

# Object-Oriented Programming

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# Overview

Object-  
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Programming

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Inheritance

Derived  
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Special  
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Constructors  
and  
destructors for  
derived classes

Substitution  
principle

Method  
overriding

UML diagrams

Multiple  
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- 1 Inheritance
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- 4 Constructors and destructors for derived classes
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- 6 Method overriding
- 7 UML diagrams
- 8 Multiple inheritance

# Primary OOP features

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- **Abstraction:** separating an object's *specification* from its *implementation*.
- **Encapsulation:** grouping related data and functions together as objects and defining an interface to those objects.
- **Inheritance:** allowing code to be reused between related types.
- **Polymorphism:** allowing an object to be one of several types, and determining at runtime how to "process" it, based on its type.

# Inheritance I

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- Allows defining a new class (subclass) by using the definition of another class (superclass).
- Inheritance makes code reusability possible.
- Reusability refers to using already existing code (classes).
- The time and effort needed to develop a program are reduced, the software is more robust.

# Inheritance II

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- Through inheritance, new classes can be derived from already existing ones.
- The existing class is not modified.
- The new class can use all the features of the old one and add new features of its own.
- Inheritance can be used if there is a **kind of** or **is a** relationship between the objects.

# Example

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Inheritance

Derived classes

Special functions and inheritance

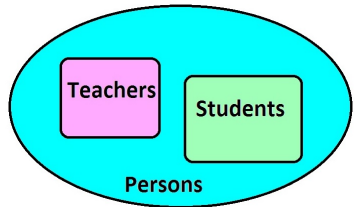
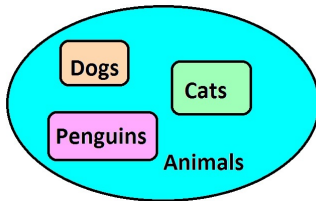
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- What are the characteristics/responsibilities that all animals or all persons have in common?
- What are some characteristics that only dogs/penguins/cats have?

# Simple inheritance - Derived classes I

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- Inheritance requires at least two classes: a *base class* and a *derived class*.
- If B and D are two classes,
  - D *inherits from* B or
  - D *is derived from* B or
  - D *is a specialization of* B
- means that:
  - class D has all variables and methods of class B;
  - class D may redefine methods of class B;
  - class D may add new members besides the ones inherited from B.

# Simple inheritance - Derived classes II

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- If class D inherits from class B then:
  - an object of class D includes all member variables of class B;
  - the member functions of class B can be applied to objects of class D (unless they are hidden).

## Syntax

```
class D: public B
{
// ...
};
```



# Simple inheritance - Derived classes III

## Example

```
class Animal
{
protected:
    std::string colour;
    double weight;
//...
};

class Penguin: public Animal
{
private:
    std::string type;
//...
};
```

# Simple inheritance - Derived classes IV

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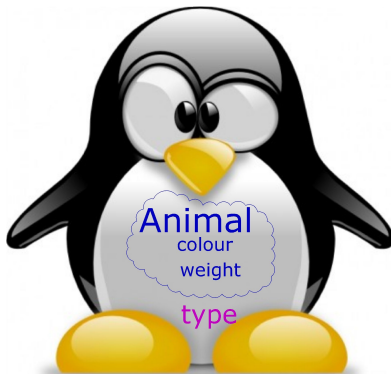
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## DEMO

Class derivation (Animal - Penguin, Dog) (*Lecture5\_demo*).



# Simple inheritance - Derived classes V

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## Terminology

- class B = superclass, base class, parent class.
- class D = subclass, derived class, descendent class.
- *inherited member (function, variable)* = a member defined in B, and used unchanged in D.
- *redefined member (overridden)* = defined in B and D.
- *added member (new)* = defined only in D.

