
# Programming in Java – Inheritance

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# *Agenda*

**Inheritance**

**Access control**

**Polymorphism**

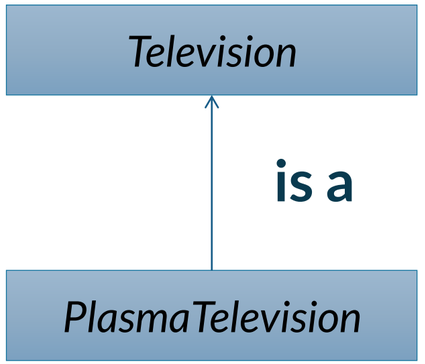
**Interfaces**

# Inheritance

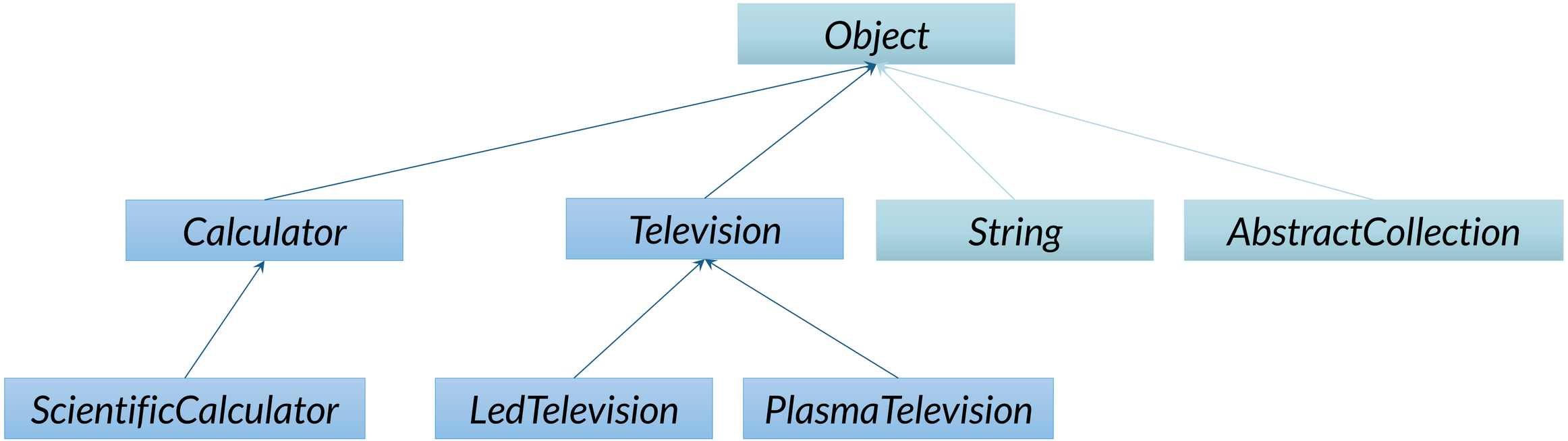
*Inheritance allows to define new classes by reusing other classes, specifying just the differences.*

```
package it.units.sdm;

public class PlasmaTelevision extends Television {

    double usageHours;

}
```

*It is possible to define a new class (subclass) by specifying that the class must be like other class (superclass)*



