

# C/C++ Programming Language

CS219 Spring

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Lecture 12



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# Content

- Review
- Class Inheritance
- Static and Dynamic Binding
- Access Control: protected
- Inheritance and Dynamic Memory Allocation
- Class Design Review

# Brief Review



# Review

- An example of causing problems (auto generated functions)
  - Default constructors
  - Copy constructors
  - Assignment operators
- Improved class example of string
  - Comparison members
  - Static class member functions
  - Assignment operator overloading
- Using pointers to objects



# Class Inheritance



# The Reasons for Inheritance

- Traditional C
  - Function libraries: the number of functions is **limited**
  - Many vendors furnish specialized C libraries
    - ✓ Problem 1: **can't extend or modify** the functions to meet particular needs
    - ✓ Problem 2: run the **risk of unintentionally** modifying or altering the relationships
- One of the main goals of object-oriented programming is to provide **reusable code**
  - Often class libraries are available in source code, which means you can modify them to meet your needs
  - Class **inheritance**: lets you derive **new classes** from old ones, with the derived class inheriting the **properties** of the base class



# How to Inheriting a Fortune: Add and Modify

- What is the fortune of a class?
- Add **functionality** to an existing class
  - For example, given a basic array class, you could add arithmetic operations
- Add to the **data** that a class represents
  - For example, given a basic string class, you could derive a class that adds a data member representing a color to be used when displaying the string
- **Modify** how a class method **behaves**
  - For example, given a Passenger class that represents the services provided to an airline passenger, you can derive a FirstClassPassenger class that provides a higher level of services



# Deriving a Class

- Beginning with a simple **base** class
  - Run `tblt.h`, `tabtenn0.cpp`, `usett0.cpp`
- How to include a new member (point rating)?

- Derive a class

- Header: the colon ":"
- Header: **public** derivation:

- ✓ The **public** members become **public** members of the derived class
- ✓ The **private** portions become part of the derived class, but they can be accessed only through **public and protected methods** of the **base** class

```
// RatedPlayer derives from the TableTennisPlayer base class
class RatedPlayer : public TableTennisPlayer
{
    ...
};
```

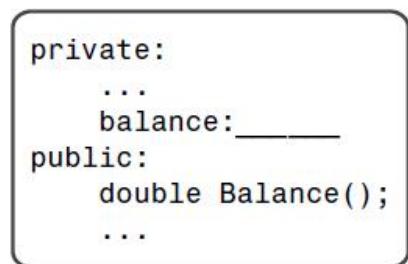




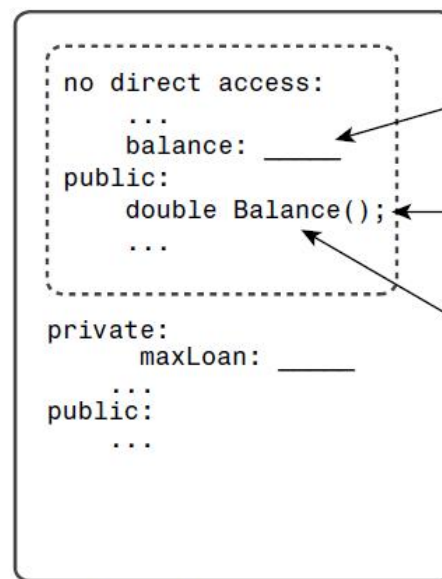
# More Operations for Derivation

- What needs to be added to the inherited features?
  - A derived class needs its own constructors
  - A derived class can **add** additional **data** members and member **functions** as needed

```
class Overdraft : public BankAccount {...};
```



BankAccount object



Overdraft object

private balance  
member inherited  
but not directly  
accessible

public member  
Balance() inherited  
as a public member

value of balance  
member indirectly  
accessible via inherited  
public member function  
Balance()



# Constructors: Access Considerations

- A derived class
  - Don't have direct access to the private members of the base class
  - Has to work through the **base-class methods**
    - ✓ The derived-class **constructors** have to use the base-class constructors
    - ✓ A program constructs a derived-class object, it **first** constructs the **base-class** object
- Key points
  - The base-class object is constructed **first**
  - The derived-class constructor should
    - ✓ pass information to a base-class constructor via a member **initializer list**
    - ✓ **initialize** the data members that were **added** to the derived class
- Run `tblt1.h`, `tabtenn1.cpp`, `usett1.cpp`



# Special Relationships Between Derived and Base Classes

- Relationships

- A derived-class object

- ✓ Can use base-class methods, provided that the methods are not private (question?)

```
RatedPlayer rplayer1(1140, "Mallory", "Duck", true);  
rplayer1.Name(); // derived object uses base method
```

