# Chapter 14
# Strings, Characters and Regular Expressions

Java How to Program, 11/e

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# Strings, Characters and Regular Expressions

# OBJECTIVES

In this chapter you'll:

- Create and manipulate immutable character-string objects of class `String`.
- Create and manipulate mutable character-string objects of class `StringBuilder`.
- Create and manipulate objects of class `Character`.
- Break a `String` object into tokens using `String` method `split`.
- Use regular expressions to validate `String` data entered into an application.

# OUTLINE

# OUTLINE (cont.)

## 14.4 Class `StringBuilder`

- 14.4.1 `StringBuilder` Constructors
- 14.4.2 `StringBuilder` Methods `length`, `capacity`, `setLength` and `ensureCapacity`
- 14.4.3 `StringBuilder` Methods `charAt`, `setCharAt`, `getChars` and `reverse`
- 14.4.4 `StringBuilder` `append` Methods
- 14.4.5 `StringBuilder` Insertion and Deletion Methods

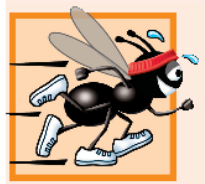
# OUTLINE (cont.)

# 14.1 Introduction

- This chapter discusses class `String`, class `StringBuilder` and class `Character` from the `java.lang` package.
- These classes provide the foundation for string and character manipulation in Java.
- The chapter also discusses regular expressions that provide applications with the capability to validate input.

# 14.2 Fundamentals of Characters and Strings

- A program may contain character literals.
  - An integer value represented as a character in single quotes.
  - The value of a character literal is the integer value of the character in the Unicode character set.
- String literals (stored in memory as `String` objects) are written as a sequence of characters in double quotation marks.

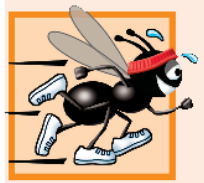


## Performance Tip 14.1

To conserve memory, Java treats all string literals with the same contents as a single `String` object that has many references to it.

# 14.3 Class `String`

- Class `String` is used to represent strings in Java.
- The next several subsections cover many of class `String`'s capabilities.



## Performance Tip 14.2

As of Java SE 9, Java uses a more compact `String` representation. This significantly reduces the amount of memory used to store `String`s containing only Latin-1 characters—that is, those with the character codes 0–255. For more information, see JEP 254's proposal at `http://openjdk.java.net/jeps/254`.

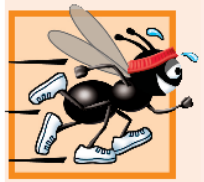
# 14.3.1 `String` Constructors

- No-argument constructor creates a `String` that contains no characters (i.e., the empty string, which can also be represented as `""`) and has a length of 0.
- Constructor that takes a `String` object copies the argument into the new `String`.
- Constructor that takes a `char` array creates a `String` containing a copy of the characters in the array.
- Constructor that takes a `char` array and two integers creates a `String` containing the specified portion of the array.

```
1  // Fig. 14.1: StringConstructors.java
2  // String class constructors.
3
4  public class StringConstructors {
5     public static void main(String[] args) {
6        char[] charArray = {'b', 'i', 'r', 't', 'h', ' ', 'd', 'a', 'y'};
7        String s = new String("hello");
8
9        // use String constructors
10       String s1 = new String();
11       String s2 = new String(s);
12       String s3 = new String(charArray);
13       String s4 = new String(charArray, 6, 3);
14
15       System.out.printf(
16          "s1 = %s%ns2 = %s%ns3 = %s%ns4 = %s%n", s1, s2, s3, s4);
17    }
18 }
```

```
s1 =
s2 = hello
s3 = birth day
s4 = day
```

**Fig. 14.1** | `String` class constructors.



## Performance Tip 14.3

It's not necessary to copy an existing `String` object. `String` objects are immutable, because class `String` does not provide methods that allow the contents of a `String` object to be modified after it is created. In fact, it's rarely necessary to call `String` constructors.

# 14.3.2 `String` Methods `length`, `charAt` and `getChars`

- `String` method `length` determines the number of characters in a string.
- `String` method `charAt` returns the character at a specific position in the `String`.
- `String` method `getChars` copies the characters of a `String` into a character array.
  - The first argument is the starting index in the `String` from which characters are to be copied.
  - The second argument is the index that is one past the last character to be copied from the `String`.
  - The third argument is the character array into which the characters are to be copied.
  - The last argument is the starting index where the copied characters are placed in the target character array.

```
1  // Fig. 14.2: StringMiscellaneous.java
2  // This application demonstrates the length, charAt and getChars
3  // methods of the String class.
4
5  public class StringMiscellaneous {
6     public static void main(String[] args) {
7        String s1 = "hello there";
8        char[] charArray = new char[5];
9
10       System.out.printf("s1: %s", s1);
11
12       // test length method
13       System.out.printf("%nLength of s1: %d", s1.length());
14
15       // loop through characters in s1 with charAt and display reversed
16       System.out.printf("%nThe string reversed is: ");
17
18       for (int count = s1.length() - 1; count >= 0; count--) {
19          System.out.printf("%c ", s1.charAt(count));
20       }
```

**Fig. 14.2** | `String` methods `length`, `charAt` and `getChars`. (Part 1 of 2.)

```
21
22          // copy characters from string into charArray
23          s1.getChars(0, 5, charArray, 0);
24          System.out.printf("%nThe character array is: ");
25
26          for (char character : charArray) {
27             System.out.print(character);
28          }
29
30          System.out.println();
31       }
32    }
```

```
s1: hello there
Length of s1: 11
The string reversed is: e r e h t   o l l e h
The character array is: hello
```

**Fig. 14.2** | `String` methods `length`, `charAt` and `getChars`. (Part 2 of 2.)

# 14.3.3 Comparing Strings

- Strings are compared using the numeric codes of the characters in the strings.
- Figure 14.3 demonstrates `String` methods `equals`, `equalsIgnoreCase`, `compareTo` and `regionMatches` and using the equality operator == to compare `String` objects.

```
1  // Fig. 14.3: StringCompare.java
2  // String methods equals, equalsIgnoreCase, compareTo and regionMatches.
3
4  public class StringCompare {
5     public static void main(String[] args) {
6        String s1 = new String("hello"); // s1 is a copy of "hello"
7        String s2 = "goodbye";
8        String s3 = "Happy Birthday";
9        String s4 = "happy birthday";
10
11       System.out.printf(
12          "s1 = %s%ns2 = %s%ns3 = %s%ns4 = %s%n%n", s1, s2, s3, s4);
13
```

**Fig. 14.3** | `String` methods `equals`, `equalsIgnoreCase`, `compareTo` and `regionMatches`. (Part 1 of 5.)

```
14          // test for equality
15          if (s1.equals("hello")) {  // true
16             System.out.println("s1 equals \"hello\"");
17          }
18          else {
19             System.out.println("s1 does not equal \"hello\"");
20          }
21
22          // test for equality with ==
23          if (s1 == "hello") { // false; they are not the same object
24             System.out.println("s1 is the same object as \"hello\"");
25          }
26          else {
27             System.out.println("s1 is not the same object as \"hello\"");
28          }
29
```

