OBJECT-ORIENTED LANGUAGE AND THEORY

5. MEMORY MANAGEMENT AND CLASS ORGANIZATION

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Outline

1. Memory management in Java
2. Class organization
3. Utility classes in Java

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1. Memory management in Java

- Java does not use pointer, hence memory addresses can not be overwritten accidentally or intentionally.
- The allocation or re-allocation of memory, management of memory that is controlled by JVM, are completely transparent with developers.
- Developers do not need to care about the allocated memory in heap in order to free it later.

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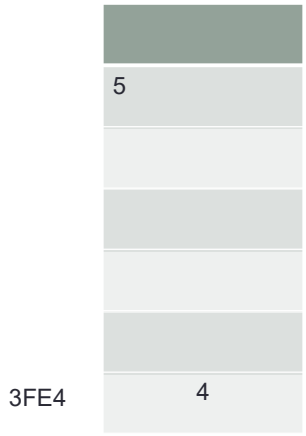
```
byte i;
i = 4;

byte *j;

j+2
```



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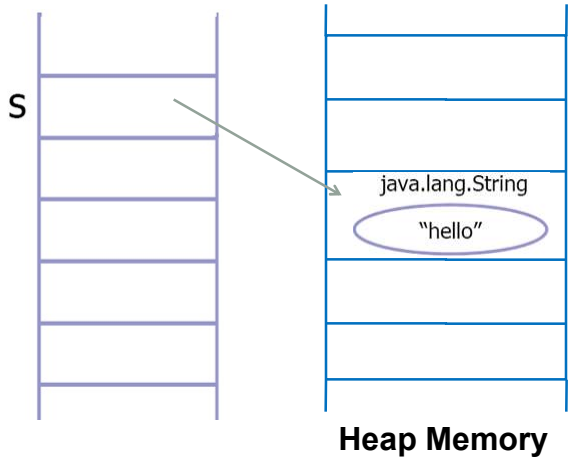
1.1. Heap memory

```
String s = new String("hello");
```

- Heap memory is used to write information created by **new** operator.



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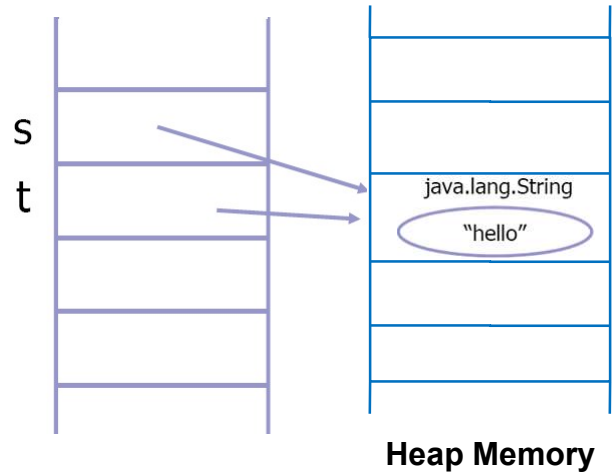
1.1. Heap memory (2)

```
String s = new String("hello");
String t = s;
```

- Heap memory is used to write information created by **new** operator.



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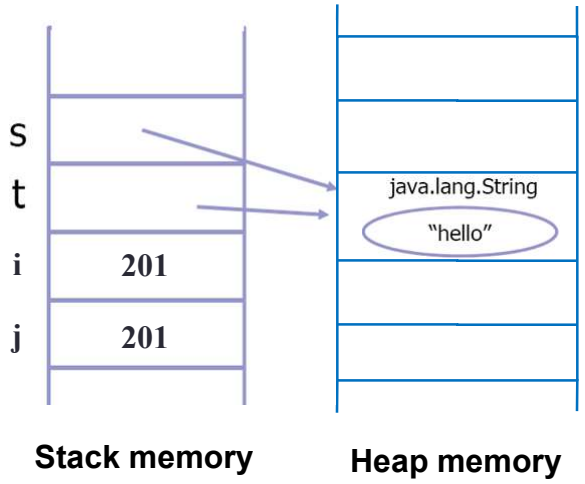
1.2. Stack memory

```
String s = new String("hello");
String t = s;
int i = 201;
int j = i;
```

