# OOP Inheritance

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# Motivation

- They all move, have a shape, shields, and weapons. Can they share the same code?

# Motivation

- Frequently, a class is merely a modification of another class. Inheritance allows minimal repetition of the same code
- A new design created by changing an existing design. (The new design consists of only the changes)
- Localization of code
  - Fixing a bug in the base class automatically fixes it in the subclasses
  - Adding functionalities to the base class automatically adds them to the subclasses
  - Reduced chances of different (and inconsistent) implementations of the same operation

# Inheritance

- A class can be a sub-type of another class
- The inheriting class contains all the attributes and methods of the class it inherited from
- The inheriting class can define additional attributes and methods
- The inheriting class can override the definition of existing methods by providing its own implementation
- The code of the inheriting class consists only of the changes and additions to the base class

# Example I (extension)

```
Class Car {
    boolean isOn;
    String licensePlate;

    void turnOn() {…}
    void turnOff() {…}
}
```

```
Class SDCar extends Car {
    boolean isSelfDriving;

    void turnSDOn() {…}
    void turnSDOff() {…}
}

SDCar c = new SDCar();
c.turnOn();      // OK!
c.turnSDOn();    // OK!
```

*SD = Self Driving*

# Example II (override)

```
Class Car {
     boolean isOn;
     String licensePlate;

     void turnOn() {…}
     void turnOff() {…}
}
```

```
Class SDCar extends Car {
     boolean isSelfDriving;

     /* method override */
     void turnOn() {
          turnSDOff();
          /* … */
     }
     /* method override */
     void turnOff() {
          turnSDOff();
          /* … */
     }

     void turnSDOn() {…}
     void turnSDOff() {…}
}
```

# Example III (override)

```
Class Car {
    boolean isOn;
    string licensePlate;

    void turnOn() {…}
    void turnOff() {…}
}
```

```
Class SDCar extends Car {
    boolean isSelfDriving;

    /* override */
    void turnOn() {
        turnSDOff();
        super.turnOn();
    }

    void turnOff() {
        turnSDOff();
        super.turnOff();
    }

    void turnSDOn() {…}
    void turnSDOff() {…}
}
```

# Class SDCar

- Inherits
  - attributes (isOn, licencePlate)
  - methods (turnOn, turnOff)
- Adds
  - attributes (isSelfDriving)
  - methods (turnSDOn, turnSDOff)
- Modifies (overrides)
  - methods (turnOn, turnOff)

```
Class SDCar extends Car {
     boolean isSelfDriving;

     /* override */
     void turnOn() {
          turnSDOff();
          super.turnOn();
     }

     void turnOff() {
          turnSDOff();
          super.turnOff();
     }

     void turnSDOn() {…}
     void turnSDOff() {…}
}
```

# this and super

- this is a reference to the current object
- super is a reference to the parent class

# Terminology

- **Class one above**
  - Parent class
- **Class one below**
  - Child class
- **Class one or more above**
  - Superclass, Ancestor class, Base class
- **Class one or more below**
  - Subclass, Descendent class

# Visibility and Inheritance

# Visibility

```
Class Car {
     private boolean isOn;
     private string licensePlate;

     public void turnOn() {…}
     public void turnOff() {…}
}
```

```
Class SDCar extends Car {
  void print() {
    /* Do not work! Not visible! */
    System.out.println(licencePlate);
  }
}
```

# Visibility

```
Class Car {
     protected boolean isOn;
     protected string licensePlate;

     public void turnOn() {…}
     public void turnOff() {…}
}
```

```
Class SDCar extends Car {
  void print() {
    /* Works! */
    System.out.println(licencePlate);
  }
}
```

# Recap

| | Method in the same **class** | Method of another class in the same **package** | Method of **subclass** | Method of another public class in the outside **world** |
|---|---|---|---|---|
| *private* | ✓ | | | |
| *package* | ✓ | ✓ | | |
| *protected* | ✓ | ✓ | ✓ | |
| *public* | ✓ | ✓ | ✓ | ✓ |

# Inheritance and constructors

# Construction of child objects

- Since each subclass “contains” an instance of the parent class, the latter must be initialized
- Java compiler automatically calls the default constructor (no params!) of parent class
- The call is inserted as the first statement of each child constructor. If parent class disabled default constructor (by defining others) parent constructor must be called explicitly!

