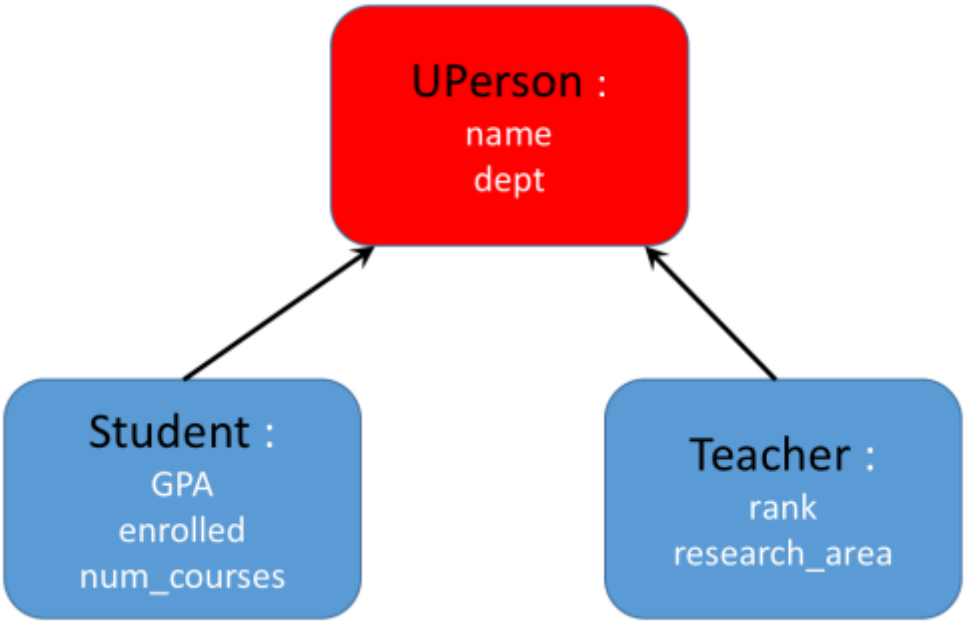
overview

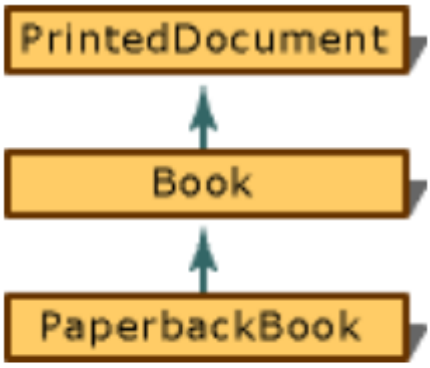
Inheritance-- new class can be derived from exiting class.



Single Inheritance

Definition

In "single inheritance," a common form of inheritance, classes have only **one base class**.



Simple Single-Inheritance Graph

```cpp
// deriv_SingleInheritance.cpp
// compile with: /LD
class PrintedDocument {};

// Book is derived from PrintedDocument.
class Book : public PrintedDocument {};

// PaperbackBook is derived from Book.
class PaperbackBook : public Book {};
```

Notes:

- `Book` is a kind of a `PrintedDocument`
- `PaperbackBook` is a kind of `Book`
- `PrintedDocument` is considered a "direct base" class to `Book`
- `printedDocument`it is an "indirect base" class to `PaperbackBook`

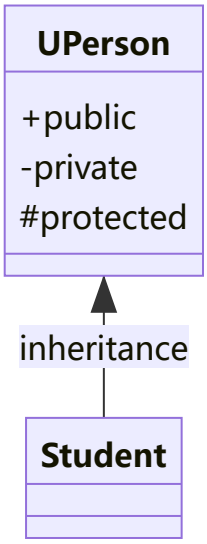
> *Difference between direct base class and indirect base class*
>
> - *direct base class is in base list of a class declaration*
> - *and an indirect base does not*

Warning: It is not sufficient to provide a forward-referencing declaration for a base class; it must be a complete declaration.

Member Access Control

type of access	meaning
public	Class members declared as `public` can be used by any function.
private	Class members declared as `private` can be used only by member functions and friends (classes or functions) of the class.
protected	Class members declared as `protected` can be used by: + **member** functions and **friends** (classes or functions) of the class. + Be used by classes derived from the class.(member and friend)

Access Control in Derived Class



private	protected	public
Always inaccessible with any derivation access		`private` in derived class if you use `private` derivation
		`protected` in derived class if you use `protected` derivation
	`protected` in derived class if you use `public` derivation	`public` in derived class if you use `public` derivation

Polymorphic or Liskov Substitution Principle

Inheritance implements the **is-a relationship**:

1. **Book** inherits from **PrintDocument**
    1. `Book` objects could be treated as `PrintDocument`
    2. All methods of `PrintDocument`can be called by a `Book` object.
2. A **Book** object is a **PrintDocument** object.

an object of the **derived class** can be **treated like** an object of the **base class** *under all circumstances*.

