Strings

covering

** String Classes: `String`, `StringBuffer`, `StringBuilder`, `StringTokenizer`, `Scanner` and `Character`

** Formatting numerical data

Chapter 3 (sections 3.6+3.7) – "Big Java" book
Chapter 10 + Appendix B – "Head First Java" book
Chapter 9 – "Introduction to Java Programming" book
Chapter 9 – "Java in a Nutshell" book

Strings

- **Strings** are not a basic type in Java – they are objects!
  - But are so common that Java provides some language level support for strings.
  - As in C, string literals are delimited by double quote marks.
    - **Example**: **"Hello"** is an acceptable string literal.

- To use strings, we can (*but don't have to!*) input the **java.lang** package, by adding the statement **import java.lang.String;**.
  - The **java.lang** package is part of the JDK Class Library and provides classes that are fundamental to the Java programming language's design.
  - The **import** keyword tells the compiler that the program uses external packages.

> The **java.lang** package is automatically imported into every Java program.

Strings: Another Property

- Strings are **immutable** (i.e. *can't be changed*): this is for security purposes and to minimise memory usage.
  - **Example**: Ten **String** objects are created (with values **"0"**, **"01"**, …, **"0123456789"**). At the end,
    - variable **s** refers to the **String** object with value **"0123456789"**;
    - there exist 10 **String**s.
      ```
      String s = "0";
      for (int x=1; x<10; x++) { s = s + x; }
      ```

- **String Pool**: Area of memory where **String** literals are put by the JVM when created.
  - JVM doesn't create a duplicate if there's already a **String** in memory with the same value; it refers the reference variable to the existing entry.
  - **Garbage Collector** doesn't cleanup the String Pool!

Strings are immutable (i.e. *can't be changed*) ...

- How *general objects* behave (remember the **Rabbit** class ...):

```java
Rabbit r1 = new Rabbit();
r1.setName("Benji");
Rabbit r2 = r1;
r2.setName("Blinky");
System.out.println(r1.getName());
System.out.println(r2.getName());
```

Prints:

- How *Strings* behave:

```java
String s1 = "Sherlock";
String s2 = s1;
s2 = "Holmes";
System.out.println(s1);
System.out.println(s2);
```

Prints:

Example: <u>Mutable</u> & <u>Immutable</u> Objects

```java
public class Rectangle {
  private int width, height;

  public Rectangle(int h, int w) {
    height = h;
    width = w;
  }
  public int getWidth() {
    return width;
  }
  public int getHeight() {
    return height;
  }
  public void setWidth(int w) {
    width = w;
  }
  public void setHeight(int h){
    height = h;
  }
}
```

```java
public class Colouring {
  private int red, green, blue;

  public Colouring(int r, int g, int b) {
    red = Math.max(0, Math.min(255, r));
    green = Math.max(0, Math.min(255, g));
    blue = Math.max(0, Math.min(255, b));
  }
  public int getRed() { return red; }
  public int getGreen() { return green; }
  public void getBlue() { return blue; }
  public Colouring tint(double t) {
    int r = Math.round(red*t);
    int g = Math.round(green*t);
    int b = Math.round(blue*t);
    return new Colouring(r,g,b);
  }
}
```

Examples of Java API classes whose objects are immutable:
String, **Character**, **Integer**, …

… and things for you to try out!

String Classes: `String`

- Java overloads the **+** operator for string concatenations.
  - Unlike C++, this is pretty much the only operator overloading in Java!
- As strings in Java are objects, methods can be invoked on them.
- String classes:
  - for **constant strings** → `String`;
  - **indexing of string elements**: starts at `0` and ends at `length()-1`.
  - `String` class has several constructors:

```
String s = "HelloWorld!";              // s = "HelloWorld"
String s = new String("HelloWorld!");  // s = "HelloWorld"
String s = new String();               // s is an empty string

char[] Cat_Array ={'t','i','g','e','r','s'};  // like an array
String s = new String(Cat_Array);             // s = "tigers"
String s = new String(Cat_Array,1,2);         // s = "ig"
```

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Methods: `String` Class (1/3)

