



# An introduction to Java

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**INRA - UMR AMAP**

botAny and Modelling of Plant Architecture and vegetation





# Java training - Contents

## Introduction

- history
- specificities
- programming environment
- installation

## Bases

## Object oriented programming (O.O.P.)

## Resources

## James Gosling and Sun Microsystems

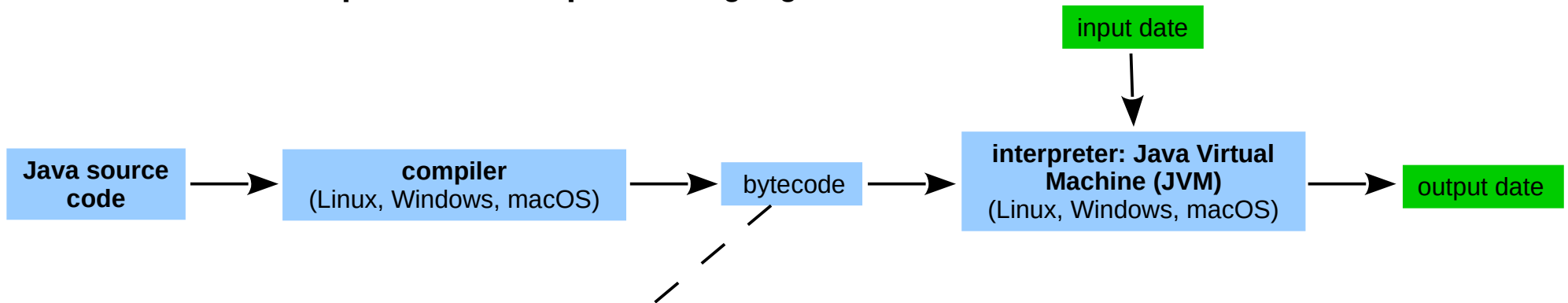
- Java: May 20, 1995
- Java 1 → Java 8 (i.e. 1.8), March 2014
- Oracle since 2010

# Specificities

Java is an object oriented language

**object** = a software brick (see later)

- **clean, simple** and **powerful**
- Java: **compiled** and **interpreted** language



- *bytecode* is **not** *machine code*
- compilation on Linux, Windows or macOS: produces **same bytecode**



Java is **portable** (Linux, Windows, macOS):  
*"write once, run everywhere"* (**no recompilation** is needed)

- **static typing** (checks during compilation)
- simpler than C++ (automatic memory management, no pointers, no headers...)



# Programming environment

## Java environment

- JRE (Java Runtime Environment)
- JDK (Java Development Kit)

contains the '**java**' interpreter:  
JVM (Java Virtual Machine)

JRE + the '**javac**' compiler + ...

## Several versions

- Java SE (Standard Edition)
- Java EE (Enterprise Edition → Web)
- Java ME (Micro Edition)

## Editors

- simple editors: **Notepad++** (Windows), **TextPad** (Windows), **SciTE** (multi-platform), **gedit** (multi-platform) → syntax coloring...
- IDEs (Integrated Development Environment):  
**Eclipse** (multi-platform), **NetBeans** (multi-platform) → completion, refactoring...

# Installation

## Windows / Linux

- download and install the **JDK (Java SE 8)**
- modify the **PATH environment variable**
  - add the **java/bin/** directory (contains **javac** and **java** programs) at the beginning of the **PATH** variable
  - e.g. C:/Program Files/Java/jdk1.8.0\_102/bin (*Windows*)
  - /home/beudez/applications/jdk1.8.0\_102/bin (*Linux*)
- install **text editor**:
  - TextPad** or **Notepad++** (*Windows*)
  - gedit**, **SciTE** (*multi-platform*)

## Check the installation

- in a terminal: **java -version** and **javac -version**

```
beudez@nicolas-HP:~$ java -version
java version "1.8.0_102"
Java(TM) SE Runtime Environment (build 1.8.0_102-b14)
Java HotSpot(TM) 64-Bit Server VM (build 25.102-b14, mixed mode)
beudez@nicolas-HP:~$
beudez@nicolas-HP:~$ javac -version
javac 1.8.0_102
beudez@nicolas-HP:~$
```

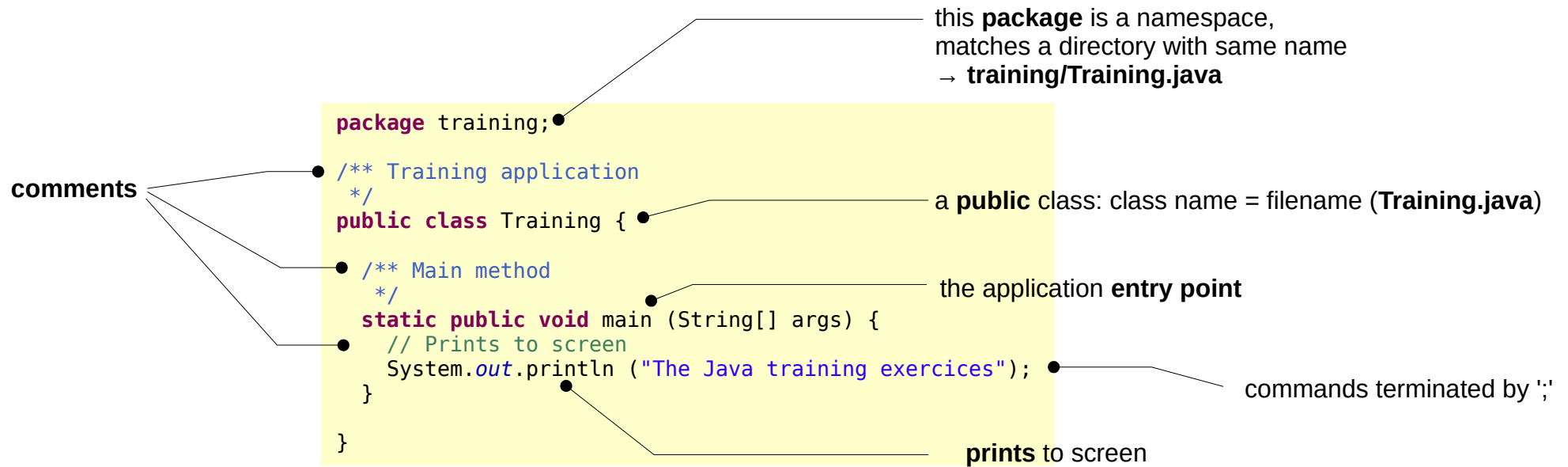


# Bases

- a Java application
- the development process
- variables, simple types
- operators
- boolean calculation
- mathematical tools
- arrays
- conditions: if, else if, else
- loops: while, do... while
- loops: for
- loops: continue or break
- runtime exceptions
- exceptions management



# A Java application

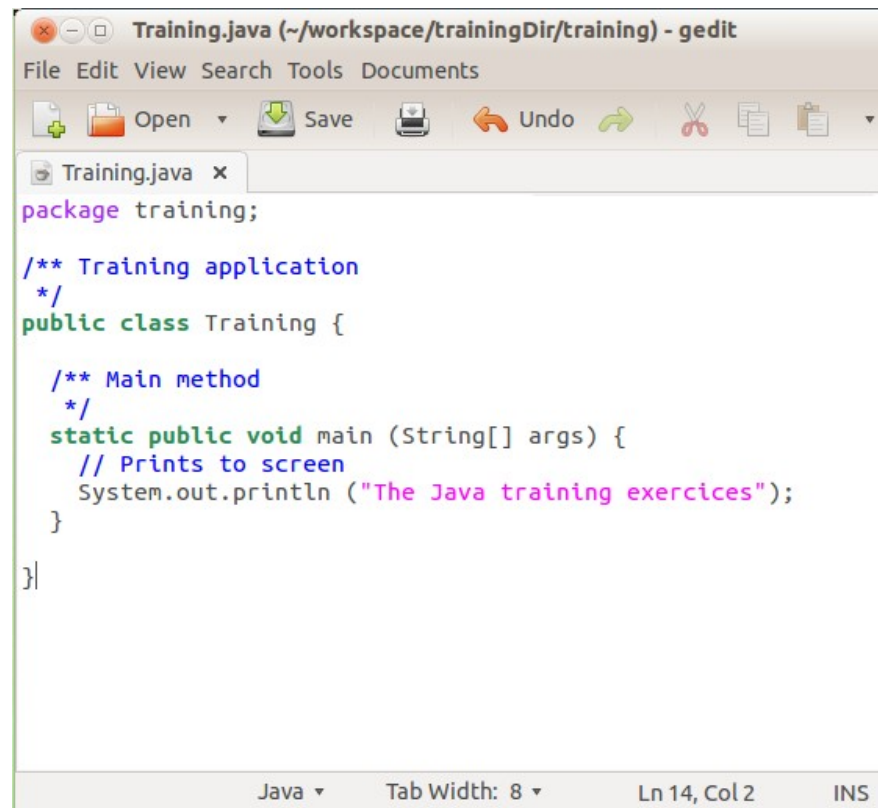
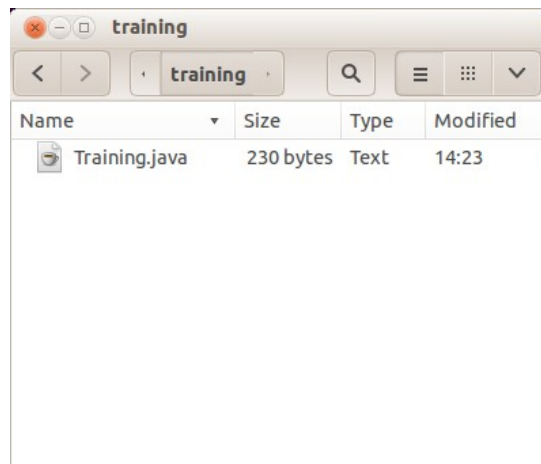






## A Java application

- Java programs are written with a text editor in files with a '.java' extension: **sources files**
- applications are .java files with a **public static void main(...) {...}** method





## A Java application

- to compile a Java application, use the javac compiler (part of the JDK) in a terminal
- returns a Java bytecode file: Training.class

```
coligny@marvin-13: ~/workspace/trainingDir
File Edit View Search Terminal Help
coligny@marvin-13:~/workspace/trainingDir$ javac training/Training.java
coligny@marvin-13:~/workspace/trainingDir$
```

Name	Size	Type	Modified
Training.class	446 bytes	Unknown	14:40
Training.java	230 bytes	Text	14:23



## A Java application

- to run a Java application, use the `java interpreter` (or Java Virtual Machine, JVM) in a terminal