- A base-class

- ✓ Pointer can point to a derived class object without an explicit type cast
    - ✓ Reference can refer to a derived-class object without an explicit type cast
    - ✓ Pointer or reference can invoke just base-class methods but couldn't use the derived-class method

```
RatedPlayer rplayer1(1140, "Mallory", "Duck", true);  
TableTennisPlayer & rt = rplayer;  
TableTennisPlayer * pt = &rplayer;  
rt.Name(); // invoke Name() with reference  
pt->Name(); // invoke Name() with pointer
```



# More Relationships Between Two Classes

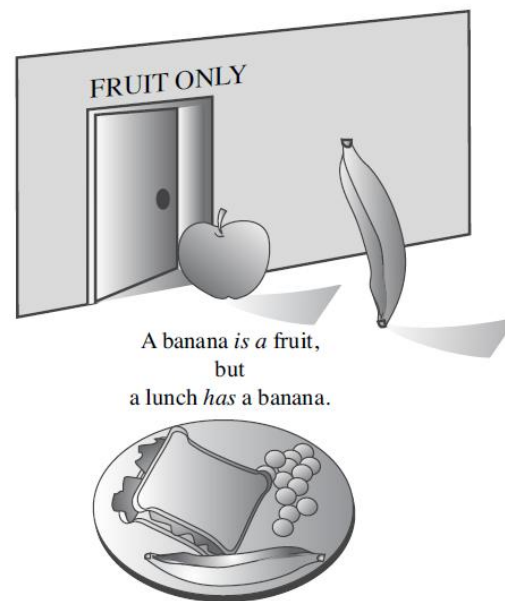
- Generally, references and pointer types **should match** but this rule is relaxed for inheritance
  - The rule relaxation is just in **one direction**
  - Functions defined with **base-class reference or pointer** arguments can be used with **either** base-class **or** derived-class objects
  - **Why???**

```
TableTennisPlayer player("Betsy", "Bloop", true);  
RatedPlayer & rr = player;           // NOT ALLOWED  
RatedPlayer * pr = player;          // NOT ALLOWED
```



# Inheritance: An *Is-a* Relationship

- Public inheritance is the most **common** inheritance form
  - Model an ***is-a*** relationship
  - An object of a derived class **should be** an object of the base class
  - Anything you do with a base-class object, you **should be able to** do with a derived-class object
- Five relationships
  - ***is-a-kind-of*** (is-a): apple-→fruit
  - ***has-a***: meal-→apple
  - ***is-like-a***: lawyer-→shark
  - ***is-implemented-as-a***: stack-→array
  - ***uses-a***: computer-→printer





# Polymorphic Public Inheritance

- How to do when you want a method to **behave differently** for the derived class than it does for the base class?
- Polymorphic: have **multiple behaviors** for a method
  - **Redefining** base-class methods in a derived class
  - Using **virtual** methods: keyword- **virtual**
- Run `usebrass1.cpp`, `brass.cpp`, `brass.h`
- An array of pointers: run `usebrass2.cpp`
  - Showing **virtual** method behavior

# Static and Dynamic Binding



# Binding

- What is binding?
  - Interpreting a **function call** in the source code **as executing** a particular block of function code
  - **Compiler** has to look at the function arguments as well as the function name to figure out **which function to use**
    - ✓ Static binding (or early binding): take place during compilation
  - Dynamic binding (or late binding): the **correct virtual** method is selected as the program runs
    - ✓ Virtual functions
    - ✓ Take place during program **running**





# Pointer and Reference Type Compatibility

- General rules
  - Doesn't assign an address of one type to a **pointer** of another type
  - Nor does it let a **reference** to one type refer to another type
- Public inheritance
  - **Upcasting**: converting a derived-class reference or pointer to a base-class reference or pointer
    - ✓ This rule is part of expressing the **is-a relationship**
    - ✓ Using an **implicit** type cast
  - **Downcasting**: converting a base-class pointer or reference to a derived-class pointer or reference
    - ✓ It is **not** a is-a relationship
    - ✓ Using an **explicit** type cast



# Virtual Member Functions and Dynamic Binding

- An example: **invoking** a method with a reference or pointer

```
BrassPlus ophelia;    // derived-class object
Brass * bp;           // base-class pointer
bp = &ophelia;        // Brass pointer to BrassPlus object
bp->ViewAcct();        // which version?
```

- Nonvirtual function: the compiler uses static binding
- Virtual function: the compiler uses dynamic binding
- Questions:
  - **Why** have two kinds of binding?
  - If dynamic binding is so good, why **isn't it the default**?
  - How does dynamic binding **work**?



