Object-Oriented Thinking

Introduction to Programming and Computational Problem Solving - 2

CSE 8B

Lecture 9

Announcements

- Assignment 4 is due Oct 26, 11:59 PM
- Quiz 4 is Oct 28
- Assignment 5 will be released Oct 26
  – Due Nov 2, 11:59 PM
- Educational research study
  – Oct 28, weekly survey
- Reading
  – Liang
    - Chapter 10

Object-oriented thinking

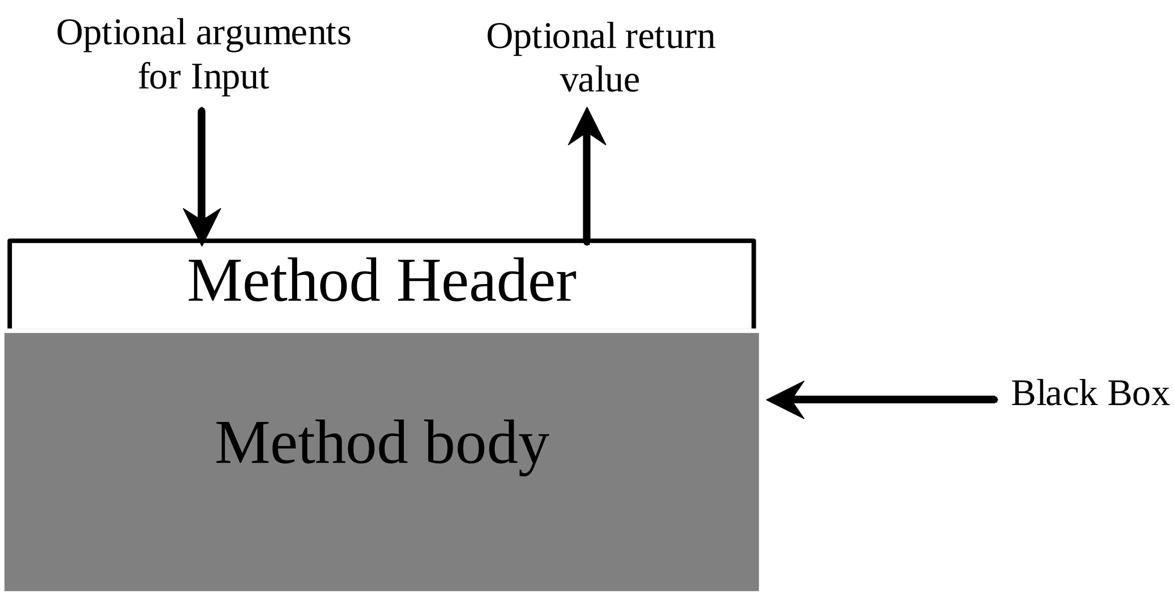
- The advantages of object-oriented programming over procedural programming
- Classes provide more flexibility and modularity for building reusable software
- How to solve problems using the object-oriented paradigm
- Class design

Procedural programming vs object-oriented programming

- Procedural programming
  - Data and operations on data are separate
  - Requires passing data to methods
- Object-oriented programming
  - Data and operations on data are in an object
  - Organizes programs like the real world
    - All objects are associated with both attributes and activities
  - Using objects improves software reusability and makes programs easier to both develop and maintain

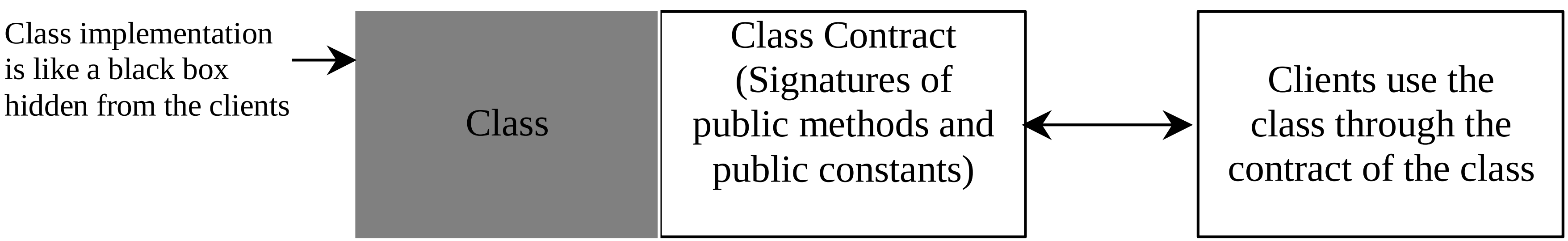
Procedural programming: method abstraction