**Fig. 14.3** | `String` methods `equals`, `equalsIgnoreCase`, `compareTo` and `regionMatches`. (Part 2 of 5.)

```
30          // test for equality (ignore case)
31          if (s3.equalsIgnoreCase(s4)) { // true
32             System.out.printf("%s equals %s with case ignored%n", s3, s4);
33          }
34          else {
35             System.out.println("s3 does not equal s4");
36          }
37
38          // test compareTo
39          System.out.printf(
40             "%ns1.compareTo(s2) is %d", s1.compareTo(s2));
41          System.out.printf(
42             "%ns2.compareTo(s1) is %d", s2.compareTo(s1));
43          System.out.printf(
44             "%ns1.compareTo(s1) is %d", s1.compareTo(s1));
45          System.out.printf(
46             "%ns3.compareTo(s4) is %d", s3.compareTo(s4));
47          System.out.printf(
48             "%ns4.compareTo(s3) is %d%n%n", s4.compareTo(s3));
```

**Fig. 14.3** | `String` methods `equals`, `equalsIgnoreCase`, `compareTo` and `regionMatches`. (Part 3 of 5.)

```
49
50          // test regionMatches (case sensitive)
51          if (s3.regionMatches(0, s4, 0, 5)) {
52             System.out.println("First 5 characters of s3 and s4 match");
53          }
54          else {
55             System.out.println(
56                "First 5 characters of s3 and s4 do not match");
57          }
58
59          // test regionMatches (ignore case)
60          if (s3.regionMatches(true, 0, s4, 0, 5)) {
61             System.out.println(
62                "First 5 characters of s3 and s4 match with case ignored");
63          }
64          else {
65             System.out.println(
66                "First 5 characters of s3 and s4 do not match");
67          }
68       }
69    }
```

**Fig. 14.3** | `String` methods `equals`, `equalsIgnoreCase`, `compareTo` and `regionMatches`. (Part 4 of 5.)

```
s1 = hello
s2 = goodbye
s3 = Happy Birthday
s4 = happy birthday

s1 equals "hello"
s1 is not the same object as "hello"
Happy Birthday equals happy birthday with case ignored

s1.compareTo(s2) is 1
s2.compareTo(s1) is -1
s1.compareTo(s1) is 0
s3.compareTo(s4) is -32
s4.compareTo(s3) is 32

First 5 characters of s3 and s4 do not match
First 5 characters of s3 and s4 match with case ignored
```

**Fig. 14.3** | `String` methods `equals`, `equalsIgnoreCase`, `compareTo` and `regionMatches`. (Part 5 of 5.)

# 14.3.3 Comparing Strings (cont.)

- Method `equals` tests any two objects for equality
  - The method returns `true` if the contents of the objects are equal, and `false` otherwise.
  - Uses a lexicographical comparison.
- When primitive-type values are compared with ==, the result is `true` if both values are identical.
- When references are compared with ==, the result is `true` if both references refer to the same object in memory.
- Java treats all string literal objects with the same contents as one `String` object to which there can be many references.

## Common Programming Error 14.1

Comparing references with == can lead to logic errors, because == compares the references to determine whether they refer to the same object, not whether two objects have the same contents. When two separate objects that contain the same values are compared with ==, the result will be `false`. When comparing objects to determine whether they have the same contents, use method `equals`.

# 14.3.3 Comparing Strings (cont.)

- `String` method `equalsIgnoreCase` ignores whether the letters in each `String` are uppercase or lowercase when performing the comparison.
- Method `compareTo` is declared in the `Comparable` interface and implemented in the `String` class.
  - Returns 0 if the `String`s are equal, a negative number if the `String` that invokes `compareTo` is less than the `String` that is passed as an argument and a positive number if the `String` that invokes `compareTo` is greater than the `String` that is passed as an argument.

# 14.3.3 Comparing Strings (cont.)

- Method `regionMatches` compares portions of two `String`s for equality.
  - The first argument to this version of the method is the starting index in the `String` that invokes the method.
  - The second argument is a comparison `String`.
  - The third argument is the starting index in the comparison `String`.
  - The last argument is the number of characters to compare.
- Five-argument version of method `regionMatches`:
  - When the first argument is `true`, the method ignores the case of the characters being compared.
  - The remaining arguments are identical to those described for the four-argument `regionMatches` method.

# 14.3.3 Comparing Strings (cont.)

- `String` methods startsWith and endsWith determine whether strings start with or end with a particular set of characters

```
1  // Fig. 14.4: StringStartEnd.java
2  // String methods startsWith and endsWith.
3
4  public class StringStartEnd {
5     public static void main(String[] args) {
6        String[] strings = {"started", "starting", "ended", "ending"};
7
8        // test method startsWith
9        for (String string : strings) {
10          if (string.startsWith("st")) {
11             System.out.printf("\"%s\" starts with \"st\"%n", string);
12          }
13       }
14
15       System.out.println();
16
```

**Fig. 14.4** | `String` methods `startsWith` and `endsWith`. (Part 1 of 3.)

```
17          // test method startsWith starting from position 2 of string
18          for (String string : strings) {
19             if (string.startsWith("art", 2)) {
20                System.out.printf(
21                   "\"%s\" starts with \"art\" at position 2%n", string);
22             }
23          }
24
25          System.out.println();
26
27          // test method endsWith
28          for (String string : strings) {
29             if (string.endsWith("ed")) {
30                System.out.printf("\"%s\" ends with \"ed\"%n", string);
31             }
32          }
33       }
34    }
```

**Fig. 14.4** | `String` methods `startsWith` and `endsWith`. (Part 2 of 3.)

```
"started" starts with "st"
"starting" starts with "st"

"started" starts with "art" at position 2
"starting" starts with "art" at position 2

"started" ends with "ed"
"ended" ends with "ed"
```

**Fig. 14.4** | `String` methods `startsWith` and `endsWith`. (Part 3 of 3.)

# 14.3.4 Locating Characters and Substrings in Strings

- Figure 14.5 demonstrates the many versions of `String` methods indexOf and lastIndexOf that search for a specified character or substring in a `String`.

```
1  // Fig. 14.5: StringIndexMethods.java
2  // String searching methods indexOf and lastIndexOf.
3
4  public class StringIndexMethods {
5     public static void main(String[] args) {
6        String letters = "abcdefghijklmabcdefghijklm";
7
8        // test indexOf to locate a character in a string
9        System.out.printf(
10          "'c' is located at index %d%n", letters.indexOf('c'));
11       System.out.printf(
12          "'a' is located at index %d%n", letters.indexOf('a', 1));
13       System.out.printf(
14          "'$' is located at index %d%n%n", letters.indexOf('$'));
15
```

**Fig. 14.5** | String-searching methods `indexOf` and `lastIndexOf`. (Part 1 of 4.)

```
16          // test lastIndexOf to find a character in a string
17          System.out.printf("Last 'c' is located at index %d%n",
18             letters.lastIndexOf('c'));
19          System.out.printf("Last 'a' is located at index %d%n",
20             letters.lastIndexOf('a', 25));
21          System.out.printf("Last '$' is located at index %d%n%n",
22             letters.lastIndexOf('$'));
23
24          // test indexOf to locate a substring in a string
25          System.out.printf("\"def\" is located at index %d%n",
26             letters.indexOf("def"));
27          System.out.printf("\"def\" is located at index %d%n",
28             letters.indexOf("def", 7));
29          System.out.printf("\"hello\" is located at index %d%n%n",
30             letters.indexOf("hello"));
```

**Fig. 14.5** | String-searching methods `indexOf` and `lastIndexOf`. (Part 2 of 4.)

```
31
32          // test lastIndexOf to find a substring in a string
33          System.out.printf("Last \"def\" is located at index %d%n",
34             letters.lastIndexOf("def"));
35          System.out.printf("Last \"def\" is located at index %d%n",
36             letters.lastIndexOf("def", 25));
37          System.out.printf("Last \"hello\" is located at index %d%n",
38             letters.lastIndexOf("hello"));
39       }
40    }
```