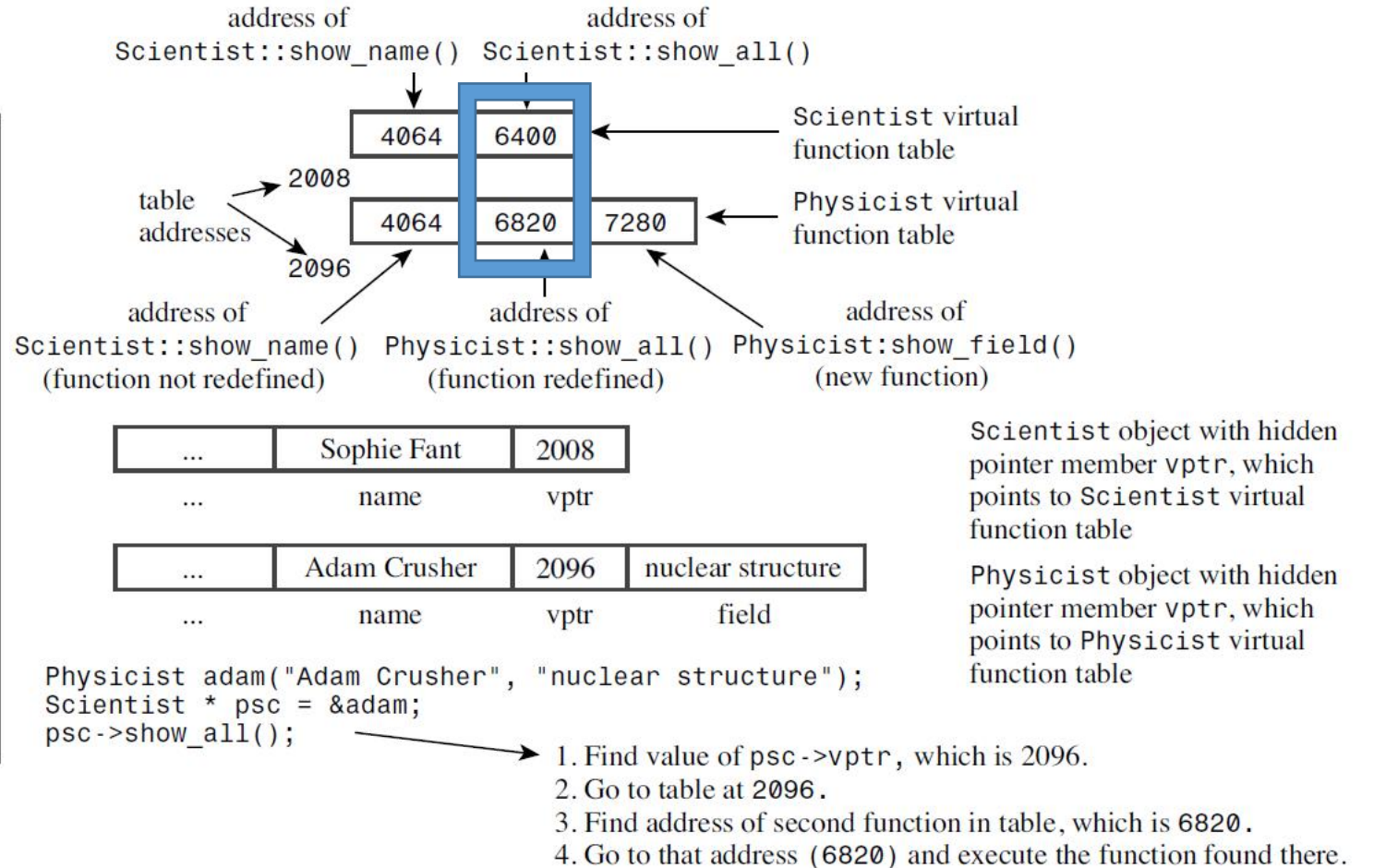
# Why and How it works

- Why two kinds of binding and why static is the default
  - **Efficiency**: static binding is more efficient
  - A conceptual model
    - ✓ Making this function **nonvirtual** in base class, if **no need** to redefine it
    - ✓ Reserving the **virtual** label just for methods expected to be redefined
- How virtual functions work
  - Leave the implementation up to the **compiler writer** 虚拟表中包含所有虚拟函数
  - **Add a hidden pointer member to each object**
  - Hold a pointer to an **array of function addresses**: **virtual function table (vtbl)**
  - Contain the addresses of the **virtual** functions of that class
  - An object of a derived class contains a pointer to a **separate table** of addresses
    - ✓ Provide a new definition of a **virtual** function, the **vtbl** holds the address of the **new** function
    - ✓ Doesn't redefine the **virtual** function, the **vtbl** holds the address of the original version of the function
    - ✓ Define a new function and makes it **virtual**, its address is added to the vtbl



