Inheritance

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1.1-1.2

Object Oriented Design Components

Encapsulation

- Combine data and operations on that data into a single unit and only expose a desired public interface and prevent modification/alteration of the implementation

Inheritance

- Creating new objects (classes) from existing ones to specify functional relationships and extend behavior

Polymorphism

- Using the same expression to support different types with different behavior for each type

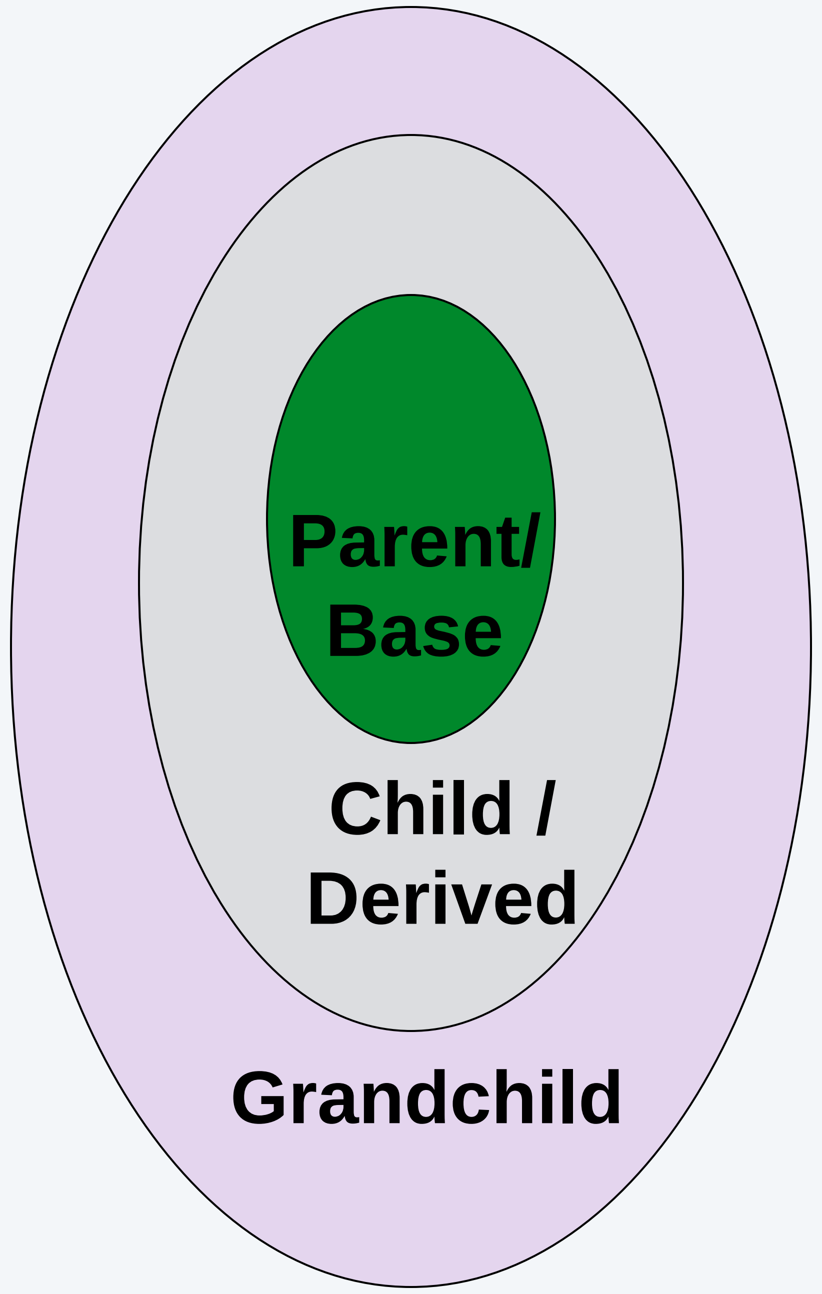
Inheritance

A way of defining interfaces, reusing capabilities and extending capabilities

Allows a new class to inherit all the data members and member functions from a previously defined class

Works from more general objects to more specific objects

- Public inheritance defines an "is-a" relationship
- Square is-a rectangle is-a shape
- Square inherits from Rectangle which inherits from Shape

