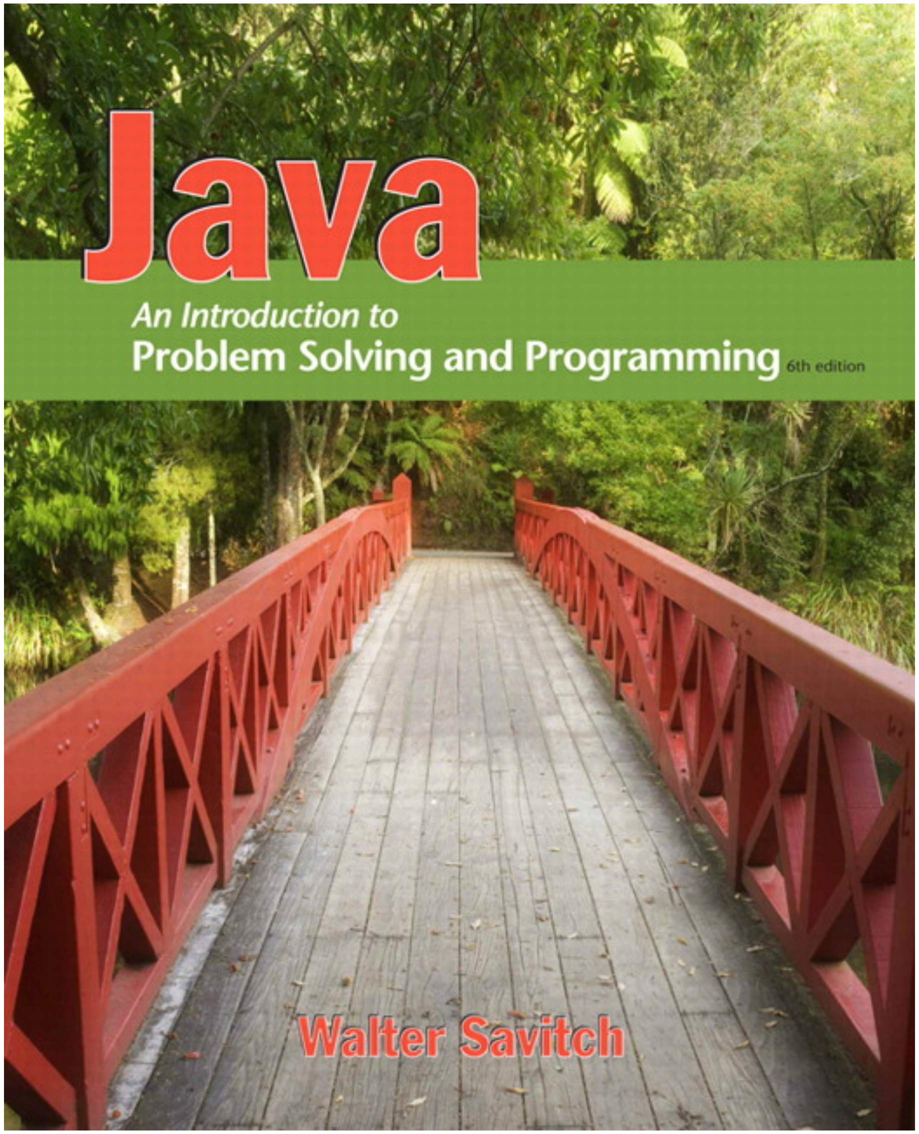
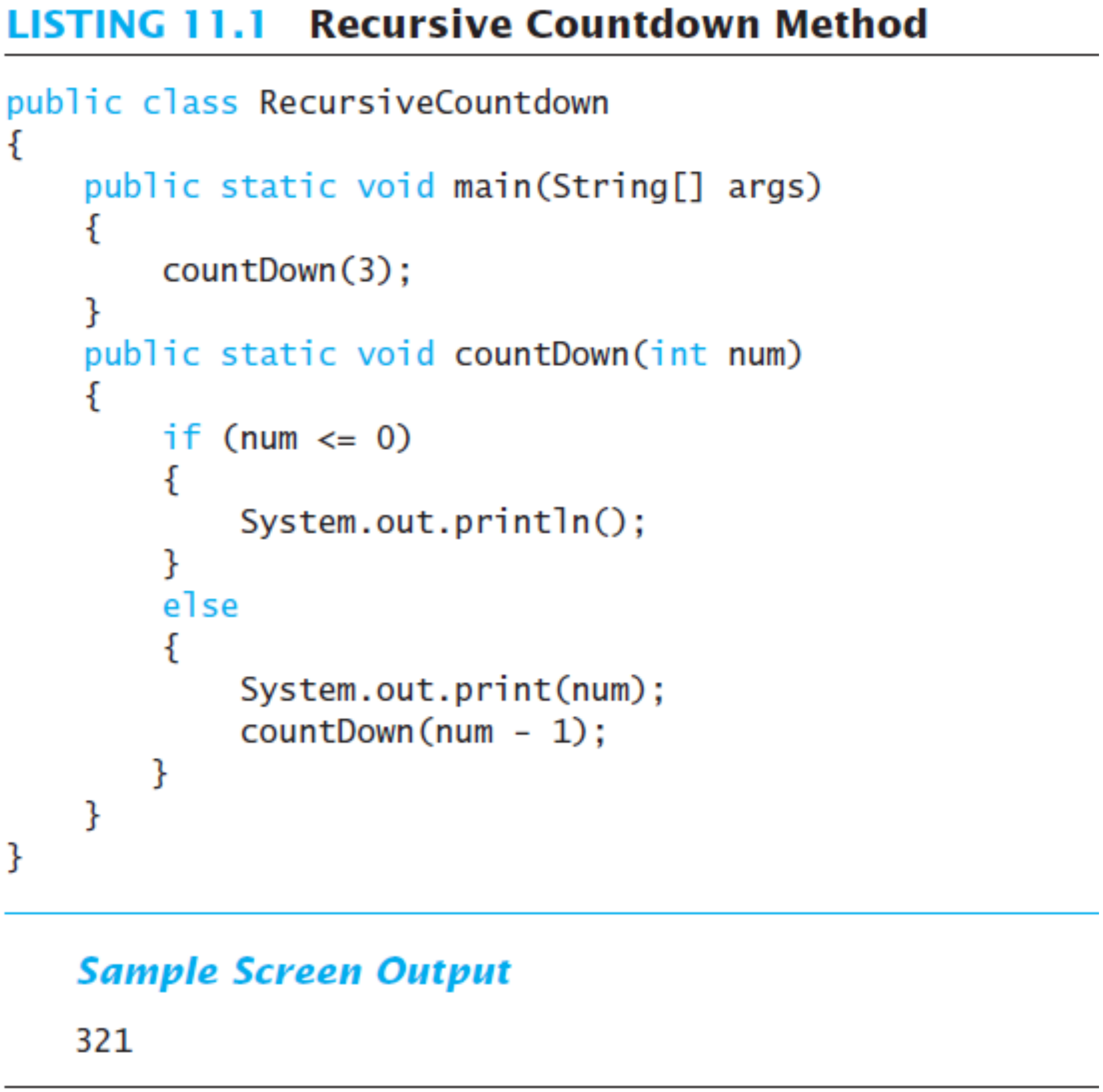


Recursion 11



LISTING 11.1 Recursive Countdown Method

```
public class RecursiveCountdown
{
    public static void main(String[] args)
    {
        countDown(3);
    }
    public static void countDown(int num)
    {
        if (num <= 0)
        {
            System.out.println();
        }
        else
        {
            System.out.print(num);
            countDown(num - 1);
       }
    }
}
```

Sample Screen Output

```
321
```

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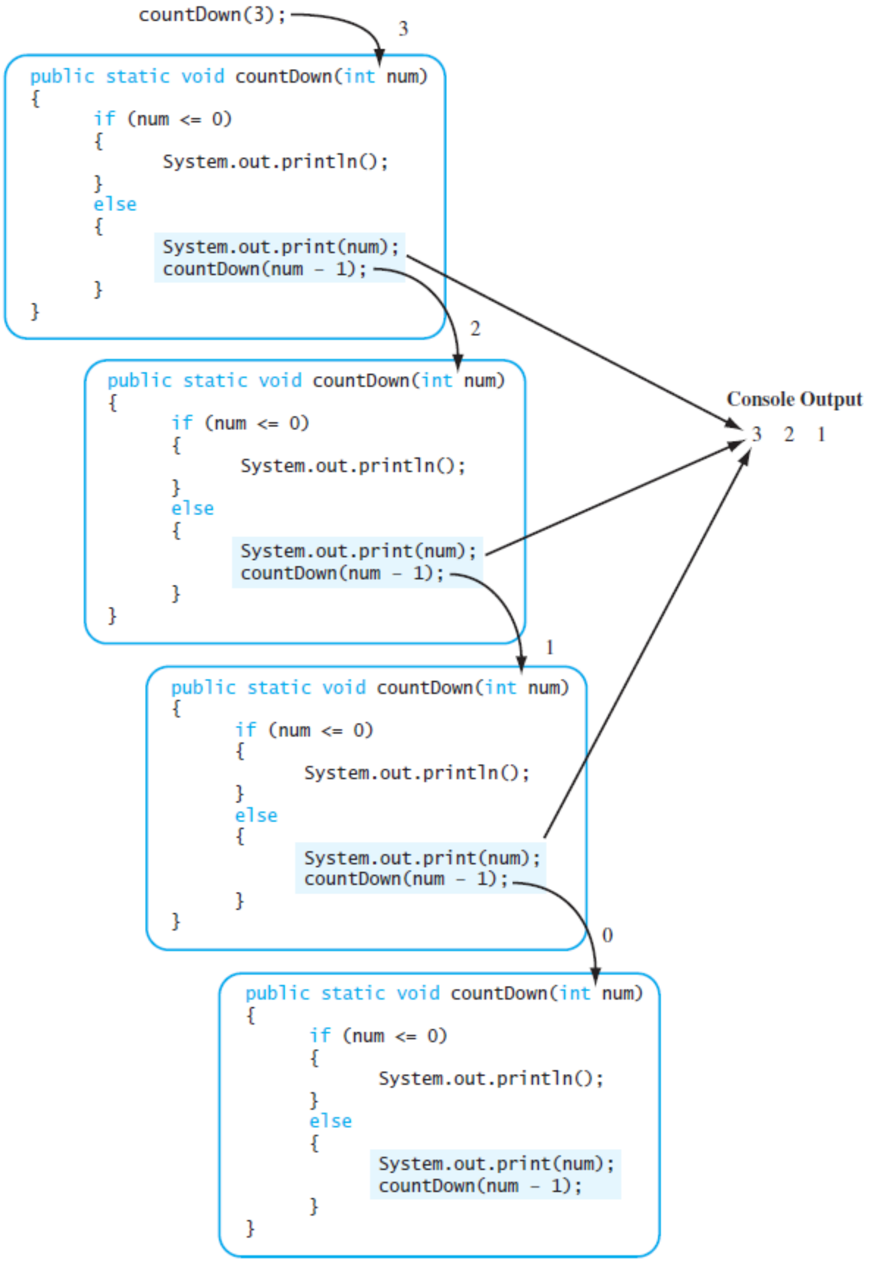
FIGURE 11.1 Recursive Calls for the countDown Method



```
countDown(3);
```

```
public static void countDown(int num)
{
        if (num <= 0)
        {
                System.out.println();
        }
        else
        {
                System.out.print(num);
                countDown(num - 1);
        }
}
```

```
public static void countDown(int num)
{
        if (num <= 0)
        {
                System.out.println();
        }
        else
        {
                System.out.print(num);
                countDown(num - 1);
        }
}
```

```
public static void countDown(int num)
{
        if (num <= 0)
        {
                System.out.println();
        }
        else
        {
                System.out.print(num);
                countDown(num - 1);
        }
}
```

```
public static void countDown(int num)
{
        if (num <= 0)
        {
                System.out.println();
        }
        else
        {
                System.out.print(num);
                countDown(num - 1);
        }
}
```

