SUBTOPIC 5

INHERITANCE – FIRST PART

Cristina Cachero, Pedro J. Ponce de León

Translated into English by Juan Antonio Pérez

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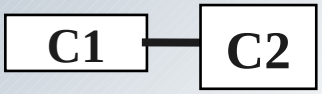
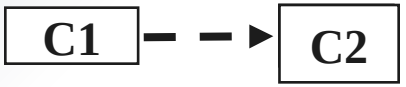
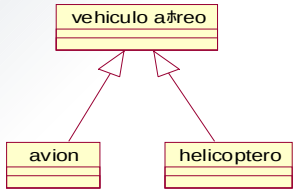
Department of Computer Languages and Systems

Universitat d'Alacant
Universidad de Alicante

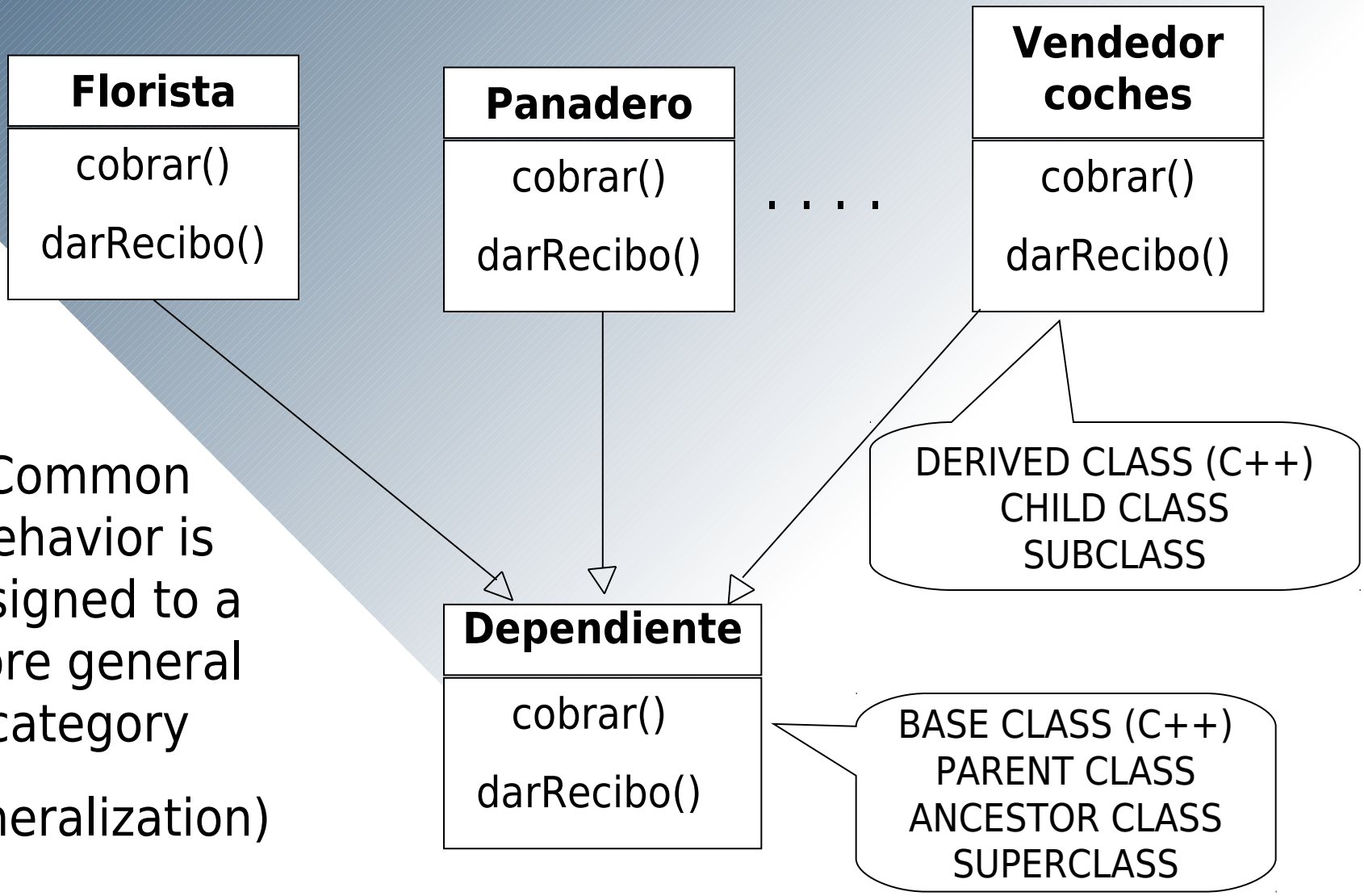
INHERITANCE
Objectives

- Understanding inheritance as a powerful abstraction mechanism.
- Distinguishing among the different types of inheritance.
- Knowing how to implement inheritance hierarchies in Java.
- Distinguishing between safe (well defined) and unsafe inheritance hierarchies.
- Code reuse: deciding when to use inheritance and when to use composition.

Inheritance Previously…

	Persistent	Non-persistent
Object level relationships	▪ **Association** Ladybugs and flowers  ▪ **Whole/part** (“part of”/”has a”) ▪ Aggregation  ▪ Composition  A petal is a part of a flower	▪ **Using (dependency)** 
Class level relationships	▪ **Generalization/Specialization** (“is a”) (inheritance)  A rose is a kind of flower	

INHERITANCE
Motivation



Common behavior is assigned to a more general category

(generalization)

Classification and generalization

- The human mind groups concepts as:
  - Membership (HAS-A) -> *Whole/part relationships*
  - Variety (IS-A) -> *Inheritance*

- Using inheritance implies classifying abstractions (concepts):

  - A generalization of a concept is an extension of the concept to less-specific criteria. It is a foundational element of logic and human reasoning. Specialization is somehow the opposite concept.

  - When implemented in a programming language, generalization leads to inheritance hierarchies.

Inheritance as implementation of generalization

- Generalization is a semantic relationship between classes. Instances of a child class include all the properties of its parent class.
- The number of relationships (aggregations, compositions) in the model is reduced.
- Legibility and expressiveness of the model improves.
- The number of resulting classes usually increases.

INHERITANCE
Definition

- Inheritance is the mechanism by which more specific elements incorporate structure and behavior of more general elements (Rumbaugh 99)

- Inheritance makes possible **specializing** or **extending** the functionality of a class by deriving new classes from it.

- Inheritance is always **transitive**, so a class can inherit features from superclasses many levels away.
  - That is, if class *Dog* is a subclass of class *Mammal*, and class *Mammal* is a subclass of class *Animal*, then *Dog* will inherit attributes both from *Mammal* and from *Animal*.

INHERITANCE
Is-a test

- To tell if concept A should be linked by inheritance to concept B, try forming the English sentence "**An A is a B**". If the sentence sounds right to your ear, the inheritance is most likely appropriate in this situation:
  - A bird is an animal
  - A cat is a mammal
  - An apple pie is a pie
  - An IntegerArray is an array

INHERITANCE
Is-a test

- On the other hand, the following assertions seem strange for one reason or another, and hence inheritance is likely not appropriate:
  - A bird is a mammal
  - An apple pie is an apple
  - An IntegerArray is an integer
  - An engine is a car
- Rarely, the is-a test fails.