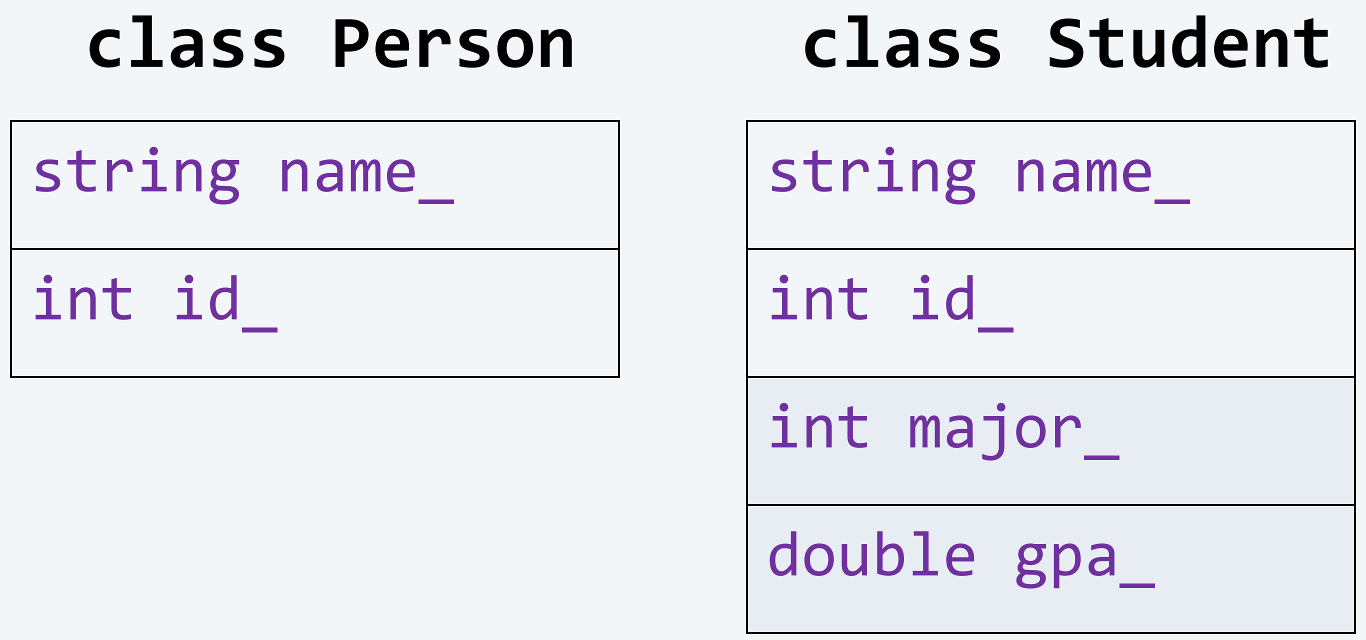


Base and Derived Classes

Derived classes inherit all data members and functions of base class

Student class inherits:

- get_name() and get_id()
- name_ and id_ member variables



class Person

string name_

int id_

class Student

string name_

int id_

int major_

double gpa_

```
class Person {
 public:
  Person(string n, int ident);
  string get_name();
  int get_id();
 private:
  string name_; int id_;
};
class Student : public Person {
 public:
  Student(string n, int ident, int mjr);
  int get_major();
  double get_gpa();
  void set_gpa(double new_gpa);
 private:
  int major_; double gpa_;
};

int main()
{
  Student s1("Tommy", 1, 9);
  // Student has Person functionality
  // as if it was written as part of
  // Student
  cout << s1.get_name() << endl;

}
```

MEMBER FUNCTIONS AND INHERITANCE

Constructors and Inheritance

How do we initialize base class data members?

```
class Person {
 public:
  Person(string n, int ident);
  ...
 private:
  string name_;
  int id_;
};
class Student : public Person {
 public:
  Student(string n, int ident, int mjr);
  ...
 private:
  int major_;
  double gpa_;
};

Student::Student(string n, int ident, int mjr)
{
   name_ = n;

   id_ = ident;
   major_ = mjr;
}
```

Constructors and Inheritance

Constructors are only called when a variable is created and cannot be called directly from another constructor

To initialize base class private data members or other members:

Use constructor initialization list format instead

```
class Person {
 public:
  Person(string n, int ident);
  ...
 private:
  string name_;
  int id_;
};
class Student : public Person {
 public:
  Student(string n, int ident, int mjr);
  ...
 private:
  int major_;
  double gpa_;
};
```

```
Student::Student(string n, int ident, int mjr) :
   Person(n, ident)
{
  cout << "Constructing student: " << name_ << endl;
  major_ = mjr;   gpa_ = 0.0;
}
```

Constructors

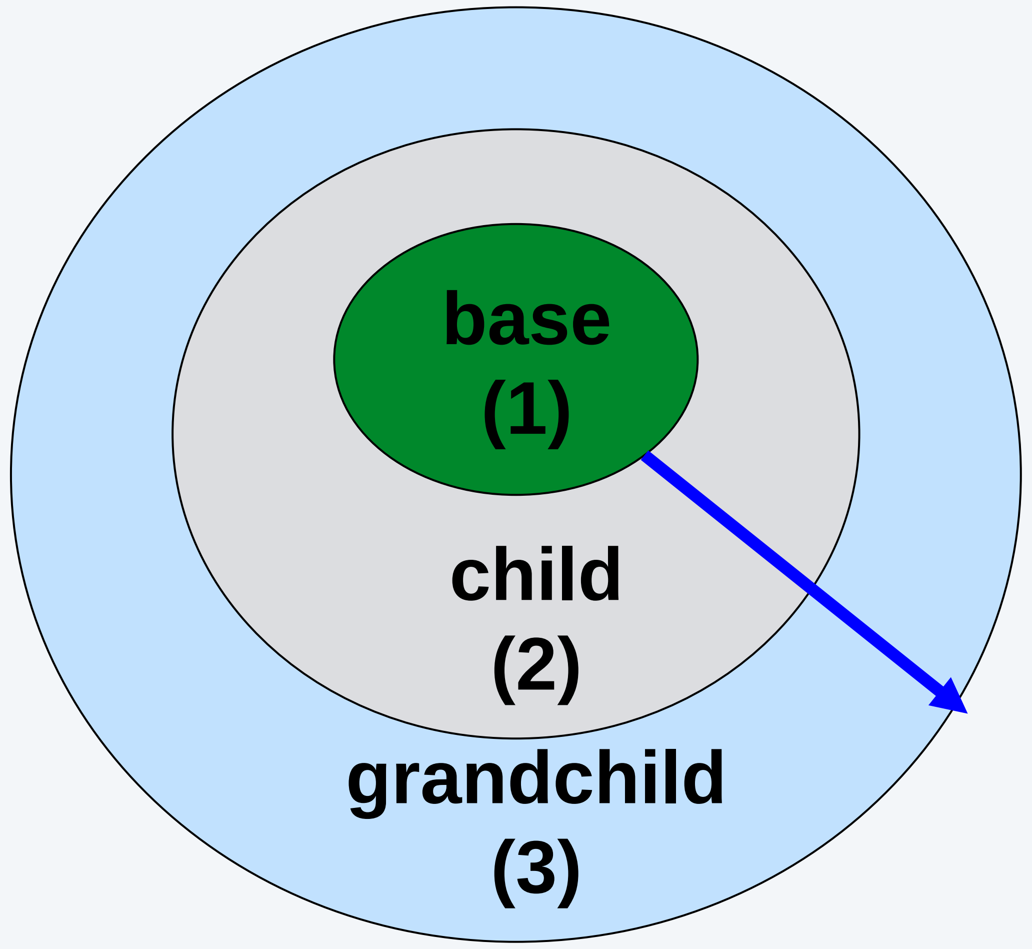
Constructors

- A Derived class will automatically call its Base class constructor **BEFORE** its own constructor executes, either:

Explicitly calling a specified base class constructor in the initialization list

Implicitly calling the default base class constructor if no base class constructor is called in the initialization list

- **Constructors get called from base->derived**

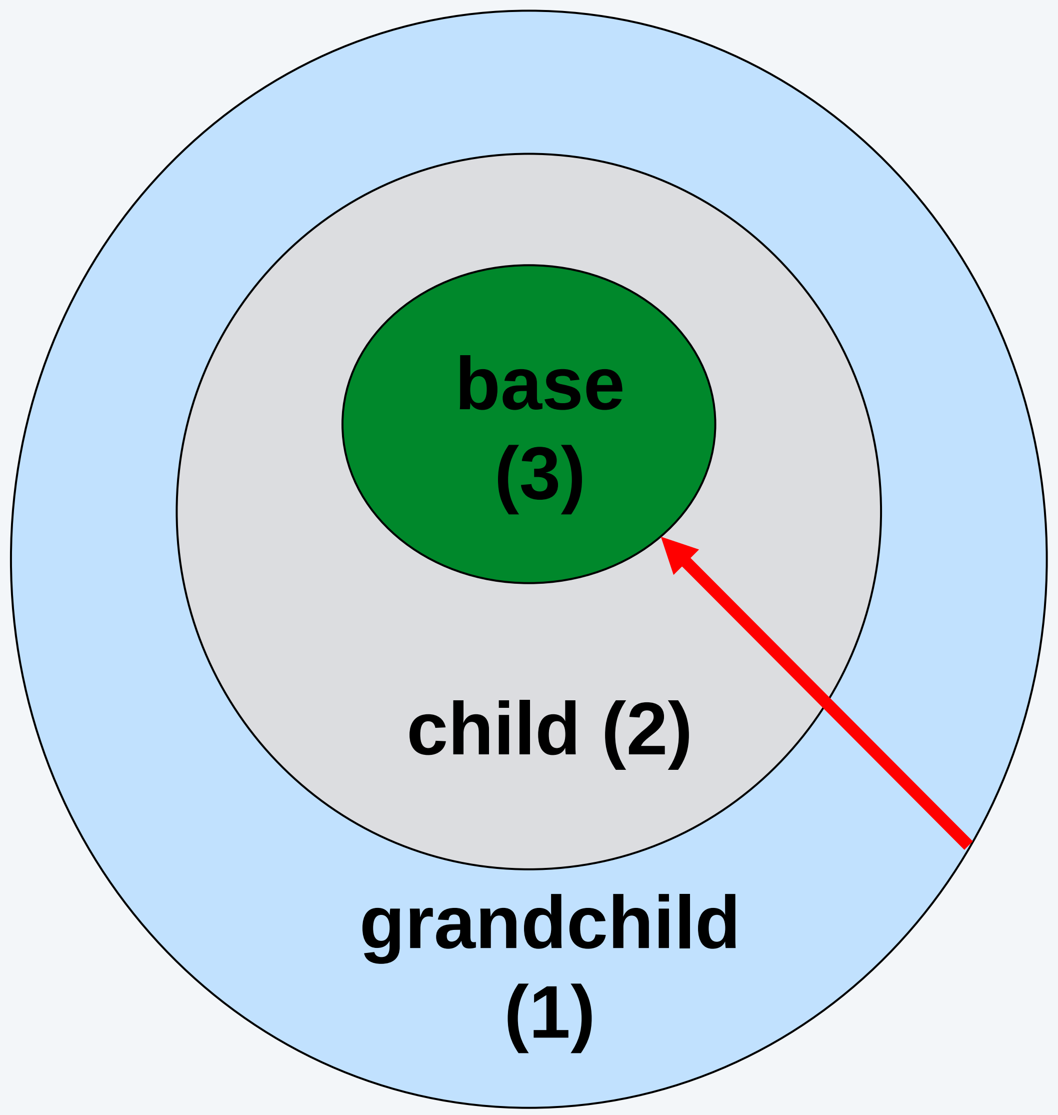


Constructor call ordering

Destructors

Destructors

- The derived class will call the Base class destructor automatically **AFTER** its own destructor executes
- **Destructors get called from derived->base**



Destructor call ordering

Constructor & Destructor Ordering

```
class A {
  int a;
public:
  A()  { a=0; cout << "A:" << a << endl; }
  ~A() { cout << "~A" << endl; }
  A(int mya) { a = mya;
               cout << "A:" << a << endl; }
};

class B : public A {
  int b;
public:
  B()  { b = 0; cout << "B:" << b << endl; }
  ~B() { cout << "~B "; }
  B(int myb) { b = myb;
               cout << "B:" << b << endl; }
};

class C : public B {
  int c;
public:
  C()  { c = 0; cout << "C:" << c << endl; }
  ~C() { cout << "~C "; }
  C(int myb, int myc) : B(myb) {
     c = myc;
     cout << "C:" << c << endl; }
};
```

Sample Classes

```
int main()
{
  cout << "Allocating a B object" << endl;
  B b1;
  cout << "Allocating 1st C object" << endl;
  C* c1 = new C;
  cout << "Allocating 2nd C object" << endl;
  C c2(4,5);
  cout << "Deleting c1 object" << endl;
  delete c1;
  cout << "Quitting" << endl;
  return 0;
}
```

Test Program

```
Allocating a B object
A:0
B:0
Allocating 1st C object
A:0
B:0
C:0
Allocating 2nd C object
A:0
B:4
C:5
Deleting c1 object
~C ~B ~A
Quitting
~C ~B ~A
~B ~A
```

