Lecture 3: Strings (Ch 9), This Pointer, and Wrapper Classes (Ch 10)

Adapted by Fangzhen Lin for COMP3021 from Y. Danial Liang’s PowerPoints for Introduction to Java Programming, Comprehensive Version, 9/E, Pearson, 2013.

Motivations

- More on Java classes: variable scopes and the “this” pointer.
- To learn some important build-in classes, especially those related to string processing which is very important in many programs: A majority of the programs process textual information
  - Reports/Financial Information/Documents in general.
- Two main functions
  - Editing/Filtering
  - Storing/Retrieving

Objectives

- To determine the scope of variables in the context of a class (§10.3).
- To use the keyword **this** to refer to the calling object itself (§10.4).
- To use the **String** class to process fixed strings (§9.2).
- To construct strings (§9.2.1).
- To understand that strings are immutable and to create an interned string (§9.2.2).
- To learn operators on strings (§9.2).
- To check whether a string is a palindrome (§9.3).
- To convert hexadecimal numbers to decimal numbers (§9.4).
- To use the **Character** class to process a single character (§9.5).
- To use the **StringBuilder** and **StringBuffer** classes to process flexible strings (§9.6).
- To distinguish among the **String**, **StringBuilder**, and **StringBuffer** classes (§9.2–9.6).
- To learn how to pass arguments to the **main** method from the command line (§9.7).
- To create objects for primitive values using the wrapper classes (**Byte**, **Short**, **Integer**, **Long**, **Float**, **Double**, **Character**, and **Boolean**) (§10.12).
- To simplify programming using automatic conversion between primitive types and wrapper class types (§10.13).
- To use the **BigInteger** and **BigDecimal** classes for computing very large numbers with arbitrary precisions (§10.14).

Scope of Variables

- The scope of instance and static variables is the entire class. They can be declared anywhere inside a class.
- The scope of a local variable starts from its declaration and continues to the end of the block that contains the variable. A local variable must be initialized explicitly before it can be used.

The this Keyword

- The this keyword is the name of a reference that refers to an object itself. One common use of the this keyword is reference a class's *hidden data fields*.
- Another common use of the this keyword to enable a constructor to invoke another constructor of the same class.

Reference the Hidden Data Fields

```
public class F {
  private int i = 5;
  private static double k = 0;

  void setI(int i) {
    this.i = i;
  }

  static void setK(double k) {
    F.k = k;
  }
}
```

```
Suppose that f1 and f2 are two objects of F.
F f1 = new F(); F f2 = new F();

Invoking f1.setI(10) is to execute
   this.i = 10, where this refers f1

Invoking f2.setI(45) is to execute
   this.i = 45, where this refers f2
```

Calling Overloaded Constructor

```
public class Circle {
  private double radius;

  public Circle(double radius) {
    this.radius = radius;
  }

  public Circle() {
    this(1.0);
  }

  public double getArea() {
    return this.radius * this.radius * Math.PI;
  }
}
```

this must be explicitly used to reference the data field radius of the object being constructed

this is used to invoke another constructor

Every instance variable belongs to an instance represented by this, which is normally omitted

The `String` Class

- Constructing a String:
  - `String message = "Welcome to Java“;`
  - `String message = new String("Welcome to Java“);`
  - `String s = new String();`
- Obtaining String length and Retrieving Individual Characters in a string
- String Concatenation (concat)
- Substrings (substring(index), substring(start, end))
- Comparisons (equals, compareTo)
- String Conversions
- Finding a Character or a Substring in a String
- Conversions between Strings and Arrays
- Converting Characters and Numeric Values to Strings

Constructing Strings

String newString = new String(stringLiteral);

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";

Strings Are Immutable

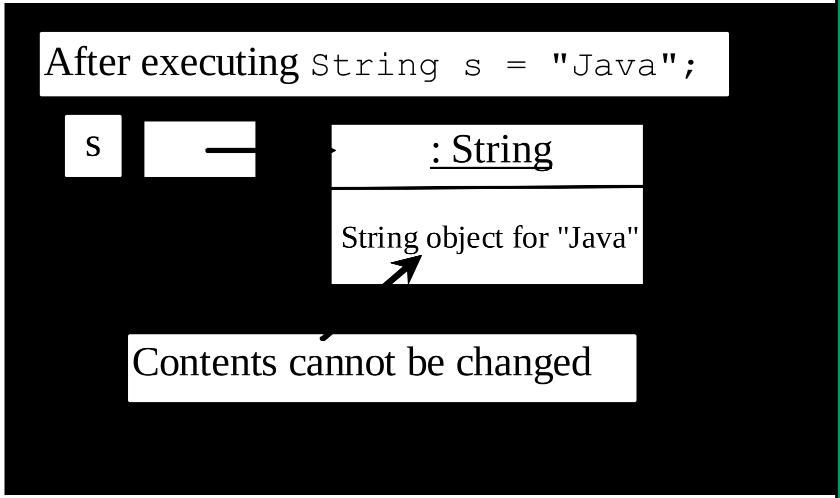
A String object is immutable; its contents cannot be changed. Does the following code change the contents of the string?