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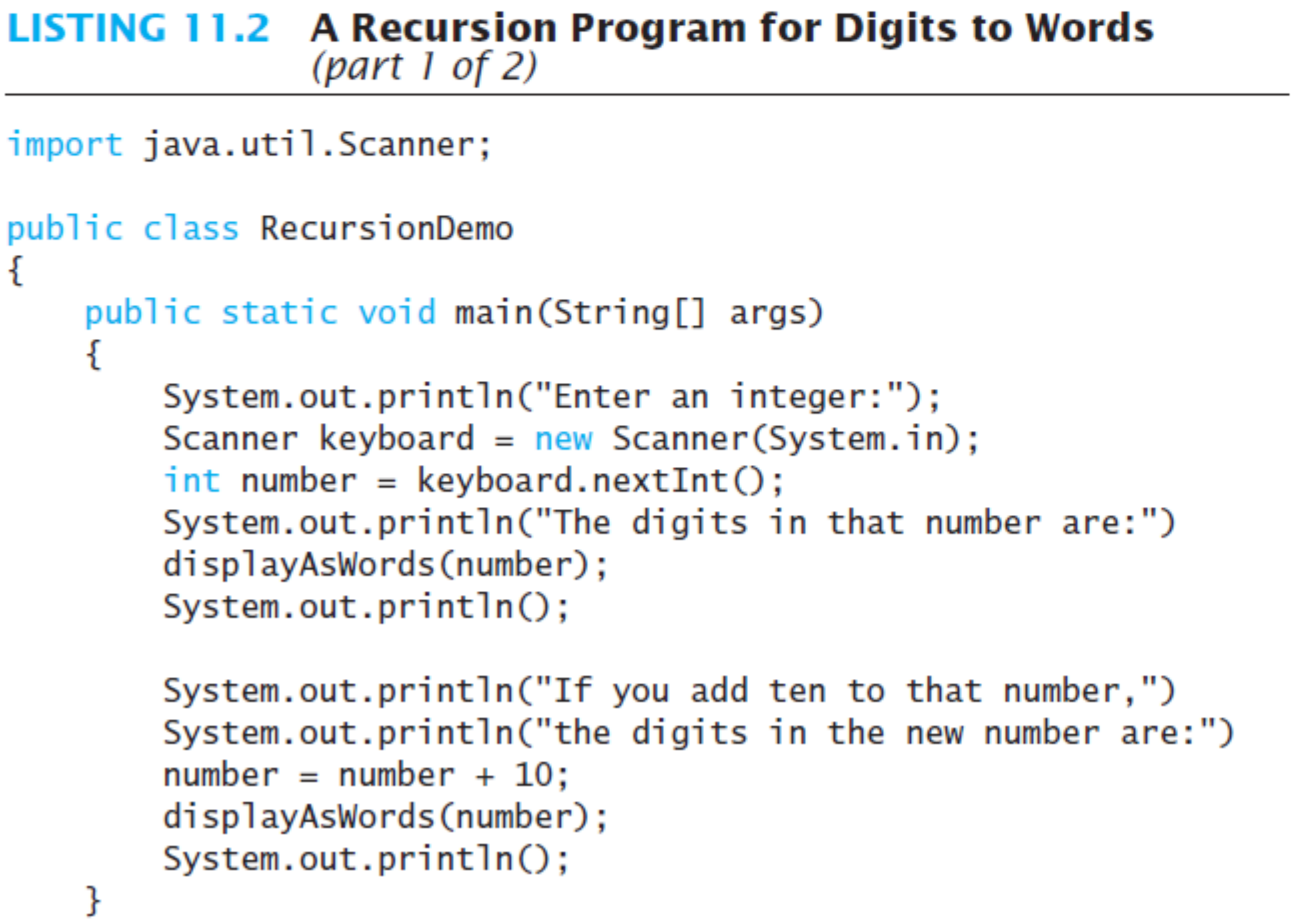
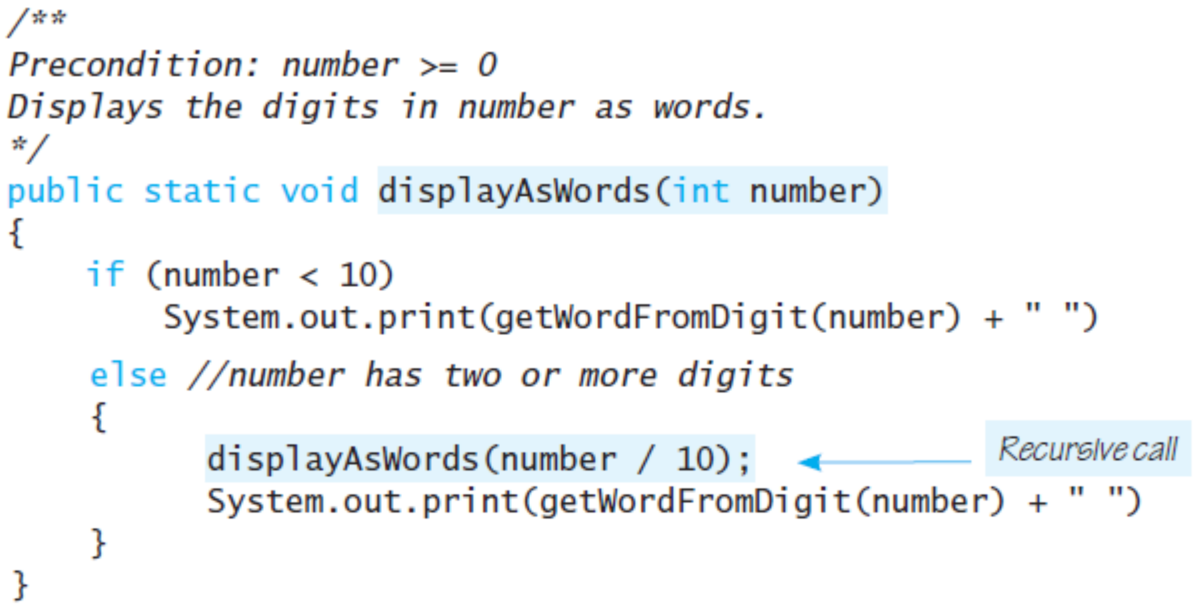


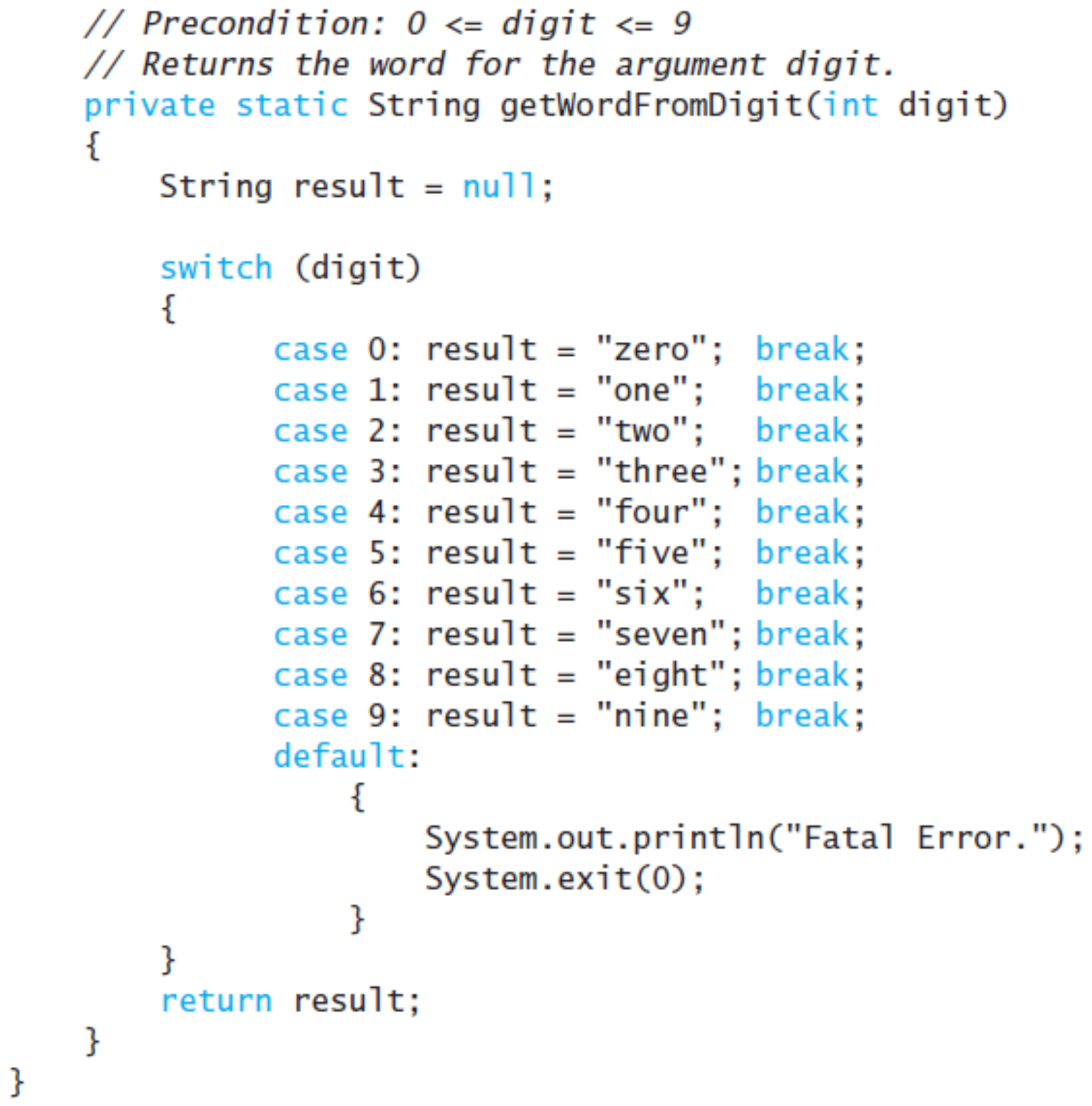
LISTING 11.2 **A Recursion Program for Digits to Words** *(part 1 of 2)*

```java
import java.util.Scanner;

public class RecursionDemo
{
    public static void main(String[] args)
    {
        System.out.println("Enter an integer:");
        Scanner keyboard = new Scanner(System.in);
        int number = keyboard.nextInt();
        System.out.println("The digits in that number are:")
        displayAsWords(number);
        System.out.println();

        System.out.println("If you add ten to that number,")
        System.out.println("the digits in the new number are:")
        number = number + 10;
        displayAsWords(number);
        System.out.println();
    }
```



