Composition & Inheritance

Object-Oriented Programming with C++

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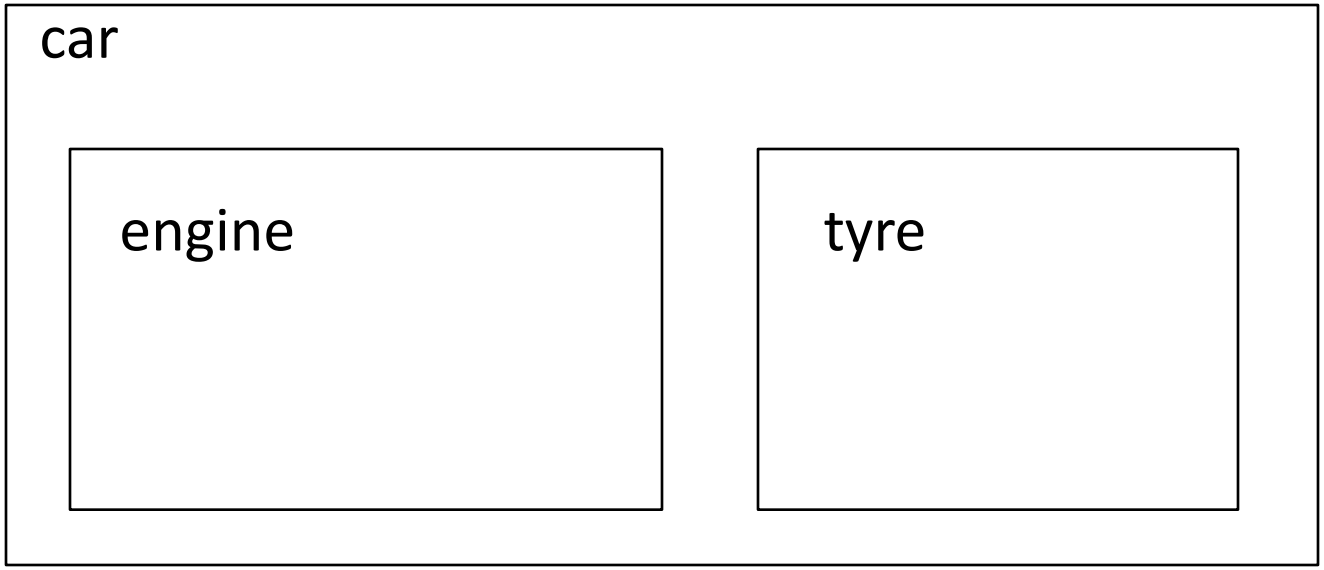
Reusing the implementation

- Composition: construct new object with existing objects
- It is the relationship of ***has-a***



Composition

- Objects can be used to build up other objects
- Ways of inclusion
  - Fully
  - By reference
- Inclusion by reference allows sharing
- For example, an Employee has a
  - Name
  - Address
  - Health Plan
  - Salary History
    - Collection of Raise objects
  - Supervisor
    - Another Employee object!

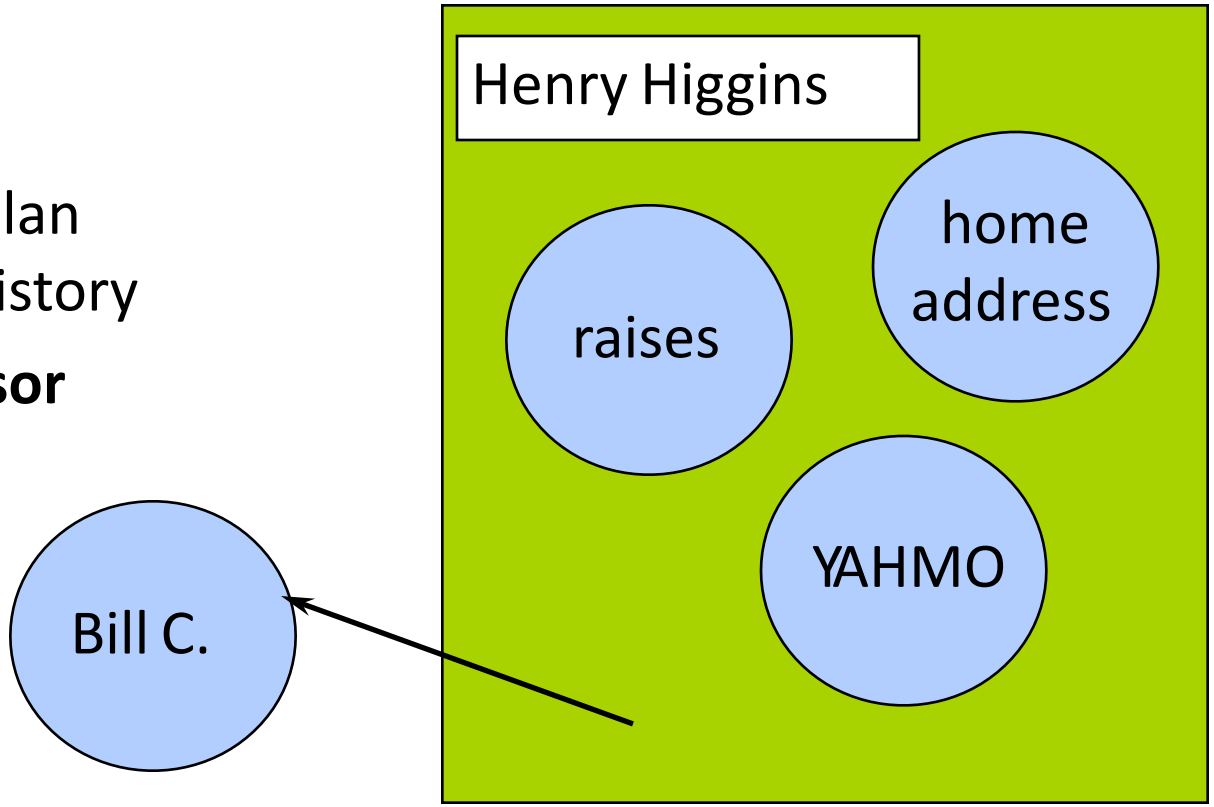
Composition in action

Classes

Employee

- Name
- Address
- Health Plan
- Salary History
- **Supervisor**

Instances



Example 1

```
class HealthPlan {…};
class SalaryHistory {…};

class Employee {
private:
    std::string name;
    std::string address;
    HealthPlan healthPlan;
    std::vector<SalaryHistory> salaryHistories;
    Employee* supervisor;  // Pointer to the
supervisor. Can be nullptr if no supervisor.
```

Example 1…

```
public:
    Employee(const std::string& name, const
std::string& address): name(name), address(address),
supervisor(nullptr) {}
    void addSalaryHistory(const SalaryHistory&
history) { salaryHistories.push_back(history); }
    std::vector<SalaryHistory> getSalaryHistories()
const { return salaryHistories; }
    void setSupervisor(Employee* sup) { supervisor =
sup; }
    Employee* getSupervisor() const { return
supervisor; }
    ~Employee() {}
};
```

Example 2

```
class Person { … };
class Currency { … };
class SavingsAccount {
public:
    SavingsAccount( const char* name,
                    const char* address, int cents);
    ~SavingsAccount();
    void print();
private:
    Person m_saver;
    Currency m_balance;
};
```

Example 2…

```
SavingsAccount::SavingsAccount(
 const char* name, const char* address, int cents)
 : m_saver(name, address),
   m_balance(0, cents)
{}

void SavingsAccount::print()
{
    m_saver.print();
    m_balance.print();
}
```

Embedded objects

- All embedded objects must be initialized
  - The default constructor is called if
    - you don't supply the arguments, and there is a default constructor (or one can be built)
- Initializer list on Constructor
  - any number of objects separated by commas
  - is optional
  - Provide arguments to sub-constructors
- Syntax:

```
name( args ) [':' init-list] '{'
```

A nonobvious problem

- If we implement the constructor as below (assuming we have the set accessors for the sub-objects), then the default constructors of the sub-objects would be called.

```
SavingsAccount::SavingsAccount(
 const char* name, const char* address, int cents) {
  m_saver.set_name( name );
  m_saver.set_address( address );
  m_balance.set_cents( cents );
}
```