- Local value in Stack memory is used as a reference pointer to Heap
- Value of primitive data is written directly in Stack



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1.3. Garbage collector (gc)

- The garbage collector sweeps through the JVM's list of objects periodically and reclaims the resources held by unreferenced objects
- All objects that have no object references are eligible for garbage collection
  - References out of scope, objects to which you have assigned null, and so forth
- The JVM decides when the gc is run
  - Typically, the gc is run when memory is low
  - May not be run at all
  - Unpredictable timing

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Working with the garbage collector

- You cannot prevent the garbage collector from running, but you can request it to run soon
  - `System.gc();`
  - This is only a request, not a guarantee
- The `finalize()` method of an object will be run immediately before garbage collection occurs
  - This method should only be used for special cases (e.g. cleaning up memory allocation from native calls) because of the unpredictability of the garbage collector
  - Things like open sockets, files, and so forth should be cleaned up during normal program flow before the object is dereferenced

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Java destructors?

- Java does not have the concept of a destructor for objects that are no longer in use
- Deallocation of memory is done automatically by the JVM through the finallize() method
  - A background process called the garbage collector reclaims the memory of unreferenced objects
  - The association between an object and an object reference is severed by assigning another value to the object reference, for example:
    - objectReference = null;
  - An object with no references is a candidate for deallocation during garbage collection

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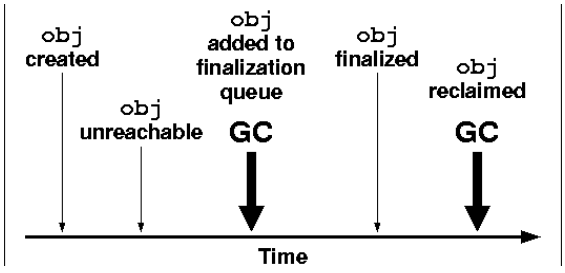
`finalize()` method

- Any class has method finalize() – that is executed right after the garbage collection process takes place (considered as destructor in Java despite not)
- Override this method in some special cases in order to "self-clean" used resources when objects are freed by `gc`
  - E.g. pack socket, file,... that should be handled in the main thread before the objects are disconnected from reference.



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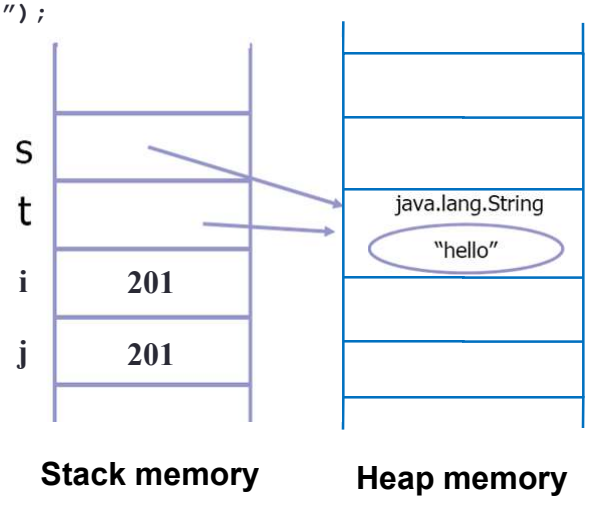
```
String s = new String("hello");
String t = s;
int i = 201;
int j = i;
s = new String("goodbye");
t = new String("bye");
```



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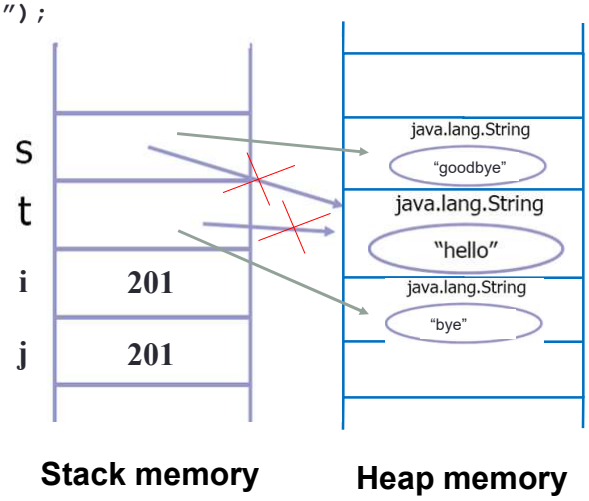
```
String s = new String("hello");
String t = s;
int i = 201;
int j = i;
s = new String("goodbye");
t = new String("bye");
```