INHERITANCE
Main uses

- *Inheritance as a means of code reuse.* Because a child class can inherit behavior from a parent class, the code does not need to be rewritten for the child. This can greatly reduce the amount of code needed to develop a new idea.
  - **Implementation inheritance**

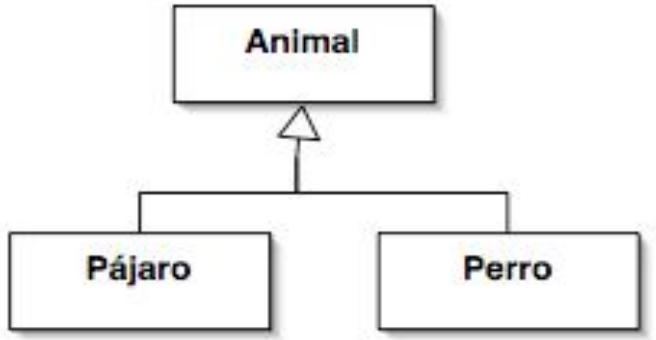
- *Inheritance as a means of concept reuse.* This occurs when a child class **overrides** behavior defined in the parent. Although no code is shared between parent and child, the child and parent share the definition of the method.
  - **Interface inheritance**

Types of inheritance

- Single/multiple inheritance
- Implementation/interface inheritance

Types of inheritance

- Single/Multiple
  - **Single**: one parent class
  - **Multiple**: two or more parent classes



Types of inheritance

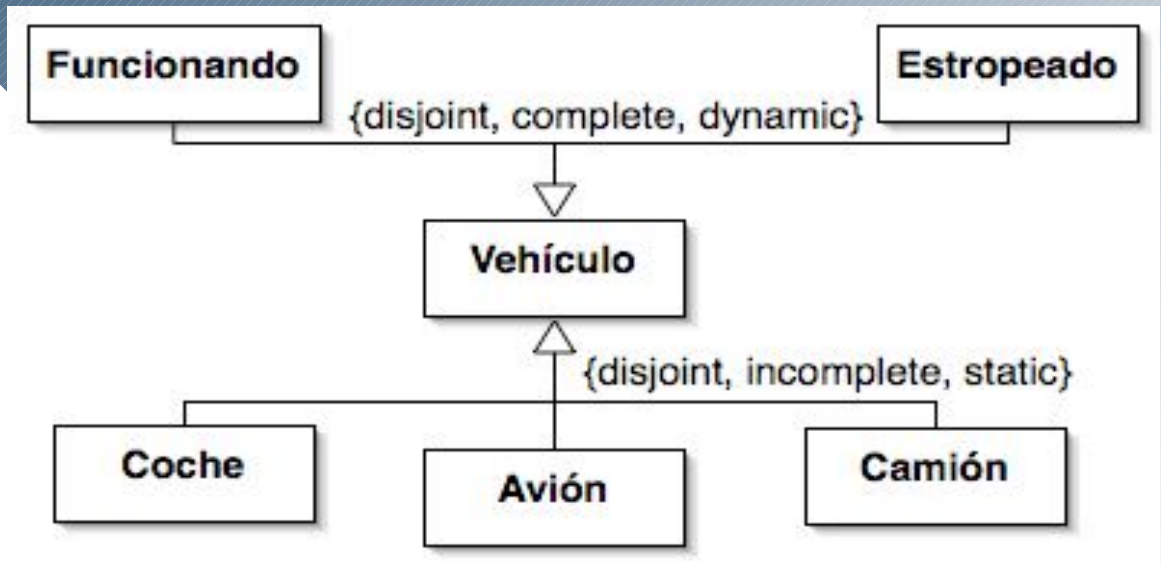
- Implementation/interface inheritance
  - **Implementation inheritance**: the subclass inherits the implementation of the methods, although they can be overriden in the subclass.
  - **Interface implementation**: only the interface is inherited; no implementation is provided by the base class (*interfaces* in Java, *abstract classes* in C++)

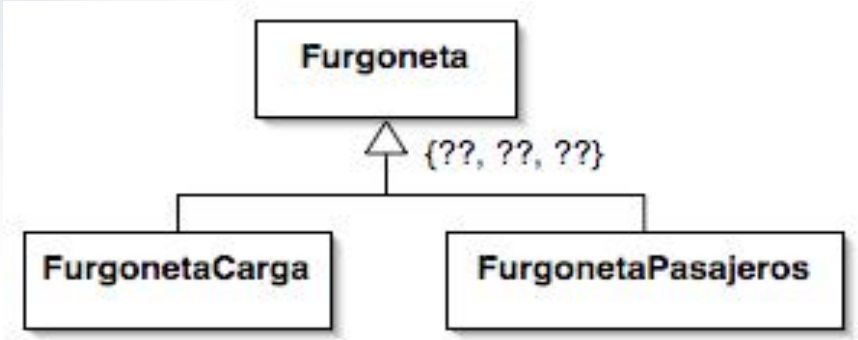
Inheritance
Semantic description

- Generalization constraints:

  - **Overlapping/Disjoint**
    - Determines whether an instance of the superclass can be an instance of multiple subclasses (overlapping) or not.
    - Overlapping inheritance is not supported in Java/C++ (strong typing)
  - **Complete/Incomplete**
    - Determines whether every instance of the superclass is an instance of at least one subclass (complete) or not.
  - **Static/Dynamic**
    - Determines whether an object which is an instance of a subclass may become an instance of a sibling class.
    - Dynamic inheritance is not supported in Java/C++ (strong typing)

Inheritance
Semantic description





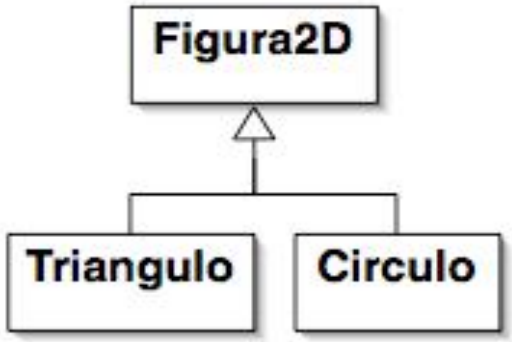
IMPLEMENTATION INHERITANCE

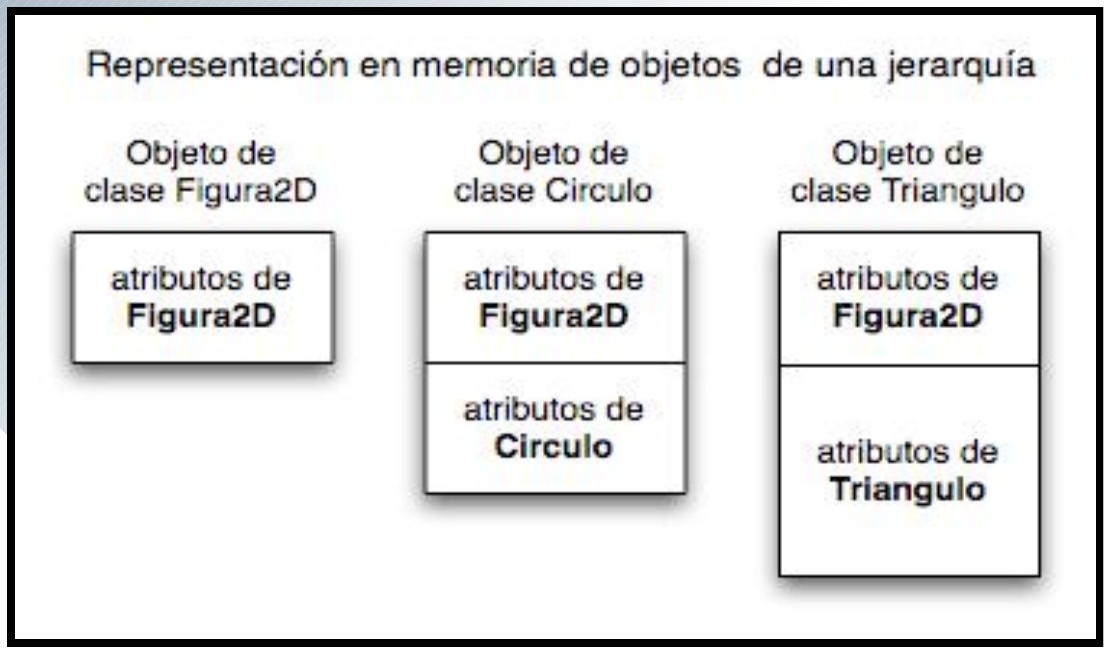
Single Inheritance

Single Inheritance

- By inheritance, we mean the property that instances of a child class can access both data and behavior (methods) associated with a parent class.

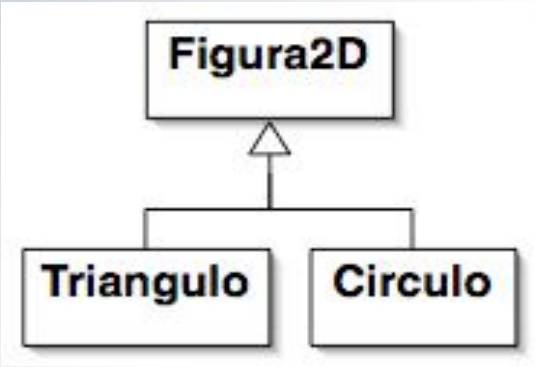
- Derived classes may add new attributes, methods or roles.