**Fig. 14.5** | String-searching methods `indexOf` and `lastIndexOf`. (Part 3 of 4.)

```
'c' is located at index 2
'a' is located at index 13
'$' is located at index -1

Last 'c' is located at index 15
Last 'a' is located at index 13
Last '$' is located at index -1

"def" is located at index 3
"def" is located at index 16
"hello" is located at index -1

Last "def" is located at index 16
Last "def" is located at index 16
Last "hello" is located at index -1
```

**Fig. 14.5** | String-searching methods `indexOf` and `lastIndexOf`. (Part 4 of 4.)

# 14.3.4 Locating Characters and Substrings in Strings (cont.)

- Method `indexOf` locates the first occurrence of a character in a `String`. If the method finds the character, it returns the character's index in the `String`—otherwise, it returns `-1`.
- A second version of `indexOf` takes two integer arguments—the character and the starting index at which the search of the `String` should begin.
- Method `lastIndexOf` locates the last occurrence of a character in a `String`. The method searches from the end of the `String` toward the beginning. If it finds the character, it returns the character's index in the `String`—otherwise, it returns –1.
- A second version of `lastIndexOf` takes two integer arguments—the integer representation of the character and the index from which to begin searching backward.
- There are also versions of these methods that search for substrings in `String`s.

# 14.3.5 Extracting Substrings from Strings

- Class `String` provides two `substring` methods to enable a new `String` object to be created by copying part of an existing `String` object. Each method returns a new `String` object.
- The version that takes one integer argument specifies the starting index in the original `String` from which characters are to be copied.
- The version that takes two integer arguments receives the starting index from which to copy characters in the original `String` and the index one beyond the last character to copy.

```
1  // Fig. 14.6: SubString.java
2  // String class substring methods.
3
4  public class SubString {
5     public static void main(String[] args) {
6        String letters = "abcdefghijklmabcdefghijklm";
7
8        // test substring methods
9        System.out.printf("Substring from index 20 to end is \"%s\"%n",
10          letters.substring(20));
11       System.out.printf("%s \"%s\"%n",
12          "Substring from index 3 up to, but not including, 6 is",
13          letters.substring(3, 6));
14    }
15 }
```

```
Substring from index 20 to end is "hijklm"
Substring from index 3 up to, but not including, 6 is "def"
```

**Fig. 14.6** | `String` class `substring` methods.

# 14.3.6 Concatenating Strings

- `String` method concat concatenates two `String` objects (similar to using the + operator) and returns a new `String` object containing the characters from both original `String`s.
- The original `String`s to which `s1` and `s2` refer are *not modified*.

```
1  // Fig. 14.7: StringConcatenation.java
2  // String method concat.
3
4  public class StringConcatenation {
5     public static void main(String[] args) {
6        String s1 = "Happy ";
7        String s2 = "Birthday";
8
9        System.out.printf("s1 = %s%ns2 = %s%n%n",s1, s2);
10       System.out.printf(
11          "Result of s1.concat(s2) = %s%n", s1.concat(s2));
12       System.out.printf("s1 after concatenation = %s%n", s1);
13    }
14 }
```

```
s1 = Happy
s2 = Birthday

Result of s1.concat(s2) = Happy Birthday
s1 after concatenation = Happy
```

**Fig. 14.7** | `String` method `concat`.

# 14.3.7 Miscellaneous `String` Methods

- Method `replace` returns a new `String` object in which every occurrence of the first `char` argument is replaced with the second.
  - An overloaded version enables you to replace substrings rather than individual characters.
- Method toUpperCase generates a new `String` with uppercase letters.
- Method toLowerCase returns a new `String` object with lowercase letters.
- Method trim generates a new `String` object that removes all whitespace characters that appear at the beginning or end of the `String` on which `trim` operates.
- Method toCharArray creates a new character array containing a copy of the characters in the `String`.

```
1  // Fig. 14.8: StringMiscellaneous2.java
2  // String methods replace, toLowerCase, toUpperCase, trim and toCharArray.
3
4  public class StringMiscellaneous2 {
5     public static void main(String[] args) {
6        String s1 = "hello";
7        String s2 = "GOODBYE";
8        String s3 = "   spaces   ";
9
10       System.out.printf("s1 = %s%ns2 = %s%ns3 = %s%n%n", s1, s2, s3);
11
12       // test method replace
13       System.out.printf(
14          "Replace 'l' with 'L' in s1: %s%n%n", s1.replace('l', 'L'));
15
16       // test toLowerCase and toUpperCase
17       System.out.printf("s1.toUpperCase() = %s%n", s1.toUpperCase());
18       System.out.printf("s2.toLowerCase() = %s%n%n", s2.toLowerCase());
```

**Fig. 14.8** | `String` methods `replace`, `toLowerCase`, `toUpperCase`, `trim` and `toCharArray`. (Part 1 of 3.)

```
19
20          // test trim method
21          System.out.printf("s3 after trim = \"%s\"%n%n", s3.trim());
22
23          // test toCharArray method
24          char[] charArray = s1.toCharArray();
25          System.out.print("s1 as a character array = ");
26
27          for (char character : charArray) {
28             System.out.print(character);
29          }
30
31          System.out.println();
32       }
33    }
```

**Fig. 14.8** | `String` methods `replace`, `toLowerCase`, `toUpperCase`, `trim` and `toCharArray`. (Part 2 of 3.)

```
s1 = hello
s2 = GOODBYE
s3 =    spaces

Replace 'l' with 'L' in s1: heLLo

s1.toUpperCase() = HELLO
s2.toLowerCase() = goodbye

s3 after trim = "spaces"

s1 as a character array = hello
```

**Fig. 14.8** | `String` methods `replace`, `toLowerCase`, `toUpperCase`, `trim` and `toCharArray`. (Part 3 of 3.)

# 14.3.8 `String` Method `valueOf`

- Class `String` provides `static` valueOf methods that take an argument of any type and convert it to a `String` object.
- Class StringBuilder is used to create and manipulate dynamic string information.
- Every `StringBuilder` is capable of storing a number of characters specified by its capacity.
- If the capacity of a `StringBuilder` is exceeded, the capacity expands to accommodate the additional characters.

```
1  // Fig. 14.9: StringValueOf.java
2  // String valueOf methods.
3
4  public class StringValueOf {
5     public static void main(String[] args) {
6        char[] charArray = {'a', 'b', 'c', 'd', 'e', 'f'};
7        boolean booleanValue = true;
8        char characterValue = 'Z';
9        int integerValue = 7;
10       long longValue = 10000000000L; // L suffix indicates long
11       float floatValue = 2.5f; // f indicates that 2.5 is a float
12       double doubleValue = 33.333; // no suffix, double is default
13       Object objectRef = "hello"; // assign string to an Object reference
14
15       System.out.printf(
16          "char array = %s%n", String.valueOf(charArray));
17       System.out.printf("part of char array = %s%n",
18          String.valueOf(charArray, 3, 3));
```

**Fig. 14.9** | `String` `valueOf` methods. (Part 1 of 3.)

```
19          System.out.printf(
20             "boolean = %s%n", String.valueOf(booleanValue));
21          System.out.printf(
22             "char = %s%n", String.valueOf(characterValue));
23          System.out.printf("int = %s%n", String.valueOf(integerValue));
24          System.out.printf("long = %s%n", String.valueOf(longValue));
25          System.out.printf("float = %s%n", String.valueOf(floatValue));
26          System.out.printf(
27             "double = %s%n", String.valueOf(doubleValue));
28          System.out.printf("Object = %s", String.valueOf(objectRef));
29       }
30    }
```

**Fig. 14.9** | `String valueOf` methods. (Part 2 of 3.)

```
char array = abcdef
part of char array = def
boolean = true
char = Z
int = 7
long = 10000000000
float = 2.5
double = 33.333
Object = hello
```

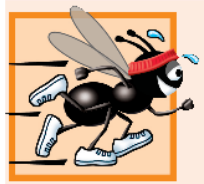
**Fig. 14.9** | `String valueOf` methods. (Part 3 of 3.)