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Memory Management in Java (Method and variables)

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1.4. Object comparison

- **Primitive data types:** == checks whether their values are the equal

```
int a = 1;
int b = 1;
if (a==b)... // true
```

- **Objects**: == checks whether two objects are unique ~ whether they **refer to the same object**

```
Employee a = new Employee(1);
Employee b = a;
if (a==b)... // true
```

```
Employee a = new Employee(1);
Employee b = new Employee(1);
if (a==b)... // false
```

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equals() method

- For primitive data types → does not exist.
- For objects: every object has this method
  - Compares values of objects

```
public class Equivalence {
 public static void main(String[] args) {
      Integer n1 = new Integer(47);
      Integer n2 = new Integer(47);
      System.out.println(n1 == n2);
      System.out.println(n1.equals(n2));
 }
}
```

```
false
true
```

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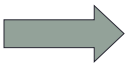
equals() method of your class

```
class Value {
 int i;
 public Value(int i) { this.i = i;}
}
public class EqualsMethod2 {
 public static void main(String[] args) {
   Value v1 = new Value(10);
   Value v2 = new Value(10);
   System.out.println(v1.equals(v2));
 }
}
```



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Outline

1. Memory management in Java
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3. Utility classes in Java

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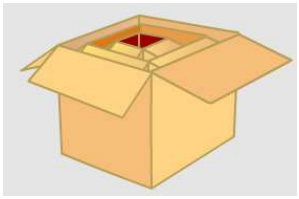
Class organization with Package

- Package is as a folder that helps:
  - Organize and locate easily the classes and use classes in a appropriate manner
  - Avoid conflict in naming classes
    - Different packages can contains classes with same name
  - Protect classes, data and methods in a larger area compared to relation between classes
- A package can also contain another package
  - "com" package contains "google" package
    - com.google



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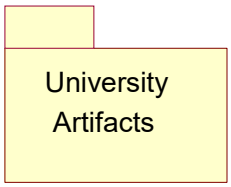
Package in UML

- A general purpose mechanism for organizing elements into groups.
- A model element that can contain other model elements.
- A package can be used:
  - To organize the model under development
  - As a unit of configuration management



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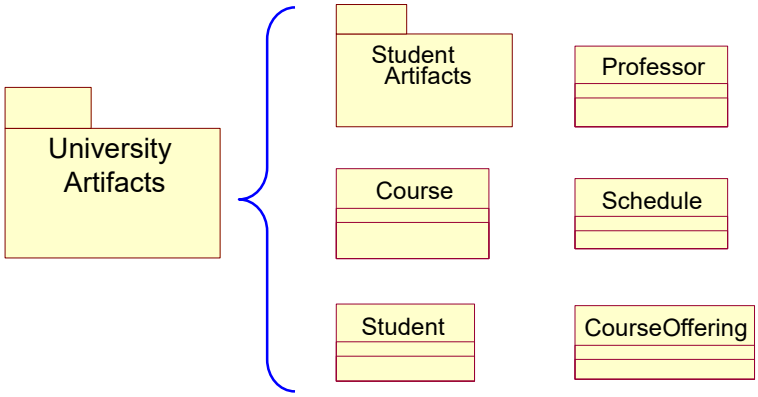
A Package Can Contain Classes

- The package, University Artifacts, contains one package and five classes.



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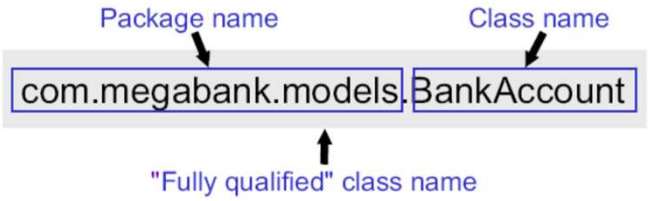
Fully qualified class name

- A fullname of a class includes package name and class name:



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- package oolt.hedspi;
- class AS1{
  - int as11;
  - void as1_method(){
    - IS1 as1 = new IS1();
    - is1.is1_method();
  - }
- }