Single Inheritance

```
class Figura2D {
  public void setColor(Color c) {...}
  public Color getColor() {...}
  private Color colorRelleno;
... }

class Circulo extends Figura2D {
...
  public void vaciar() {
      colorRelleno=Color.NINGUNO;
      // ERROR! colorRelleno is private
      setColor(Color.NINGUNO); // OK
    }
}
```



Private members of the superclass are not directly accessible from the subclasses.

```
// client code
  Circulo c = new Circulo();
  c.setColor(AZUL);
  c.getColor();
  c.vaciarCirculo();
```

Single inheritance
Attribute/method visibility

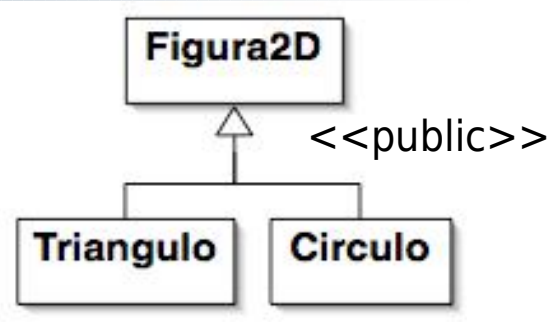
- **Protected** visibility scope
  - A protected feature is accessible only within a class definition or within the definition of any child classes. They are identified in UML by the symbol '#'.

```
class Figura2D {
    protected Color colorRelleno;
...
}

class Circulo extends Figura2D {
   public void vaciarCirculo() {
       colorRelleno=NINGUNO; // OK, protected
     }
...
}
```

```
// client code
  Circulo c;
  c.colorRelleno=NINGUNO;
 // ERROR! colorRelleno
 // is private here
```

Types of single inheritance

- Public inheritance
  - Both implementation and interface are inherited.



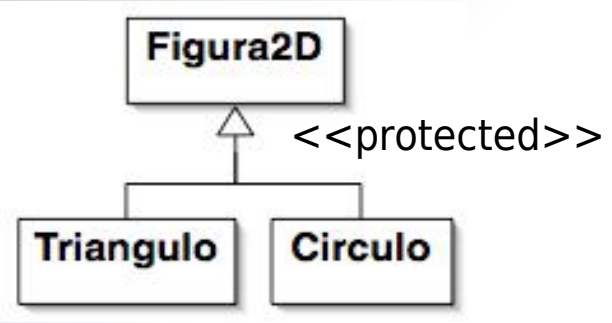

```
// JAVA only supports public inheritance
class Circulo extends Figura2D
{
...
}
```

```
// C++
class Circulo : public Figura2D
{
...
};
```

Types of single inheritance

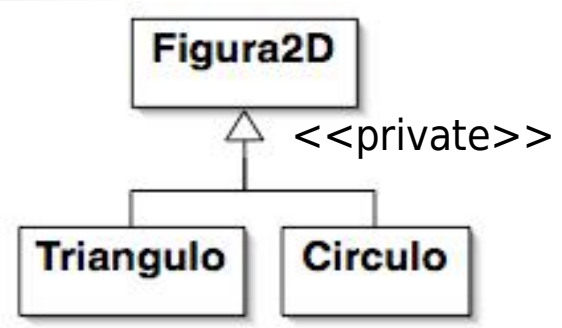
- Protected inheritance (C++)

```
class Circulo : protected Figura2D {
...
};
```



- Private inheritance (C++, default)

```
class Circulo : private Figura2D {
...
};
```



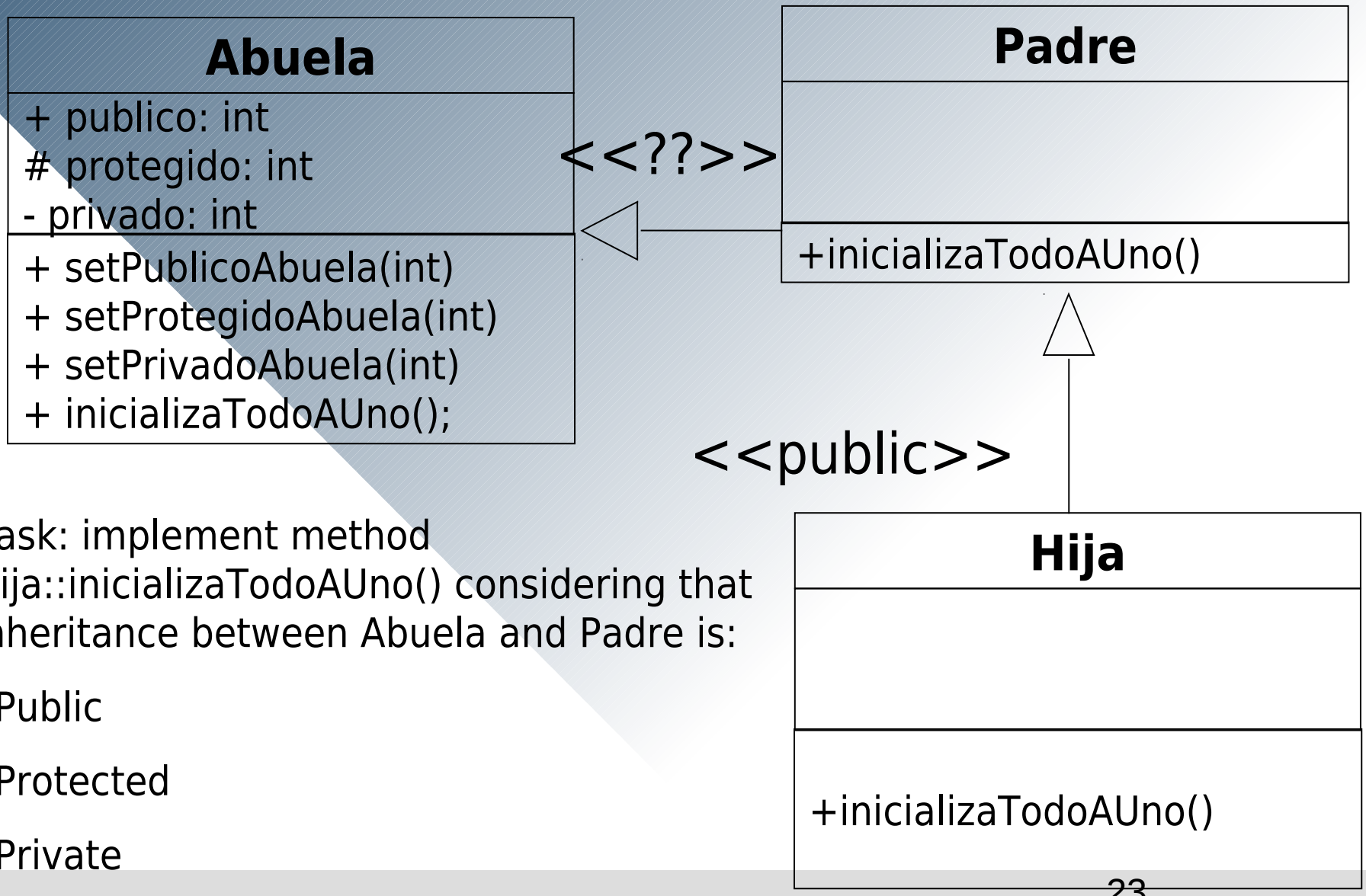
These types of inheritance in C++ only allow to inherit implementation. The interface of the base class is not shared with the derived class. More information.

Types of single inheritance

Inheritance Scope / Visibility In base class	DC (*) Public inheritance	DC Protected inheritance	DC Private inheritance
Private	Not directly accessible	Not directly accessible	Not directly accessible
Protected	Protected	Protected	Private
Public	Public	Protected	Private

(*) DC: Derived class

Types of single inheritance Task



Task: implement method Hija::inicializaTodoAUno() considering that inheritance between Abuela and Padre is:

- Public
- Protected
- Private

Single Inheritance
Methods in derived classes

- Derived classes may...
  - Add new methods/attributes
  - Modify methods inherited from the base class
    - **REFINEMENT**: a style of overriding in which the inherited code is merged (before and/or after) with the code defined in the child class (it can be simulated in C++, Java)
      - *C++*, *Java*: constructors and destructors are usually refined
    - **REPLACEMENT**: a style of overriding in which the inherited code is completely replaced by the code defined in the child class.