- You can think of the method body as a black box that contains the detailed implementation for the method



Object-oriented programming: class abstraction and encapsulation

- *Class abstraction* means to separate class implementation from the use of the class
- The creator of the class provides a description of the class and lets the user know how the class can be used
  - The *class contract*
- The user of the class does not need to know how the class is implemented
- The detail of implementation is encapsulated and hidden from the user
  - *Class encapsultion*
  - A class is called an *abstract data type* (ADT)



Class abstraction and encapsulation

- For example, a class for a loan

Loan	
-annualInterestRate: double	The annual interest rate of the loan (default: 2.5).
-numberOfYears: int	The number of years for the loan (default: 1)
-loanAmount: double	The loan amount (default: 1000).
-loanDate: Date	The date this loan was created.
+Loan()	Constructs a default Loan object.
+Loan(annualInterestRate: double, numberOfYears: int, loanAmount: double)	Constructs a loan with specified interest rate, years, and loan amount.
+getAnnualInterestRate(): double	Returns the annual interest rate of this loan.
+getNumberOfYears(): int	Returns the number of the years of this loan.
+getLoanAmount(): double	Returns the amount of this loan.
+getLoanDate(): Date	Returns the date of the creation of this loan.
+setAnnualInterestRate(annualInterestRate: double): void	Sets a new annual interest rate to this loan.
+setNumberOfYears(numberOfYears: int): void	Sets a new number of years to this loan.
+setLoanAmount(loanAmount: double): void	Sets a new amount to this loan.
+getMonthlyPayment(): double	Returns the monthly payment of this loan.
+getTotalPayment(): double	Returns the total payment of this loan.

The creator of the class provides a description of the class and lets the user know how the class can be used

The *class contract*

Class abstraction and encapsulation

- A class is designed for use by many different users (or customers or clients)
- To be useful in a wide range of applications, a class should provide a variety of ways for customization through properties, and constructors and methods that, together, are **minimal and complete**

Thinking in objects

- Procedural programming focuses on designing methods
- Object-oriented programming
  - Couples data and methods together into objects
  - Focuses on designing objects and operations on objects
- Object-orientated programming combines the power of procedural programming with an additional component that integrates data with operations into objects

Class relationships

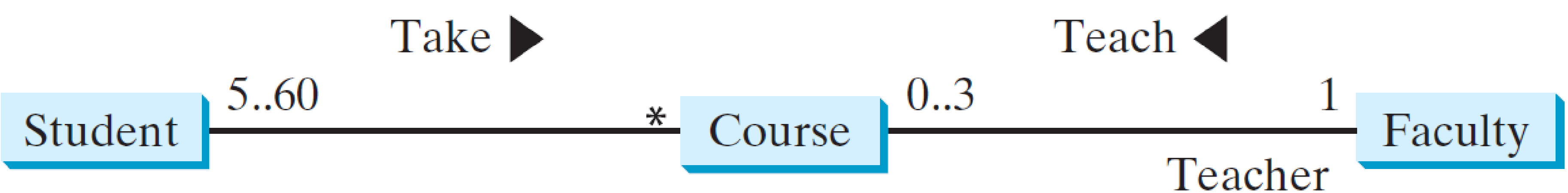
- To design classes, one must understand the relationships among classes
  - Association
  - Aggregation
  - Composition
  - Inheritance (covered next week)

Association

- A general binary relationship that describes an activity between two classes
- For example
  - A student taking course is an association between the `Student` class and the `Course` class
  - A faculty member teaching a course is an association between the `Faculty` class and the `Course` class

Association

- Multiplicity
  - The number of objects of a class
- For example
  - Each student may take any number (*) of courses
  - Each course must have 5 to 60 students
  - Each course is taught by 1 faculty member
  - Each faculty member must teach 0 to 3 courses



