Object – Oriented Programming
Week 12, Spring 2009

Polymorphism

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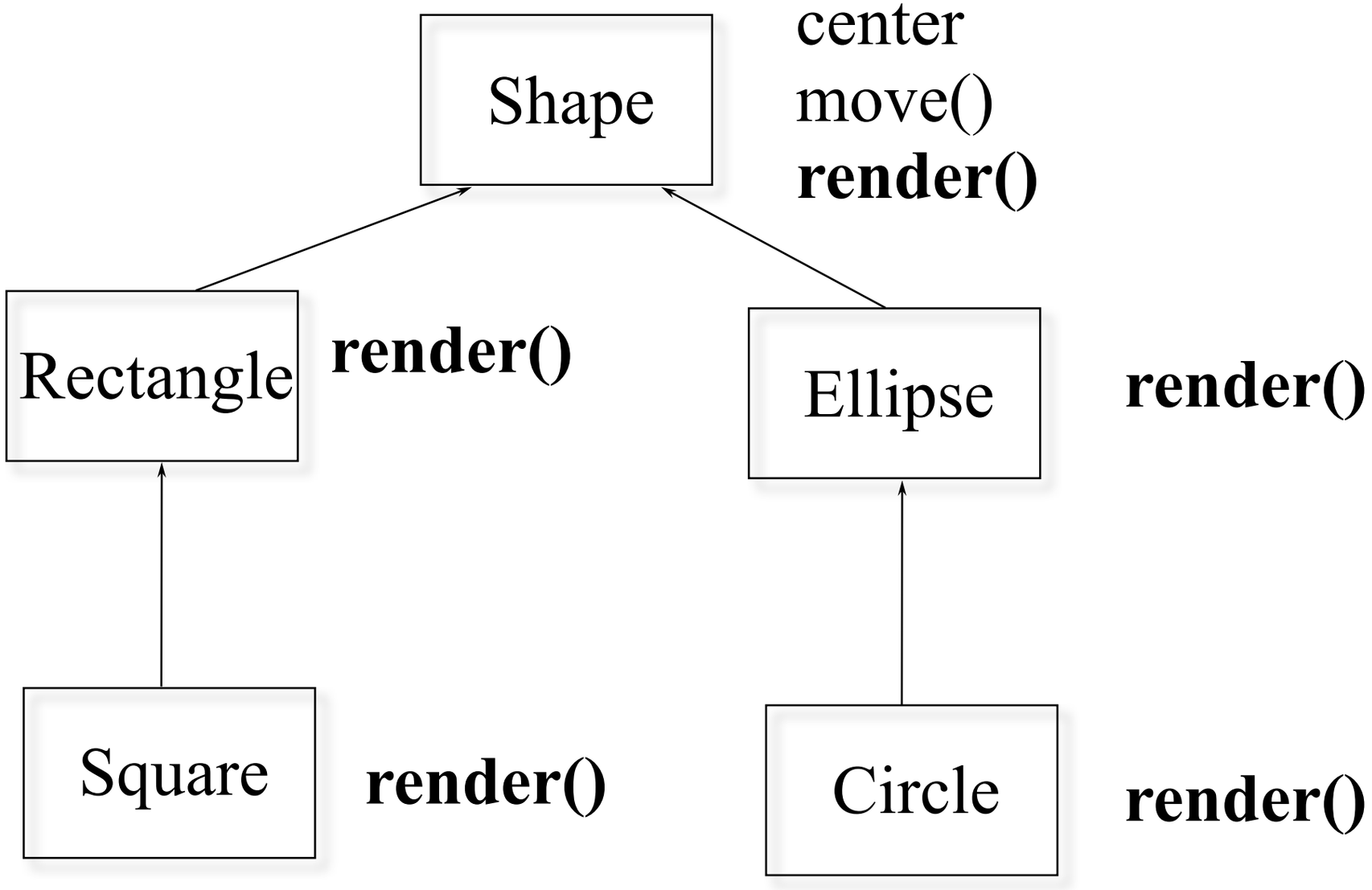
Conceptual model



Note: Deriving Circle from Ellipse is a poor design choice!

Shape

- Define the general properties of a Shape

```
class XYPos{ ... };    // x,y point
class Shape {
public:
   Shape();
   virtual ~Shape();
   virtual void render();
   void move(const XYPos&);
   virtual void resize();
protected:
   XYPos center;
};
```

Add new shapes

```
class Ellipse : public Shape {
public:
  Ellipse(float maj, float minr);
  virtual void render(); // will define own
protected:
   float major_axis, minor_axis;
};

class Circle : public Ellipse {
public:
  Circle(float radius) : Ellipse(radius, radius){}
  virtual void render();
};
```

