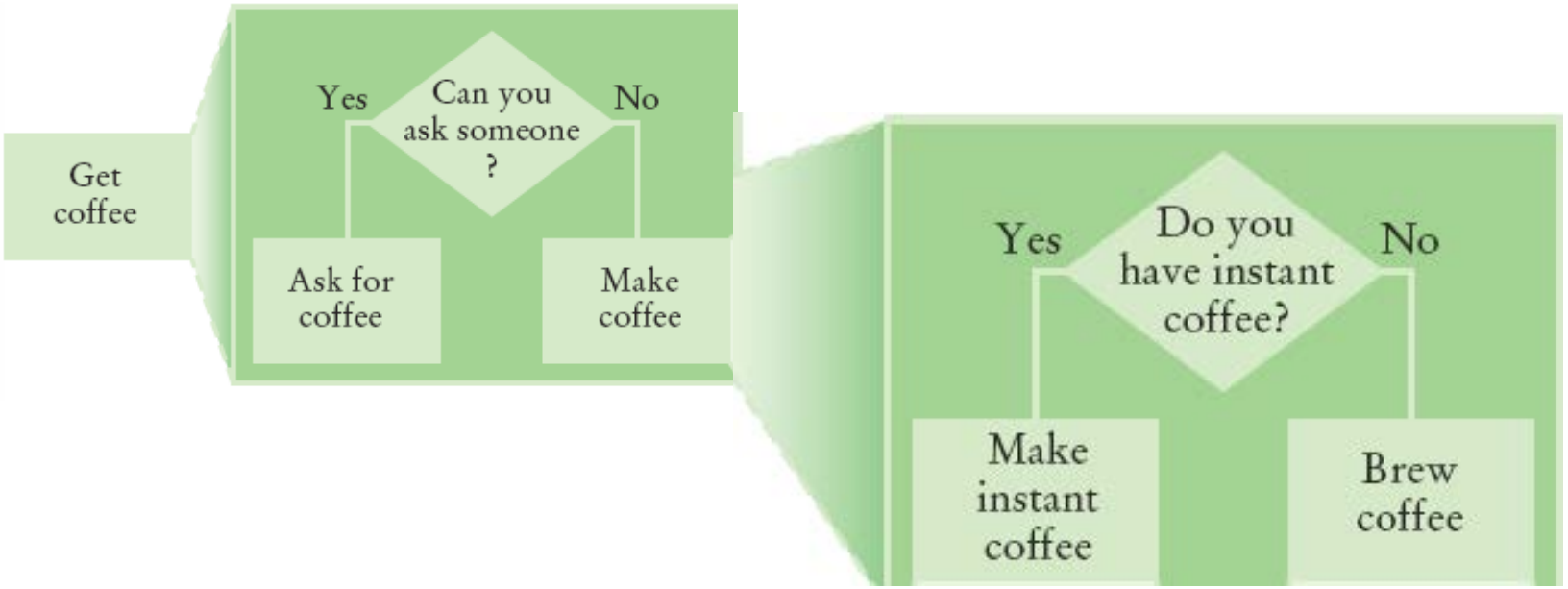
8

5.7 Problem Solving

- Stepwise Refinement
  - To solve a difficult task, break it down into simpler tasks
  - Then keep breaking down the simpler tasks into even simpler ones, until you are left with tasks that you know how to solve