# A Virtual Function Mechanism

```
class Scientist{
{
    ...
    char name[40];
public:
    virtual void show_name();
    virtual void show_all();
    ...
};
class Physicist : public Scientist
{
    ...
    char field[40];
public:
    void show_all(); // redefined
    virtual void show_field(); // new
    ...
};
```





# Things to Know About Virtual Methods

- Main points
  - **virtual** makes the function virtual for the **base** and **all derived classes**
  - If a virtual method is invoked by a reference or a pointer, the program uses the **method defined for the object type**
  - If a class will be used as a base class for inheritance and the **methods** which may have to be **redefined** in derived classes should be **virtual**
  - **Constructors can't be virtual**
  - Destructors should be **virtual** unless a class isn't as a base class
    - ✓ Provide a base class with a virtual destructor even if the class doesn't need a destructor
  - **Friends can't be virtual functions**
  - Fail to redefine a function
    - ✓ Use the **base** class version of the function
    - ✓ Use the **most recently** defined version of the function, if there is a long chain

Access Control:  
protected



# Reasons for Protected Members

- Two introduced keywords
  - **public** and **private**: control access to class members
- The **protected** keyword like **private**
  - The outside world can access class members in a protected section only by using **public class members**
- The difference between **private** and **protected**
  - Members of a derived class **can** access **protected members** directly, but **cannot** directly access **private members** of the base class
- Protected **access control** can be quite useful for member functions, giving derived classes access to **internal** functions that are not available publicly

# Inheritance and Dynamic Memory Allocation





# Questions for Inheritance and Dynamic Memory Allocation

- How does inheritance **interact** with dynamic memory allocation?
  - More specifically, if a base class uses dynamic memory allocation and redefines assignment and a copy constructor, how does that affect the implementation of the derived class?
- The answer depends on the nature of the derived class
  - If the derived class **does not** itself use **dynamic** memory allocation, you **needn't** take any special steps.
  - If the derived class **does also** use dynamic memory allocation, then there are a couple new tricks to learn



# Case 1: Derived Class Doesn't Use new

- An example of no new used in derived
  - Base class has included constructors use new, a destructor, a copy constructor, and an overloaded assignment operator
  - You needn't to define an explicit destructor, copy constructor, and assignment operator for the derived class
    - ✓ Default destructor for a derived class always **does** something
    - ✓ Default copy constructor does **member-wise** copying
    - ✓ The **same** to overloaded assignment operators

```
// Base Class Using DMA
class baseDMA
{
private:
    char * label;
    int rating;

public:
    baseDMA(const char * l = "null", int r = 0);
    baseDMA(const baseDMA & rs);
    virtual ~baseDMA();
    baseDMA & operator=(const baseDMA & rs);
    ...
};
```

```
// derived class without DMA
class lacksDMA :public baseDMA
{
private:
    char color[40];

public:
    ...
};
```



# Case 2: Derived Class Does Use new

- An example of new used in derived class
  - **Have to** define an explicit destructor, copy constructor, and assignment operator for the derived class
    - ✓ A derived class destructor **automatically calls** the base-class destructor, so its own responsibility is to clean up **after** what the derived-class constructors do
    - ✓ Copy constructors and assignment operator follows the **usual patterns**
- An Inheritance Example with Dynamic Memory Allocation and Friends
  - Run dma.h, dma.cpp, usedma.cpp

```
// derived class with DMA
class hasDMA :public baseDMA
{
private:
    char * style; // use new in constructors
public:
    ...
};

hasDMA::hasDMA(const hasDMA & hs)
    : baseDMA(hs)
{
    style = new char[std::strlen(hs.style) + 1];
    std::strcpy(style, hs.style);
}
```

```
hasDMA & hasDMA::operator=(const hasDMA & hs)
{
    if (this == &hs)
        return *this;
    baseDMA::operator=(hs); // copy base portion
    delete [] style;        // prepare for new style
    style = new char[std::strlen(hs.style) + 1];
    std::strcpy(style, hs.style);
    return *this;
}
```