Public vs. Private

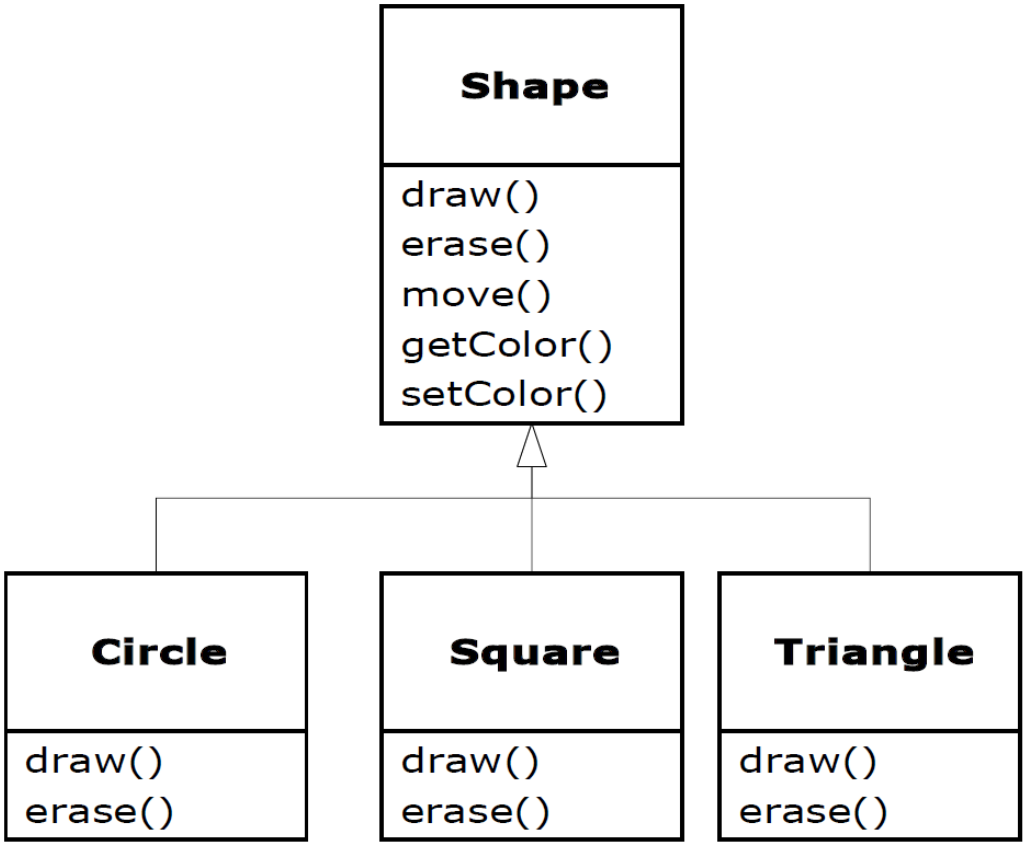
- It is common to make embedded objects private:
  - they are part of the underlying implementation
  - the new class only has part of the public interface of the old class
- Can embed as a public object if you want to have the entire public interface of the sub-object available in the new object:

```
class SavingsAccount{
public:
    Person m_saver;
    ...
};   // assume Person class has set_name()
SavingsAccount account;
account.m_saver.set_name("Fred");
```

Inheritance

Reusing the interface

- Inheritance is to take the existing class, clone it, and then make additions and modifications to the clone.
- It is the relationship of ***is-a***

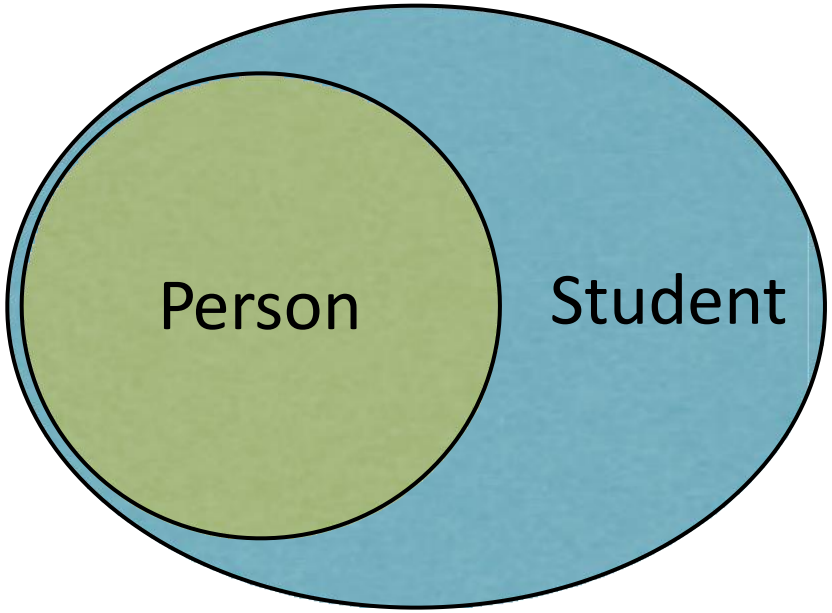


Inheritance

- Language implementation technique
- Also an important component of the OO design methodology
- Allows sharing of design for
  - Member data
  - Member functions
  - Interfaces
- Key technology in C++

Inheritance

- The ability to define the behavior or implementation of one class as a ***derived one*** of another ***base*** class



DoME

DoME is an application that let us store information about CDs and DVDs. We can

- enter information about CDs and DVDs
- search, for example, all CDs in the database by a certain artist, or all DVDs by a given director

CD

- the title of the album;
- the artist (name of the band or singer);
- the number of tracks on the CD;
- the total playing time;
- a ‘got it’ flag that indicates whether I own a copy of this CD;
- and a comment (some arbitrary text).

DVD

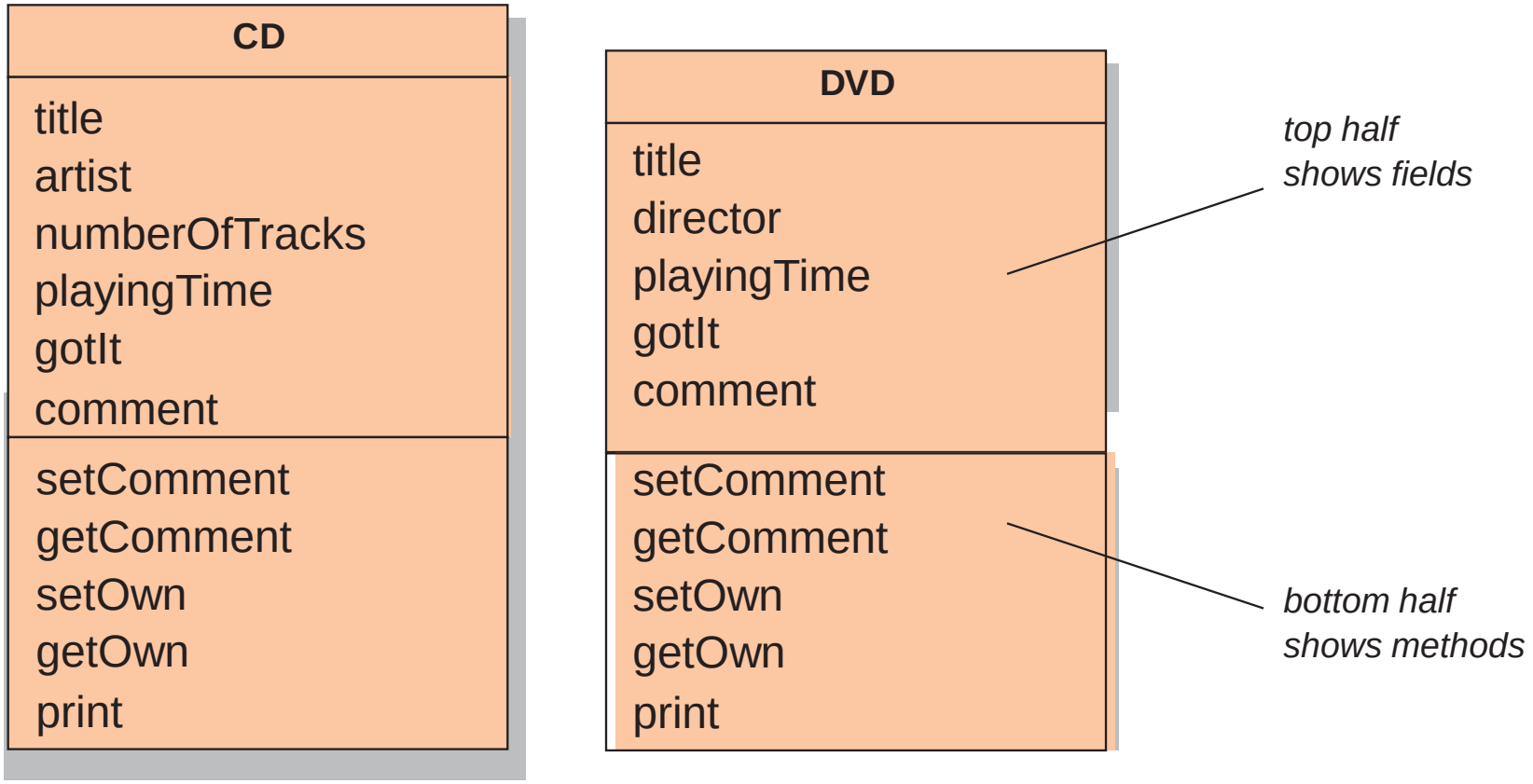
- the title of the DVD;
- the name of the director;
- the playing time (we define this as the playing time of the main feature);
- a ‘got it’ flag that indicates whether I own a copy of this DVD;
- and a comment (some arbitrary text).