# Real world examples (applications) I

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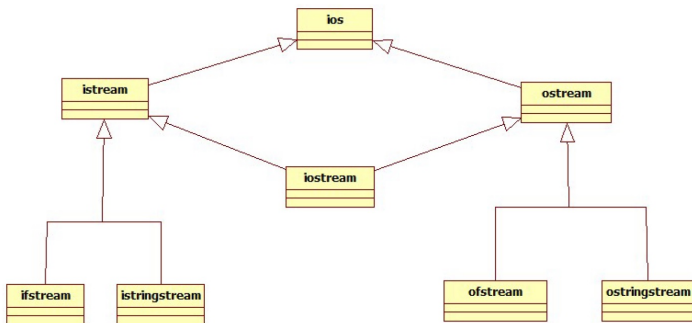
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- STL: IO class hierarchy.

## IO Class hierarchy



# Real world examples (applications) II

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- Windows Presentation Foundation (WPF) controls.

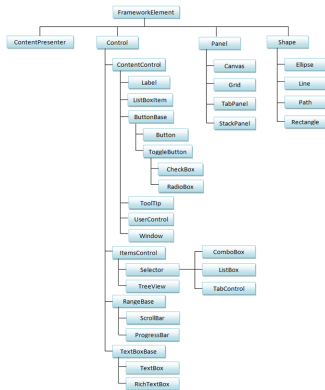


Figure source: <https://soumya.wordpress.com/2010/01/10/wpfsimplified-part-10-wpf-framework-class-hierarchy/>

# Real world examples (applications) III

- Java: the **java.lang** package.

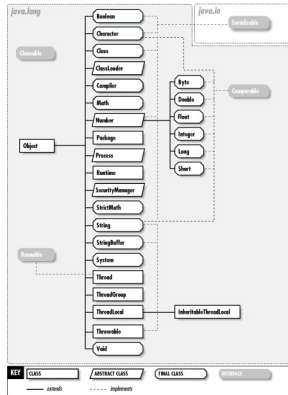


Figure source: [https://docstore.mik.ua/oreilly/java-ent/jnut/ch12\\_01.htm](https://docstore.mik.ua/oreilly/java-ent/jnut/ch12_01.htm)

# Access modifiers I

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Access modifiers define where the members of a class (fields or methods) can be accessed from.

- **public**: public members can be accessed from anywhere.
- **private**: private members can be accessed from within the class or from friend functions or classes.
- **protected**: protected members can be accessed from within the derived classes; **protected** acts just like **private**, except that inheriting classes have access to protected members, but **not** to private members. Friend functions or classes can access protected members.

# Access modifiers II

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Access	public	protected	private
Class	Yes	Yes	Yes
Derived class	Yes	Yes	No
Client code	Yes	No	No



# Access control I

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- Public inheritance:
  - The access rights of the members of the base class are not changed.

```
class A: public B { ... }
```

- Protected inheritance:
  - Inherited public or protected members from the base class become protected members in the derived class.

```
class A: protected B { ... }
```

- Private inheritance:
  - Inherited public or protected members from the base class become private members in the derived class.

```
class A: private B { ... }
```

# Access control II

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Inheritance type	public	protected	private
Base access specifier	Derived access specifier		
Public	Public	Protected	Private
Protected	Protected	Protected	Private
Private	Private	Private	Private

# Special member functions and inheritance

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- Some functions will need to do different things in the base class and the derived class.
- These special functions cannot be inherited.
- **Constructors**: derived class constructor must create different data from base class constructors.
- **Assignment operator**: in the derived class, this operator must assign values to the derived class data.
- **Destructors**

# Constructors and destructors for derived classes I

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- Constructors and destructors are not automatically inherited.
- Constructors in the derived class need to invoke a constructor from the base class.
- If no constructor is explicitly invoked, the *default constructor* from the base class is invoked automatically.
- If there are no default constructors → compiler error.
- ? How is it possible to *not* have a default constructor?

# Constructors and destructors for derived classes II

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- When an object of a derived class is created, the constructor of the base class is called first and then the constructor of the derived class.
- The destructor of the base class is automatically invoked by the destructor of the derived class.
- When an object of a derived class is destroyed, the destructor of the derived class is called first and then the destructor of the base class.

## Object creation in derived classes

- Creation:
  - 1 allocate memory for member variables from base class;
  - 2 allocate memory for member variables from derived class;
  - 3 a constructor is selected and called to initialize the variables from the base class;
  - 4 a constructor is selected and called to initialize the variables from the derived class.
- Destruction:
  - 1 destructor call for derived class;
  - 2 destructor call for base class.