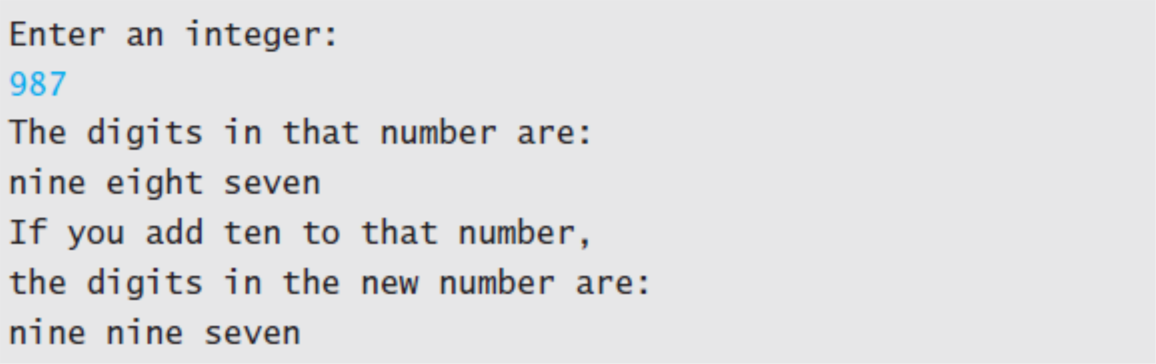
```
/**
Precondition: number >= 0
Displays the digits in number as words.
*/
public static void displayAsWords(int number)
{
    if (number < 10)
        System.out.print(getWordFromDigit(number) + " ")
    else //number has two or more digits
    {
        displayAsWords(number / 10);
        System.out.print(getWordFromDigit(number) + " ")
    }
}
```

Recursive call



```
    // Precondition: 0 <= digit <= 9
    // Returns the word for the argument digit.
    private static String getWordFromDigit(int digit)
    {
        String result = null;

        switch (digit)
        {
              case 0: result = "zero";  break;
              case 1: result = "one";   break;
              case 2: result = "two";   break;
              case 3: result = "three"; break;
              case 4: result = "four";  break;
              case 5: result = "five";  break;
              case 6: result = "six";   break;
              case 7: result = "seven"; break;
              case 8: result = "eight"; break;
              case 9: result = "nine";  break;
              default:
                  {
                      System.out.println("Fatal Error.");
                      System.exit(0);
                  }
        }
        return result;
    }
}
```

Sample Screen Output



```
Enter an integer:
987
The digits in that number are:
nine eight seven
If you add ten to that number,
the digits in the new number are:
nine nine seven
```

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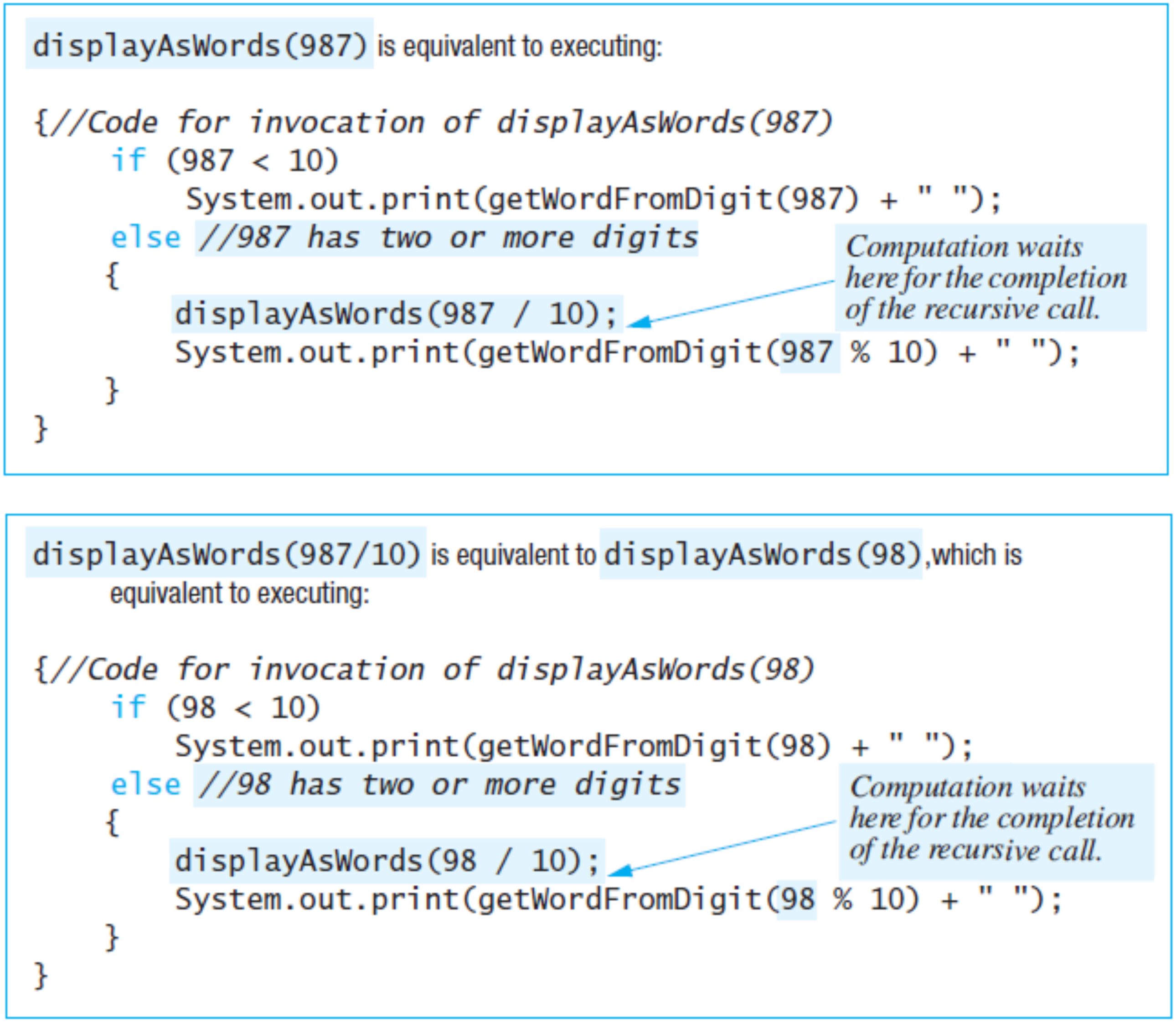
FIGURE 11.2 Executing a Recursive Call



`displayAsWords(987)` is equivalent to executing:

```
{//Code for invocation of displayAsWords(987)
    if (987 < 10)
        System.out.print(getWordFromDigit(987) + " ");
    else //987 has two or more digits
    {
        displayAsWords(987 / 10);
        System.out.print(getWordFromDigit(987 % 10) + " ");
    }
}
```

Computation waits here for the completion of the recursive call.

`displayAsWords(987/10)` is equivalent to `displayAsWords(98)`,which is equivalent to executing:

```
{//Code for invocation of displayAsWords(98)
    if (98 < 10)
        System.out.print(getWordFromDigit(98) + " ");
    else //98 has two or more digits
    {
        displayAsWords(98 / 10);
        System.out.print(getWordFromDigit(98 % 10) + " ");
    }
}
```

Computation waits here for the completion of the recursive call.

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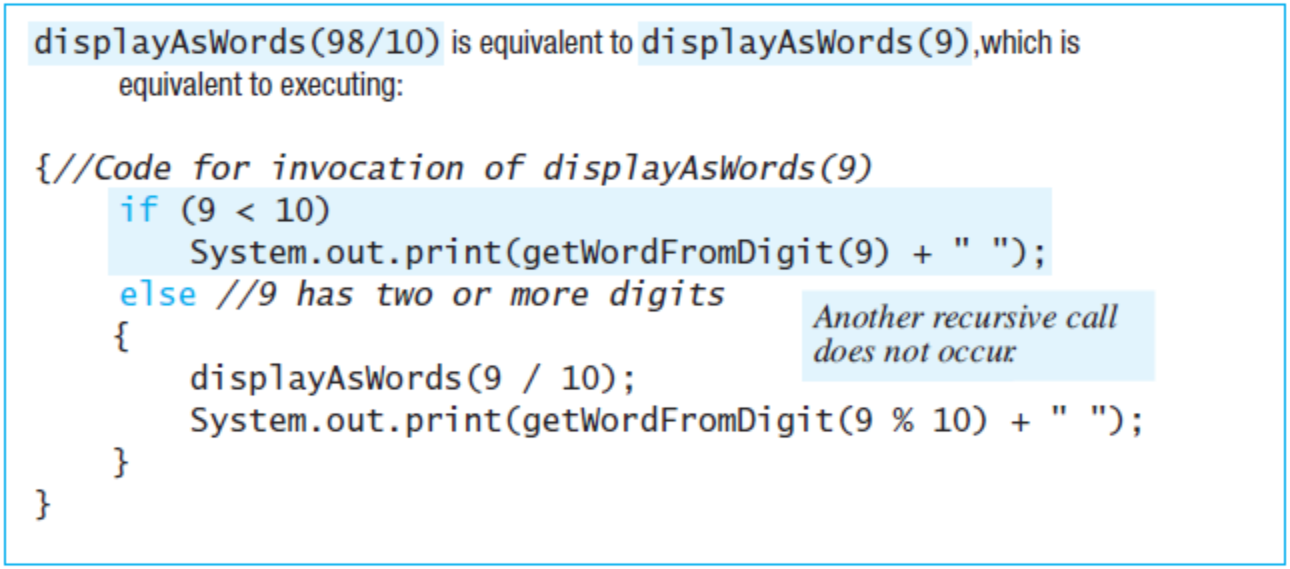
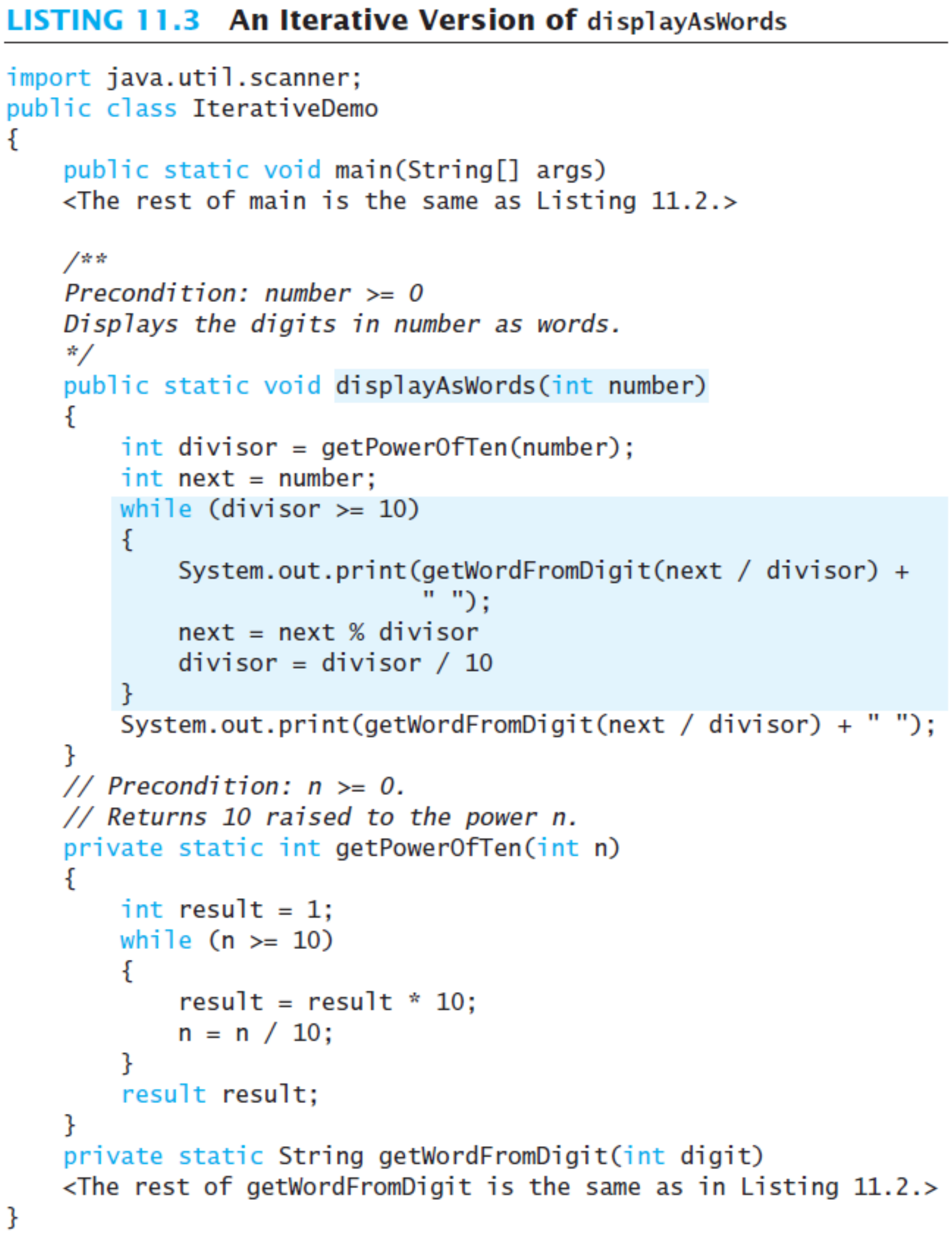