- **`int length()`**: returns number of characters in a `String` object.

```java
String s = "HelloWorld!";
System.out.println(s.length());         // output is 11
int i = "The rain in Spain".length(); // i = 17
```

- **`char charAt(int index)`**: returns the character at `index`.

```java
char c = "The rain in Spain".charAt(4); // c = 'r'
String s = "HelloWorld!";
System.out.println(s.charAt(5)); // output is W
```

- **`int indexOf(ch)`**: returns `ch`'s first occurrence position; if not found returns **-1**.

```java
int i = "She sells sea-shells on the sea shore".indexOf('s');
// i = 4
```

```
Method                    Return Value
==================================================
indexOf(char ch)          position of first ch
indexOf(String str)       position of first str (string)
lastIndexOf(char ch)      position of last ch
lastIndexOf(String str)   position of last str (string)
==================================================
```

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- **`boolean equals(obj)` / `boolean equalsIgnoreCase(str)`**:

```
if ("black".equals("white")) {
  System.out.println("A deer is a horse.");
}
```

- **`int compareTo(str)`**: compares two strings, returns < ,> , =0 if the compared string is smaller, larger, or equal to **`str`**.

```
String str1 = "Joanna";
String str2 = "James";
int result = str1.compareTo(str2);
if (result < 0)
  System.out.println("str1 comes before str2");
else if (result > 0)
  System.out.println("str1 comes after str2");
else
  System.out.println("str1 and str2 are equal");
```

Methods: `String` Class (3/3)

- **`substring(index1,index2)`**: returns the substring between **index1** and (excluding) **index2**.

  ```
  String s = "HelloWorld!".substring(1,6);
  // S = "elloW";
  ```
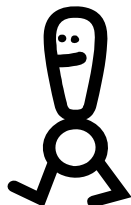
- **`concat(s)`**: concatenates two strings.

  ```
  String s = "Hello".concat("World"); // s = "HelloWorld"
  ```

- **`toUpperCase()`** / **`toLowerCase()`**: convert all characters in string to upper/lower case.

  ```
  String sUpper = "Cat".toUpperCase(); // sUpper = "CAT"
  String sLower = "Cat".toLowerCase(); // sLower = "cat"
  ```

- **`toString()`**: convert input to a string.

  ```
  double d = 12.3;
  String dString = Double.toString(d); // dString = "12.3"
  ```

When you write a new class, you should override the **`toString()`** method.

… and things for you to try out!

String Class : The split() Method

- **split(String s)**: splits the string around matches of the given *regular expression* **s** and returns an array with those substrings.

```java
public class UsingSplit {
    public static void main(String[] args) {
        String str = "bar:foo:bar";
        String[] splitStr = str.split(":");
        for (int i=0; i < splitStr.length; i++)
            System.out.println(splitStr[i]);
    }
}
```

Output is …

```
bar
foo
bar
```

Another example …

```
String[] splitStr = str.split("a");
then output is …
b
r:foo:b
r
```

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Some other methods of the `String` class

- **`void getChars(i,j,A,k)`**: returns characters from **`i`** to **`j`** (excluding), and stores them into *array* **`A`** starting from **`A[k]`**.
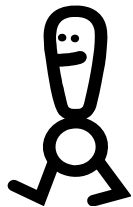
  ```
  char[] A = new char[4];
  "The rain in Spain".getChars(4,8,A,0);
  // A = {'r','a','i','n'}
  ```

- **`substring(index)`**: returns substring from **`index`** to end.

  ```
  String s = "Monkeys".substring(3);          // s = "keys"
  String s = "Monkeys".substring(3,"Monkeys".length()-1);
                                               // s = "key"
  ```

- **`replace(oldCh,newCh)`**: replace **`oldCh`** by **`newCh`** everywhere in the string.

  ```
  String s = "goose".replace('o','e'); // s = "geese"
  ```

For other **`String`** class methods, see the Java API:
https://docs.oracle.com/en/java/javase/13/docs/api/java.base/java/lang/String.html.

StringBuffer & StringBuilder Classes

- Used for <u>variable strings</u>, whereas `String` class is used for constant strings.

  – Usually, you leave it to the system to use the `StringBuffer` class.