Association

- In Java, associations can be implemented using data fields and methods
  - For example
    - A student takes a course
      `addCourse` method in `Student` class
      `addStudent` method in `Course` class
    - A faculty member teaches a course
      `addCourse` method in `Faculty` class
      `setFaculty` method in `Course` class
    - The Student class may store the courses a student is taking
      `private Course[] courseList;`
    - The Faculty class may store the courses a faculty member is teaching
      `private Course[] courseList;`
- **There are many possible ways to implement association relationships**

Aggregation

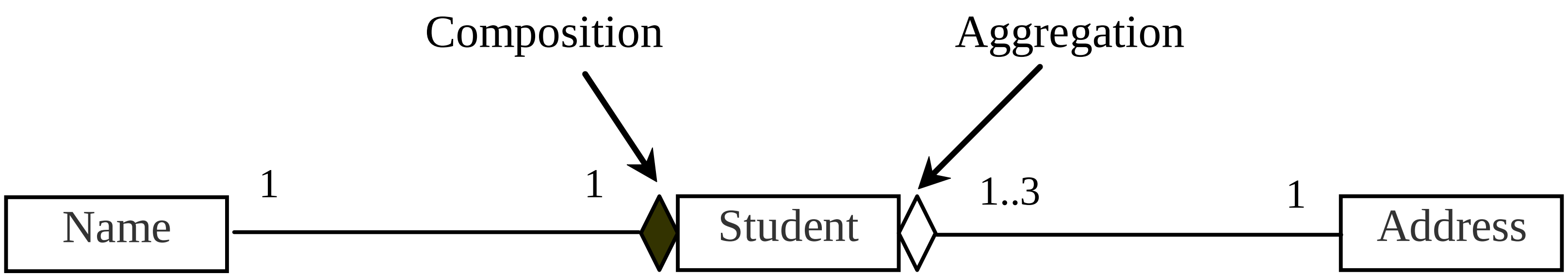
- Special form of association representing an owner-subject relationship
  - The *owner* object is called an *aggregating object* and its class is called an *aggregating class*
  - The *subject* object is called an *aggregated object* and its class is called an *aggregated class*
- Models **has-a** relationships
  - For example
    - A student **has-a** name
    - A student **has-a**n address

Composition

- Aggregation between two objects is called *composition* if the existence of the aggregated object is dependent on the aggregating object
  - Exclusive ownership of the subject
  - The subject (i.e., aggregated object) cannot (conceptually) exist on its own
    - For example
      - A book **has-a** page and when the book is destroyed, so is the page
      - A page has no meaning or purpose without the book

Aggregation and composition

- For example
  - When the student object is destroyed
    - Their name is destroyed (composition)
    - Their address is not destroyed (aggregation)



Each address is shared by up to 3 students

Aggregation and composition

- Usually represented as a data field in the aggregating class

```
public class Name {
  ...
}
```

Aggregated class

```
public class Student {
  private Name name;
  private Address address;

  ...
}
```

Aggregating class

```
public class Address {
  ...
}
```

Aggregated class

Aggregation between same class

- Aggregation may exist between objects of the same class
  - For example, a person may have a supervisor

```
public class Person {
  // The type for the data is the class itself
  private Person supervisor;
  ...
}
```

  - For example, a person may have multiple supervisors

```
public class Person {
  // The type for the data is the class itself
  private Person[] supervisors;
  ...
}
```

Aggregation or composition

- Warning: Since aggregation and composition relationships are represented using classes in similar ways, many texts do not differentiate them, calling both compositions

Class design and development

- For example, a class for a course

Course	
-courseName: String	The name of the course.
-students: String[]	An array to store the students for the course.
-numberOfStudents: int	The number of students (default: 0).
+Course(courseName: String)	Creates a course with the specified name.
+getCourseName(): String	Returns the course name.
+addStudent(student: String): void	Adds a new student to the course.
+dropStudent(student: String): void	Drops a student from the course.
+getStudents(): String[]	Returns the students in the course.
+getNumberOfStudents(): int	Returns the number of students in the course.