# Class Design Review



# Class Design Review

- Member functions that the compiler **generates** for you (5)
  - Default constructors
  - Copy constructors: a constant reference for argument
  - Assignment operators (Don't confuse assignment with initialization)
- **Constructor** considerations (default, copy, conversion)
  - ✓ Different from other class methods
  - ✓ Constructors aren't inherited
- **Destructor** considerations
  - ✓ Define an explicit destructor if **new** is used in the constructors
  - ✓ Provide a **virtual** destructor for **base** class



# Class Design Review

- Conversion considerations (type cast)
  - ✓ Any **constructor** that can be invoked with exactly one argument defines conversion from the argument type to the class type
  - ✓ A **conversion function** is a class member function with **no** arguments or declared return type that has the name of the type to be converted to
- **Passing** an object by value versus passing a **reference**
  - ✓ For efficiency
  - ✓ A function defined as accepting a **base-class** reference argument can also be used successfully with **derived** object
- **Returning** an object versus returning a **reference**
  - ✓ Shouldn't return a reference to a temporary object



# Class Design Review

- Using **const** (variable, argument, member function)
  - Use it to guarantee that a method **doesn't modify** an **argument**
  - Use **const** to guarantee that a method **won't modify the object**
  - Use **const** to ensure that a **reference or pointer** return value can't be used to modify data in an object
- Public inheritance considerations
  - **Is-a** relationship
  - What's **not** inherited:
    - ✓ Constructors
    - ✓ Destructors
    - ✓ Assignment operators



# Class Design Review

- Assignment operator considerations
  - ✓ Need to provide an **explicit** assignment operator if class constructors use **new** to initialize pointers
- Private versus protected members
- Virtual method considerations
  - ✓ Define the method as virtual in the base class, which could be redefined
  - ✓ Enable late, or dynamic, binding (a table used)
- Destructor considerations
  - ✓ A base class **destructor** should be **virtual**
- Friend considerations
  - ✓ **It's not inherited**
  - ✓ **To use:** Type cast a derived-class reference or pointer to the **base-class** equivalent and then invoke the **base-class friend**





# Class Design Review

- Observations on using base-class methods
  - ✓ A derived-class destructor **automatically** invokes the base-class **destructor**
  - ✓ A derived-class constructor (in a member-initialization list)
    - **automatically** invokes the base-class **default constructor** if **don't specify** in list
    - **explicitly invokes** the base-class constructor specified in list
  - ✓ A derived object **automatically uses** inherited base-class methods if the derived class **hasn't redefined** the method
  - ✓ **Derived-class methods** can use the **scope-resolution operator** to invoke public and protected base-class methods
  - ✓ Friend functions



# Class Function Summary

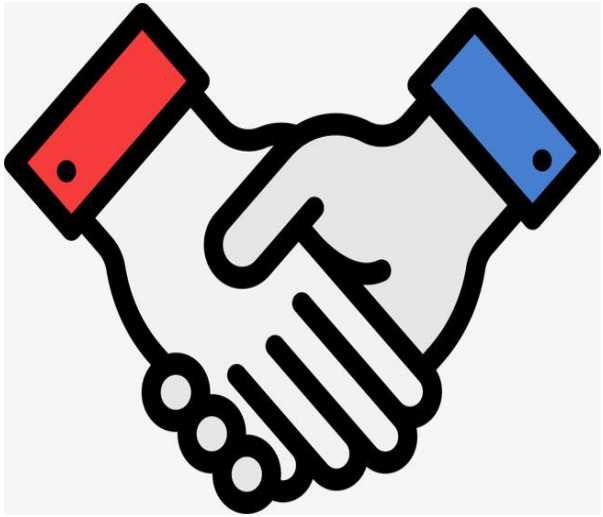
- Member function properties

Function	Inherited	Member or Friend	Generated by Default	Can Be Virtual	Can Have a Return Type
Constructor	No	Member	Yes	No	No
Destructor	No	Member	Yes	Yes	No
=	No	Member	Yes	Yes	Yes
&	Yes	Either	Yes	Yes	Yes
Conversion	Yes	Member	No	Yes	No
()	Yes	Member	No	Yes	Yes
[]	Yes	Member	No	Yes	Yes
->	Yes	Member	No	Yes	Yes
op=	Yes	Either	No	Yes	Yes
new	Yes	Static member	No	No	void *
delete	Yes	Static member	No	No	void
Other operators	Yes	Either	No	Yes	Yes
Other members	Yes	Member	No	Yes	Yes
Friends	No	Friend	No	No	Yes

copy

address

No return type but has return value



Thanks



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