Example

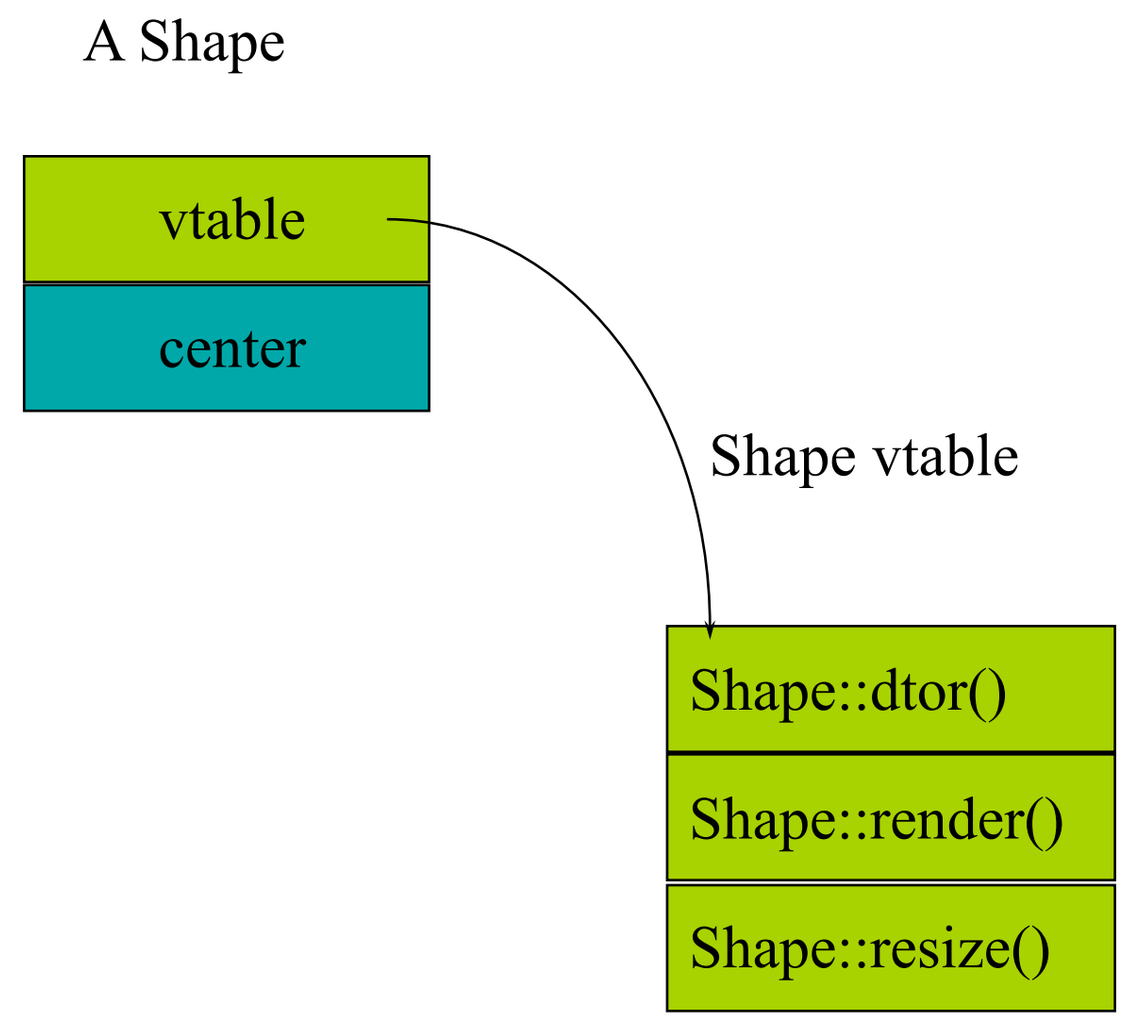
```
void render(Shape* p) {
   p->render();     // calls correct render function
}                   // for given Shape!
void func() {
   Ellipse ell(10, 20);
   ell.render();
   Circle circ(40);
   circ.render();
   render(&ell);
   render(&circ);
}
```

Polymorphism

- Upcast: take an object of the derived class as an object of the base one.
  - –Ellipse can be treated as a Shape
- Dynamic binding:
  - –Binding: which function to be called
    - Static binding: call the function as the code
    - Dynamic binding: call the function of the object

How virtuals work in C++

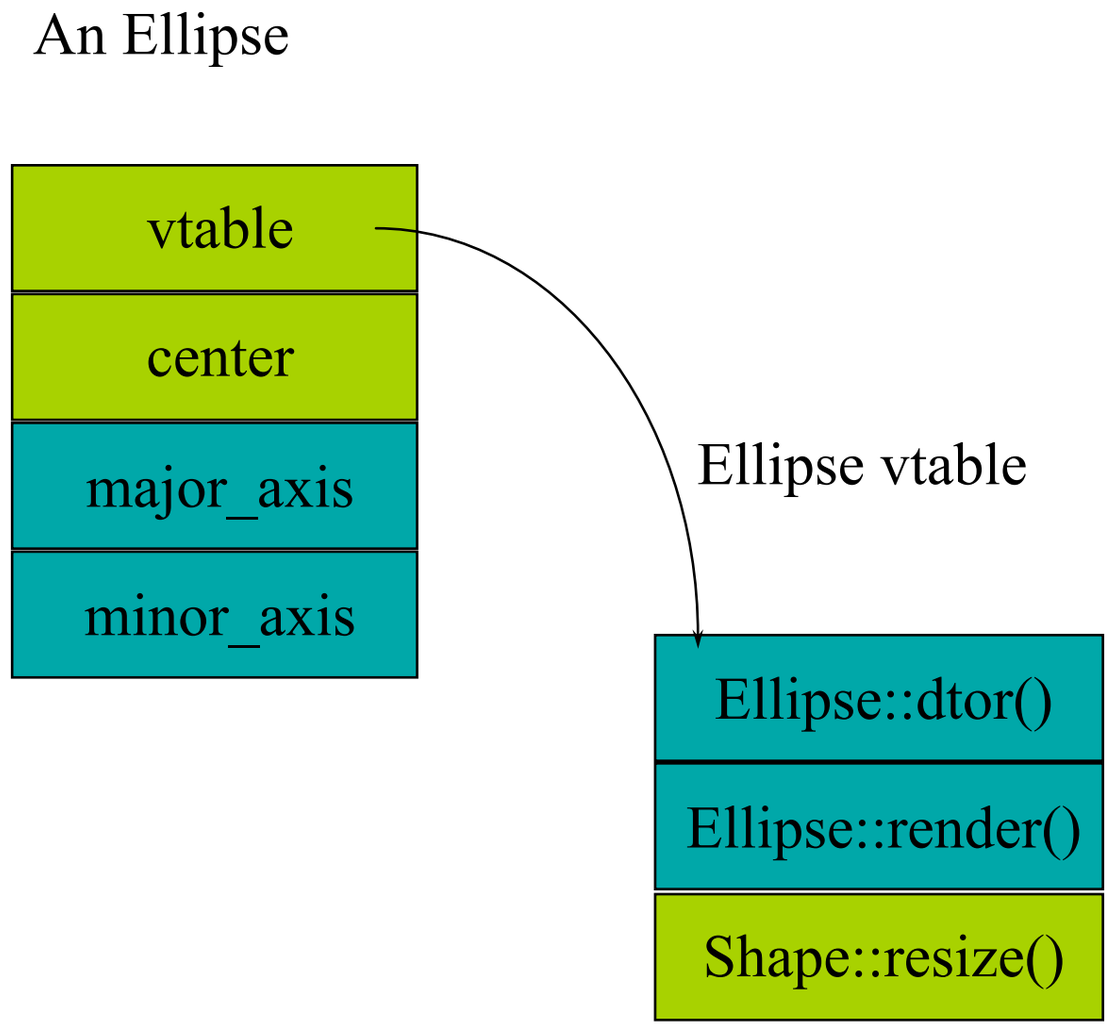
```
class Shape {
public:
   Shape();
   virtual ~Shape();
   virtual void render();
   void move(const
    XYPos&);
   virtual void resize();
protected:
   XYPos center;
};
```