- package oolt.hedspi;
- class IS1{
  - void is1_method(){}
- }

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2.1. References between classes

- In the same package: use class name
- In different packages: must provide the full-name of class defined in other packages.
- Example:

```
package oolt.hedspi;
public class HelloNameDialog{
  public static void main(String[] args){
    String result;
    result = javax.swing.JOptionPane.
          showInputDialog("Please enter your name:");
    javax.swing.JOptionPane.
          showMessageDialog(null, "Hi "+ result + "!");
  }
}
```

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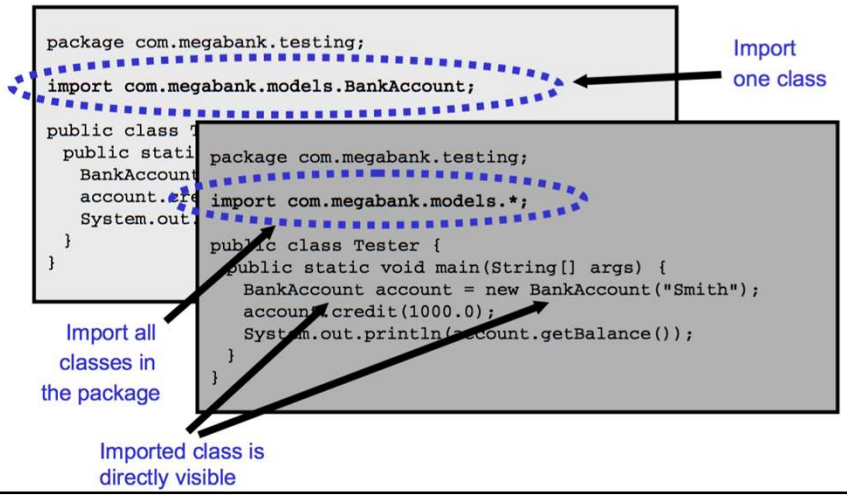
Using import command

To import packages or classes to make other classes directly visible to your class



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More example

```
package oolt.hedspi;
public class HelloNameDialog{
 public static void main(String[] args){
   System.out.print("Hello world!");
 }
}
```

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2.2. Packages in Java

- java.applet
- java.awt
- java.beans
- java.io
- java.lang
- java.math
- java.net
- java.nio
- java.rmi
- java.security
- java.sql
- java.text
- java.util
- javax.accessibility
- javax.crypto
- javax.imageio
- javax.naming
- javax.net
- javax.print
- javax.rmi
- javax.security
- javax.sound
- javax.sql
- javax.swing
- javax.transaction
- javax.xml
- org.apache.commons
- org.ietf.jgss
- org.omg.CORBA
- org.omg.IOP
- org.omg.Messaging
- org.omg.PortableInterceptor
- org.omg.PortableServer
- org.omg.SendingContext
- org.omg.stub.java.rmi
- org.w3c.dom
- org.xml

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Basic packages in Java

- **java.lang**
  - Provides classes that are fundamental to the design of the Java programming language
  - Includes wrapper classes, String and StringBuffer, Object, and so on
  - Imported implicitly into all classes
- **java.util**
  - Contains the collections framework, event model, date and time facilities, internationalization, and miscellaneous utility classes
- **java.io**
  - Provides for system input and output through data streams, serialization and the file system

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Basic packages in Java

- **java.math**
  - Provides classes for performing arbitrary-precision integer arithmetic and arbitrary-precision decimal arithmetic
- **java.sql**
  - Provides the API for accessing and processing data stored in a data source (usually a relational database)
- **java.text**
  - Provides classes and interfaces for handling text, dates, numbers, and messages in a manner independent of natural languages
- **javax.swing**
  - Provides classes and interfaces to create graphics

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Sample package: java.lang

- **Basic Entities**
  - Class, Object, Package, System
- **Wrappers**
  - Number, Boolean, Byte, Character, Double, Float, Integer, Long, Short, Void
- **Character and String Manipulation**
  - Character.Subset, String, StringBuffer, Character.UnicodeBlock
- **Math Functions**
  - Math, StrictMath
- **Runtime Model**
  - Process, Runtime, Thread, ThreadGroup, ThreadLocal, InheritableThreadLocal, RuntimePermission
- **JVM**
  - ClassLoader, Compiler, SecurityManager
- **Exception Handling**
  - StackTraceElement, Throwable
- Also contains Interfaces, Exceptions and Errors