  – **Example**: If we write **"Bugs" + " Bunny"**, Java will automatically call a `StringBuffer` class method to generate the string **"Bugs Bunny"**.

- Java uses Unicode (2 bytes per character) → not very efficient. Class `StringBuffer` makes it worse (always has to re-allocate space). To alleviate this, Java always allocates 16 more characters than needed.

  ```
  StringBuffer s = new StringBuffer();
  StringBuffer s = new StringBuffer(20);
  StringBuffer s = new StringBuffer("cat");  // s = "cat"
  ```

- Old Java uses **StringBuffer** – *from Java 5.0 onwards*, **StringBuilder** is used (as it's more efficient).
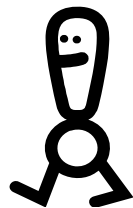
Use when you have <u>lots</u> of **String** manipulation in a program!

StringBuilder Class (*from Java 5.0*)

- Defines the **same methods** as `StringBuffer`, but doesn't declare them as synchronised.
    - Use `StringBuilder` class when a program:
        - uses only one thread: it results in better performance;
        - requires lots of string manipulations.
    - **Synchronised methods**: only one thread at a time can access them!
    - **Thread**: a given "thread" of execution.
        - Java allows for multithreading, i.e. the capability of performing several tasks simultaneously.

Synchronisation and Multithreading: out of scope for this course!

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… and things for you to try out!

Character Class

- The **Character** class is a Wrapper class for a single character, and belongs to the **java.lang** package.
  - Some of its static methods:

    ```
    isLetter(char c)      //    isDigit(char c)

    isUpperCase(char c)   //    isLowerCase(char c)
    ```

  - You can create a **Character** object from a **char** value:

    ```
    Character myCharacter = new Character('p');
    char c = myCharacter.charValue(); // char value wrapped in
                                      // the Character object
    ```

- **Examples** using the **Character** class:

  ```
  Character myCharacter = new Character('c');


  myCharacter.compareTo(new Character('f')); // returns -3
  myCharacter.compareTo(new Character('a')); // returns 2
  myCharacter.equals(new Character('e')); // returns false
  Character.isLetterOrDigit(new Character('?')); // returns false
  ```

StringTokenizer Class

- The **StringTokenizer** class is used to extract tokens and process text from a string, and it belongs to the **java.util** package.

  - It breaks strings into several pieces, e.g. a line of text can be broken into substrings each containing a word.

    ```
    1 string      → "I like learning Java"
    4 substrings  → I    like    learning    Java
    ```

  - Individual words are identified by using individual characters as delimiters.

  - The substrings resulting from breaking a string into several pieces are known as tokens.

  - Delimiters are specified in **StringTokenizer** constructors; the default ones are *space*, *tab*, *new line* and *carriage return*.

StringTokenizer is a <u>legacy class</u>; should **not** be used with new code, but should be understood in relation to existing/old code. Instead, use **String.split()** …

StringTokenizer Constructors

- Constructors:

StringTokenizer for a string with default delimiters; doesn't count delimiters as tokens.
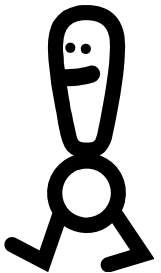
```
StringTokenizer(String s)
StringTokenizer(String s, String delimeters)
StringTokenizer(String s, String delimiters, boolean returnDelimiters)
```

StringTokenizer for a string with specified delimiters; doesn't count delimiters as tokens.

StringTokenizer for a string with specified delimiters; may count delimiters as tokens.

Good programming practice (usually): to provide a no-arguments constructor for a class. **StringTokenizer** doesn't have a no-arguments constructor, because a **StringTokenizer** object must be created for a string!

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Using `StringTokenizer`

```java
String s = "I am from Portugal.";

// Create a StringTokenizer.
StringTokenizer myTokenizer = new StringTokenizer(s);

System.out.println("Number of tokens is " +
                    myTokenizer.countTokens() + ".");
while (myTokenizer.hasMoreTokens())
    System.out.println(myTokenizer.nextToken());
```

Output is …

```
Number of tokens is 4.
I
am
from
Portugal.
```

- **Other Examples**:

```java
StringTokenizer myTokenizer = new StringTokenizer(s, "nu");
StringTokenizer myTokenizer = new StringTokenizer(s, "nu", true);
```

What is the **output**?