see: virtual.cpp

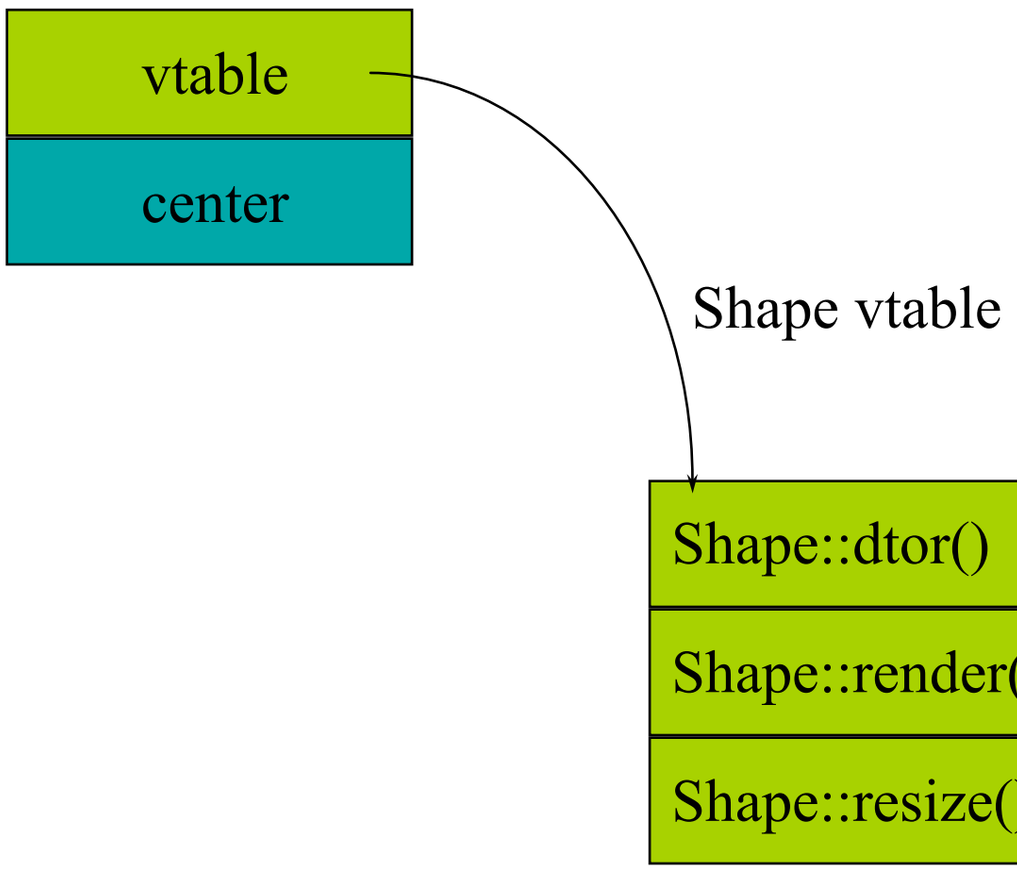
Ellipse

```
class Ellipse :
                public Shape
   {
public:
   Ellipse(float majr,
           float minr);
   virtual void render();
protected:
   float major_axis;
   float minor_axis;
};
```