The DoME example

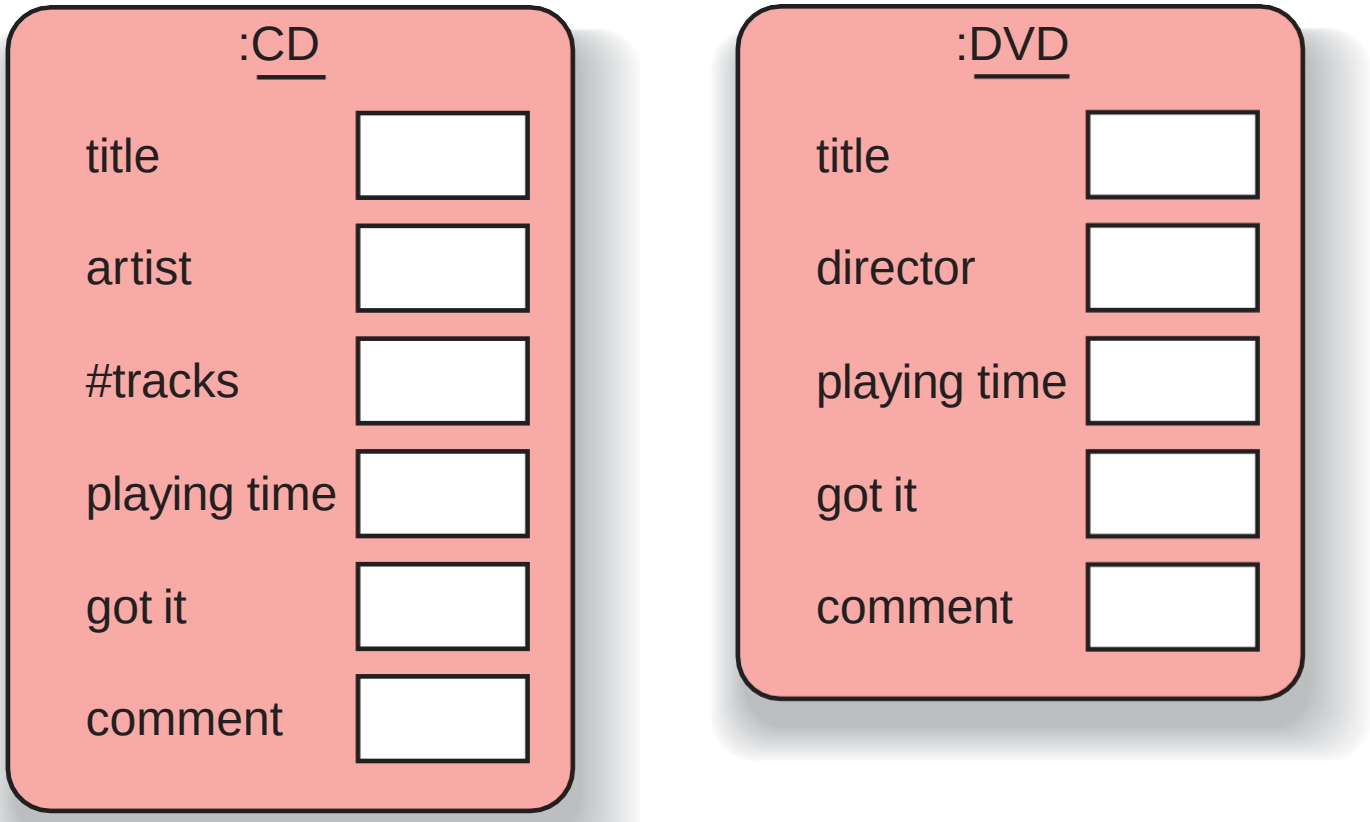
“Database of Multimedia Entertainment”

- stores details about CDs and DVDs
  - CD: title, artist, #tracks, playing time, got-it, comment
  - DVD: title, director, playing time, got-it, comment
- allows (later) to search for information or print lists