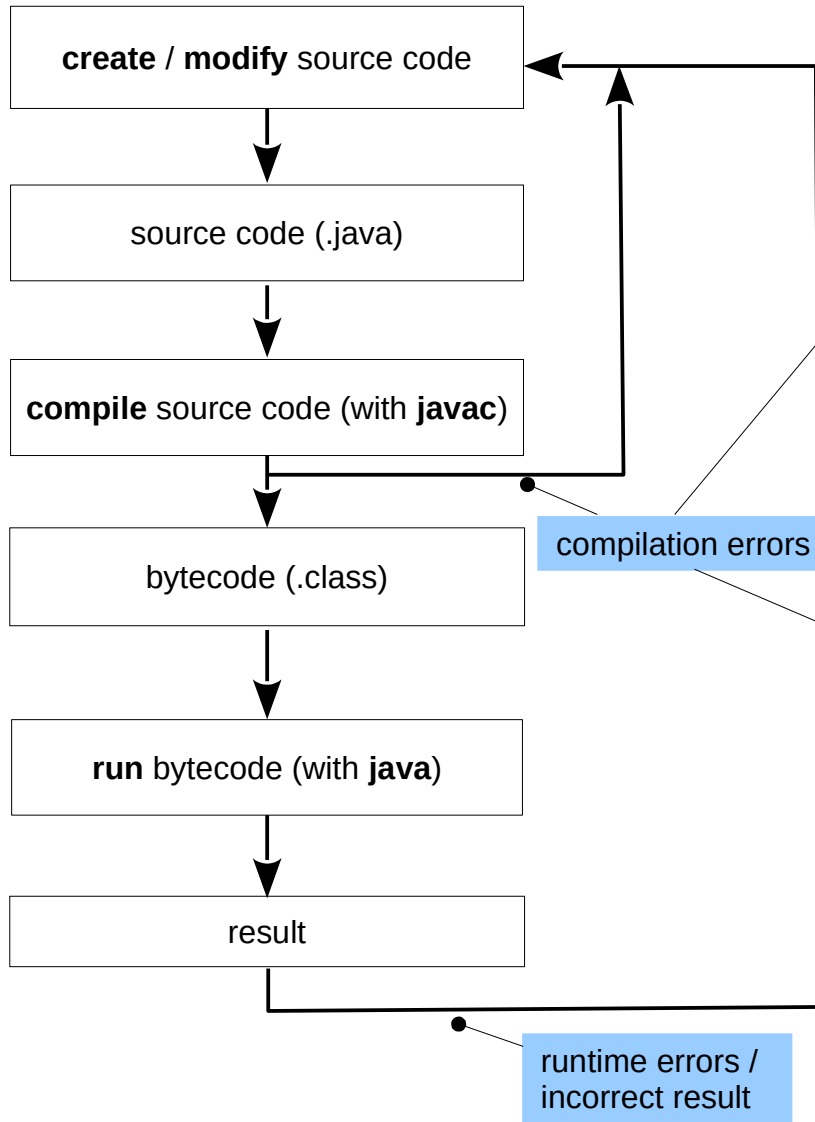
the result

A screenshot of a terminal window. The title bar reads "coligny@marvin-13: ~/workspace/trainingDir". The terminal content shows the command "java training.Training" being executed, which outputs "The Java training exercices". The prompt "coligny@marvin-13:~/workspace/trainingDir\$" is visible on the line below the output.

```
coligny@marvin-13: ~/workspace/trainingDir
File Edit View Search Terminal Help
coligny@marvin-13:~/workspace/trainingDir$ java training.Training
The Java training exercices
coligny@marvin-13:~/workspace/trainingDir$
```



# The development process



The image shows three overlapping screenshots illustrating the development process:

- Top-left:** A code editor window showing the initial source code for `Training.java`. The code includes package declarations, class declarations, and a `main` method.
- Top-right:** A code editor window showing the source code after a correction. The `main` method now prints "The Java training exercises".
- Bottom-left:** A terminal window showing the command `javac training/Training.java` and the output: `1 error`. This indicates a compilation error.
- Bottom-right:** A terminal window showing the command `java training/Training.class` and the output: `The Java training exercises`. This indicates that the errors were fixed and the program ran successfully.

errors fixed, result is correct



# Variables, simple types

## Variable

- a variable has a **type** and holds a **value**
- a **variable name** starts with a lowercase letter, e.g. myVariable

### Integer types:

Type	Size (bits)	Minimum value	Maximum value	Example
<b>byte</b>	8	-128 ( $= -2^8/2$ )	127 ( $= 2^8/2-1$ )	byte b = 65;
<b>short</b>	16	-32 768 ( $= -2^{16}/2$ )	32 767 ( $= 2^{16}/2-1$ )	short s = 65;
<b>int</b>	32	-2 147 483 648 ( $= -2^{32}/2$ )	-2 147 483 647 ( $= 2^{32}/2-1$ )	int i = 65;
<b>long</b>	64	-9 223 372 036 854 775 808 ( $= -2^{64}/2$ )	9 223 372 036 854 775 807 ( $= 2^{64}/2-1$ )	long l = 65L;

### Floating types:

Type	Size (bits)	Absolute minimum value	Absolute maximum value	Example
<b>float</b>	32	$1.40239846 \times 10^{-45}$	$3.40282347 \times 10^{38}$	float f = 65f;
<b>double</b>	64	$4.9406564584124654 \times 10^{-324}$	$1.797693134862316 \times 10^{308}$	double d = 65.55;

### Character:

Type	Size (bits)	Example
<b>char</b>	16	char c = 'A';

### Boolean:

Type	Size (bits)	Example
<b>boolean</b>	1	boolean b = true;

### Declaration

```
int i = 0;
double a = 5.3;
boolean found = false;
char letter = 'z';
```

```
String name = "Robert";
```

value assignment

not a simple type (seen later)



# Operators

## Arithmetic

- simple: +, -, \*, /, %
- increment / decrement: ++, --
- combined: +=, -=, \*=, /=
- precedence with **parentheses**
- comparison: <, <=, >, >=, ==, !=
- boolean: &&, ||, ! (see next slide)

index = index + 2;

i++; (same as: i = i+1;)

index += 2; (same as: index = index+2;)

(a + b) \* c;

## Beware of the int division

```
double r = 3d / 2d;
double s = 3 / 2;
System.out.println ("r: " + r + " s: " + s);
```

String concatenation:  
"a string" + *something* turns *something* into a String and appends it

```
coligny@marvin-13:~/workspace/trainingDir$ javac training/PrimitiveTypes.java
coligny@marvin-13:~/workspace/trainingDir$ java training.PrimitiveTypes
r: 1.5 s: 1.0
```

Caution



## Boolean calculation

### Boolean variables are true or false

- boolean v = **true**;
- AND: **&&**
- inclusive OR: **||**
- NOT: **!**
- test equality: **==**
- test non equality: **!=**
- use **()** for precedence

### **(a<b) && (c<d)**

is *true* if the two expressions  $a < b$  and  $c < d$  are both *true*, is *false* otherwise

### **(a<b) || (c<d)**

is *true* if **at least** one of the two expressions  $a < b$  and  $c < d$  is *true*, is *false* otherwise

### **!(a<b)**

is *true* if the expression  $a < b$  is *false*, is *false* otherwise (same value than  $a >= b$ )

```
// Did we find ?  
boolean found = isFileInSystem("trees.txt");  
boolean trouble = !found && fileRequested;
```



# Mathematical tools

## Constants

- Math.PI, Math.E

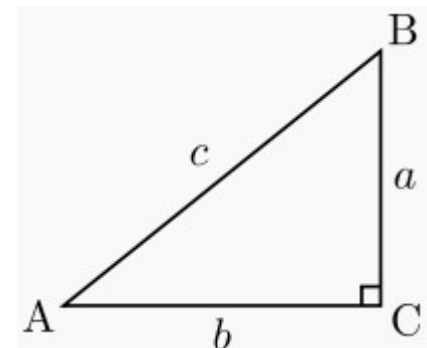
## Trigonometry and other operations

- Math.cos(), Math.sin(), Math.tan()...
- Math.pow(), Math.sqrt(), Math.abs(), Math.exp(), Math.log()...
- Math.min(), Math.max(), Math.round(), Math.floor(), Math.ceil()...
- Math.toDegrees(), Math.toRadians()...

```
// Square root
double a = 3;
double b = 4;
double c = Math.sqrt(a * a + b * b);

System.out.println("c: " + c);
```

```
coligny@marvin-13:~/workspace/trainingDir$ java training.PrimitiveTypes
c: 5.0
```







# Arrays

- 1, 2 or more dimensions arrays
- managed by references
- dynamic allocation: with the **new** keyword
- **null** if not initialised
- can not be resized
- access elements with the **[ ]** operator
- indices begin at 0
- **size**: myArray.length

```
String[] a = new String[12];
a[11] = "Bob";
```

```
String[] b = {"Jack", "William", "Joe"};
```

```
int size = 4;
double[] c = new double[size];
```

```
double[][] d = new double[4][6];
d[0][2] = 3d ;
d[3][5] = 1d ;
```

```
// Index error: max is d[3][5]
System.out.println(d[4][6]);
```

null	null	null	null	null	null	null	null	null	null	null	Bob
------	------	------	------	------	------	------	------	------	------	------	-----

Jack	William	Joe
------	---------	-----

0	0	0	0
---	---	---	---

2 dimensions

	0	1	2	3	4	5
0	0	0	3	0	0	0
1	0	0	0	0	0	0
2	0	0	0	0	0	0
3	0	0	0	0	0	1

Exception in thread "main" java.lang.ArrayIndexOutOfBoundsException: 4  
at training.Training.main(Training.java:31)

a runtime exception



## Conditions: if, else if, else

### Tests a simple condition

- can be combined

```
// Simple if
if (i == 10) {
    // do something
}

// Complex if
if (count < 50) {
    // do something
} else if (count > 50) {
    // do something else
} else {
    // count == 50
}

// Boolean expression
if (index >= 5 && !found) {
    System.out.println ("Could not find in 5 times");
}
```



## Loops: while, do... while

### Loop with condition

- while (condition) {...}
- do {...} while (condition);

while:  
condition is tested **first**

```
int count = 0;
while (count < 10) {
    count++;
}

System.out.println ("count: " + count);
```

count: 10

do... while:  
condition is tested at the **end**  
--> always at least one iteration

```
int count = 0;
do {
    count++;
} while (count < 10);

System.out.println ("count: " + count);
```

count: 10

test is at the end



# Loops: for

## Loop a number of times

- for (initialisation; stop condition; advance code) {...}

```
// With an array
int[] array = new int[12];
int sum = 0 ;
for (int i = 0; i < array.length; i++) {
    array[i] = i;
    sum += array[i];
}
```

from 0 to 11

sum: 66



## Loops: continue or break

```
// Search an array
int sum = 0;
int i = 0;

for (i = 0; i < array.length; i++) {
    if (array[i] == 0) continue;
    sum += array[i];
    if (sum > 50) break;
}
System.out.println ("i: " + i+" sum: " + sum);
```

from 0 to 11

```
i: 10 sum: 55
```

- an internal **continue** jumps to the next iteration
- an internal **break** gets out of the loop
- for all kinds of loops (for, while, do while)



## Runtime exceptions

### Something wrong during the execution

- could not be checked at compilation time
- e.g. try to **access to an element outside the bounds of an array**
  - `java.lang.ArrayIndexOutOfBoundsException`
- e.g. try to **use an array that was not initialised**
  - `java.lang.NullPointerException`
- e.g. try to **read a file that could not be found**
  - `java.io.FileNotFoundException`
- exceptions stop the program if not managed...