# super()

- this is a reference to the current object
- super is a reference to the parent class

- super() calls the default constructor of parent class
- super(params) calls other constructors of parent class
  - Must be the first statement in child constructors

# Example

```
class Car {
    boolean isOn;
    String licensePlate;
    /* Default constructor enabled! */
}

class SDCar extends Car {
    boolean isSelfDriving;
    /* Default constructor enabled! */
}  // Works!
```

# Example

```
class Car {
    boolean isOn;
    String licensePlate;
    /* Default constructor enabled! */
}

class SDCar extends Car {
    boolean isSelfDriving;
    /* Default constructor disabled! */
    public SDCar() {
      /* automatic call to parent default constructor here! */
    }
}   // Works!
```

# Example

```
class Car {
     boolean isOn;
     String licensePlate;
      /* Default constructor disabled! */
     public Car(String licensePlate) {
       this.licencePlate = licensePlate;
   }
}

class SDCar extends Car {
     boolean isSelfDriving;
      /* Default constructor disabled! */
     public SDCar() {
       /* automatic call to parent default constructor here! */
   }
}  // Not working!
```

# Example

```
class Car {
     boolean isOn;
     String licensePlate;
      /* Default constructor disabled! */
     public Car(String licensePlate) {
       this.licencePlate = licensePlate;
   }
}

class SDCar extends Car {
     boolean isSelfDriving;
      /* Default constructor disabled! */
     public SDCar() {
       super("DD543EF");
   }
}  // Works!
```

# Construction of child objects

- Execution of constructors proceeds top-down along the inheritance hierarchy
- In this way, when a method of the child class is executed (constructor included), the super-class is completely initialized already

# Example

```
class Car{
     Car() {
          super();
          System.out.println("New Car created");
     }
}
Class SDCar extends Car {
     SDCar() {
          super();
          System.out.println("New SDCar created");
     }
}

SDCar c = new SDCar();  // Which output?
```

# Dynamic binding and polymorphism

```
Car[] garage = new Car[4];

garage[0] = new Car();
garage[1] = new SDCar();
garage[2] = new SDCar();
garage[3] = new Car();

for(Car c : garage) {
    c.turnOn();
    /* which method is actually called
     * is not knowable at compile time! */
}
```

# Dynamic binding and polymorphism

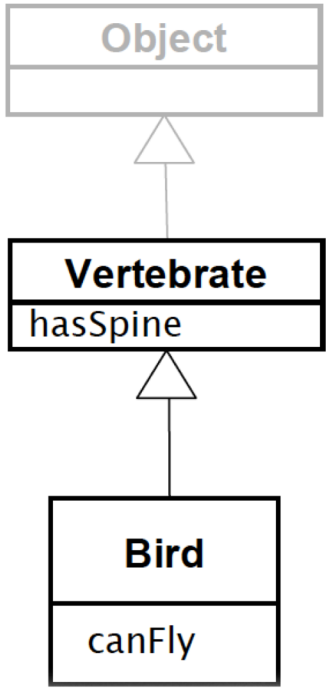
- When using collections of objects belonging to a hierarchy of classes, methods actually called are known only at runtime.
- The same call (methods with the same signature) might have different results (polymorphism) depending on the actual class of the object.

* https://en.wikipedia.org/wiki/Late_binding

# Object

# Java.lang.Object

- **`java.lang.Object`**
- All classes are subtypes of Object




```
class Vertebrate  {
   ...
}
```

extends Object — Implicitly

```
class Bird extends Vertebrate{
   ...
}
```

# Java.lang.Object

- All objects can be seen as Object instances
- Object defines basic services, which are useful for all classes. They are often overridden in sub-classes. For example:
  - toString(): returns a string representation
  - equals(Object o): tests equality
  - clone(): returns a shallow copy of the object