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

animation

Trace Code

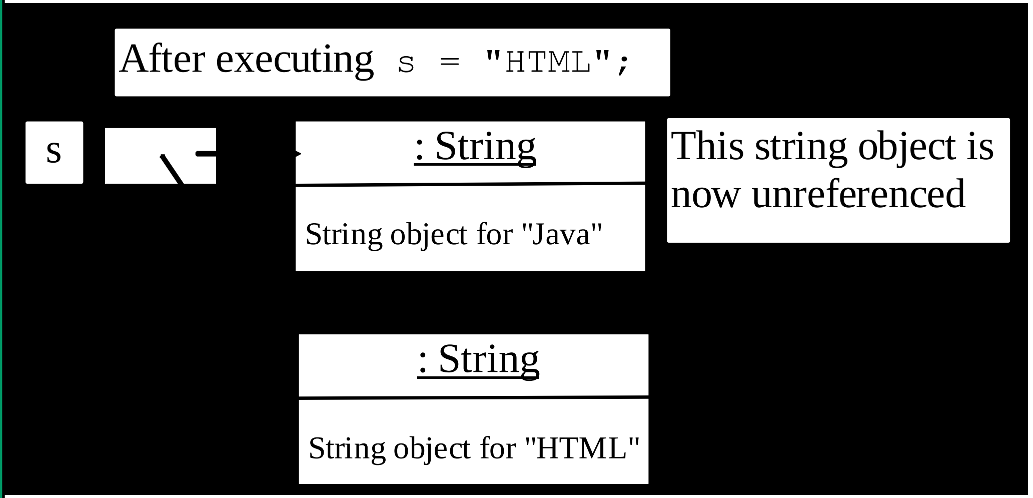
```
String s = "Java";

s = "HTML";
```


After executing String s = "Java";
s
: String
String object for "Java"
Contents cannot be changed

animation

Trace Code

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

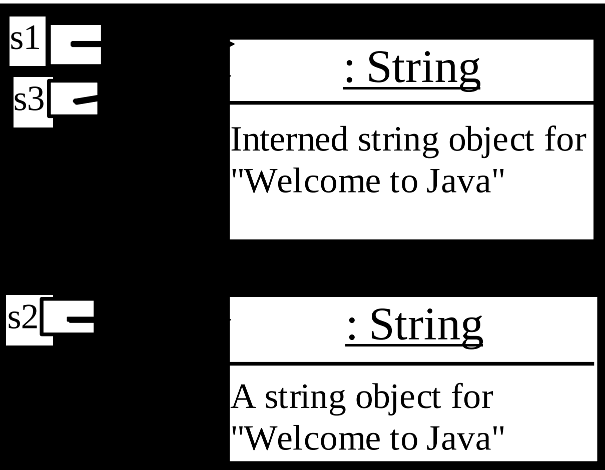

After executing s = "HTML";
s
: String
String object for "Java"
This string object is now unreferenced
: String
String object for "HTML"

Interned Strings

Since strings are immutable and are frequently used, to improve efficiency and save memory, the JVM uses a unique instance for string literals with the same character sequence. Such an instance is called *interned*. For example, the following statements:

Examples

```
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
s3
s2
: String
Interned string object for "Welcome to Java"
: String
A string object for "Welcome to Java"

display

s1 == s2 is false

s1 == s3 is true

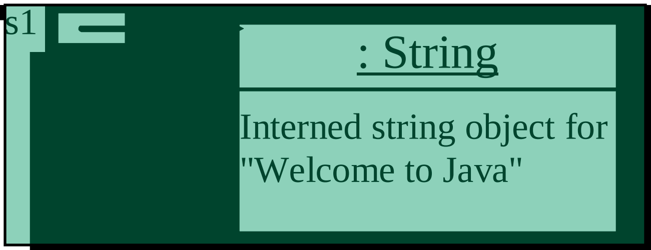
A new object is created if you use the new operator.

If you use the string initializer, no new object is created if the interned object is already created.

animation

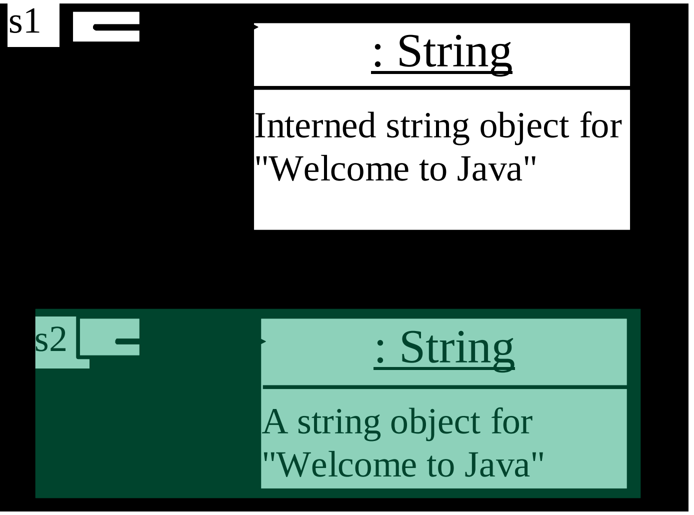
Trace Code

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

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

String s3 = "Welcome to Java";
```