Single Inheritance
Methods in derived classes

- **Replacement** in Java

```
class A {
  public void doIt() {
    System.out.println(“HECHO en A”);
  }
}

class B extends A {
  public void doIt() {
    System.out.println(“HECHO en B”);
  }
}
```

Single Inheritance
Methods in derived classes

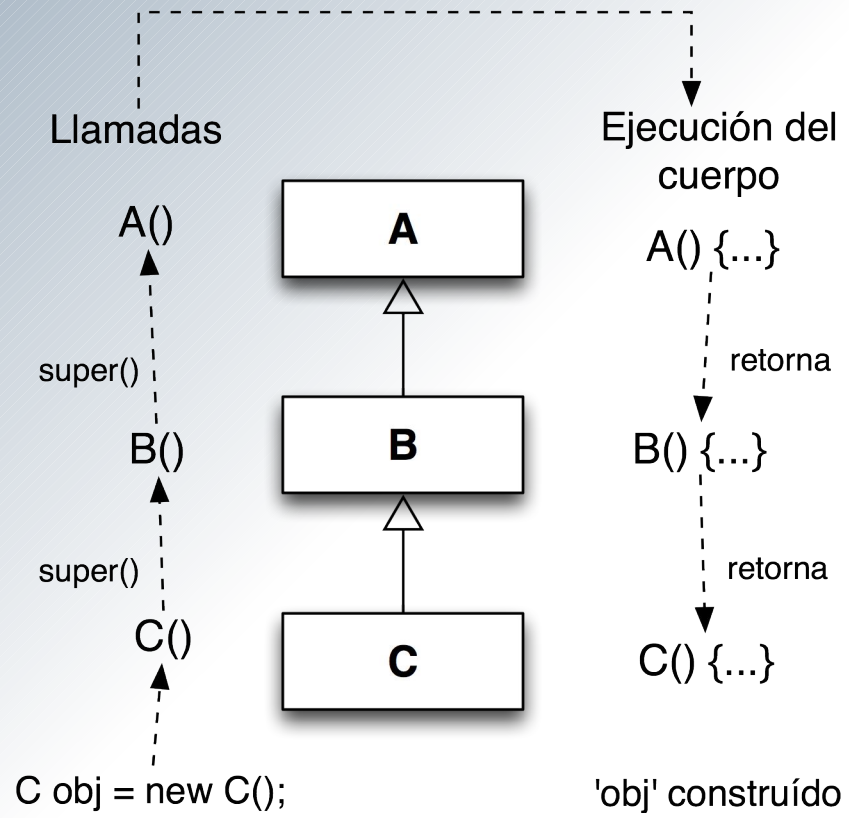
- **Refinement** in Java

```
class A {
  public void doIt() { System.out.println("HECHO en A."); }
  public void doItAgain() {
    System.out.println("HECHO otra vez en A.");
  }
}
class B extends A {
  public void doIt() {
    System.out.println("HECHO en B.");
    super.doIt(); // base implementation after child implementation
  }
  public void doItAgain() {
    super.doItAgain(); // before
    System.out.println("HECHO otra vez en B.");
  }
}
```

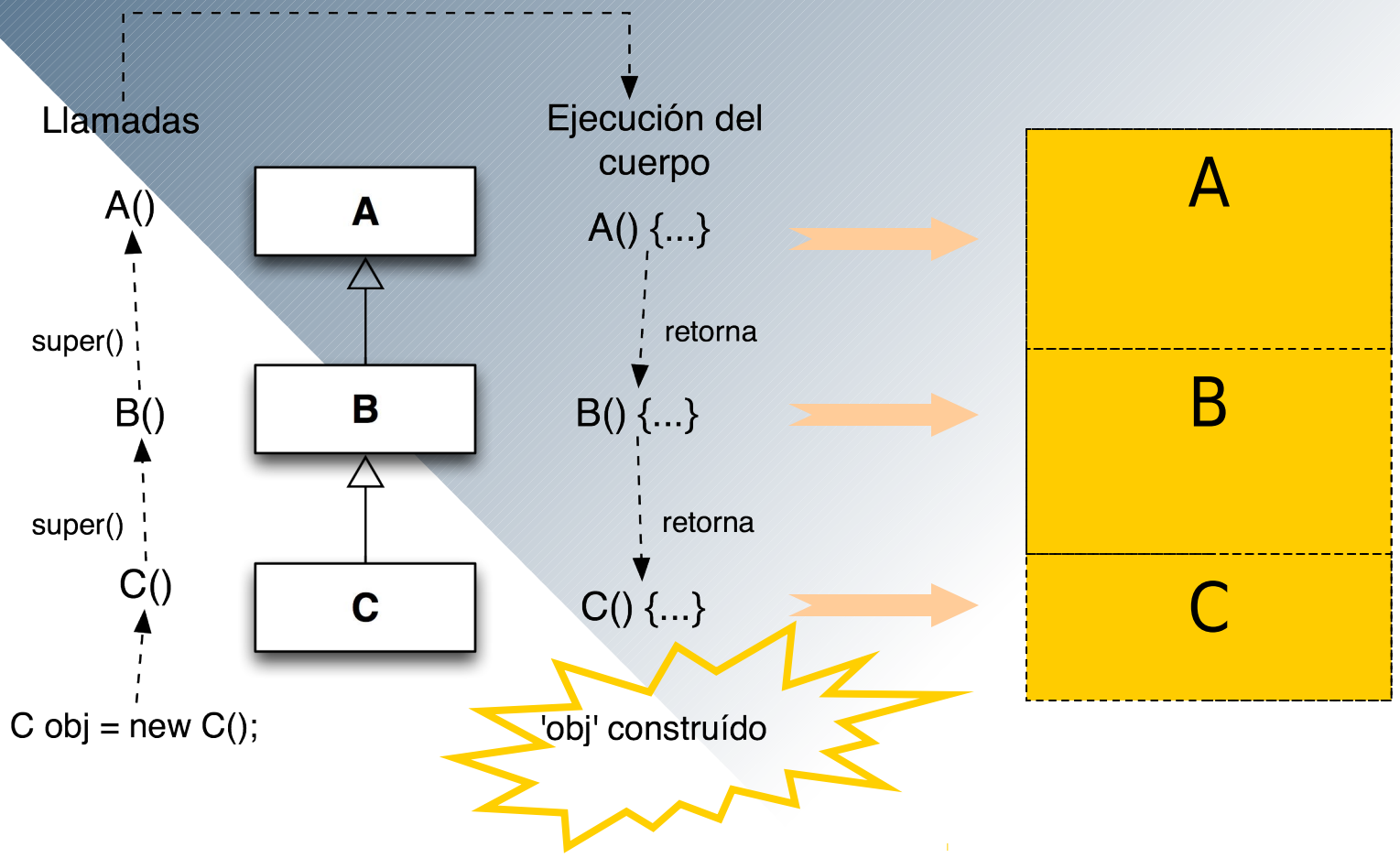
this : reference to the receiver of the message (current class implementation)
super : reference to the receiver of the message (using parent implementation)

Constructors under single inheritance

- Constructors are not inherited
  - Code in both classes must be executed.
  - Constructors must be defined in subclasses.
  - Creation of an object of the subclass: all the constructors (starting with the “highest” parent) are invoked.



Constructors under single inheritance



Constructors under single inheritance

- Derived classes **refine** the constructor in the base class.
- Implicit execution of the default parent constructor when invoking a constructor in the child class.
- Explicit execution of any other constructor (usually, requiring parameters) in the initialization part (explicit refinement); this happens, for instance, with copy constructors.

