Lecture 6

Inheritance

Topics

- Reusability
- Base class and derived class
- Function Overriding
- Access Control and Inheritance
- Public Inheritance
- Constructors and Destructors in Inheritance
- Assignment Operator and Inheritance
- Multiple Inheritance
- Virtual Base Classes

Reusability in Object-Oriented Programming

- Reusability is the process of taking an existing class, and using it in a new program.
- By reusing the classes, the time and effort needed to develop a program can be reduced.

- The simplest way to reuse a class is to use an object of that class directly.
  - Standard library of the C++ provides many built-in classes.
  - Example: The std::string class.

- The second way to reuse a class is to place an object of that class inside a new class.
  - The new class contains objects of existing classes.
  - It is referred to as composition (has-a).

Reusability in Object-Oriented Programming

The third way to reuse a class is inheritance.

- Inheritance is one of the ways in object-oriented programming that makes reusability possible.

- By the help of inheritance, programmer can write more special classes from general classes.

- Inheritance is referred to as (is-a) or (a-kind-of).

Example : Using built-in string class

- To use built-in C++ strings, the C++ header file **<string>** is included.
- Built-in overloaded operators such as +, +=, etc can be used with strings.

```
#include <string>              // String class header file is included
#include <iostream>
using namespace std;

int main()
{
   string  s1 = "ABC";          // Initialized by assignment
   string  s2 ("DEF");          // Initialized by constructor
   string  s3;                  // Empty string

   s3   =   s1  +  " , "  +  s2; // Combining strings (overloaded +)
   s3   +=   "XYZ";             // Appending a string (overloaded +=)

   cout << s3 << endl;          // Screen output :  ABC , DEFXYZ
}
```

Inheritance

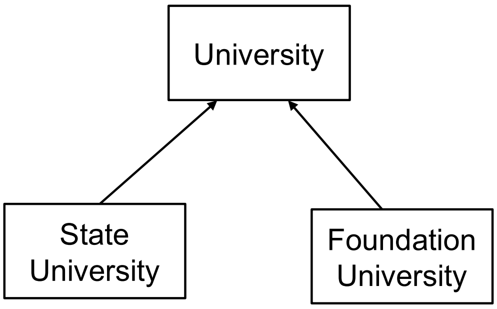
- OOP provides a way to modify a class without changing its code.
- It is achieved by using inheritance to derive a new class from the old one.
- The old class (**base class**) is not modified,
  but the new class (**derived class**) can use all the features
  of the old one, and additional features of its own.

Generalization and Specialization

- With inheritance, special classes can be written from general classes.
- Special classes (derived) may have more members (data and functions) than general classes (base).

- Example:

University	is base class	(general)
StateUniversity	is-a-kind of University	(special)
FoundationUniversity	is-a-kind of University	(special)



University

State University

Foundation University

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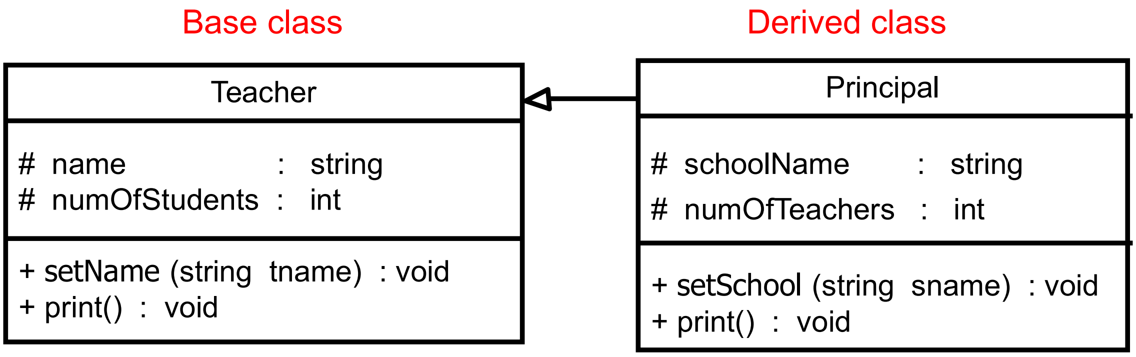
Example: Class Diagrams for Inheritance