# Constructors and destructors for derived classes IV

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## DEMO

Creation and destruction in derived classes (*Lecture5\_demo*).

# Liskov substitution principle

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- If S is a declared subtype of T, objects of type S should behave as objects of type T are expected to behave, if they are treated as objects of type T.  
(Barbara H. Liskov and Jeannette M. Wing, *A Behavioral Notion of Subtyping*, ACM Transactions on Programming Languages and Systems, 1994.)
- An object of the derived class (public inheritance) can be used in any context expecting an object of the base class (upcast is implicit).

## DEMO

Substitution principle (*Lecture5\_demo*).



# Pointers and inheritance

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- If class D publicly inherits from class B, then a pointer to D can be assigned to a variable of type pointer to B.
- A pointer to an object of type B can carry the address of an object of type D.
- E.g.: A pointer to an animal can point to objects of type Animal, Dog and Penguin (all dogs and penguins are animals).

## DEMO

Pointers and inheritance (*Lecture5\_demo*).

# Method overriding I

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- A derived class may override (redefine) some methods of the base class.
- In defining derived classes, we only need to specify what is different about them from their base classes (programming by difference).
- Inheritance allows only overriding methods and adding new members and methods. We cannot remove functionality that was present in the base class.

# Method overriding II

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- Use the scope resolution operator `::` to access the overridden function of base class from derived class.
- Overriding  $\neq$  overloading. ? What is the difference?

## DEMO

Overriding the *toString* method. (*Lecture5\_demo*).

- UML - Unified Modeling Language.
- UML is the industry-standard language for specifying, visualizing, constructing, and documenting the artifacts of software systems.
- UML is the standard notation for software architecture.
- It is language independent.

# UML class diagrams I

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- A UML class diagram specifies the entities in a program and the relationships among them.
- It contains and specifies:
  - class name
  - variables (name, type)
  - methods (name, parameter types, return type)
- private members are denoted by -;
- public members are denoted by +;
- protected members are denoted by #.

# UML class diagrams II

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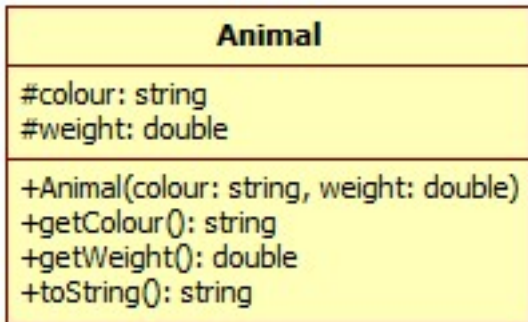
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- UML associations describe relationships of structural dependency between classes.
- An association may have:
  - a role name;
  - a multiplicity;
  - navigability (uni/bi-directional).

# Associations II

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## Association types

- **Association** (*knows a*) - is a reference based relationship between two classes. A class A holds a class level reference to another class B.





# Associations III

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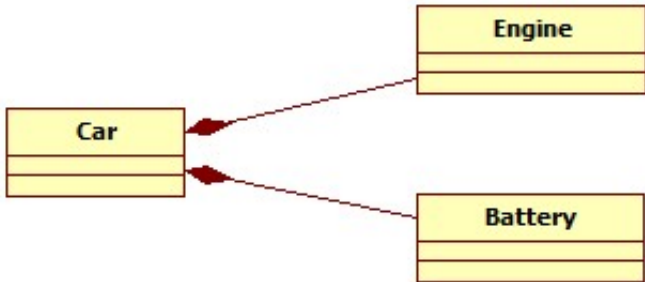
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- **Composition** (*has a*) - when class B is composed by class A, class A instance owns the creation or controls lifetime of instance of class B. When class A instance is destructed, so is the class B instance.