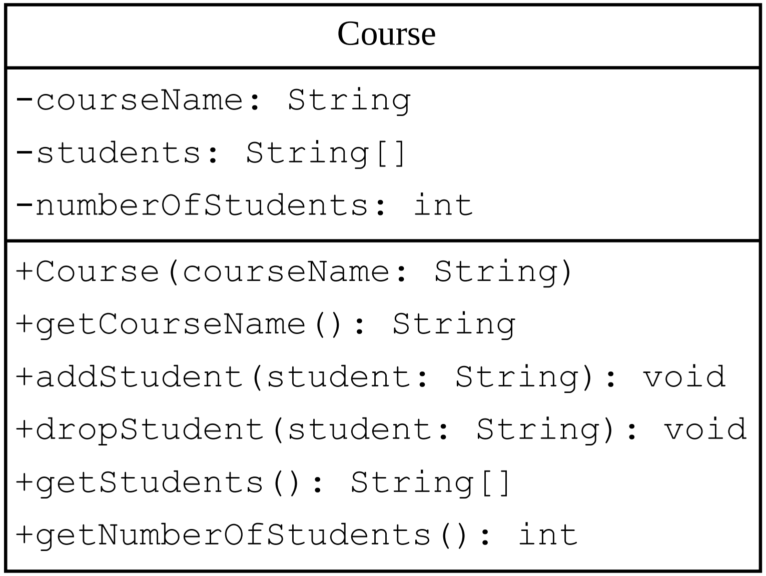
Class design and development

Course
-courseName: String
-students: String[]
-numberOfStudents: int
+Course(courseName: String)
+getCourseName(): String
+addStudent(student: String): void
+dropStudent(student: String): void
+getStudents(): String[]
+getNumberOfStudents(): int

```
public class TestCourse {
  public static void main(String[] args) {
    Course course1 = new Course("Data Structures");
    Course course2 = new Course("Database Systems");

    course1.addStudent("Peter Jones");
    course1.addStudent("Brian Smith");
    course1.addStudent("Anne Kennedy");

    course2.addStudent("Peter Jones");
    course2.addStudent("Steve Smith");

    System.out.println("Number of students in course1: "
      + course1.getNumberOfStudents());
    String[] students = course1.getStudents();
    for (int i = 0; i < course1.getNumberOfStudents(); i++)
      System.out.print(students[i] + ", ");

    System.out.println();
    System.out.print("Number of students in course2: "
      + course2.getNumberOfStudents());
  }
}
```

Class design and development

```
public class Course {
  private String courseName;
  private String[] students = new String[4];
  private int numberOfStudents;

  public Course(String courseName) {
    this.courseName = courseName;
  }

  public void addStudent(String student) {
    students[numberOfStudents] = student;
    numberOfStudents++;
  }

  public String[] getStudents() {
    return students;
  }

  public int getNumberOfStudents() {
    return numberOfStudents;
  }

  public String getCourseName() {
    return courseName;
  }

  public void dropStudent(String student) {
    // TODO
  }
}
```



Class design and development

- Use a UML class diagram to design the class
- Write a test program that uses the class
  - Developing a class and using a class are two separate tasks
  - It is easier to implement a class if you must use the class
- Implement the class
- Use Javadoc to document the class (contract)

Object-oriented thinking

- Classes provide more flexibility and modularity for building reusable software
- Class abstraction and encapsulation
  - Separate class implementation from the use of the class
  - The creator of the class provides a description of the class and let the user know how the class can be used
  - The user of the class does not need to know how the class is implemented
  - The detail of implementation is encapsulated and hidden from the user

Primitive data type values as objects

- A primitive data type is not an object
- But it can be wrapped in an object using a Java API wrapper class

  `Boolean`

  `Character` (**not** `Char`)

  `Short`

  `Byte`

  `Integer` (**not** `Int`)

  `Long`

  `Float`

  `Double`

Notes

- The wrapper classes **do not have no-arg constructors**
- The instances of all wrapper classes are **immutable** (i.e., their internal values cannot be changed once the objects are created)