# Inheritance



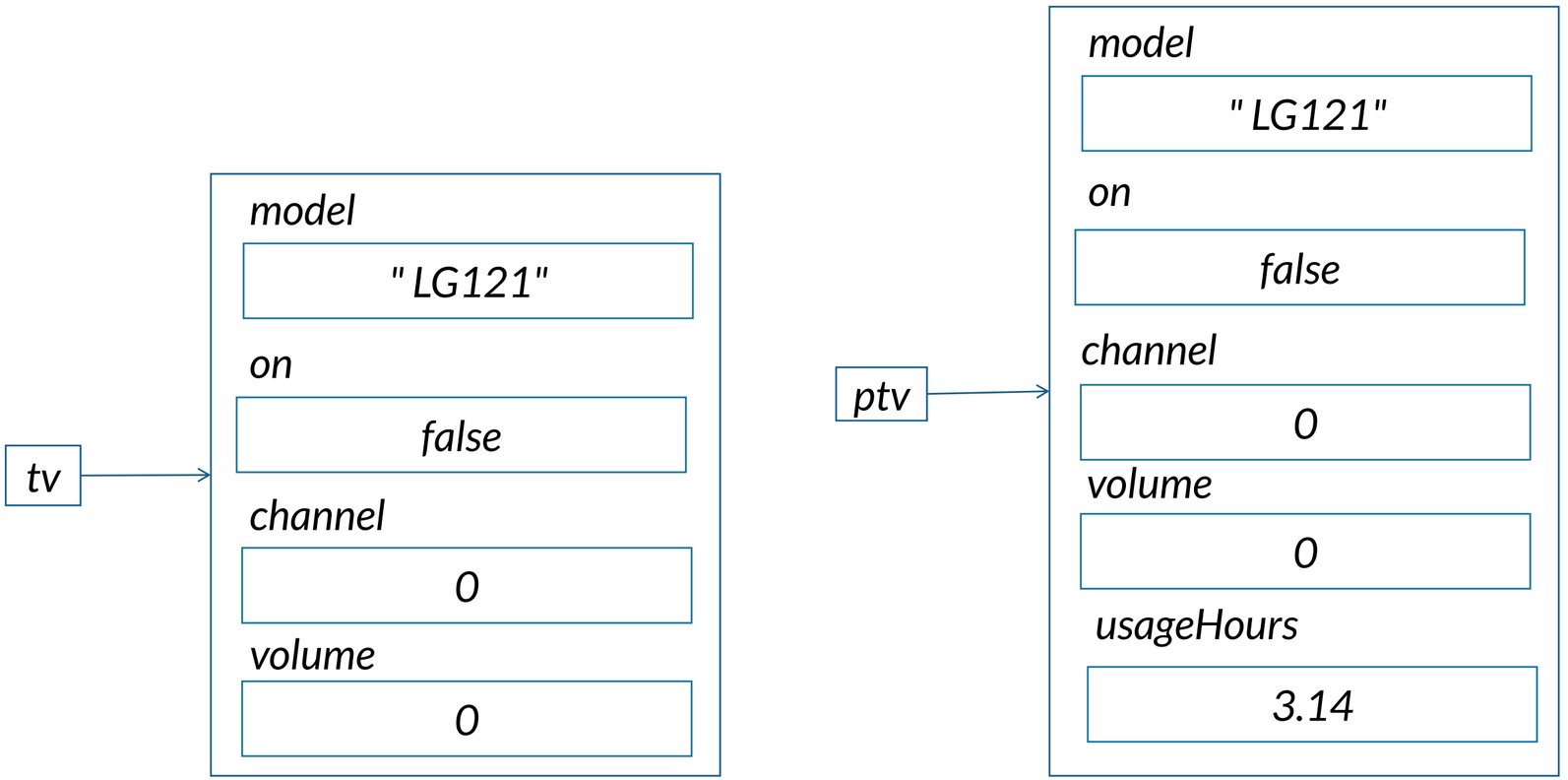
# Constructors definition

```
package it.units.sdm;

public class PlasmaTelevision extends Television {

    double usageHours;

    public PlasmaTelevision(String model, double usageHours) {
        super(model);
        this.usageHours = usageHours;
    }
}
```

*If the superclass defines at least one constructor, the subclass must define a constructor and it must invoke one constructor of the superclass by using super*

# Constructors

```
PlasmaTelevision ptv = new PlasmaTelevision("LG121", 3.14);
Television tv = new Television("LG121");
```



# Inheritance with methods

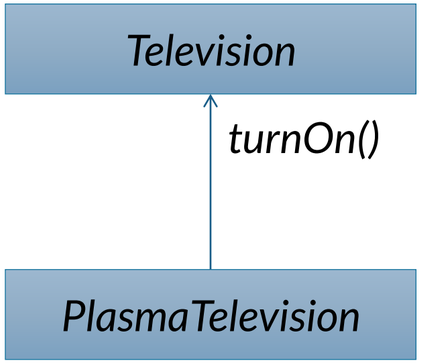
✓ *New methods can be defined in the subclass to specify the behavior of the objects of the subclass*

✓ *When a message is sent to an object, the method is searched for in the class of the receptor object.*

✓ *If it is not found then it is searched for higher up in the hierarchy.*

# Inherited methods

*Inherited method can be used directly on the instances of the subclass*

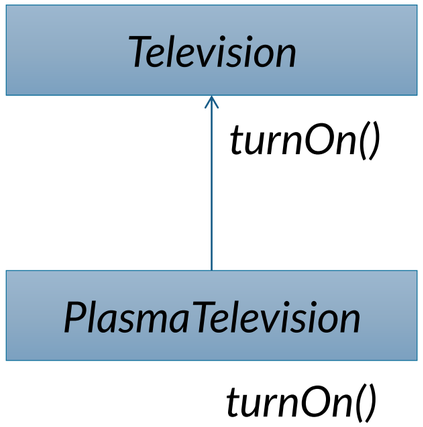



```
PlasmaTelevision ptv = new PlasmaTelevision("LG121", 0.0);
ptv.turnOn();
```

# Overridden methods 1/2

```
package it.units.sdm;

public class PlasmaTelevision extends Television {

    double usageHours;
    long startTime;

    public PlasmaTelevision(String model) {
        super(model);
    }

    @Override
    void turnOn() {
        super.turnOn();
        startTime = System.currentTimeMillis();
    }

}
```

*Methods in the subclass can override the methods in the superclass*



# Overridden methods 2/2

```
public class PlasmaTelevision extends Television {

    private double usageHours;
    private long startTime;

    public PlasmaTelevision(String model) {
        super(model);
    }

    void turnOn() {
        super.turnOn();
        startTime = System.currentTimeMillis();
    }

    void turnOff() {
        super.turnOff();
        var endTime = System.currentTimeMillis();
        usageHours += (endTime-startTime) / (1000.0 * 60 * 60);
    }

    public double getUsageHours() {
        return usageHours;
    }
}
```