Output

Overloading Base Functions

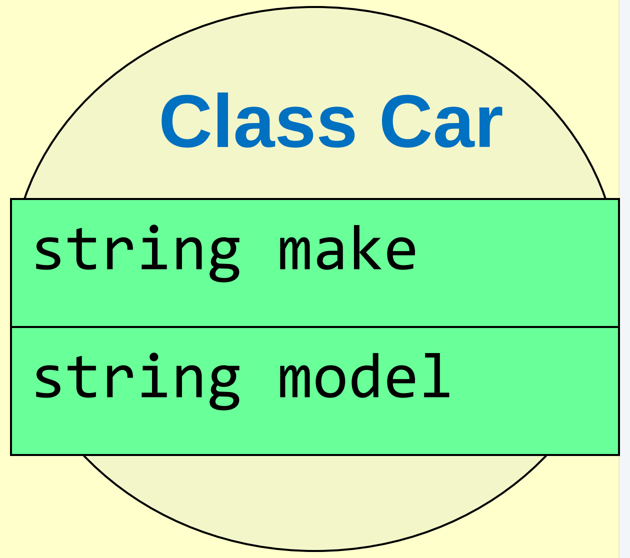
A derived class may overload a based member function

When derived objects call that function the derived version will be executed

When a base objects call that function the base version will be executed

```
class Car{
 public:
  double compute_mpg();
 private:
  string make; string model;
};

double Car::compute_mpg()
{
  if(speed > 55) return 30.0;
  else return 20.0;
}
```



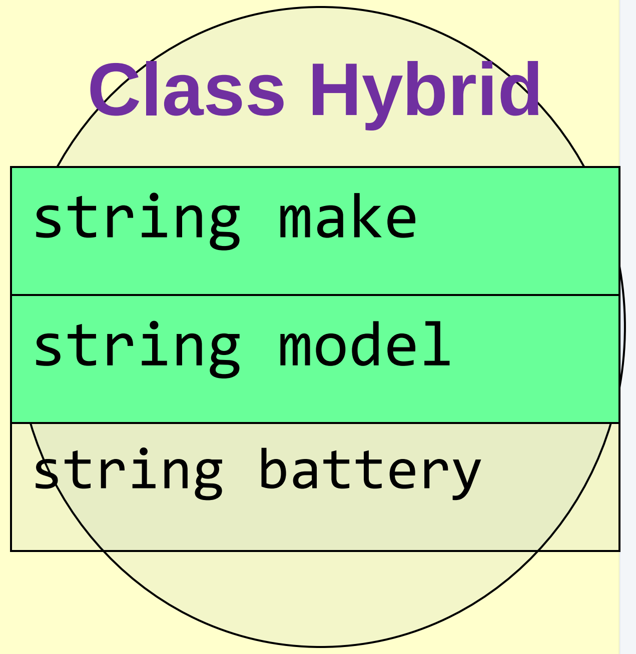
Class Car

string make

string model

```
class Hybrid : public Car {
 public:
  void drive_w_battery();
  double compute_mpg();
 private:
  string batteryType;
};

double Hybrid::compute_mpg()
{
  if(speed <= 15) return 45; // hybrid mode
  else if(speed > 55) return 30.0;
  else return 20.0;
}
```



Class Hybrid

string make

string model

string battery

Scoping Base Functions

We can still call the base function version by using the scope operator (::)

- base_class_name::function_name()

```
class Car{
 public:
  double compute_mpg();
 private:
  string make; string model;
};

double Car::compute_mpg()
{
  if(speed > 55) return 30.0;
  else return 20.0;
}


class Hybrid : public Car {
 public:
  void drive_w_battery();
  double compute_mpg();
 private:
  string batteryType;
};

double Hybrid::compute_mpg()
{
  if(speed <= 15) return 45; // hybrid mode
  else return Car::compute_mpg();
}
```

ACCESS: PUBLIC, PRIVATE, PROTECTED

Private and Protected Members

Private members of a base class can not be accessed directly by a derived class member function

Base class can declare variables with protected storage class which means:

- Private to any object or code not inheriting from the base
- Accessible to any derived class

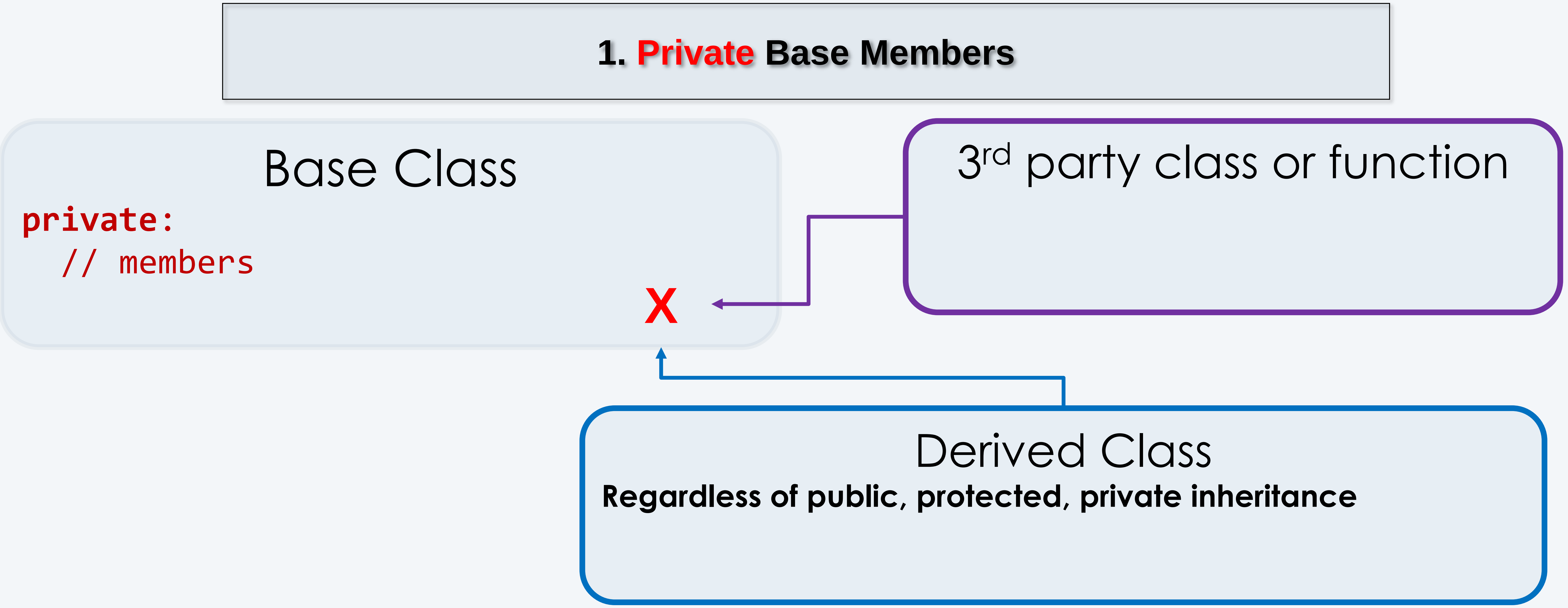
```
class Person {
 public:
  ...
 private:
  string name; int id;
};
class Student : public Person {
 public:
   void print_grade_report();
 private:
   int major; double gpa;
};
```

```
void Student::print_grade_report()
{
  cout << “Student “ << name << ...          X
}
```

```
class Person {
 public:
  ...
 protected:
  string name; int id;
};
```