Integer and Double wrapper classes

java.lang.Integer	**java.lang.Double**
-value: int	-value: double
+MAX_VALUE: int	+MAX_VALUE: double
+MIN_VALUE: int	+MIN_VALUE: double
+Integer(value: int)	+Double(value: double)
+Integer(s: String)	+Double(s: String)
+byteValue(): byte	+byteValue(): byte
+shortValue(): short	+shortValue(): short
+intValue(): int	+intValue(): int
+longVlaue(): long	+longVlaue(): long
+floatValue(): float	+floatValue(): float
+doubleValue():double	+doubleValue():double
+compareTo(o: Integer): int	+compareTo(o: Double): int
+toString(): String	+toString(): String
+valueOf(s: String): Integer	+valueOf(s: String): Double
+valueOf(s: String, radix: int): Integer	+valueOf(s: String, radix: int): Double
+parseInt(s: String): int	+parseDouble(s: String): double
+parseInt(s: String, radix: int): int	+parseDouble(s: String, radix: int): double

Wrapper classes

- Constructors
- Class Constants `MAX_VALUE` and `MIN_VALUE`
- Conversion Methods

Numeric wrapper class constructors

- You can construct a wrapper object either from a primitive data type value or from a string representing the numeric value
  - For example, the constructors for `Integer` and `Double` are

```
public Integer(int value)
public Integer(String s)
public Double(double value)
public Double(String s)
```

Numeric wrapper class constants

- Each numerical wrapper class has the constants `MAX_VALUE` and `MIN_VALUE`
- `MAX_VALUE` represents the maximum value of the corresponding primitive data type
- For `Byte`, `Short`, `Integer`, and `Long`, `MIN_VALUE` represents the minimum byte, short, int, and long values
- For `Float` and `Double`, `MIN_VALUE` represents the minimum **positive** `float` and `double` values

Numeric wrapper class conversion methods

- Each numeric wrapper class implements the abstract methods `doubleValue`, `floatValue`, `intValue`, `longValue`, and `shortValue`
  - Defined in the abstract `Number` class (covered in three weeks)
- These methods "convert" objects into primitive type values

Numeric wrapper class static `valueOf` methods

- The numeric wrapper classes have a useful class method `valueOf(String s)`
- This method creates a new object initialized to the value represented by the specified string
  - For example

```
Double doubleObject = Double.valueOf("12.4");
Integer integerObject = Integer.valueOf("12");
```

Numeric wrapper class static parsing methods

- Each numeric wrapper class has two overloaded parsing methods to parse a numeric string into an appropriate numeric value based on 10 or any specified radix (e.g., 2 for binary, 8 for octal, 10 for decimal, 16 for hexadecimal)
  - For example

    `Integer.parseInt("13")` returns `13`

    `Integer.parseInt("13", 10)` returns `13`

    `Integer.parseInt("1A", 16)` returns `26`

Automatic conversion between primitive types and wrapper class types

- Converting a primitive value to a wrapper object is called *boxing*
- Converting a wrapper object to a primitive value is called *unboxing*
- The Java compiler will automatically convert a primitive data type value to an object using a wrapper class (*autoboxing*) and vice versa (*autounboxing*), depending on the context

Automatic conversion between primitive types and wrapper class types

```
Integer[] intArray = {new Integer(2),
  new Integer(4), new Integer(3)};
```

(a)

Equivalent

```
Integer[] intArray = {2, 4, 3};
```

(b)

Autoboxing

```
Integer[] intArray = {1, 2, 3};
System.out.println(intArray[0] + intArray[1] + intArray[2]);
```

Autounboxing

`BigInteger` and `BigDecimal` classes

- If you need to compute with very large integers or high precision floating-point values, you can use the `BigInteger` and `BigDecimal` classes in the `java.math` package
- Both are **immutable**
- Both extend the `Number` class and implement the `Comparable` interface (covered in three weeks)

BigInteger and BigDecimal classes

```
BigInteger a = new BigInteger("9223372036854775807");
BigInteger b = new BigInteger("2");
BigInteger c = a.multiply(b); // 9223372036854775807 * 2
System.out.println(c);
```

```
BigDecimal a = new BigDecimal(1.0);
BigDecimal b = new BigDecimal(3);
BigDecimal c = a.divide(b, 20, BigDecimal.ROUND_UP);
System.out.println(c);
```

Scale (the argument 20)