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3.1. Wrapper class

- Primitives have no associated methods; there is no behavior associated with primitive data types
- Each primitive data type has a corresponding class, called a wrapper
  - Each wrapper object simply stores a single primitive variable and offers methods with which to process it
  - Wrapper classes are included as part of the base Java API

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Wrapper classes

Primitive Type	Wrapper Class
boolean	Boolean
byte	Byte
char	Character
double	Double
float	Float
int	Integer
long	Long
short	Short

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Converting data type

- Use **`toString()`** to convert number values to string.
- Use **`<type>Value()`** to convert an object of a wrapper class to the corresponding primitive value

```
Float objF = new Float("4.67");
float f = objF.floatValue(); // f=4.67F
int i = objF.intValue();  //i=4
```

- Use **`parse<type>()`** and **`valueOf()`** to convert string to number values.

```
int i = Integer.parseInt("123");  //i=123
double  d = Double.parseDouble("1.5") ; // d=1.5
Double objF2 = Double.valueOf("-36.12");
long l = objF2.longValue(); // l=-36L
```

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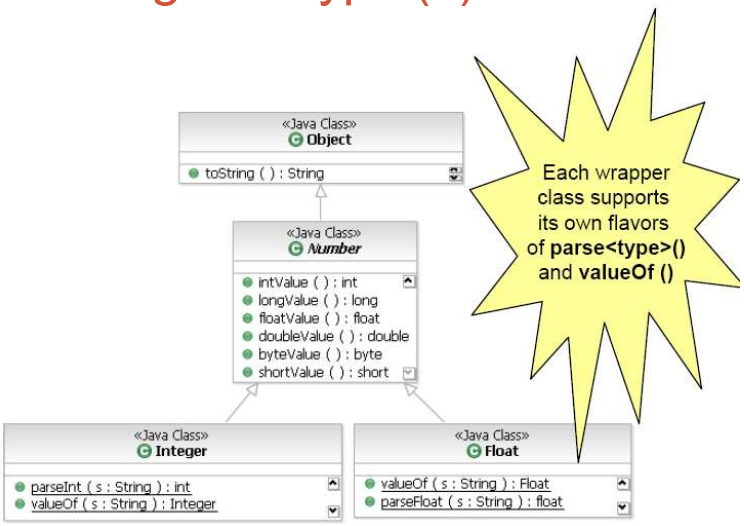
Converting data type (2)



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Constants

- **Boolean**
  - Boolean FALSE
  - Boolean TRUE
- **Byte**
  - byte MIN_VALUE
  - byte MAX_VALUE
- **Character**
  - int MAX_RADIX
  - char MAX_VALUE
  - int MIN_RADIX
  - char MIN_VALUE
  - Unicode classification constants
- **Double**
  - double MAX_VALUE
  - double MIN_VALUE
  - double NaN
  - double NEGATIVE_INFINITY
  - double POSITIVE_INFINITY

- **Float**
  - float MAX_VALUE
  - float MIN_VALUE
  - float NaN
  - float NEGATIVE_INFINITY
  - float POSITIVE_INFINITY
- **Integer**
  - int MIN_VALUE
  - int MAX_VALUE
- **Long**
  - long MIN_VALUE
  - long MAX_VALUE
- **Short**
  - short MIN_VALUE
  - short MAX_VALUE

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Example

```
double d = (new Integer(Integer.MAX_VALUE)).
                                        doubleValue();
System.out.println(d); // 2.147483647E9

String input = "test 1-2-3";
int output = 0;
for (int index = 0; index < input.length(); index++)
{
   char c = input.charAt(index);
   if (Character.isDigit(c))
     output = output * 10 + Character.digit(c, 10);
}
System.out.println(output);     // 123
```

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3.2. String

- The String type is a class, not a primitive data type
- A String literal is made up of any number of characters between double quotes:

```
String a = "A String";
String b = "";
```

- A String object can be initialized in other ways:

```
String c = new String();
String d = new String("Another String");
String e = String.valueOf(1.23);//"1.23"
String f = null;
```

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a. String concatenation

- The + operator concatenates Strings:

```
String a = "This" + " is a " + "String";
//a = "This is a String"
```

There are more efficient ways to concatenate Strings (this will be discussed later)

- Primitive data types used in in a call to println() are automatically converted to String

```
System.out.println("answer = " + 1 + 2 + 3);
System.out.println("answer = " + (1+2+3));
```

→ Do two above commands print out the same output?