Member access specifiers

is protected

+ is public

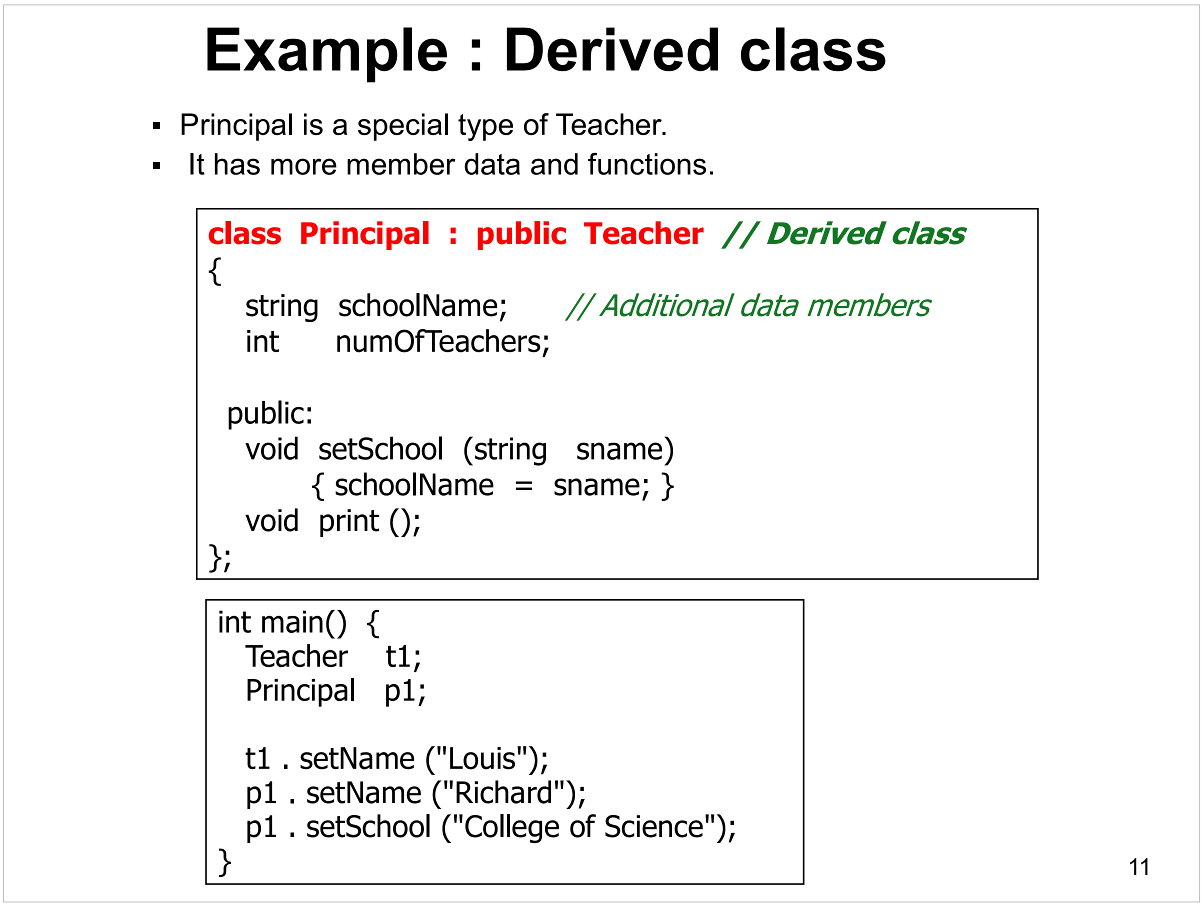
- is private

Example : Base class

- Defining the classes Teacher and Principal (director) in a school.
- First, the Teacher class should be defined as the base class.
- Then, the Principal class can be defined, which is derived from Teacher class.
- Protected members of base class will be public in derived class members.

```
class Teacher    // Base class
{
 protected:
   string  name;
   int       numOfStudents;

  public:
    void  setName (string  tname)
    {
         name = tname;
    }
    void  print ();
};
```