`String` class

- The `String` class has 13 constructors and more than 40 methods
- A good example for learning classes and objects

Constructing strings

- Create from a string literal
  - Syntax
    ```
    String newString = new String(stringLiteral);
    ```
  - Example
    ```
    String message = new String("Welcome to Java");
    ```
  - Since strings are used frequently, Java provides a shorthand initializer for creating a string
    ```
    String message = "Welcome to Java";
    ```
- Create from an array of characters
  - Syntax
    ```
    String newString = new String(charArray);
    ```
    - where, for example
      ```
      char[] charArray = {'C', 'S', 'E', ' ', '8', 'B'};
      ```

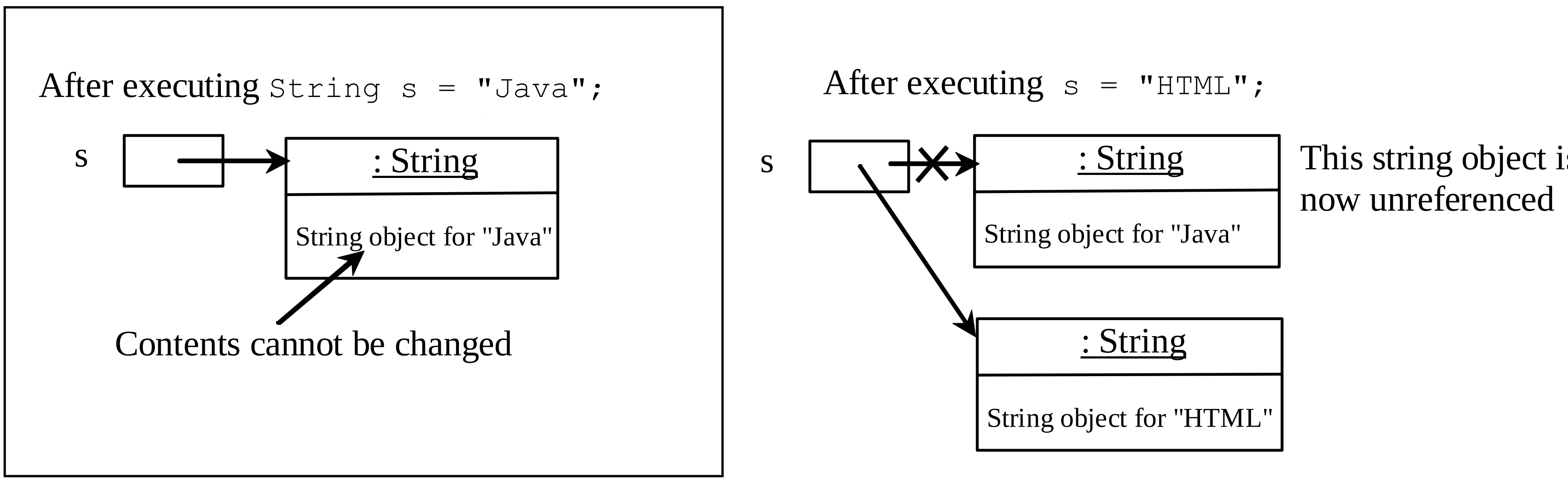
Strings are immutable

- A `String` object is immutable (i.e., its contents cannot be changed once the string is created)
- The following code does not change the contents of the string

```
String s = "Java";
s = "HTML";
```