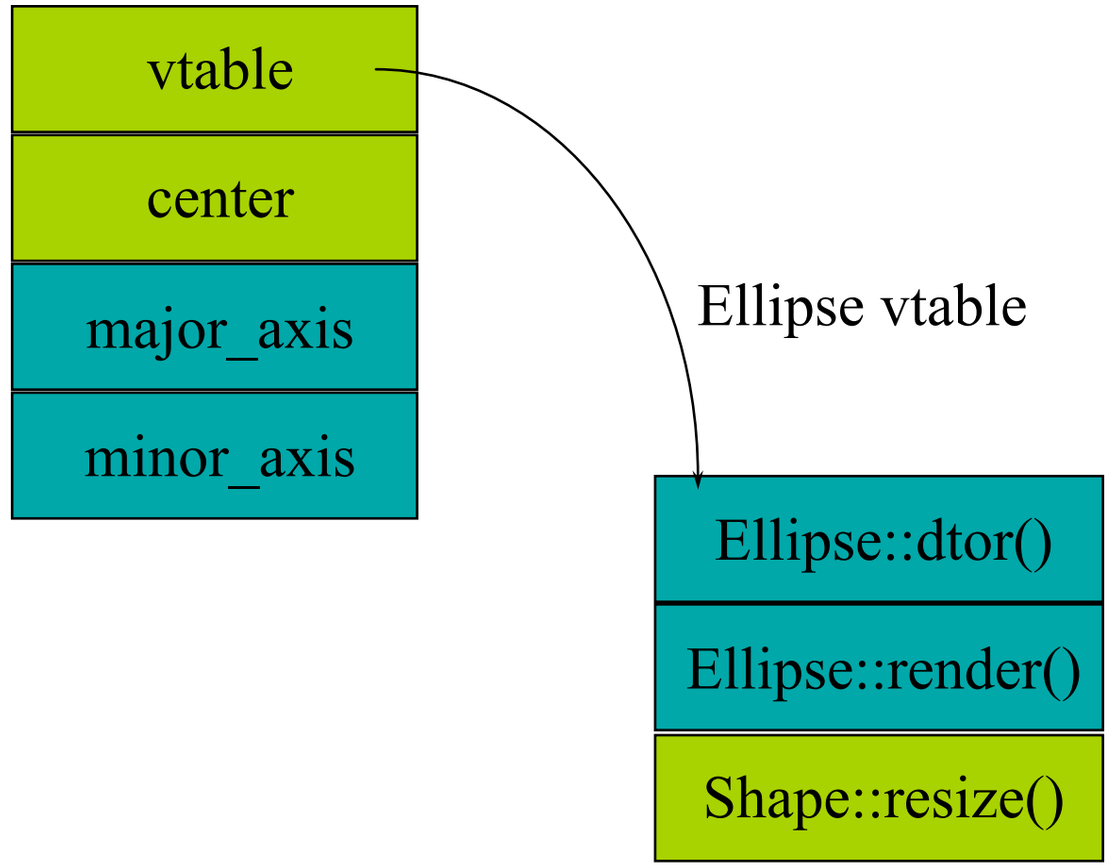


Shape vs Ellipse

A Shape

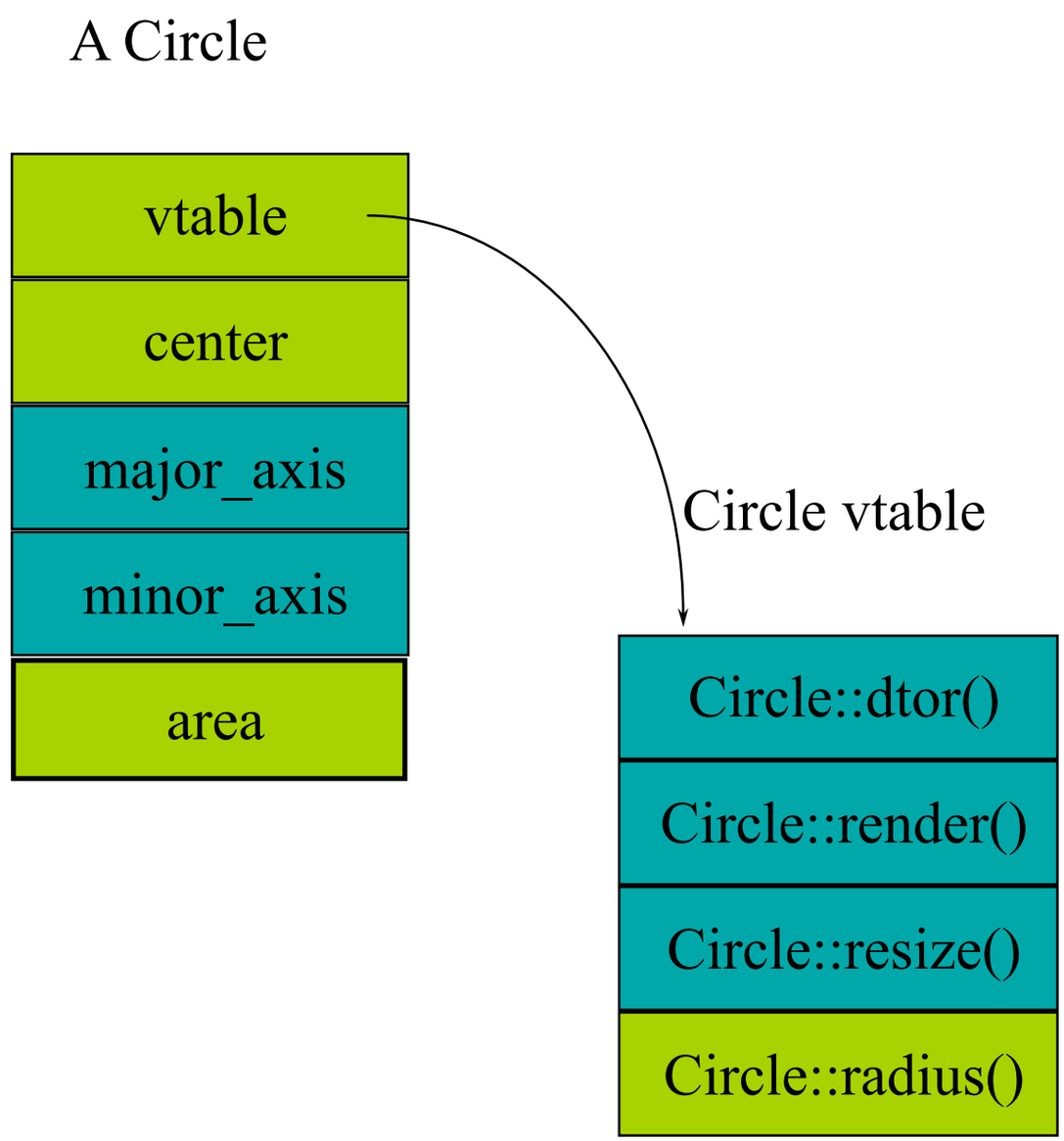


An Ellipse



Circle

```
class Circle :
          public Ellipse
   {
public:
   Circle(float radius);
   virtual void render();
   virtual void resize();
   virtual float radius();
protected:
   float area;
};
```



What happens if

```
Ellipse elly(20F, 40F);
Circle  circ(60F);
elly = circ; // 10 in 5?
```

- Area of `circ` is sliced off
  - (Only the part of `circ` that fits in `elly` gets copied)
- Vtable from `circ` is ignored; the vtable in `elly` is the Ellipse vtable

```
elly.render(); // Ellipse::render()
```

What happens with pointers?

```
Ellipse* elly = new Ellipse(20F, 40F);
Circle*  circ = new Circle(60F);
elly = circ;
```

- Well, the original Ellipse for `elly` is lost....
- `elly` and `circ` point to the same Circle object!

```
elly->render(); // Circle::render()
```

Virtuals and reference arguments

```
void func(Ellipse& elly) {
  elly.render();
}

Circle  circ(60F);
func(circ);
```

- References act like pointers
- Circle::render() is called

Virtual destructors

- Make destructors ***virtual*** if they might be inherited

```
Shape *p = new Ellipse(100.0F, 200.0F);
...
delete p;
```

- Want `Ellipse::~Ellipse()` to be called
  - Must declare `Shape::~Shape()` virtual
  - It will call `Shape::~Shape()` automatically
- If `Shape::~Shape()` is not virtual, only `Shape::~Shape()` will be invoked!