Function Expecting an Argument of Type	Will Also Accept
UPerson	**Student**
pointer to **UPerson**	pointer to **Student**
UPerson reference	**Student** reference

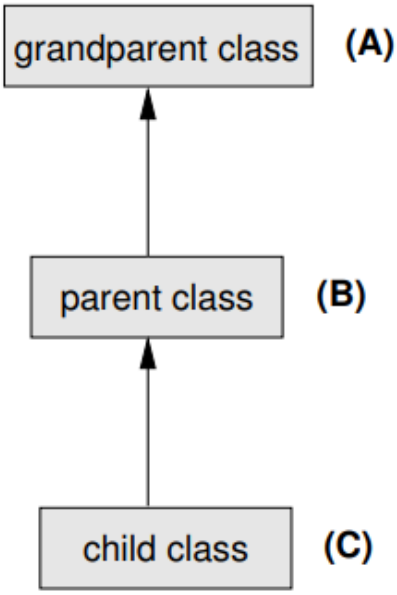
3. base-class pointer cannot access the derived class variable

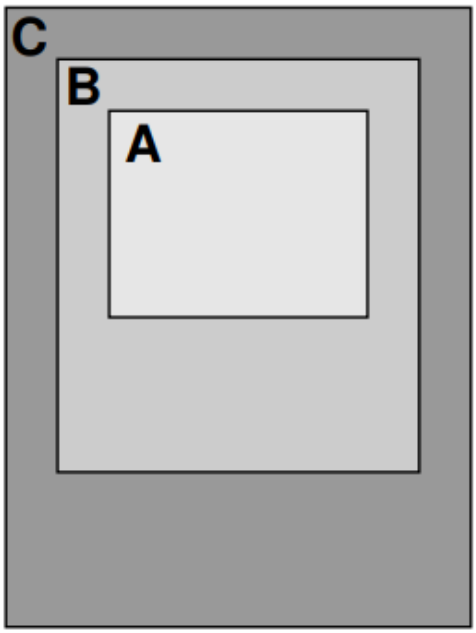
Indirect Inheritance

- The difference between a direct inheritance and an indirect one is that:
  - the base list of a class declaration and an indirect base does not.

```
1  #ifndef PG_STUDENT_H    /* File: pg-student.h */
2  #define PG_STUDENT_H
3
4  #include "student.h"
5
6  class PG_Student : public Student
7  {
8    private:
9      string research_topic;
10
11   public:
12     PG_Student(string n, Department d, float x) :
13         Student(n, d, x), research_topic("") { }
14
15     string get_topic() const { return research_topic; }
16     void set_topic(const string& x) { research_topic = x; }
17 };
18
19 #endif
```

Initialization of Base Class Objects





- Before a Student object can come into existence, we have to create its `UPerson` parent first.
- Student's constructors have to call a `UPerson's` constructor through the member initializer list.

Every derived class have the responsibility to use the constructor of its direct base class to create it before itself created.

Order of Construction/Destruction:

The order is construction of a class object

0. Parents' member
1. its parent
2. its data members (in the order of their appearance in the class definition)
3. itself

The order is destruction of a class object

1. itself
2. its data members (in the order of their appearance in the class definition)
3. its parent

Problems in Inheritance:

1. **Slicing**:

```
1  #include <iostream>     /* File: slice.cpp */
2  #include <string>
3  using namespace std;
4  #include "../basics/uperson.h"
5  #include "../basics/student.h"
```

```
6
7  int main()
8  {
9      Student student("Snoopy", CSE, 3.5);
10     UPerson* pp = &student;
11     UPerson* pp2 = new Student("Mickey", ECE, 3.4);
12
13     UPerson uperson("Unknown", CIVL);
14     uperson = student; // What does "uperson" have?
15     return 0;
16 }
```

`UPerson` here will only have part of the object `student`, which is the inherited part.

2. **name conflict**

summary:

- Behavior and structure of the base class is inherited by the derived class.
- However, constructors and destructor are an exception. They are never inherited.
- There is a kind of contract between a base class and a derived class:
    - The base class provides functionality and structure (methods and data members).
    - The derived class guarantees that the base class is initialized in a consistent state by calling an appropriate constructor.

      A base class is constructed before the derived class.

      A base class is destructed after the derived class.

Dynamic Binding & Virtual

Static Binding

In polymorphic substitution principle,

a function accepting 1. a **base class object**

2. its **derived objects**.

The binding (association) of a function name to appropriate method is done by static analysis of the code at compile time based on the static(declared) type of object.

- By default, C++ uses **static binding**. (Same as C, Pascal, and FORTRAN.)