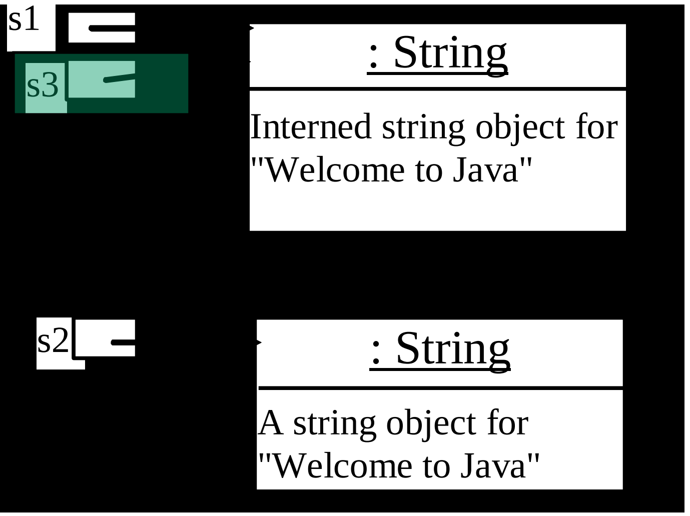
Trace Code

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

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

String s3 = "Welcome to Java";
```


s1
: String
Interned string object for "Welcome to Java"
s2
: String
A string object for "Welcome to Java"

Trace Code

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

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

String s3 = "Welcome to Java";
```


s1
s3
s2
: String
Interned string object for "Welcome to Java"
: String
A string object for "Welcome to Java"

String Comparisons

java.lang.String	
+equals(s1: Object): boolean	Returns true if this string is equal to string s1.
+equalsIgnoreCase(s1: String): boolean	Returns true if this string is equal to string s1 case-insensitive.
+compareTo(s1: String): int	Returns an integer greater than 0, equal to 0, or less than 0 to indicate whether this string is greater than, equal to, or less than s1.
+compareToIgnoreCase(s1: String): int	Same as compareTo except that the comparison is case-insensitive.
+regionMatches(toffset: int, s1: String, offset: int, len: int): boolean	Returns true if the specified subregion of this string exactly matches the specified subregion in string s1.
+regionMatches(ignoreCase: boolean, toffset: int, s1: String, offset: int, len: int): boolean	Same as the preceding method except that you can specify whether the match is case-sensitive.
+startsWith(prefix: String): boolean	Returns true if this string starts with the specified prefix.
+endsWith(suffix: String): boolean	Returns true if this string ends with the specified suffix.

String Comparisons

☞ `equals`

```
String s1 = new String("Welcome“);
String s2 = “Welcome";

if (s1.equals(s2)){
  // s1 and s2 have the same contents
}

if (s1 == s2) {
 // s1 and s2 have the same reference
}
```

String Comparisons, cont.

☞ `compareTo(Object object)`

```
String s1 = new String("Welcome“);
String s2 = “Welcome";

if (s1.compareTo(s2) > 0) {
  // s1 is greater than s2
}
else if (s1.compareTo(s2) == 0) {
  // s1 and s2 have the same contents
}
else
   // s1 is less than s2
```

String Length, Characters, and Combining Strings

java.lang.String	
+length(): int	Returns the number of characters in this string.
+charAt(index: int): char	Returns the character at the specified index from this string.
+concat(s1: String): String	Returns a new string that concatenate this string with string s1.

Finding String Length

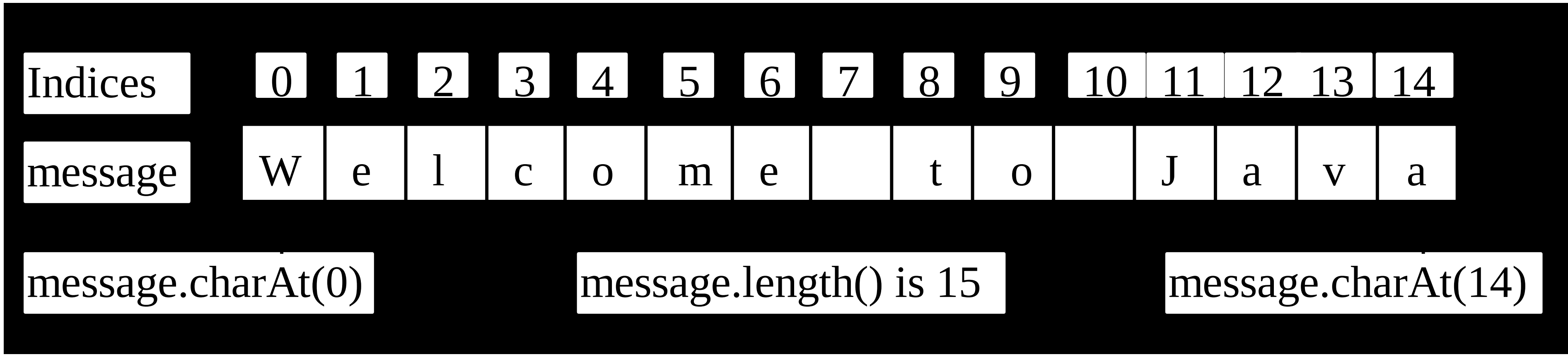
Finding string length using the `length()` method:

```
message = "Welcome";
```