Overriding

- Overriding redefines the body of a virtual function

```
class Base {
public:
   virtual void func();
}
class Derived : public Base {
public:
   virtual void func();
   //overrides Base::func()
}
```

Calls up the chain

- You can still call the overridden function:

```
void
Derived::func() {
  cout << "In Derived::func!";
  Base::func(); // call to base class
}
```

- This is a common way to add new functionality
- No need to copy the old stuff!

Return types relaxation (current)

- Suppose `D` is publicly derived from `B`
- `D::f()` can return a subclass of the return type defined in `B::f()`
- Applies to pointer and reference types
  - e.g. `D&, D*`
- In most compilers now

Relaxation example

```
class Expr {
public:
    virtual Expr* newExpr();
    virtual Expr& clone();
    virtual Expr  self();
};

class BinaryExpr : public Expr {
public:
    virtual BinaryExpr* newExpr();    // Ok
    virtual BinaryExpr& clone();      // Ok
    virtual BinaryExpr self(); // Error!
};
```

Overloading and virtuals

- Overloading adds multiple signatures

```
class Base {
   public:
      virtual void func();
      virtual void func(int);
   };
```

- If you *override* an *overloaded* function, you must override all of the variants!
  - Can't override just one
  - If you don't override all, some will be hidden

Overloading example

- When you *override* an *overloaded* function, override all of the variants!

```
class Derived : public Base {
   public:
      virtual void func() {
         Base::func();
      }
      virtual void func(int) { ... } ;
   };
```

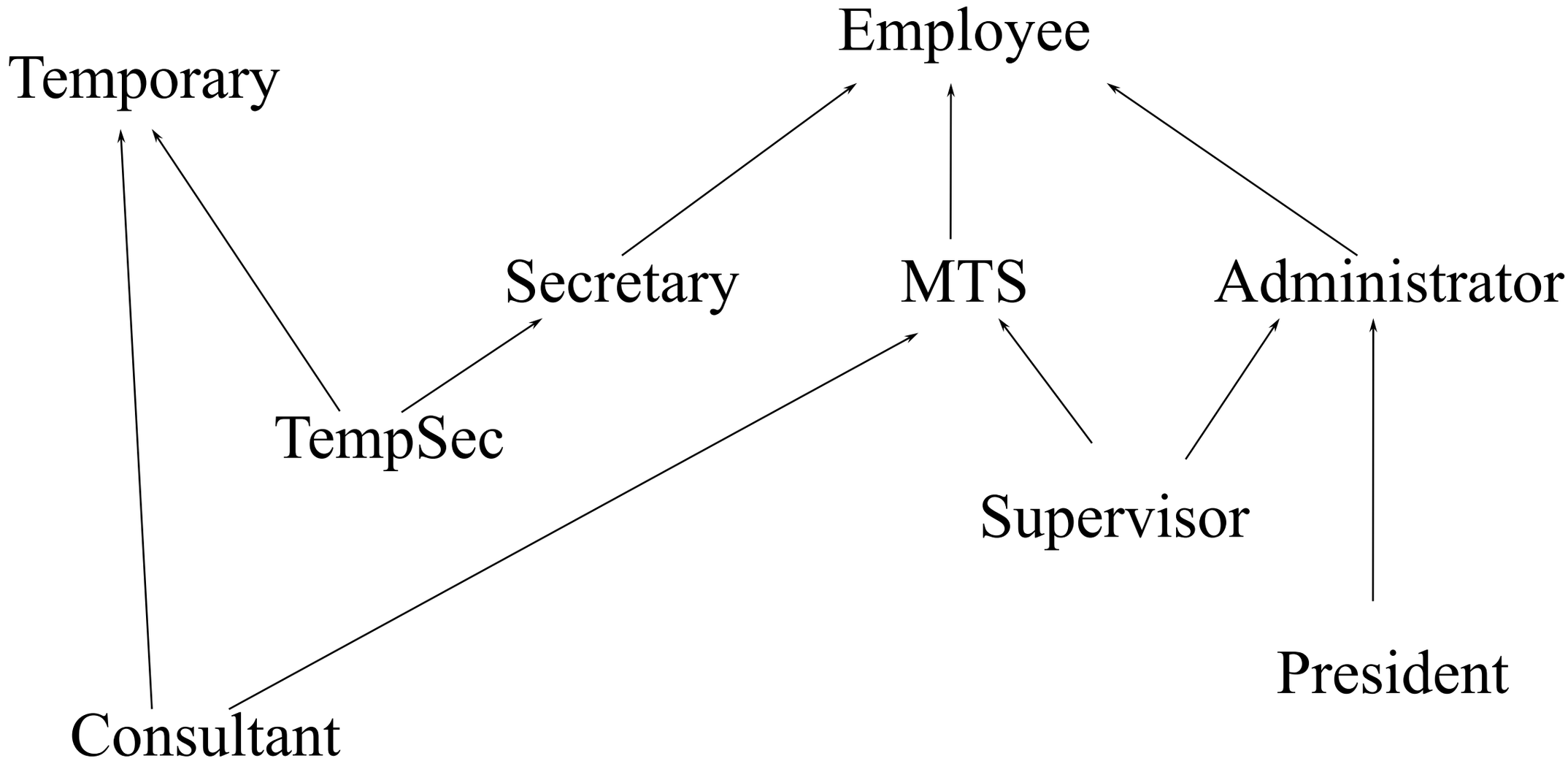
Tips

- Never redefine an inherited non-virtual function
  - –Non-virtuals are statically bound
  - –No dynamic dispatch!
- Never redefine an inherited default parameter value
  - –They’re statically bound too!
  - –And what would it mean?