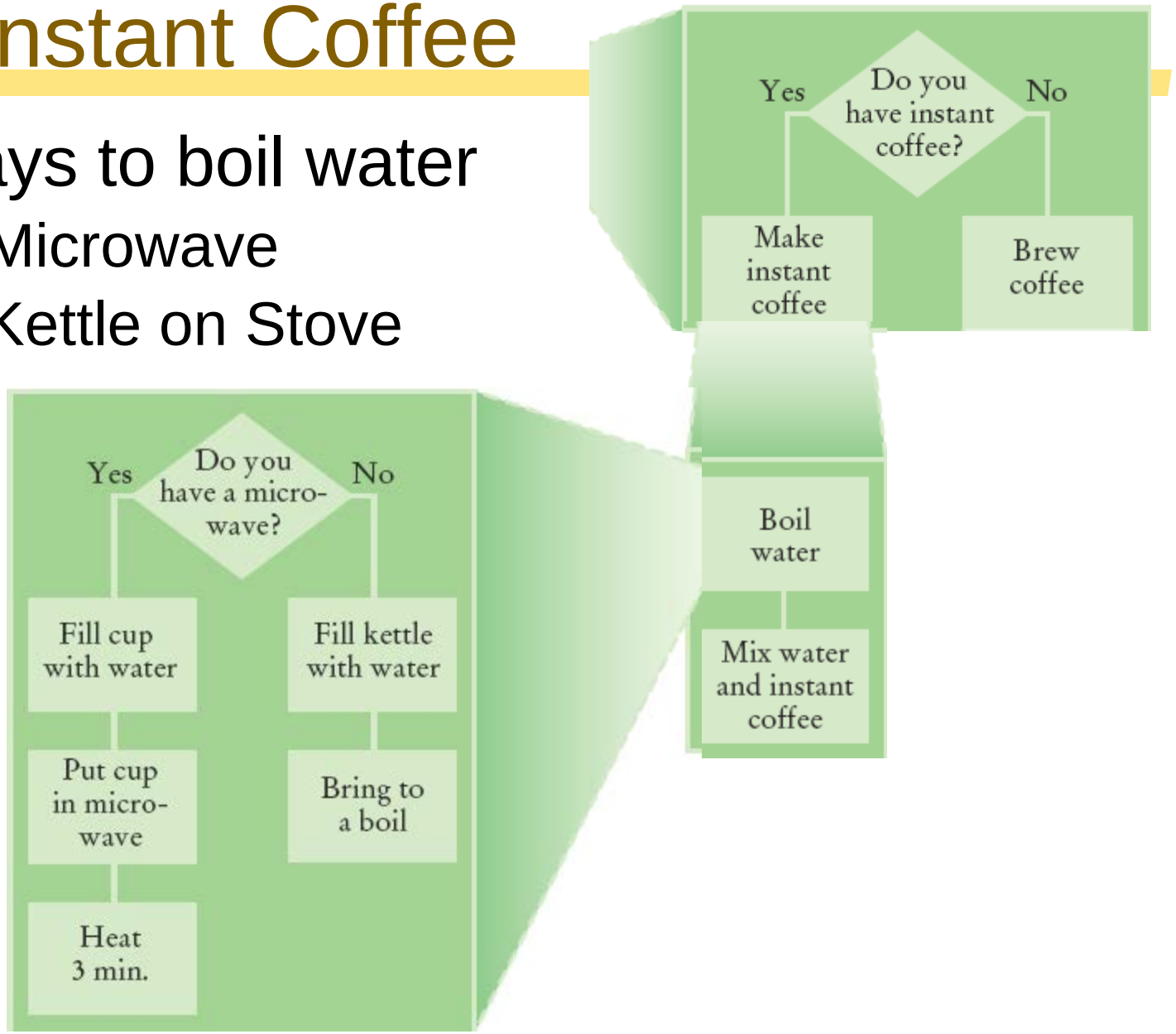
Get Coffee



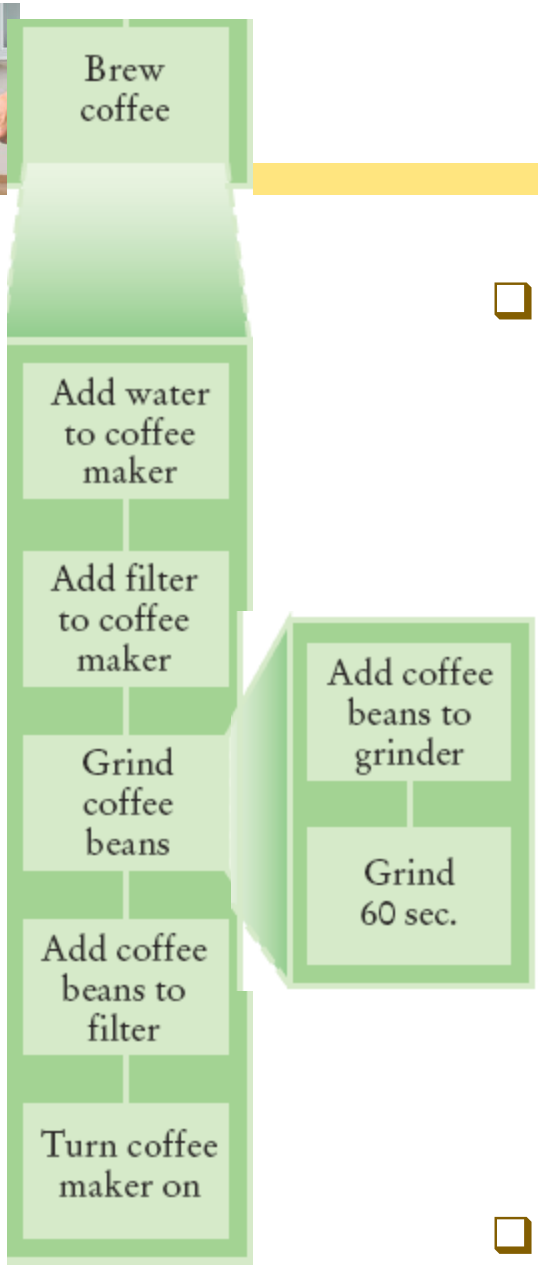
- If you must make coffee, there are two ways:
  - Make Instant Coffee
  - Brew Coffee