# toString()

```
class Car{
    String licencePlate;
    public String toString(){
        return “[Car] ” + licencePlate;
    }
}

Car c = new Car();
// println(Object) call
System.out.println(c);

// println(String) call
System.out.println(c.toString());
```

# equals(Object o)

```
public class Car {
    boolean isOn;
    String licencePlate;
    public Car(boolean isOn, String licencePlate) {
        this.isOn = isOn;
        this.licencePlate = licencePlate;
    }
    public static void main(String[] args) {
        Car c1 = new Car(true, "AA334GG");
        Car c2 = new Car(true, "AA334GG");
        System.out.println(c1.equals(c2)); //false!
    }
}
```

# equals(Object o)

```
public class Car {
     boolean isOn;
     String licencePlate;
     public Car(boolean isOn, String licencePlate) {
          this.isOn = isOn;
          this.licencePlate = licencePlate;
     }

     /* the equals() methods must be overridden */
     public boolean equals(Object obj) {
          Car other = (Car) obj;
          if (isOn != other.isOn)
               return false;
          if (licencePlate != other.licencePlate)
               return false;
          return true;
     }
}
```

# Casting

# Types

- Java is a strictly typed language
- Each variable has a type
- float f;

```
f = 4.7;                    //OK!
f = “hello!”;               //!OK
```

- Car c;

```
c = new Car();              //OK!
c = new String();           //!OK
```

# Upcasting and Downcasting

```
class Car {};
class SDCar extends Car {};

Car c1 = new Car();       // OK!
SDcar c2 = new SDCar (); // OK!

But also…
Car c3 = new SDcar();
```

# Upcasting and Downcasting

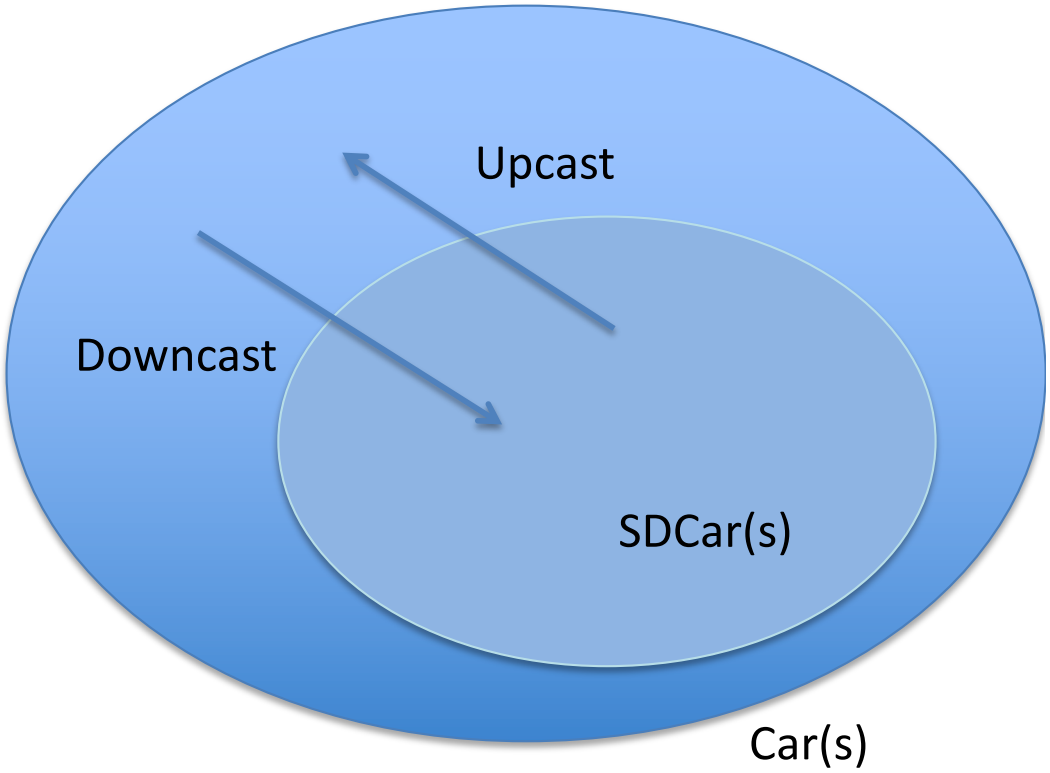
```
Car c3 = new SDcar();
```

Specialization defines a sub-typing relationship (is a ).