Example : Derived class

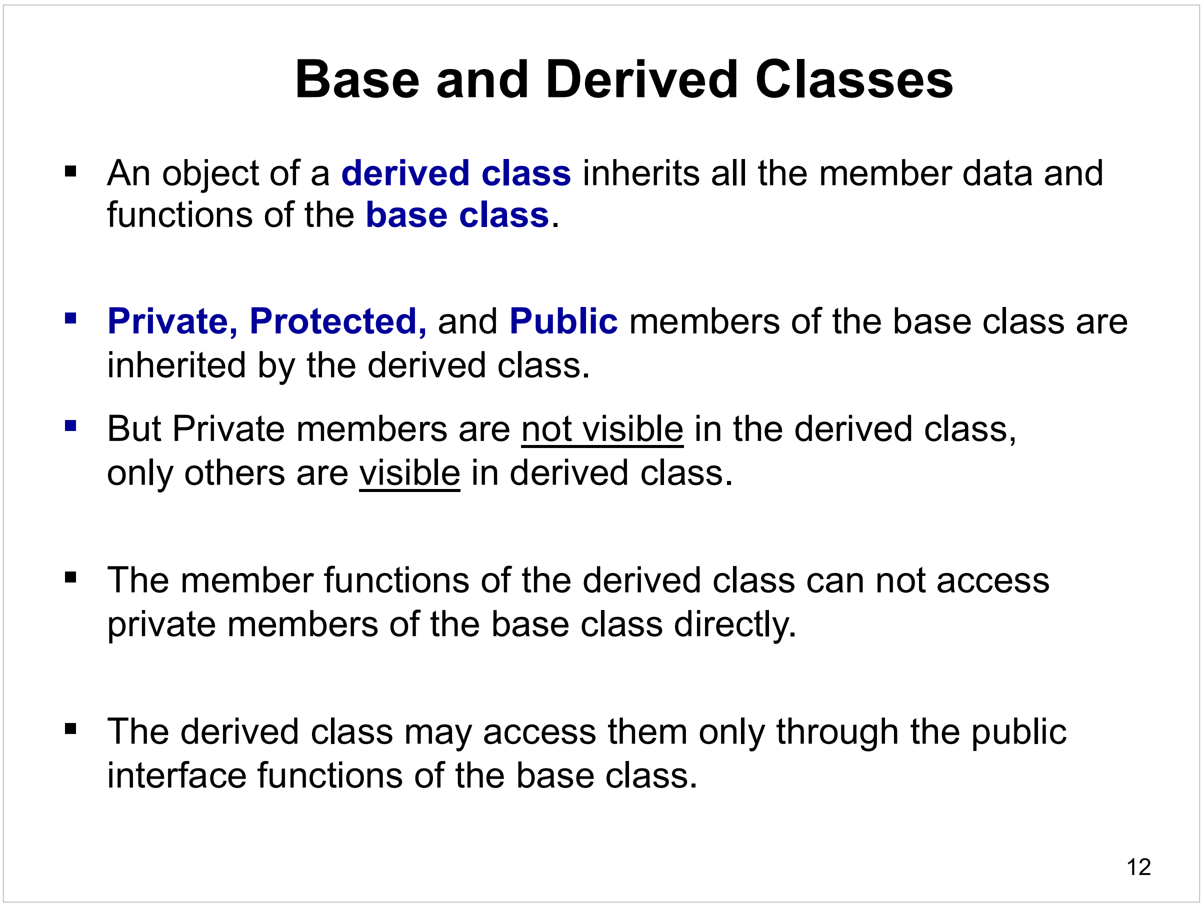
- Principal is a special type of Teacher.
- It has more member data and functions.

```
class  Principal  :  public  Teacher   // Derived class
{
   string  schoolName;      // Additional data members
   int      numOfTeachers;

 public:
   void  setSchool  (string   sname)
         { schoolName  =  sname; }
   void  print ();
};
```

```
int main()  {
   Teacher    t1;
   Principal   p1;

   t1 . setName ("Louis");
   p1 . setName ("Richard");
   p1 . setSchool ("College of Science");
}
```



Base and Derived Classes

- An object of a **derived class** inherits all the member data and functions of the **base class**.
- **Private, Protected,** and **Public** members of the base class are inherited by the derived class.
- But Private members are not visible in the derived class, only others are visible in derived class.
- The member functions of the derived class can not access private members of the base class directly.
- The derived class may access them only through the public interface functions of the base class.

Redefining the Members (Overriding)

- Sometimes member data and functions should be redefined in the derived class.
- Example : The print function must be redefined in Principal class, because principals have more properties to print.

```
class Teacher     // Base class
{
 protected:
   string  name;
   int      numOfStudents;

 public:
   void  setName (string  tname) { name = tname; }
   void  print ();
};
```

```
void  Teacher :: print ()   // Print function of Teacher class
{
   cout << "Name: " << name << endl;
   cout << "Number of Students: " << numOfStudents << endl;
}
```

- The print() function of the derived Principal class **overrides** (hides) the print() function of the base Teacher class.
- The Principal class has actually two print() functions. (Inherited print function and also its own print function.)

```
class Principal : public Teacher    // Derived class
{
     string  schoolName;
     int      numOfTeachers;

   public:
     void setSchool (string  sname) { schoolName = sname; }
     void print() ;    // Print function of Principal class (Overridden)
};
```

```
void  Principal :: print()   // Print function of Principal class (Overridden)
{
   cout << "Name: " << name << endl;
   cout << "Number of Students: " << numOfStudents << endl;
   cout << "Name of the school: " <<  schoolName << endl;
}
```

Alternative method :

(Calling the print function of base class Teacher)

- Members (data and function) of the base class can be accessed by using the scope operator (::) .
- The print function of base class can be called, from the print function of derived class.

```
void  Principal :: print()    // Print function of Principal class (Overridden)
{
   Teacher :: print();    // Calls print function of Teacher class (base)

   cout << "Name of the school: " << schoolName << endl;
}
```

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Overriding the member functions

- If the programmer of the **derived class** redefines a member function, it means he changes the interface of the **base class**.
- In this case the member function of the base class is hidden (**overridden**).
- The hidden members in base class are still accessible through the scope **::** operator.
- The derived class will have **two member functions** with the same name.