(WARNING: base class attributes should be initialized in the base class, not in the child class)

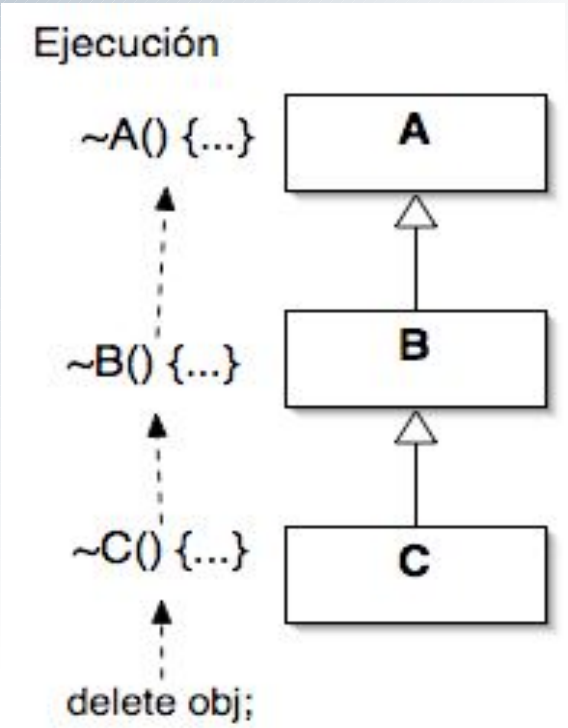
Constructors under single inheritance

- Example

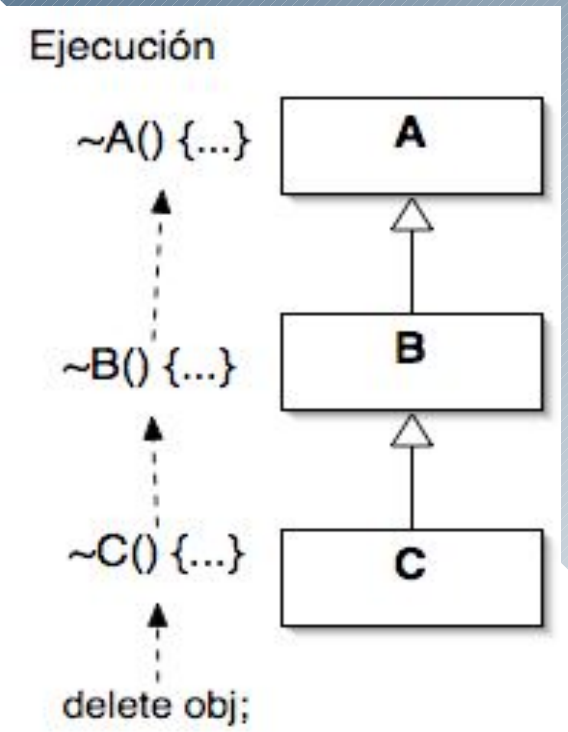
```
class Figura2D {
    private Color colorRelleno;
    public Figura2D() { colorRelleno= Color.NINGUNO; }
    public Figura2D(Color c) { colorRelleno=c; }
    public Figura2D(Figura2D f) { colorRelleno=f.colorRelleno; }

...}

class Circulo extends Figura2D {
  private  double radio;
  public Circulo() { radio=1.0; } // implicit call to Figura2D()
  public Circulo() { super(); radio=1.0; } // explicit call
  public Circulo(Color col, double r) { super(col); radio=r; }
  public Circulo(Circulo cir) { super(cir); radio=cir.radio; }
...}
```

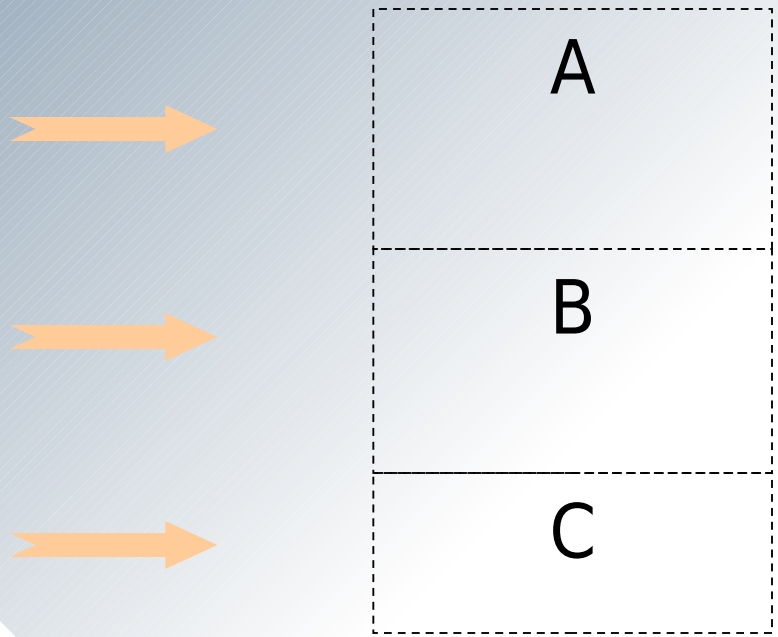
Constructors under single inheritance (C++)

- C++: destructors are not inherited.
  - They must be defined for the derived class.
  - Destruction of an object of the subclass: all the destructors (starting with the subclass) in the hierarchy are invoked.
  - Base class destructors are called implicitly.



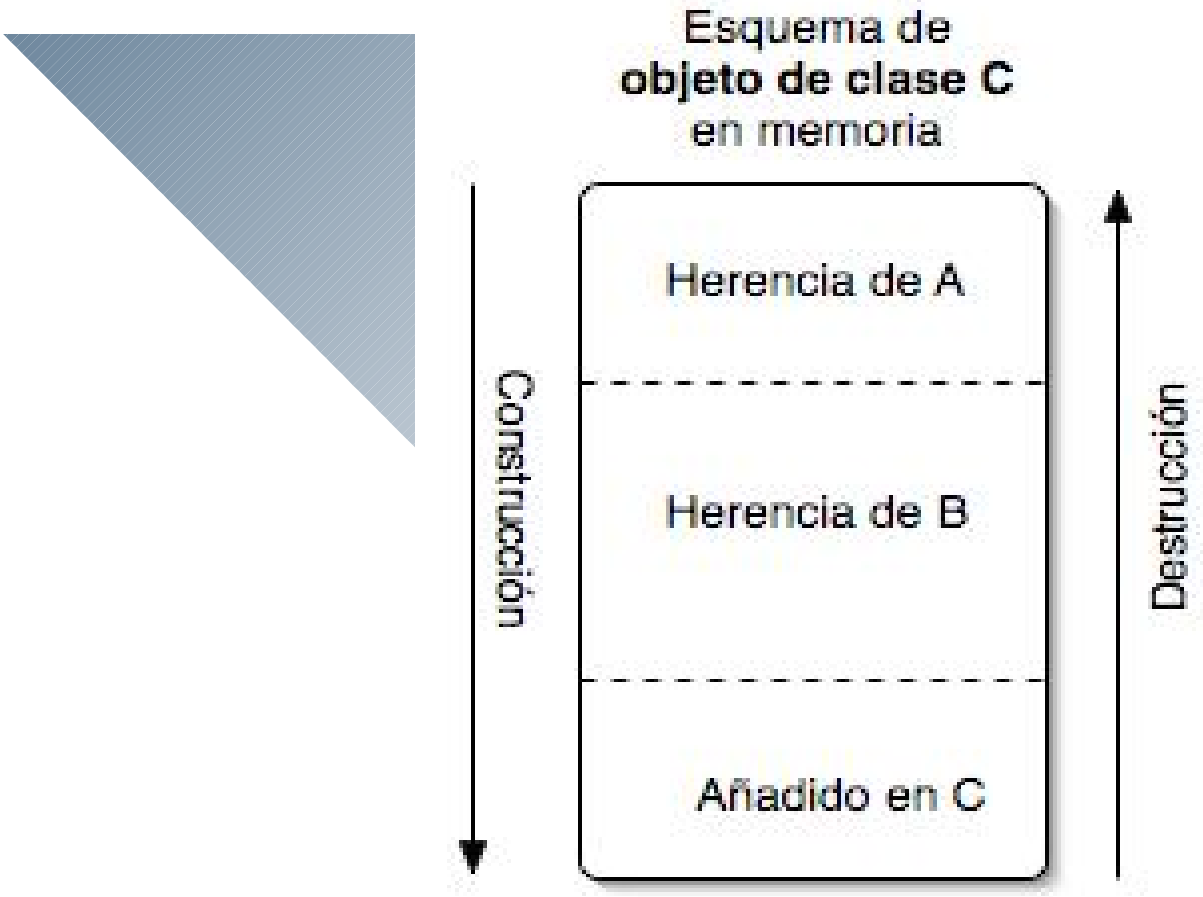
Destructors under single inheritance (C++)





Destruction/construction order in C++

- The destruction order in derived objects goes in exactly the reverse order of construction.