# toString()

*public String toString() is an instance method defined in Object tha returns the string representation of an object.*

```
public static void main(String[] args) {
    Television tv = new Television("LG120");
    PlasmaTelevision ptv = new PlasmaTelevision("LG121");

    System.out.println("tv: " + tv);
    System.out.println(ptv);
}
```

*The toString() method is automatically used by Java when converting an object to a String*

*In general, the toString() method returns a string that "textually represents" this object. The result should be a concise but informative representation that is easy for a person to read. It is recommended that all subclasses override this method. The string output is not necessarily stable over time or across JVM invocations.*

# getClass()

```
public static void main(String[] args) {
    Television tv = new Television("LG120");
    PlasmaTelevision ptv = new PlasmaTelevision("LG121");
    Television ptv2 = new PlasmaTelevision("LG121");
    Object ptv3 = new PlasmaTelevision("LG121");

    System.out.println("tv.getClass() " + tv.getClass().getName());
    System.out.println("ptv.getClass() " + ptv.getClass().getName());
    System.out.println("ptv2.getClass() " + ptv2.getClass().getName());
    System.out.println("ptv3.getClass() " + ptv3.getClass().getName());
}
```

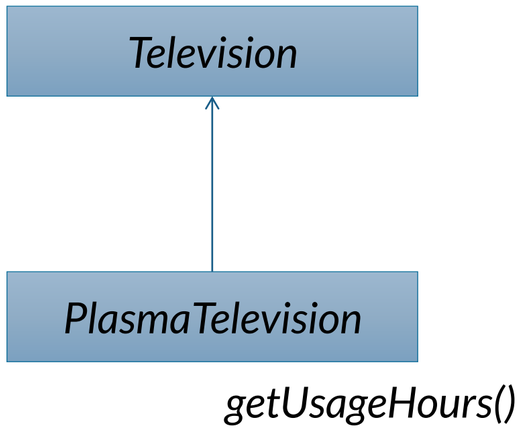
```
tv.getClass() it.units.sdm.Television
ptv.getClass() it.units.sdm.PlasmaTelevision
ptv2.getClass() it.units.sdm.PlasmaTelevision
ptv3.getClass() it.units.sdm.PlasmaTelevision
```

*getClass() is an instance method defined in Object that returns the class of an object*

# New methods definition

```
public class PlasmaTelevision extends Television {

    double usageHours;
    long startTime;

    public PlasmaTelevision(String model) {
        super(model);
    }

    public double getUsageHours() {
        return usageHours;
    }
}
```

*New methods can also be defined*



# instanceOf

*instanceof is an operator that determines if an object is an instance of a specified class*

```
public static void main(String[] args) {
    Television tv = new Television("LG120");
    Television ptv = new PlasmaTelevision("LG121");

    System.out.println("is tv a Television? " + (tv instanceof Television));
    System.out.println("is tv a PlasmaTelevision? " + (tv instanceof PlasmaTelevision));
    System.out.println("is ptv a Television? " + (ptv instanceof Television));
    System.out.println("is ptv a PlasmaTelevision? " + (ptv instanceof PlasmaTelevision));
}
```

```
is tv a Television? true
is tv a PlasmaTelevision? false
is ptv a Television? true
is ptv a PlasmaTelevision? true
```

# Late binding

**com.esteco.sdm.Televsion**

```
class Television {

    private String model;
    private boolean on;

    Television(String model) {
        this.model = model;
    }

    void turnOn() {
        on = true;
    }

    void turnOff() {
        on = false;
    }
}
```

**com.esteco.sdm.PlasmaTelevsion**

```
class PlasmaTelevision extends Television {

    double usageHours;
    long startTime;

    PlasmaTelevision(String model) {
        super(model);
    }

    @Override
    void turnOn() {
        super.turnOn();
        startTime = System.currentTimeMillis();
    }
}
```

*Which turnOn() is invoked?* →

```
Television tv = new PlasmaTelevision("LG121");
tv.turnOn();
```

# Class casting

```
PlasmaTelevision ptv0 = new PlasmaTelevision("FullHD");
Television tv0 = ptv0;
Object obj0 = ptv0;

Television tv = new PlasmaTelevision("LG121");
PlasmaTelevision ptv = tv; //illegal assignment

PlasmaTelevision ptv2 = (PlasmaTelevision) tv;

Object obj = new PlasmaTelevision("LG121");
PlasmaTelevision ptv3 = (PlasmaTelevision) obj;

Calculator calculator = new Calculator();
PlasmaTelevision ptv4 = (PlasmaTelevision) calculator;
```

*It is always possible to assign a variable referring a subclass to a variable of a superclass*

*To assign a variable of a superclass to a subclass we must use the cast operator*