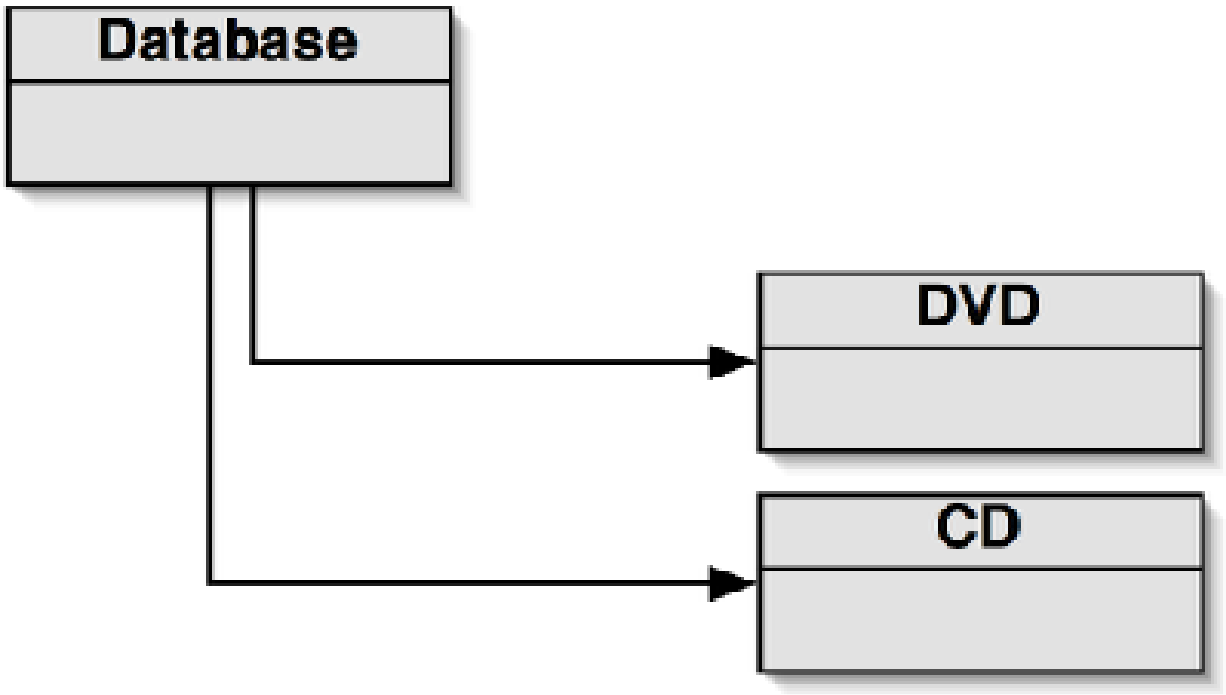
Class diagram



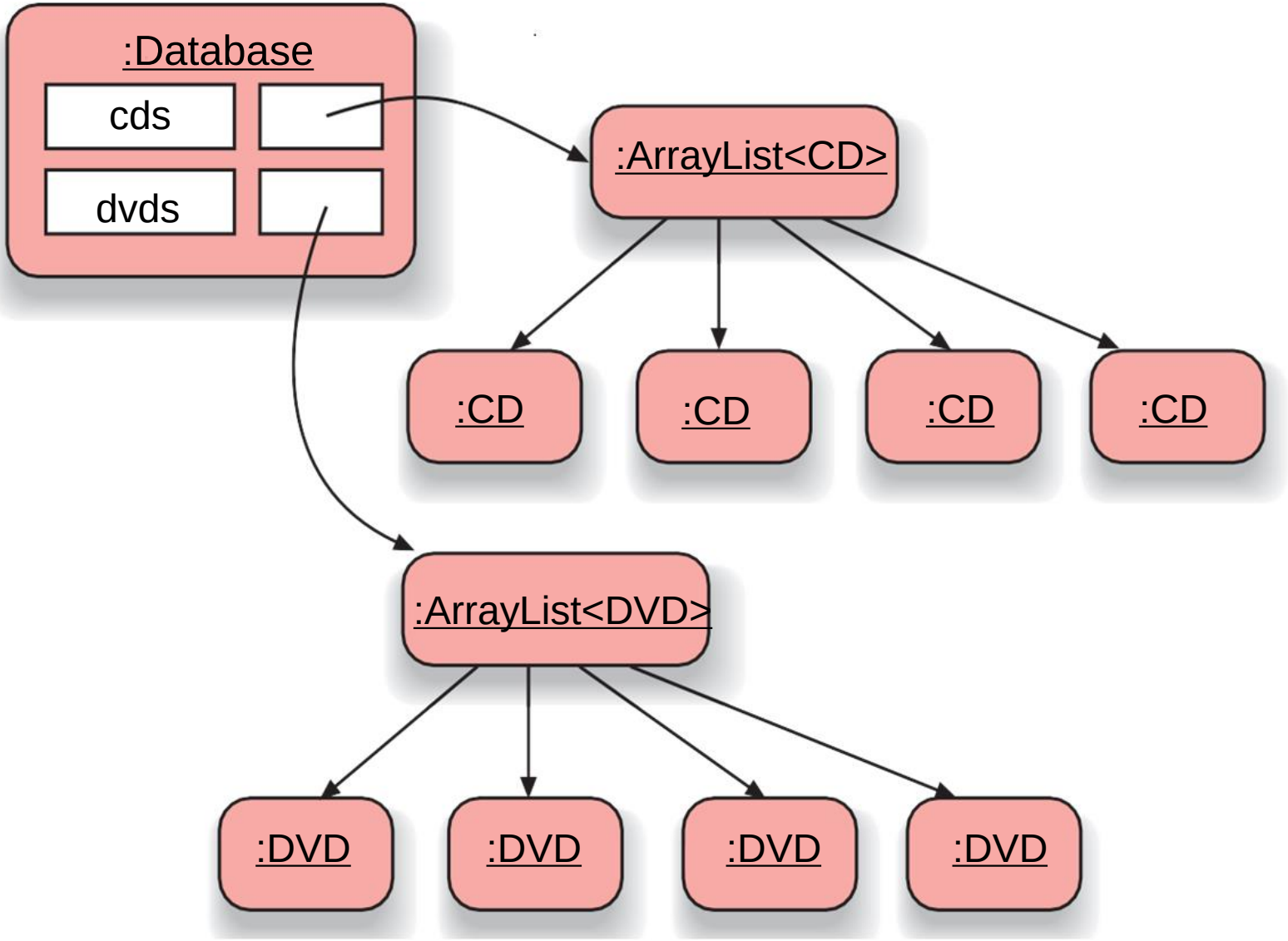
DoME classes



Class diagram



Object Model



Source code

```
public class Database
{
    private ArrayList<CD> cds;
    private ArrayList<DVD> dvds;
}
```

```
public void addCD( CD theCD )
{
    cds.add(theCD);
}
```

```
public void addDVD(DVD theDVD)
{
    dvds.add(theDVD);
}
```

```
public void list()
{
    // print list of CDs
    for(CD cd : cds) {
        cd.print();
        System.out.println();
    }

    // print list of DVDs
    for(DVD dvd : dvds) {
        dvd.print();
        System.out.println();
    }
}
```

Critique of DoME

- Code duplication
  - CD and DVD classes very similar (large part are identical)
  - makes maintenance difficult/more work
  - introduces danger of bugs through incorrect maintenance
- Code duplication also in Database class

Discuss

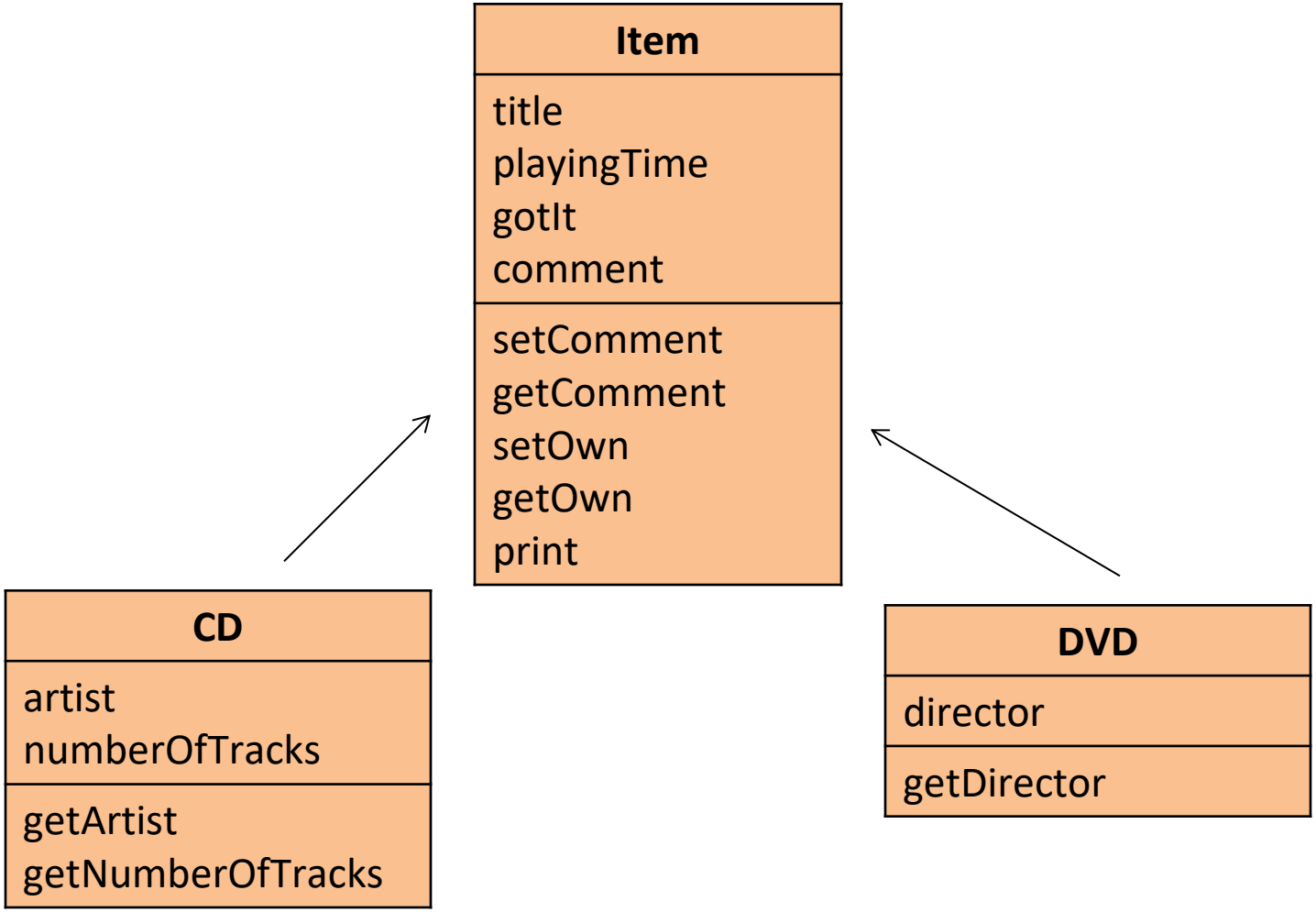
- The CD and DVD classes are very similar. In fact, the majority of the classes' source code is identical, with only a few differences

- In the Database class. We can see that everything in that class is done twice – once for CDs and once for DVDs
  - What if we'd add new types of media?