Virtual in Ctor?

```
class A {
public:
   A() { f(); }
   virtual void f() { cout << “A::f()”; }
};
class B : public A {
public:
   B() { f(); }
   void f() { cout << “B::f()”; }
};
```

Multiple Inheritance



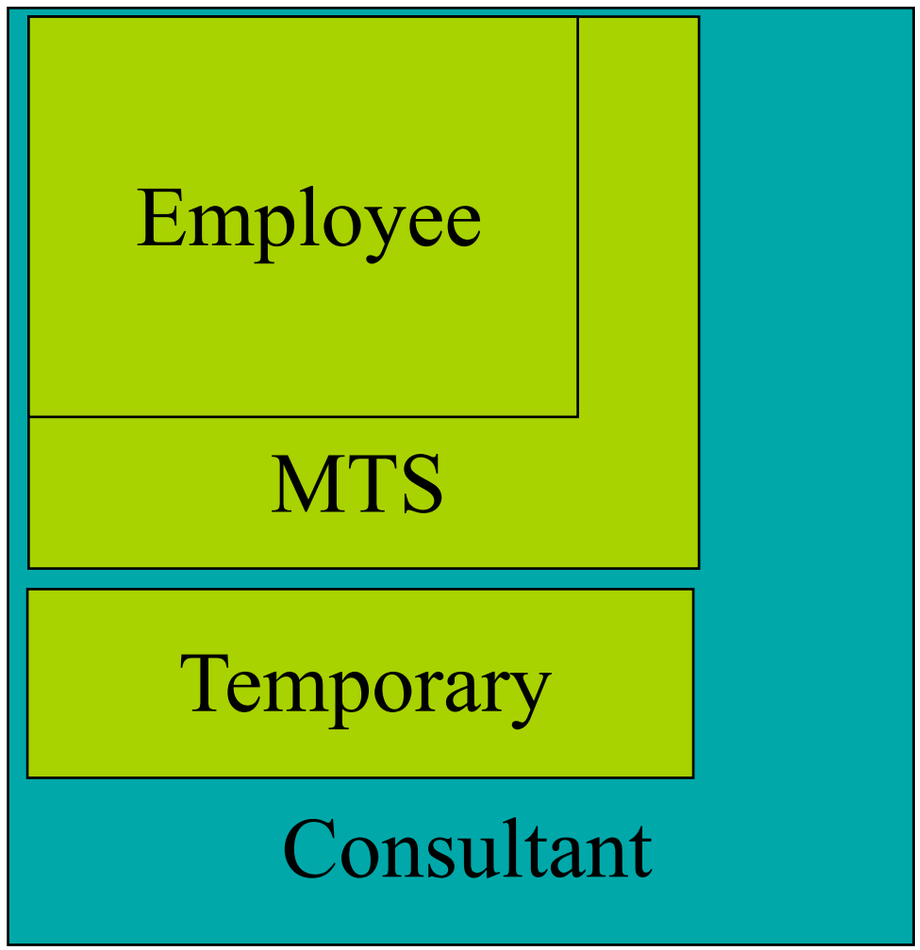
Mix and match

```
class Employee {
protected:
String name;
EmpID id;
};

class MTS : public Employee {
protected:
Degrees degree_info;
};

class Temporary {
protected:
Company employer;
};
```

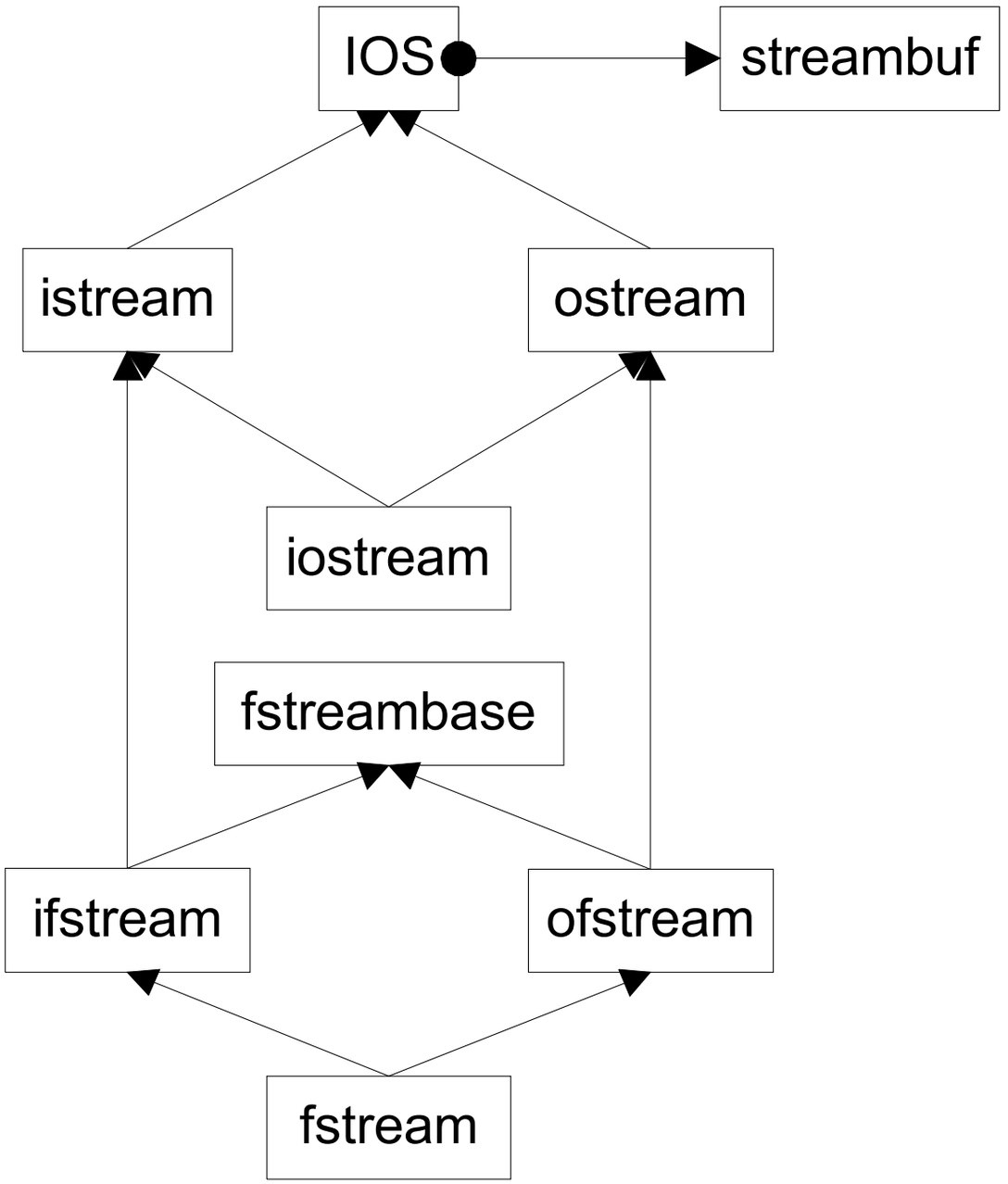
```
class Consultant:
   public MTS,
   public Temporary {

...
};
```