# Exceptions management

## Exceptions can be managed everywhere

→ use a try / catch statement

```
String fileName = "wrongName";  
  
try {  
    BufferedReader in = new BufferedReader (new FileReader (fileName));  
    String str;  
    while ((str = in.readLine ()) != null) {  
        //process (str);  
    }  
    in.close();  
} catch (Exception e) {  
    System.out.println ("Trouble: " + e);  
}
```

this file does not exist

-1- this code raises an exception

-2- this code  
is skipped

-3- the catch  
clause is evaluated

-4- the trouble is reported  
catch should never be empty!

Trouble: java.io.FileNotFoundException: wrongName (No such file or directory)



## Object oriented programming (O.O.P.)

Java is an object oriented language...

- **encapsulation**
- vocabulary
- **class**
- properties
- **constructor**
- **instance(s)**
- **method**
- calling methods
- memory management
- **inheritance**
- specific references
- constructors chaining
- method overloading / overriding
- static method and variable
- **interface**
- abstract class
- the 'Object' superclass
- enums
- **polymorphism**
- cast using the 'instanceof' operator
- packages and import
- lifetime of variables
- Java reserved keywords
- Java modifiers

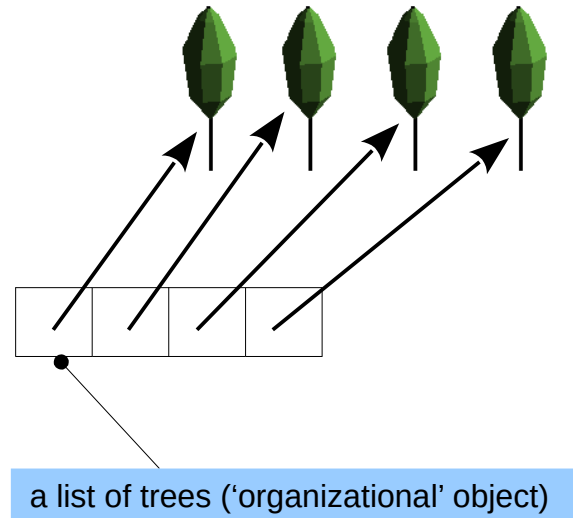
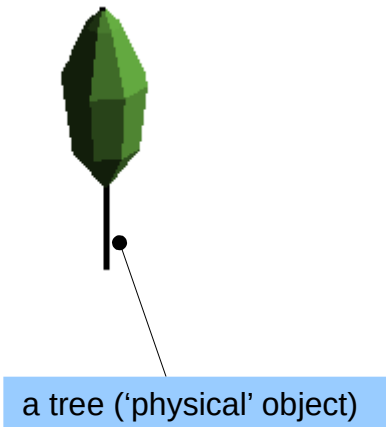
Not presented here:

- static initializer
- nested class
- ...

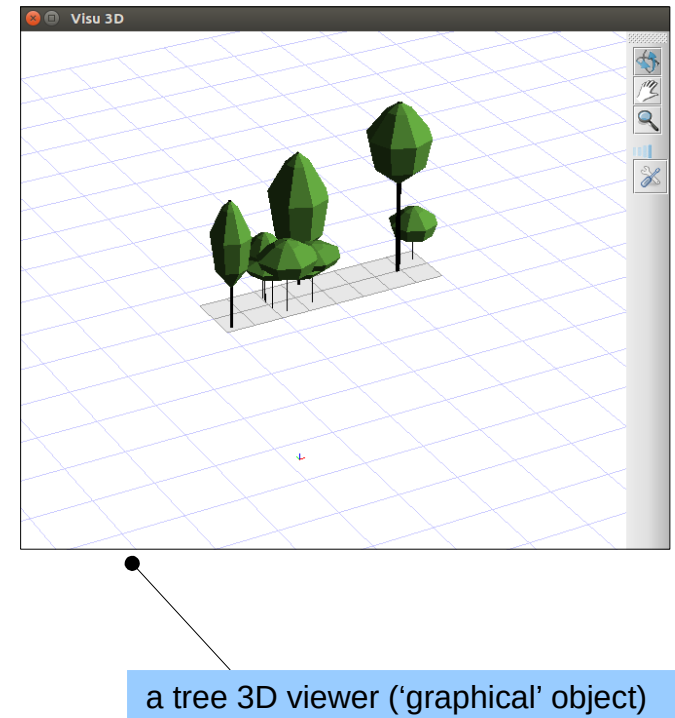


# Introduction to object oriented programming (O.P.P.)

- The **O.O.P.**:
  - is based on structured programming
  - contributes to the **reliability** of softwares
  - makes it easy to **reuse** existing codes
  - introduces new concepts: object, encapsulation, classe, inheritance
- In **O.O.P.** a program implements different **objects** (= a software brick).
- Different kinds of objects:



and many others...





# Encapsulation

**Bundle** data and methods operating on these data in a unique container:  
→ the object

**Hide** the implementation details to the users (developers) of the object, they only know its 'interface' (interface = the functions that one wishes to show to the user)

```
package training;

/** A simple tree
 */
public class Tree {

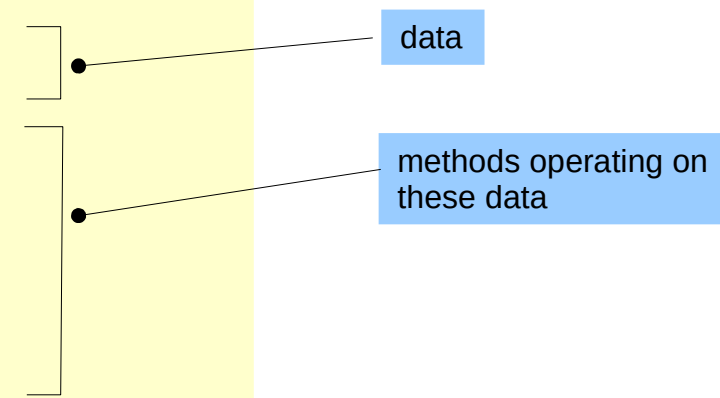
    // diameter at breast height, cm
    private double dbh;

    public Tree () {}

    public void setDbh (double d) {
        dbh = d;
    }

    public double getDbh () {
        return dbh;
    }

}
```

A diagram on the right side of the code block illustrates the encapsulation of data and methods. Two blue boxes are connected to the code by lines. The top box, labeled 'data', points to the line 'private double dbh;'. The bottom box, labeled 'methods operating on these data', points to the three method definitions: 'public Tree () {}', 'public void setDbh (double d) {', and 'public double getDbh () {'.

data

methods operating on these data



## Vocabulary

### Class

- a class = a **new data type** → generalization of the concept of simple type (example: Tree)
- source files describe classes

### Object

- instance of a class at runtime
- memory allocation
- several objects may be built with the same class (example: 3 instances of Tree class)

### Instance variable (iv)

- variables of an object (example: dbh)
- (field, attribute, member data)

### Method

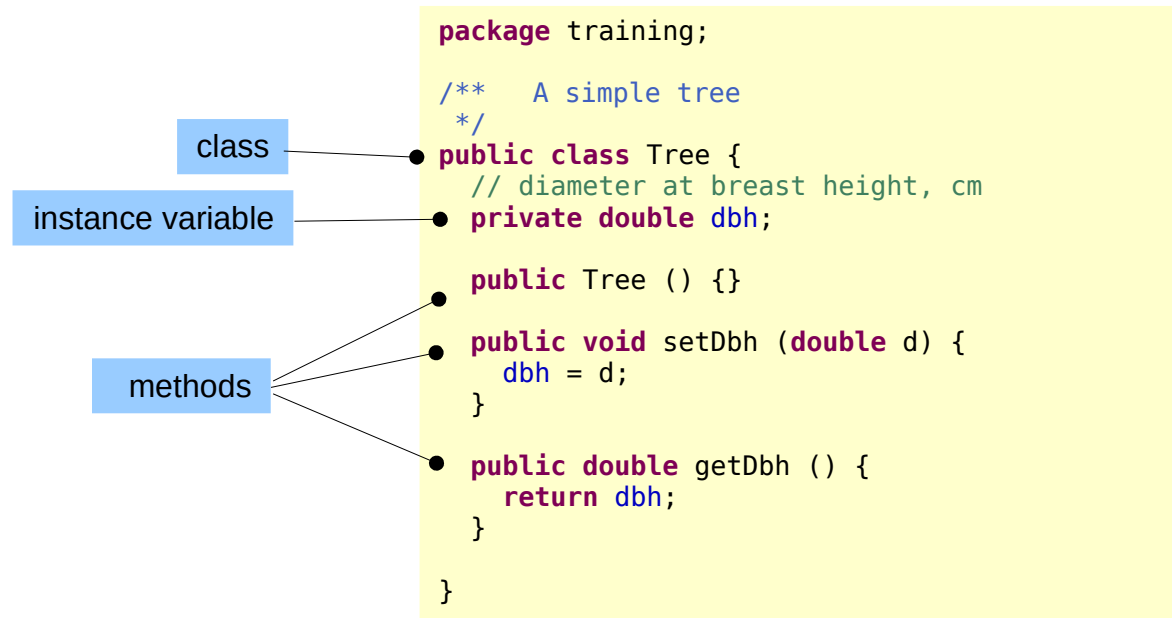
- function of an object (example: setDbh(), getDbh())
- (procedure, member function)

### Property

- instance variable or method



# Class



## A class is a new data type

e.g. int, double, float, boolean, String, Tree...