Solution – Inheritance

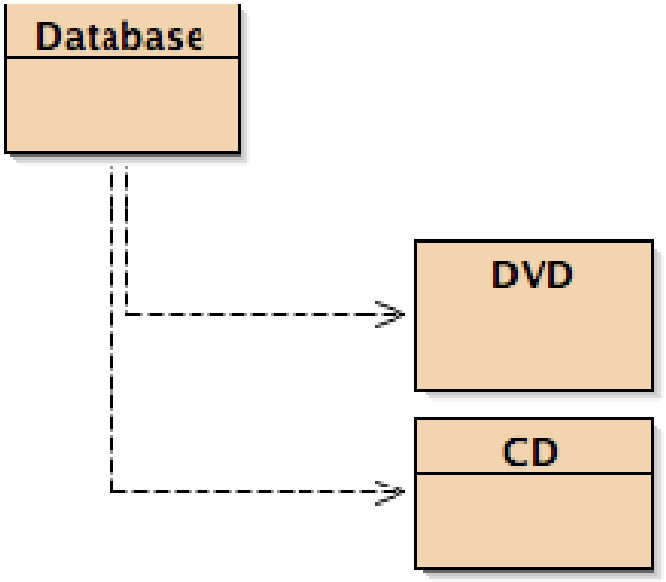
- Define one **superclass** : Item
- Define **subclasses** for DVD and CD
- The superclass defines common attributes
- The subclasses **inherit** the superclass attributes
- The subclasses add own attributes

Solution – Inheritance

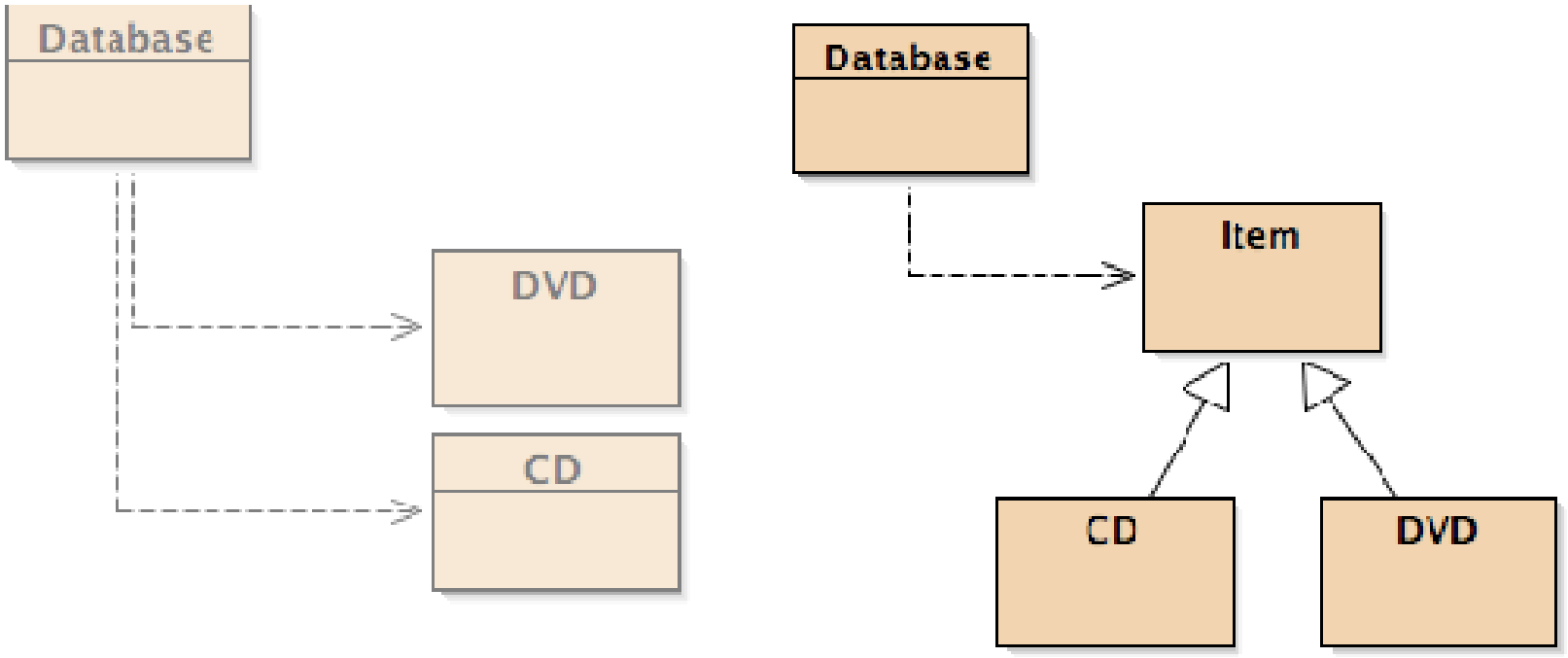


- Inheritance allows us to define one class as an extension of another.