Example: Overriding of member data and functions

```
class A
{
 public:
   int    i1;
   int    i2;
   void  f1 ();
   int    f2 (int);
};
```

```
class B: public A
{
 public:
   float  i1;            // overrides  i1
   float  f1 (float);  // overrides  f1
};
```

```
int main() {
  B   b;
  int   j     =   b . f2 (10);         // A :: f2
  b . i1     =   40;                   // B :: i1
  b . i2     =   30;                   // A :: i2, because i2 is public in A
  float   y  =   b . f1 (3.14);      // B :: f1
  b . f1 ();          // Compiler error  f1(float) in B hides the f1(void) of A
  b . A :: f1 ();                      // OK, because f1(void) is public in A
  b . A :: i1  =  20;                  // OK, because i1 is public in A
}
```

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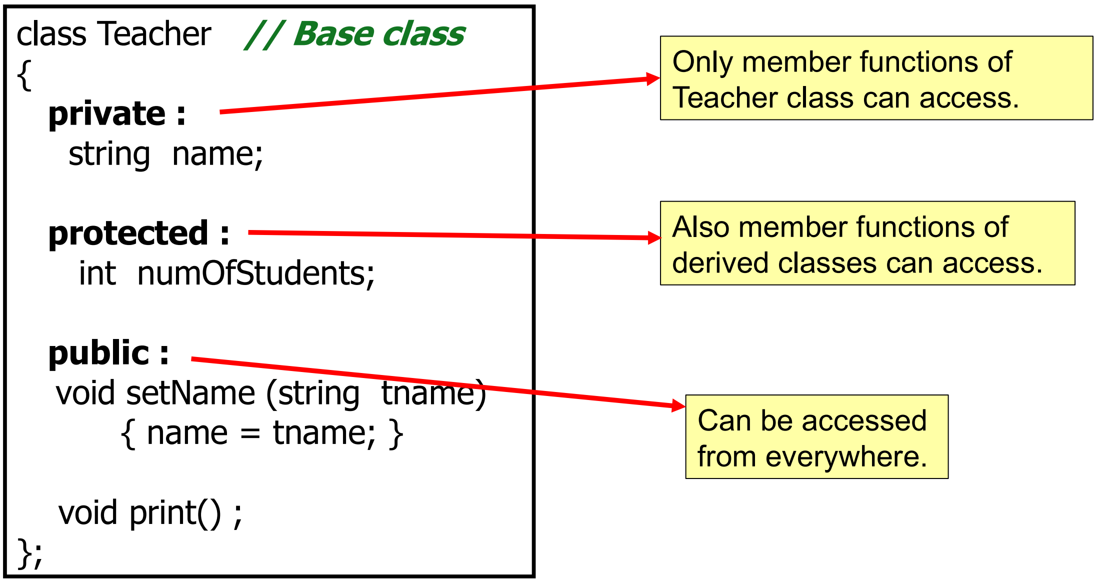
Access Control and Inheritance

- When inheritance is not involved, class member functions have access to anything in the class, whether public or private. But objects of that class have access only to public members.
- Member functions of a derived class can access **public** and **protected** members of base class, but not **private** members.
- Objects of a derived class can access only public members of base class.

Access specifier	Accessible from own class	Accessible from derived class	Accessible from other objects or from main
public	Yes	Yes	Yes
protected	Yes	Yes	No
private	Yes	No	No

Example : Access Specifiers



```
class Teacher   // Base class
{
   private :
     string  name;

   protected :
      int  numOfStudents;

   public :
    void setName (string  tname)
          { name = tname; }

     void print() ;
};
```

Only member functions of Teacher class can access.

Also member functions of derived classes can access.

Can be accessed from everywhere.

```
class  Principal   :   public  Teacher  // Derived class
{
   private:                            // Default access specifier
     string  schoolName;
     int      numOfTeachers;

   public:
     void  setSchool (string  sname)  { schoolName = sname; }
     void  print();
     int  getNumOfStudents()  { return numOfStudents; }   // Protected
     string  get_name() { return name;}  //Error (name is private)
};
```

```
int main()  {
    Teacher    T1;
    Principal    P1;
    T1 . numOfStudents  =  100;
    //Error  (numOfStudents  is  protected)

    T1 . setName ("John");
    P1 . setSchool ("College of Science");
}
```

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Public Inheritance

- The access specifier of derivation is usually written as public.
- In **public inheritance**, the objects of derived class can access public members of base class.
- Public members of base class are also public members of derived class.

```
class Base { ...... };
```

```
class Derived : public Base { ...... };
```