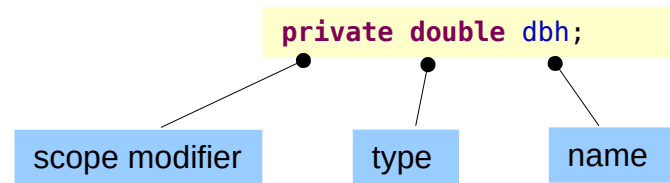
## Scope modifiers for the properties

- **public** : visible by all (interface)
- **protected** : visible in the package (and in later seen subclasses...)
- **private** : scope is limited to the class (hidden to the others)

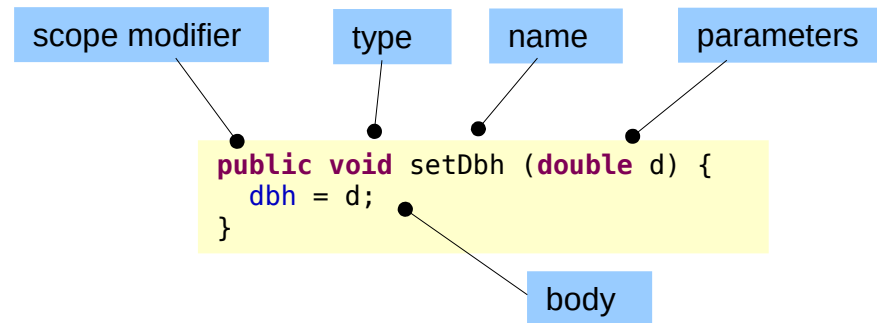


# Properties

## Instance variable



## Method



### A rule:

parentheses after the name → it is a method



## Method

### Classes contain instance variables and methods

- a class can contain several methods
- if no parameters, use **()**
- if no return type, use **void**

```
package training;

/** A simple tree
 */
public class Tree {
    // diameter at breast height, cm
    private double dbh;

    public Tree () {}

    public void setDbh (double d) {
        dbh = d;
    }

    public double getDbh () {
        return dbh;
    }
}
```

**constructors** are particular methods without a return type

setDbh () method: 1 parameter

getDbh () is an **accessor** returns something



# Constructor

- **particular method** called at object creation time
- **same name** than the class (starts with an uppercase letter)
- **no return type**
- deals with instance variables **initialisation**
- **several** constructors may coexist if they have different number and/or types of parameters

```
package training;

/**   A simple tree
 */
public class Tree {
    // diameter at breast height, cm
    private double dbh;

    public Tree () {}

    public Tree (double d) {
        dbh = d;
    }

    public void setDbh (double d) {
        dbh = d;
    }

    public double getDbh () {
        return dbh;
    }
}
```

a default constructor (no parameter)

another constructor (takes a parameter)

regular method with a parameter

## Notes:

this default constructor does nothing particular  
→ 'dbh' is a numeric instance variable  
→ set to 0 automatically  
the other constructor initializes 'dbh'



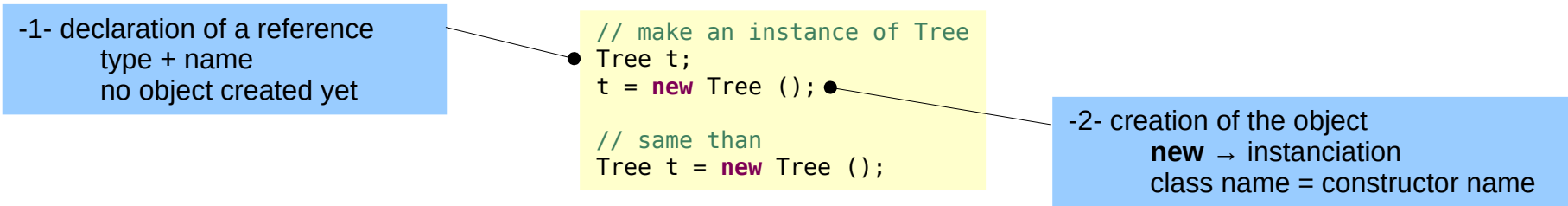
# Instance

**Vocabulary:**  
object = instance

**Vocabulary:**  
the properties of the object  
the properties of the class  
→ instance variables + methods

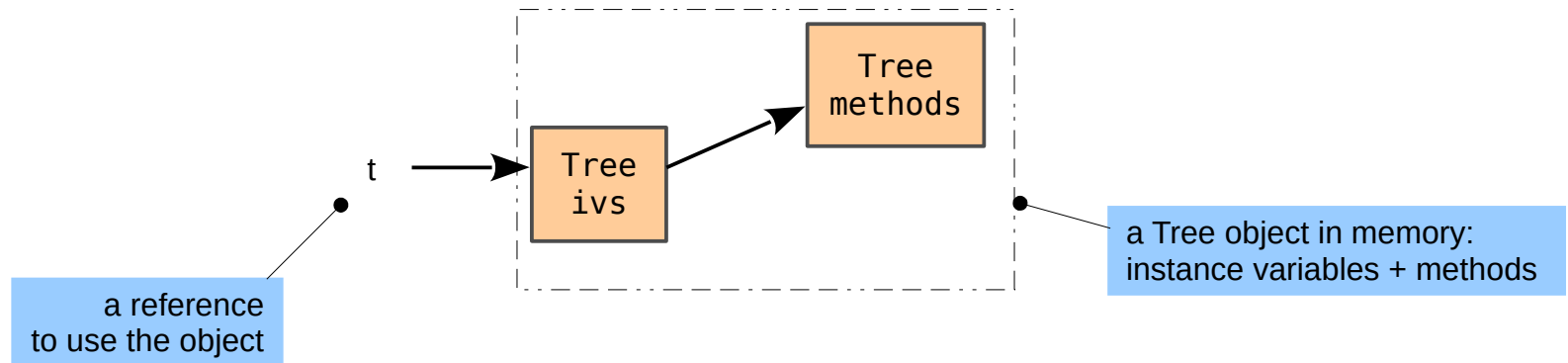
## Instanciación

- creates an instance of a given class
- i.e. an object



## What happens in memory

- new → instanciación = memory reservation for the instance variables (ivs) + the methods
- the constructor is called (initialisations)
- returns a reference to the created object
- we assign it to the reference named 't'







# Instances

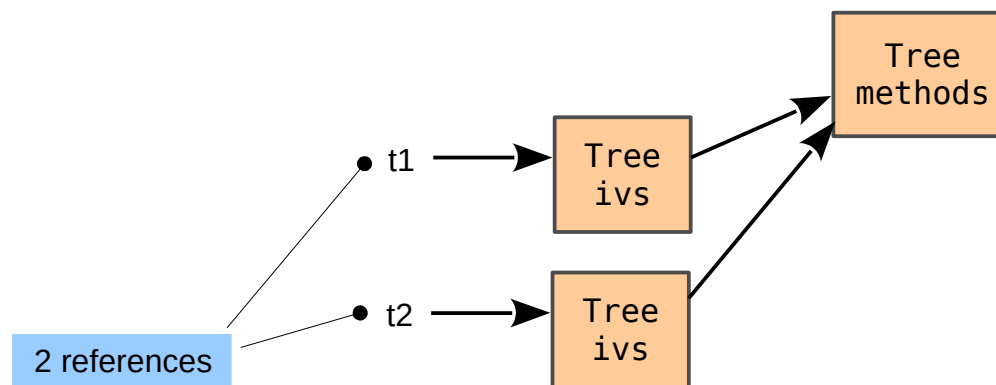
## Creation of several objects

```
// create 2 trees  
Tree t1 = new Tree ();  
Tree t2 = new Tree ();
```

2 times new → 2 objects

## What happens in memory

- 2 times 'new': 2 memory reservations for the instance variables of the 2 objects (their 'dbh' may be different)
- the constructor is called for each object
- the methods of the 2 objects are shared in memory
- each 'new' returns a reference to the corresponding object
- we assign them to 2 different references named 't1' and 't2'

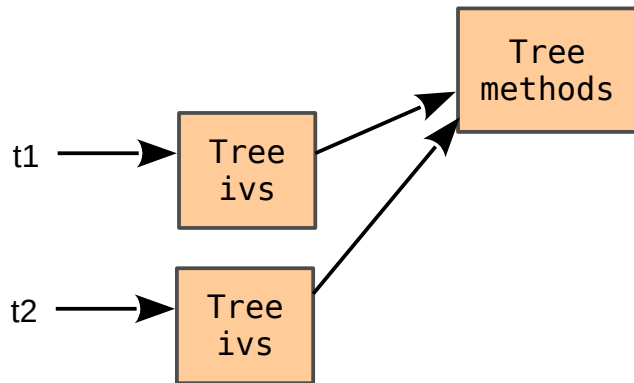




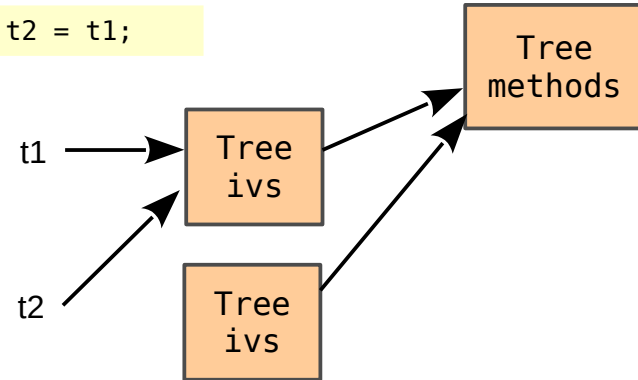
# Instances

## Using the references

```
// Create 2 trees
Tree t1 = new Tree ();
Tree t2 = new Tree ();
```

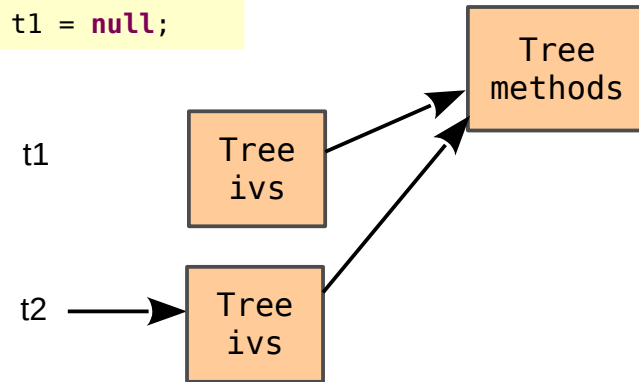


```
t2 = t1;
```



- both 't1' and 't2' point to the first tree
- the second tree is 'lost'

```
t1 = null;
```



- 't1' points to nothing
- 't2' points to the second Tree
- the first Tree is 'lost'



## Calling methods

### Method returning nothing (void)

reference.method (parameters);

### Method returning something

returnType variable = reference.method (parameters);

#### Definition of Tree class (Tree.java file)

```
package training;

/**   A simple tree
 */
public class Tree {
    // diameter at breast height, cm
    private double dbh;

    public Tree () {}

    public void setDbh (double d) {
        dbh = d;
    }

    public double getDbh () {
        return dbh;
    }
}
```



#### Use of Tree class (Training.java file)

```
// Create a tree
Tree t1 = new Tree ();

// Set its diameter
t1.setDbh (12.5);

// Print the diameter
double d1 = t1.getDbh ();

System.out.println ("t1 dbh: " + d1);
```

System is a class  
out is a static public instance variable of type PrintStream  
println () is a method of PrintStream  
writing in out writes on the 'standard output'



## Memory management

- objects are instantiated with the keyword **new** → memory allocation
- objects are **destroyed** when there is no more reference on them → **garbage collecting**
  - this process is automatic
  - to help remove a big object from memory, set all references to null

```
// declare two references
```

```
Tree t1 = null; ●
```

no object created yet

```
// create an object (instanciation)
```

```
t1 = new Tree ();
```

```
// the object can be used
```

```
double v = t1.getDbh ();
```

```
// set reference to null
```

```
t1 = null; ●
```

the object will be destroyed by the garbage collector



# Inheritance

How to create a spatialized tree ?