*Assignments between variables of different hierarchies are not allowed*

# Access control

*A class may be declared with the modifier public, in which case that class is visible to all classes everywhere. If a class has no modifier (the default, also known as package-private), it is visible only within its own package.*

| Modifier | Class | Package | Subclass | World |
|---|---|---|---|---|
| **public** | *Y* | *Y* | *Y* | *Y* |
| **protected** | *Y* | *Y* | *Y* | *N* |
| ***no modifier*** | *Y* | *Y* | *N* | *N* |
| **private** | *Y* | *N* | *N* | *N* |

*A member with access modifier private can only be accessed from its own class*

*A member without an access modifier can only be accessed from within its own package (package-private)*

*A member with access modifier protected can be accessed from within its own package and from the subclasses of its class in another package*

*A member with access modifier public is visible from all the classes*

# Who can access this class? 1/3

**com.esteco.sdm.Televsion**

```
package com.esteco.sdm;

public class Television {

    private String model;

    public Television(String model) {
        this.model = model;
    }

    public String getModel() {
        return model;
    }
}
```

*Anyone from any package!*

# Who can access this class? 2/3

**com.esteco.sdm.Televsion**

```
package com.esteco.sdm;

class Television {

    private String model;

    public Television(String model) {
        this.model = model;
    }

    public String getModel() {
        return model;
    }
}
```

*Anyone from the com.esteco.sdm package!*

# Who can access this class? 3/3

**com.esteco.sdm.Televsion**

```
package com.esteco.sdm;

private class Television {

    private String model;

    public Television(String model) {
        this.model = model;
    }

    public String getModel() {
        return model;
    }
}
```

*No one, this declaration is illegal!*

# Who can instantiate this class? 1/3

**com.esteco.sdm.Televsion**

```
package com.esteco.sdm;

public class Television {

    private String model;

    public Television(String model) {
        this.model = model;
    }

    public String getModel() {
        return model;
    }
}
```

*Anyone from any package!*

# Who can instantiate this class? 2/3

**com.esteco.sdm.Televsion**

```
package com.esteco.sdm;

public class Television {

    private String model;

    private Television(String model) {
        this.model = model;
    }

    public String getModel() {
        return model;
    }
}
```

*Only someone within this class!*

# Who can instantiate this class? 3/3

**com.esteco.sdm.Televsion**

```
package com.esteco.sdm;

class Television {

    private String model;

?   public Television(String model) {
        this.model = model;
    }

    public String getModel() {
        return model;
    }
}
```

*Only someone within the same package!*

# Who can access the model variable? 1/3

**com.esteco.sdm.Televsion**

```
package com.esteco.sdm;

public class Television {

    private String model;

    public Television(String model) {
        this.model = model;
    }

    public String getModel() {
        return model;
    }
}
```

*Only someone within the same class!*

# Who can access the model variable? 2/3

**com.esteco.sdm.Televsion**

```
package com.esteco.sdm;

public class Television {

    public String model;

    public Television(String model) {
        this.model = model;
    }

    public String getModel() {
        return model;
    }
}
```

*Everyone can read and write the model variable.*

*In general, very dangerous.*

# Who can access the model variable? 3/3

**com.esteco.sdm.Televsion**

```
package com.esteco.sdm;

public class Television {

    public final String model;

    public Television(String model) {
        this.model = model;
    }

    public String getModel() {
        return model;
    }
}
```

*Everyone can read the model variable.*

*But only the constructor can assign it!*

# Who can invoke the getModel() method? 1/4

**com.esteco.sdm.Televsion**

```
package com.esteco.sdm;

public class Television {

    private final String model;

    public Television(String model) {
        this.model = model;
    }

    public String getModel() {
        return model;
    }
}
```

*Everyone can invoke the getModel() method*

# Who can invoke the getModel() method? 2/4

**com.esteco.sdm.Televsion**

```
package com.esteco.sdm;

public class Television {

    private final String model;

    public Television(String model) {
        this.model = model;
    }

    private String getModel() {
        return model;
    }
}
```

*No one outside the Television class.*

# Who can invoke the getModel() method? 3/4

**com.esteco.sdm.Televsion**

```
package com.esteco.sdm;

public class Television {

    private final String model;

    public Television(String model) {
        this.model = model;
    }

    protected String getModel() {
        return model;
    }
}
```

*Anyone from the same package, or from any subclass.*

# Who can invoke the getModel() method? 4/4

**com.esteco.sdm.Televsion**

```
package com.esteco.sdm;

class Television {

    private final String model;

    public Television(String model) {
        this.model = model;
    }

    public String getModel() {
        return model;
    }
}
```

*Everyone with a reference to a Television object.*

*In more details, everyone with a reference to a Television object or an object of a subclass of Television.*

# You cannot reduce the access level with extension

**com.esteco.sdm.Televsion**

```
public class Television {

    private String model;
    private boolean on;

    public Television(String model) {
        this.model = model;
    }

    public void turnOn() {
        on = true;
    }

    public void turnOff() {
        on = false;
    }
}
```

**com.esteco.sdm.PlasmaTelevsion**

```
class PlasmaTelevision extends Television {

    double usageHours;
    long startTime;

    public PlasmaTelevision(String model) {
        super(model);
    }

    @Override
    protected void turnOn() {
        super.turnOn();
        startTime = System.currentTimeMillis();
    }

}
```