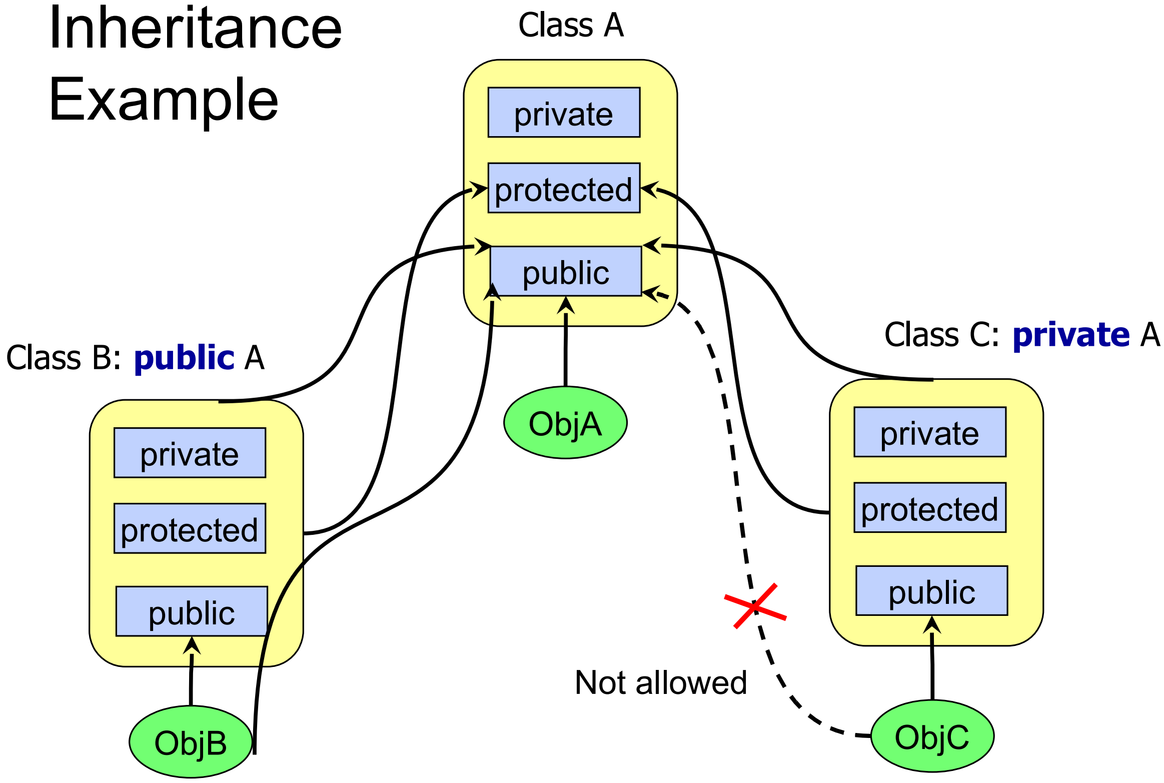
Private Inheritance

- In **private inheritance**, the public members of base class are private members of derived class.
- Objects of derived class can not access any members of base class.
- Member functions of derived class can still access public and protected members of base class.

```
class Base { …… };
```

```
class Derived : private Base { …… };
```

Inheritance Example



Special Member Functions and Inheritance

- Some special functions will need to do different things in the base class and in the derived class.
- **Overloaded assignment operator:**
  The = operator in the derived class must assign values to derived class data, and the = operator in the base class must assign values to base class data.
- **Constructors** :
  Because the derived class and base class constructors initialize different data, one constructor cannot be used in place of another.

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Constructors and Inheritance

- When an object of a derived class is defined, the base class constructor will be automatically invoked (called) before the derived class constructor.

```
class Teacher    //Base class
{
    string  name;
    int      numOfStudents;
  public:

    // Constructor of base class
    Teacher (string  tname)  :  name (tname) { }
};
```

```
class  Principal :  public  Teacher  // Derived class
{
    int  numOfTeachers;
  public:
    // Constructor of derived class
    Principal (string , int );
};
```

Correct method to invoke base class constructor:

- If the base class has a constructor, which must take some arguments, then the derived class must also have a constructor that calls the constructor of the base with proper arguments.
- The definition below uses an initializer list to invoke the base class constructor.

```
// Constructor of derived class
Principal :: Principal  (string  tname,  int numOT)  :  Teacher (tname)
{
     numOfTeachers  =  numOT;
}
```

Base class constructor

Wrong method to invoke base class constructor:

- The following definition gives a compiler error.
- Because the base class constructor can not be called directly like a function call.

```
Principal : : Principal  (string  tname,  int  numOT)
{
    numOfTeachers  =  numOT;
    Teacher (tname) ;   // Compiler error.
                        // Base class constructor
                        // can not be called directly.
}
```