`message.length()` (returns `7`)

Retrieving Individual Characters in a String

- ☞ Do not use `message[0]`
- ☞ Use `message.charAt(index)`
- ☞ Index starts from `0`



String Concatenation

```
String s3 = s1.concat(s2);
```

String s3 = s1 + s2;

s1 + s2 + s3 + s4 + s5 same as

(((s1.concat(s2)).concat(s3)).concat(s4)).concat(s5);

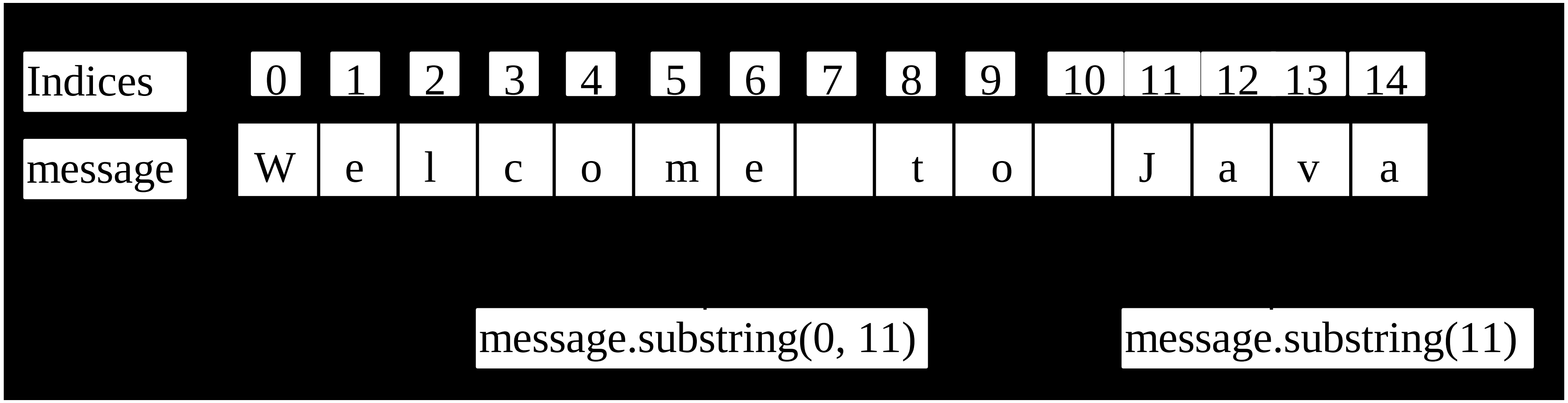
Extracting Substrings

java.lang.String	
+substring(beginIndex: int): String	Returns this string's substring that begins with the character at the specified beginIndex and extends to the end of the string, as shown in Figure 8.6.
+substring(beginIndex: int, endIndex: int): String	Returns this string's substring that begins at the specified beginIndex and extends to the character at index endIndex – 1, as shown in Figure 8.6. Note that the character at endIndex is not part of the substring.

Extracting Substrings

You can extract a single character from a string using the charAt method. You can also extract a substring from a string using the substring method in the String class.

```
String s1 = "Welcome to Java";
String s2 = s1.substring(0, 11) + "HTML";
```



Converting, Replacing, and Splitting Strings

java.lang.String	
+toLowerCase(): String	Returns a new string with all characters converted to lowercase.
+toUpperCase(): String	Returns a new string with all characters converted to uppercase.
+trim(): String	Returns a new string with blank characters trimmed on both sides.
+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.

Examples

"Welcome".toLowerCase() returns a new string, welcome.

"Welcome".toUpperCase() returns a new string, WELCOME.

" Welcome ".trim() returns a new string, Welcome.

"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

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

displays

Java HTML Perl

Matching, Replacing and Splitting by Patterns

You can match, replace, or split a string by specifying a pattern. This is an extremely useful and powerful feature, commonly known as *regular expression*. Regular expression is complex to beginning students. For this reason, two simple patterns are used in this section. Please refer to Supplement III.F, “Regular Expressions,” for further studies.

