INHERITANCE & AGGREGATION

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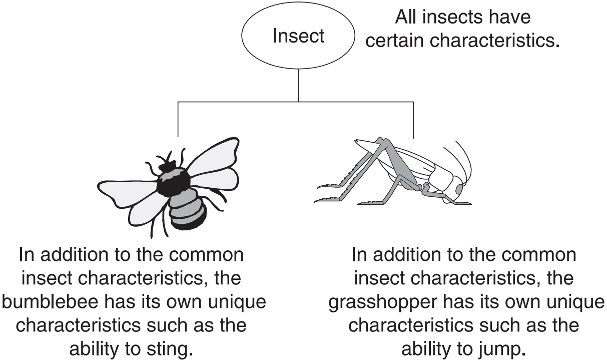
Introduction to inheritance

What Is Inheritance?

Concept 1

Inheritance allows a new class to be based on an existing class. The new class inherits all the member variables and functions (except the constructors and destructor) of the class it is based on.



Insect

All insects have certain characteristics.

In addition to the common insect characteristics, the bumblebee has its own unique characteristics such as the ability to sting.

In addition to the common insect characteristics, the grasshopper has its own unique characteristics such as the ability to jump.

Inheritance and the “Is a” Relationship

When one object is a specialized version of another object, there is an “is a” relationship between them. For example, a grasshopper is an insect. Here are a few other examples of the “is a” relationship.

- A poodle *is a* dog.
- A car *is a* vehicle.
- A tree *is a* plant.
- A rectangle *is a* shape.
- A football player *is an* athlete.

Inheritance involves a **base class** and **a derived class**.

- The base class is the general class and the derived class is the specialized class.
- The derived class is based on, or derived from, the base class.

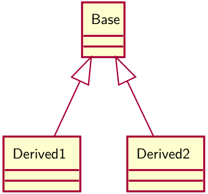
C++ Syntax of Derivation

Syntax

```
class <Derived Class> : <Type Of Inheritance> <Base class>
{
public:
    <public attributes/functions>
private:
    <private attributes/functions>
};
```

Inheritance in UML

- Inheritance between classes.



Examples of Inheritance Taken from Daily Life

Base Class	Example Derived Classes
Fish	Goldfish, Carp, Tuna
Mammal	Human, Elephant, Lion, Platypus
Bird	Crow, Parrot, Ostrich, Kiwi, Platypus
Shape	Circle, Polygon
Polygon	Triangle, Octagon

Listing 1

```
#include <iostream>
using namespace std;
class Fish {
public:
   bool FreshWaterFish;
   void Swim() {
      if (FreshWaterFish)
         cout << "Swims in lake" << endl;
      else
         cout << "Swims in sea" << endl;
   }
};
class Tuna: public Fish {
public:
   Tuna() {
      FreshWaterFish = false;
   }
};
class Carp: public Fish {
```

Listing 1 (cont.)

```
public:
   Carp() {
      FreshWaterFish = true;
   }
};
int main() {
   Carp myLunch;
   Tuna myDinner;
   cout << "Getting my food to swim" << endl;
   cout << "Lunch: ";
   myLunch.Swim();
   cout << "Dinner: ";
   myDinner.Swim();
   return 0;
}
```

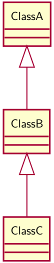
Hierarchical organization of concepts

Class Hierarchies

Concept 2

A base class can also be derived from another class.

- Sometimes it is desirable to establish a hierarchy of classes in which one class inherits from a second class, which in turn inherits from a third class
- In some cases, the inheritance of classes goes on for many layers.



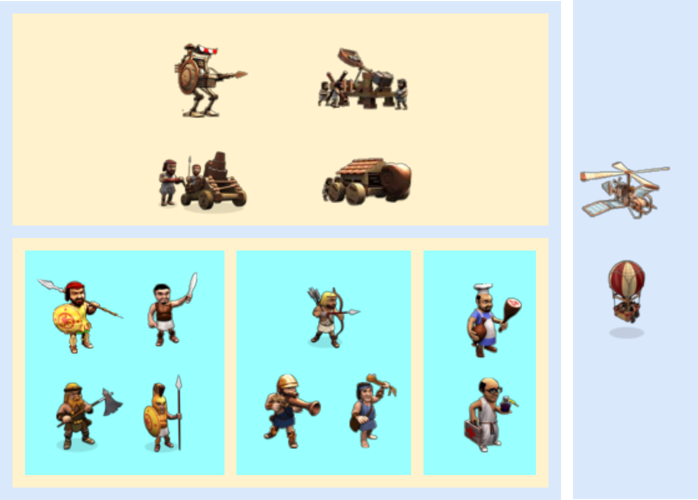
Hierarchical organization of concepts

- A group of concepts is divided into sub-groups according to some criterion.
- We should use only one criterion at a time to classify a group of concepts.