- Consultant picks up the attributes of both MTS and Temporary.
  - name
  - id
  - employer
  - degree_info

MI Complicates Data Layouts

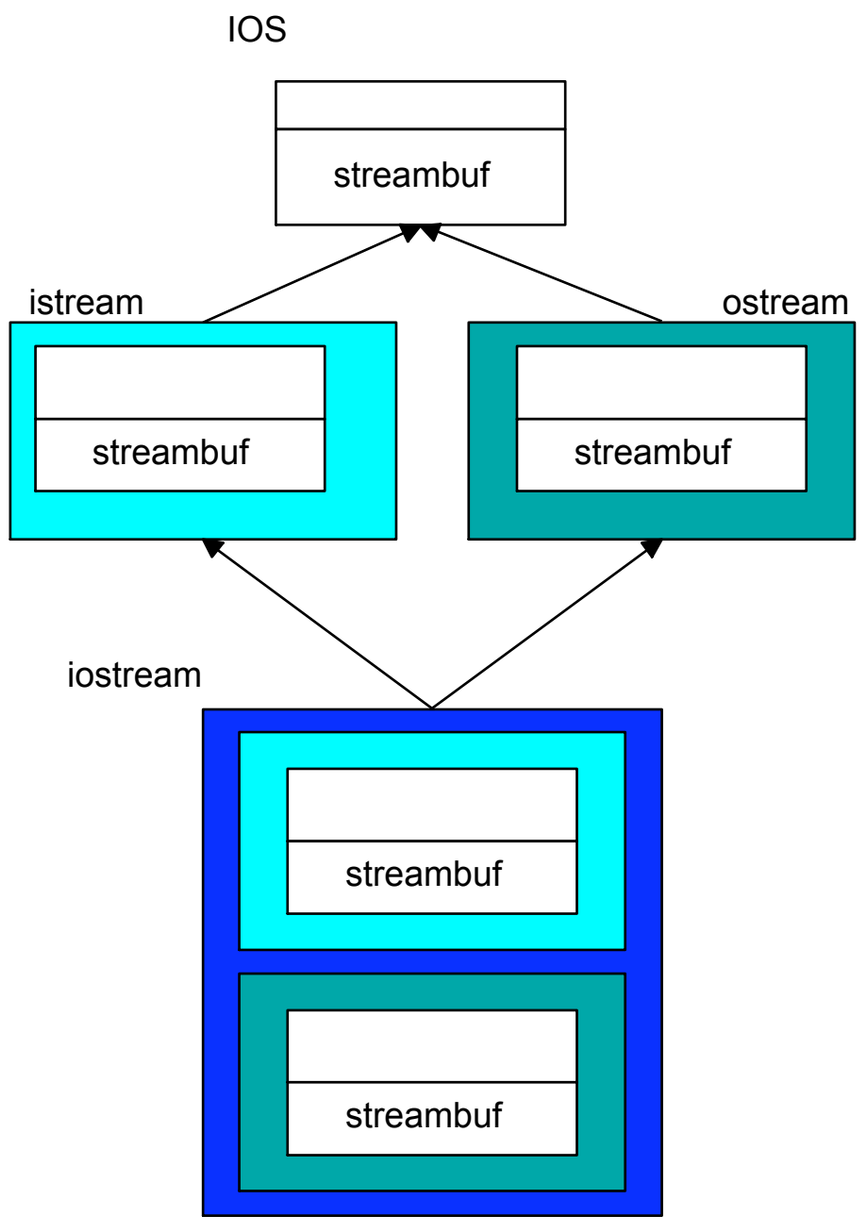


IOStreams package



Vanilla MI

- Members are duplicated
- Derived class has access to full copies of each base class
- This ***can*** be useful!
  - Multiple links for lists
  - Multiple streambufs for input and output



More on MI...

```
class B1 { int m_i; };
class D1 : public B1 {};
class D2 : public B1 {};
class M : public D1, public D2 {};
```

```
void main() {
  M m;  // OK
  B1* p = new M; // ERROR: which B1
  B1* p2 = dynamic_cast<D1*>(new M); // OK
}
```

B1 is a *replicated* sub-object of M.