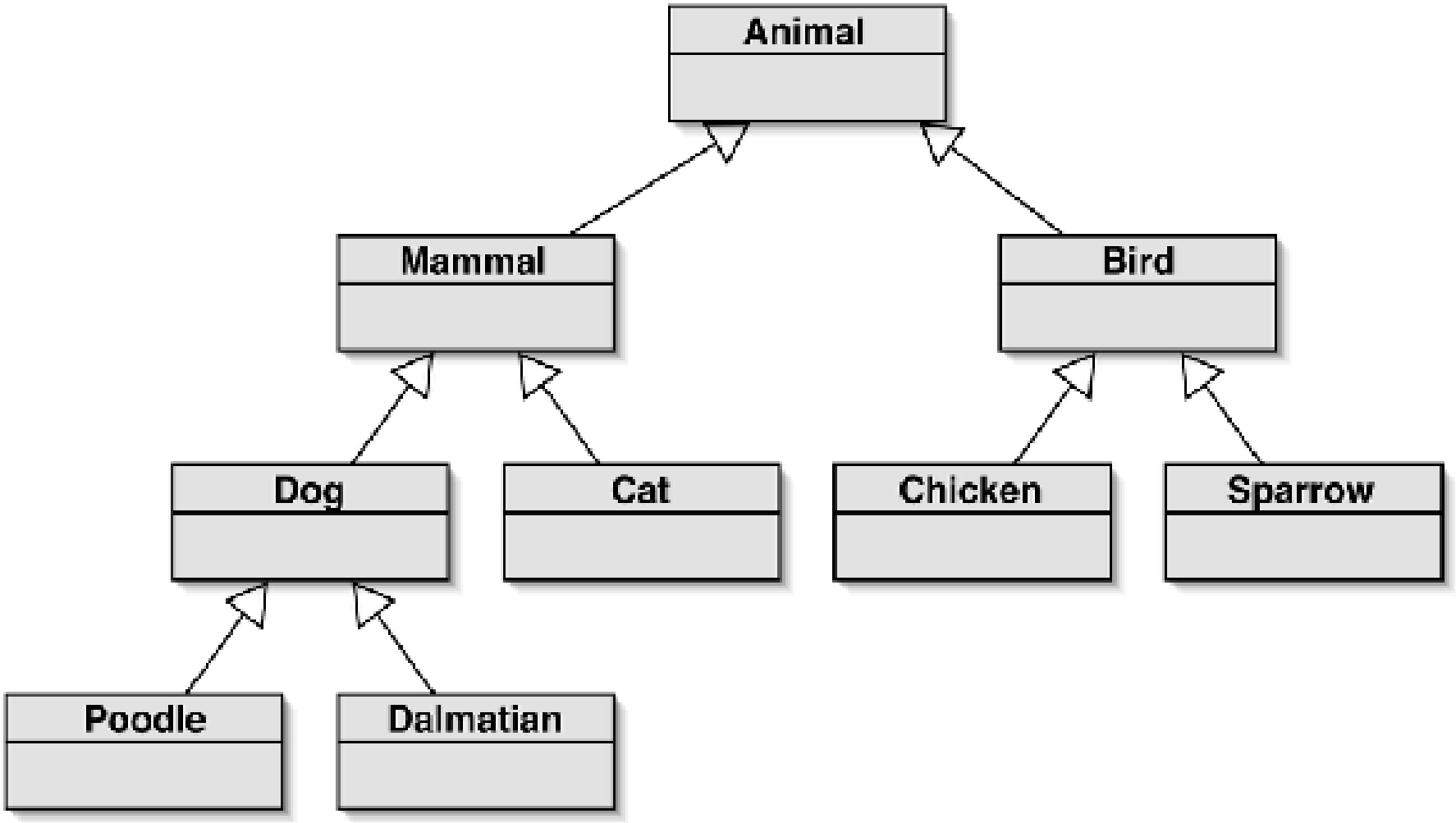
Class diagram



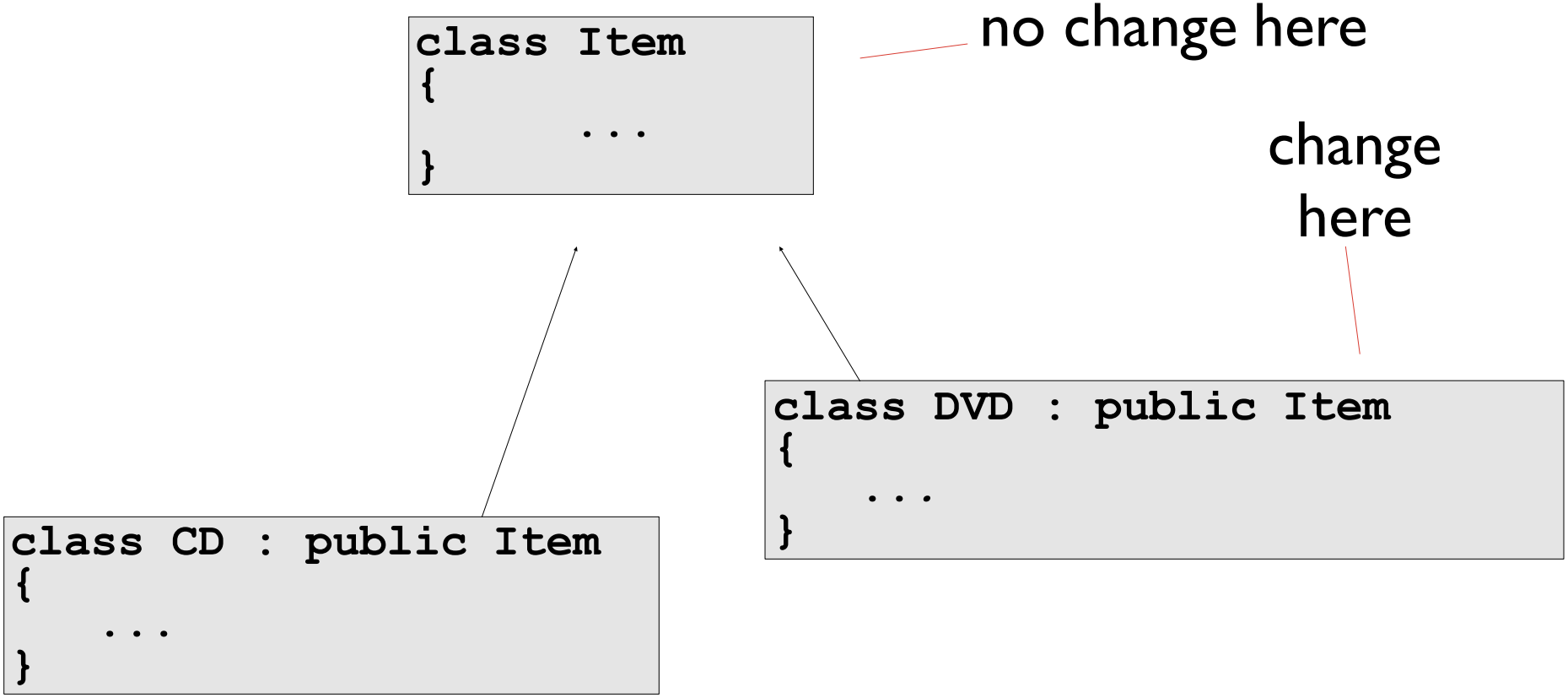
Class diagram



Inheritance hierarchies



Inheritance



Database v2.0

```
public void addItem(Item theItem)
{
    items.add(theItem);
}

/**
 * Print a list of all currently stored items to
 * the text terminal.
 */
public void list()
{
    for(Item item :items){
        item.print();
        System.out.println(); // empty line between items
    }
}
```

```
public void addCD(CD theCD)
{
    cds.add(theCD);
}
```

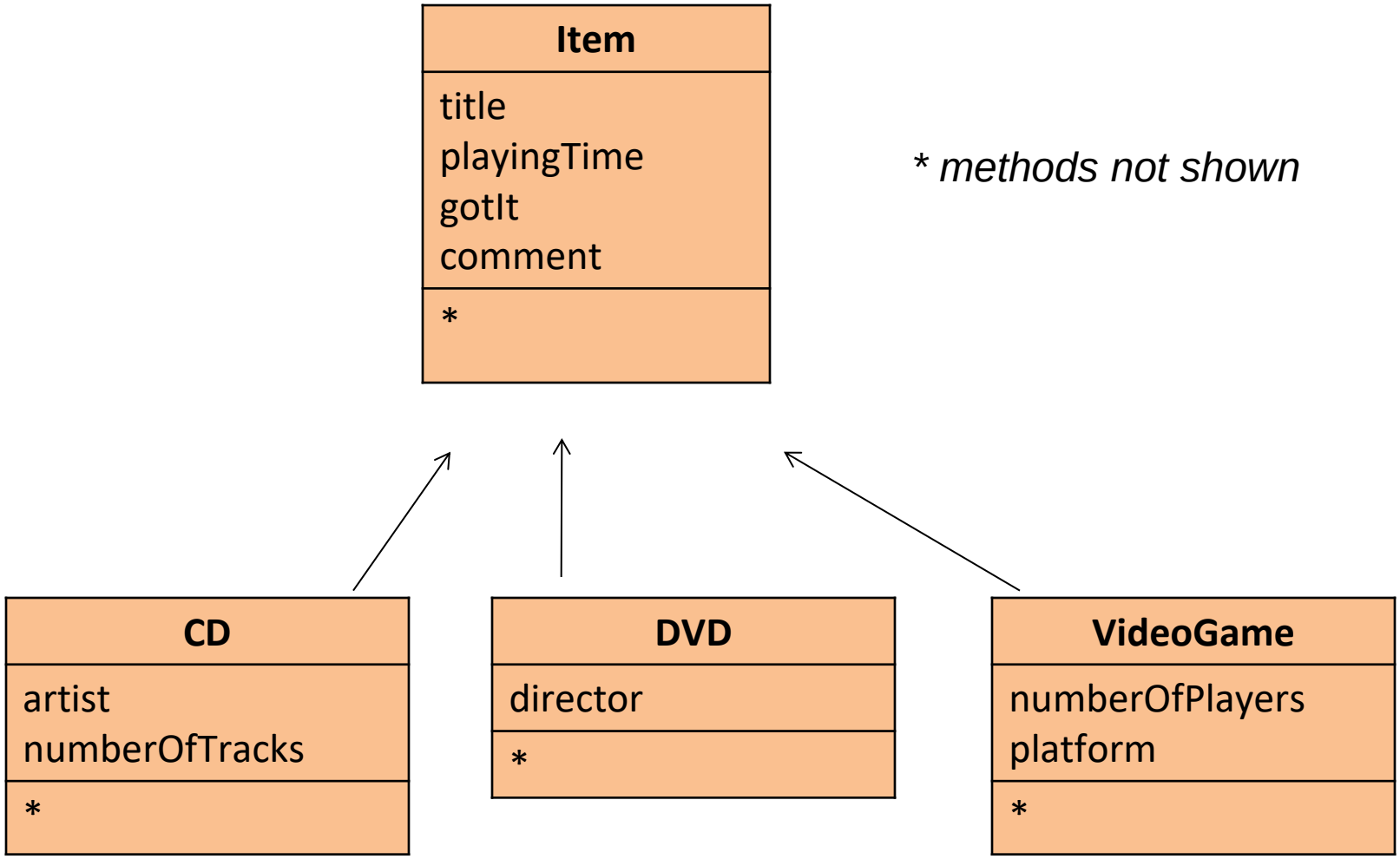
```
public void addItem(Item theItem)
{
    items.add(theItem);
}
```

```
public void addDVD(DVD theDVD)
{
    dvds.add(theDVD);
}
```