Private Access

Derived class can access base class members using the base class' specification



1. **Private Base Members**

Base Class

```
private:
  // members
```

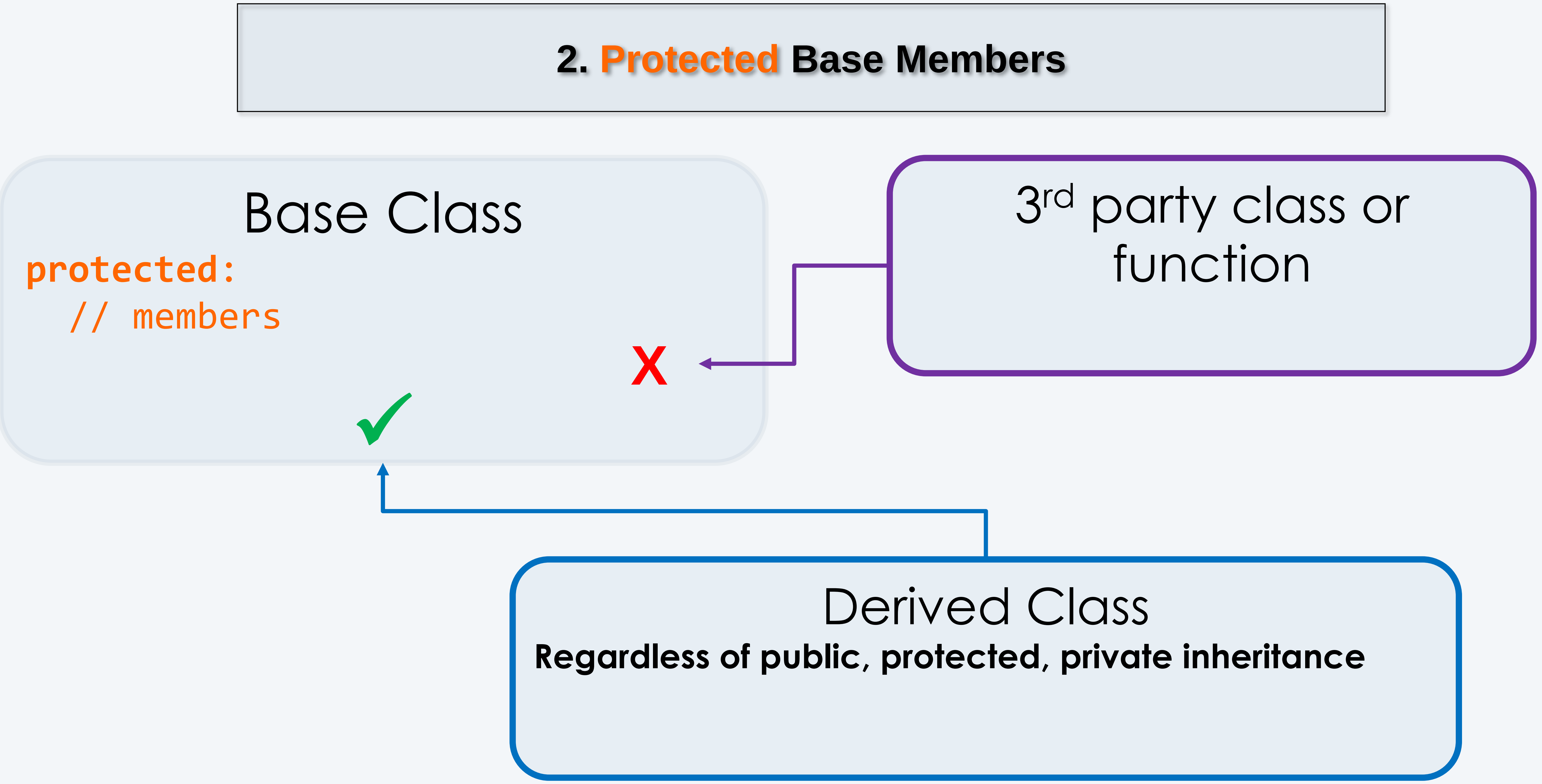
3rd party class or function

Derived Class

Regardless of public, protected, private inheritance

Protected Access

Derived class access base class members using the base class' specification



2. Protected Base Members

Base Class

```
protected:
  // members
```

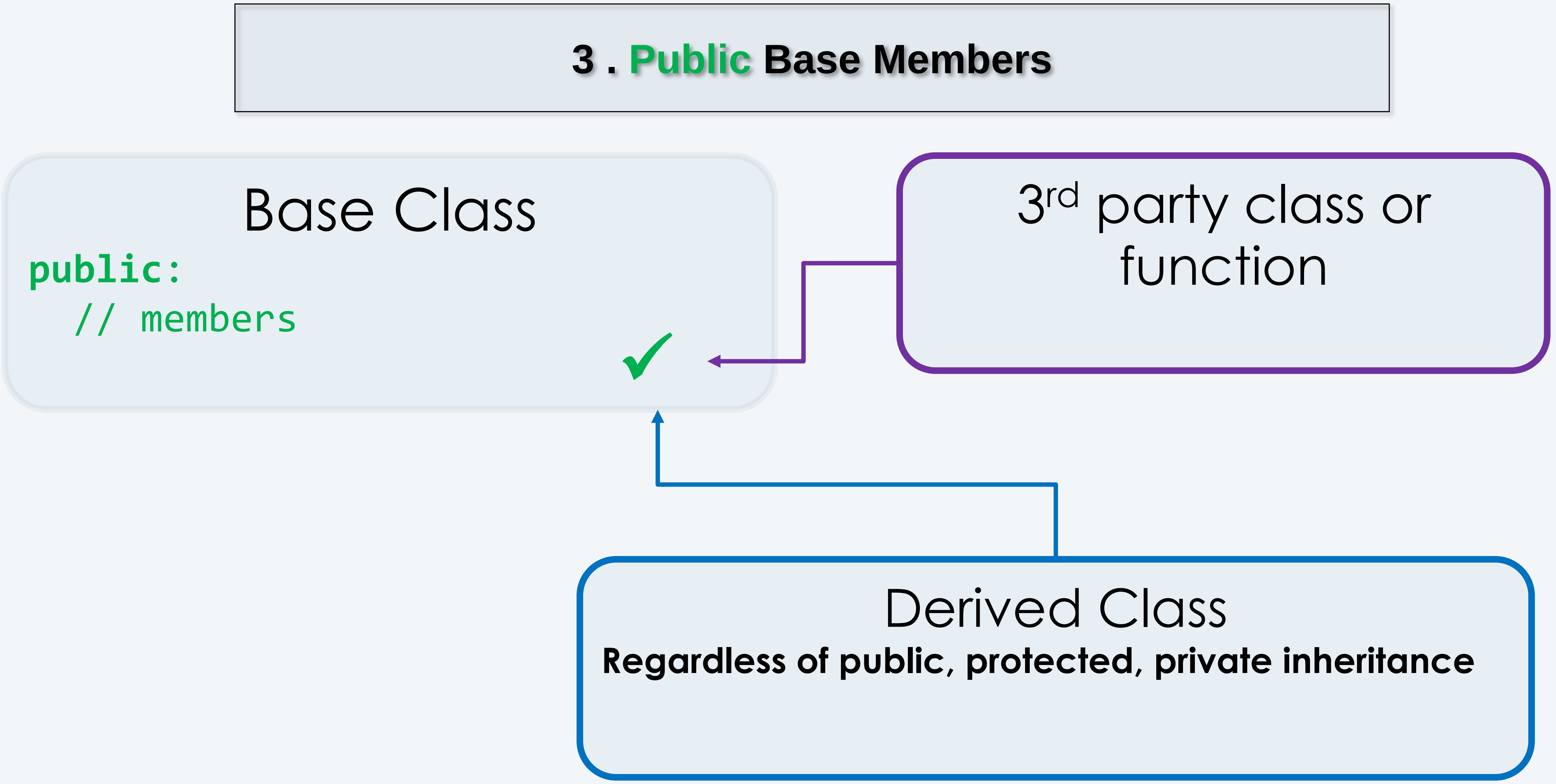
3rd party class or function

Derived Class

Regardless of public, protected, private inheritance

Public Access

Derived class access base class members using the base class' specification



3 . Public Base Members

```
public:
  // members
```

Regardless of public, protected, private inheritance

INHERITANCE: PUBLIC, PRIVATE, PROTECTED

Public Inheritance

Public inheritance before base class indicates how the public base class members are accessed by clients and derived classes

For **public inheritance:**

- public and protected base class members are accessible to the child class and grandchild classes
- Only public base class members are accessible to 3rd party clients

```
class Person {                          Base Class
 public:
  Person(string n, int ident);
  string get_name();
  int get_id();
 private: // INACCESSIBLE TO DERIVED
  string name_; int id_;
};
```

```
class Student : public Person {
 public:
  Student(string n, int ident, int mjr);
  int get_major();
  double get_gpa();
  void set_gpa(double new_gpa);
 private:
  int major_; double gpa_;
};
```

```
int main(){
  Student s1("Tommy", 73412, 1);

  cout << s1.get_name() << endl; // works

}
```

Private Inheritance

Private inheritance before base class indicates how the public base class members are accessed by clients and derived classes

For **private inheritance:**

- public and protected base class members are accessible to the child class
- No base class members are accessible to grandchild classes or 3rd party clients