`displayAsWords(98/10)` is equivalent to `displayAsWords(9)`,which is equivalent to executing:

```
{//Code for invocation of displayAsWords(9)
    if (9 < 10)
        System.out.print(getWordFromDigit(9) + " ");
    else //9 has two or more digits
    {
        displayAsWords(9 / 10);
        System.out.print(getWordFromDigit(9 % 10) + " ");
    }
}
```

Another recursive call does not occur.



LISTING 11.3 An Iterative Version of displayAsWords

```
import java.util.scanner;
public class IterativeDemo
{
    public static void main(String[] args)
    <The rest of main is the same as Listing 11.2.>

    /**
    Precondition: number >= 0
    Displays the digits in number as words.
    */
    public static void displayAsWords(int number)
    {
        int divisor = getPowerOfTen(number);
        int next = number;
        while (divisor >= 10)
        {
            System.out.print(getWordFromDigit(next / divisor) +
                                 " ");
            next = next % divisor
            divisor = divisor / 10
        }
        System.out.print(getWordFromDigit(next / divisor) + " ");
    }
    // Precondition: n >= 0.
    // Returns 10 raised to the power n.
    private static int getPowerOfTen(int n)
    {
        int result = 1;
        while (n >= 10)
        {
            result = result * 10;
            n = n / 10;
        }
        result result;
    }
    private static String getWordFromDigit(int digit)
    <The rest of getWordFromDigit is the same as in Listing 11.2.>
}
```

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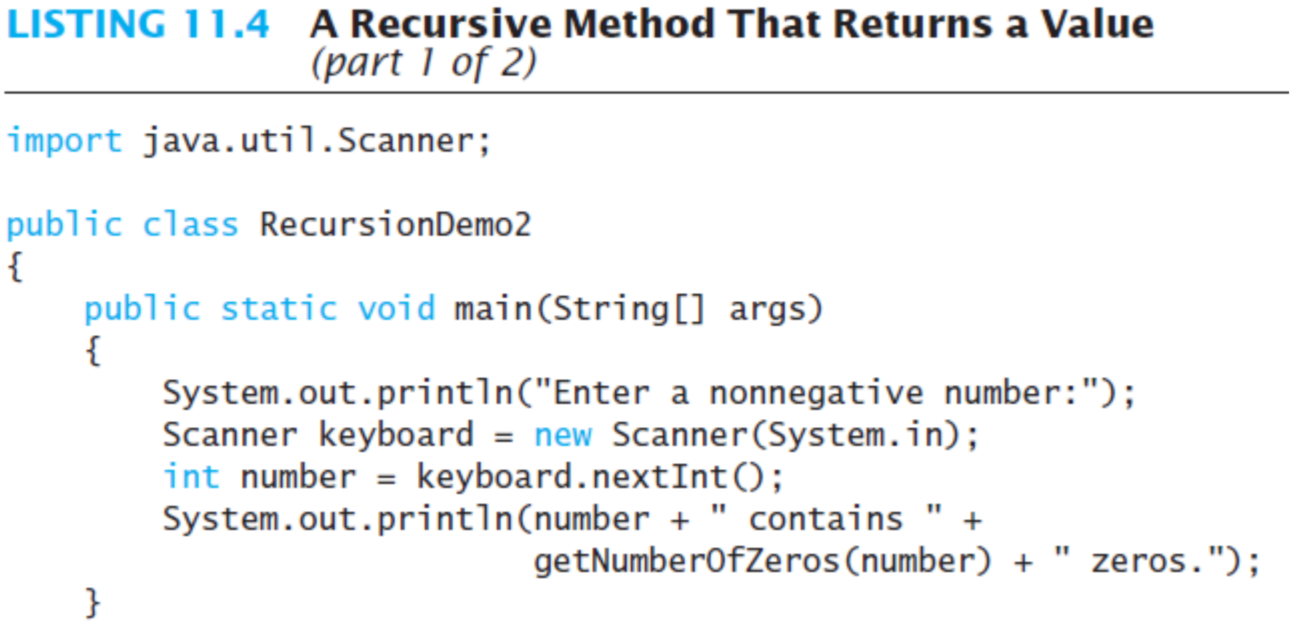
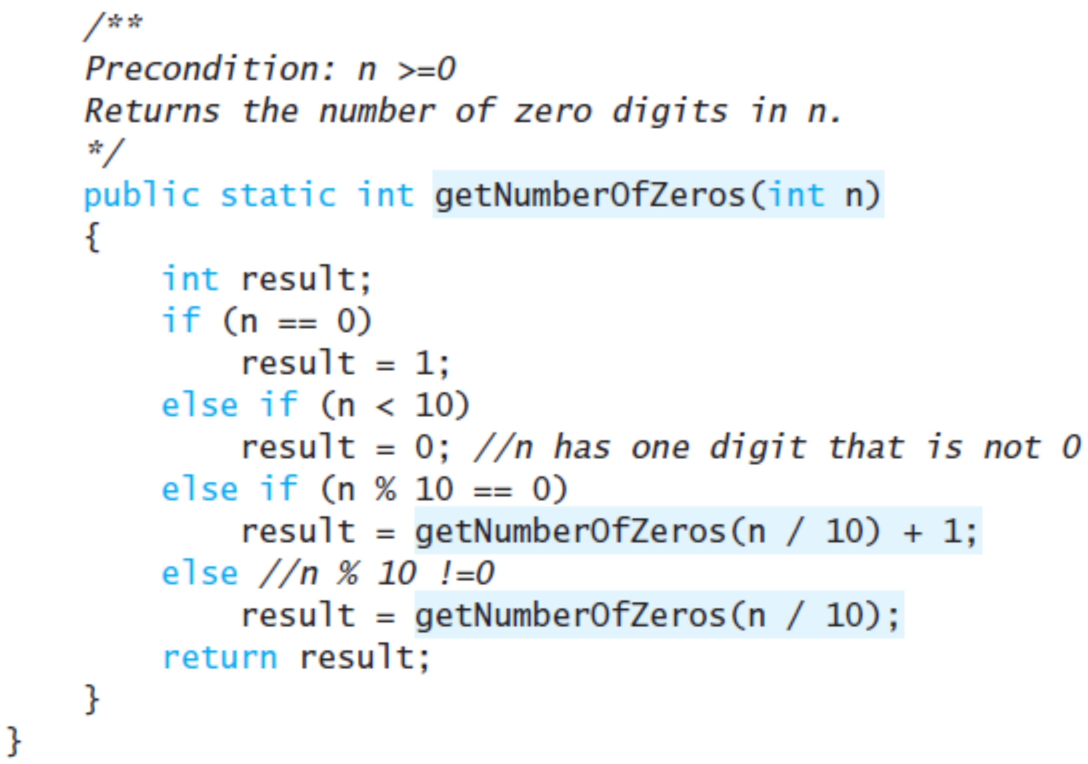


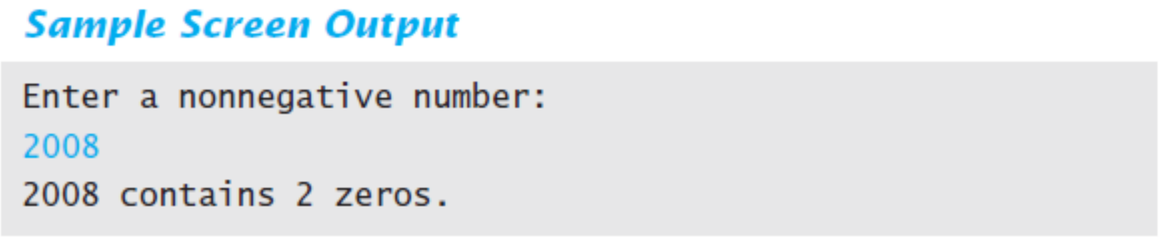
LISTING 11.4 A Recursive Method That Returns a Value *(part 1 of 2)*

```
import java.util.Scanner;

public class RecursionDemo2
{
    public static void main(String[] args)
    {
        System.out.println("Enter a nonnegative number:");
        Scanner keyboard = new Scanner(System.in);
        int number = keyboard.nextInt();
        System.out.println(number + " contains " +
                           getNumberOfZeros(number) + " zeros.");
    }
```