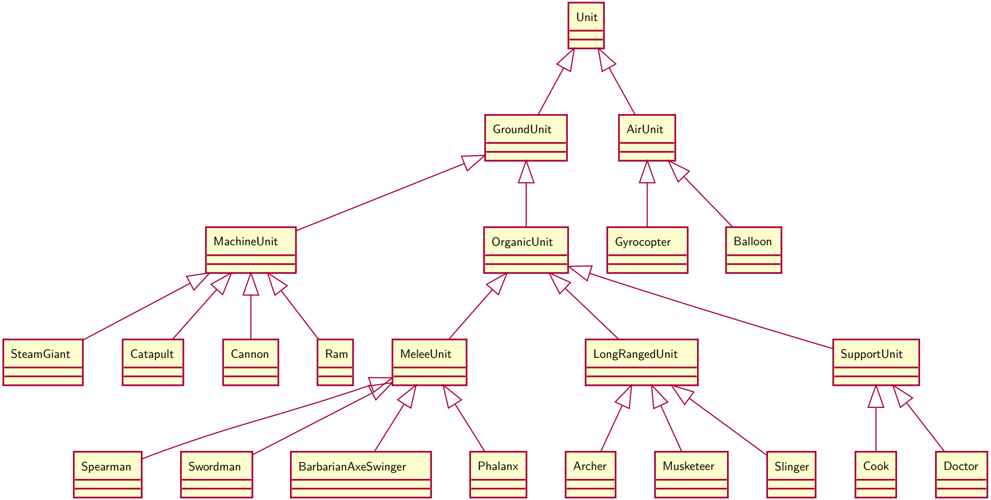
Steam giant
Catapult
Cannon
Ram
Gyrocopter
Spearman
Swordman
Archer
Cook
Balloon
Barbarian-axe swinger
Phalanx
Musketeer
Slinger
Doctor

Hierarchical organization of concepts (cont.)

- Concepts are recursively classified into subgroups



Hierarchical organization of concepts (cont.)



Types of inheritance

Introduction to inheritance
Hierarchical organization of concepts
Types of inheritance
Derived class
Multiple inheritance
Aggregation
Workshop

Protected Members and Class Access

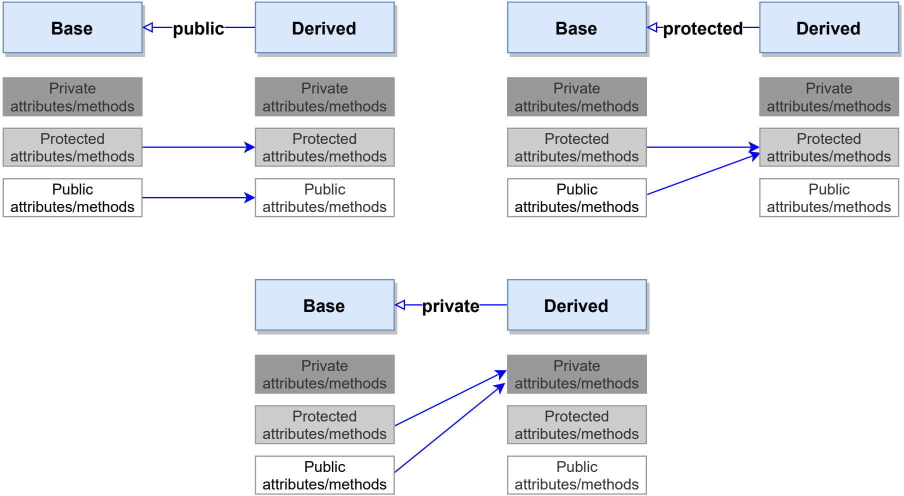
Concept 3

Protected members of a base class are like private members, but they may be accessed by derived classes. The base class access specification determines how private, public, and protected base class members are accessed when they are inherited by the derived classes.