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

"Java is fun".matches("Java.*");
"Java is cool".matches("Java.*");
```

Matching, Replacing and Splitting by Patterns

The replaceAll, replaceFirst, and split methods can be used with a regular expression. For example, the following statement returns a new string that replaces $, +, or # in "a+b$#c" by the string NNN.

```
String s = "a+b$#c".replaceAll("[$+#]", "NNN");
System.out.println(s);
```

Here the regular expression [$+#] specifies a pattern that matches $, +, or #. So, the output is aNNNbNNNNNNc.

Matching, Replacing and Splitting by Patterns

The following statement splits the string into an array of strings delimited by some punctuation marks.

```
String[] tokens = "Java,C?C#,C++".split("[.,:;?]");

for (int i = 0; i < tokens.length; i++)
  System.out.println(tokens[i]);
```

Finding a Character or a Substring in a String

java.lang.String	
+indexOf(ch: char): int	Returns the index of the first occurrence of ch in the string. Returns -1 if not matched.
+indexOf(ch: char, fromIndex: int): int	Returns the index of the first occurrence of ch after fromIndex in the string. Returns -1 if not matched.
+indexOf(s: String): int	Returns the index of the first occurrence of string s in this string. Returns -1 if not matched.
+indexOf(s: String, fromIndex: int): int	Returns the index of the first occurrence of string s in this string after fromIndex. Returns -1 if not matched.
+lastIndexOf(ch: int): int	Returns the index of the last occurrence of ch in the string. Returns -1 if not matched.
+lastIndexOf(ch: int, fromIndex: int): int	Returns the index of the last occurrence of ch before fromIndex in this string. Returns -1 if not matched.
+lastIndexOf(s: String): int	Returns the index of the last occurrence of string s. Returns -1 if not matched.
+lastIndexOf(s: String, fromIndex: int): int	Returns the index of the last occurrence of string s before fromIndex. Returns -1 if not matched.

Finding a Character or a Substring in a String

`"Welcome to Java".indexOf('W')` returns 0.

`"Welcome to Java".indexOf('x')` returns -1 .

`"Welcome to Java".indexOf('o', 5)` returns 9.

`"Welcome to Java".indexOf("come")` returns 3.

`"Welcome to Java".indexOf("Java", 5)` returns 11.

`"Welcome to Java".indexOf("java", 5)` returns -1.

`"Welcome to Java".lastIndexOf('a')` returns 14.

Convert Character and Numbers to Strings

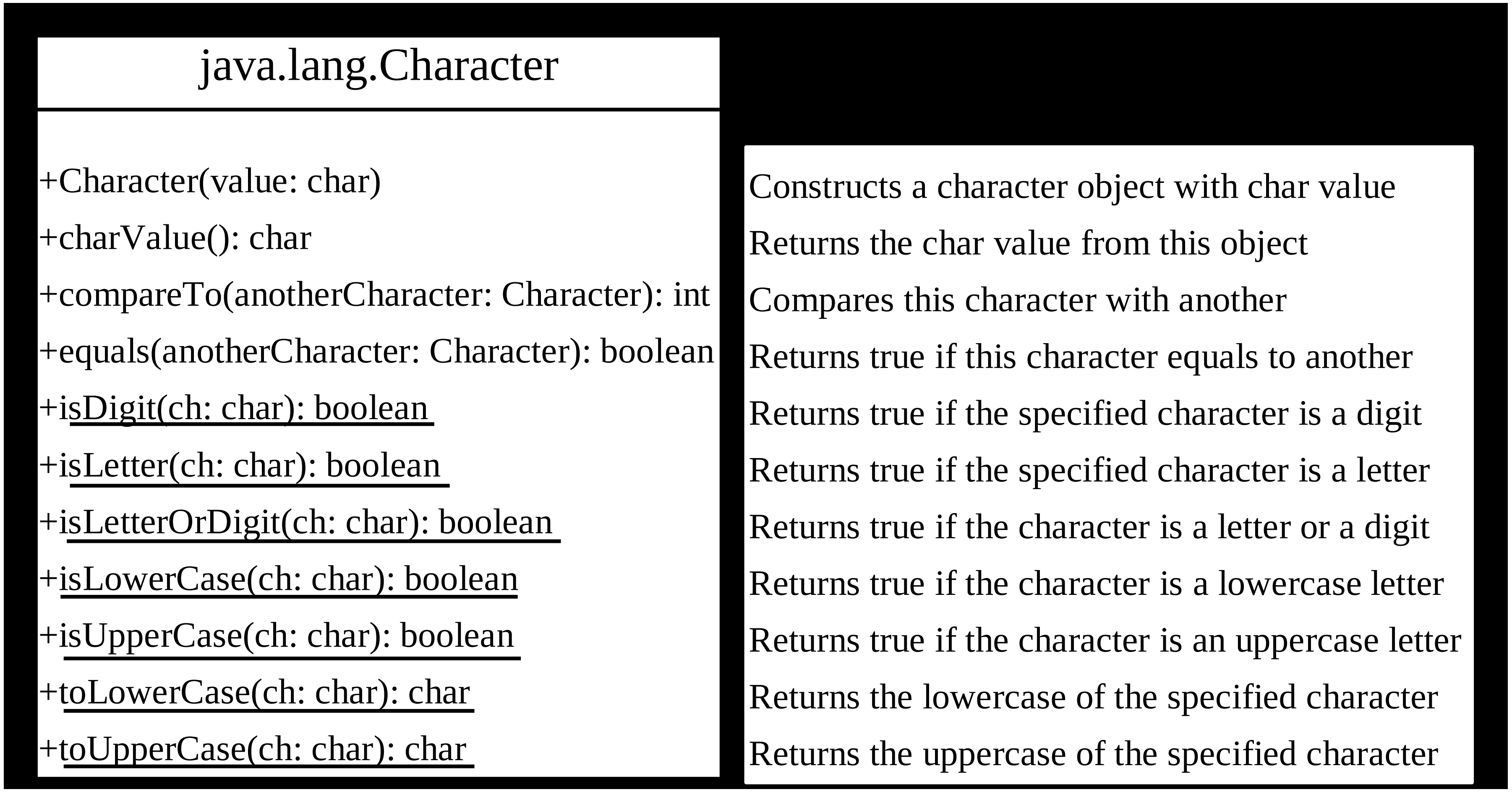
The String class provides several static valueOf methods for converting a character, an array of characters, and numeric values to strings. These methods have the same name valueOf with different argument types char, char[], double, long, int, and float. For example, to convert a double value to a string,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