Destructors and Inheritance

- When an object of derived class goes out of scope, the destructors are called in reverse order.
- The derived object is automatically destroyed first, then the base class object is destroyed.

```
class  B     // Base class
{
  public:
    B()    { cout << "Base constructor called \n";  }
   ~B()    { cout << "Base destructor called \n";   }
};
```

```
class  D  :  public  B    // Derived class
{
  public:
    D()    { cout << "Derived constructor  called \n";  }
    ~D()  { cout << "Derived destructor called \n";     }
};
```

```
int  main ()
{
   cout << "Program started \n";

   D  x ;     // Object of derived class

   cout << " Program ended \n";
}
```

Screen output

```
Program started
Base constructor called
Derived constructor called

Program ended
Derived destructor called
Base destructor called
```

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Overloaded Assignment Operator and Inheritance

In inheritance, assignment operator of derived class should be different than assignment operator of base class.

```
class  String   //Base class
{
  protected:
     int  size;
     char  *contents;
  public:
     const  String  &  operator=  (const  String &);
     // Overloaded assignment operator
};
```

```
const  String  &   String :: operator=  (const  String &   in_object)
{
    delete [ ]  contents;         // Delete old contents
    size  =  in_object.size;
    contents  =  new char[size+1];
    strcpy (contents,  in_object . contents);
    return  *this;
}
```

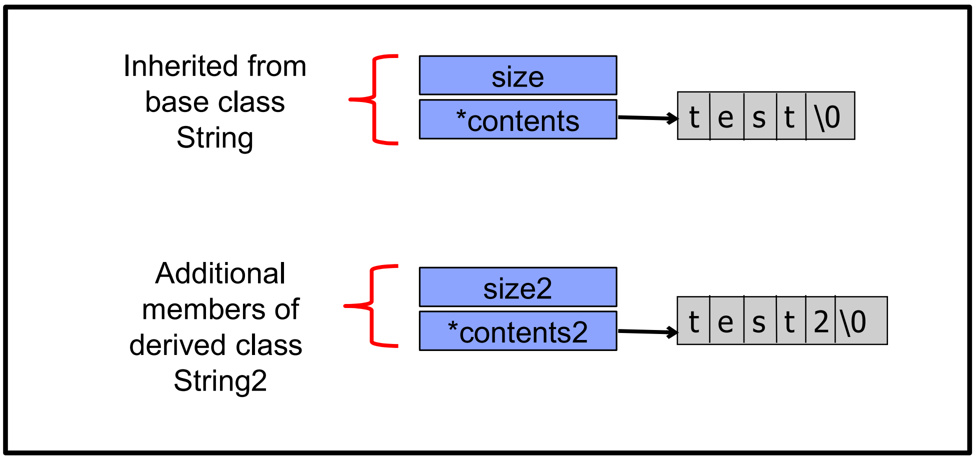
- String2 class is derived from String class.
- It has two contents.
- First is inherited from base class, second is declared as an extra.

```
class  String2  :  public  String   // Derived class
{
  int  size2;
  char  *contents2;
                                contents          contents2
  public:
  String2 ();                                          // Default constructor
  String2 (const  char * , const char *);   // Parametered constructor
  String2 (const  String2  &);                   // Copy constructor

  const  String2 &   operator=  (const  String2  &);
   // Overloaded assignment operator

  void  print()  const;
  ~String2 ();
};
```

Members of derived class String2


Inherited from base class String
size
*contents
t e s t \0
Additional members of derived class String2
size2
*contents2
t e s t 2 \0