Simple manner results in **duplicates...**

```
package training;

/** A simple tree
 */
public class Tree {
    // diameter at breast height, cm
    private double dbh;

    public Tree () {}

    public void setDbh (double d) {
        dbh = d;
    }

    public double getDbh () {
        return dbh;
    }
}
```

fichier *Tree.java*

```
package training;

/** A tree with coordinates
 */
public class SpatializedTree {
    // diameter at breast height, cm
    private double dbh;
    // x, y of the base of the trunk (m)
    private double x;
    private double y;

    /** Default constructor
     */
    public SpatializedTree () {
        setXY (0, 0);
    }

    public void setDbh (double d) {
        dbh = d;
    }

    public double getDbh () {
        return dbh;
    }

    public void setXY (double x, double y) {
        this.x = x;
        this.y = y;
    }

    public double getX () {return x;}
    public double getY () {return y;}
}
```

fichier *SpatializedTree.java*

**No scalable and no maintainable**

# Inheritance



UML notation

Tree

SpatializedTree



## Reuse a class to make more specific classes

- e.g. a tree with coordinates
- inheritance corresponds to a **'is a' relation** • a spatialized tree **is a** tree (with coordinates)
- a **subclass** has all the instance variables and methods of its parent: the **superclass**
- all classes inherit from the **Object** class
- multiple inheritance is not allowed in Java

```
package training; superclass
```

```
/** A simple tree
 */
public class Tree {
    // diameter at breast height, cm
    private double dbh;

    public Tree () {}

    public void setDbh (double d) {
        dbh = d;
    }

    public double getDbh () {
        return dbh;
    }
}
```

fichier Tree.java

```
package training; subclass
```

```
/** A tree with coordinates
 */
public class SpatializedTree extends Tree {
    // x, y of the base of the trunk (m)
    private double x;
    private double y;

    /** Default constructor
    */
    public SpatializedTree () {
        super ();
        setXY (0, 0);
    }

    public void setXY (double x, double y) {
        this.x = x;
        this.y = y;
    }

    public double getX () {return x;}
    public double getY () {return y;}
}
```

• inheritance keyword

• calls constructor of the superclass

• new methods

fichier SpatializedTree.java

```
// SpatializedTree
SpatializedTree t3 = new SpatializedTree ();

t3.setDbh (15.5);
t3.setXY (1, 5);

double d = t3.getDbh (); // 15.5
double x = t3.getX (); // 1
```

• inherited methods

fichier Training.java



## Specific references

A keyword for the reference to the current class: **this**

- to remove ambiguities

A keyword for the reference to the superclass: **super**

call to the  
constructor of the  
superclass

```
package training;

/** A tree with coordinates
 */
public class SpatializedTree extends Tree {
    // x, y of the base of the trunk (m)
    private double x;
    private double y;

    /** Default constructor
     */
    public SpatializedTree () {
        ● super ();
        setXY (0, 0);
    }

    public void setXY (double x, double y) {
        this.x = x;
        this.y = y;
    }

    public double getX () {return x;}
    public double getY () {return y;}
}

```

instance variable: this.x

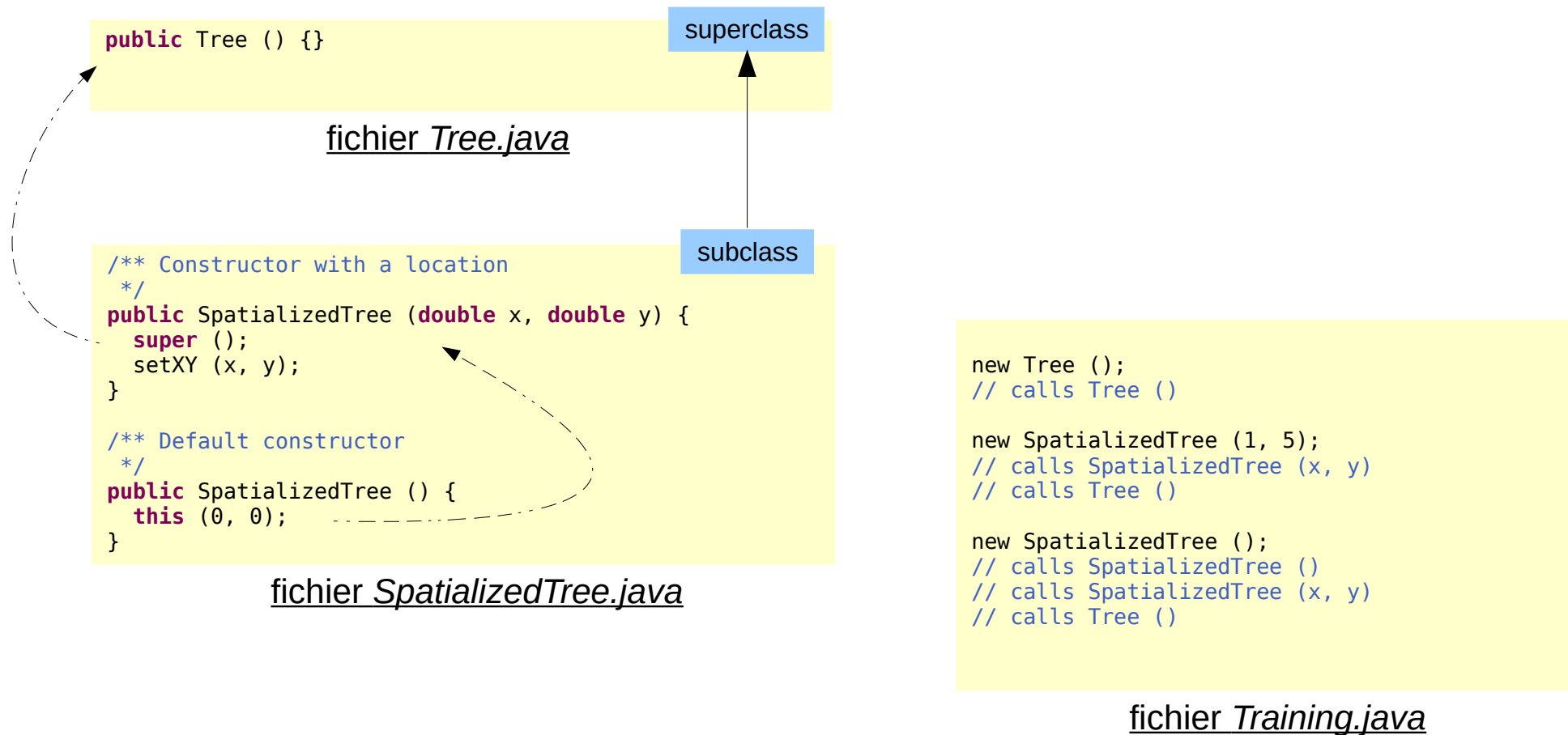
a parameter

no ambiguity here



# Constructors chaining

Chain the constructors to avoid duplication of code







## Method overloading / overriding

### Overload (“surcharge”)

- in the same class
- several methods with same name and
- different types of parameters and/or a different number of parameters

BiomassCalculator

```
public double calculateBiomass (Tree t) {
    return t.getTrunkBiomass ();
}

public double calculateBiomass (TreeWithCrown t) {
    return t.getTrunkBiomass () + t.getCrownBiomass ();
}
```

### Override (“redéfinition”)

- in a class and a subclass
- several methods with:
  - same signature i.e. same name and same types of parameters in the same order
- and
- same type of return value (or a derivated type since JDK 5.0)

```
public double getVolume () {
    return trunkVolume;
}
```

superclass

```
@Override
public double getVolume () {
    return trunkVolume + crownVolume;
}
```

subclass

e.g. if TreeWithCrown **extends** Tree

optional:  
tell the compiler  
--> it will check



## Static method and variable

### A method at the class level: no access to the instance variables

- no need to instantiate a class, example: the methods of the 'Math' class like 'Math.sqrt(double a)'
- a utility method: to reuse a block of code
- uses only its parameters (and not the instance variables)

```
/**
 * Quadratic diameter
 */
public static double calculate_dg (double basalArea, int numberOfTrees) {
    return Math.sqrt (basalArea / numberOfTrees * 40000d / Math.PI);
}
```

example: in class **Tree**

- 'basalArea' and 'numberOfTrees' are the parameters
- their names have a local scope: they are only available in the method

```
double dg = Tree.calculate_dg (23.7, 1250);
```

ClassName.method (parameters)