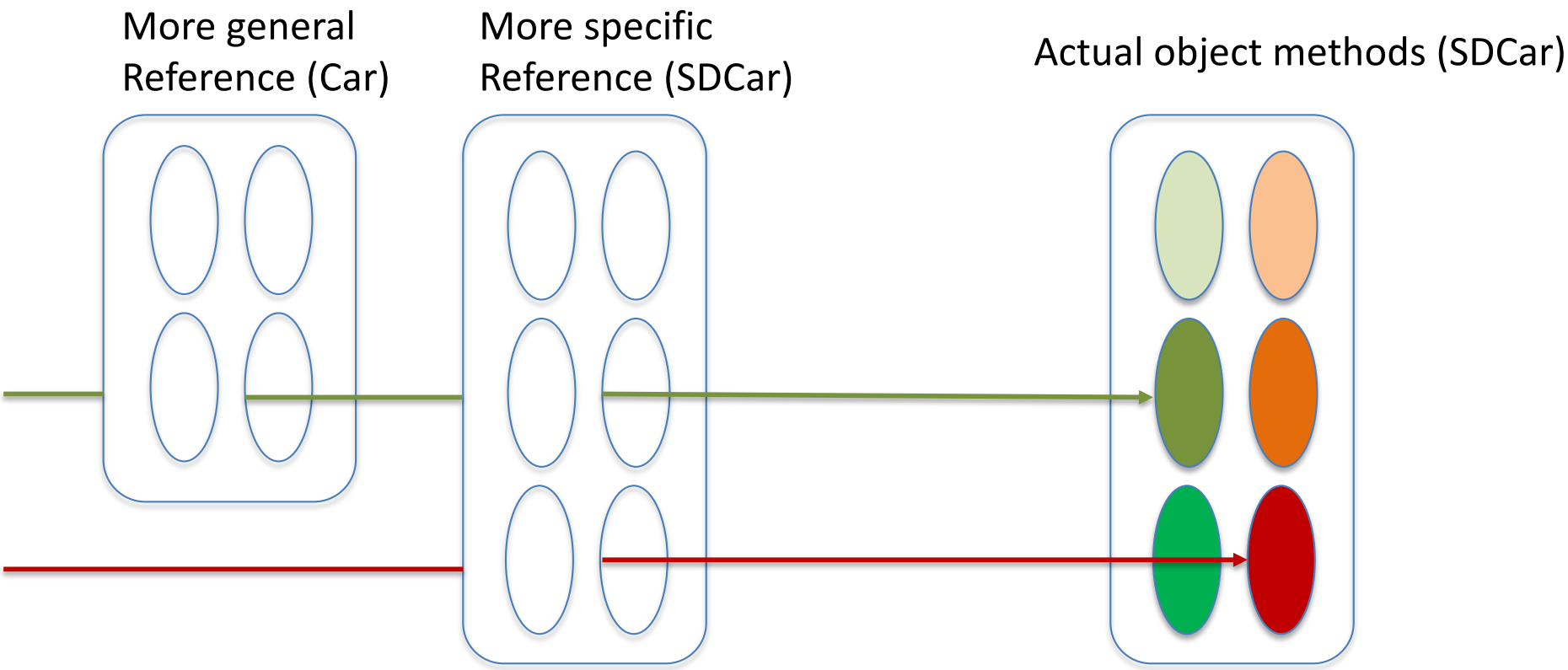
All ECar(s) are Car(s). Not all Car(s) are ECar(s).

Upcasting and downcasting refer to the possibility of changing the reference type of a given object.

Upcasting consists in using more general references, while downcasting more specific references.



# Upcasting and Downcasting



# Upcasting

```
class Car {};
class SDCar extends Car {};
Car c = new SDCar();
```

- Assignment from a more specific type to a more general type
- Note well: reference type and object type are separate concepts. Object referenced by ‘c’ continues to be of SDCar type! Only the interface changes!