Replicated bases

- Normally replicated bases aren't a problem (usage of B1 by D1 and D2 is an implementation detail).
- Replication becomes a problem if replicated data makes for confusing logic:

```
M m;
m.m_i++; // ERROR: D1::B1.m_i or
D2::B1.m_i?
```

Safe uses

- Protocol classes

Protocol/Interface classes

- Abstract base class with
  - –All non-static member functions are *pure* virtual except destructor
  - –Virtual destructor with empty body
  - –No non-static member variables, inherited or otherwise
    - May contain static members

Example interface

- Unix character device

```
class CDevice {
public:
        virtual ~CDevice();

        virtual int read(...)   = 0;
        virtual int write(...)  = 0;
        virtual int open(...)   = 0;
        virtual int close(...)  = 0;
        virtual int ioctl(...)  = 0;
};
```

Safe uses

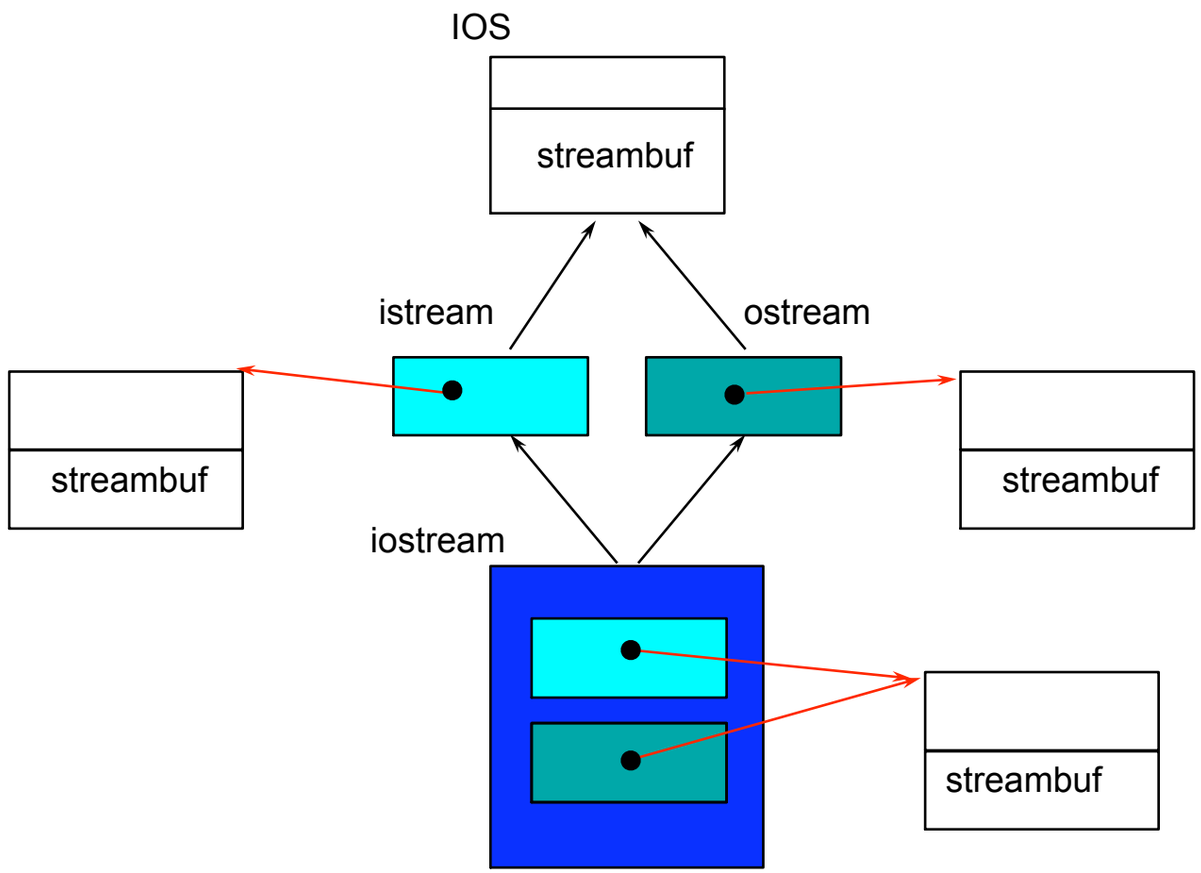
- Protocol classes

What about sharing?

- How do you avoid having two streambufs?
- Base classes can be ***virtual***
  - To C++ people, “virtual” means “indirect”
- Virtual member functions have dynamic binding
  - They use pointer indirection
- Virtual base classes are represented indirectly
  - They use pointer indirection

Using virtual base classes

- Virtual base classes are ***shared***
- Derived classes have a single copy of the virtual base
- Full control over sharing
  - Up to you to choose
- Cost is in complications



has-a ●——→

isa ——→

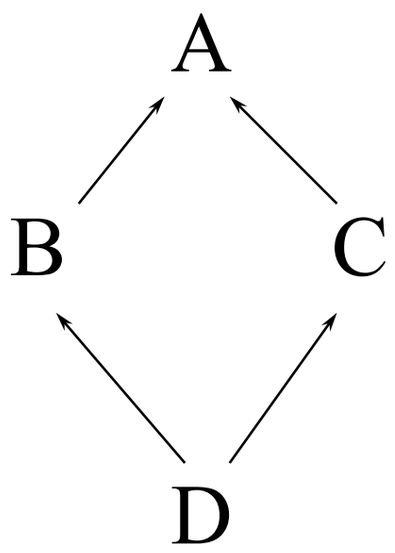
Virtual bases

```
class B1 { int m_i; };
class D1 : virtual public B1 {};
class D2 : virtual public B1 {};
class M : public D1, public D2 {};
```

```
void main() {
    M m;  // OK
    m.m_i++; // OK, there is only one B1 in
  m.
    B1* p = new M; // OK
}
```

Complications of MI

- Name conflicts
  - Dominance rule
- Order of construction
  - Who constructs virtual base?
- Virtual bases not declared when you need them



- Code in virtual bases called more than once
- Compilers are still iffy
- Moral:
  - Use sparingly
  - Avoid diamond patterns
    - expensive
    - hard

Virtual bases

- Use of virtual base imposes some runtime and space overhead.
- If replication isn’t a problem then you don’t need to make bases virtual.
- Abstract base classes (that hold no data except for a vptr) can be replicated with no problem - virtual base can be eliminated.

TIPS for MI

- SAY

NO