Destruction/construction order in Java

- In Java the construction order is the same than in C++: from the parent class to the child class.

- The destruction order is responsibility of the programmer. It must be implemented whenever resources (memory not included) to be released exist.

  - Two strategies:
    - Use **finalize**() methods
      - Disadvantage: it cannot be determined when they will be executed.

    - Create specific methods responsible of releasing the resources.
      - Disadvantage: client code must invoke explicitly those methods.

Destruction/construction order in Java

Cleanup/destruction using finalize()

```
class Animal  {
  Animal() {
    System.out.println("Animal()");
  }
  protected void finalize() throws Throwable{
    System.out.println("Animal finalize");
  }
}

class Amphibian extends Animal {
  Amphibian() {
    System.out.println("Amphibian()");
  }
  protected void finalize()  throws Throwable
  {
    System.out.println("Amphibian finalize");
      try {
        super.finalize();
      } catch(Throwable t) {}
  }
}
```

```
public class Frog extends Amphibian {
  Frog() {
    System.out.println("Frog()");
  }
  protected void finalize() throws Throwable {
    System.out.println("Frog finalize");
      try {
        super.finalize();
      } catch(Throwable t) {}
  }
  public static void main(String[] args) {
    new Frog(); // Instantly becomes garbage
    System.out.println("bye!");
    // Must do this to guarantee that all
    // finalizers will be called:
    System.runFinalizersOnExit(true);
    // Warning: this method is deprecated
  }
} ///:~
```

(taken from 'Piensa en Java', 4th ed., Bruce Eckl)

Destruction/construction order in Java

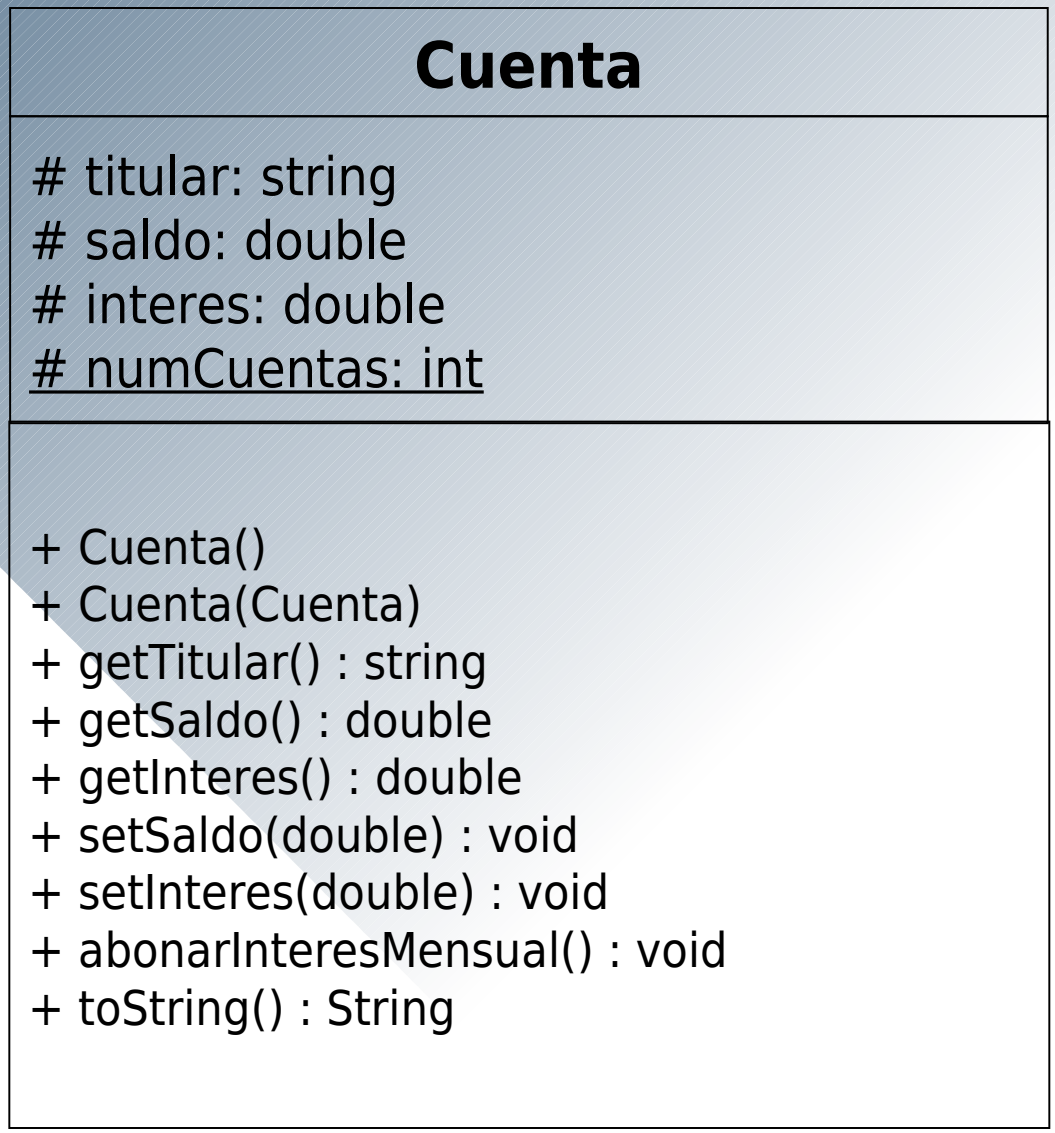
Cleanup/destruction using specific methods:

```
class Shape {
  Shape(int i) { print("Shape ctor"); }
  void dispose() { print("Shape dispose"); }
}

class Circle extends Shape {
  Circle(int i) {
    super(i);
    print("Drawing Circle");
  }
  void dispose() {
    print("Erasing Circle");
    super.dispose();
  }
}

class Triangle extends Shape {
  Triangle(int i) {
    super(i);
    print("Drawing Triangle");
  }
  void dispose() {
    print("Erasing Triangle");
    super.dispose();
  }
}
```

```
public class CADSystem extends Shape {
  private Circle c;
  private Triangle t;

  public CADSystem(int i) {
    super(i + 1);
    c = new Circle(1);
    t = new Triangle(1);
    print("Combined constructor");
  }
  public void dispose() {
    print("CADSystem.dispose()");
    // The order of cleanup is the reverse
    // of the order of initialization:
    t.dispose();
    c.dispose();
    super.dispose();
  }
  public static void main(String[] args) {
    CADSystem x = new CADSystem(47);
    try {
      // Code and exception handling...
    } finally {
      x.dispose();
    }
  }
}
```

(taken from 'Piensa en Java', 4th ed., Bruce Eckl)

Example: base class



Single inheritance (base class): Cuenta

```
class Cuenta{
   public Cuenta(String t, double s, double i)
    { titular=t; saldo=s; interes=i; numCuentas++; }
    ...
   protected string titular;
   protected double saldo;
   protected double interes;
   protected static int numCuentas;
//...
```