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b. Methods of String

Strings are objects; objects respond to messages

- ✓ Use the dot (.) operator to send a message
- ✓ String is a class, with methods

```
String name = "Joe Smith";
name.toLowerCase();          // "joe smith"
name.toUpperCase();          // "JOE SMITH"
"Joe Smith ".trim();         // "Joe Smith"
"Joe Smith".indexOf('e');    // 2
"Joe Smith".length();        // 9
"Joe Smith".charAt(5);       // 'm'
"Joe Smith".substring(5);    // "mith"
"Joe Smith".substring(2,5);  // "e S"
```

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c. String comparison

- `oneString.equals(anotherString)`
  - Tests for equivalence
  - Return `true` or `false`

```
String name = "Joe";
if ("Joe".equals(name))
      name += " Smith";
```

- `oneString.equalsIgnoreCase(anotherString)`
  - Case insensitive test for equivalence

```
boolean same = "Joe".equalsIgnoreCase("joe");
```

- `oneString == anotherString` is problematic
  - Compare two objects

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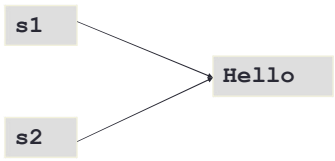
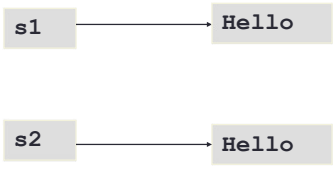
c. Comparing two Strings (2)

```
String s1 = new String("Hello");
String s2 = s1;
```
`(s1==s2)` returns true




```
String s1 = new String("Hello");
String s2 = new String("Hello");
```
`(s1==s2)` returns false

s1.equals(s2) return true



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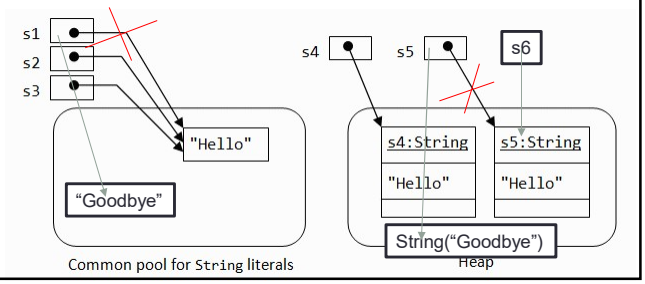
String Literal vs. String Object

```
String s1 = "Hello";                // String literal
String s2 = "Hello";                // String literal
String s3 = s1; // same reference
String s4 = new String("Hello");  // String object
String s5 = new String("Hello");  // String object
String s6 = s5;
s5 = new String("Goodbye");
s1 = "Goodbye";
```



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- String str = "";
- for (int i=0; i<1.000.000; i++){
  - //read a line from a file
  - str += line;
- }

- StringBuffer str = "";
- for (int i=0; i<1.000.000; i++){
  - //read a line from a file
  - str.append(line);
- }

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3.3. StringBuffer/StringBuilder

- String is an immutable type:
  - Object does not change the value after being created → Strings are designed for not changing their values.
  - Concatenating strings will create a new object to store the result → String concatenation is memory consuming.
- StringBuffer/StringBuilder is a mutable type:
  - Object can change the value after being created

=> String concatenation can get very expensive, only use in building a simple String