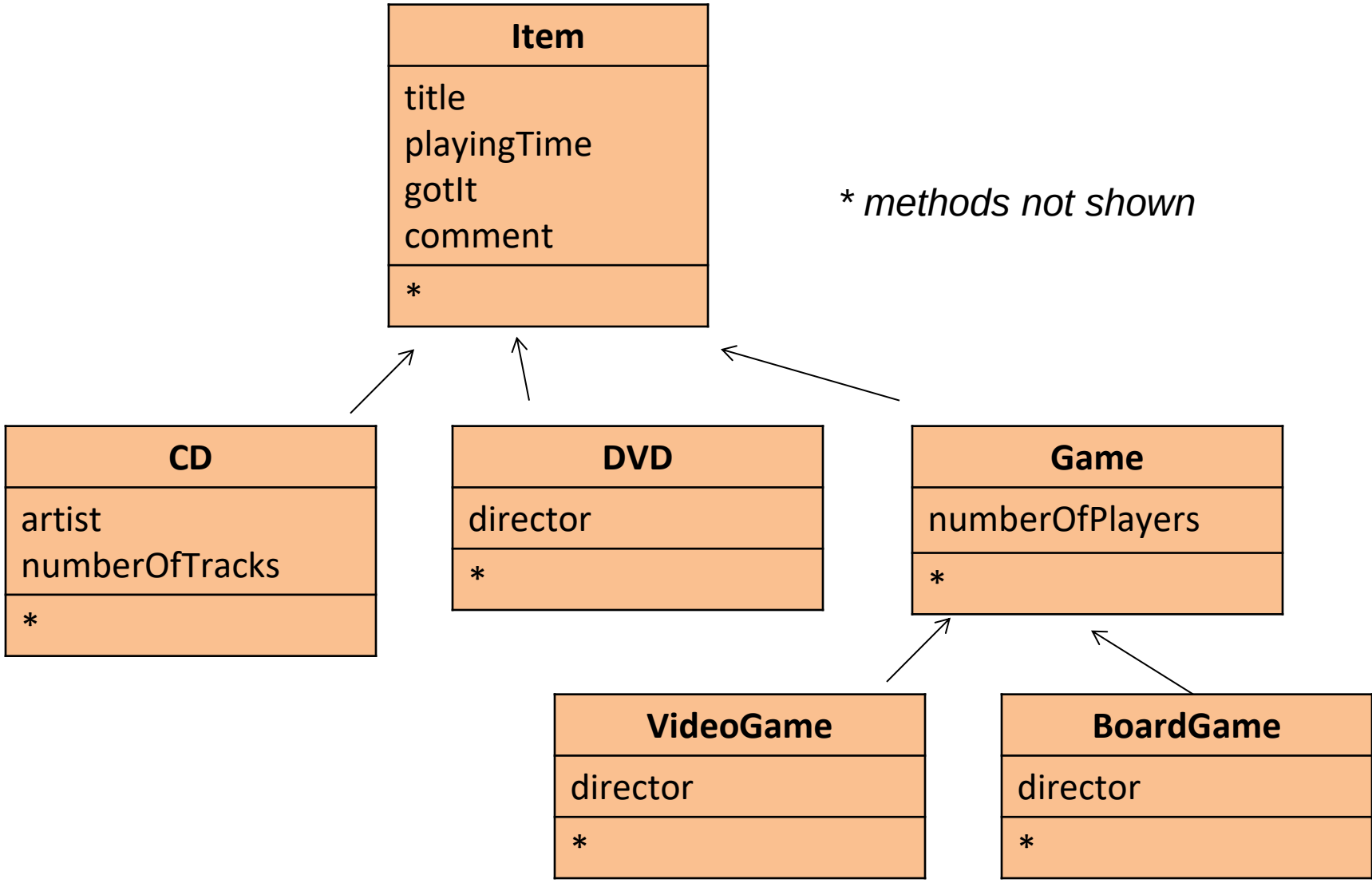
```
public void list()
{
    // print list of CDs
    for(CD cd : cds)   {
        cd.print();
        System.out.println();
    }

    // print list of DVDs
    for(DVD dvd :dvds){
        dvd.print();
        System.out.println();
    }
}
```

```
public void list()
{
    for(Item item:items){
        item.print();
        System.out.println();
    }
}
```

Adding other item types



Deeper hierarchies

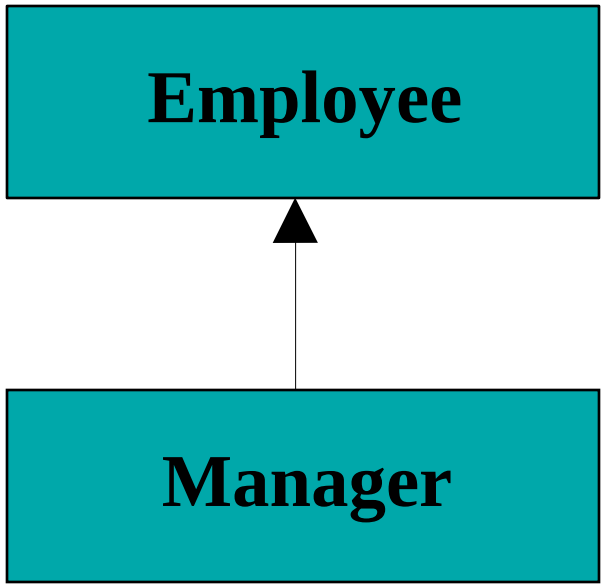


Advantages of inheritance

- Avoiding code duplication
- Code reuse
- Easier maintenance
- Extendibility

Inheritance

- **Class relationship:** *is-a*



Base Class
Super
Parent

Derived Class
Sub
Child

Declare an Employee class

```
class Employee {
public:
    Employee(const std::string& name,
        const std::string& ssn);
    const std::string& get_name() const;
    void print(std::ostream& out) const;
    void print(std::ostream& out,
        const std::string& msg) const;
protected:
    std::string m_name;
    std::string m_ssn;
};
```

Constructor for Employee

```
Employee::Employee(const string& name,
                   const string& ssn)
    : m_name(name), m_ssn(ssn)
{
    // initializer list sets up the values!
}
```

Employee member functions

```
inline const std::string& Employee::get_name() const
{
    return m_name;
}
inline void Employee::print(std::ostream& out) const
{
    out << m_name << endl;
    out << m_ssn << endl;
}
inline void Employee::print(std::ostream& out,
    const std::string& msg) const
{
    out << msg << endl;
    print(out);
}
```

Now add Manager

```
class Manager : public Employee {
public:
    Manager(const std::string& name,
            const std::string& ssn,
            const std::string& title);
    const std::string title_name() const;
    const std::string& get_title() const;
    void print(std::ostream& out) const;
private:
    std::string m_title;
};
```

Inheritance and constructors

- Think of inherited traits as an embedded object
- Base class is mentioned by class name

```
Manager::Manager( const std::string& name,
                  const std::string& ssn,
                  const std::string& title = "" )
    : Employee(name, ssn), m_title( title )
{
}
```

More on constructors

- Base class is always constructed first
- If no explicit arguments are passed to base class
  - Default constructor will be called
- Destructors are called in exactly the reverse order of the constructors.

Manager member functions

```
inline void Manager::print( std::ostream& out ) const
{
    Employee::print( out ); //call the base class print
    out << m_title << endl;
}

inline const std::string& Manager::get_title() const
{
    return m_title;
}

inline const std::string Manager::title_name() const
{
    return string( m_title + ": " + m_name );
    // access base m_name
}
```

Uses

```
int main () {
    Employee bob( "Bob Jones", "555-44-0000" );
    Manager bill( "Bill Smith", "666-55-1234",
"ImportantPerson" );

    string name = bill.get_name(); // okay
Manager  inherits Employee
    string title = bob.get_title(); // Error --
         bob is an Employee!
    cout << bill.title_name() << '\n' << endl;
    bob.print(cout);
    bob.print(cout, "Employee:");
    bill.print(cout);
    bill.print(cout, "Employee:"); // Error -- hidden!
}
```

Name Hiding

- If you redefine a member function in the derived class, all other overloaded functions in the base class are inaccessible.

- We'll see how the keyword `virtual` affects function overloading next time.

What is not inherited?

- Constructors
  - synthesized constructors use memberwise initialization
  - In explicit copy ctor, explicity call base-class copy ctor or the default ctor will be called instead.
- Destructors
- Assignment operation
  - synthesized operator= uses memberwise assignment
  - explicit operator= be sure to explicity call the base class version of operator=
- Private data is hidden, but still present

class vs. struct

- ***class*** defaults to ***private***
- ***struct*** defaults to ***public***

Access protection

- Members

  - Public: visible to all clients

  - Protected: visible to classes derived from self (and to friends)

  - Private: visible only to self and to friends!