# 14.4 Class `StringBuilder`

- We now discuss the features of class `StringBuilder` for creating and manipulating *dynamic* string information—that is, *modifiable* strings.
- Every `StringBuilder` is capable of storing a number of characters specified by it's *capacity*.
- If a `StringBuilder`'s capacity is exceeded, the capacity expands to accommodate additional characters.

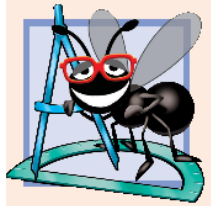
## Performance Tip 14.4

Java can perform certain optimizations involving `String` objects (such as referring to one `String` object from multiple variables) because it knows these objects will not change. `Strings` (not `StringBuilders`) should be used if the data will not change.



## Performance Tip 14.5

In programs that frequently perform string concatenation, or other string modifications, it's often more efficient to implement the modifications with class `StringBuilder`.



## Software Engineering Observation 14.1

`StringBuilder`s are not thread safe. If multiple threads require access to the same dynamic string information, use class **StringBuffer** in your code. Classes `StringBuilder` and `StringBuffer` provide identical capabilities, but class `StringBuffer` is thread safe. For more details on threading, see Chapter 23.

# 14.4.1 `StringBuilder` Constructors

- No-argument constructor creates a `StringBuilder` with no characters in it and an initial capacity of 16 characters.
- Constructor that takes an integer argument creates a `StringBuilder` with no characters in it and the initial capacity specified by the integer argument.
- Constructor that takes a `String` argument creates a `StringBuilder` containing the characters in the `String` argument. The initial capacity is the number of characters in the `String` argument plus 16.
- Method `toString` of class `StringBuilder` returns the `StringBuilder` contents as a `String`.

```
1  // Fig. 14.10: StringBuilderConstructors.java
2  // StringBuilder constructors.
3
4  public class StringBuilderConstructors {
5     public static void main(String[] args) {
6        StringBuilder buffer1 = new StringBuilder();
7        StringBuilder buffer2 = new StringBuilder(10);
8        StringBuilder buffer3 = new StringBuilder("hello");
9
10       System.out.printf("buffer1 = \"%s\"%n", buffer1);
11       System.out.printf("buffer2 = \"%s\"%n", buffer2);
12       System.out.printf("buffer3 = \"%s\"%n", buffer3);
13    }
14 }
```

```
buffer1 = ""
buffer2 = ""
buffer3 = "hello"
```

**Fig. 14.10** | `StringBuilder` constructors.

# 14.4.2 `StringBuilder` Methods `length`, `capacity`, `setLength` and `ensureCapacity`

- Methods length and capacity return the number of characters currently in a `StringBuilder` and the number of characters that can be stored in a without allocating more memory, respectively.
- Method ensureCapacity guarantees that a `StringBuilder` has at least the specified capacity.
- Method `setLength` increases or decreases the length of a `StringBuilder`.
  - If the specified length is less than the current number of characters, the buffer is truncated to the specified length.
  - If the specified length is greater than the number of characters, `null` characters are appended until the total number of characters in the `StringBuilder` is equal to the specified length.

```
1  // Fig. 14.11: StringBuilderCapLen.java
2  // StringBuilder length, setLength, capacity and ensureCapacity methods.
3
4  public class StringBuilderCapLen {
5     public static void main(String[] args) {
6        StringBuilder buffer = new StringBuilder("Hello, how are you?");
7
8        System.out.printf("buffer = %s%nlength = %d%ncapacity = %d%n%n",
9           buffer.toString(), buffer.length(), buffer.capacity());
10
11       buffer.ensureCapacity(75);
12       System.out.printf("New capacity = %d%n%n", buffer.capacity());
13
14       buffer.setLength(10));
15       System.out.printf("New length = %d%nbuffer = %s%n",
16          buffer.length(), buffer.toString());
17    }
18 }
```

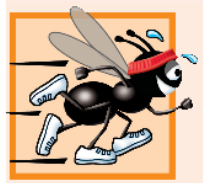
**Fig. 14.11** | `StringBuilder` `length`, `setLength`, `capacity` and `ensureCapacity` methods. (Part 1 of 2.)

```
buffer = Hello, how are you?
length = 19
capacity = 35

New capacity = 75

New length = 10
buffer = Hello, how
```

**Fig. 14.11** | `StringBuilder` `length`, `setLength`, `capacity` and `ensureCapacity` methods. (Part 2 of 2.)



## Performance Tip 14.6

Dynamically increasing the capacity of a `StringBuilder` can take a relatively long time. Executing a large number of these operations can degrade the performance of an application. If a `StringBuilder` is going to increase greatly in size, possibly multiple times, setting its capacity high at the beginning will increase performance.

# 14.4.3 `StringBuilder` Methods `charAt`, `setCharAt`, `getChars` and `reverse`

- Method `charAt` takes an integer argument and returns the character in the `StringBuilder` at that index.
- Method `getChars` copies characters from a `StringBuilder` into the character array argument.
  - Four arguments—the starting index from which characters should be copied, the index one past the last character to be copied, the character array into which the characters are to be copied and the starting location in the character array where the first character should be placed.
- Method `setCharAt` takes an integer and a character argument and sets the character at the specified position in the `StringBuilder` to the character argument.
- Method `reverse` reverses the contents of the `StringBuilder`.

```
1  // Fig. 14.12: StringBuilderChars.java
2  // StringBuilder methods charAt, setCharAt, getChars and reverse.
3
4  public class StringBuilderChars {
5     public static void main(String[] args) {
6        StringBuilder buffer = new StringBuilder("hello there");
7
8        System.out.printf("buffer = %s%n", buffer.toString());
9        System.out.printf("Character at 0: %s%nCharacter at 4: %s%n%n",
10          buffer.charAt(0), buffer.charAt(4));
11
12       char[] charArray = new char[buffer.length()];
13       buffer.getChars(0, buffer.length(), charArray, 0);
14       System.out.print("The characters are: ");
15
```

**Fig. 14.12** | `StringBuilder` methods `charAt`, `setCharAt`, `getChars` and `reverse`. (Part 1 of 3.)

```
16          for (char character : charArray) {
17             System.out.print(character);
18          }
19
20          buffer.setCharAt(0, 'H');
21          buffer.setCharAt(6, 'T');
22          System.out.printf("%n%nbuffer = %s", buffer.toString());
23
24          buffer.reverse();
25          System.out.printf("%n%nbuffer = %s%n", buffer.toString());
26       }
27    }
```

**Fig. 14.12** | `StringBuilder` methods `charAt`, `setCharAt`, `getChars` and `reverse`. (Part 2 of 3.)

```
buffer = hello there
Character at 0: h
Character at 4: o

The characters are: hello there

buffer = Hello There

buffer = erehT olleH
```

**Fig. 14.12** | `StringBuilder` methods `charAt`, `setCharAt`, `getChars` and `reverse`. (Part 3 of 3.)

# 14.4.4 `StringBuilder` `append` Methods

- *Overloaded* `append` methods allow values of various types to be appended to the end of a `StringBuilder`.
- Versions are provided for each of the primitive types and for character arrays, `String`s, `Object`s, and more.