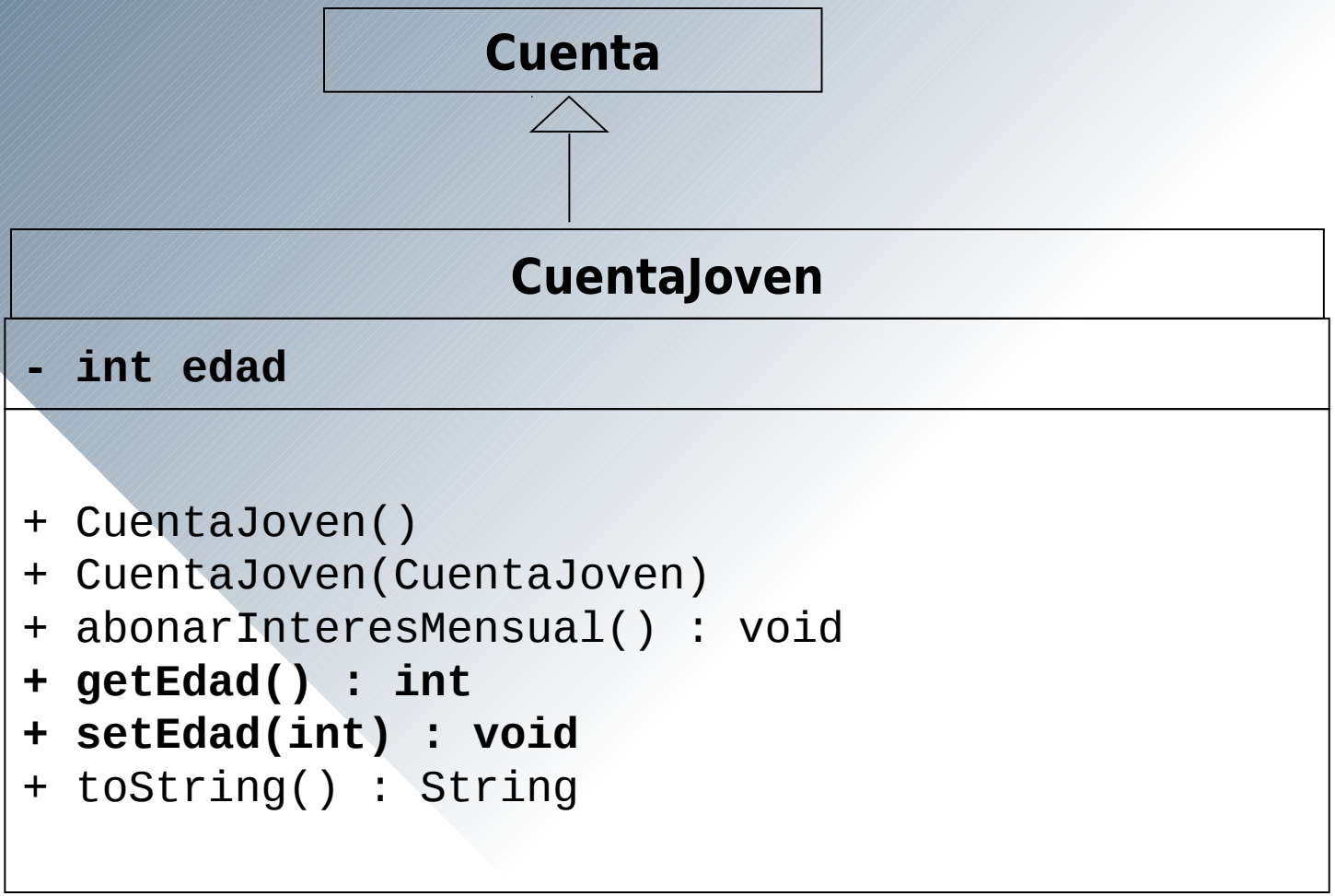
Single inheritance (base class): Cuenta (II)

```
// ... (cont.)

public Cuenta(Cuenta tc)
{ titular=tc.titular; saldo=tc.saldo;
interes=tc.interes; numCuentas++; }

protected void finalize() throws Throwable
{ numCuentas--; }
```

Single inheritance (base class): Cuenta (III)

```
  … (cont.)
  void abonarInteresMensual()
  { setSaldo(getSaldo()*(1+getInteres()/100/12)); }


  String toString ()
  {
    return “NumCuentas=“ + Cuenta.numCuentas + “\n”
      + “Titular=“ + unaCuenta.titular + “\n”
      + “Saldo=“ + unaCuenta.saldo + “\n”
      + “Interes=“ + unaCuenta.interes + “\n”;
  }
}
```

Example: derived class



(Methods whose implementation is inherited from the base class are not specified in UML)

Single inheritance (child class): CuentaJoven (I)

```
class CuentaJoven extends Cuenta {

  private int edad;

  public CuentaJoven(String unNombre,int unaEdad,
    double unSaldo, double unInteres)
  {
    super(unNombre,unSaldo,unInteres);
    edad=unaEdad;
  }

  public CuentaJoven(CuentaJove tcj)
  // explicit call to the copy constructor in Cuenta
  {
    super(tcj);
    edad=tcj.edad;
  }

...
```

Should numCuentas be incremented?

Refinement

Single inheritance (child class): CuentaJoven (II)

```
   ...
   void abonarInteresMensual() {
        // no interest if balance is below limit
        if (getSaldo()>=10000)
          setSaldo(getSaldo()*(1+getInteres()/12/100));
   }

   int getEdad() {return edad;}
   void setEdad(int unaEdad) {edad=unaEdad;}

   void toString(){
        String s = super.toString();
        s = s + "Edad:"+edad;
   }
}// end of class CuentaJoven
```

Replacement

New methods added

Refined method

Single Inheritance
Upcasting

Upcasting is converting a derived-class reference to a base-class.

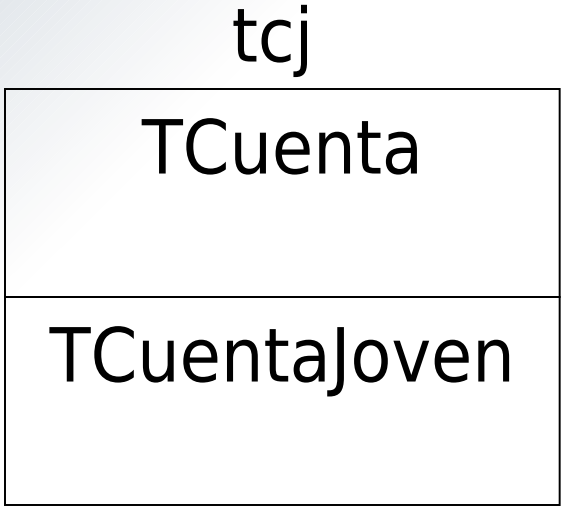
```
CuentaJoven tcj = new CuentaJoven();
Cuenta c;

c = (Cuenta)tcj; // explicit
c = tcj; // implicit

tcj.setEdad(18); // OK
c.setEdad(18); // ERROR!
```

An object of the child class accessed through a reference to the base class can only be handled by using the interface of the base class.

Single inheritance: upcasting

Object slicing is used when converting objects (not pointers) in C++: fields in CuentaJoven which are not found in TCuenta are sliced off during the process.

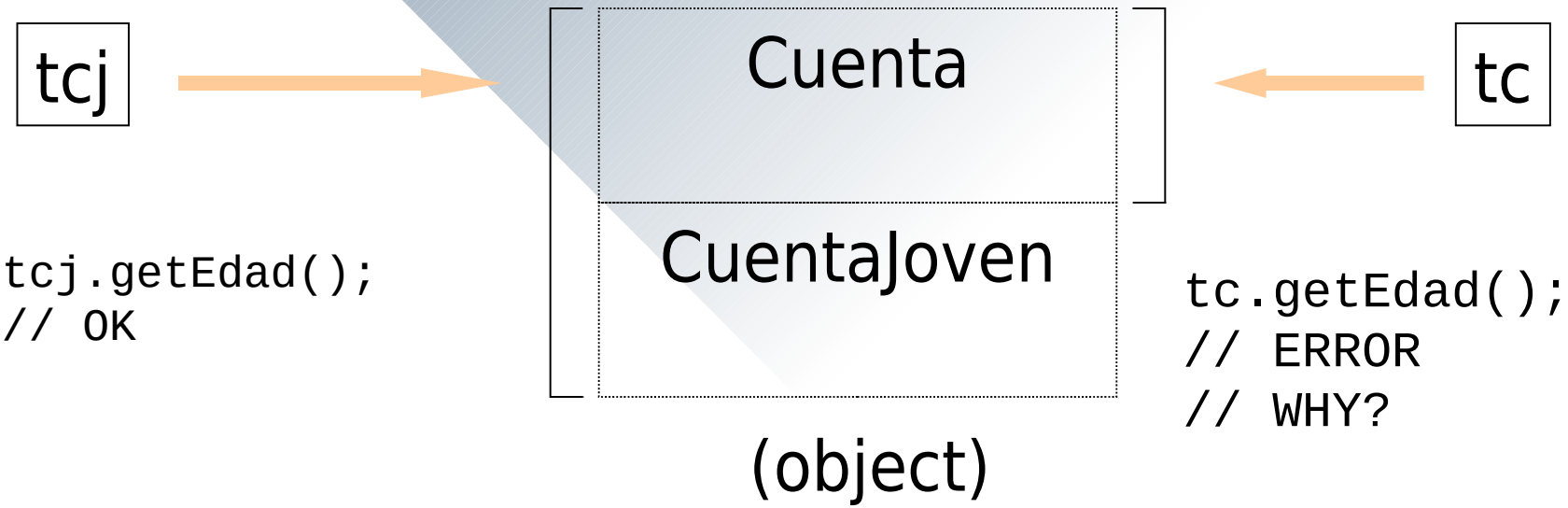
```
CuentaJoven tcj;

(TCuenta)tcj
```



Single inheritance: upcasting

When using references (in Java or C++),
no **object slicing** is performed

```
CuentaJoven tcj = new CuentaJoven();
Cuenta tc = tcj; // upcasting
```




```
tcj.getEdad();
// OK
```

```
tc.getEdad();
// ERROR
// WHY?
```

Some facts about inheritance

- In inheritance hierarchies an implicit refinement exist for:
  - Default constructors

- Overloaded constructors are refined explicitly.