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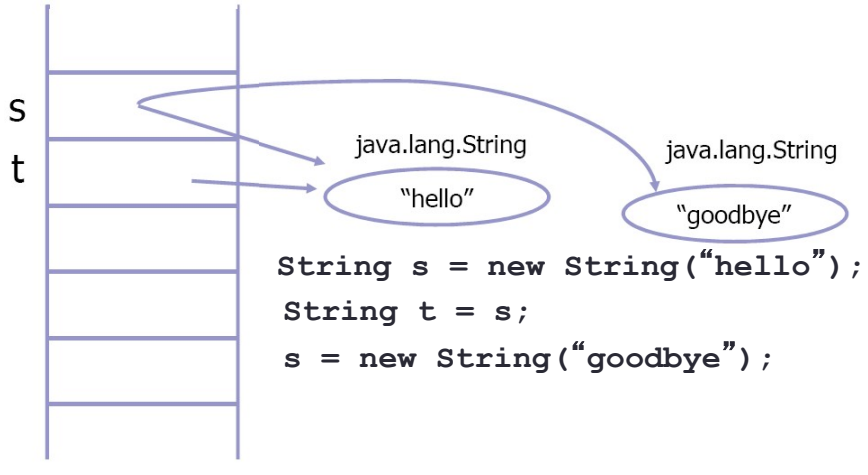
3.3. StringBuffer (2)



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3.3. StringBuffer (3)

- **`StringBuffer`**:
  - Provides String object that can change the value → Use **`StringBuffer`** when:
    - Predict that characters in the String can be changed
    - When processing a string, e.g. reading text data from a text file or building a String through a loop
  - Provides a more efficient mechanism for building and concatenating strings:
    - String concatenation is often done by compiler in class **`StringBuffer`**

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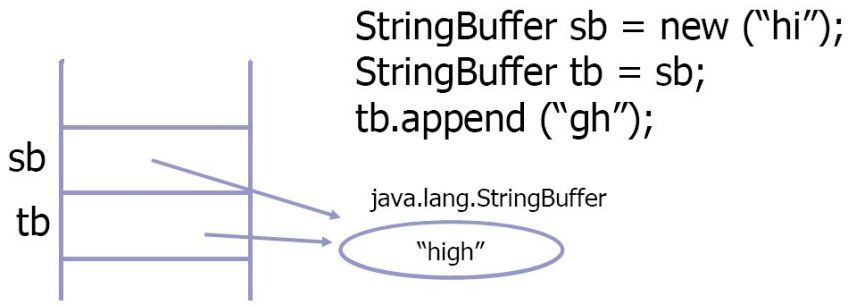
3.3. StringBuffer (4)

- Changing attribute: If an object is changed, all the relations with the object will receive the new value.



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3.3. StringBuffer (5)

- If we create a String by a loop, we should use **`StringBuffer`**

```
StringBuffer buffer = new StringBuffer(15);
buffer.append("This is ") ;
buffer.append("String") ;
buffer.insert(7," a") ;
buffer.append('.');
System.out.println(buffer.length());      // 17
System.out.println(buffer.capacity());    // 32
String output = buffer.toString() ;
System.out.println(output); // "This is a String."
```

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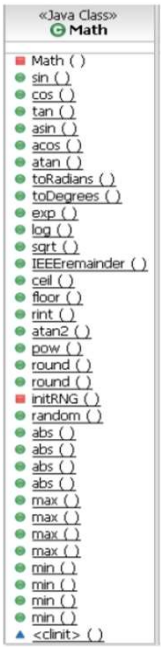
3.4. Math class

- java.lang.Math provides static data:
  - Math constants:
    - Math.E
    - Math.PI
  - Math functions:
    - max, min...
    - abs, floor, ceil…
    - sqrt, pow, log, exp…
    - cos, sin, tan, acos, asin, atan…
    - random



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3.4. Math class (2)

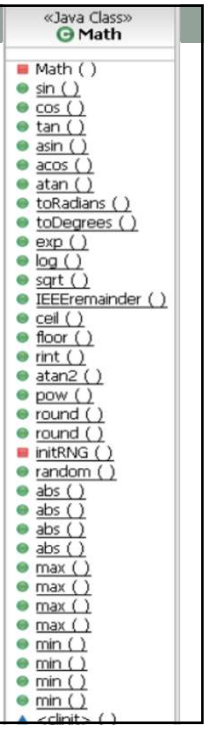
- Most of functions receive arguments with type **`double`** and also return values with tye **`double`**
  - Example:

$$e^{\sqrt{2\pi}}$$

```
Math.pow(Math.E,
     Math.sqrt(2.0*Math.PI))
```

Or:

```
Math.exp(Math.sqrt(2.0*Math.PI))
```



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