# Associations IV

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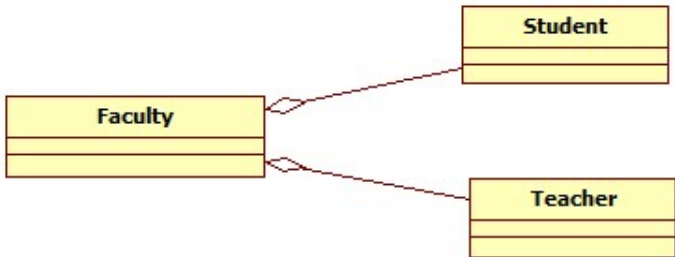
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- **Aggregation** (*has a*) - when class B contains instances of class A, but those instances can exist independently.



# Associations V

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- **Dependency** (*uses a*) - when class A uses a reference to class B, as part of a particular method (parameter or local variable). A modification to the class B's interface may influence class A.



# Associations VI

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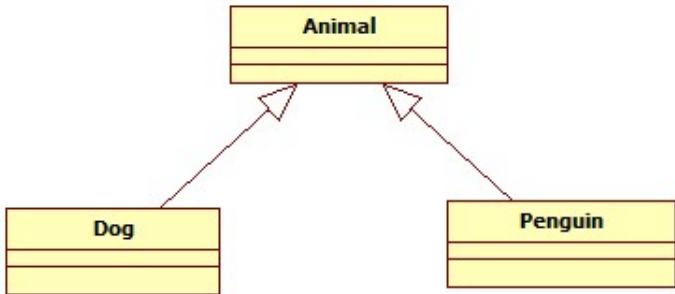
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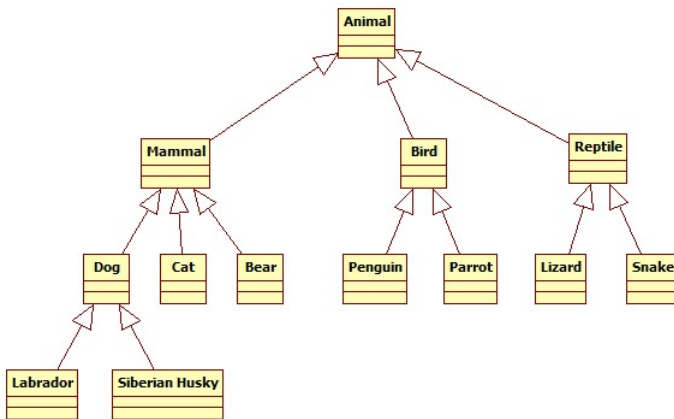
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- **Inheritance** (*is a*) - every instance of the derived class **is an** instance of the base class.



# Associations VII

- Inheritance allows us to define hierarchies of related classes.



# Multiple inheritance I

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- Unlike many object-oriented languages, C++ allows a class to have multiple base classes.
- The class will inherit all the members from all the base classes.
- Multiple inheritance can be dangerous:
  - the same field/method could be inherited from different classes;
  - the situation of repeated base classes might arise.

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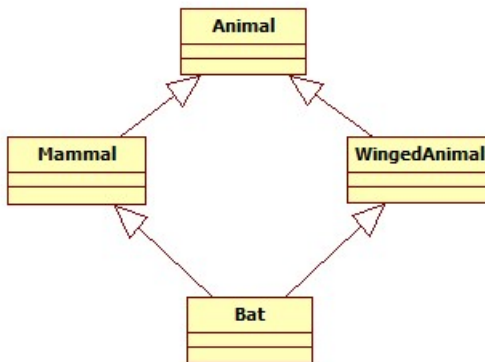
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## Problems with multiple inheritance

- **Ambiguity:**

- multiple base classes contain a function with the same name.
- 2 copies of the base class member variables are inherited by class **Bat**

- **Diamond problem:**

- if a method from class **Animal** was overridden in both classes (**Mammal** and **WingedAnimal**), which of the two versions should be inherited?
- if a **Bat** to **Animal** cast is attempted, which **Animal** sub-object should the **Bat** cast into?

- **C++ (partial) solution:** virtual inheritance.



## Inheritance

- Allows code to be reused between related types.
- Defines an **is a** relationship.
- Constructors and destructors are **not** inherited.
- An object of the derived class (public inheritance) can be used in any context expecting an object of the base class (upcast is implicit), but **not** viceversa.
- Methods can be redefined (overridden) in derived classes.