Instant Coffee

- Two ways to boil water
  1) Use Microwave
  2) Use Kettle on Stove



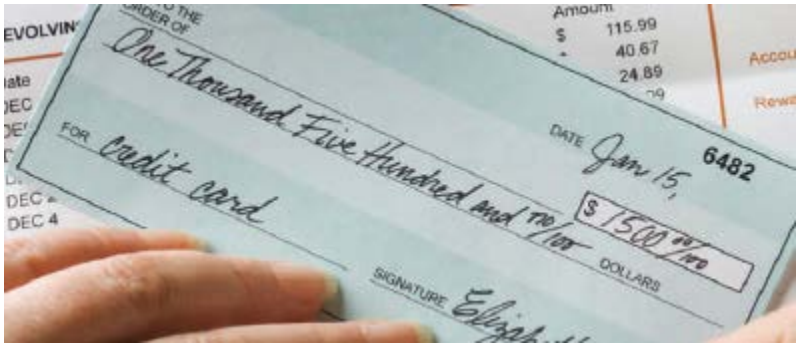
Brew Coffee



- Assumes coffee maker
  - Add water
  - Add filter
  - Grind Coffee
    - Add beans to grinder
    - Grind 60 seconds
  - Fill filter with ground coffee
  - Turn coffee maker on
- Steps are easily done

Stepwise Refinement Example

- When printing a check, it is customary to write the check amount both as a number (“$274.15”) and as a text string (“two hundred seventy four dollars and 15 cents”). Write a program to turn a number into a text string.
- Wow, sounds difficult!
- Break it down
  - Let’s take the dollar part (274) and come up with a plan
  - Take an Integer from 0 – 999
  - Return a String
  - Still pretty hard…



Stepwise Refinement Example

- Take it digit by digit (2, 7, 4) – left to right
- Handle the first digit (hundreds)
  - If empty, we're done with hundreds
  - Get first digit (Integer from 1 – 9)
  - Get digit name ("one", "two ", "three"…)
  - Add the word " hundred"
  - Sounds easy!
- Second digit (tens)
  - Get second digit (Integer from 0 – 9)
  - If 0, we are done with tens… handle third digit
  - If 1, … may be eleven, twelve.. Teens… Not easy!
    - Let's look at each possibility left (1x-9x)…

Stepwise Refinement Example

- If second digit is a 0
  - Get third digit (Integer from 0 – 9)
  - Get digit name (“”, “one”, “two”…) … Same as before?
  - Sounds easy!
- If second digit is a 1
  - Get third digit (Integer from 0 – 9)
  - Return a String (“ten”, “eleven”, “twelve”…)
- If second digit is a 2-9
  - Start with string “twenty”, “thirty”, “forty”…
  - Get third digit (Integer from 0 – 9)
  - Get digit name (“”, “one”, “two”…) … Same as before
  - Sounds easy!

Name the Sub-Tasks

- `digitName`
  - Takes an Integer from 0 – 9
  - Return a String (“”, “one”, “two”…)
- `tensName` (second digit >= 20)
  - Takes an Integer from 0 – 9
  - Return a String (“twenty”, “thirty”…) plus
    - `digitName`(third digit)
- `teenName`
  - Takes an Integer from 0 – 9
  - Return a String (“ten”, “eleven”…)

Write Pseudocode

```
part = number (The part that still needs to be converted)
name = "" (The name of the number)
If part >= 100
   name = name of hundreds in part + " hundred"
   Remove hundreds from part.
If part >= 20
   Append tensName(part) to name.
   Remove tens from part.
Else if part >= 10
   Append teenName(part) to name.
   part = 0
If (part > 0)
   Append digitName(part) to name.
```

Identify methods that we can use (or re-use!) to do the work.