Types of inheritance (in C++)

- There are 3 types of inheritance in C++:
  - **public inheritance**: public and protected of the base class become public and protected of the derived class.
  - **protected inheritance**: public and protected of the base class become protected of the derived class.
  - **private inheritance**: public and protected of the base class become private of the derived class.
- **Notes**: from now on, if there is no mention of what type of inheritance, it means public inheritance

Types of inheritance (in C++) (cont.)



Base public Derived

Private attributes/methods

Protected attributes/methods

Public attributes/methods

Private attributes/methods

Protected attributes/methods

Public attributes/methods

Base protected Derived

Private attributes/methods

Protected attributes/methods

Public attributes/methods

Private attributes/methods

Protected attributes/methods

Public attributes/methods

Base private Derived

Private attributes/methods

Protected attributes/methods

Public attributes/methods

Private attributes/methods

Protected attributes/methods

Public attributes/methods

Derived class

Member functions inheritance

- Member functions of the base class are inherited in the derived class, except:
  - Constructors
  - Destructors
  - Assignment operators

Order of Construction/Deconstruction

Concept 4

The base class's constructor is called before the derived class's constructor. The destructors are called in reverse order, with the derived class's destructor being called first.

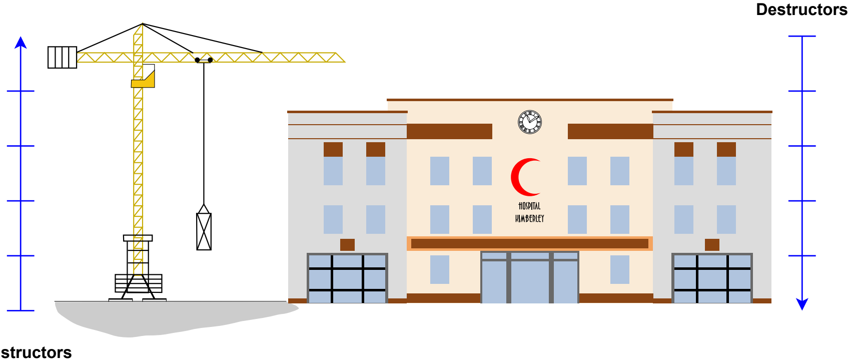
When a new object of a derived class is created:

- The constructor of the base class is invoked first.
- Then, the constructor of the derived class is invoked.
- In the constructor of the derived class, we can specify which constructor of the base class is called. Otherwise, the default constructor of the base class will be invoked.

When an object of the derived class finishes its lifespan:

- The destructor of the derived class is invoked first.
- Then, the destructor of the base class is called later.

Order of Construction/Deconstruction (cont.)



Base Class Initialization

- Using **initialization lists** and in invoking the appropriate base class constructor via the constructor of the derived class

```
class Base {
public:
   Base(int SomeNumber) { // overloaded constructor
      // Do something with SomeNumber
   }
};
class Derived: public Base {
public:
   Derived(): Base(25) { // instantiate class Base with
                         // argument 25
      // derived class constructor code
   }
};
```

Derived Class Overriding Base Class' Methods

- Sometimes, we need to "re-define" the member functions of a base class in a derived class. It can be done by implements the same functions in the `class Derived` with the same return values and signatures as in the `class Base` it inherits from

Notes

This re-definition will **hide other overloading member functions** of this function from the base class.

Listing 2

```
#include <iostream>
using namespace std;
class Fish {
private:
   bool FreshWaterFish;
public:
   // Fish constructor
   Fish(bool IsFreshWater) : FreshWaterFish(IsFreshWater){}
   void Swim() {
      if (FreshWaterFish)
         cout << "Swims in lake" << endl;
      else
         cout << "Swims in sea" << endl;
   }
};
class Tuna: public Fish {
```

Listing 2 (cont.)

```
public:
   Tuna(): Fish(false) {}
   void Swim() {
      cout << "Tuna swims real fast" << endl;
   }
};
class Carp: public Fish {
public:
   Carp(): Fish(true) {}
   void Swim() {
      cout << "Carp swims real slow" << endl;
   }
};
int main() {
   Carp myLunch;
   Tuna myDinner;
   cout << "Getting my food to swim" << endl;
```

Listing 2 (cont.)

```
    cout << "Lunch: ";
    myLunch.Swim();
    cout << "Dinner: ";
    myDinner.Swim();
    return 0;
}
```

Invoking Overridden Methods of a Base Class

- If we want to be invoke `Fish::Swim()`, we need to use the scope resolution operator (`::`)

```
int main() {
  ...
  myDinner.Fish::Swim();
  ...
}
```