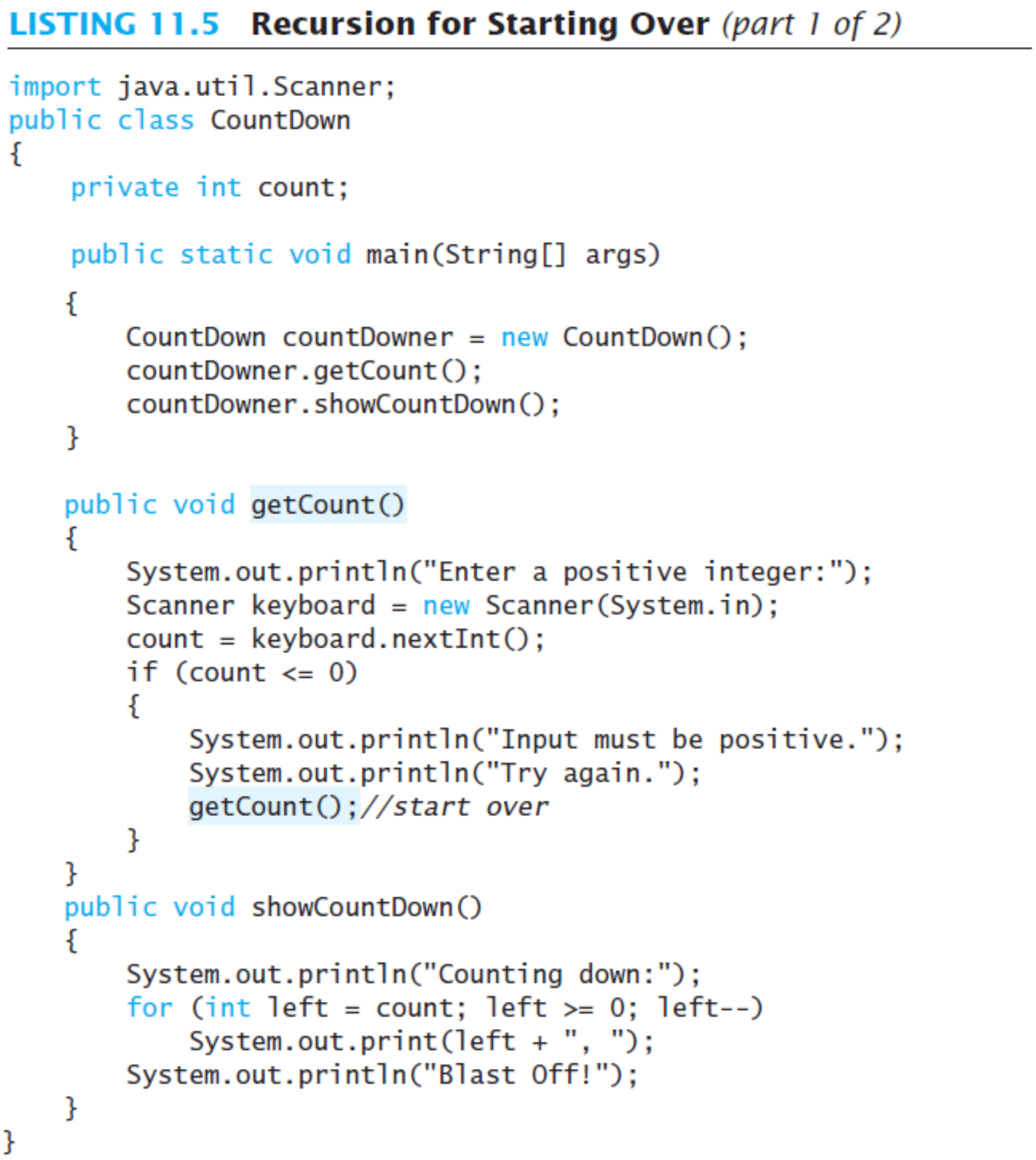


```
    /**
    Precondition: n >=0
    Returns the number of zero digits in n.
    */
    public static int getNumberOfZeros(int n)
    {
        int result;
        if (n == 0)
            result = 1;
        else if (n < 10)
            result = 0; //n has one digit that is not 0
        else if (n % 10 == 0)
            result = getNumberOfZeros(n / 10) + 1;
        else //n % 10 !=0
            result = getNumberOfZeros(n / 10);
        return result;
    }
}
```



Sample Screen Output

```
Enter a nonnegative number:
2008
2008 contains 2 zeros.
```



LISTING 11.5 Recursion for Starting Over *(part 1 of 2)*

```
import java.util.Scanner;
public class CountDown
{
    private int count;

    public static void main(String[] args)

    {
        CountDown countDowner = new CountDown();
        countDowner.getCount();
        countDowner.showCountDown();
    }

    public void getCount()
    {
        System.out.println("Enter a positive integer:");
        Scanner keyboard = new Scanner(System.in);
        count = keyboard.nextInt();
        if (count <= 0)
        {
            System.out.println("Input must be positive.");
            System.out.println("Try again.");
            getCount();//start over
        }
    }
    public void showCountDown()
    {
        System.out.println("Counting down:");
        for (int left = count; left >= 0; left--)
            System.out.print(left + ", ");
        System.out.println("Blast Off!");
    }
}
```

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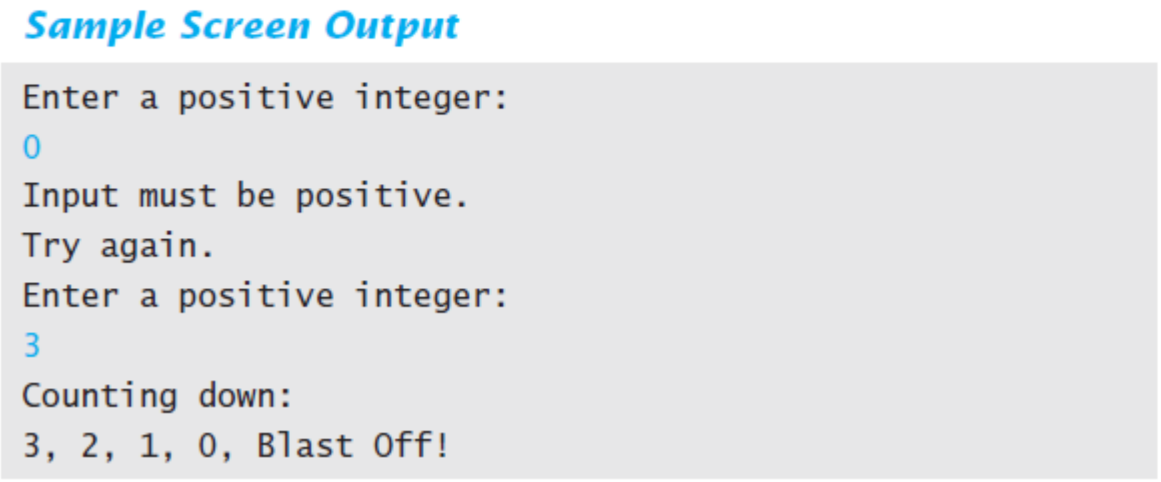
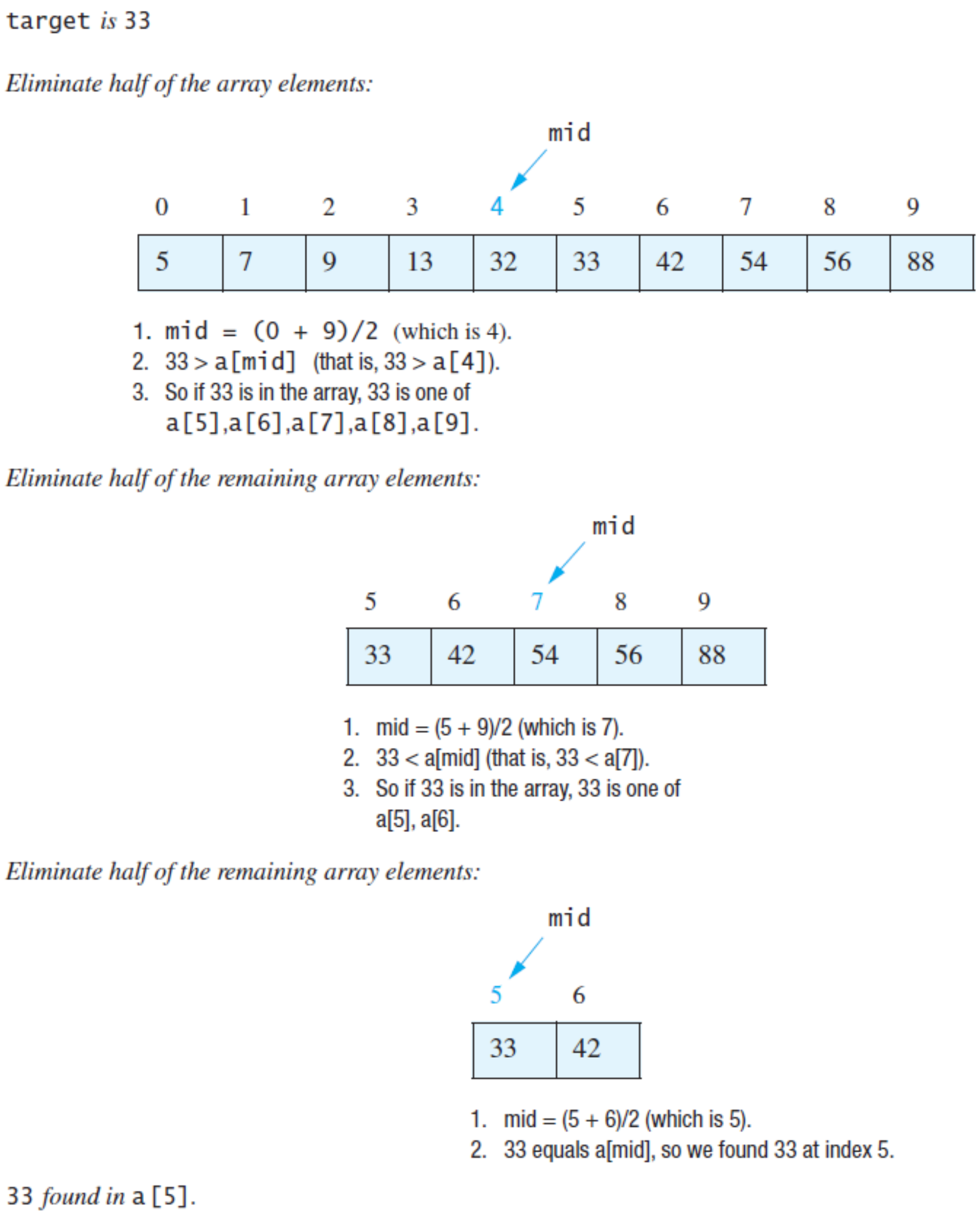


Sample Screen Output

```
Enter a positive integer:
0
Input must be positive.
Try again.
Enter a positive integer:
3
Counting down:
3, 2, 1, 0, Blast Off!
```

FIGURE 11.3 A Binary Search Example



`target` *is* 33

Eliminate half of the array elements:

0	1	2	3	4	5	6	7	8	9
5	7	9	13	32	33	42	54	56	88

1. `mid = (0 + 9)/2` (which is 4).
2. 33 > `a[mid]` (that is, 33 > `a[4]`).
3. So if 33 is in the array, 33 is one of `a[5]`,`a[6]`,`a[7]`,`a[8]`,`a[9]`.