Plan The Methods

- Decide on name, parameter(s) and types and return type
- `String digitName (int number)`
  - Return a String (“”, “one”, “two”…)
- `String tensName (int number)`
  - Return a String (“twenty”, “thirty”…) plus
    - Return from `digitName`(thirdDigit)
- `String teenName (int number)`
  - Return a String (“ten”, “eleven”…)

Convert to Java: `intName` method

```
21    public static String intName(int number)
22    {
23       int part = number; // The part that still needs to be converted
24       String name = ""; // The name of the number
25
26       if (part >= 100)
27       {
28          name = digitName(part / 100) + " hundred";
29          part = part % 100;
30       }
```

```
32       if (part >= 20)
33       {
34          name = name + " " + tensName(part);
35          part = part % 10;
36       }
37       else if (part >= 10)
38       {
39          name = name + " " + teenName(part);
40          part = 0;
41       }
42
43       if (part > 0)
44       {
45          name = name + " " + digitName(part);
46       }
47
48       return name;
49    }
```

- `main` calls `intName`
  - Does all the work
  - Returns a String
- Uses methods:
  - `tensName`
  - `teenName`
  - `digitName`

digitName, teenName, tensName

```
56    public static String digitName(int digit)
57    {
58       if (digit == 1) { return "one"; }
59       if (digit == 2) { return "two"; }
60       if (digit == 3) { return "three"; }
61       if (d
62       if (d
63       if (d
64       if (d
65       if (d
66       if (d
67       retur
68    }
```

```
75    public static String teenName(int number)
76    {
77       if (number == 10) { return "ten"; }
78       if (number == 11) { return "eleven"; }
79       if (number == 12) { return "twelve"; }
80       if (number == 13) { return "thirteen"; }
81       if (number ==
82       if (number ==
83       if (number ==
84       if (number ==
85       if (number ==
86       if (number ==
87       return "";
88    }
```

```
95    public static String tensName(int number)
96    {
97       if (number >= 90) { return "ninety"; }
98       if (number >= 80) { return "eighty"; }
99       if (number >= 70) { return "seventy"; }
100      if (number >= 60) { return "sixty"; }
101      if (number >= 50) { return "fifty"; }
102      if (number >= 40) { return "forty"; }
103      if (number >= 30) { return "thirty"; }
104      if (number >= 20) { return "twenty"; }
105      return "";
106   }
```

Program Run

```
Please enter a positive integer: 729
seven hundred twenty nine
```

Programming Tips

- Keep methods short
  - If more than one screen, break into ‘sub’ methods
  - Make the method reusable rather than tied to a specific context
- Trace your methods
  - One line for each step
  - Columns for key variables

intName(number = 416)

part	name
~~416~~	~~""~~
~~16~~	~~"four hundred"~~
0	"four hundred sixteen"

- Use Stubs as you write larger programs
  - Unfinished methods that return a ‘dummy’ value

```
public static String digitName(int digit)
{
  return "mumble";
}
```

5.8 Variable Scope

The scope of a variable is the part of the program in which it is visible.

- Variables can be declared:
  - Inside a method
    - Known as 'local variables'
    - Only available inside this method
    - Parameter variables are like local variables
  - Inside a block of code { }
    - Sometimes called 'block scope'
    - If declared inside block { ends at end of block }
  - Outside of a method
    - Sometimes called 'global scope'
    - Can be used (and changed) by code in any method
- How do you choose?

Examples of Scope

- `sum` is a local variable in `main`
- `square` is only visible inside the for loop block
- `i` is only visible inside the for loop

```
public static void main(String[] args)
{
   int sum = 0;
   for (int i = 1; i <= 10; i++)
   {
      int square = i * i;
      sum = sum + square;
   }
   System.out.println(sum);
}
```

sum

i

square

The **scope** of a variable is the part of the program in which it is visible.