# Tips on choosing an access level

*If other programmers use your class, you want to ensure that errors from misuse cannot happen. Access levels can help you do this.*

*Use the most restrictive access level that makes sense for a particular member. Use private unless you have a good reason not to.*

*Avoid public fields except for constants. Public fields tend to link you to a particular implementation and limit your flexibility in changing your code.*

https://docs.oracle.com/javase/tutorial/java/javaOO/accesscontrol.html

# Final classes

**com.esteco.sdm.Televsion**

```
package com.esteco.sdm;

public final class Television {

    private String model;

    public Television(String model) {
        this.model = model;
    }

    public String getModel() {
        return model;
    }
}
```

*Final classes cannot be extended.*

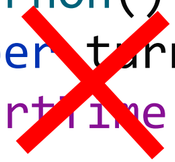
# Final methods

**com.esteco.sdm.Televsion**

```
public class Television {

    private String model;
    private boolean on;

    public Television(String model) {
        this.model = model;
    }

    final void turnOn() {
        on = true;
    }

    final void turnOff() {
        on = false;
    }
}
```

**com.esteco.sdm.PlasmaTelevsion**

```
class PlasmaTelevision extends Television {

    double usageHours;
    long startTime;

    public PlasmaTelevision(String model) {
        super(model);
    }

    @Override
    void turnOn() {
        super.turnOn();
        startTime = System.currentTimeMillis();
    }

}
```



*Final methods cannot be overridden.*

# Writing for others

*If other programmers use your class, you want to ensure that errors from misuse cannot happen.*

*Please consider yourself as another programmer too!*

*What's wrong with extending Television and overriding turnOn()?*

**com.esteco.sdm.PlasmaTelevsion**

```
class PlasmaTelevision extends Television {

    private double usageHours;
    private long startTime;

    public PlasmaTelevision(String model) {
        super(model);
    }

    @Override
    public void turnOn() {
        super.turnOn();
        startTime = System.currentTimeMillis();
    }
}
```

# Abstract methods 1/2

*If the turnOn() method is final, how do we allow other programmers to do something when a Television is turned on?*

*turnedOn() is the entry point for subclasses to perform operations after a Television is turned on.*

*turnOn() is defining a protocol. How the Television class works and how it should be extended.*

**com.esteco.sdm.Televsion**

```
public class Television {

    private String model;
    private boolean on;

    public Television(String model) {
        this.model = model;
    }

    final void turnOn() {
        on = true;
        turnedOn();
    }

    protected void turnedOn() {
    }
}
```

# Abstract methods 2/2

*What if we want all subclasses to be forced to define the turnedOn() method?*

*We define turnedOn() as an abstract method. As a consequence, the Television class becomes abstract too.*

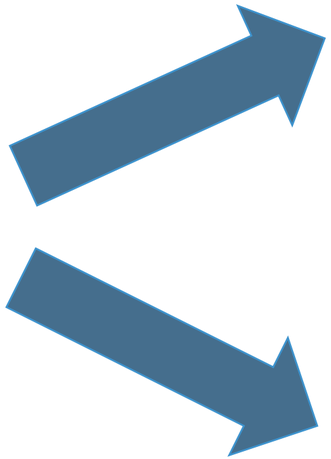
*Abstract classes cannot be instantiated. But they can be extended by subclasses.*

**com.esteco.sdm.Televsion**

```
public abstract class Television {

    private String model;
    private boolean on;

    protected Television(String model) {
        this.model = model;
    }

    public final void turnOn() {
        on = true;
        turnedOn();
    }

    protected abstract void turnedOn();
}
```

# Final and abstract

*The modifiers final and abstract can be applied to both classes and methods, and they are mutually exclusive*



*A final class does not allow sub-classing*

*A final method cannot be overridden in a subclass*

*An abstract class cannot be instantiated*

*An abstract method has no body, and must be overridden in a subclass*

# Interfaces

**it.units.sdm.Display**

```
public interface Display {

    void display(String text);

}
```

**it.units.sdm.Calculator**

```
public class Calculator {

    final Display display;
    //...

    Calculator(Display display) {
        this.display = display;
    }

     void onePressed() {
        string += "1";
        display.display(string);
    }
}
```

*Interfaces are used to abstract what a class must do from how it does it.*

*Interfaces are syntactically like classes, but*

1. *they don't have instance variables*
2. *all methods are abstract (with the exception of methods with a default implementation)*
3. *all methods are implicitly public*

*An interface definition doesn't say anything about how the methods are implemented*

# Interface implementation 1/2

**it.units.sdm.Display**

```
public interface Display {

    void display(String text);

}
```

```
class ConsoleDisplay implements Display {

    @Override
    public void display(String text) {
        System.out.println(text);
    }
}

class PopupDisplay implements Display {

    @Override
    public void display(String text) {
        JOptionPane.showMessageDialog(null, text);
    }
}
```

*An interface can be implemented by any number of classes*

*A class can implement any number of interfaces.*

*Interfaces are not inherited, they are implemented, so the single inheritance does not apply. There is no inheritance of instance members.*