Eliminate half of the remaining array elements:

5	6	7	8	9
33	42	54	56	88

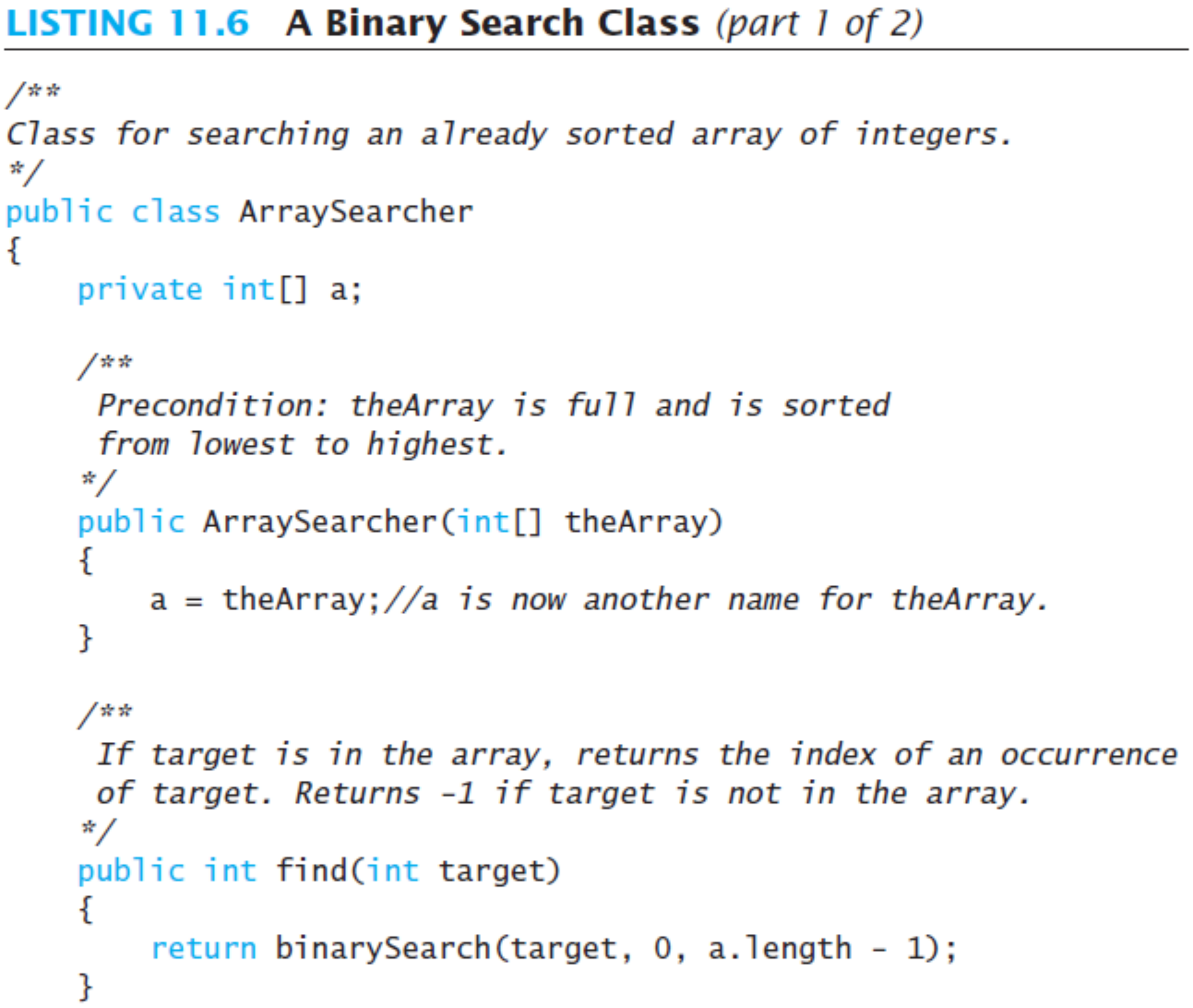
1. mid = (5 + 9)/2 (which is 7).
2. 33 < a[mid] (that is, 33 < a[7]).
3. So if 33 is in the array, 33 is one of a[5], a[6].

Eliminate half of the remaining array elements:

5	6
33	42

1. mid = (5 + 6)/2 (which is 5).
2. 33 equals a[mid], so we found 33 at index 5.

33 *found in* `a[5]`.



LISTING 11.6 A Binary Search Class *(part 1 of 2)*

```
/**
Class for searching an already sorted array of integers.
*/
public class ArraySearcher
{
    private int[] a;

    /**
     Precondition: theArray is full and is sorted
     from lowest to highest.
    */
    public ArraySearcher(int[] theArray)
    {
        a = theArray;//a is now another name for theArray.
    }

    /**
     If target is in the array, returns the index of an occurrence
     of target. Returns -1 if target is not in the array.
    */
    public int find(int target)
    {
        return binarySearch(target, 0, a.length - 1);
    }
```

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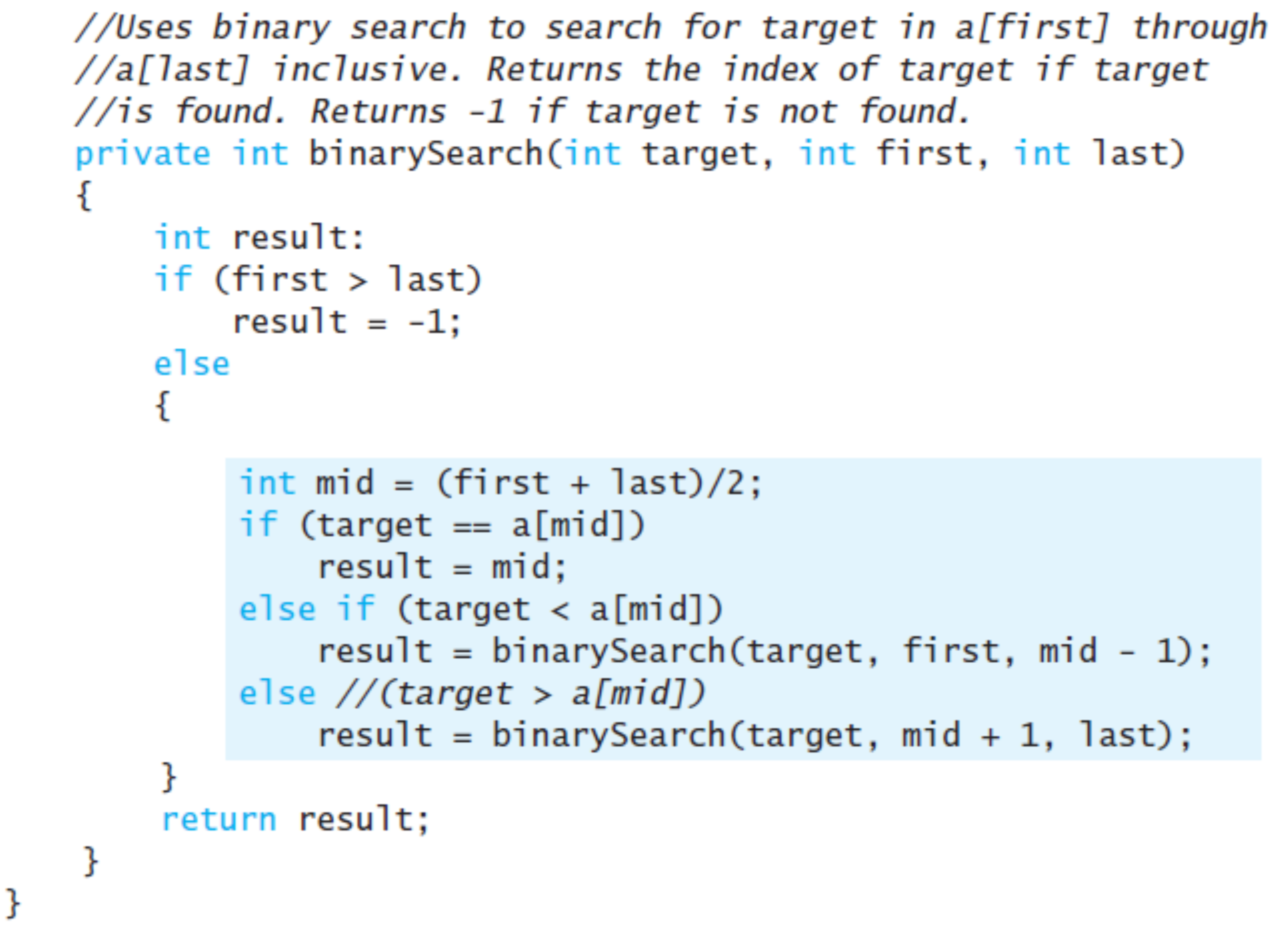
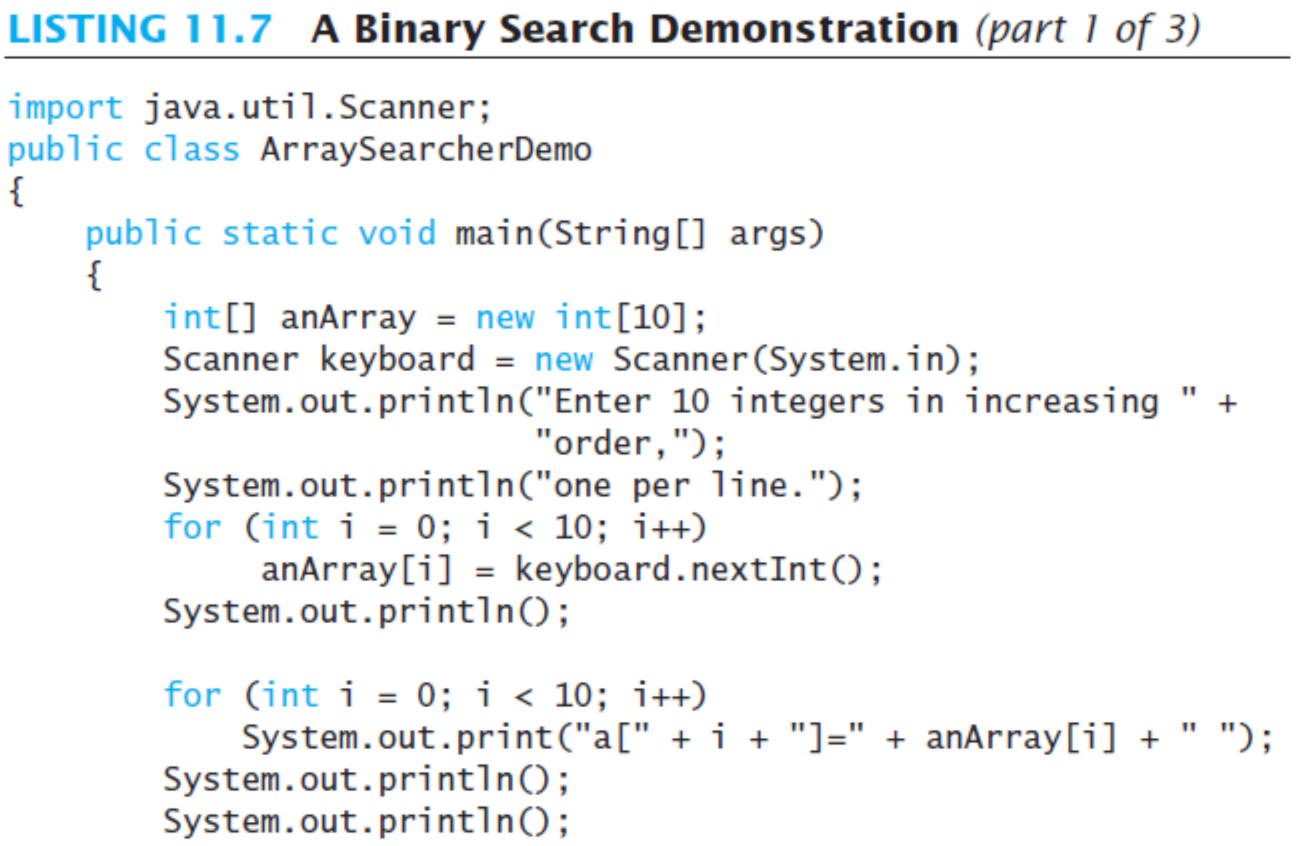


```
  //Uses binary search to search for target in a[first] through
  //a[last] inclusive. Returns the index of target if target
  //is found. Returns -1 if target is not found.
  private int binarySearch(int target, int first, int last)
  {
      int result:
      if (first > last)
          result = -1;
      else
      {
          int mid = (first + last)/2;
          if (target == a[mid])
              result = mid;
          else if (target < a[mid])
              result = binarySearch(target, first, mid - 1);
          else //(target > a[mid])
              result = binarySearch(target, mid + 1, last);
      }
      return result;
  }
}
```