### A common variable shared by all the instances of a class

- can be a constant: 'Math.PI'

```
public static final double PI = 3.14...;
```

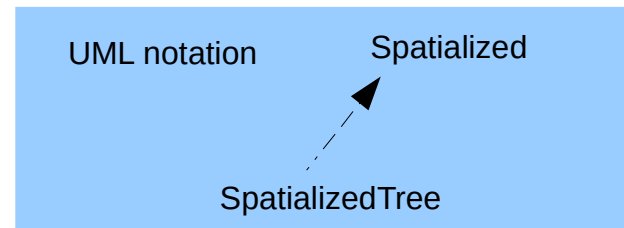
- can be a variable

```
public static int counter;
```

e.g. 'counter' can be incremented each time the class is instantiated



# Interface



## A particular kind of class

- a list of methods without a body
- a way to **make sure** a class implements a set of methods
- a kind of **contract**
- classes extend other classes
- classes **implement** interfaces
- implementing several interfaces is possible

```
public interface Spatialized {
    public void setXYZ (double x, double y, double z);
    public double getX ();
    public double getY ();
    public double getZ ();
}
```

no method body in the interface

```
/** A tree with coordinates
 */
public class SpatializedTree extends Tree implements Spatialized {
    ...

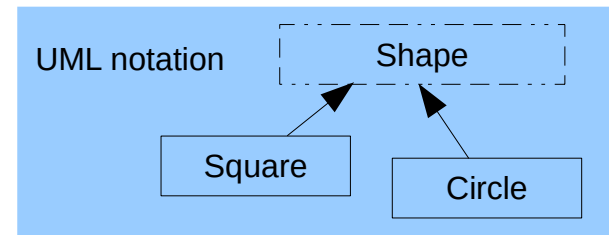
    public void setXYZ (double x, double y, double z) {
        this.x = x;
        this.y = y;
        this.z = z;
    }

    public double getX () {return x;}
    public double getY () {return y;}
    public double getZ () {return z;}
}
```

an implementation is required for the methods in the class or the subclasses



# Abstract class



## An incomplete superclass with common methods

- class 'template' containing **abstract methods** to be implemented in all subclasses (contains at least one abstract method)
- can also have regular methods (unlike an interface)
- each subclass implements the abstract methods
- can not be instanciated directly

fichier Shape.java

```

public abstract class Shape {
    private String name;
    ...
    public String getName () {return name;}
    public abstract double area (); // m2
}
    
```

an **abstract class** (at least one abstract method): can not be instanciated

a regular method

an **abstract method**: no body

```

public class Square extends Shape {
    private double width; // m
    ...
    @Override
    public double area () {
        return width * width;
    }
}
    
```

two subclasses: they **implement** the abstract method

fichier Square.java

```

public class Circle extends Shape {
    private double radius; // m
    ...
    @Override
    public double area () {
        return Math.PI * radius * radius;
    }
}
    
```

fichier Circle.java

```

// Example
Shape sh = new Shape (); // ** Compilation error

Square s = new Square ("square 1", 10);
Circle c = new Circle ("circle 1", 3);

String name1 = s.getName (); // square 1

double a1 = s.area (); // 100
double a2 = c.area (); // 28.27
    
```

fichier Training.java



# Polymorphism

Write generic code to be executed with several types

- more abstract and general implementations

```
public abstract class Shape {
    public abstract double area (); // m2
}
```

fichier Shape.java

```
public class Square extends Shape {
    private double width; // m
    ...
    @Override
    public double area () {
        return width * width;
    }
}
```

fichier Square.java

```
public class Circle extends Shape {
    private double radius; // m
    ...
    @Override
    public double area () {
        return Math.PI * radius * radius;
    }
}
```

fichier Circle.java

```
private float totalArea (Shape[] a) {
    double sum = 0;
    for (int i = 0; i < a.length; i++) {
        // the program knows what method to call
        sum += a[i].area ();
    }
    return sum;
}
```

fichier Training.java

this code is generic  
works with all shapes

several classes, all Shapes

Example of use

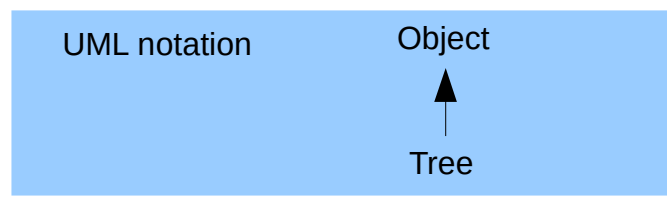
```
Shape[] a = {new Square (5), new Circle (3), new Square (10)};
float total = totalArea (a);
```

fichier Training.java



# The 'Object' superclass

If no 'extends' keyword...  
... then the class extends Object  
→ All classes extend Object



## fichier *Tree.java*

extends Object

```

package training;

/** A simple tree
 */
public class Tree {
    // diameter at breast height, cm
    private double dbh;

    public Tree () {}

    public void setDbh (double d) {
        dbh = d;
    }

    public double getDbh () {
        return dbh;
    }

    public String toString () {
        return "Tree dbh: " + dbh;
    }
}

```

## fichier *Object.java*

note: native methods have a body in native language (e.g. C)  
-> they are not abstract

```

package java.lang;

public class Object {

    public final native Class<?> getClass();

    public native int hashCode();

    public boolean equals(Object obj) {
        return (this == obj);
    }

    protected native Object clone() throws CloneNotSupportedException;

    public String toString() {
        return getClass().getName() + "@" + Integer.toHexString(hashCode());
    }

    (...)

}

```

a superclass for all classes

all these methods can be called on all objects

## fichier *Training.java*

```

// Tree
Tree t = new Tree ();
t.setDbh (14.5);
System.out.println (" " + t);

```

appended to a String:  
i.e. t.toString ()

toString () can be overridden for a better result

```

training.Tree@37dd7056
Tree dbh: 14.5

```



# Enum

## Another particular kind of class: a type for enumerations

- an enum is a type with a limited number of value

### Declaration

```
public enum Day {  
    SUNDAY, MONDAY, TUESDAY, WEDNESDAY,  
    THURSDAY, FRIDAY, SATURDAY  
}
```

### An example of use

```
private Day day;  
...  
day = Day.SUNDAY;  
...
```



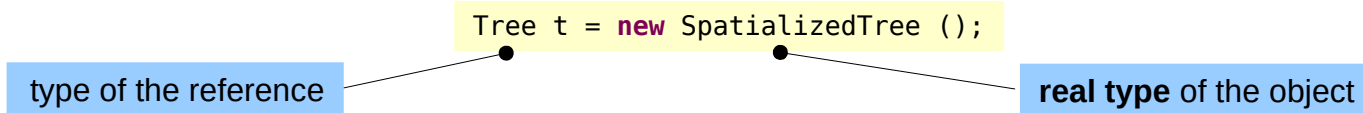
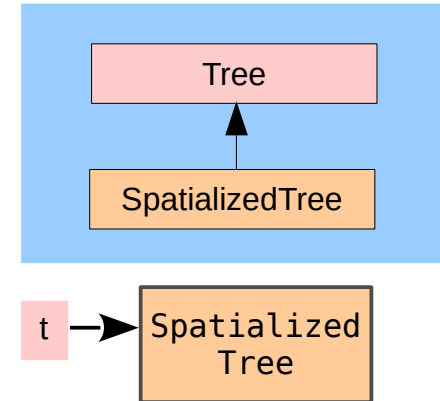
# Cast

## Cast of numbers

```
double d = 12.3;
int i = (int) d; // 12
```

## In an inheritance graph

- a reference can have any supertype of the real type



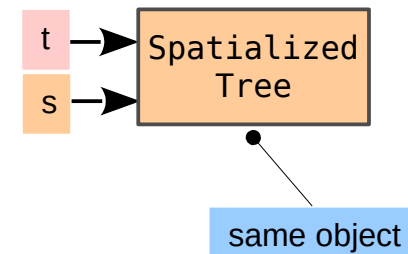
- we can only use the methods the reference knows

```
t.setDbh (10); // ok
t.setXY (2, 10); // ** compilation error: Tree does not define setXY ()
```

- to access the methods of the real type, we can create another reference

```
SpatializedTree s = (SpatializedTree) t; // cast: creates another reference
s.setXY (2, 1); // ok: SpatializedTree does define setXY ()
```

- example of use (with the 'instanceof' operator)



instanceof operator: checks the type of an object

calculates the rectangle enclosing the spatialized trees

```
List trees = forest.getTrees();
for (Object o : trees) {
    if (o instanceof SpatializedTree) {
        SpatializedTree s = (SpatializedTree) o;
        updateRectangle(s.getX(), s.getY());
    }
}
```





# Packages and import

## Packages

- namespaces to organize the developments: groups of related classes
- first statement in the class (all lowercase)
- match directories with the same names

e.g.

- **java.lang**: String, Math and other basic Java classes
- **java.util**: List, Set... (see below)
- **training**: Tree and SpatializedTree

The package is part of the class name: **java.lang.String**, **training.Tree**

## Import

- to simplify notation, import classes and packages

instead of:

```
training.Tree t = new training.Tree ();
```

write:

```
import training.Tree;  
...  
Tree t = new Tree ();
```



## Lifetime of variables

**Lifetime** of a variable: defined by the **scope** delimited by {...} in which the variable has been defined

- **instance variable** of a class: as long as the **object** it belongs is referenced  
(lifetime = lifetime of the object)

```
package training;

/** A simple tree
 */
public class Tree {
    // diameter at breast height, cm
    private double dbh;

    public Tree () {}

    public void setDbh (double d) {
        dbh = d;
    }

    public double getDbh () {
        return dbh;
    }
}
```

fichier Tree.java

scope = the body of the class

```
// Before instantiation of
// Tree class

// Create a tree
Tree t1 = new Tree ();

// Set its diameter
t1.setDbh (12.5);

// t1 is no more referenced
t1 = null;
```

fichier Training.java

dbh does not exist

an object of type Tree is created and its reference is placed in t1: dbh (of t1) exists and is initialized to 0.0 (default value)

dbh has value 12.5

the created Tree is no more referenced: it becomes candidate to the garbage collector and dbh does not exist anymore