How would you rewrite this code using `String.split()`?

Practice Exercise 1

- Answer the following questions:
  - Define the two terms: *token*, *delimiter*.

  - What is the output of this code:

    ```
    StringTokenizer stuff = new
                    StringTokenizer("abc,def,ghi");
    System.out.println(stuff.nextToken());
    ```

  - What is the output of this code:

    ```
    StringTokenizer stuff = new
                    StringTokenizer("abc,def,ghi", ",");
    System.out.println(stuff.nextToken());
    ```

… and things for you to try out!

Scanner Class (*from Java 5.0*)

- Delimiters are single characters in the **StringTokenizer** class; however, the **Scanner** class (of **java.util** package) allows a *word* to be specified as a delimiter.

- Example:

```
String s = "Let your heart guide you.";
Scanner myScanner = new Scanner(s);
myScanner.useDelimiter("you");
while (myScanner.hasNext())
   System.out.println(myScanner.next());
```

Output is …
```
Let
r heart guide
.
```

returns **true** if there are tokens left

returns a token as a string

A word can be a single character, so **Scanner** can specify a single character delimiter!

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Scanner **Class: Other Uses**

- Scanning primitive type values: several methods can be used to obtain a token with a primitive data type value.
    - **Example**:
      ```
      String s = "1 10 100 1000";
      Scanner myScanner = new Scanner(s);
      int sum = 0;
      while (myScanner.hasNext()) { sum += myScanner.nextInt(); }
      System.out.println("Sum = " + sum);
      ```

- Reading console input
    - **Example**:
      ```
      System.out.print("Please enter an int value: ");
      Scanner myScanner = new Scanner(System.in);
      int i = myScanner.nextInt();
      ```

> To scan a string with multiple single characters as delimiters, use `String.split()`. To use a word as the delimiter, use `Scanner`.

The Format Specifier

% [argument_number$] [flags] [width] [.precision] type

```
String.format("I have %,6.2f bugs to fix", 12345.6789);
```

which argument it refers to, if there's more than one

special formatting options, e.g. *inserting commas*, putting *negative numbers in parentheses, left/right alignment*

minimum number of characters used

number of decimal places

%d – decimal
%f – floating point
%x – hexadecimal
%c – character

What about when there's more than one argument?

Output is …
```
I have 12,345.68 bugs to fix
```

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Example: printf *versus* println

```java
public class TestPrintMethods {
  public void printSomeStrings(String firstName, String lastName,
                          int numPets, String petType) {
    System.out.printf("Using printf: %s %s has %d %s.\n",
                      firstName, lastName, numPets, petType);
    System.out.println("Using println: " + firstName + " " +
                      lastName + " has " + numPets + " " +
                      petType + ".");
  }
  public static void main(String args[]) {
    TestPrintMethods test = new TestPrintMethods();
    test.printSomeStrings("John", "Doe", 7, "chickens");
  }
}
```

Output …

```
Using printf: John Doe has 7 chickens.
Using println: John Doe has 7 chickens.
```

Example: Controlling Width and Precision

```java
public void printSomeSalaries() {
  CEO[] softwareCEOs = { new CEO("Jeff Bezos", 567.986323),
                         new CEO("Larry Ellison", 6789.0),
                         new CEO("Bill Gates", 78901234567890.12) };
  System.out.println("SALARIES:");
  for (CEO ceo: softwareCEOs) {
    System.out.printf("%15s: $%,8.2f%n", ceo.getName(), ceo.getSalary());
  }
}
```

```java
public class CEO {
  private String name;
  private double salary; // In millions ($).
  public CEO(String name,double salary) {
    this.name = name; this.salary = salary;
  }
  public String getName() { return(this.name); }
  public double getSalary() { return(this.salary); }
}
```

Output …

```
SALARIES:
     Jeff Bezos: $   567.99
  Larry Ellison: $6,789.00
     Bill Gates: $78,901,234,567,890.12
```

… and things for you to try out!