Base Class

```
class Person {
 public:
  Person(string n, int ident);
  string get_name();
  int get_id();
 private: // INACCESSIBLE TO DERIVED
  string name; int id;
};
```

```
class Faculty : private Person {
 public:
  Faculty(string n, int ident, bool tnr);
  bool get_tenure();
  void print_name() {
        cout << get_name() << endl;
    }
 private:
  bool tenure;
};
Class Visiting : public Faculty {
  public:
  Visiting(int months);
  string get_name() {
     return Faculty::get_name();
  } // will not compile!
  private:
   int duration;
};
```

```
int main(){
  Faculty f1(“Brian K.", 123, true);
  cout << f1.get_name() << endl;
}
```

Protected Inheritance

Protected inheritance before base class indicates how the public base class members are accessed by clients and derived classes

For **protected inheritance:**

- Public and protected base class members are accessible to the child class and grandchild classes
- no base class members are accessible to 3rd parties

Base Class

```
class Person {
 public:
  Person(string n, int ident);
  string get_name();
  int get_id();
 private: // INACCESSIBLE TO DERIVED
  string name; int id;
};
```

```
class Student : protected Person {
 public:
  Student(string n, int ident, int mjr);
  int get_major();
  double get_gpa();
  void set_gpa(double new_gpa);
 private:
  int major; double gpa;
};


class HonorsStudent : public Student {
 public:
  HonorsStudent(string n, int ident,int 
mjr);

  string f1() {return get_name();}//works
 private:
  bool thesis;
};
```

```
int main(){
  Student s1(“Hannah", 73412, 1);
  HonorsStudent h1(“Emily", 53201, 2);
  cout << s1.get_name() << endl;
  cout << h1.get_name() << endl;
}
```

Public Inheritance

Base Class

```
public: void f1();
protected: void f2();
private: void f3();
```

How a **grandchild** class or **3rd party** sees what is inherited is the MORE restrictive of the how the **base class** declared it or how the derived class inherited.