## Lifetime of variables

**Lifetime** of a variable: defined by the **scope** delimited by {...} in which the variable has been defined

- **argument (parameter)** and **local variable** of a **method**: *exist only inside the method*

scope = the body of the method

```
package training;

/** A simple tree
 */
public class Tree {
    // diameter at breast height, cm
    private double dbh;

    public Tree () {}

    public void setDbh (double d) {
        dbh = d;
    }

    public double getDbh () {
        return dbh;
    }

    public double getDbhSquared () {
        double res = dbh*dbh;
        return res;
    }
}
```

fichier Tree.java

d is an argument of the setDbh() method: d exists only **inside** this method

```
// Create a tree
Tree t1 = new Tree ();

// Set its diameter
t1.setDbh (12.5);

// Call getDbhSquared() method
double dbhSquared = t1.getDbhSquared ();
```

fichier Training.java

d does not exist

d exists inside the method

d does not exist anymore



## Lifetime of variables

**Lifetime** of a variable: defined by the **scope** delimited by {...} in which the variable has been defined

- **argument (parameter)** and **local variable** of a **method**: *exists only inside the method*

```
package training;

/** A simple tree
 */
public class Tree {
    // diameter at breast height, cm
    private double dbh;

    public Tree () {}

    public void setDbh (double d) {
        dbh = d;
    }

    public double getDbh () {
        return dbh;
    }

    public double getDbhSquared () {
        double res = dbh*dbh;
        return res;
    }
}
```

fichier *Tree.java*

**scope = the body of the method**

**res** is declared in the getDbhSquared() method: **res** exists only **inside** this method

```
// Create a tree
Tree t1 = new Tree ();

// Set its diameter
t1.setDbh (12.5);

// Call getDbhSquared() method
double dbhSquared = t1.getDbhSquared ();
```

fichier *Training.java*

**res** does not exist

**res** exists inside the method

**res** does not exist anymore



## Lifetime of variables

**Lifetime** of a variable: defined by the **scope** delimited by {...} in which the variable has been defined

- **index** of a **loop**: exists *inside the loop* (at least...)

```
// With an array
int[] array = new int[12];
int sum = 0 ;
for (int i = 0; i < array.length; i++) {
    array[i] = i;
    sum += array[i];
}
```

i does not exist

i is created

i exists inside the loop

i does not exist anymore

scope = the body of the loop

*lifetime of i = exists only  
inside the loop*



# Lifetime of variables

**Lifetime** of a variable: defined by the **scope** delimited by {...} in which the variable has been defined

- **index** of a **loop**: exists *inside the loop* (at least...)

```
// With an array
int[] array = new int[12];
int sum = 0 ;
for (int i = 0; i < array.length; i++) {
    array[i] = i;
    sum += array[i];
}
```

i does not exist

i is created

i exists inside the loop

i does not exist anymore

scope = the body of the loop

*lifetime of i = exists only inside the loop*

**sum** has the same value with *i* declared before the loop:

```
// With an array
int[] array = new int[12];
int sum = 0 ;
int i;
for (i = 0; i < array.length; i++) {
    array[i] = i;
    sum += array[i];
}
```

i is created

i exists inside the loop

i still exists and its value is 12

scope = the body of the loop

*lifetime of i = from its declaration + inside the loop + after the loop*



## Lifetime of variables

**Lifetime** of a variable: defined by the **scope** delimited by {...} in which the variable has been defined

- **local variable** of a **loop**: *exists only inside the loop*

```
// With an array
int[] array = new int[12];
int sum = 0 ;
for (int i = 0; i < array.length; i++) {
    int j = i+2;
    array[i] = i;
    sum += array[i];
}
```

j does not exist

j is created

j does not exist anymore

scope = the body of the loop



## Names of variables

Use **explicit names** for:

- **instance variables**

```
package training;

/** A simple tree
 */
public class Tree {
    // diameter at breast height, cm
    private double dbh;
    private int age;
    private double height;
    private String speciesName;

    public Tree () {}
}
```

- **local variables** having a long range

```
package training;

/** A simple tree
 */
public class Tree {
    // diameter at breast height, cm
    private double dbh;

    public Tree () {}

    public void makeCalculations () {
        int anExplicitName;
        ...
        some long calculations...
        anExplicitName = ...
        ...
        anExplicitName = ...
    }
}
```

**Short names** are authorized for variables having a **short range**:

```
// With an array
int[] array = new int[12];
int sum = 0 ;
for (int i = 0; i < array.length; i++) {
    array[i] = i;
    sum += array[i];
}
```

} only 3 lines





## Java reserved keywords

<b>abstract</b>	<b>float</b>	<b>super</b>
<b>boolean</b>	<b>for</b>	<b>switch</b>
<b>break</b>	goto (unused)	<b>synchronized</b>
<b>byte</b>	<b>if</b>	<b>this</b>
case	<b>implements</b>	<b>throw</b>
cast	<b>import</b>	<b>throws</b>
<b>catch</b>	<b>instanceof</b>	transient
<b>char</b>	<b>int</b>	<b>true</b>
<b>class</b>	<b>interface</b>	<b>try</b>
const	<b>long</b>	<b>void</b>
<b>continue</b>	native	volatile
default	<b>new</b>	<b>while</b>
<b>do</b>	<b>null</b>	
<b>double</b>	<b>package</b>	
<b>else</b>	<b>private</b>	
enum	<b>protected</b>	
<b>extends</b>	<b>public</b>	
<b>false</b>	<b>return</b>	
<b>final</b>	<b>short</b>	
finally	<b>static</b>	



# Java modifiers

	class	interface	field	method	initializer	variable
<b>abstract</b>	X	X		X		
<b>final</b>	• X		X •	X •		X
<b>native</b>				X		
<b>none (package)</b>	X	X	X	X		
<b>private</b>			X	X		
<b>protected</b>			X	X		
<b>public</b>	X	X	X	X		
<b>static</b>	X		X	X	X	
<b>synchronized</b>				X		
<b>transient</b>			X			
<b>volatile</b>			X			

a final class can not be subclassed

a final field cannot be changed e.g. Math.PI

a final method can not be overridden



## Resources

- a focus on the collection framework
- the Collection interface
- ArrayList
- HashSet
- Map
- the tools in the Collections class
- how to iterate on objects in collections
- how to iterate on objects in maps
- generics
- online documentation
- online documentation: javadoc
- online documentation: tutorials
- links to go further



## A focus on the collection framework

**A collection is like an array, but without a size limitation** (size can vary during execution)

- contains references
- may have distinctive features
  - a **list** keeps insertion order
  - a **set** contains no duplicates and has no order
- the 8 simple types (int, double, boolean...) are not objects → need a **wrapper object**  
**Byte, Short, Integer, Long, Float, Double, Character, Boolean**  
Java helps: **Integer i = 12;** (autoboxing / unboxing)
- all collections implement **the Collection interface**



# The Collection interface

Implemented by all collections

```
public boolean add (Object o);      // adds o
public boolean remove (Object o);   // removes o

public void clear ();               // removes all objects
public boolean isEmpty ();          // true if the collection is empty

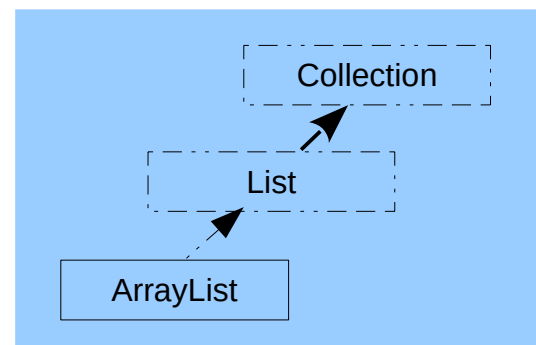
public int size ();                 // number of objects in the collection
public boolean contains (Object o); // true if o is in the collection
...
```



# ArrayList

## ArrayList

- implements the **List** interface
- keeps insertion order
- accepts duplicates
- specific methods added



```
public void add (int index, Object o); // adds o at the given index (shifts subsequent elts)
public Object get (int index); // returns the object at the given index
public int indexOf (Object o); // returns the index of o
public Object remove (int index); // removes the object at the given index
...
```

```
List l = new ArrayList ();
l.add ("Robert"); // add () comes from Collection
l.add ("Brad");
l.add ("Robert");

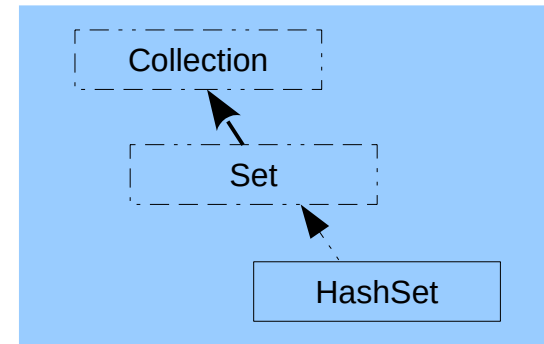
int n = l.size (); // 3
String s = (String) l.get (0); // "Robert"
```



# HashSet

## HashSet

- implements the **Set** interface
- does **not** keep insertion order
- does **not** accept duplicates



```
Set s = new HashSet ();

s.add ("one");
s.add ("two");
s.add ("one"); // duplicate, ignored

int n = s.size (); // 2

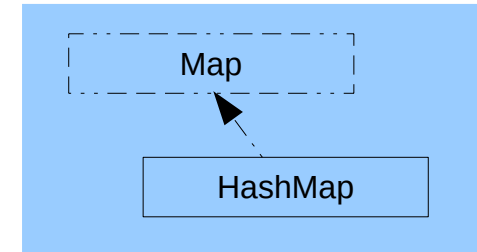
if (s.contains ("one"))... // true
if (s.contains ("three"))... // false
```



# Maps

## A Map associates a key with a value

- the common Map implementation is **HashMap**
- keys must be unique (like in a Set)
- keys and values are references



```
Map m = new HashMap ();

m.put ("Red", new Color (1, 0, 0));
m.put ("Green", new Color (0, 1, 0));
m.put ("Blue", new Color (0, 0, 1));

Color c = (Color) m.get ("Red"); // returns a color object

if (m.containsKey ("Blue"))... // true

Set s = m.keySet (); // set of keys: Red, Green, Blue
```





## The tools in the Collections class

Tools for the collections are proposed in a class: Collections

```
public static final List EMPTY_LIST
public static final Set EMPTY_SET
public static final Map EMPTY_MAP

public static void sort(List list)
public static void sort(List list, Comparator c)

public static void shuffle(List list)
public static void reverse(List list)

public static Object min(Collection coll)
public static Object max(Collection coll)
```

empty collections and maps

sorting

changing elements order

```
// Random order
Collections.shuffle (list);
```



# How to iterate on objects in collections

## Two syntaxes to loop on a list

```
// List of Tree
List l = new ArrayList ();
l.add (new Tree (5.5));
l.add (new Tree (2.3));
l.add (new Tree (4.1));
...
```

constructor takes a dbh

an Iterator + a cast

```
// Loop with an Iterator
for (Iterator i = l.iterator (); i.hasNext ();) {
    Tree t = (Tree) i.next ();

    if (t.getDbh () < 3) {i.remove ();}
}
```

the iterator can remove the current element from the list

a cast is needed at iteration time

```
// Loop with a foreach
for (Object o : l) {
    Tree t = (Tree) o;

    t.setDbh (t.getDbh () * 1.1);
}
```



## How to iterate on objects in maps

```
Map m = new HashMap ();  
m.put ("Red", new Color (1, 0, 0));  
m.put ("Green", new Color (0, 1, 0));  
m.put ("Blue", new Color (0, 0, 1));
```

```
for (Object o : m.keySet ()) {  
    String key = (String) o;  
    //...  
}
```

iterate on keys

```
for (Object o : m.values ()) {  
    Color value = (Color) o;  
    //...  
}
```