- If our specialized implementations in `Tuna:Swim()` and `Carp::Swim()` need to reuse the base class' generic implementation of `Fish::Swim()`, we use the scope resolution operator (`::`)

```
class Carp: public Fish {
public:
   Carp(): Fish(true) {}
   void Swim() {
      cout << "Carp swims real slow" << endl;
      Fish::Swim();  // use scope resolution operator::
   }
};
```

Problem with re-definition

```
class Base {
public:
  void test() {...}
  void test(int) {...}
  void test(int, int) {...}
};
class Derived : public Base {
public:
  void test(int) {...}
};
```

```
int main() {
  Derived obj;
  int x, y;
  ...
  obj.test(x);     // OK
  obj.test(x, y); // compile error
}
```

- Solution 1: Use the scope resolution operator `::`
- Solution 2: Use the `using` keyword in class `Derived` to unhide other overloaded methods
- Solution 3: Override all overloaded methods

The Problem of Slicing

- What happens when a programmer does the following?

```
Derived objectDerived;
Base objectBase = objectDerived;
```

- Or, alternatively, what if a programmer does this?

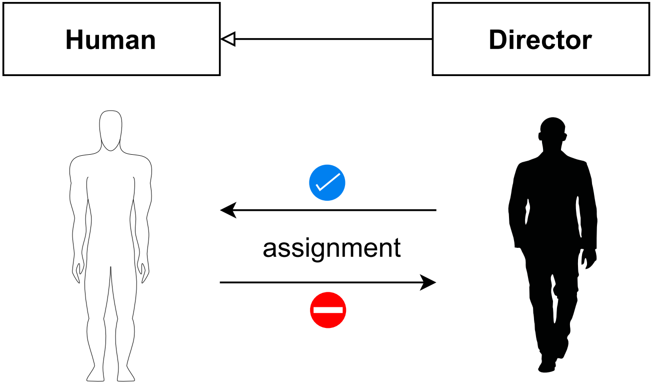
```
void FuncUseBase(Base input);
...
Derived objectDerived;
FuncUseBase(objectDerived);
```

- The compiler copies only the `Base` part of `objectDerived`—that is, not the complete object—rather than only that part of it that would fit `Base`.

Concept 5

The unwanted reduction of the part of data that makes the `Derived` a specialization of `Base` is called *slicing*.

The Problem of Slicing (cont.)



Human

Director

assignment

Caution

To avoid slicing problems, **don’t pass parameters by value**.

Assignment operator

- Assignment operator is not inherited from the base class. To implement the assignment operator for the derived class:
    - First, calling the assignment operator of the base class to assign data members of the base class .
    - Then, implement the assignment for data member of the derived class part.

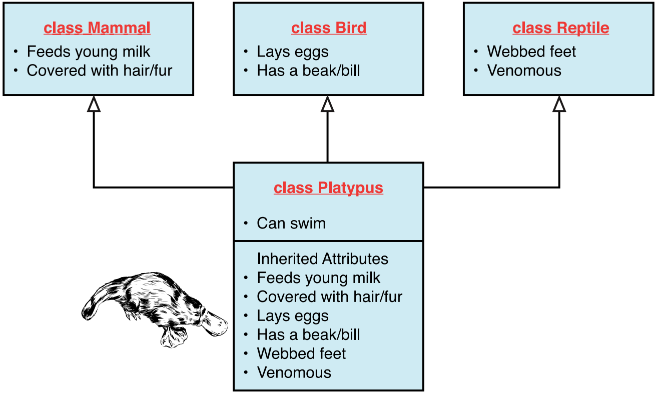
```
Derived& operator= (const Derived& CopySource)
{
    if(this != &copySource) { // do not copy itself
        // the base class copy
        Base::operator=(CopySource)
        // the derived class copy
    }
    return *this;
}
```

Multiple inheritance

Multiple inheritance

Concept 6

Multiple inheritance is when a derived class has two or more base classes.



class Mammal
- Feeds young milk
- Covered with hair/fur

class Bird
- Lays eggs
- Has a beak/bill

class Reptile
- Webbed feet
- Venomous

class Platypus
- Can swim

Inherited Attributes
- Feeds young milk
- Covered with hair/fur
- Lays eggs
- Has a beak/bill
- Webbed feet
- Venomous