Child

```
class ChildA :
 public Base
{ /* . . . */  };
```

Grandchild

```
class GCA :
  public ChildA
{ public:
 void g1()
 { f1(); f2(); f3();}
}     ✓      ✓      X
```

3rd Party

```
int main()
{ ChildA a;
  a.f1(); a.f2();a.f3();
}    ✓        X       X
```

Protected Inheritance

Base Class

```
public: void f1();
protected: void f2();
private: void f3();
```

How a **grandchild** class or **3rd party** sees what is inherited is the **MORE restrictive** of the how the **base class** declared it or how the derived class inherited.

```
class ChildB :
 protected Base
{ /* . . . */  };
```

```
class GCB :
  public ChildB
{ public:
  void g1()
  { f1(); f2(); f3(); }
}      ✓     ✓      X
```

```
int main()
{ ChildB b;
  b.f1(); b.f2(); b.f3();
}     X       X       X
```

Private Inheritance

Base Class

```
public: void f1();
protected: void f2();
private: void f3();
```

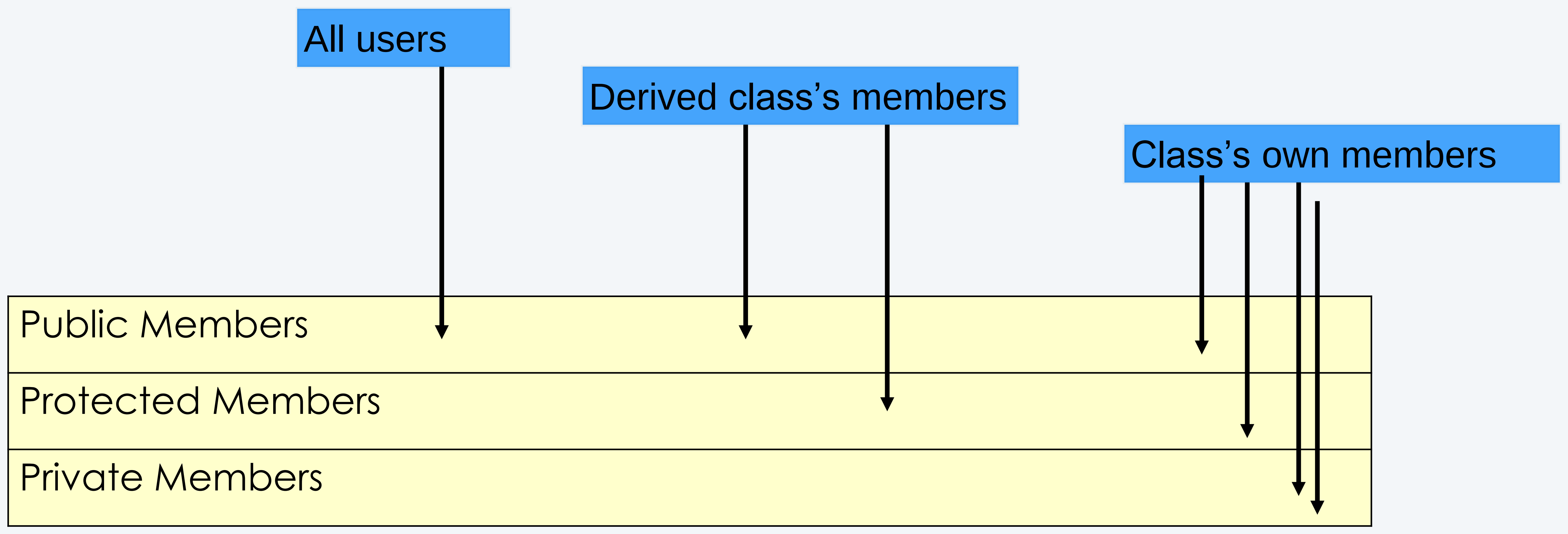
How a grandchild class or 3rd party sees what is inherited is the MORE restrictive of the how the base class declared it or how the derived class inherited.

```
class ChildC :
 private Base
{ /* . . . */  };
```

```
class GCC :
  public ChildC
{ public:
  void g1()
  { f1(); f2(); f3(); }
}     X     X      X
```

```
int main()
{ ChildC c;
  c.f1(); c.f2(); c.f3();
}     X      X      X
```

Inheritance and Access Summary



If a base class inheritance is

1. Public: its public members can be used by all functions
2. Protected: its public and protected members can only be used by derived classes and their derived classes
3. Private: its public and protected members can only be used by the directly derived class

Reference: Bjarne Stroustrup. 2014. Programming: Principles and Practice Using C++ (2nd. ed.). Addison-Wesley Professional, pg. 511

COMPOSITION VS. INHERITANCE

When to Inherit Privately

For protected or private inheritance, "as-a" relationship or "Is-Implemented-In-Terms-Of" (IITO)

- Queue "as-a" List / FIFO "IIITO" list

```
class List{
 public:
  List();
  void insert(int loc, const int& val);
  int size();
  int& get(int loc);
  void pop(int loc;)
// private data and function members
};
```

Base Class

```
class Queue : private List // or protected
{ public:
  Queue();
  push_back(const int& val)
    { insert(size(), val); }
  int& front();
    { return get(0); }
  void pop_front();
    { pop(0); }
};
```

Derived Class

```
Queue q1;
q1.push_back(7); q1.push_back(8);
q1.insert(0,9) // not permitted!
```

Composition

Composition defines a "has-a" relationship

- A Queue "has-a" List in its implementation

Some advise to prefer composition rather than inheritance.