LISTING 11.7 A Binary Search Demonstration *(part 1 of 3)*

```
import java.util.Scanner;
public class ArraySearcherDemo
{
    public static void main(String[] args)
    {
        int[] anArray = new int[10];
        Scanner keyboard = new Scanner(System.in);
        System.out.println("Enter 10 integers in increasing " +
                           "order,");
        System.out.println("one per line.");
        for (int i = 0; i < 10; i++)
             anArray[i] = keyboard.nextInt();
        System.out.println();

        for (int i = 0; i < 10; i++)
            System.out.print("a[" + i + "]=" + anArray[i] + " ");
        System.out.println();
        System.out.println();
```

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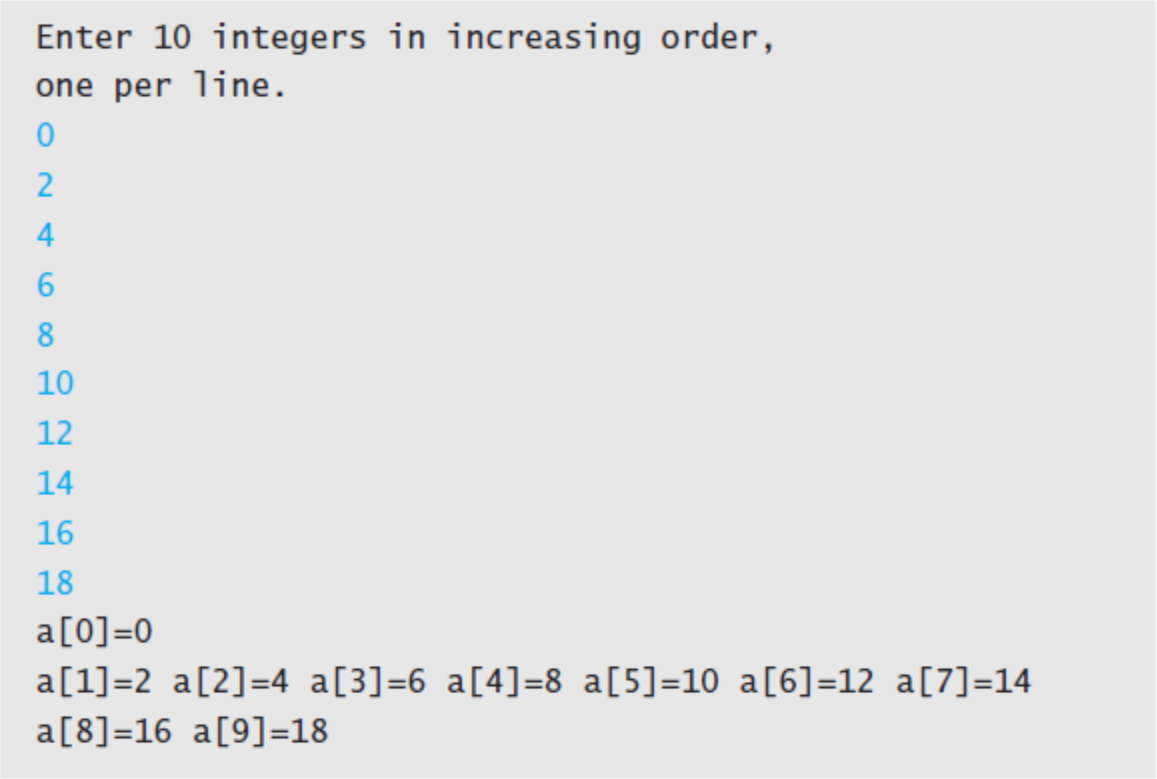
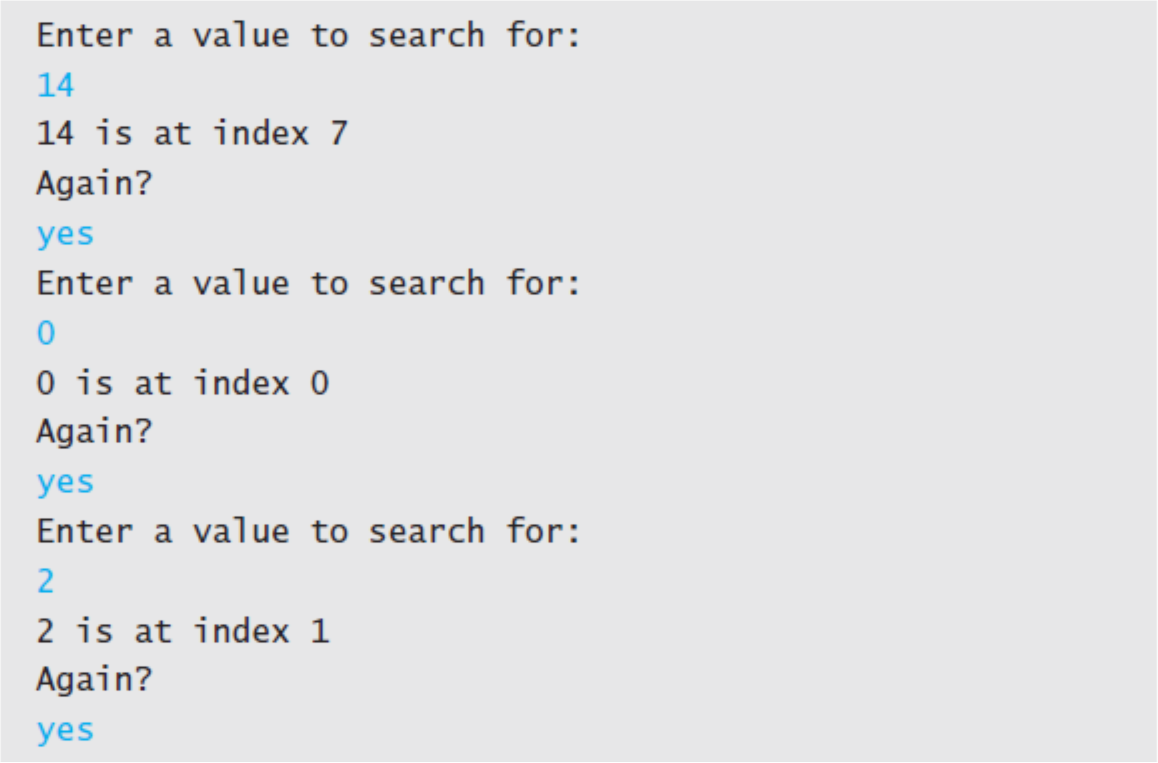
```
        ArraySearcher finder = new ArraySearcher(anArray);
        String ans;
        do
        {
            System.out.println("Enter a value to search for:");
            int target = keyboard.nextInt();
            int result = finder.find(target);

            if (result < 0)
                System.out.println(target + "is not in the array.");
            else
                System.out.println(target + "is at index" + result);
            System.out.println("Again?");
            ans = keyboard.next();

        } while (ans.equalsIgnoreCase("yes"));

        System.out.println(
                   "May you find what you're searching for.");
    }
}
```

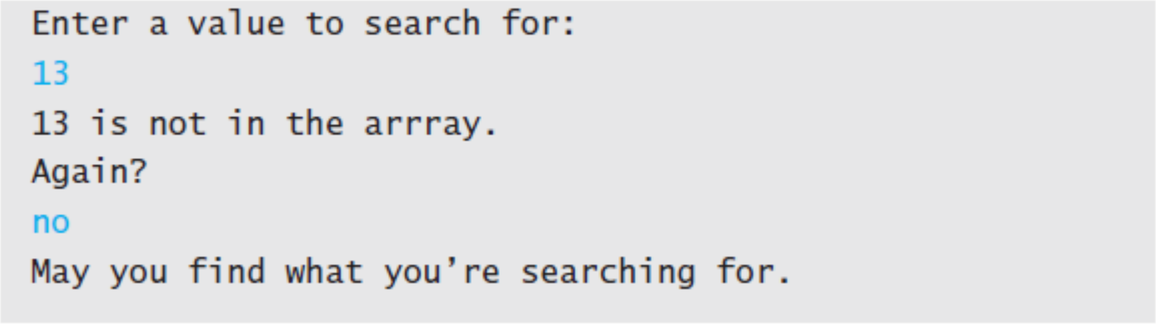
Sample Screen Output



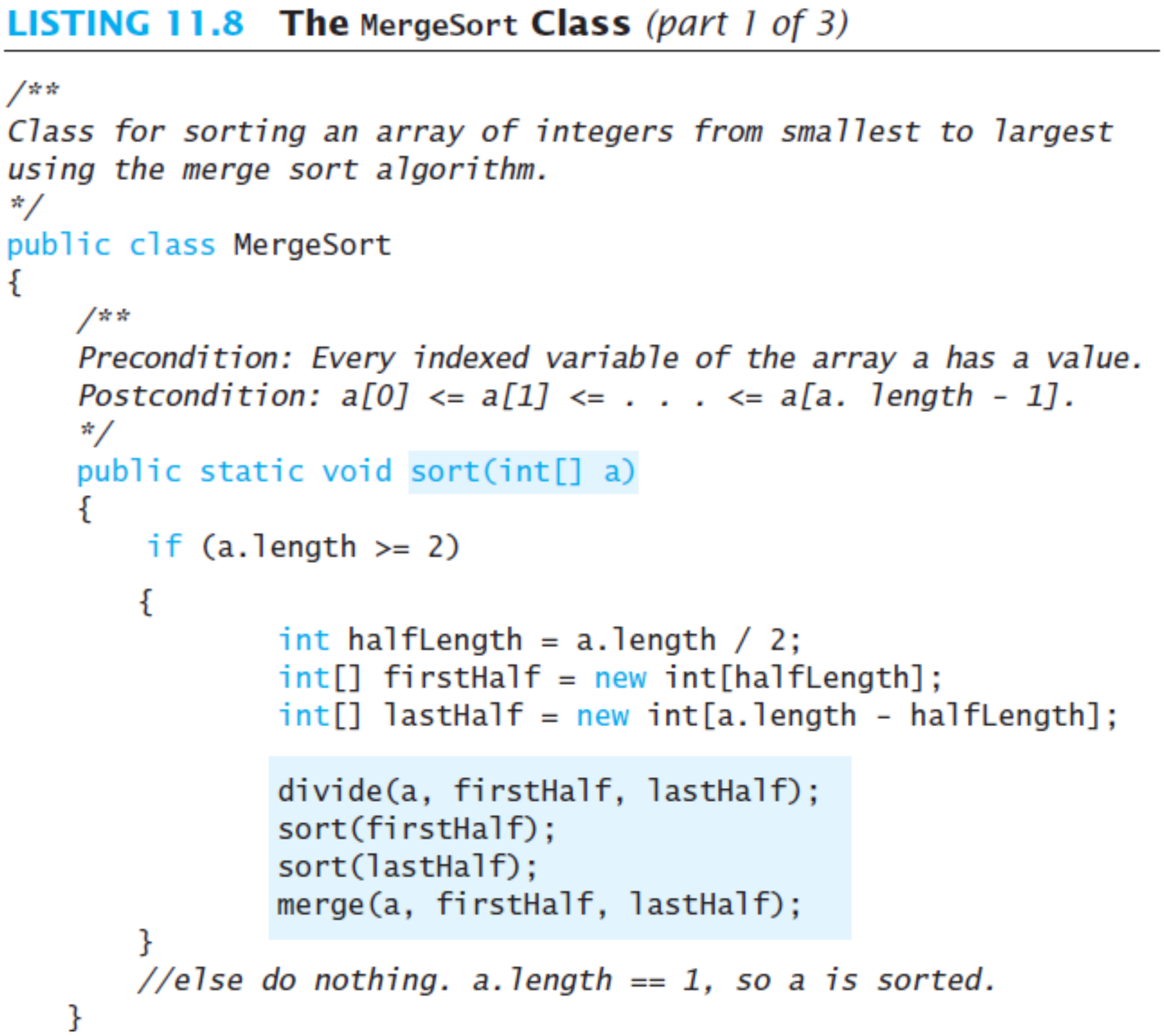
```
Enter 10 integers in increasing order,
one per line.
0
2
4
6
8
10
12
14
16
18
a[0]=0
a[1]=2 a[2]=4 a[3]=6 a[4]=8 a[5]=10 a[6]=12 a[7]=14
a[8]=16 a[9]=18
```



```
Enter a value to search for:
14
14 is at index 7
Again?
yes
Enter a value to search for:
0
0 is at index 0
Again?
yes
Enter a value to search for:
2
2 is at index 1
Again?
yes
```



```
Enter a value to search for:
13
13 is not in the arrray.
Again?
no
May you find what you're searching for.
```