Example: Finding Palindromes

- Objective: Checking whether a string is a palindrome: a string that reads the same forward and backward.

CheckPalindrome

The `Character` Class



java.lang.Character	
+Character(value: char)	Constructs a character object with char value
+charValue(): char	Returns the char value from this object
+compareTo(anotherCharacter: Character): int	Compares this character with another
+equals(anotherCharacter: Character): boolean	Returns true if this character equals to another
+isDigit(ch: char): boolean	Returns true if the specified character is a digit
+isLetter(ch: char): boolean	Returns true if the specified character is a letter
+isLetterOrDigit(ch: char): boolean	Returns true if the character is a letter or a digit
+isLowerCase(ch: char): boolean	Returns true if the character is a lowercase letter
+isUpperCase(ch: char): boolean	Returns true if the character is an uppercase letter
+toLowerCase(ch: char): char	Returns the lowercase of the specified character
+toUpperCase(ch: char): char	Returns the uppercase of the specified character

Examples

Character charObject = new Character('b');

charObject.compareTo(new Character('a')) returns 1

charObject.compareTo(new Character('b')) returns 0

charObject.compareTo(new Character('c')) returns -1

charObject.compareTo(new Character('d') returns –2

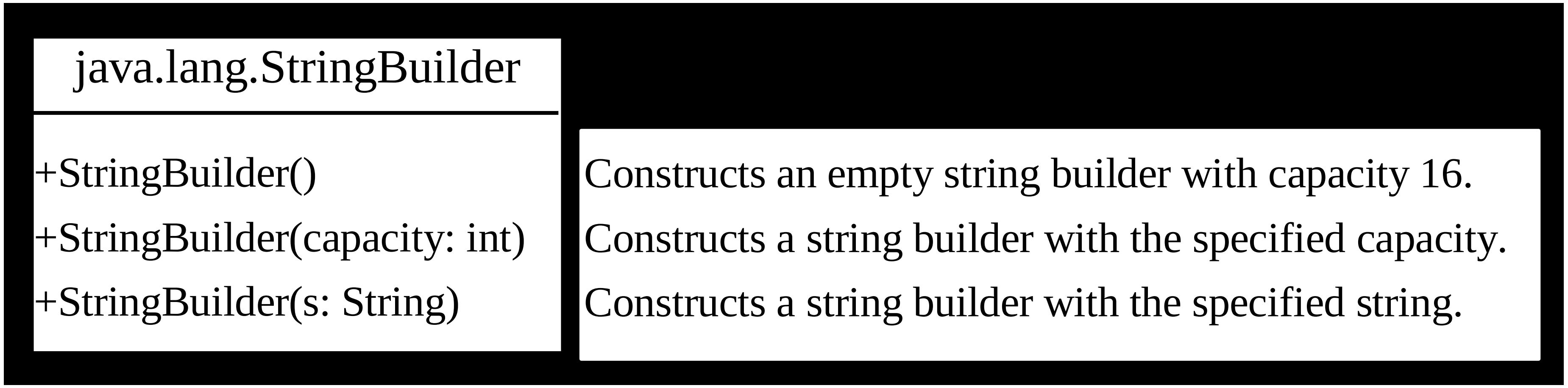
charObject.equals(new Character('b')) returns true

charObject.equals(new Character('d')) returns false

StringBuilder and StringBuffer

The StringBuilder/StringBuffer class is an alternative to the String class. In general, a StringBuilder/StringBuffer can be used wherever a string is used. StringBuilder/StringBuffer is 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.

Examples

stringBuilder.append("Java");

stringBuilder.insert(11, "HTML and ");

stringBuilder.delete(8, 11) changes the builder to Welcome Java.

stringBuilder.deleteCharAt(8) changes the builder to Welcome o Java.

stringBuilder.reverse() changes the builder to avaJ ot emocleW.

stringBuilder.replace(11, 15, "HTML")

changes the builder to Welcome to HTML.

stringBuilder.setCharAt(0, 'w') sets the builder to welcome to Java.

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.

Problem: Checking Palindromes Ignoring Non-alphanumeric Characters

PalindromeIgnoreNonAlphanumeric

Main Method Is Just a Regular Method

You can call a regular method by passing actual parameters. Can you pass arguments to main? Of course, yes. For example, the main method in class B is invoked by a method in A, as shown below:

```
public class A {
  public static void main(String[] args) {
    String[] strings = {"New York",
      "Boston", "Atlanta"};
    B.main(strings);
  }
}
```

```
class B {
  public static void main(String[] args) {
    for (int i = 0; i < args.length; i++)
      System.out.println(args[i]);
  }
}
```

Command-Line Parameters

```
class TestMain {
  public static void main(String[] args) {
   ...
   }
}

java TestMain arg0 arg1 arg2 ... argn
```

Processing Command-Line Parameters

In the main method, get the arguments from `args[0], args[1], ..., args[n]`, which corresponds to `arg0, arg1, ..., argn` in the command line.

Problem: Calculator

- ☞ Objective: Write a program that will perform binary operations on integers. The program receives three parameters: an operator and two integers.

Calculator

```
java Calculator "2 + 3"
java Calculator "2 - 3"
java Calculator "2 / 3"
java Calculator "2 * 3"
```

Wrapper Classes

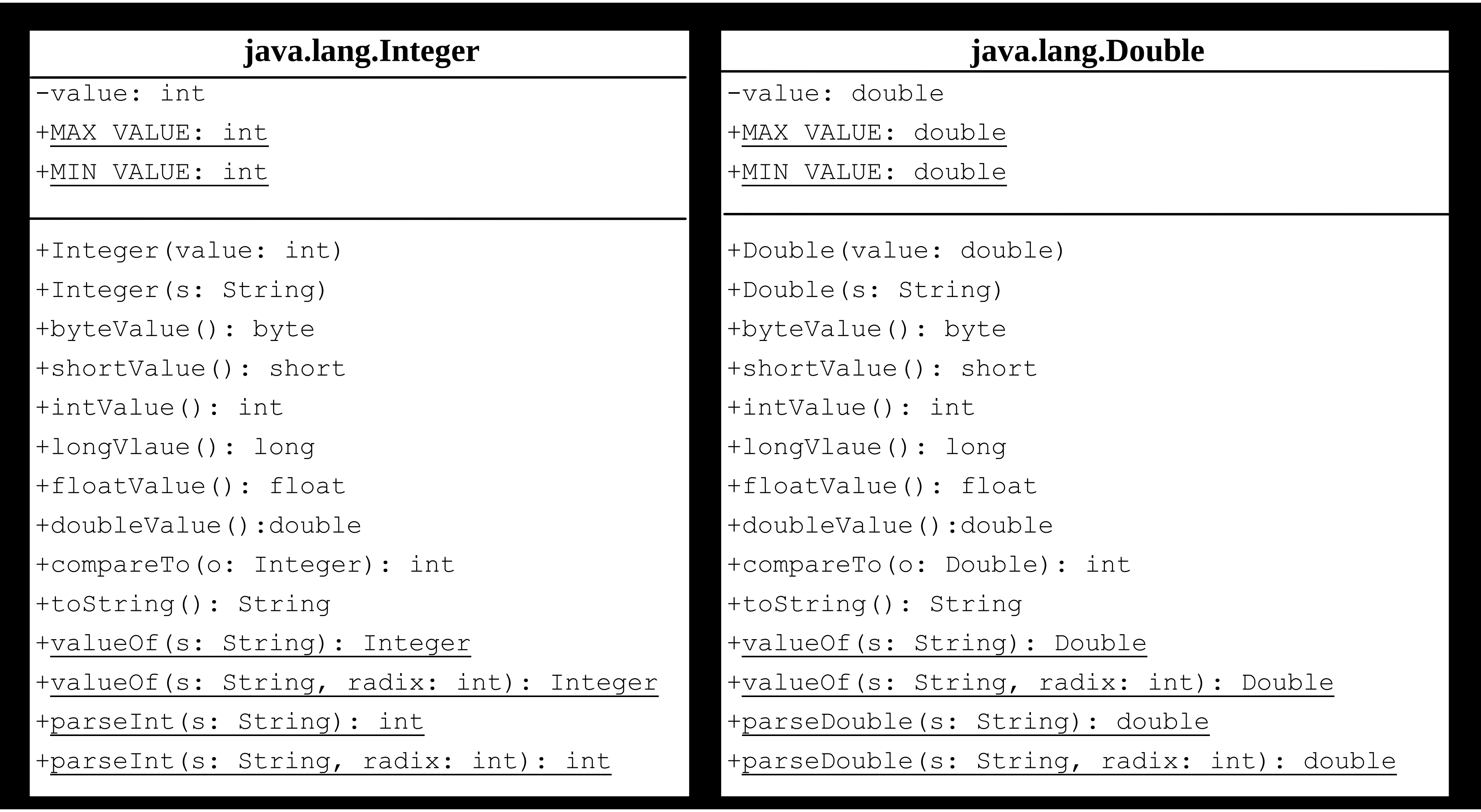
- Boolean
- Character
- Short
- Byte
- Integer
- Long
- Float
- Double

NOTE: (1) The wrapper classes do not have no-arg constructors. (2) The instances of all wrapper classes are immutable, i.e., their internal values cannot be changed once the objects are created.

The toString, equals, and hashCode Methods

Each wrapper class overrides the toString, equals, and hashCode methods defined in the Object class. Since all the numeric wrapper classes and the Character class implement the Comparable interface, the compareTo method is implemented in these classes.

The `Integer` and `Double` Classes



java.lang.Integer