Deciding between inheritance and composition

requires discernment:

https://www.thoughtworks.com/insights/blog/composition-vs-inheritance-how-choose

```
class List{
 public:
  List();
  void insert(int loc, const int& val);
  int size();
  int& get(int loc);
  void pop(int loc;)
 // private data members and functions
};
```

Base Class

```
class Queue
{ private:
   List mylist;
  public:
   Queue();
   push_back(const int& val)
    { mylist.insert(size(), val); }
   int& front();
    { return mylist.get(0); }
   void pop_front();
    { mylist.pop(0); }
   int size() // need to create wrapper
     { return mylist.size(); }
};
```

Queue via Composition

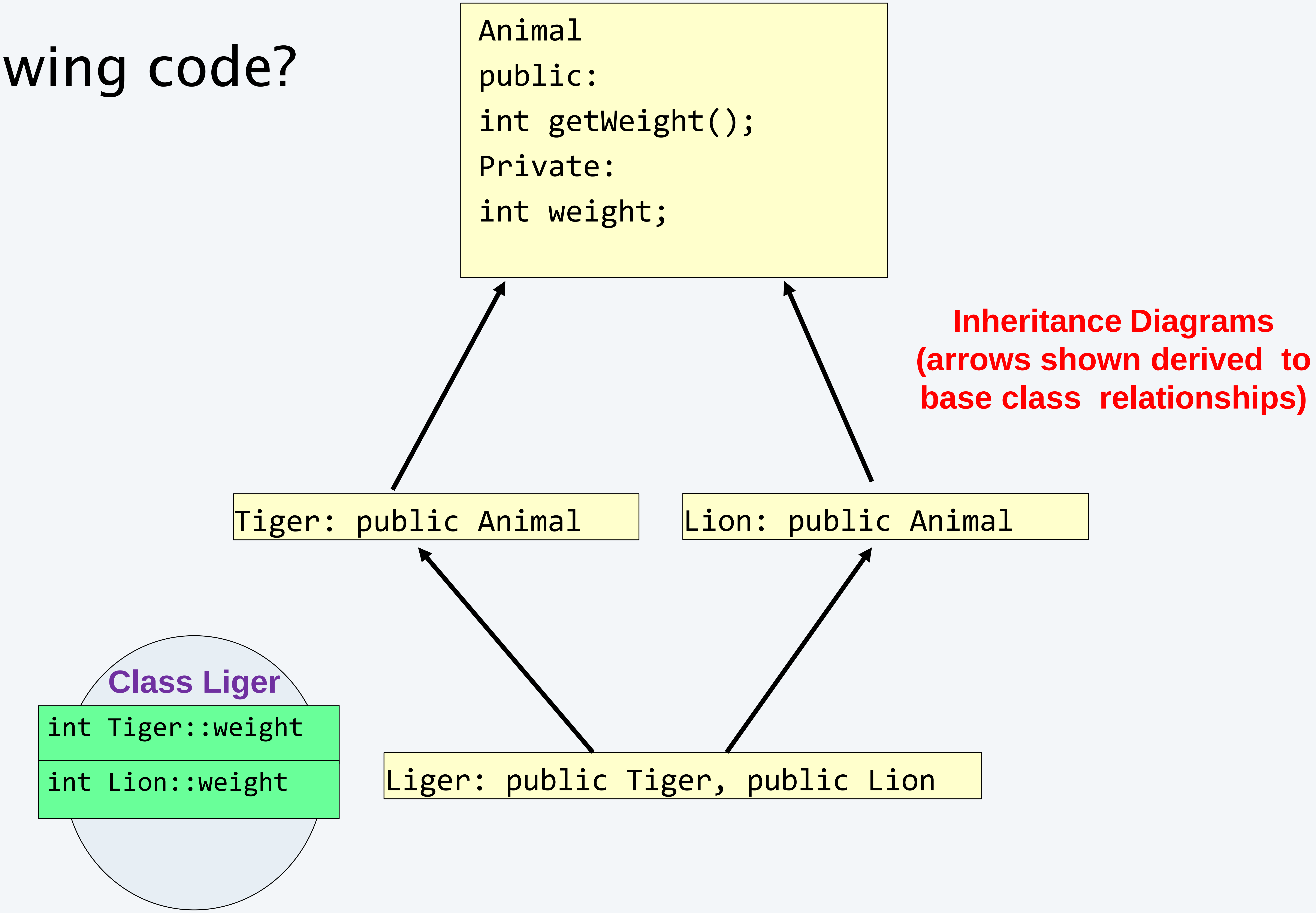
Warning: Multiple Inheritance

C++ allows multiple inheritance but it is not usually recommended

What happens for the following code?

Suppose in main()

- `Liger x;`
- `int wt = x.getWeight();`



```
Animal
public:
int getWeight();
Private:
int weight;
```

```
Tiger: public Animal
```

```
Lion: public Animal
```

```
Liger: public Tiger, public Lion
```

Class Liger

```
int Tiger::weight
int Lion::weight
```

Inheritance Diagrams (arrows shown derived to base class relationships)

Example source: https://www.programmerinterview.com/index.php/c-cplusplus/diamond-problem

Inheritance Summary

- Public Inheritance =>
  "is-a" relationship
- Public inheritance usually for subtype to develop more specialized behavior

- Composition =>
  "has-a" relationship

- Private/Protected Inheritance =>
  "as-a" relationship or
  "implemented-as" or
  "implemented-in-terms-of"

```
class List{
 public:
  List();
  void insert(int loc, const int& val);
  int size();
  int& get(int loc);
  void pop(int loc;)
 // private data function and members
};
```

Base Class

```
class Queue
{ private:
   List mylist;
  public:
   Queue();
   push_back(const int& val)
    { mylist.insert(size(), val); }
   int& front();
    { return mylist.get(0); }
   void pop_front();
    { mylist.pop(0); }
   int size() // need to create wrapper
     { return mylist.size(); }
};
```

Queue via Composition