*The methods that implement an interface must be declared public so there no way to restrict the access.*

# Interface implementation 2/2

**it.units.sdm.Display**

```
public interface Display {

    void display(double d);

}
```

```
class ConsoleDisplay implements Display {

    @Override
    public void display(double d) {
        System.out.println(format(d));
    }

    public String format(double d) {
        return String.valueOf(d);
    }
}
```

*A class that implement interfaces can have it own instance variables and it can define its own constructors and methods*

# Partial interface implementation

**it.units.sdm.Display**

```
public interface Display {

    void display(String text);
    void display(double d);

}
```

*A class implementing an interface must implement all the methods. Otherwise, it must be declared abstract.*

```
abstract class ConsoleDisplay implements Display {

    @Override
    public void display(String text) {
        System.out.println(text);
    }
}
```

# Implementation of multiple interfaces 1/4

```
interface AutonomousCar {

    void driveTo(String address);

    void stop();
}

interface KeylessCar {

    void start();

    void stop();
}
```

*If a class implements two interfaces that declare the same method, then the same method will be used by clients of either interface.*

```
class FiatTopolino implements KeylessCar, AutonomousCar {

    @Override
    public void driveTo(String address) {
        //Do something
    }

    @Override
    public void start() {
        //Do something
    }

    @Override
    public void stop() {
        //Should I stop as a KeylessCar
        //or as an AutonomousCar?
    }
}
```

*If a class implements more than one interface, the interfaces are separated with a comma.*

# Implementation of multiple interfaces 2/4

```
interface AutonomousCar {

    void driveTo(String address);

    void stop();
}

interface KeylessCar {

    void start();

    boolean stop();
}
```

```
class FiatTopolino implements KeylessCar, AutonomousCar {

    @Override
    public void driveTo(String address) {
        //Do something
    }

    @Override
    public void start() {
        //Do something
    }

    @Override
    public void/boolean stop() {
        //FiatTopolino cannot implement both interfaces
    }
}
```

*A class cannot implement methods with the same name, the same parameters, but a different return type.*

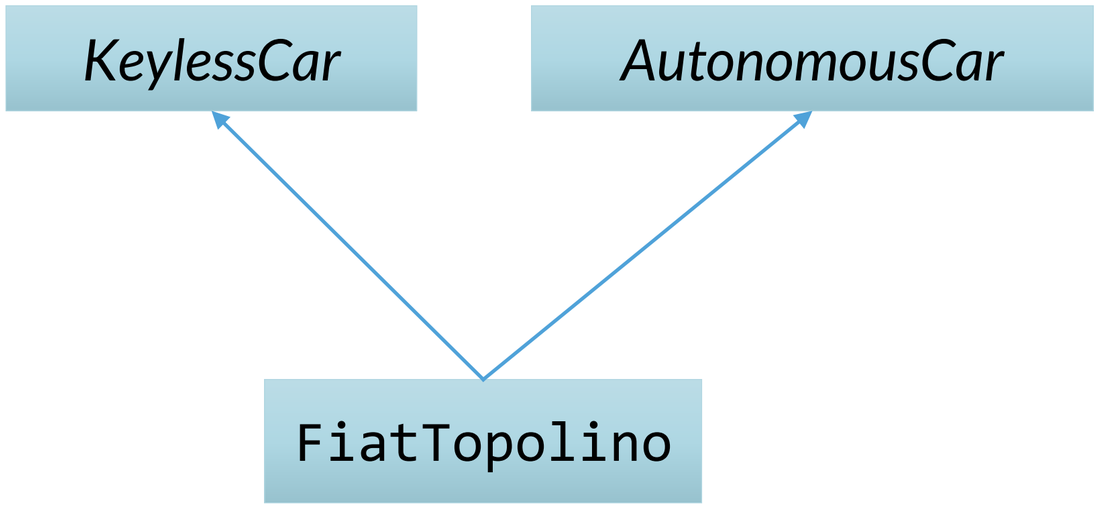
# Implementation of multiple interfaces 3/4

```
FiatTopolino c = new FiatTopolino();
AutonomousCar ac = c;
KeylessCar kc = c;

ac = kc;
```

*Is this a legal assignment?*

*Can I cast kc to an Autonomous car?*

```
ac = (AutonomousCar) kc
```



# Implementation of multiple interfaces 4/4

```
FiatTopolino c = new FiatTopolino();
AutonomousCar ac = c;
KeylessCar kc = c;

Display d1 = (Display) c;
Display d2 = (Display) kc;
```

*This code compiles, I will get a ClassCastException error at runtime.*

```
FiatTopolino c = new FiatTopolino();
AutonomousCar ac = c;
KeylessCar kc = c;

Calculator c1 = (Calculator) c;
```

*This code doesn't compile, cannot cast a FiatTopolino into a Calculator.*

# Interface extension

```
interface Collection {

    int getSize();

    boolean isEmpty();
}

interface MutableCollection {

    void clear();
}

interface List extends Collection, MutableCollection {

    void addElement(Object obj);
}
```