Listing 3

```cpp
#include <iostream>
using namespace std;
class Mammal {
public:
   void FeedBabyMilk() {
      cout << "Mammal: Baby says glug!" << endl;
   }
};
class Reptile {
public:
   void SpitVenom() {
      cout << "Reptile: Shoo enemy! Spits venom!" << endl;
   }
};
class Bird {
public:
   void LayEggs() {
      cout << "Bird: Laid my eggs, am lighter now!" << endl;
   }
```

Listing 3 (cont.)

```
};
class Platypus: public Mammal, public Bird, public Reptile {
public:
   void Swim() {
      cout << "Platypus: Voila, I can swim!" << endl;
   }
};
int main() {
   Platypus realFreak;
   realFreak.LayEggs();
   realFreak.FeedBabyMilk();
   realFreak.SpitVenom();
   realFreak.Swim();
   return 0;
}
```

Aggregation

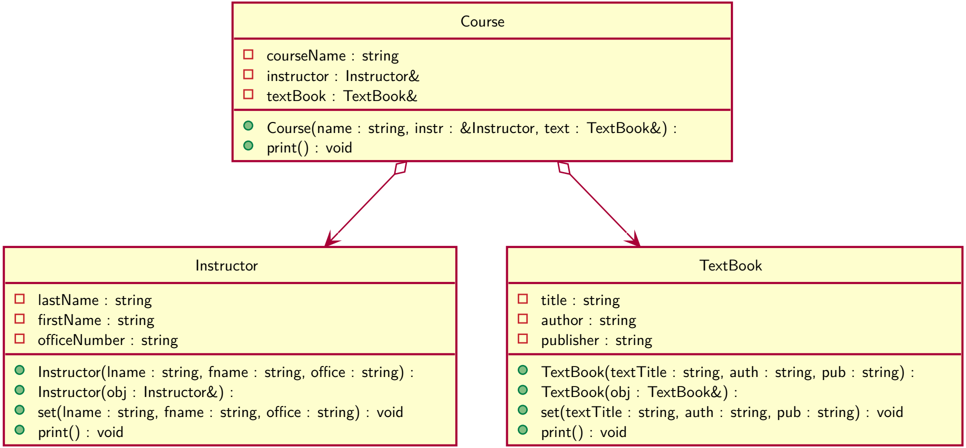
Aggregation

Concept 7

Aggregation occurs when a class contains an instance of another class.

- When an instance of one class is a member of another class, it is said that there is a “has a” relationship between the classes.
- For example, the relationships that exist among the `Course`, `Instructor`, and `TextBook` classes can be described as follows:
    - The course *has an* instructor.
    - The course *has a* textbook.

Aggregation



Course

□ courseName : string
□ instructor : Instructor&
□ textBook : TextBook&

● Course(name : string, instr : &Instructor, text : TextBook&) :
● print() : void

Instructor

□ lastName : string
□ firstName : string
□ officeNumber : string

● Instructor(lname : string, fname : string, office : string) :
● Instructor(obj : Instructor&) :
● set(lname : string, fname : string, office : string) : void
● print() : void

TextBook

□ title : string
□ author : string
□ publisher : string

● TextBook(textTitle : string, auth : string, pub : string) :
● TextBook(obj : TextBook&) :
● set(textTitle : string, auth : string, pub : string) : void
● print() : void

Examples of Aggregation Taken from Daily Life

Part	Whole
Motor	Car (Car has a Motor)
Heart	Mammal (Mammal has a Heart)
Refill	Pen (Pen has a Refill)
Moon	Sky (Sky has a Moon)

Workshop

Quiz

1. I want some base class members to be accessible to the derived class but not outside the class hierarchy. What access specifier do I use?

   . . . .

   . . . .

   . . . .

2. If I pass an object of the derived class as an argument to a function that takes a parameter of the base class by value, what happens?

   . . . .

   . . . .

   . . . .

Quiz (cont.)

3. Which one should I favor? Private inheritance or composition?

   . . . .

   . . . .

   . . . .

4. How does the `using` keyword help me in an inheritance hierarchy?

   . . . .

   . . . .

   . . . .

5. A `class Derived` inherits `private` from `class Base`. Another class `SubDerived` inherits `public` from `class Derived`. Can `SubDerived` access public members of `class Base`?

   . . . .

   . . . .

   . . . .

Exercises

- Programming Challenges of chapter 13 [Gaddis, 2014]
  1. **Employee and ProductionWorker Classes**
  2. **ShiftSupervisor Class**
  3. **TeamLeader Class**

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