# 14.4.4 `StringBuilder` `append` Methods (cont.)

- The compiler can use `StringBuilder` and the `append` methods to implement the `+` and `+=` `String` concatenation operators.

```
1  // Fig. 14.13: StringBuilderAppend.java
2  // StringBuilder append methods.
3
4  public class StringBuilderAppend
5  {
6     public static void main(String[] args)
7     {
8        Object objectRef = "hello";
9        String string = "goodbye";
10       char[] charArray = {'a', 'b', 'c', 'd', 'e', 'f'};
11       boolean booleanValue = true;
12       char characterValue = 'Z';
13       int integerValue = 7;
14       long longValue = 10000000000L;
15       float floatValue = 2.5f;
16       double doubleValue = 33.333;
17
18       StringBuilder lastBuffer = new StringBuilder("last buffer");
19       StringBuilder buffer = new StringBuilder();
20
21       buffer.append(objectRef)
22             .append(System.getProperty("line.separator"))
23             .append(string)
```

**Fig. 14.13** | `StringBuilder` append methods. (Part 1 of 3.)

```
24              .append(System.getProperty("line.separator"))
25              .append(charArray)
26              .append(System.getProperty("line.separator"))
27              .append(charArray, 0, 3)
28              .append(System.getProperty("line.separator"))
29              .append(booleanValue)
30              .append(System.getProperty("line.separator"))
31              .append(characterValue);
32              .append(System.getProperty("line.separator"))
33              .append(integerValue)
34              .append(System.getProperty("line.separator"))
35              .append(longValue)
36              .append(System.getProperty("line.separator"))
37              .append(floatValue)
38              .append(System.getProperty("line.separator"))
39              .append(doubleValue)
40              .append(System.getProperty("line.separator"))
41              .append(lastBuffer);
42
43          System.out.printf("buffer contains%n%s%n", buffer.toString());
44      }
45  }
```

**Fig. 14.13** | `StringBuilder` append methods. (Part 2 of 3.)

```
buffer contains
hello
goodbye
abcdef
abc
true
Z
7
10000000000
2.5
33.333
last buffer
```

**Fig. 14.13** | `StringBuilder` `append` methods. (Part 3 of 3.)

# 14.4.5 `StringBuilder` Insertion and Deletion Methods

- Overloaded insert methods insert values of various types at any position in a `StringBuilder`.
  - Versions are provided for the primitive types and for character arrays, `String`s, `Object`s and `CharSequence`s.
  - Each method takes its second argument, converts it to a `String` and inserts it at the index specified by the first argument.
- Methods delete and deleteCharAt delete characters at any position in a `StringBuilder`.
- Method `delete` takes two arguments—the starting index and the index one past the end of the characters to delete.
- Method `deleteCharAt` takes one argument—the index of the character to delete.

```
1  // Fig. 14.14: StringBuilderInsertDelete.java
2  // StringBuilder methods insert, delete and deleteCharAt.
3
4  public class StringBuilderInsertDelete {
5     public static void main(String[] args) {
6        Object objectRef = "hello";
7        String string = "goodbye";
8        char[] charArray = {'a', 'b', 'c', 'd', 'e', 'f'};
9        boolean booleanValue = true;
10       char characterValue = 'K';
11       int integerValue = 7;
12       long longValue = 10000000;
13       float floatValue = 2.5f; // f suffix indicates that 2.5 is a float
14       double doubleValue = 33.333;
15
16       StringBuilder buffer = new StringBuilder();
17
18       buffer.insert(0, objectRef);
19       buffer.insert(0, "  "); // each of these contains two spaces
20       buffer.insert(0, string);
21       buffer.insert(0, "  ");
22       buffer.insert(0, charArray);
23       buffer.insert(0, "  ");
```

**Fig. 14.14** | `StringBuilder` methods `insert`, `delete` and `deleteCharAt`. (Part 1 of 3.)

```
24          buffer.insert(0, charArray, 3, 3);
25          buffer.insert(0, "  ");
26          buffer.insert(0, booleanValue);
27          buffer.insert(0, "  ");
28          buffer.insert(0, characterValue);
29          buffer.insert(0, "  ");
30          buffer.insert(0, integerValue);
31          buffer.insert(0, "  ");
32          buffer.insert(0, longValue);
33          buffer.insert(0, "  ");
34          buffer.insert(0, floatValue);
35          buffer.insert(0, "  ");
36          buffer.insert(0, doubleValue);
37
38          System.out.printf(
39             "buffer after inserts:%n%s%n%n", buffer.toString());
40
41          buffer.deleteCharAt(10); // delete 5 in 2.5
42          buffer.delete(2, 6); // delete .333 in 33.333
43
44          System.out.printf(
45             "buffer after deletes:%n%s%n", buffer.toString());
46       }
47    }
```

**Fig. 14.14** | `StringBuilder` methods `insert`, `delete` and `deleteCharAt`. (Part 2 of 3.)

```
buffer after inserts:
33.333  2.5  10000000  7  K  true  def  abcdef  goodbye  hello

buffer after deletes:
33  2.  10000000  7  K  true  def  abcdef  goodbye  hello
```

**Fig. 14.14** | `StringBuilder` methods `insert`, `delete` and `deleteCharAt`. (Part 3 of 3.)

# 14.5 Class `Character`

- Eight type-wrapper classes that enable primitive-type values to be treated as objects:
  - `Boolean`, `Character`, `Double`, `Float`, `Byte`, `Short`, `Integer` and `Long`
- Most `Character` methods are `static` methods designed for convenience in processing individual `char` values.

# 14.5 Class Character (cont.)

- Method isDefined determines whether a character is defined in the Unicode character set.
- Method isDigit determines whether a character is a defined Unicode digit.
- Method isJavaIdentifierStart determines whether a character can be the first character of an identifier in Java—that is, a letter, an underscore (_) or a dollar sign ($).
- Method isJavaIdentifierPart determine whether a character can be used in an identifier in Java—that is, a digit, a letter, an underscore (_) or a dollar sign ($).

```
1  // Fig. 14.15: StaticCharMethods.java
2  // Character static methods for testing characters and converting case.
3  import java.util.Scanner;
4
5  public class StaticCharMethods {
6     public static void main(String[] args) {
7        Scanner scanner = new Scanner(System.in); // create scanner
8        System.out.println("Enter a character and press Enter");
9        String input = scanner.next();
10       char c = input.charAt(0); // get input character
11
12       // display character info
13       System.out.printf("is defined: %b%n", Character.isDefined(c));
14       System.out.printf("is digit: %b%n", Character.isDigit(c));
15       System.out.printf("is first character in a Java identifier: %b%n",
16          Character.isJavaIdentifierStart(c));
```

**Fig. 14.15** | `Character` `static` methods for testing characters and converting case. (Part 1 of 5.)

```
17          System.out.printf("is part of a Java identifier: %b%n",
18             Character.isJavaIdentifierPart(c));
19          System.out.printf("is letter: %b%n", Character.isLetter(c));
20          System.out.printf(
21             "is letter or digit: %b%n", Character.isLetterOrDigit(c));
22          System.out.printf(
23             "is lower case: %b%n", Character.isLowerCase(c));
24          System.out.printf(
25             "is upper case: %b%n", Character.isUpperCase(c));
26          System.out.printf(
27             "to upper case: %s%n", Character.toUpperCase(c));
28          System.out.printf(
29             "to lower case: %s%n", Character.toLowerCase(c));
30       }
31    }
```