- Class (static) properties defined in the base class are shared (inherited) with the child classes.

IMPLEMENTATION INHERITANCE

Multiple Inheritance

Multiple inheritance

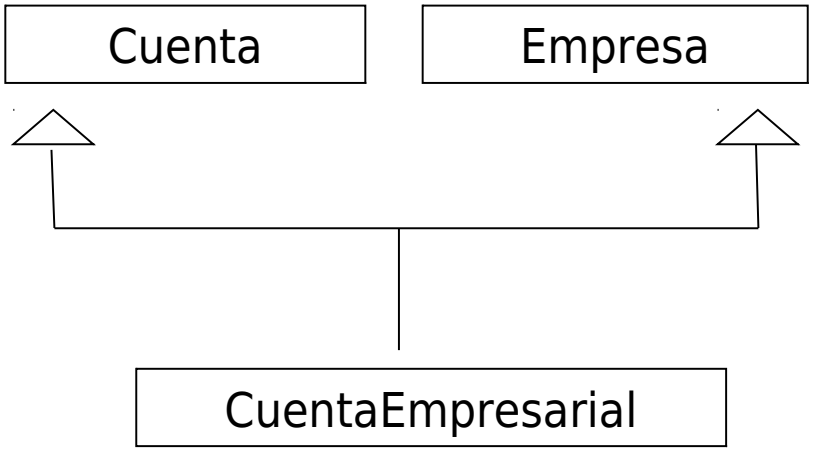
- An object can have two or more different parent classes and inherit both data and behavior from each.
- **C++** supports multiple implementation inheritance.
  - Both interfaces and implementation are inherited from the base class.
- **Java** only supports multiple interface inheritance.
  - Interface is inherited but not the implementation.

In these slides we will focus on multiple implementation inheritance.

Multiple implementation inheritance

(Examples in C++)

```
class Empresa {
  protected:
     string nomEmpresa;

  public:
     Empresa(string unaEmpresa)
     { nomEmpresa=unaEmpresa; }
     void setNombre(string nuevo)
     { nomEmpresa = nuevo; }
};
```

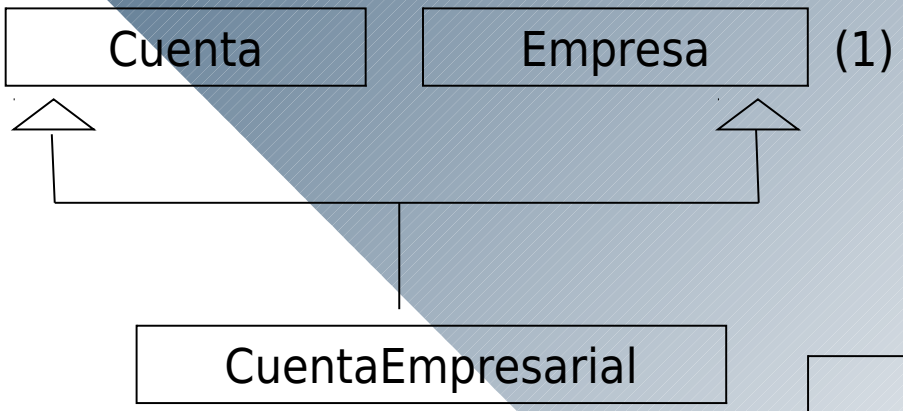


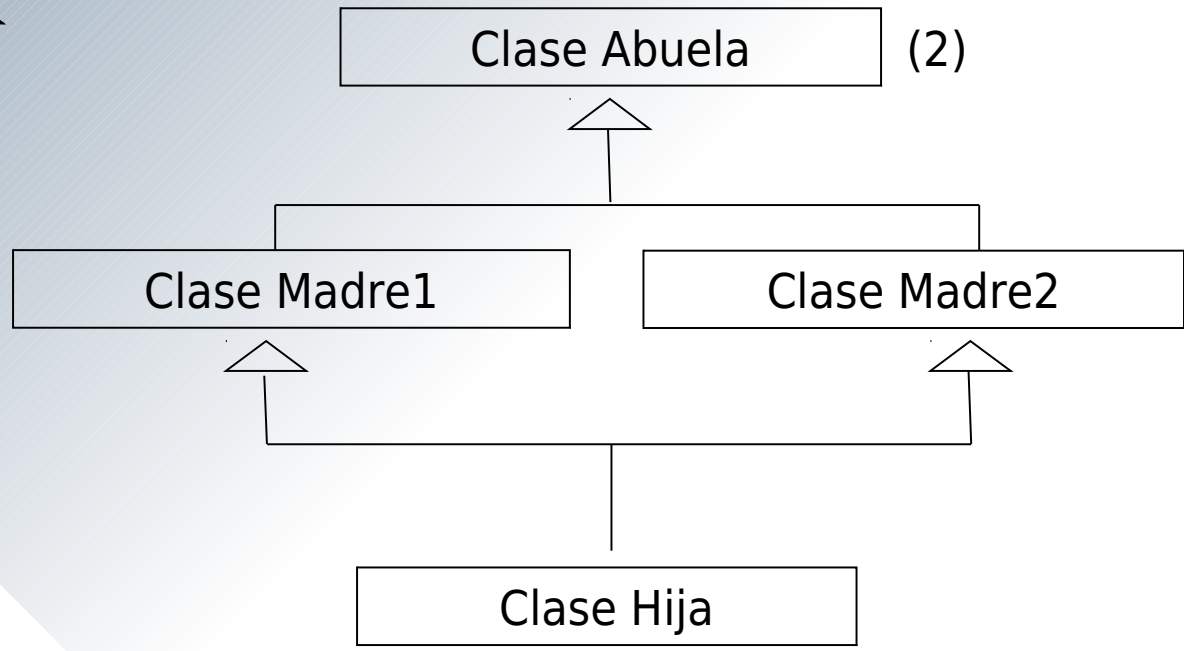
What is the implementation of CuentaEmpresarial?

Multiple implementation inheritance in C++

```
class CuentaEmpresarial
: public Cuenta, public Empresa {

    public:

     CuentaEmpresarial(string unNombreCuenta,
       string unNombreEmpresa,
       double unSaldo=0, double unInteres=0)
       : Cuenta(unNombreCuenta,unSaldo,unInteres),
         Empresa(unNombreEmpresa)
     {};
};
```

Problems with multiple implementation inheritance





Which problems may arise in (1)? And in (2)?

Name clash under multiple inheritance (C++)

The problem is with the child and not with the parents.

Possible solution: use fully qualified names:

```
class CuentaEmpresarial: public TCuenta, public
  Empresa {
  …
  { … string n;
    if …
      n= Cuenta::getNombre();
    else
      n= Empresa::getNombre();
  }
};
```

Property duplication under multiple inheritance

In C++ this "diamon problem" is overcome by using **virtual inheritance**:

```
class Madre_1: virtual public Abuela{
…
}

class Madre_2: virtual public Abuela{
…
}

class Hija: public Madre_1, public Madre_2 {
   …
   Hija() : Madre_1(), Madre_2(), Abuela(){
   };
}
```