- Inheritance

  – Public: `class Derived : public Base ...`

  – Protected: `class Derived : protected Base ...`

  – Private: `class Derived : private Base ...`

How inheritance affects access

Suppose class B is derived from A. Then:

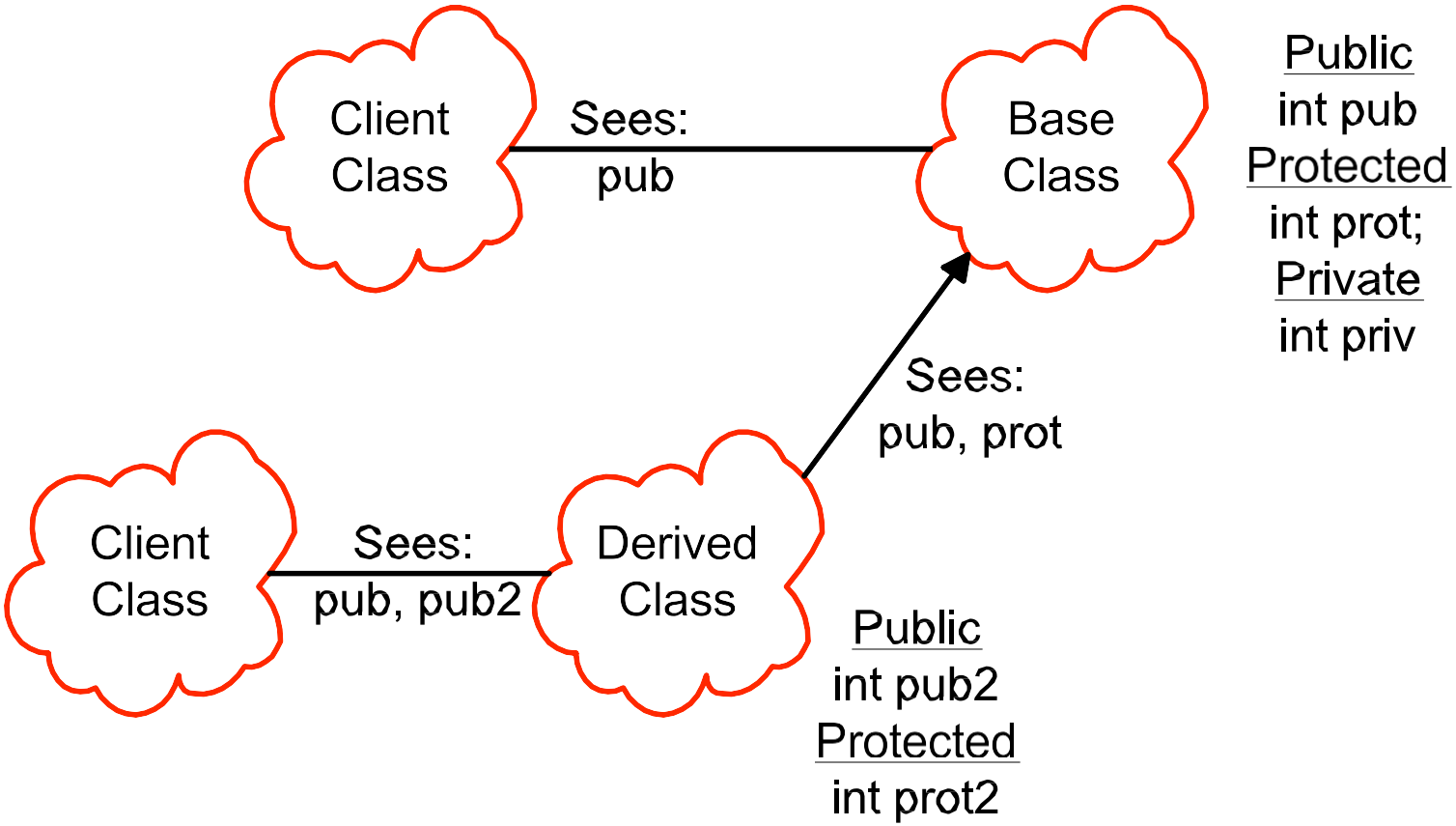
Base class member access specifier

Inheritance Type (B is)	*public*	*protected*	*private*
`:public` `A`	public in B	protected in B	private
`:private` `A`	private in B	private in B	private
`:protected` `A`	protected in B	protected in B	private

Scopes and access in C++

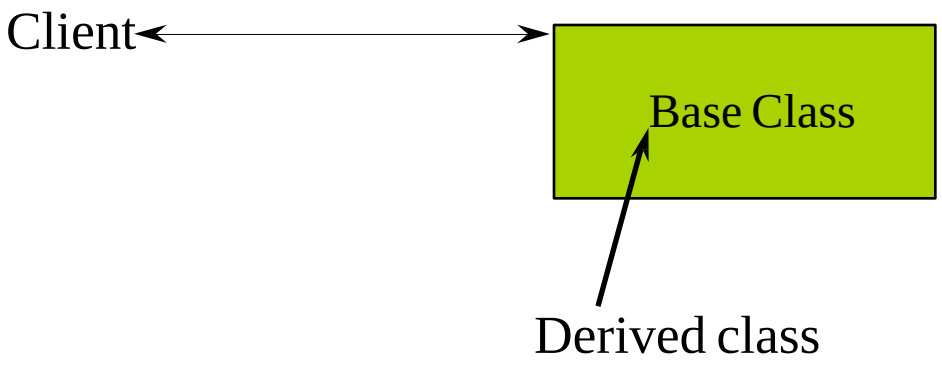
Specifiers	Within same class	In derived class	Outside the class
private	Yes	No	No
protected	Yes	Yes	No
public	Yes	Yes	Yes

Scopes and access in C++



When is protected not protected?

- When your derived classes are ill-behaved!
- Protected is public to all derived classes
- For this reason
  - make member *functions* protected
  - keep member *variables* private



Friends

- To explicitly grant access to a function that isn't a member of the structure.
- The class itself controls which code has access to its members.
- Can declare a global function as a ***friend***, as well as a member function of another class, or even an entire class, as a ***friend***.

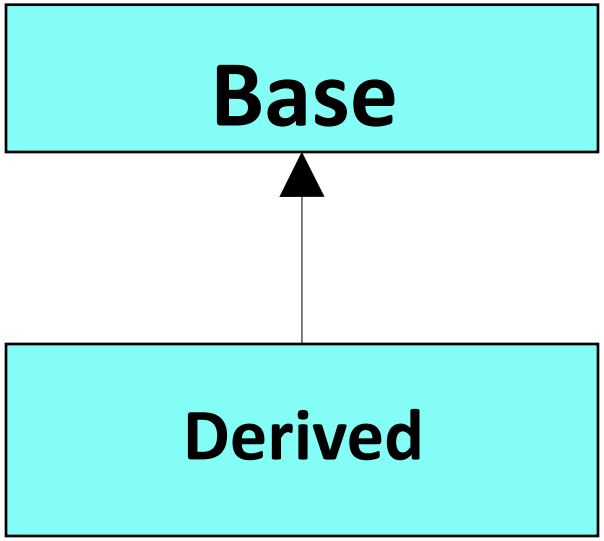
Conversions

- Public Inheritance should imply substitution
  - If B *is-a* A, you can use a B anywhere an A can be used.
  - if B *is-a* A, then everything that is true for A is also true of B.
  - Be careful if the substitution is not valid!

D is derived from B		
D	⇒	B
D*	⇒	B*
D&	⇒	B&

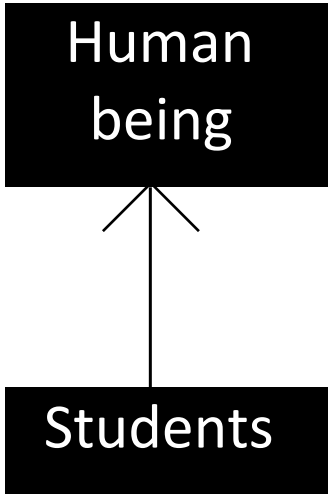
Up-casting

- Upcasting is the act of converting from a derived reference or pointer to a base class reference or pointer.



Up-casting

- Regard an object of the derived class as an object of the base class.
  - only valid on reference or pointer.
- It is to say: Students are human beings. You are students. So you are human being.



Up-casting examples

```
Manager pete("Pete", "444-55-6666", "Bakery");
Employee* ep = &pete; // Upcast
Employee& er = pete;  // Upcast
```

- Lose type information about the object:

```
ep->print(cout);  // prints base class version
```