# Upcasting

- It is dependable
  - It is always true that an electric car is a car too
- It is automatic
  - `Car c = new SDCar();`

# Example

```
Class Car {
     boolean isOn;
     string licensePlate;

     void turnOn() {…}
     void turnOff() {…}
}
```

```
Class SDCar extends Car {
     boolean isSelfDriving;

     void turnSDOn() {…}
     void turnSDOff() {…}
}
```

```
SDCar c1 = new SDCar();
c1.turnSDOn() // OK!

Car c2 = c1;  // Upcast
c2.turnSDOn() // Compile time error!
(Car interface does not provide turnSDOn() call)
```

# Downcasting

- Assignment from a more general type (super-type) to a more specific type (sub-type)
  - Reference type and object type do not change
- MUST be explicit
  - It's a risky operation, no automatic conversion provided by the compiler (it's up to you!)

# Example

```
Class Car {
    boolean isOn;
    string licensePlate;

    void turnOn() {…}
    void turnOff() {…}
}
```

```
Class SDCar extends Car {
    boolean isSelfDriving;

    void turnSDOn() {…}
    void turnSDOff() {…}
}
```

```
Car c1 = new SDCar();
c1.turnSDOn() // Compile time error!

SDCar c2 = (SDcar)c1;  // Downcast
c2.turnSDOn() // Accidentally OK! The object
referenced by c1 was actually of class SDCar
```

# Example

```
Class Car {
    boolean isOn;
    string licensePlate;

    void turnOn() {…}
    void turnOff() {…}
}
```

```
Class SDCar extends Car {
    boolean isSelfDriving;

    void turnSDOn() {…}
    void turnSDOff() {…}
}
```

```
Car c1 = new Car();
c1.turnSDOn() // Compile time error!

SDCar c2 = (SDcar)c1;  // Downcast
c2.turnSDOn() // Run time error!
```

# Runtime is evil

- Compilers aid developers in writing working code. Runtime errors cannot be identified by compilers. Developers must be careful!
- Use the instanceof operator

```
Car c = new SDCar();
if (c instanceof SDCar){
   SDCar sdc = (SDCar) c;
   ec.turnSDOn();
}
```

# Upcast to object

- Each class is either directly or indirectly a subclass of Object
- It is always possible to upcast any instance to Object type (see Collection)

```
AnyClass any = new AnyClass();
Object obj = (Object)any;
```

# Abstract Classes and Interfaces

# Abstract methods

- You can *declare* an object without *defining* it:

  Person p;

- Similarly, you can declare a *method* without defining it (i.e., the body of the method is missing):

  public abstract void draw(int size);

- A method that has been declared but not defined is an abstract method

# Abstract classes

- Any class containing one or more abstract method is an abstract class
- You must declare the class with the keyword abstract:

```
abstract class MyClass {...}
```

- An abstract class is *incomplete* (It has missing method bodies)
- You cannot instantiate (create a new instance of) an abstract class

# Abstract classes

- You can extend (subclass) an abstract class
  - If the subclass defines all the inherited abstract methods, it is concrete and can be instantiated
  - If the subclass does *not* define all the inherited abstract methods, it must be abstract too
- You can declare a class to be abstract even if it does not contain any abstract methods
  - This just prevents the class from being instantiated

# Why use abstract classes?

- Suppose you wanted to create a class Shape, with subclasses Oval, Rectangle, Triangle, Hexagon, etc.
- Each subclass has a method draw() for representing its shape on a 2D graphic panel

# A problem

```
class Shape { ... }
class Star extends Shape {
    void draw() { ... }
    ...
}
class Circle extends Shape {
    void draw() { ... }
    ...
}
Shape s;
s = new Shape(); // Legal, but unwanted
s.draw();        // Illegal, Shape does not have draw()
s = new Star();  // Legal, because a Star is a Shape
s.draw();        // Illegal, Shape does not have draw()
```

# Same problem, another view

```
Shape[] shapes = new Shape[16];
shapes[0] = new Circle();
shapes[1] = new Star();
…
for (Shape s : shapes) {
    s.draw(); // Illegal, Shape does not have draw()
}
```