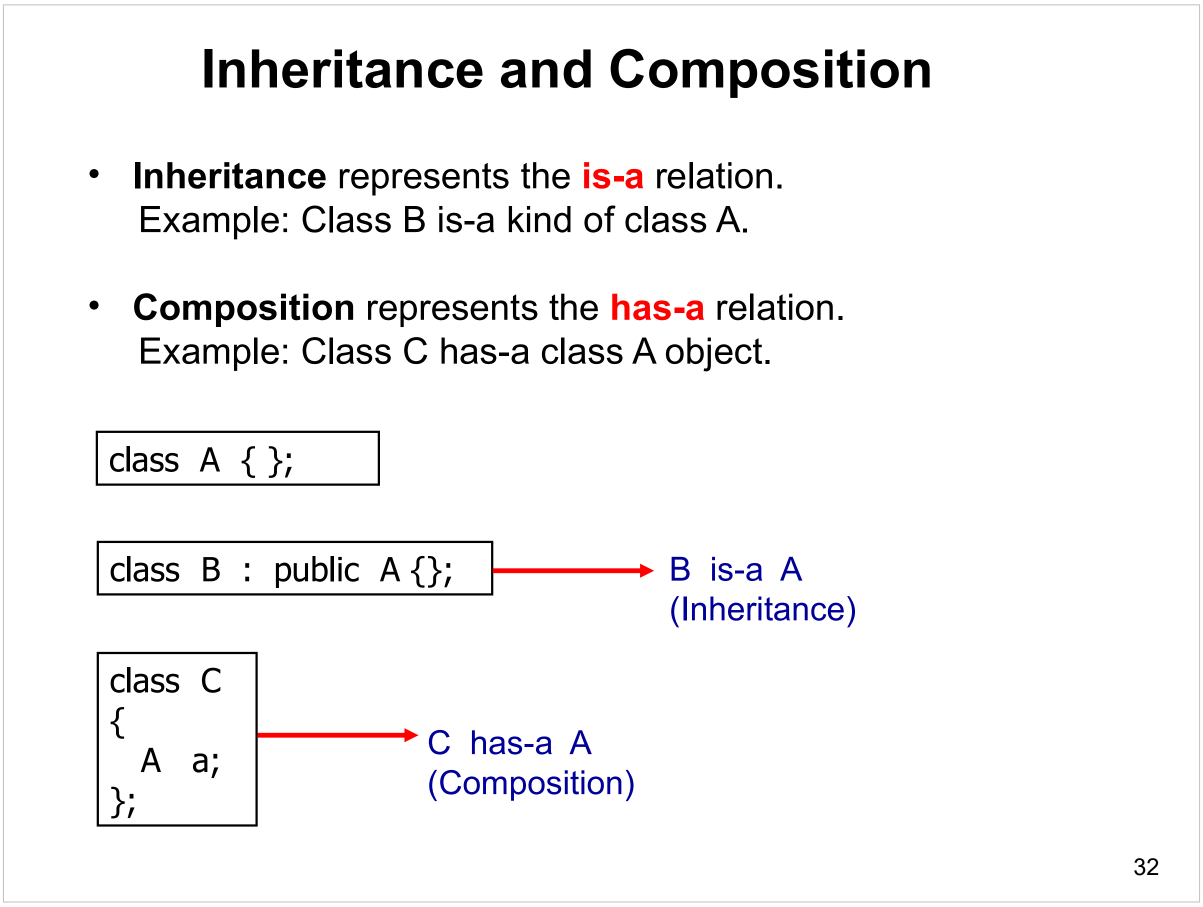
Overloaded assignment operator of String2 class

- Data members of String class (base) must be protected.
- Otherwise functions of String2 class (derived) can not access them.

```
const  String2 &    String2 :: operator=   (const  String2   &in_object)
{
    // Copy the inherited data members (base class)
    size = in_object.size;
    delete [ ] contents;
    contents = new  char[size + 1];
    strcpy (contents,  in_object.contents);

    // Copy the additional data members (derived class)
    size2  =  in_object . size2;
    delete [ ]  contents2;
    contents2  =  new  char[size2 + 1];
    strcpy (contents2,  in_object . contents2);

    return  *this;
}
```



Inheritance and Composition

- **Inheritance** represents the **is-a** relation.
  Example: Class B is-a kind of class A.

- **Composition** represents the **has-a** relation.
  Example: Class C has-a class A object.