LISTING 11.8 The `MergeSort` Class *(part 1 of 3)*

```
/**
Class for sorting an array of integers from smallest to largest
using the merge sort algorithm.
*/
public class MergeSort
{
    /**
    Precondition: Every indexed variable of the array a has a value.
    Postcondition: a[0] <= a[1] <= . . . <= a[a. length - 1].
    */
    public static void sort(int[] a)
    {
        if (a.length >= 2)
        {
                int halfLength = a.length / 2;
                int[] firstHalf = new int[halfLength];
                int[] lastHalf = new int[a.length - halfLength];

                divide(a, firstHalf, lastHalf);
                sort(firstHalf);
                sort(lastHalf);
                merge(a, firstHalf, lastHalf);
        }
        //else do nothing. a.length == 1, so a is sorted.
    }
```

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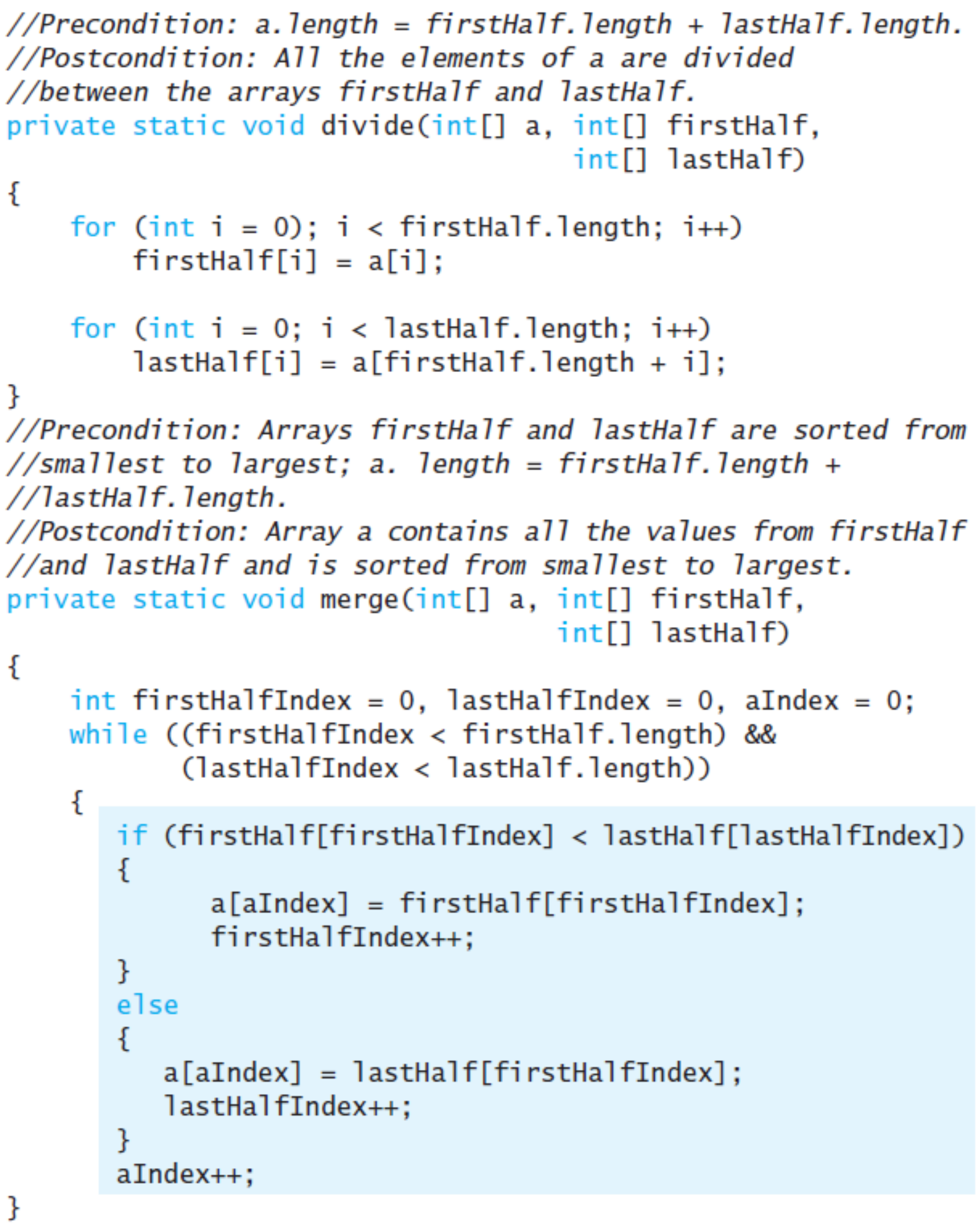

```
//Precondition: a.length = firstHalf.length + lastHalf.length.
//Postcondition: All the elements of a are divided
//between the arrays firstHalf and lastHalf.
private static void divide(int[] a, int[] firstHalf,
                                    int[] lastHalf)
{
    for (int i = 0); i < firstHalf.length; i++)
        firstHalf[i] = a[i];

    for (int i = 0; i < lastHalf.length; i++)
        lastHalf[i] = a[firstHalf.length + i];
}
//Precondition: Arrays firstHalf and lastHalf are sorted from
//smallest to largest; a. length = firstHalf.length +
//lastHalf.length.
//Postcondition: Array a contains all the values from firstHalf
//and lastHalf and is sorted from smallest to largest.
private static void merge(int[] a, int[] firstHalf,
                                   int[] lastHalf)
{
    int firstHalfIndex = 0, lastHalfIndex = 0, aIndex = 0;
    while ((firstHalfIndex < firstHalf.length) &&
           (lastHalfIndex < lastHalf.length))
    {
       if (firstHalf[firstHalfIndex] < lastHalf[lastHalfIndex])
       {
             a[aIndex] = firstHalf[firstHalfIndex];
             firstHalfIndex++;
       }
       else
       {
          a[aIndex] = lastHalf[firstHalfIndex];
          lastHalfIndex++;
       }
       aIndex++;
}
```

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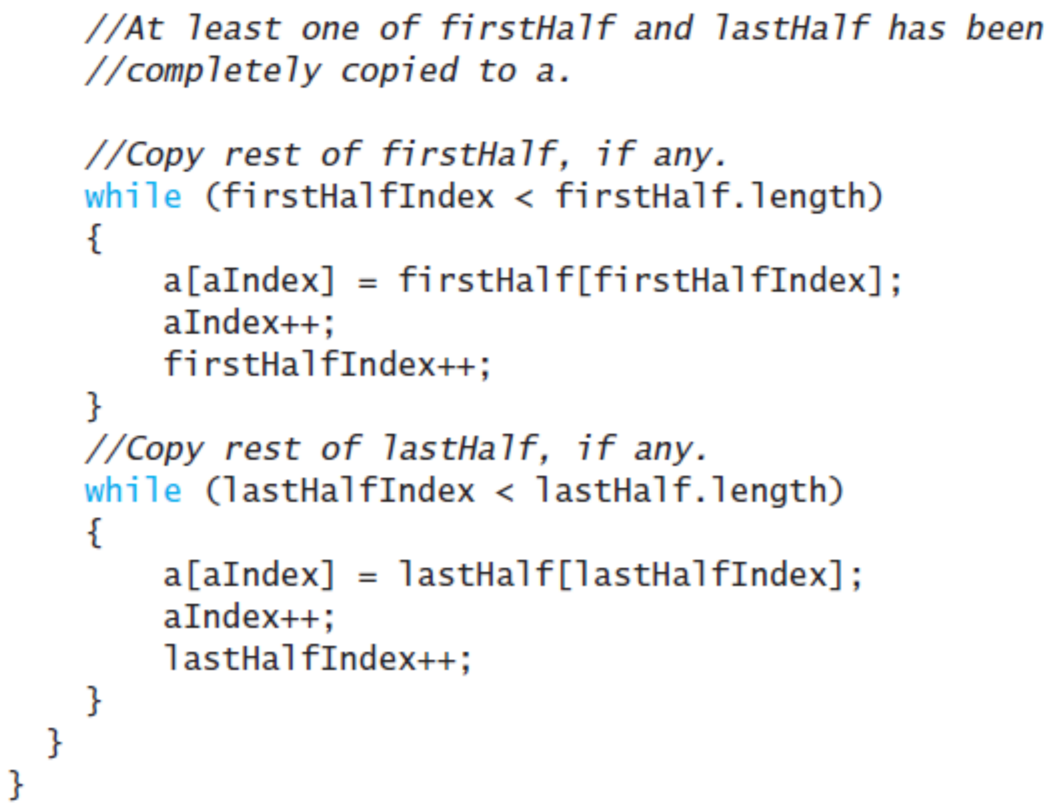

```
    //At least one of firstHalf and lastHalf has been
    //completely copied to a.

    //Copy rest of firstHalf, if any.
    while (firstHalfIndex < firstHalf.length)
    {
        a[aIndex] = firstHalf[firstHalfIndex];
        aIndex++;
        firstHalfIndex++;
    }
    //Copy rest of lastHalf, if any.
    while (lastHalfIndex < lastHalf.length)
    {
        a[aIndex] = lastHalf[lastHalfIndex];
        aIndex++;
        lastHalfIndex++;
    }
  }
}
```

LISTING 11.9 Demonstration of the `MergeSort` Class

```
public class MergeSortDemo
{
    public static void main(String[] args)
    {
        int[] anArray = {7, 5, 11, 2, 16, 4, 18, 14, 12, 30};
        System.out.println("Array values before sorting:");
        for (int i = 0; i < anArray.length; i++)
            System.out.print(anArray[i] + " ");
        System.out.println();

        MergeSort.sort(anArray);

        System.out.println("Array values after sorting:");
        for (int i = 0; i < anArray.length; i++)
            System.out.print(anArray[i] + " ");
        System.out.println();
    }
}
```

Screen Output

```
Array values before sorting:
7 5 11 2 1 4 18 14 12 30
Array values after sorting:
2 4 5 7 11 12 14 16 18 30
```

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