*An interface can extend multiple interfaces*

# What’s wrong with this interface?

```
interface AutonomousCar {

    void driveTo(String address);

    void toString();
}
```

*The return type of the toString() method clashes with Object.toString()*

# Anonymous classes 1/3

**it.units.sdm.Display**

```
public interface Display {

    void display(String text);

}
```

```
Display display = new Display() {
    @Override
    public void display(String text) {
        System.out.println();
    }
};
```

*Interfaces can be implemented by anonymous classes too.*

*An anonymous class is a class without a name.*

*The new operator creates an object of a class that has no name.*

# Anonymous classes 2/3

```
public class Calculator {

    public static void main(String[] args) {
        Display display = new Display() {
            @Override
            public void display(String text) {
                System.out.println();
            }
        };
        var calculator = new Calculator(display);
        calculator.onePressed();
        calculator.plusPressed();
        calculator.twoPressed();
        calculator.plusPressed();
        calculator.twoPressed();
        calculator.equalPressed();
    }
    //…
}
```

*By compiling this code, two classes are created:*

```
Calculator.class
Claculator$1.class
```

*Calculator$1.class represents the anonymous class. That is anonymous in the source code, but it is not anonymous for the virtual machine.*

# Anonymous classes 3/3

```
Object a = new Object() {

    int a;

    {
        //there are no constructors but
        //we can use initializer blocks
    }

    public int getA() {
        return a;
    }

    @Override
    public String toString() {
        return "toString() redefined";
    }
};
```

*Anonymous classes are not used to implement interfaces only, but they can be used to extends objects, of any type.*

*Can we invoke the getA() public method?*

```
a.getA()
```

# Interface static fields 1/2

```
interface AutonomousCar {

    String DEFAULT_ADDRESS = "3500 Deer Creek Road, Palo Alto, California";

    void driveTo(String address);

    void stop();
}
```

*Variables can be declared inside interface declarations. They are implicitly public, final, and static, meaning they cannot be changed by the implementing class and that they must be initialized.*

*They can be used as constants shared among the implementing classes.*

# Interface static fields 2/2

```
class FiatTopolino implements KeylessCar, AutonomousCar {

    @Override
    public void driveTo(String address) {
        if (address == null) {
            address = DEFAULT_ADDRESS;
        }
        //drive to address
    }

    @Override
    public void start() {
        //Do something
    }

    @Override
    public void stop() {
        //Just stop!
    }
}
```

# Static method in interfaces 1/2

*Static methods in interfaces are exactly like static methods in classes.*

*All static methods in interfaces are implicitly public.*

```
interface AutonomousCar {

    static String getDefaultAddress() {
        return "3500 Deer Creek Road, Palo Alto, California";
    }

    void driveTo(String address);

    void stop();
}
```

# Static method in interfaces 2/2

*Static methods in interfaces can be used as factory methods.*

```
interface Display {

    void display(String text);


    static Display createDefaultDisplay() {
        return new Display() {
            @Override
            public void display(String text) {
                System.out.println();
            }
        };
    }

}
```

# Default methods 1/2

```
interface CollectionOfStrings {

    default boolean isEmpty() {
        return getSize() == 0;
    }

    int getSize();

    String[] getValues();
}
```

*Java 8 introduced the default methods in interfaces.*

*Default methods can be overridden by classes implementing the interface.*

# Default methods 2/2

```
interface CollectionOfStrings {

    default boolean isEmpty() {
        return getSize() == 0;
    }

    int getSize();

    String[] getValues();

    default boolean contains(String string) {
        for (String s: getValues()) {
            if (Objects.equals(s, string))
                return true;
        }
        return false;
    }
}
```

*When we add the method* `boolean contains(String)` *to the CollectionOfStrings interface, most of the classes implementing CollectionOfStrings become unusable, because their source code don't compile anymore.*

*By defining a default method, we preserve the compatibility with older code bases.*

# Why Java introduced default methods

*A primary motivation for the default method was to provide a means by which interfaces can be expanded without breaking existing code.*

*Another motivation for the default method was the desire to specify methods in an interface that are, essentially, optional, depending on how the interface is used.*

*It is important to point out that the addition of default methods does not change a key aspect of interface: its inability to maintain state information.*

# Default methods clash

```
interface AutonomousCar {

    void driveTo(String address);

    default void stop() {
        //do something
    }
}

interface KeylessCar {

    void start();

    default void stop() {
        //do something
    }
}
```

```
class FiatTopolino implements KeylessCar, AutonomousCar {

    @Override
    public void driveTo(String address) {
        //drive to address
    }

    @Override
    public void start() {
        //Do something
    }

    @Override
    public void stop() {
        //FiatTopolino must override this method
    }
}
```

*When a class implements two interfaces that both have the same default method, the class must override that method, otherwise a compilation error will result.*

# Default methods overriding

```
interface KeylessCar {

    void start();

    default void stop() {
        //do something
    }
}

interface AutonomousCar extends KeylessCar {

    void driveTo(String address);

    default void stop() {
        KeylessCar.super.stop();
        //do something
    }
}
```