- In static binding, what a pointer really points to, or what a reference actually refers to **is not considered**; only the pointer/reference **type** is.

```
#include <iostream>     /* File: print-label.cpp */
using namespace std;
#include "student.h"
#include "teacher.h"

void print_label_v(UPerson uperson) { uperson.print(); }
void print_label_r(const UPerson& uperson) { uperson.print(); }
void print_label_p(const UPerson* uperson) { uperson->print(); }

int main() {
    UPerson uperson("Charlie Brown", CBME);
    Student student("Edison", ECE, 3.5);
    Teacher teacher("Alan Turing", CSE, PROFESSOR, "CS Theory");
    student.add_course("COMP2012"); student.add_course("MATH1003");

    cout << "\n##### PASS BY VALUE  #####\n";
    print_label_v(uperson); print_label_v(student);
print_label_v(teacher);

    cout << "\n##### PASS BY REFERENCE  #####\n";
    print_label_r(uperson); print_label_r(student);
print_label_r(teacher);

    cout << "\n##### PASS BY POINTER  #####\n";
    print_label_p(&uperson); print_label_p(&student);
print_label_p(&teacher);
}

```

It is ok to put both **base class** and **derived class** as the arguments:

```
void print_label_v(UPerson uperson) { uperson.print(); }
```

However, only the `UPerson` part will be bond in this function (even the object of `teacher` , only the inherited `UPerson` part will be linked).

`static_cast`:

```
#include <iostream> /* File: static-example.cpp */
using namespace std;
#include "teacher.h"

int main()
{
    UPerson uperson("Charlie Brown", CBME);
    Teacher teacher("Alan Turing", CSE, PROFESSOR, "CS Theory");

```

```
    UPerson *u;
    Teacher *t;
    /*cout << "\nUPerson object pointed by Teacher pointer:\n";
    t = &uperson; t->print(); // Error: convert base-class ptr*/
    //        to derived-class ptr
    cout << "cast____static";
    t = static_cast<Teacher *>(&uperson);
    t->print(); // Ok, but ...
}
```

> *If you static_cast a derived class to a base class pointer, it's ok to compile but* ***its output is non-sense.***

dynamic_cast()

when dynamic_cast fails, it will return null pointer for you.

dynamic Binding

- When dynamic binding is used, the actual method to be called is selected using the actual type of the object in the call, but only if the object is **passed by reference or pointer**.
    - reference can be considered as an alias
    - pointer is obvirous.

Virtual Functions

- A virtual function is declared using the keyword `virtual` in the **class definition**, and **not** in the method **implementation**, if it is defined outside the class.
- Once a method is declared `virtual` in the base class, it is automatically virtual in **all directly or indirectly derived classes**.
- Even though it is not necessary to use the virtual keyword in the derived classes, it is **a good style** to do so because it improves the **readability** of header files.
- Calls to virtual functions are a little bit **slower than normal** function calls. The difference is extremely small and it is not worth worrying about, unless you write very speed-critical code.

Note:

- Functions in derived classes override virtual functions in base classes only if their **type is the same**.
- A call to a virtual function is resolved according to the underlying type of object for which it is called.
- A call to a nonvirtual function is resolved according to the type of the pointer or reference.

```cpp
// deriv_VirtualFunctions2.cpp
// compile with: /EHsc
#include <iostream>
using namespace std;

class Base {
public:
   virtual void NameOf();   // Virtual function.
   void InvokingClass();   // Nonvirtual function.
};

// Implement the two functions.
void Base::NameOf() {
   cout << "Base::NameOf\n";
}

void Base::InvokingClass() {
   cout << "Invoked by Base\n";
}

class Derived : public Base {
public:
   void NameOf();   // Virtual function.
   void InvokingClass();   // Nonvirtual function.
};

// Implement the two functions.
void Derived::NameOf() {
   cout << "Derived::NameOf\n";
}

void Derived::InvokingClass() {
   cout << "Invoked by Derived\n";
}

int main() {
   // Declare an object of type Derived.
   Derived aDerived;

   // Declare two pointers, one of type Derived * and the other
   //  of type Base *, and initialize them to point to aDerived.
   Derived *pDerived = &aDerived;
   Base    *pBase    = &aDerived;

   // Call the functions.
   pBase->NameOf();           // Call virtual function.
   pBase->InvokingClass();    // Call nonvirtual function.
   pDerived->NameOf();        // Call virtual function.
   pDerived->InvokingClass(); // Call nonvirtual function.
```

```
}
/*
output:
Derived::NameOf
Invoked by Base
Derived::NameOf
Invoked by Derived
*/
```

Note that:

- **Virtual function is always called form derived**. Regardless of whether the `NameOf` function is invoked through a pointer to `Base` or a pointer to `Derived`, it calls the function for `Derived`.
- **None virtual function called from the type-of pointer objects**. It calls the function for `Derived` because `NameOf` is a virtual function, and both `pBase` and `pDerived` point to an object of type `Derived`.

override

The override function is binding at run time, so it will ignore the member access control, for after compiling, every function is global.

Which means: if there is a function `virtual print()` at base class and this function is override by the derived class private `print()`. Its ok to compile and ok to override!

```cpp
#include <iostream> /* File: override.cpp */
using namespace std;

class Base
{
public:
  virtual void f(int a) const { cout << a << endl; }
};

class Derived : public Base
{
  int x{25};

private:
  void f(int) const override;
};

// Don't repeat the keyword override here
void Derived::f(int b) const { cout << x + b << endl; }

int main()
{
  Derived d;
```

```
  Base &b = d;
  b.f(5);         //though f() is overridev by private, it could be called as well
  return 0;
}
```

```
output:
30
```