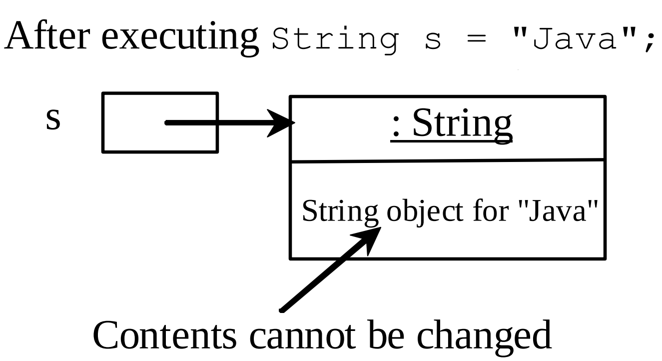
Strings are immutable

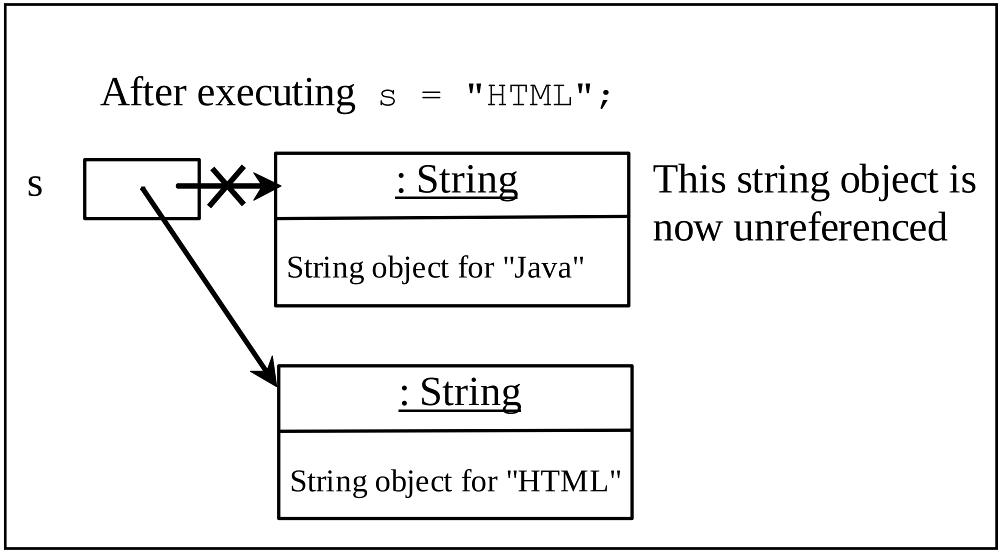
```
String s = "Java";
s = "HTML";
```



Strings are immutable

```
String s = "Java";
s = "HTML";
```





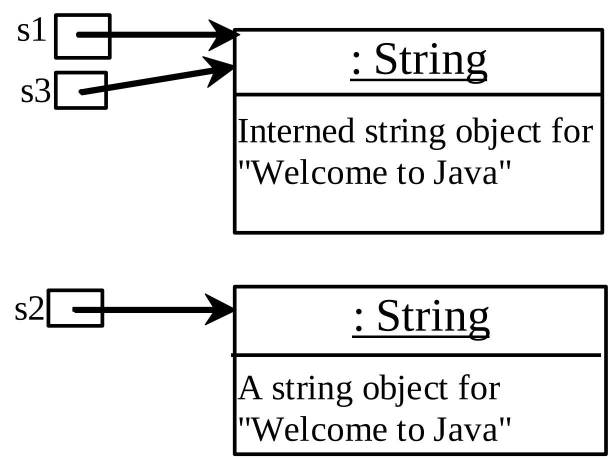
Interned strings

- Since strings are immutable and are frequently used, to improve efficiency and save memory, the Java Virtual Machine (JVM) uses a unique instance for string literals with the same character sequence
- Such an instance is called *interned*

Interned strings

- A new object is created if you use the new operator
- If you use the string initializer, no new object is created if the interned object is already created

```
String s1 = "Welcome to Java";

String s2 = new String("Welcome to Java");

String s3 = "Welcome to Java";

System.out.println("s1 == s2 is " + (s1 == s2));
System.out.println("s1 == s3 is " + (s1 == s3));
```



`s1 == s2` is `false`

`s1 == s3` is `true`

Replacing and splitting strings

java.lang.String	
+replace(oldChar: char, newChar: char): String	Returns a new string that replaces all matching character in this string with the new character.
+replaceFirst(oldString: String, newString: String): String	Returns a new string that replaces the first matching substring in this string with the new substring.
+replaceAll(oldString: String, newString: String): String	Returns a new string that replace all matching substrings in this string with the new substring.
+split(delimiter: String): String[]	Returns an array of strings consisting of the substrings split by the delimiter.