**Fig. 14.15** | `Character` `static` methods for testing characters and converting case. (Part 2 of 5.)

```
Enter a character and press Enter
A
is defined: true
is digit: false
is first character in a Java identifier: true
is part of a Java identifier: true
is letter: true
is letter or digit: true
is lower case: false
is upper case: true
to upper case: A
to lower case: a
```

**Fig. 14.15** | `Character` `static` methods for testing characters and converting case. (Part 3 of 5.)

```
Enter a character and press Enter
8
is defined: true
is digit: true
is first character in a Java identifier: false
is part of a Java identifier: true
is letter: false
is letter or digit: true
is lower case: false
is upper case: false
to upper case: 8
to lower case: 8
```

**Fig. 14.15** | `Character` `static` methods for testing characters and converting case. (Part 4 of 5.)

```
Enter a character and press Enter
$
is defined: true
is digit: false
is first character in a Java identifier: true
is part of a Java identifier: true
is letter: false
is letter or digit: false
is lower case: false
is upper case: false
to upper case: $
to lower case: $
```

**Fig. 14.15** | `Character` `static` methods for testing characters and converting case. (Part 5 of 5.)

# 14.5 Class Character (cont.)

- Method isLetter determines whether a character is a letter.
- Method isLetterOrDigit determines whether a character is a letter or a digit.
- Method isLowerCase determines whether a character is a lowercase letter.
- Method isUpperCase determines whether a character is an uppercase letter.
- Method toUpperCase converts a character to its uppercase equivalent.
- Method toLowerCase converts a character to its lowercase equivalent.

# 14.5 Class Character (cont.)

- Methods digit and forDigit convert characters to digits and digits to characters, respectively, in different number systems.
- Common number systems: decimal (base 10), octal (base 8), hexadecimal (base 16) and binary (base 2).
- The base of a number is also known as its radix.
- For more information on conversions between number systems, see Appendix I.

# 14.5 Class `Character` (cont.)

- `Character` method `forDigit` converts its first argument into a character in the number system specified by its second argument.
- `Character` method `digit` converts its first argument into an integer in the number system specified by its second argument.
  - The radix (second argument) must be between 2 and 36, inclusive.

```
1  // Fig. 14.16: StaticCharMethods2.java
2  // Character class static conversion methods.
3  import java.util.Scanner;
4
5  public class StaticCharMethods2 {
6     public static void main(String[] args) {
7        Scanner scanner = new Scanner(System.in);
8
9        // get radix
10       System.out.println("Please enter a radix:");
11       int radix = scanner.nextInt();
12
13       // get user choice
14       System.out.printf("Please choose one:%n1 -- %s%n2 -- %s%n",
15          "Convert digit to character", "Convert character to digit");
16       int choice = scanner.nextInt();
17
```

**Fig. 14.16** | `Character` class `static` conversion methods. (Part 1 of 3.)

```
18          // process request
19          switch (choice) {
20             case 1: // convert digit to character
21                System.out.println("Enter a digit:");
22                int digit = scanner.nextInt();
23                System.out.printf("Convert digit to character: %s%n",
24                   Character.forDigit(digit, radix));
25                break;
26             case 2: // convert character to digit
27                System.out.println("Enter a character:");
28                char character = scanner.next().charAt(0);
29                System.out.printf("Convert character to digit: %s%n",
30                   Character.digit(character, radix));
31                break;
32          }
33       }
34    }
```

**Fig. 14.16** | `Character` class `static` conversion methods. (Part 2 of 3.)

```
Please enter a radix:
16
Please choose one:
1 -- Convert digit to character
2 -- Convert character to digit
2
Enter a character:
A
Convert character to digit: 10
```

```
Please enter a radix:
16
Please choose one:
1 -- Convert digit to character
2 -- Convert character to digit
1
Enter a digit:
13
Convert digit to character: d
```

**Fig. 14.16** | `Character` class `static` conversion methods. (Part 3 of 3.)

# 14.5 Class `Character` (cont.)

- Java automatically converts `char` literals into `Character` objects when they are assigned to `Character` variables
  - Process known as autoboxing.
- Method `charValue` returns the `char` value stored in the object.
- Method `toString` returns the `String` representation of the `char` value stored in the object.
- Method `equals` determines if two `Character`s have the same contents.

```
1  // Fig. 14.17: OtherCharMethods.java
2  // Character class instance methods.
3  public class OtherCharMethods {
4     public static void main(String[] args) {
5        Character c1 = 'A';
6        Character c2 = 'a';
7
8        System.out.printf(
9           "c1 = %s%nc2 = %s%n%n", c1.charValue(), c2.toString());
10
11       if (c1.equals(c2)) {
12          System.out.println("c1 and c2 are equal%n");
13       }
14       else {
15          System.out.println("c1 and c2 are not equal%n");
16       }
17    }
18 }
```

**Fig. 14.17** | `Character` class instance methods. (Part 1 of 2.)

```
c1 = A
c2 = a

c1 and c2 are not equal
```

**Fig. 14.17** | `Character` class instance methods. (Part 2 of 2.)

# 14.6 Tokenizing `Strings`

- When you read a sentence, your mind breaks it into tokens—individual words and punctuation marks that convey meaning.
- Compilers also perform tokenization.
- `String` method split breaks a `String` into its component tokens and returns an array of `String`s.
- Tokens are separated by delimiters
  - Typically white-space characters such as space, tab, newline and carriage return.
  - Other characters can also be used as delimiters to separate tokens.

```
1  // Fig. 14.18: TokenTest.java
2  // Tokenizing with String method split
3  import java.util.Scanner;
4
5  public class TokenTest {
6     // execute application
7     public static void main(String[] args) {
8        // get sentence
9        Scanner scanner = new Scanner(System.in);
10       System.out.println("Enter a sentence and press Enter");
11       String sentence = scanner.nextLine();
12
13       // process user sentence
14       String[] tokens = sentence.split(" ");
15       System.out.printf("Number of elements: %d%nThe tokens are:%n",
16          tokens.length);
17
18       for (String token : tokens) {
19          System.out.println(token);
20       }
21    }
22 }
```

**Fig. 14.18** | Tokenizing with `String` method `split`. (Part 1 of 2.)

```
Enter a sentence and press Enter
This is a sentence with seven tokens
Number of elements: 7
The tokens are:
This
is
a
sentence
with
seven
tokens
```

**Fig. 14.18** | Tokenizing with `String` method `split`. (Part 2 of 2.)

# 14.7 Regular Expressions, Class `Pattern` and Class `Matcher`

- A regular expression is a specially formatted `String` that describes a search pattern for matching characters in other `String`s.
- Useful for validating input and ensuring that data is in a particular format.
- One application of regular expressions is to facilitate the construction of a compiler.
  - Often, a large and complex regular expression is used to *validate the syntax of a program*.
  - If the program code does *not* match the regular expression, the compiler knows that there is a syntax error within the code.

# 14.7 Regular Expressions, Class `Pattern` and Class `Matcher` (cont.)

- `String` method matches receives a `String` that specifies the regular expression and matches the contents of the `String` object on which it's called to the regular expression.
  - The method returns a `boolean` indicating whether the match succeeded.
- A regular expression consists of literal characters and special symbols.

# 14.7 Regular Expressions, Class `Pattern` and Class `Matcher` (cont.)

- Figure 14.19 specifies some predefined character classes that can be used with regular expressions.
- A character class is an escape sequence that represents a group of characters.
- A digit is any numeric character.
- A word character is any letter (uppercase or lowercase), any digit or the underscore character.
- A white-space character is a space, a tab, a carriage return, a newline or a form feed.
- Each character class matches a single character in the `String` we're attempting to match with the regular expression.
- Regular expressions are not limited to predefined character classes.
- The expressions employ various operators and other forms of notation to match complex patterns.