Local Variables of Methods

- *Variables declared inside one method are not visible to other methods*
  - `sideLength` is local to `main`
  - Using it outside `main` will cause a compiler error

```
public static void main(String[] args)
{
   double sideLength = 10;
   int result = cubeVolume();
   System.out.println(result);
}

public static double cubeVolume()
{
   return sideLength * sideLength * sideLength; // ERROR
}
```

Fix: pass the *sideLength* as an argument (ch5.2)

Re-using names for local variables

- Variables declared inside one method are not visible to other methods
  - `result` is local to square and `result` is local to `main`
  - *They are **two different variables** and **do not overlap***

```
public static int square(int n)
{
   int result = n * n;
   return result;
}

public static void main(String[] args)
{
   int result = square(3) + square(4);
   System.out.println(result);
}
```

`result`

`result`

Re-using names for block variables

- Variables declared inside one block are *not visible to other methods*
  - `i` is inside the first for block and `i` is inside the second
  - They are two different variables and do not overlap

```
public static void main(String[] args)
{
   int sum = 0;
   for (int i = 1; i <= 10; i++)
   {
      sum = sum + i;
   }
   for (int i = 1; i <= 10; i++)
   {
      sum = sum + i * i;
   }
   System.out.println(sum);
}
```

i

i

Overlapping Scope

- Variables (including parameter variables) must have unique names within their scope
  - n has local scope and n is in a block inside that scope
  - The compiler will complain when the block scope n is declared

```
public static int sumOfSquares(int n)
{
   int sum = 0;
   for (int i = 1; i <= n; i++)
   {
      int n = i * i; // ERROR
      sum = sum + n;
   }
   return sum;
}
```

Local n

block scope n

Global and Local Overlapping

- Global and Local (method) variables can overlap
  - The local `same` will be used when it is in scope
  - No access to global `same` when local `same` is in scope

```
public class Scoper
{
  public static int same;   // 'global'
  public static void main(String[] args)
  {
    int same = 0;      // local
    for (int i = 1; i <= 10; i++)
    {
      int square = i * i;
      same = same + square;
    }
    System.out.println(same);
  }
}
```

same

same

Variables in different scopes with the same name will compile, but it is not a good idea

5.9 Recursive Methods

- A recursive method is a method that calls itself
- A recursive computation solves a problem by using the solution of the same problem with simpler inputs
- For a recursion to terminate, there must be special cases for the simplest inputs

Recursive Triangle Example

```
public static void printTriangle(int sideLength)
{
  if (sideLength < 1) { return; }

  printTriangle(sideLength - 1);
  for (int i = 0; i < sideLength; i++)
  {
    System.out.print("[]");
  }
  System.out.println();
}
```

Special Case

Recursive Call

```
[]
[][]
[][][]
[][][][]
```

Print the triangle with side length 3.
Print a line with four [].

- The method will call itself (and not output anything) until `sideLength` becomes < 1
- It will then use the return statement and each of the previous iterations will print their results
  - 1, 2, 3 then 4

Recursive Calls and Returns

Here is what happens when we print a triangle with side length 4.

- The call `printTriangle(4)` calls `printTriangle(3)`.
  - The call `printTriangle(3)` calls `printTriangle(2)`.
    - The call `printTriangle(2)` calls `printTriangle(1)`.
      - The call `printTriangle(1)` calls `printTriangle(0)`.
        - The call `printTriangle(0)` returns, doing nothing.
      - The call `printTriangle(1)` prints `[]`.
    - The call `printTriangle(2)` prints `[][]`.
  - The call `printTriangle(3)` prints `[][][]`.
- The call `printTriangle(4)` prints `[][][][]`.

Summary: Methods

- A method is a named sequence of instructions.
- Arguments are supplied when a method is called. The return value is the result that the method computes.
- When declaring a method, you provide a name for the method, a variable for each argument, and a type for the result.
- Method comments explain the purpose of the method, the meaning of the parameters and return value, as well as any special requirements.
- Parameter variables hold the arguments supplied in the method call.

Summary: Method Returns

- The `return` statement terminates a method call and yields the method result.
  - Turn computations that can be reused into methods.
  - Use a return type of `void` to indicate that a method does not return a value.
- Use the process of stepwise refinement to decompose complex tasks into simpler ones.
  - When you discover that you need a method, write a description of the parameter variables and return values.
  - A method may require simpler methods to carry out its work.

Summary: Scope

- The scope of a variable is the part of the program in which it is visible.
  - Two local or parameter variables can have the same name, provided that their scopes do not overlap.
  - You can use the same variable name within different methods since their scope does not overlap.
  - Local variables declared inside one method are not visible to code inside other methods

Summary: Recursion

- A recursive computation solves a problem by using the solution of the same problem with simpler inputs.
  - For a recursion to terminate, there must be special cases for the simplest inputs.
  - The key to finding a recursive solution is reducing the input to a simpler input for the same problem.
  - When designing a recursive solution, do not worry about multiple nested calls. Simply focus on reducing a problem to a slightly simpler one.