Replacing a string

- `"Welcome".replace('e', 'A')` returns a new string `WAlcomA`
- `"Welcome".replaceFirst("e", "AB")` returns a new string `WABlcome`
- `"Welcome".replace("e", "AB")` returns a new string `WABlcomAB`
- `"Welcome".replace("el", "AB")` returns a new string `WABcome`

Splitting a string

- Split a string into an array of strings
  - For example, using # as a delimiter

```
String[] tokens = "CSE#8B#uses#Java".split("#", 0);
for (int i = 0; i < tokens.length; i++)
  System.out.print(tokens[i] + " ");
```

  - Displays `CSE 8B uses Java`

Matching, replacing, and splitting by patterns

- You can match, replace, or split a string by specifying a pattern
  - For example

```
"Java".equals("Java");
"Java".matches("Java");
```

- This is an extremely useful and powerful feature known as *regular expression*
  - Liang, appendix H
  - https://docs.oracle.com/javase/8/docs/api/java/util/regex/Pattern.html#sum
  - https://docs.oracle.com/en/java/javase/11/docs/api/java.base/java/util/regex/Pattern.html#sum

Convert character and numbers to strings

- The `String` class provides several static `valueOf` methods for converting a character, an array of characters, and numeric values to strings
- These methods have the same name `valueOf` with different argument types `char`, `char[]`, `double`, `long`, `int`, and `float`
  - For example, to convert a `double` value to a string, use `String.valueOf(5.44)`
    - The return value is string consists of characters `'5'`, `'.'`, `'4'`, and `'4'`
    - Compare with `String s = 5.44 + "";`

`StringBuilder` and `StringBuffer` classes

- The `StringBuilder` and `StringBuffer` classes are alternatives to the `String` class
- In general, a `StringBuilder` or `StringBuffer` can be used wherever a string is used
- `StringBuilder` and `StringBuffer` are more flexible than `String`
- You can add, insert, or append new contents into a string buffer, whereas the value of a `String` object is fixed once the string is created

`StringBuilder` constructors

java.lang.StringBuilder	
+StringBuilder()	Constructs an empty string builder with capacity 16.
+StringBuilder(capacity: int)	Constructs a string builder with the specified capacity.
+StringBuilder(s: String)	Constructs a string builder with the specified string.

Modifying strings in the builder

java.lang.StringBuilder	
+append(data: char[]): StringBuilder	Appends a char array into this string builder.
+append(data: char[], offset: int, len: int): StringBuilder	Appends a subarray in data into this string builder.
+append(v: *aPrimitiveType*): StringBuilder	Appends a primitive type value as a string to this builder.
+append(s: String): StringBuilder	Appends a string to this string builder.
+delete(startIndex: int, endIndex: int): StringBuilder	Deletes characters from startIndex to endIndex.
+deleteCharAt(index: int): StringBuilder	Deletes a character at the specified index.
+insert(index: int, data: char[], offset: int, len: int): StringBuilder	Inserts a subarray of the data in the array to the builder at the specified index.
+insert(offset: int, data: char[]): StringBuilder	Inserts data into this builder at the position offset.
+insert(offset: int, b: *aPrimitiveType*): StringBuilder	Inserts a value converted to a string into this builder.
+insert(offset: int, s: String): StringBuilder	Inserts a string into this builder at the position offset.
+replace(startIndex: int, endIndex: int, s: String): StringBuilder	Replaces the characters in this builder from startIndex to endIndex with the specified string.
+reverse(): StringBuilder	Reverses the characters in the builder.
+setCharAt(index: int, ch: char): void	Sets a new character at the specified index in this builder.

The `toString`, `capacity`, `length`, `setLength`, and `charAt` methods

java.lang.StringBuilder	
+toString(): String	Returns a string object from the string builder.
+capacity(): int	Returns the capacity of this string builder.
+charAt(index: int): char	Returns the character at the specified index.
+length(): int	Returns the number of characters in this builder.
+setLength(newLength: int): void	Sets a new length in this builder.
+substring(startIndex: int): String	Returns a substring starting at startIndex.
+substring(startIndex: int, endIndex: int): String	Returns a substring from startIndex to endIndex-1.
+trimToSize(): void	Reduces the storage size used for the string builder.

Next Lecture

- Inheritance
- Reading
  - Liang
    - Chapter 11