# A solution

```
abstract class Shape {
    abstract void draw();
}
class Star extends Shape {
    void draw() { ... }
    ...
}
class Circle extends Shape {
    void draw() { ... }
    ...
}
Shape s;
s = new Shape(); // Illegal, Shape is abstract
s = new Star();  // Legal, because a Star is a Shape
s.draw();        // Legal, Shape does have draw()
```

# Another problem

- Let's suppose that all shapes must have two capabilities:
  - Drawing their own shape [draw() method]
  - Setting a unique ID [setID() method]

# A solution

We can keep the Shape class abstract while providing an implementation to its methods.

Benefits:

1. Shape cannot be instantiated
2. Shape subclasses can redefine draw()

Drawbacks:

1. We partially loose the possibility to define abstract concepts such as Shape. Now Shape contains code!

```
abstract class Shape {
  void setID() { . . . };
  abstract void draw();
}

class Star extends Shape {
    void draw() { ... }
    ...
}

class Circle extends Shape {
    void draw() { ... }
    ...
}
```

# A better solution

We can use a Shape Interface.

- Interfaces are special classes for declaring methods without supplying implementations
- All their methods are implicitly public and abstract
- Interfaces cannot be instantiated because they do not contain actual code
- When a class implements an interface, it promises to *define* all the methods *declared* in the interface

```
interface Shape() {
  public abstract void setID();
  public abstract void draw();
}

abstract class AbstractShape implements
Shape {
    void setID() { . . . };
    abstract void draw();
}

class Star extends AbstractShape {
    void draw() { ... }
    ...
}

class Circle extends AbstractShape {
    void draw() { ... }
    ...
}
```

Level of abstraction

# Specialization and partial implementation

- Interfaces can be specialized
  - Specializing an interface means adding new methods in derived interfaces. Overriding methods does not make sense in interfaces because code is absent.
- Interfaces can be partially implemented
  - Partial implementations of interfaces can be found in abstract classes. The unimplemented methods must be marked as abstract.

# Multiple inheritance

- In Java, a class can only extend one class, but can implement multiple interfaces
  - This lets the class fill multiple *roles* (i.e., multiple set of methods)
  - In graphical interfaces (GUIs), it is common to have one class implementing several listeners (i.e., interfaces)

```
class Application extends JFrame implements
ActionListener, KeyListener {
    ...
}
```

# Multiple inheritance

```
public class GroudVehicle {
    activateWheels() {…}
    …
}
public class WaterVehicle {
    activateWaterFan() {…}
    …
}
// Not allowed in Java!! Only one class can be extended!
public class Anphibian extends GroudVehicle, WaterVehicle {
    …
}
```

# Multiple inheritance

```
public interface GroudVehicle {
    activateWheels();
    …
}
public interface WaterVehicle {
    activateWaterFan();
    …
}
public class Anphibian implements GroudVehicle, WaterVehicle {
    activateWheels() {…}
    activateWaterFan() {…}

    …
}
```

# Interfaces and instanceof

- instanceof is a keyword that tells you whether a variable "is a" member of a class or interface
- Membership of a class or interfaces can be translated with "has its methods implemented"

```
class Dog extends Animal implements Pet {...}
Dog lessie = new Dog();

lessie instanceof Dog        //OK!
lessie instanceof Animal     //OK!
lessie instanceof Pet        //OK!
```

# Vocabulary

- abstract method—a method which is declared but not defined (it has no method body)
- abstract class—a class which either (1) contains abstract methods, or (2) has been declared abstract
- instantiate—to create an instance (object) of a class
- interface—similar to a class, but contains only abstract methods (and possibly constants)
- adapter class—a class that implements an interface but has only empty method bodies

*Complexity has nothing to do with intelligence, simplicity does.*

*— Larry Bossidy*
*Ex CEO Honeywell*

*Perfection is achieved, not when there is nothing more to add, but when there is nothing left to take away.*

*— Antoine de Saint Exupery*
*Scrittore, aviatore francese*