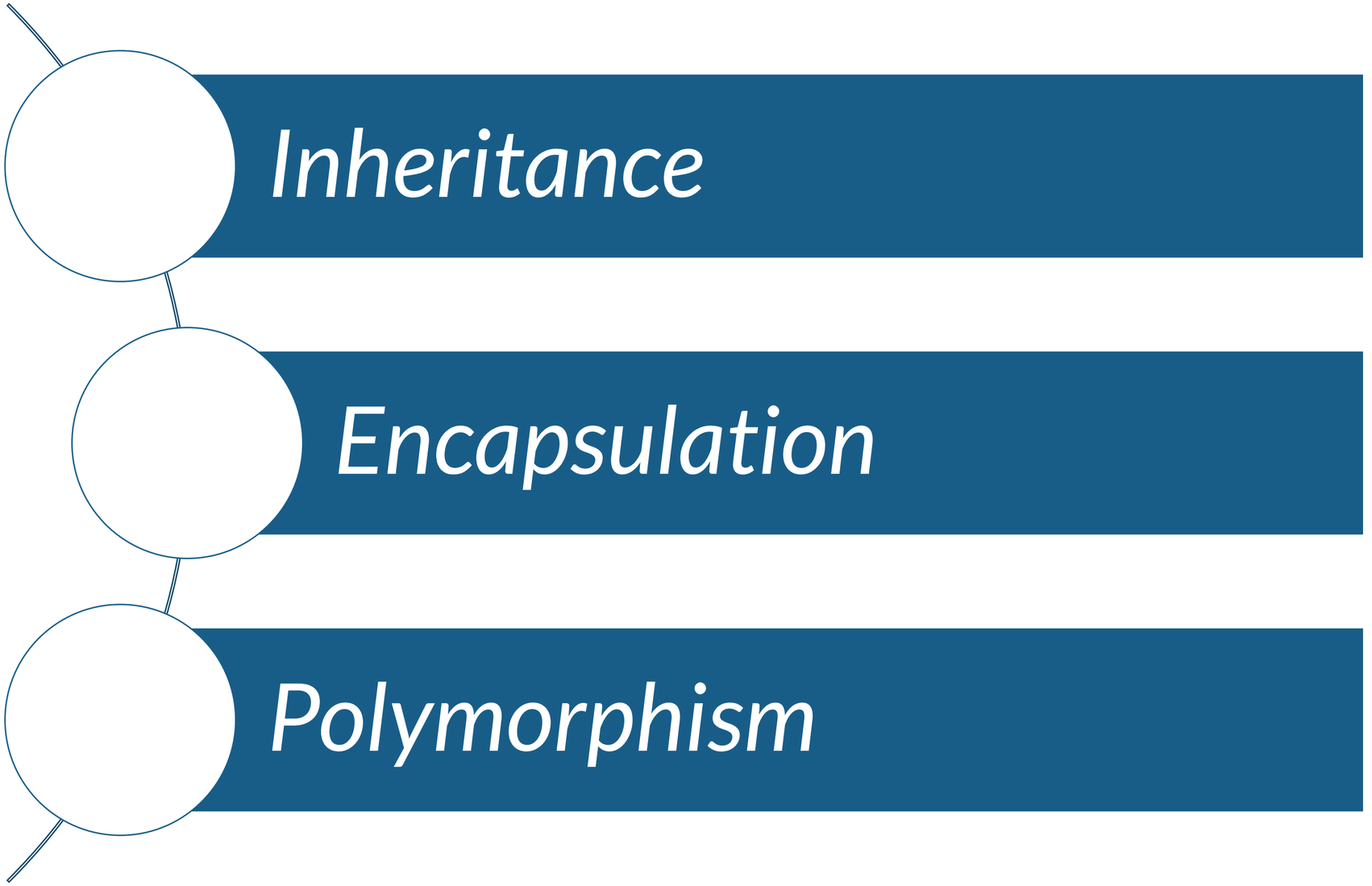
*When one interface extends another, with both defining a common default method, the extending interface version of the method takes precedence.*

*It is possible to explicitly refer to a default implementation in an extended interface by using super.*

# Private interface methods

```
interface Interface {

    default void defaultMethodA() {
        //do something
        privateMethod("A");
    }

    default void defaultMethodB() {
        //do something
        privateMethod("B");
    }

    private void privateMethod(String message) {
        System.out.println(message);
    }
}
```

*Private methods can be used only from the default methods of the same interface*



# Assignment

```
public interface Collection {

    boolean isEmpty();

    int getSize();

    boolean contains(String string);

    String[] getValues();
}

public interface Stack extends Collection {

    void push(String string);

    String pop();

    String top();
}
```

```
public interface List extends Collection {

    void add(String string);

    String get(int index);

    void insertAt(int index, String string);

    void remove(int index);

    int indexOf(String string);

}
```

*Implement the Stack and List interfaces. Minimize code duplication.*

*Hint: consider the usage of both inheritance and composition.*

# Thank you!

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