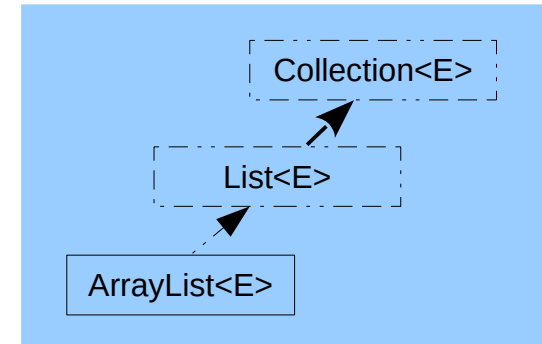
iterate on values



# Generics

Collections are manipulated by generic classes that implement **Collection<E>**

**E** represents the type of the elements of the collection



```
// List of Tree
List<Tree> l = new ArrayList<Tree> ();
l.add (new Tree (1.1));
l.add (new Tree (2.5));
l.add (new Tree (3.4));

// Simplified foreach, no cast needed
for (Tree t : l) {

    t.setDbh (t.getDbh () * 1.1);

}
...

// Print the result
for (Tree t : l) {
    System.out.println ("Tree dbh: " + t.getDbh ());
}
```

longer: specify type

shorter: no cast



# Online documentation

<http://download.oracle.com/javase/8/docs/>

## ORACLE Java SE Documentation

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### Java SE 6 Documentation



#### What's New

- Documentation
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#### JDK Components

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- Supported Systems Configurations
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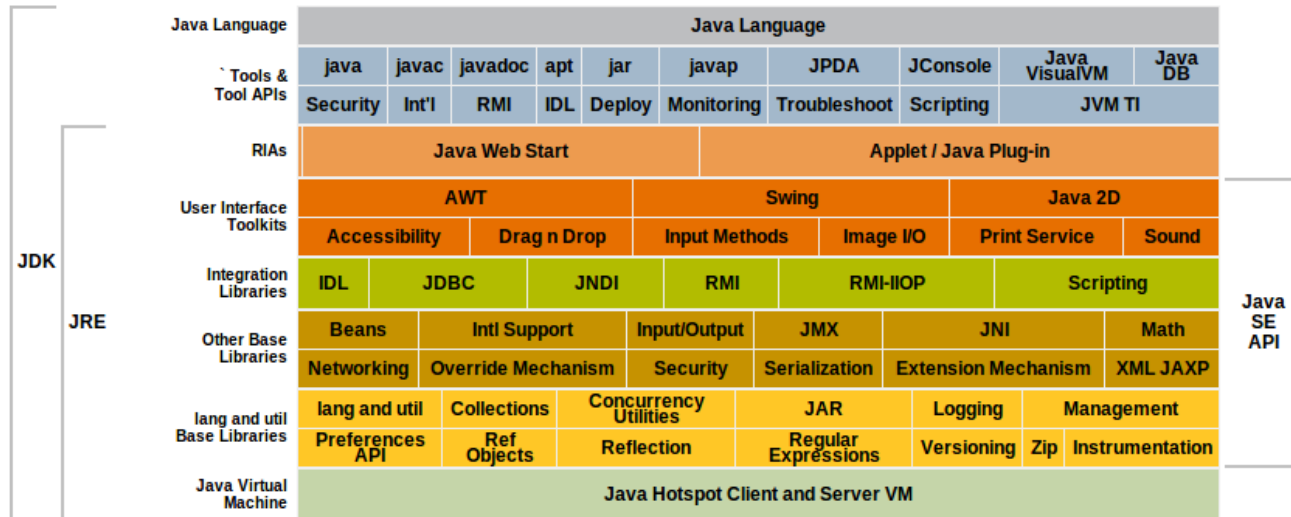
#### Resources

- Java for Business
- Open JDK
- Bugs Database

The two principal products in the Java SE platform are: Java Development Kit (JDK) and Java SE Runtime Environment (JRE).

The JDK is a superset of the JRE, and contains everything that is in the JRE, plus tools such as the compilers and debuggers necessary for developing applets and applications. The Java Runtime Environment (JRE) provides the libraries, the Java Virtual Machine, and other components to run applets and applications written in the Java programming language.

The following conceptual diagram illustrates all the component technologies in Java SE platform and how they fit together.



#### [Java SE 6 API Documentation](#)

#### What's New in Java SE Documentation

Java SE documentation is regularly updated to provide developers with in-depth information about new features in the Java platform. Some recent updates include:

##### [Customizing the RIA Loading Experience](#)

Customize the rich Internet application loading experience by providing a splash screen or a customized loading progress indicator to engage the end user when the RIA is loading and to communicate measurable progress information.

See the following topics for more information:

- [Customizing the RIA Loading Experience](#) topic for conceptual information
- [Customizing the Loading Experience](#) topic in the Java Tutorials for step-by-step instructions and examples

##### [Mixing Signed and Unsigned Code](#)

Signed Java Web Start applications and applets that contain signed and unsigned components could potentially be unsafe unless the mixed code was intended by the application vendor. As of the 6 update 19 release, when mixed code is detected in a program, a warning dialog is raised. [Mixing Signed and Unsigned Code](#) explains this warning dialog and options that the user, system administrator, developer, and deployer have to manage it.

See [Oracle Java SE and Java for Business Critical Patch Update Advisory - March 2010](#) for details.



# Online documentation: javadoc

<http://download.oracle.com/javase/8/docs/api/>

[java.awt.event](#)  
[java.awt.font](#)  
[java.awt.geom](#)  
[java.awt.im](#)  
[java.awt.im.spi](#)  
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Overview Package **Class** Use Tree Deprecated Index Help

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DETAIL: FIELD | [CONSTR](#) | [METHOD](#)

Java™ Platform  
Standard Ed. 6

java.lang

## Class Object

java.lang.Object

public class Object

Class `Object` is the root of the class hierarchy. Every class has `Object` as a superclass. All objects, including arrays, implement the methods of this class.

Since:

JDK1.0

See Also:

[Class](#)

### Constructor Summary

[Object\(\)](#)

### Method Summary

protected <a href="#">Object</a>	<a href="#">clone()</a> Creates and returns a copy of this object.
boolean	<a href="#">equals(Object obj)</a> Indicates whether some other object is "equal to" this one.
protected void	<a href="#">finalize()</a> Called by the garbage collector on an object when garbage collection determines that there are no more references to the object.
<a href="#">Class</a> <?>	<a href="#">getClass()</a> Returns the runtime class of this <code>Object</code> .
int	<a href="#">hashCode()</a> Returns a hash code value for the object.
void	<a href="#">notify()</a> Wakes up a single thread that is waiting on this object's monitor.
void	<a href="#">notifyAll()</a> Wakes up all threads that are waiting on this object's monitor.
<a href="#">String</a>	<a href="#">toString()</a> Returns a string representation of the object.
void	<a href="#">wait()</a> Causes the current thread to wait until another thread invokes the <a href="#">notify()</a> method or the <a href="#">notifyAll()</a> method for this object.
void	<a href="#">wait(long timeout)</a> Causes the current thread to wait until either another thread invokes the <a href="#">notify()</a> method or the <a href="#">notifyAll()</a> method for this object, or a specified amount of time has elapsed.



# Online documentation: tutorials

<http://docs.oracle.com/javase/tutorial/>

## Trails Covering the Basics

These trails are available in book form as *The Java Tutorial, Fifth Edition*. To buy this book, refer to the box to the right.

- » [Getting Started](#) — An introduction to Java technology and lessons on installing Java development software and using it to create a simple program.
- » [Learning the Java Language](#) — Lessons describing the essential concepts and features of the Java Programming Language.
- » [Essential Java Classes](#) — Lessons on exceptions, basic input/output, concurrency, regular expressions, and the platform environment.
- » [Collections](#) — Lessons on using and extending the Java Collections Framework.
- » [Date-Time APIs](#) — How to use the `java.time` pages to write date and time code.
- » [Deployment](#) — How to package applications and applets using JAR files, and deploy them using Java Web Start and Java Plug-in.
- » [Preparation for Java Programming Language Certification](#) — List of available training and tutorial resources.

## Creating Graphical User Interfaces

- » [Creating a GUI with Swing](#) — A comprehensive introduction to GUI creation on the Java platform.
- » [Creating a JavaFX GUI](#) — A collection of JavaFX tutorials.

## Specialized Trails and Lessons

These trails and lessons are only available as web pages.

- » [Custom Networking](#) — An introduction to the Java platform's powerful networking features.
- » [The Extension Mechanism](#) — How to make custom APIs available to all applications running on the Java platform.
- » [Full-Screen Exclusive Mode API](#) — How to write applications that more fully utilize the user's graphics hardware.
- » [Generics](#) — An enhancement to the type system that supports operations on objects of various types while providing compile-time type safety. Note that this lesson is for advanced users. The [Java Language](#) trail contains a [Generics](#) lesson that is suitable for beginners.
- » [Internationalization](#) — An introduction to designing software so that it can be easily adapted (localized) to various languages and regions.
- » [JavaBeans](#) — The Java platform's component technology.
- » [JDBC Database Access](#) — Introduces an API for connectivity between the Java applications and a wide range of databases and data sources.
- » [JMX](#) — Java Management Extensions provides a standard way of managing resources such as applications, devices, and services.
- » [JNDI](#) — Java Naming and Directory Interface enables accessing the Naming and Directory Service such as DNS and LDAP.
- » [JAXP](#) — Introduces the Java API for XML Processing (JAXP) technology.
- » [JAXB](#) — Introduces the Java architecture for XML Binding (JAXB) technology.
- » [RMI](#) — The Remote Method Invocation API allows an object to invoke methods of an object running on another Java Virtual Machine.
- » [Reflection](#) — An API that represents ("reflects") the classes, interfaces, and objects in the current Java Virtual Machine.
- » [Security](#) — Java platform features that help protect applications from malicious software.
- » [Sound](#) — An API for playing sound data from applications.
- » [2D Graphics](#) — How to display and print 2D graphics in applications.
- » [Sockets Direct Protocol](#) — How to enable the Sockets Direct Protocol to take advantage of InfiniBand.



## Links to go further

### Oracle and Sun's tutorials

<http://docs.oracle.com/javase/tutorial/>  
see the 'Getting Started' section

### Learning the Java language

<http://docs.oracle.com/javase/tutorial/java/index.html>

### Coding conventions

<http://www.oracle.com/technetwork/java/codeconvtoc-136057.html>

### Resources on the Capsis web site

<http://capsis.cirad.fr>

Millions of **books**... including these references

“Java In A Nutshell”, David Flanagan - O'Reilly (several editions)

“Programmer en Java”, Claude Delannoy - Eyrolles