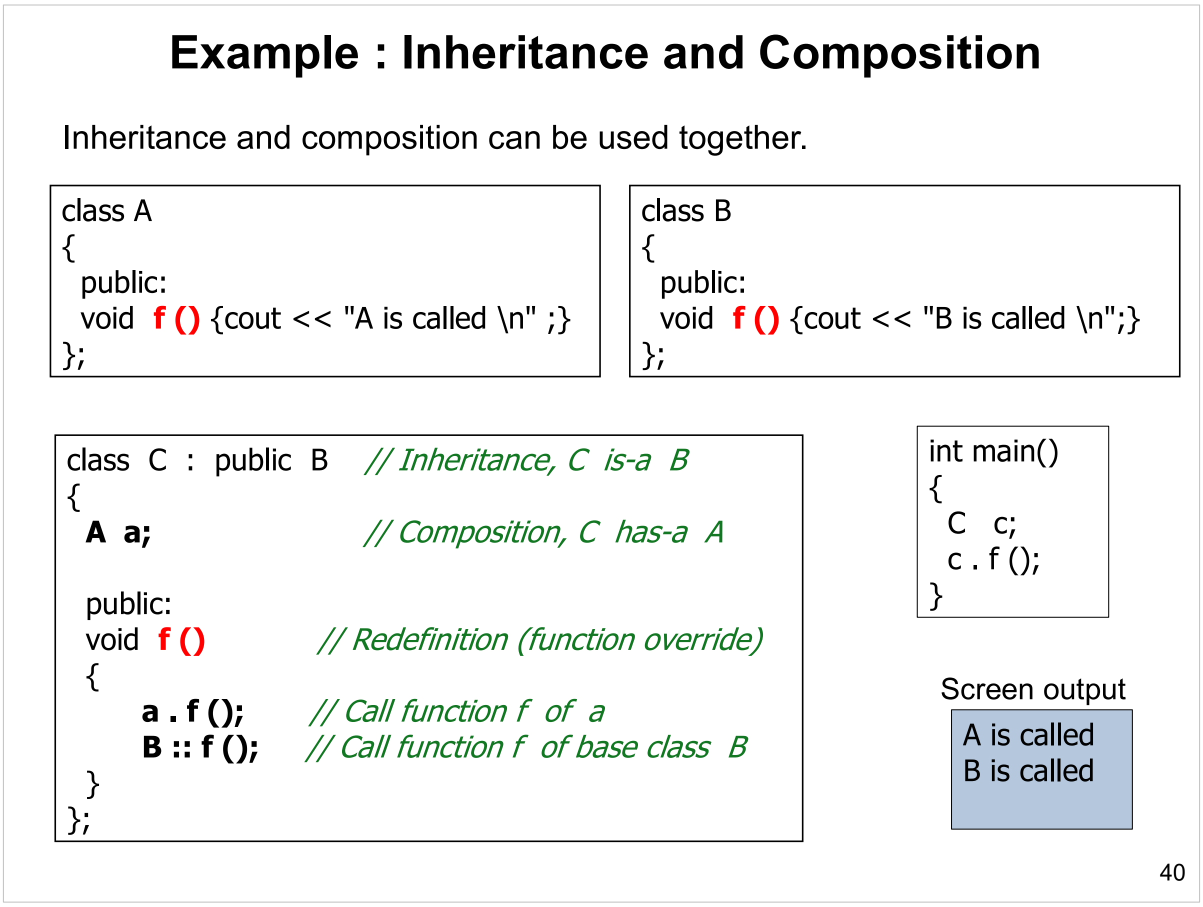
```
class  A  { };
```

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

B is-a A
(Inheritance)

```
class  C
{
   A   a;
};
```

C has-a A
(Composition)



Example : Inheritance and Composition

Inheritance and composition can be used together.

```
class A
{
  public:
  void  f () {cout << "A is called \n" ;}
};
```

```
class B
{
  public:
  void  f () {cout << "B is called \n";}
};
```

```
class  C  :  public  B    // Inheritance, C  is-a  B
{
  A  a;                   // Composition, C  has-a  A

  public:
  void  f ()              // Redefinition (function override)
  {
       a . f ();          // Call function f  of  a
       B :: f ();         // Call function f  of base class  B
  }
};
```

```
int main()
{
  C   c;
  c . f ();
}
```

Screen output

```
A is called
B is called
```

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Multiple Inheritance

Multiple inheritance occurs when a class inherits from two or more base classes.

```
class  Base1
{
   public:
   void    f1 ()
   char*  f2 (int);
};
```

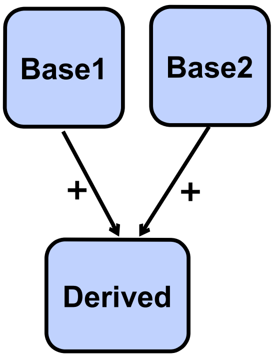
```
class  Derived  :  public  Base1 ,  public  Base2
{
    public:
    float  f1 (float);   // override Base1
    void  f4 ();         // override Base2
    int    f5 (int);
};
```

```
class  Base2
{
   public:
   char*  f2 (int, char);
   int      f3 ();
   void    f4 ();
};
```

```
int main()
{
  Derived  d;
  float  y  =  d . f1 (0.8);   // Derived :: f1
  d . f3 ();                   // Base2 :: f3
  d . f4 ();                   // Derived :: f4
  d . Base2 :: f4 ();          // Base2 :: f4
}
```

The Derived class contains the following 8 member functions.

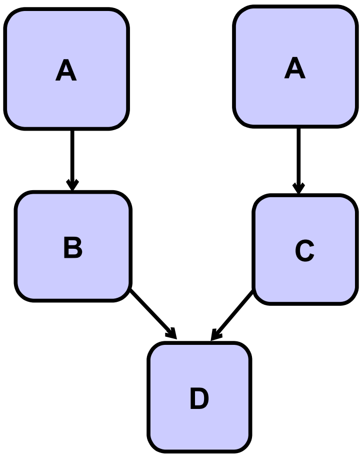
```
Base1 :: f1

Base1 :: f2
----------------
Base2 :: f2

Base2 :: f3

Base2 :: f4
----------------
Derived :: f1

Derived :: f4

Derived :: f5
```



Repeated Base Classes

- In example below, D object will contain two A subobjects, one inherited via B and one inherited via C.
- It is a repeated (duplicated) inheritance.
- There are two subobjects when really there should be only one.

```
class A   {   };

class B : public A    {   };

class C : public A    {   };

class D : public B, public C    {   };
```



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Virtual Base Classes

- To fix repeated inheritance, the **virtual** keyword can be used, when deriving B and C from A.
- The **virtual** keyword tells the compiler to inherit only one A subobject from base class A.

```
class A    {   };

class B : virtual public A   {   };

class C : virtual public A   {   };

class D : public B, public C   {   };
```