```
-value: int
+MAX_VALUE: int
+MIN_VALUE: int

+Integer(value: int)
+Integer(s: String)
+byteValue(): byte
+shortValue(): short
+intValue(): int
+longVlaue(): long
+floatValue(): float
+doubleValue():double
+compareTo(o: Integer): int
+toString(): String
+valueOf(s: String): Integer
+valueOf(s: String, radix: int): Integer
+parseInt(s: String): int
+parseInt(s: String, radix: int): int
```

java.lang.Double

```
-value: double
+MAX_VALUE: double
+MIN_VALUE: double

+Double(value: double)
+Double(s: String)
+byteValue(): byte
+shortValue(): short
+intValue(): int
+longVlaue(): long
+floatValue(): float
+doubleValue():double
+compareTo(o: Double): int
+toString(): String
+valueOf(s: String): Double
+valueOf(s: String, radix: int): Double
+parseDouble(s: String): double
+parseDouble(s: String, radix: int): double
```

The `Integer` Class and the `Double` Class

- Constructors
- Class Constants `MAX_VALUE`, `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. 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. The following statements display the maximum integer (2,147,483,647), the minimum positive float (1.4E-45), and the maximum double floating-point number (1.79769313486231570e+308d).

Conversion Methods

Each numeric wrapper class implements the abstract methods doubleValue, floatValue, intValue, longValue, and shortValue, which are defined in the Number class. These methods “convert” objects into primitive type values.

The 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:

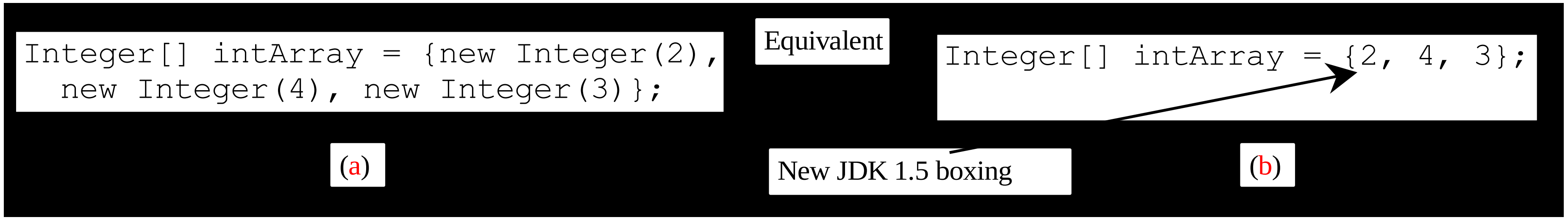
```
Double doubleObject = Double.valueOf("12.4");
Integer integerObject = Integer.valueOf("12");
```

The Methods for Parsing Strings into Numbers

You have used the parseInt method in the Integer class to parse a numeric string into an int value and the parseDouble method in the Double class to parse a numeric string into a double value. Each numeric wrapper class has two overloaded parsing methods to parse a numeric string into an appropriate numeric value.

Automatic Conversion Between Primitive Types and Wrapper Class Types

JDK 1.5 allows primitive type and wrapper classes to be converted automatically. For example, the following statement in (a) can be simplified as in (b):



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

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

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

Unboxing

BigInteger and BigDecimal

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.

BigInteger and BigDecimal

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

LargeFactorial

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