# 14.7 Regular Expressions, Class `Pattern` and Class `Matcher` (cont.)

- To match a set of characters that does not have a predefined character class, use square brackets, `[]`.
  - The pattern `"[aeiou]"` matches a single character that's a vowel.
- Character ranges are represented by placing a dash (`-`) between two characters.
  - `"[A-Z]"` matches a single uppercase letter.
- If the first character in the brackets is `"^"`, the expression accepts any character other than those indicated.
  - `"[^Z]"` is not the same as `"[A-Y]"`, which matches uppercase letters A–Y—`"[^Z]"` matches any character other than capital Z, including lowercase letters and nonletters such as the newline character.

| Character | Matches | Character | Matches |
|---|---|---|---|
| `\d` | any digit | `\D` | any nondigit |
| `\w` | any word character | `\W` | any nonword character |
| `\s` | any white-space character | `\S` | any non-whitespace character |

**Fig. 14.19** | Predefined character classes.

```
1  // Fig. 14.20: ValidateInput.java
2  // Validating user information using regular expressions.
3
4  public class ValidateInput {
5     // validate first name
6     public static boolean validateFirstName(String firstName) {
7        return firstName.matches("[A-Z][a-zA-Z]*");
8     }
9
10    // validate last name
11    public static boolean validateLastName(String lastName) {
12       return lastName.matches("[a-zA-z]+(['-][a-zA-Z]+)*");
13    }
14
15    // validate address
16    public static boolean validateAddress(String address) {
17       return address.matches(
18          "\\d+\\s+([a-zA-Z]+|[a-zA-Z]+\\s[a-zA-Z]+)");
19    }
```

**Fig. 14.20** | Validating user information using regular expressions. (Part 1 of 2.)

```
20
21      // validate city
22      public static boolean validateCity(String city) {
23         return city.matches("([a-zA-Z]+|[a-zA-Z]+\\s[a-zA-Z]+)");
24      }
25
26      // validate state
27      public static boolean validateState(String state) {
28         return state.matches("([a-zA-Z]+|[a-zA-Z]+\\s[a-zA-Z]+)");
29      }
30
31      // validate zip
32      public static boolean validateZip(String zip) {
33         return zip.matches("\\d{5}");
34      }
35
36      // validate phone
37      public static boolean validatePhone(String phone) {
38         return phone.matches("[1-9]\\d{2}-[1-9]\\d{2}-\\d{4}");
39      }
40   }
```

**Fig. 14.20** | Validating user information using regular expressions. (Part 2 of 2.)

```
1  // Fig. 14.21: Validate.java
2  // Input and validate data from user using the ValidateInput class.
3  import java.util.Scanner;
4
5  public class Validate {
6     public static void main(String[] args) {
7        // get user input
8        Scanner scanner = new Scanner(System.in);
9        System.out.println("Please enter first name:");
10       String firstName = scanner.nextLine();
11       System.out.println("Please enter last name:");
12       String lastName = scanner.nextLine();
13       System.out.println("Please enter address:");
14       String address = scanner.nextLine();
15       System.out.println("Please enter city:");
16       String city = scanner.nextLine();
17       System.out.println("Please enter state:");
18       String state = scanner.nextLine();
19       System.out.println("Please enter zip:");
20       String zip = scanner.nextLine();
21       System.out.println("Please enter phone:");
22       String phone = scanner.nextLine();
```

**Fig. 14.21** | Input and validate data from user using the `ValidateInput` class. (Part 1 of 5.)

```
23
24          // validate user input and display error message
25          System.out.printf("%nValidate Result:");
26
27          if (!ValidateInput.validateFirstName(firstName)) {
28             System.out.println("Invalid first name");
29          }
30          else if (!ValidateInput.validateLastName(lastName)) {
31             System.out.println("Invalid last name");
32          }
33          else if (!ValidateInput.validateAddress(address)) {
34             System.out.println("Invalid address");
35          }
36          else if (!ValidateInput.validateCity(city)) {
37             System.out.println("Invalid city");
38          }
```

**Fig. 14.21** | Input and validate data from user using the `ValidateInput` class. (Part 2 of 5.)

```
39          else if (!ValidateInput.validateState(state)) {
40             System.out.println("Invalid state");
41          }
42          else if (!ValidateInput.validateZip(zip)) {
43             System.out.println("Invalid zip code");
44          }
45          else if (!ValidateInput.validatePhone(phone)) {
46             System.out.println("Invalid phone number");
47          }
48          else {
49             System.out.println("Valid input.  Thank you.");
50          }
51       }
52    }
```

**Fig. 14.21** | Input and validate data from user using the `ValidateInput` class. (Part 3 of 5.)

```
Please enter first name:
Jane
Please enter last name:
Doe
Please enter address:
123 Some Street
Please enter city:
Some City
Please enter state:
SS
Please enter zip:
123
Please enter phone:
123-456-7890

Validate Result:
Invalid zip code
```

**Fig. 14.21** | Input and validate data from user using the `ValidateInput` class. (Part 4 of 5.)

```
Please enter first name:
Jane
Please enter last name:
Doe
Please enter address:
123 Some Street
Please enter city:
Some City
Please enter state:
SS
Please enter zip:
12345
Please enter phone:
123-456-7890

Validate Result:
Valid input.  Thank you.
```

**Fig. 14.21** | Input and validate data from user using the `ValidateInput` class. (Part 5 of 5.)

# 14.7 Regular Expressions, Class `Pattern` and Class `Matcher` (cont.)

- Ranges in character classes are determined by the letters' integer values.
  - `"[A-Za-z]"` matches all uppercase and lowercase letters.
- The range `"[A-z]"` matches all letters and also matches those characters (such as [ and \) with an integer value between uppercase Z and lowercase a.
- Like predefined character classes, character classes delimited by square brackets match a single character in the search object.

# 14.7 Regular Expressions, Class `Pattern` and Class `Matcher` (cont.)

- When the regular-expression operator `"*"` appears in a regular expression, the application attempts to match zero or more occurrences of the subexpression immediately preceding the `"*"`.
- Operator `"+"` attempts to match one or more occurrences of the subexpression immediately preceding `"+"`.
- The character `"|"` matches the expression to its left or to its right.
  - `"Hi (John|Jane)"` matches both `"Hi John"` and `"Hi Jane"`.
- Parentheses are used to group parts of the regular expression.

# 14.7 Regular Expressions, Class `Pattern` and Class `Matcher` (cont.)

- The asterisk (*) and plus (+) are formally called quantifiers.
- Figure 14.22 lists all the quantifiers.
- A quantifier affects only the subexpression immediately preceding the quantifier.
- Quantifier question mark (?) matches zero or one occurrences of the expression that it quantifies.
- A set of braces containing one number (`{n}`) *matches exactly n occurrences of the expression it quantifies.*
- Including a comma after the number enclosed in braces matches at least *n occurrences of the quantified expression.*
- A set of braces containing two numbers (`{n,m}`), *matches between n and m occurrences of the expression that it qualifies.*

# 14.7 Regular Expressions, Class `Pattern` and Class `Matcher` (cont.)

- Quantifiers may be applied to patterns enclosed in parentheses to create more complex regular expressions.
- All of the quantifiers are greedy.
  - They match as many occurrences as they can as long as the match is still successful.
- If a quantifier is followed by a question mark (`?`), the quantifier becomes reluctant (sometimes called lazy).
  - It will match as few occurrences as possible as long as the match is still successful.
- `String` Method `matches` checks whether an entire `String` conforms to a regular expression.

| Quantifier | Matches |
|---|---|
| * | Matches zero or more occurrences of the pattern. |
| + | Matches one or more occurrences of the pattern. |
| ? | Matches zero or one occurrences of the pattern. |
| {*n*} | Matches exactly *n* occurrences. |
| {*n*,} | Matches at least *n* occurrences. |
| {*n*,*m*} | Matches between *n* and *m* (inclusive) occurrences. |

**Fig. 14.22** | Quantifiers used in regular expressions.

# 14.7 Regular Expressions, Class `Pattern` and Class `Matcher` (cont.)

- Sometimes it's useful to replace parts of a string or to split a string into pieces. For this purpose, class `String` provides methods replaceAll, replaceFirst and split.

# 14.7 Regular Expressions, Class `Pattern` and Class `Matcher` (cont.)

- `String` method `replaceAll` replaces text in a `String` with new text (the second argument) wherever the original `String` matches a regular expression (the first argument).
- Escaping a special regular-expression character with `\` instructs the matching engine to find the actual character.
- `String` method `replaceFirst` replaces the first occurrence of a pattern match.

```
1  // Fig. 14.23: RegexSubstitution.java
2  // String methods replaceFirst, replaceAll and split.
3  import java.util.Arrays;
4
5  public class RegexSubstitution {
6     public static void main(String[] args) {
7        String firstString = "This sentence ends in 5 stars *****";
8        String secondString = "1, 2, 3, 4, 5, 6, 7, 8";
9
10       System.out.printf("Original String 1: %s%n", firstString);
11
12       // replace '*' with '^'
13       firstString = firstString.replaceAll("\\*", "^");
14
15       System.out.printf("^ substituted for *: %s%n", firstString);
16
17       // replace 'stars' with 'carets'
18       firstString = firstString.replaceAll("stars", "carets");
19
20       System.out.printf(
21          "\"carets\" substituted for \"stars\": %s%n", firstString);
```

**Fig. 14.23** | `String` methods `replaceFirst`, `replaceAll` and `split`. (Part 1 of 3.)

```
22
23          // replace words with 'word'
24          System.out.printf("Every word replaced by \"word\": %s%n%n",
25             firstString.replaceAll("\\w+", "word"));
26
27          System.out.printf("Original String 2: %s%n", secondString);
28
29          // replace first three digits with 'digit'
30          for (int i = 0; i < 3; i++) {
31             secondString = secondString.replaceFirst("\\d", "digit");
32          }
33
34          System.out.printf(
35             "First 3 digits replaced by \"digit\" : %s%n", secondString);
36
37          System.out.print("String split at commas: ");
38          String[] results = secondString.split(",\\s*"); // split on commas
39          System.out.println(Arrays.toString(results));
40       }
41    }
```

**Fig. 14.23** | `String` methods `replaceFirst`, `replaceAll` and `split`. (Part 2 of 3.)

```
Original String 1: This sentence ends in 5 stars *****
^ substituted for *: This sentence ends in 5 stars ^^^^^
"carets" substituted for "stars": This sentence ends in 5 carets ^^^^^
Every word replaced by "word": word word word word word word ^^^^^

Original String 2: 1, 2, 3, 4, 5, 6, 7, 8
First 3 digits replaced by "digit" : digit, digit, digit, 4, 5, 6, 7, 8
String split at commas: [digit, digit, digit, 4, 5, 6, 7, 8]
```

**Fig. 14.23** | `String` methods `replaceFirst`, `replaceAll` and `split`. (Part 3 of 3.)

# 14.7 Regular Expressions, Class `Pattern` and Class `Matcher` (cont.)

- In addition to the regular-expression capabilities of class `String`, Java provides other classes in package `java.util.regex` that help developers manipulate regular expressions.
- Class `Pattern` represents a regular expression.
- Class `Matcher` contains both a regular-expression pattern and a `CharSequence` in which to search for the pattern.
- `CharSequence` (package `java.lang`) is an interface that allows read access to a sequence of characters.
- The interface requires that the methods `charAt`, `length`, `subSequence` and `toString` be declared.
- Both `String` and `StringBuilder` implement interface `CharSequence`, so an instance of either of these classes can be used with class `Matcher`.

# 14.7 Regular Expressions, Class `Pattern` and Class `Matcher` (cont.)

- If a regular expression will be used only once, `static` `Pattern` method matches can be used.
  - Takes a `String` that specifies the regular expression and a `CharSequence` on which to perform the match.
  - Returns a `boolean` indicating whether the search object (the second argument) matches the regular expression.

## Common Programming Error 14.2

A regular expression can be tested against an object of any class that implements interface `CharSequence`, but the regular expression must be a `String`. Attempting to create a regular expression as a `StringBuilder` is an error.

# 14.7 Regular Expressions, Class `Pattern` and Class `Matcher` (cont.)

- If a regular expression will be used more than once, it's more efficient to use `static` `Pattern` method compile to create a specific `Pattern` object for that regular expression.
  - Receives a `String` representing the pattern and returns a new `Pattern` object, which can then be used to call method matcher
  - Method `matcher` receives a `CharSequence` to search and returns a `Matcher` object.
- `Matcher` method matches performs the same task as `Pattern` method `matches`, but receives no arguments—the search pattern and search object are encapsulated in the `Matcher` object.
- Class `Matcher` provides other methods, including find, lookingAt, replaceFirst and replaceAll.

```
1  // Fig. 14.24: RegexMatches.java
2  // Classes Pattern and Matcher.
3  import java.util.regex.Matcher;
4  import java.util.regex.Pattern;
5
6  public class RegexMatches {
7     public static void main(String[] args) {
8        // create regular expression
9        Pattern expression =
10          Pattern.compile("J.*\\d[0-35-9]-\\d\\d-\\d\\d");
11
12       String string1 = "Jane's Birthday is 05-12-75\n" +
13          "Dave's Birthday is 11-04-68\n" +
14          "John's Birthday is 04-28-73\n" +
15          "Joe's Birthday is 12-17-77";
```

**Fig. 14.24** | Classes `Pattern` and `Matcher`. (Part 1 of 2.)

```
16
17          // match regular expression to string and print matches
18          Matcher matcher = expression.matcher(string1);
19
20          while (matcher.find()) {
21             System.out.println(matcher.group());
22          }
23       }
24    }
```

```
Jane's Birthday is 05-12-75
Joe's Birthday is 12-17-77
```

**Fig. 14.24** | Classes `Pattern` and `Matcher`. (Part 2 of 2.)

# 14.7 Regular Expressions, Class `Pattern` and Class `Matcher` (cont.)

- The dot character "." in a regular expression matches any single character except a newline character.
- `Matcher` method `find` attempts to match a piece of the search object to the search pattern.
  - Each call to this method starts at the point where the last call ended, so multiple matches can be found.
- `Matcher` method `lookingAt` performs the same way, except that it always starts from the beginning of the search object and will always find the first match if there is one.

## Common Programming Error 14.3

Method `matches` (from class `String`, `Pattern` or `Matcher`) will return `true` only if the entire search object matches the regular expression. Methods `find` and `lookingAt` (from class `Matcher`) will return `true` if a portion of the search object matches the regular expression.

# 14.7 Regular Expressions, Class `Pattern` and Class `Matcher` (cont.)

- Java SE 9 adds several new `Matcher` method overloads—`appendReplacement`, `appendTail`, `replaceAll`, `results` and `replaceFirst`
- Methods `appendReplacement` and `appendTail` simply receive `StringBuilder`s rather than `StringBuffer`s
- Methods `replaceAll`, `results` and `replaceFirst` are meant for use with lambdas and streams